Science, Warfare and Society in the Renaissance, with particular reference to fortification theory

In two volumes

VOLUME I: The results of the research

(Volume II: The texts, separately bound)

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Abstract

Later 16th. century fortification theory was conceived to be a mathematical science. The mathematical approach was considered valuable for the quality of public demonstrability and certainty it gave; for the dignified and worthy art that resulted, suitable to those of a certain (elevated) station of life. Epistemologically, the general Euclidian method used was supported by the Christian model of the relationships between God, man and the world. The prince on earth had need of such a tool to govern his domain. Concentration in design on the needs of defensive guns and the principle of no dead ground established this pattern. The idea of the irresistability of attacking artillery legitimized the program.

Other disciplines of the renaissance: naval architecture, perspective, dialling, surveying, navigation and mapping, ballistics and general architecture, evidence a similar cluster of ideas. The preference of the period was for theoretical technologies as against the mere following of successful craft practices.

Earlier fortification theory involved a method of design by reference to the resisting capacity of particular forms. The increasing use of artillery in siege warfare in attack, and defence, meant that the ability of defending guns to punish the attack could no longer be so neglected in design. The shift to the diametrically opposite mode of design based on the functioning of defending artillery was facilitated by a number of factors: An increasing concentration on the urban enceinte; the changing nature of warfare, technical and otherwise; changing conception of political and war related needs; and the desirable quality of the science that arose. Many factors interacted in this process which was paralleled epistemologically in religious thought and political theory. The resultant attitudes and the emergent mathematical picture of the world of many areas of practical knowledge formed the background for the work of such figures as Descartes and Galileo.

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GENERAL INTRODUCTION

Traditionally renaissance fortification has been seen to be almost entirely a matter of changes in the forms of structures in response to the introduction of a new, effective, gunpowder powered artillery, the new weaponry having made redundant the older, high towered, medieval structures, which could not resist its power, and having led to the introduction of the low banked pointed bastion masses so characteristic of the new fortification of the 16th. century.[1]

Yet undoubtedly there is another side to renaissance fortification. The new style of fortification was accompanied, in the second half of the 16th. century, by the publication of a relatively large number of treatises on the art. These treatises did more than inform the reader of the many details of the new types of structures and their construction, they sought equally to justify the new style, to make clear its complete rationallity (in the sense of its being based in reason), and to show how that style conformed to the highest standards that could be conceived for such an art.

The primary basis of the research here presented is an attempt to grasp and understand these ideas, to trace their roots, their influence in fortification and in other areas, and their position in the whole changing cultural background of the period. In outline this means that the research at the first stage examines the ideas of the treatise writers of the later 16th. century on the nature of their art, together with the ways those ideas came to be expressed. The results at this level then lead on to an enquiry which expands ever further and further into the whole cultural background of those ideas, through the continual posing of the question as to how it was those particular ideas came to be expressed in the face of the widely changing world of which they were a part.

This mode of approach has a number of advantages. Notwithstanding that in a work such as this the reader might expect to find first of all an outline account of previous work in the same area, and an indication of the views of other students of the subject; in accord with the methodology outlined, the presentation begins with a description of the lives of the treatise writers and their ideas on their art, and an elucidation of the common assumptions they made. In this way these ideas and assumptions can be considered for their own sake, and assessed in thier own terms, without being cluttered by, and entangled with considerations about the possible causal role of such lines of thought. These ideas of the treatise writers of a general nature undoubtedly deserve to be considered in this way, for, whatever role they may have had in fortification practice they were a part of renaissance fortification and the amount of relevant material available is such as to allow a detailed examination to be carried out as to how contemporary figures did tend to think about such problems in their own time.

But in addition to bringing out such patterns of thought, the independent consideration of these ideas, separated from any preoccupation with causal patterns in the whole development of renaissance fortification, enables that particular aspect of the art to be studied unclouded by assumptions as to how such a technology as fortification must, or does, function. This is of critical importance because central to the views of the treatise writers was the contention that their methods were necessary because of a particular historical development -- the introduction of effective artillery which no material

1. A view clearly expressed by the treatise writers of the later 16th. century, for a brief indication of modern expressions of this view see below p. 243, n.1. The pointed bastion, though most characteristic of the forms used in 16th. century fortification was not the only one put forward or employed. The tenaille trace, for example, was equally consistent with the ideas of the period.

could resist -- which contention has been almost entirely uncritically accepted ever since. But such an idea has its own history and evolution in the context of the whole maze of events of which it was a part. If therefore that idea is allowed to function as a dominant aspect of the organisation and interpretation of the sources it can hardly itself come under scrutiny and have its own history elucidated in any rigorous way. Thus by first of all studying the ideas of the treatise writers as an independently functioning system a body of sources can be approached without any such considerations about the primary historical causes over predominating.

Thus the foundation of the research is set firmly in the detailed analysis of a relatively extensive body of historical sources. Only when this has been accomplished does the enquiry begin to turn to more general questions. This is done by attempting to answer the question as to how in their period these particular ideas came to be expressed. Examination of a number of the other practical mathematical sciences of the renaissance: Naval Architecture, Dialling, Perspective, Surveying, Navigation and mapping, Ballistics and general Architecture, then shows those same ideas as expressed in the fortification treatises of the second half of the 16th. century, being expressed in these other disciplines, and having roots well back into the 15th. century.

This pattern then suggests that certain processes were at work in such disciplines which were common to them all and that the genesis of those ideas in fortification in the later 16th. century can not be conceived to be merely a response to the detailed problems of that area. To account for this a general model, distinguishing between theoretical and craft technology, is set up and briefly examined. This model then provides an account of renaissance fortification alternative to the traditional view, and the early development of the art can then be examined in a balanced way in terms of the two views, in order to clarify its nature. This analysis then leads on to a general consideration of a wider range of factors, social and military, political and economic, and intellectual, against which the changing pattern of renaissance fortification must be seen.

In detail the research is presented at follows. Part I deals with the understanding of the nature of fortification as found in the treatises of the second half of the 16th. century, in two ways. Firstly by examining individual writer's biographies and their particular ideas on their art; then by a consideration of the common ideas found in the published treatises and the variation in response between different authors. The texts which support the discussion of these sections are given in Vol. II, along with their translations. In Part II other practical mathematical sciences of the renaissance as noted above are each dealt with separately as disciplines each with its own nature and development. Part III, Interpretation and Analysis, deals with both the earlier developments in fortification, developments in artillery and in siege warfare, together with more general cultural developments over the longer period, and seeks to suggest how these developments can best be understood in their inter-relationships, as well as to assess the significance of renaissance fortification theory and the other practical mathematical sciences of the period over the longer term.[1]

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1. For some remarks on the presentation of the texts see <u>II</u> p. v/vi.

This methodology however may be open to two particular kinds of criticism. Firstly it may be considered to involve the error of 'doing history backwards'. Now in a general way it ought to be pointed out that before a set of events or processes can be handled in terms of how they became what they did become, it has to be established what they did become. There is no question that a part of later renaissance fortification was the text book tradition of the published treatises. Thus by beginning with these treatises what is first established is a part of what has to be accounted for in a description of the evolution of renaissance fortification, and this is surely something that ought to be done before the earlier developments are considered. Indeed if this is not done any developmental account will all too easily become an account of what is important in terms of modern preconceptions, rather than in terms of the assumptions and modes of understanding of contemporaries. In more detail it may be said that 'doing history backwards' may involve two rather different errors. The first is more at the level of causes. It involves stating (or assuming) that event B, which took place at a later time, was the cause of event A which took place at an earlier period (in contrast to contending that because event B took place at a later date some event A must have taken place at an earlier date, which may or may not be legitimate). On the other hand 'doing history backwards' at the interpretative level may involve assuming that some type of process or behaviour for which there is some evidence at some later date, actually occured or was prevalent at an earlier date when this may not have been the case.

As to the first of these errors it may be stated that some commentators considered below come perilously close to committing it. For example, Hessen with his Marxist approach sometimes seemed to suggest that a certain type of knowledge emerged during the early modern period, because of the rise to power of the bourgeoisie, which process he described as, at least in part, taking place very much later. While in contrast it is one of the aims of this research, at the more general level, to suggest models of change which will preclude any such reverse causal pattern, and yet still account for the ways in which, for example, in the later 16th. century certain aspects of the fortification style of the time were favoured by certain general cultural patterns, which favourable conjunction can hardly be taken to have been very influential in the inception of those same aspects in fortification.

In regard to the second type of error at the interpretative level, every attempt has been made to maintain the principle that, in the earlier evolution of fortification, even though it can be shown that ideas similar to those of the fortification treatise writers of the later 16th. century were being expounded in other disciplines and discussed even within fortification circles, that these ideas can only be assumed to have been acting in fortification in the earlier period when there is direct evidence for them, or where such an effect is more consistent with the sources, than other effects. A constraint easier to enunciate perhaps than to hold to, but a strong constraint nevertheless which helps to obviate the danger of assuming, from the evidence of later events, processes as occuring earlier than was the case.

Further it must be affirmed that the problem is well nigh inescapable. There is simply no extensive body of sources in fortification from the earlier period anything like as rich and as explicit on the level of general notions about the art, as is contained in the later published treatises. If we are to reconstruct attitudes to the art in the earlier period it is surely better to make use of the ideas of these later thinkers as a guide to probable patterns than simply to assume we understand from much more scattered references and sources the attitudes of the earlier workers, which in practice means that we assume they thought as they ought to have in modern terms.

The second and perhaps more serious challenge that might be made to the above outlined methodology concerns, the depth and exhaustiveness with which the many different aspects, particularly of the whole general background to renaissance fortification, can be dealt with in any one work such as this. Certainly if the research was to reach any forseeable end many aspects had to dealt with in a rather sketchy way. This is true even in those sections on the other practical mathematical sciences of the renaissance where a good many works have been quoted from, and undoubtedly many oversimplifications, lacunae and misinterpretations will be considered to be involved in the views of specialists in the different areas. All the more so will this be the case when the more general aspects, military, political and social of the background of fortification, are considered. Further in seeking to locate this discipline within its background very general suggestions have been put forward, about the nature of cultural change, about the nature of the changes from the medieval to the modern period, and of a general epistemological nature, although more implicitly than explicitly here. Given such a pattern, clearly the treatment of these many and complex areas could be in no way exhaustive, and the methodology outlined is open to the challenge of being too grandiose to be reasonably undertaken, and that it could not possibly be completed to a sufficiently high standard so as to be worthwhile.

But it must be pointed out that any such challenge involves its own epistemological commitments, preconceptions and implications. If historical inquiry is to be limited to such areas as can be exhaustively treated in accord with the highest standards in every way, such a study as this would become well nigh impossible even with a lifetime's effort. Further the handling of limited topics in as thorough a way as possible means that willy-nilly the treatment of each area must tend to be one of analysis of that area very much in its own terms. When the time comes then to assemble many such studies to give the pattern of a period as a whole, for example, those kinds of cross connections between so many different areas, which it has been the intention at least to outline here, will tend to have been strained out of the original treatments, and will tend not to appear.

Thus, while the insistence of being governed by the highest standards is all to be desired, such a commitment involves its own closed mindedness if it makes certain kinds of studies practically impossible by insisting on too high a competency and range in terms of the number of areas dealt with, and will tend to preclude treatments which seek to deal with the many subtle underlying connections between events.

Further the research methodology employed here, which, particularly at the more general level, does not pretend to imply exhaustivness of treatment which would be desirable to achieve in accord with the highest standards from a certain point of view, involves on the other hand other kinds of constraints. The very general views put forward about the nature of cultural change, the general historical pattern of the period, and on the epistemological level, are put forward as very specific responses designed to handle a very specific problem: that is the how and the why and the significance of the rise of the later renaissance theory of fortification. They are constrained by this reference to a specific problem, and hence are not intended as definitive accounts in these areas, although if they do turn out to be useful in other contexts, so much the more may they seem relevant here. Thus what is involved is not either some armchair speculation about the nature of scientific (or other) knowledge, or any architectonic system building in history, but an attempt to come to grips with a specific problem in all the richness of its connections with its background. Within the general methodological frame work outlined above the process is further constrained by a continual interaction between the more detailed and the more general. The research begins with the details of the ideas of the fortification treatises of the later 16th. century, then those ideas are considered at a more general level in action in the other practical mathematical sciences of the renaissance. This leads to the formation of a general model to account for the technologies of the period. This model is then applied to the details of the earlier development of fortification and compared with other accounts of that area. The consideration of the details of siege warfare and the use of artillery then lead on to more general considerations about the changing nature of warfare during the period and its general cultural background, which is in turn related back to the original ideas of the fortification treatise writers. At the most general level the whole changing world of the period, cultural and epistemological is then considered by reference to the previously built up pattern. Thus the more general considerations are constrained by this interaction with the more detailed aspects of the research, as well as through their application to a specific problem.

Exhaustiveness of treatment is thus replaced by an attempt to elucidate a general framework for the detailed topic and its historical context, and while this approach is obviously no substitute for a treatment of all the complex details of the interactions involved, it does hope to provide a framework within which these details could be worked through, and without which the relevant details would remain obscure, even though in any such undertaking the detailed emphasis as given here would in all probability shift somewhat.

It ought to be admitted however that there are dangers in this type of approach. Any contention that particular areas of research can not be treated exhastively in accord with the highest standards because of the complexities involved, may all too easily an excuse for over-simplification, one sided interpretation and error. But this is a risk the author must accept if history is not to become the mere accretion of details. It would surely be a sad day when such risks are not taken because any dereliction from 'the highest standards', conceived in a narrow way, is conceived to be illegitimate and is hence able to provide a handy excuse.

On the other hand whether the risks involved and the liberties taken, the over-simplifications, lacunae and sheer elementary errors involved in this research, are worth accepting in the face of the results achieved, must be left to the reader to judge.

PART I: Renaissance fortification as a theoretical discipline

(1): The individual authors and their ideas about their art

(i): The Italian tradition

Outline of the tradition

The following authors, listed according to the date of their first publishing a work relevant to fortification, comprise the Italian tradition: delle Valle (1521); Tartaglia (1546); Pietro Cataneo (1554); Zanchi (1554); Lanteri (1557); Girolamo Cataneo (1564); Maggi and Castriotto (1564); Mora (1567); Theti (1569); Alghisi (1570); Locatelli (1575); Pasino (1579);[1] Lupicini (1582); [Aconcio (1585)];[2] Busca (1585); Gentilini (1592); Giovanni Scala (1596); Lorini (1596); Belluzzi (1598); and Marchi (1599).[3] These last two being somewhat anomolous as their works were published long after their deaths.

Valle's little book really only touched briefly on 'riparare', rather than fortification. It was however one of the very earliest published to consider the subject at all from the point of view of the newer aspects of warfare, particularly the use of artillery. Tartaglia's remarks on fortification were only a short section in a work concerned with various fields of technology, but his remarks were the first published to consider the pointed bastion system, and he did take a great interest in the application of mathematics to many areas, so his ideas are of particular significance. But despite these two works published before 1550, the great majority of treatises in the Italian tradition were published in the second half of the century.

Pietro Cataneo's treatise, though concerned with architecture in general, gave a good deal of emphasis to the military branch; he also published a mathematical work. Zanchi and Lanteri published specialized treatises on fortification, Lanteri in his first book following a strongly geometrical line. Girolamo Cataneo published on other topics, both military and mathematical, as well as in fortification. The work under Maggi and Castriotto's names was put together and published by Maggi -- much more a literary figure than the practising fortification engineer Castriotto -- after the latter's death. Mora was only a minor writer on fortification more concerned with the question of the honourable nature of the soldiers trade, than with fortification as a specialised topic. Theti's treatise in its final form was a large and elaborate work concerned with many aspects of fortification. Alghisi published an extremely elaborate and decorative work much concerned with geometrical manipulation in design. Locatelli published not so much a treatise on fortification as a prospectus for a fortification competition. Pasino wrote much about the general nature of fortification and in particular its relationship to architecture.

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1. Pasino's treatise was published in French at Antwerp, but he was definitely Italian with an Italian training and background. He clearly promulgated Italian ideas also, and therefore belongs in the Italian tradition.
2. There is some doubt whether Aconcio's treatise, now lost, was ever actually published.
3. A further writer Gian Tommaso Scala, was only a minor author whose ideas were only published in fragments after his death by others, he is therefore not included here for analysis, although sections from his writings are given with the texts in Vol. II.

Lupicini was a relatively minor and not very original writer on fortification. Aconcio, whose work is not now known, as well as writing on fortification, published a general work on method very Aristotelian in style. Busca, Gentilini and Giovanni Scala were lesser writers in various degrees. Lorini published a very extensive treatise on many aspects of fortification. Belluzzi's treatise was well known in manuscript before its publication long after his death, without its accompanying illustrations. Marchi's treatise, which the author began to compose in the 1540's was organised around many elaborate designs. Gian Tommaso Scala was of no great significance except perhaps for his strong rejection of the specialised military architect as the final arbiter in fortification, in favour of the military man.[1]

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1. Many other figures who discussed fortification in published works, are not considered here for various reasons. Machiavelli, Centorio degli Ortenzi, Francesco Ferretti, Giovanni Botero, Francesco Patrizi, were too much concerned with fortification in only a very general way, to have contributed to detailed understanding of the art. Francesco Montmellino, was too concerned with one specific structure and its details. Barbaro's work on perspective only briefly alluded to the subject. Capobianco's account is too slight. All these (with details) are mentioned by MARINI (1971). Of the authors given by RICCARDI (1893), Giorgio Zuccolo's work contains too slight an account. The two works of Barrozzi were more concerned with a weapon for defence, rather than with structures. (See PROMIS (1974).) The work by Giulio M. Ballino was only concerned with the description of fortresses. AYALA (1854) mentions La fortificazione delle piazze by Giulio Cesare Falco, but nobody appears to have seen it and it remains a rather dubious work. (See RICCARDI (1893): PROMIS (1874): MAGGIOROTTI (1933/9) Vol. II, p. 25.) MAGGIOROTTI (1933/9) mentions other works but appears to be unreliable. For example, he gives Vol. II p. 48, a work indicated as on fortification by Achille Tarducci at Venice in 1546. Yet in his biographical notes (ibid. p. 441, after Promis) gives Achille Tarducci's dates as 1550/1601. DELACROIX (1963), listed BENTIVOGLIO, Cornelio: Discorso delle fortifizationi (Venice 1598), as did Maggioroti. It has not proved possible to trace this work. BIOG DEL ITAL gives a long article on Cornelio Bentivoglio (1519/20 to 1585) and does not appear to know any such work. Delacroix may simply have been following Maggiorotti here, who gives this work.

Battista della Valle and his Work

Gian Battista della Valle seems to have been born sometime in the later 15th. century.[1] He practised the trade of war from an early age.[2] At some time he received a stipend from Giovanni Della Rovere "Prefetto di Roma", who died in 1501.[3] He became captain[4] (or colonel)[5] to Ferdinand the Catholic Kinq of Aragon in the kingdom of Naples, but returned to the service of the Della Rovere's under Francesco Maria I and in 1516 was in a position of command at S. Leo during its siege by Leon X.[6] He afterwards served under the Duke di Bracciano Orsini.[7] His death is variously given as 1535 or 1550 at Bracciano.[8]

In 1521 Valle published Vallo, a little handbook concrned with a number of practical aspects of warfare, which went through a large number of editions[9] and presumably appealled to a wide audience as Valle intended.[10] In comparison to Machiavelli's well known work on warfare of the same year,[11]

Valle's book was more concerned with the practical details of warfare and its techniques, although both his and Machiavelli's works dealt in some detail with the problem of organising soldiers in proper arrays.[12] It was probably the wide range of topics covered from a practical viewpoint, generally, rather than any particular significance of the ideas he expressed, that made Valle's work so popular: his readers presumably mainly being found amongst those connected with warfare, or interested in its practire, to some extent or other. In contrast, the many editions of Machiavelli's work were probably read much more by those with an interest in literature and politics, and the relation of warfare to politics.

The practical nature of Valle's approach can be seen in his discussion on fortification which concentrated more on remedial works, and 'bastions' as single units of defence, in terms of details of construction, rather than on larqe and idealised schemes.[13]

In the understanding of the sorts of topis with which he was dealinq Valle insisted on the value of experience, such as his own, against any dependence on a literary tradition, or authorities,[14] as a general rule. In contrast, at other points, Valle emphasised the value of 'science'.[15] However he did not seem to intend here very much more than due and prudent consideration of the problems involved.[16] Equally he tended to equate 'science' with any kind of literary activity;[17] and while he was quite willing to admit the great importance of such 'science' in a general way,[18] ultimately he insisted that the

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1. PROMIS (1841) A p.60, states c. 1470 or 80, but this seems to be purely inferential from his service with Giovanni della Rovere.
2. II p.2; l. 9/11. 3. Promis ibid.
4. TOPPI (1678) states this was his rank later. 5. Promis ibid.
6. Ibid. & MAGGIOROTTI (1933/9) Vol. II p. 22. This siege lasted more than 3 months.
7. TAFURI (1744/60), III, pt. I. p. 453.
8. TOPPI (1678) gives 1550 and is followed by PROMIS (1841)A. TAFFURI (1744/60) gives 1535. and is followed by N.U.C.
9. For contents of the work and bibliography see II, p. 1.
10. Vallo.... (1524) f. 2b. "Et ad tal che piu chiaramente da tutti potesse essere inteso (perche son certo questo libro peruenera in mano de dotti, & indotti) non ho uoluto exquisitamente solum per gli huomini eruditi, & intelligenti scriuere, ma con basso, inculto & triuial parlar, ad tutthomo cognito me ha parso exponere quello che a gli strenui, & ualorosi dignissimi militi conuienne."
11. Dell'Arte della Guerra (Firenze 1521).
12. Both works were primarily were concerned with soldiers armed with pikes, but Machiavelli particularly gave attention to their combination with others armed with hand quns.
13. II p.2, l.23/p.3, l.33. The passages given there comprise a large proportion of what Delle Valle had to say on fortification. He quite clearly expressed in them two basic needs in the structures he was considering: one, to provide artillery positions, probably internal to the structure rather than simply as platforms; and two, to be able to withstand punishment.
14. II p. 2; l. 1/9. 15. II p. 4; l 7/22. 16. II p. 4, n. 1.
17. II p. 3, l. 34/ p. 4, l. 22. 18. Ibid.

the skill of the Captain reste, not on science but on a particular kind of military skill.[1]

Valle then appears to have accepted the value of 'science' or 'letters' to the military man, to just about the minimum extent necessary to justify the writing of such a book as his, concerned with the practice of military skills with "art and reason".[2] At the same time, while he clearly conceived such science to add dignity to any who practised the military arts, nevertheless it was experience of, and practice in, his trade, that he considered the greatest aid to the soldier.[3,4]

Niccolò Tartaglia

(i) Life[5] and work

Niccolò Tartagli, born probably in 1499, was the son of a courier of Brescia. He went to a reading school at a young age for a few months. However his father dying when he was 6 years old, it was only at the age of 14 that he "willingly" went to school to learn to read; and had to leave, in the well known incident, for lack of money, having learnt only half the alphabet.[6] Thereafter Tartagli explained, he never took any other preceptor but "in company with that daughter of industry named poverty, continually studied the dead authors".[7] Tartaglia himself placed in this same period his early fascination with mathematics, saying that in 1514 "principiai a dilettarmi, et a studiare in tal faculta".[8]

In his late teens Tartaglia migrated to Verona for reasons that are not altogether clear. He lived there till 1534,[9] practising the profession of "maestro d'abbaco",[10] taking private pupils and probably teaching also. Documents relating to the end of this period (1529/33) show him in charge of a school, in possession of a family, and in poor financial circumstances. In 1534 he moved to Venice and remained there for the rest of his life except for a short period of some 18 months in the years 1548/9 when he was back in Brescia. In this later period Tartaglia is known as publically teaching, debating and publishing.[11]

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1. II p. 4, l. 23/35. 2. See II p. 2, l. 22. 3. II p. 4; l. 23/35.
4. In terms of the way Valle actually handled problems in his text, it is by no means so clear that he depended as closely on experience and actual practise as he sometimes wanted the reader to believe. A number of his machines look very much like the productions of the literary tradition of such figures as Bellifortis, Il Taccola, Francesco di Girogio and many others. His illustrations and discussion of water clocks particularly have a rather crude impractical look, and the whole subject of ranking arrays of soldiers can have had only the least connection with actual behaviour on the battlefield. TAFURI (1744/60) stated that Valle "Si esercitò equalamente nelle armi, e nelle letteri" but as there seem to be no other literary works by Valle known, this seems rather over-generous.
5. The basic outlines of Tartaglia's biography as given here are well known. A good deal of the information, particularly about his early life, comes from the Quesiti et Inventioni. The details of his biography however remain in many ways obscure.
6. Quesiti et Inventioni (1546) f. 75b.
7. Ibid. "cosi da quel giorno in qua, mai piu fui ne andai da alcun altro precettore, ma solamente in compagnia di una figlia de pouerta chiamata industria. Sopra le opere de gli huomini defonti continuamente mi son trauaglito."
8. With regard to the extraction of roots. Trattato di Numeri et Misure (1556/60) Bk. II, f. 27b. (pagination repeats here, it is the 2nd. f. 27.) (At f. 27a (1st. 27) Tartaglia had given the 'practical' example of forming a square battle of 9623 infantry, as a problem in square roots.)
9. FAVARO, A: "Per la Biografia di Niccolo Tartagil" Arch. Stor. Ital.71, vol. I (1913), 335/72, p.348. Favaro collated many of the scattered remarks of Tartaglia about dates, which do not altogether agree, and concluded that Tartaglia's migration to Verona was between 1516 and 1518, and that he left for Venice at this later date.
10. Thus he is entitled on documents of 1529 and 31, ibid. p. 349/50.
11. Ibid. generally.

Among his pupils were eventually to be Richard Wentworth, Maffeo Poveiano, who published an arithmetic in 1582, Giovanni Antonio Rusconi (c. 1520/87) whose edition of Vitruvius was posthumously published in 1590, and Giovanni Battista Benedetti (1530/90).[1] Tartaglia died in relative poverty in December 1557.[2]

The Nova Scientia seems to have been Tartaglia's first published work. He explained that it was in 1531 when he was living in Verona that he first began to get interested in the problems of gunnery, stimulated by the questions of an old bombardier,[3] and that having done quite a bit of work on the problem it suddenly came to him that he was working on a very evil problem, and so he stopped work in this area and destroyed all his notes. It was, Tartaglia explained, the new movements of the Turks that made him eventually decide to publish on this topic.[4] This seems to have been in 1537.[5]

In 1543 Tartaglia published his translation of Euclid, the first in any living language.[6] That same year, his Opera Archimedis, a Latin version of some of Archimedes writings after William of Moerbeke's 13th. century version, appeared.[7] In 1546 the first edition of the Quesiti et Inventioni appeared.[8] In 1547/8 the debate between Tartaglia and Lodouico Ferrari appeared in print. The Travagliata Inventione, a little treatise on marine salvage was published by Tartaglia in 1551, together with a translation after Archimedes' De Insidentibus Aquae. Tartaglia's last work Trattato di numeri et misure was in the process of publication when he died. Parts I and II had been published in 1556, while the other four parts did not finally appear till 1560, although many copies of parts III and IV had been printed already by the time of his death.[9] After Tartaglia's death, Curtio Troiano, who completed the publication of this last work, published from Tartaglia's papers Jordani opusculum de ponderositate (1565).[10]

During all his career as a writer of these works Tartaglia often responsible for the financial outlay in the production of his works.[11] He also probably acted at the vendor of his own works a good part of the time.[12]

1. D.S.B., which mentions a mss. (Bod.584) probably by Wentworth. Rusconi's Architetura is there stated as of 1540, but this seems to be an error. 1540 was the date when he had finished an earlier redaction. (DZ ENC ARCH URB; see also below p. 199)
2. For Tartaglia's will se BONCOMPAGNI, B: "Intorno ad un Testamento inedito de Nicolo Tartaglia" Collectanea Mathematica, L.Cremona & E.Beltrami (eds.) (1881 Milano) 363/405. For an inventory of Tartaglia's possessions at his death see TONNI-BAZZI, V: "Frammenti di nuove richerche intorno a Nicolò Tartagli" Att del Cong Int di Sc Stor, Rome 1903 (1904) Vol. XII, 293/307.
3. Nova Scientia (1537), Sg. *iiia.
4. II, p. 6.
5. See II, p.5, n.1. for the possibility that this work was only issued in 1538.
6. See II, p.7, n.3. D.S.B. by Arnaldo Masotti; see also the same author Commemorazione Niccolo Tartaglia (Brescia 1957).
7. See D.S.B. This work was published at Venice and bears the date of April.
8. See II, p. 12/13, for description and bibliography.
9. The inventory of Tartaglia's possessions at his death included "107 opere del Tartaia de numeri omisure parte prima et seconda; 150 della terza parte; 150 della quarta parte in foio". See TONNI-BAZZI p. 297 op. cit.
10. D.S.B., RICCARDI (1893)
11. The colophon of the Nova Scientia (1537) simply states "ad instantia di Nicolo Tartagli"; but the colophon of the Quesiti et Inventione (1546) stated more definitely "ad instantia et requesitione, & a propria spese de Nicolo Tartalea" (II p.5, 1.11) Opera Archimedes (1543) reads "sumptu & requisitione Nicolai de Tartaleis". The Travagliata Inventione (1551) has the same wording as the Quesiti et Inventione (1546). Neither parts I or II of the Trattato di numeri et misure (1556) have a colophon, but the title page of pt. II states "appresso dell'autore". The translation of Euclid of 1543 in contrast associates Tartaglia with others, including a bookseller, as publishers, see II p. 7, n. 3.
12. Tartaglia's will read "Io mio attrouo libri del mio general trattato de numeri, et misure, et di mei Quesiti, et inuention diuerse circa quatrocento parte nel mio magazen da basso, et parte in una mia camera. Item mi attrouo circa .60. opere della trauagliata inuentione.....Item mi attrouo circa quaranta libri di nouuo sciencia...." (BONCOMPAGNI op. cit. p. 406/7) The last edition of the Nova Scientia before Tartaglia's death was in 1553. The Quesiti, 1554. The Travagliata Inventione, 1551. After RICCARDI (1893).

(ii) Tartaglia's ideas on technology and their relationship to his personal career

Tartaglia is perhaps best remembered for his position in the history of mathematical thought. Yet the record of his published works shows him to have been equally as interested in technology and the applied arts, if not more so, than in 'pure mathematics', albeit generally in those areas where mathematics was important.[1]

Further, Tartaglia grounded his interest on a definite position with regard to applied knowledge, which, although he never attempted to discuss it in detail and at length in any one place, was clearly expressed from time to time, in different aspects, in his writings.

Firstly Tartalia refused to accept the relatively low status accredited to practical knowledge in comparison to speculative or contemplative knowledge, the utility of practical knowledge gave it its own value he insisted.[2] In additon, while Tartaglia did not reject outright the distinction between speculative and practical knowledge he did tend to gloss it over by considering the later as operative as against the former as contemplative. For example, the "practice of Arithmetic and geometry" and the "practise of knowing how to operate and actually execute and exemplify whatever proposition is wished in these two sciences", Tartaglia contrasted with "the contemplative Geometrical and Arithmetical doctrines of Euclid".[3] Thus in comparing applied knowledge to contemplative knowledge Tartaglia emphasised the active worker in the former case, whether in mathematics itself or in an applied field.[4] In this way he tended to break down the traditional distinction between these different types of knowledge, as he sought to raise the valuation of the traditionally less favoured branch, the very association of some aspects of mathematics pure and simple, with more practical tasks, aiding the process.

But Tartaglia's insistence on the benefits and significant status of operative knowledge, was not, particularly with regard to technology proper, simply an isolated declaration. It was connected with other ideas of his about the nature of knowledge. Tartaglia put forward, more than once a particular belief about the way knowledge was attained, general in nature, but asserted in technological contexts. The inner eye, he wrote, sees into universals, more

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1. The Novo Scientia, the Quesiti et Inventioni and the Travagliata Inventione were all works basically, if not wholly, concerned with technological problems. In the translation of Euclid he clearly indicated in his dedication that the practical value of geometry was one of its main benefits. (See II p. 9/10.) He expressed the same interest in practical application in his Trattato di numeri et misure (See II p.21/22.) and explained there that he felt it necessary to write on the operative aspects of mathematics in this work to complement his translation of Euclid. (See II p.22, l.13/24.) Even in the Cartelli while the tracts were explicitly related to the debate with Ferrari on mathematical problems, practical questions in such areas as architecture and geography occured. "de disputare con ambidui largamente in Geometria, in Arithmetica, & in tutte le Discipline che da quelle depēdono, come Astronomia, Musica, Cosmographia, Prospetiua, Architettura" Riposta...da Nicolo Tartalea 1547 del Mese di Febraro. (1000 copies printed.)
2. See particularly the dedication to the Trattato di numeri et misure (II p. 21/2.) But also the dedication to Euclide Megarense (II p. 9/10) Even in the dedication to his Opera Archemedis Tartaglia wrote "Accedūt etiā plurima, & maxima tua in me beneficia, quae nec ingenio, nec arte, nec ulla deniq facultate paria possent referri, ad hoc etiā me maxime inputit egregiū tui ingenij & acumē quod ego (absit ois adulato) cū in Euclidis, & Appollonij Pergei lectionibus, tum in Algebrae speculatiua pratica, ac diuinae proportionis & alijs in rebus diuinum prope noui..."
3. II p. 22, l.2 et. seq.
4. Tartaglia often used the locution "speculative practice" further weakening the boundary of the traditional distinction and emphasising this pattern. (ibid. also in the table of contents of the Quesiti et Inventioni in the section on Bk. IX, referring to cossic Algebra (see II p. 13); again in the dedication to his Opera Archimedis (see n. 1 above).

cossist ?

clearly that the corporeal eye sees particulars.[1] It was thus in the field of universals that technical knoweldge was to be found, in Tartaglia's view.

This had two important implications. Because mathematics, and particularly geometry, dealt with universals by its very nature (and then with the greatest degree of certainty) the employment of mathematics, and particularly geometry, was to the greatest advantage in technology.[2]

But additionally, because the examination of particulars could not give as clear knowledge as the consideration of universals, actual practice, or experience in the practice of an art, was largely irrelevant to any sophisticated understanding of that art. It was the kind of activity, similar to that undertaken by a mathematician in mathematics proper, quite separate from practice in the relevant field, that gave the greatest understanding in technology, in Tartaglia's view. Again and again, proudly, and as if it was something miraculous, Tartaglia affirmed his lack of experience in the practice of the arts with which he dealt, yet insisted on the great value of the contributions to understanding in them that he could provide.[3]

Thus Tartaglia believed, on the basis of an epistemological principle, that a certain type of activity, fundamentally the same as that of the contemplative mathematician, and quite different from that of the craftsman, would lead to the best technological knowledge. Hence the style of activity necessary to practical knowledge, its raised status, and its epistemological basis all interlocked in Tartaglia's thought.

Further, what might have been a difficulty with Tartagilia's position with regard to the advantage of the use of mathematics in the practical arts, was minimised by his particular approach.

Traditionally mathematics had been recognised as a particularly interesting branch of study because it involved the highest degree of certainty. But equally, traditionally, the use of mathematics in 'mixt' disciplines, was understood to give certainty only in so far as a discipline was mathematical. Tartaglia, while on the one hand he tended to ignore this reduction in certainty, though undoubtedly he was aware of this view,[4] on the other hand by reducing to the absolute minimum any contribution from practice and insisting on the predominance of the mathematical contribution in practical knowledge, he equally minimised any reduction of certainty in this kind of mixt discipline, further enhancing the strength of his position.

Tartaglia's position on the nature of practical knowledge, while it had its own internal consistency, equally reflected his own career pattern. During twenty years he published works often with a strong technological emphasis, and he simultaneously cultivated mathematical activities more distant from application. Thus his actual activities as a mathematician reflected his notion of <u>operative knowledge as covering practical knowledge and operative knowledge in</u>

1. II p. 18, l. 43/6; p. 13, l. 10/15: the first in the context of both ballistics and fortification, the second in the context of ballistics alone, where Tartaglia wrote of the 'inner sense' rather than 'eye', both from the Quesiti et Inventioni. In his translation of Euclid (II p. 9, l.1/6). Tartaglia put forward the same type of view in a rather standard way in the context of geometry.
2. II p. 9/10
3. See II p. 13, l. 4/5. from Bk. I of the Quesiti et Inventioni (1546). Note 7 ibid. for the same idea in the Nova Scientia. II p. 18; l. 33/40 from Bk 6 of the Quesiti et Inventioni all concerning the art of gunnery, with fortification design at issue also in the last case. II p. 14; l. 4/7 from the later work concerning fortification alone. II p. 17; l. 9/10 ibid. for drawing and making models. But in the Travagliata Inventione (1551) Sg. ciiiia Tartaglia was inclined to admit that his lack of familiarity with practice may have been disadvantageous. "dubitando per la mia poca experientia nelle cosa del mare de non incorrere in qualche strania opinione."
4. See the edition of Sacrobosco Tartaglia used, by Peter of Ailly for a traditional expression of the relevant views here. II p. 8 n. 2; l. 7/25, for Tartaglia's own expression of the same views. But see II p. 9; l. 7/13, for Tartaglia's tendency to ignore this problem.

mathematics itself. His activities in practical knowledge were distinct from, and little dependent upon, experience in craft practise, and he put forward views to support such activities in that field. He cultivated mathematics and emphasised the value of mathematics in technology. He cultivated practical mathematics and insisted on its high status.[1]

In another way however, in regard to the economic value of his knowledge, Tartaglia seems to have been somewhat ambiguous. On the title page of his translation of Euclid he indicated that the work could be understood without preperation in other sciences by any "mediocre ingegno".[2] He sought therefore a wide audience and implied, by his insistance on the great value of such mathematical knowledge in so many areas,[3] that it would be of great value to many. He thus seems to have favoured the wide dissemination of his knowledge, and to have attempted to encourage this with that particular work. But his publishing policy at other points, was rather different. Often he had a tendency not to disseminate his knowledge but rather to hoard it and to keep its details secret.[4]

There seem to have been two factors rather in tension in Tartaglia's position here. On the one hand it was to his advantage to sell as many of his books as possible, both in terms of a direct financial reward he might hope to reap from their sale,[5] but also by way of the widest possible advertisement of his skills,[6] from which he might have hoped to have benefited by way of paying pupils or employment by patrons. In order to sell the greatest number of books and to increase his reputation, it would then presumably have been to his advantage to include his latest and best results. But in such a case he would have tended to reduce the value of his personal tuiton or advice, no longer possessing a monopoly of those secrets to personally communicate.

Thus is seems likely that Tartaglia could not find a sufficiently secure position economically in order to confidentially publish all his wares.

(iii) Tartaglia's ideas on fortification.

Tartaglia's ideas on fortification were published in the course of a career which involved the cultivation of practical knowledge in many areas, particularly those dependant on mathematics, in conformity with a particular set of ideas, which included the publication of results in these areas, probably as much to increase the authors reputation and to attract pupils, as for any other reason. His ideas in fortification therefore not unexpectedly bear the marks of this background.

Firstly, as in other fields, Tartaglia denigrated experience or practice as the primary base for achieving the best results in fortification.[7]

1. See above his title of master of the abacus. FAVARO (1913) p. 353 notes a case of 1533 where Tartaglia acted as a computational expert in a disagrement about reciepts and monies paid. 2. II p. 7, n. 3.
3. As in the introduction to this work, see II p. 2, l. 7 et.seq.
4. As in Bks. IV & V of the *Nova Scientia*, II p. 5, n. 4ff. something on gunpowder appearing later in the *Quesiti et Inventione*. But the full account of his ballistics of Bk. IV never appeared. Equally in Bk. VI of the *Quesiti et Inventioni* in the first edition Tartaglia laid down principles for fortification, but did not publish his results showing how those principles might be conformed to until the later editions. Of course the Cardano controversy revolved around the whole question of secrecy.
5. Tartaglia may have acted as his own publisher so often for this reason (see above p.10, n.11). That he made any great sums in this way, however, is very doubtful in view of the poverty in which he died. (Above p.10, n.2f.) Again the numbers of copies in his possession of Pt IV of the *Trattato di numeri et misure*, which was not yet issued at his death, of 150, seems to indicate a run of just this number. It is hard to see much income being derived from such short runs.
6. See on the first ripost in the Cartelli where Tartaglia stated "Accioce...non vi paia molto privata ne ho fatto imprimere 1000. per mandarne anchora io generalmente per tutta Italia".
7. II p.14; l. 4/7. His remarks on the defenses of Turin as a whole follow this pattern. (See II p.15; l. 6/10ff.) The interogator says it is judged by many ingenious men to be impregnable, but Tartaglia just dismisses this.

Further he insisted the form of the structure alone, was the indicator of achievement in fortification.[1] The form of the structure being just that aspect of the fortification that could be approached through geometry, and which could be considered and discussed in terms of the universals of that discipline, in an activity distinct and different from any mere practice, wholly in accord with his general position. But here Tartaglia introduced a special consideration. It was only through the examination of the form of the structure that the skill and achievment of the designer could be assessed, he insisted, and for this reason the form was all important.[2] Places strong by nature could not indicate the skill of the designer, Tartaglia stated, and dismissed them from consideration.[3] Equally, he insisted, the disposition of mere material mass did not indicate much skill on the part of the designer, so that only the form that resulted in a strong structure was worthy of consideration.[4] But why might a strong site not be handled to become stronger? Or material selected with ingenuity ? Plainly it was only by assuming that form was the crucial aspect of design that Tartaglia could insist that this was the only aspect that could demonstrate human ingenuity. Thus his whole argument that form was crucial because it alone demonstrated human ingenuity, was hopelessly circular.[5] There seem to have been at least two very good reasons why Tartaglia did perhaps automatically assume that form was crucial in design. In the first place as noted above, this gave an approach to the problems of the field wholly consistent with the sorts of ideas he cultivated with regard to technology in general and with the kind of career he followed. Secondly there is no doubt that despite Tartaglia's insistence on the minimal role of experience and practice, he picked up a good deal from what was occurring in his period in fortification practice; and that the notion of the importance of form in fortification was, at the time to a fair extent a prevelant one. Certainly the idea of the pointed bastion, dependent on the principle of no dead ground, was an idea which concentrated on the plan form of the fortress, and Tartaglia clearly knew this form.[6] Thus his own personal views on technology and what was already happening in fortification practice allowed him all too easily to assume that form was the crucial factor in design. Once he had made this assumption his insistence that human ingenuity could only be seen in the form of a structure functioned essentially as an assertion about what was the relevant criterion in design, a criterion wholly congenial to his general ideas about technology and the activity of design. This conception then allowed Tartaglia to set up the 6 general conditions, which he stated any design had to conform to, which centered almost exclusively on form.[7] The result was to a great extent a mathematical puzzle, whose solution he withheld until the 1554 edition of the _Queseti_, where he was able to demonstrate his own personal ingenuity.[8]

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1. _II_ p. 14; l. 21/25.   2. Ibid; _II_ p. 15; l. 23/32.
3. _II_ p. 15; l. 13/24.   4. _II_ p. 15; l. 24/34.
5. Because of the significance of this argument in 16th. century fortification in general a more thorough discussion of its circularity is given _II_ p. 23/6.
6. He shows pointed bastions in his drawings of Turin, albeit on a very small scale. It is inconceivable that he did not realise what was going on there. Again in the addition to the 1554 edition he used this shape in his solutions to his 6 considerations and gave a characteristic geometric argument showing his familiarity with this form.(See _II_ p.20; l.1/14.) That he did not trumpet forth such an idea as his own, and as representing the advantage of concentrating on form in accord with his predilections, must be taken as an indication of how much common coin it had become by his time.
7. See _II_ p. 12/13.
8. Despite the rather abstract nature of Tartaglia's approach at least some contemporoary fortification workers found it of interest. For example Castriotto wrote to Tartaglia in 1549 sending some of his own designs and notes for comment, and remarked favourably on Tartaglia's contributions to military matters in this area as well as generally. See TONNI-BAZZI, op. cit. who gives the letters in full p. 301/3.

Pietro Cataneo and his life and work in fortification

Pietro di Giacomo Cataneo[1] was born in Siena around 1500.[2] He studied architecture with Baldassar Peruzzi (1481/1536)[4] who was appointed architect to the republic of Siena in 1527, and design with the painter Domenico Beccafumi (1486/1551).[3] In 1539 Pietro received the title of public architect at Siena.[2] From 1543 to 1548 he worked on the fortifications of Orbetello.[5] It was during this period in 1546, that Pietro published a textbook on mathematics.[6] In 1548 he worked at Talamone. In 1552 he was appointed to advise on the fortification of Caparbio.[2] His work on architecture and fortification appeared in 1554,[7] and he published an enlarged edition in 1567.[8] He died in 1572/3.[9]

That Pietro's first published work was in mathematics suggests that he may have been particularly interested in this area as a youth. However it was a very elementary work concerned mainly with such topics as the basic mathematical operations at a beginners level, while its geometrical sections were concerned with rather elementary problems like simple area calculations without proofs. His geometrical book in the enlarged edition of his work on Architecture was similarly concerned mainly with simple constructions mainly without proofs, comprising the geometry necessary to an architect,[10] according to Pietro himself.

Pietro's mathematical training was then probably not at any very high level,[11] and his writings on fortification as given in his I Quattro Primi libri di Architecttura, which was much concerned with this topic,[12] reflected this pattern. Mathematics, particularly at any sophisticated level, was not for Pietro of primary importance in architecture and fortification. Rather his treatment was more Vitruvian. He began with a discussion of the skills of the architect, and while mathematics figured strongly there, equally, more general topics such as History and Medicine were bracketed with arithmetic and geometry, in this context.[13] After opening on this topic Pietro then went on to discuss sites from the point of view of these general

1. Thus VENTURI (1901/39) gives his full name. DZ ENC ARCH URB prefers Cattaneo.
2. After PROMIS (1841)A.
3. VENTURI (1901/39) vol. XI,2, p. 656. Pietro's association with Beccafumi seems to have been relatively close. His sister Caterina married this painter in 1533, and Vasari mentioned a very good painting of Beccafumi's in Pietro's possession (VASARI (1878/81) Vol. 5, p. 653 & n. 4)
4. In 1520 Peruzzi had been associated with Antonio da Sangallo in connection with St. Peter's Rome. He had probably been a pupil of Francesco di Giorgio. (DZ ENC ARCH URB).
5. VENTURI (1901/39) ibid.
6. Le pratiche delle due prime Mathematiche (Venetia 1546*). Reprinted Venetia 1559; Venetia 1567. The later editions carry the original dedication of 1546. See RICCARDI (1893) for details of the first edition.
7. See II p. 27.
8. See II p. 30.
9. VENTURI (1901/39) vol. XI.2, p. 656. For further biographical details see Luigi di Angelis Elogio de Pietro Cataneo Senese (1822*) used by bothe Venturi and Promis. Venturi mentions many references to Pietro in Romagnoli, m.s. cited in Bibl. Com. di Siena, L, II, 7.
10. See II p, 30 contents & l. 1/16.
11. If Pietro had been highly sophisticated mathematically one would have expected some indication from him that his mathematical work was intended only as an elementary introduction. But nothing like this appears in the dedication for example; and Pietro seems to have been quite happy to present his work on what he terms "mathematical practice" as a reasonable contribution to the art. One suspects his mathematical training may have been not very much more than that which was felt necessary to the architect and painter of the time. He wrote there of "uolendo nel largo campo de gl'humani ingegni seminare alcun seme delle Pratiche Mathematice, mè parso i (e non senza ragione) ricorrere alla benigna S.V. come quella che ama et difende ciascuno che nelle uere dottrine si essercita, & massime in Geometria & Arithmetica lequali sino da i teneri anni suoi furono con altre nobili scientie da lei desiderate e compiutamente acquisite". To "Mons. il S.Marcello Cervini, Card. di Santa Croce".
12. Bk I is mainly concerned with fortification or related matters, and takes up nearly half the work. See contents II p.27.
13. See II p. 28; l. 16/31.

'disciplines,[1] following the Vitruvian pattern.[2] Pietro deviated from Vitruvius in these sections perhaps to the greatest degree in the very strong emphasis he put on perspective.[3] While Vitruvius listed drawing skills as important to the architect, he certainly never picked out perspective as of such importance and his whole emphasis on this whole area was nothing like as strong. The source of this emphasis must be seen in Pietro's early training with painters as well as architects and in the particular interest of the period in that area.

Still, like Vitruvius, Pietro saw fortification as but one part of architecture in general,[4] and so dealt with it in a single work under that title. Nevertheless, in contrast to Vitruvius Pietro's work was dominated by this topic while Vitruvius gave this subject only the barest passing mention. But again like Vitruvius, Pietro gave an important section on materials, which was concerned with this topic in a general way,[5] the relevant information being applied in the specialised fields as requisite.[6]

Thus Pietro's approach to fortification and architecture was rather that of the literary and discoursive[7] Vitruvian tradition, with a certain emphasis on perspective in accord with the approach of his time.[8]

Further, when Pietro came to present the actual forms of structures he presented typical geometric bastion systems, and in fact showed them clearly and explicitly in print for the first time. Yet while lines of fire as defining the layout of the faces of the bastions were clearly shown Pietro gave no general or detailed discussion on this type of geometric approach, and the employment of this form was presented rather as an accepted principle of his period.

Thus Pietro presented his ideas on fortification in the context of a rather traditional approach, even though he set out the new forms clearly in print for the first time; he accepted the literary discoursive tradition, and the approach to fortification as but one branch of an architecture concerned with a whole range of topics, of which the form of the structures was but one part. Equally he presented the desirable forms of structures as simple givens without fundamental commentary on their basis. His training with Peruzzi who had worked with Antonio da Sangallo and been influenced by Francesco di Giorgio, and his practice in fortification, which can hardly have avoided discussions with other engineers of his time,[9] must be taken as the source of

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1. As does Vitruvius in Bk. I Cap. I.
2. Vitruvius began Bk. I with a discussion on the nature of architecture in general. Then in Cap. IV he discussed sites from the health point of view, and in Cap. V walls and towers. Then he gave a section on buildings within the walls, and the sites of public buildings. In Bk. II he wrote on materials; in III & IV on temples; in V on public buildings; in VI on town and country houses. This is exactly the pattern Pietro followed. (See contents <u>II</u> p. 27.)
3. See <u>II</u> p. 28; l.24 et. seq. The 1567 edition devoted a whole book to the subject. (The 8th. see <u>II</u> p.30, contents.)
4. Pietro practised as both a civil and a military architect. The palazzo Francesconi (Siena) for example can be attributed to him by a letter of 1563. (See VENTURI (1901/39) vol. XI.2, p. 672.
5. See <u>II</u> p. 29; l. 36/41.
6. The contrast here is with Tartaglia's approach by way of the principles to which the structure had to conform; and equally with Valle's little book where the approach is that of the military man and materials are only discussed in so far as they related to fortification.
7. 'Literary and discoursive' in the sense that historical examples are often the main basis of the argument, for example. <u>I Quattro Primi Libri di Architettura</u> (1554) f. 7b, "....come Roma, Cartaigne, Atene, Capoua, Napoli, Corinto, Constantinopoli, Venetia, & altre sono state edificate in buono & perfetto sito.." This sort of comment occurs again and again in Pietro's early section on sites. Compare Tartaglia. Vitruvius's discussion on sites was very similar (Bk. I Cap. IV).
8. Pietro's emphasis on mathematics was perhaps somewhat stronger than that of Vitruvius, but compared to other authors in this field by no means so strong.
9. As for example in the well known discussion on the fortifications of Rome during the 1540's.

these particular forms.[1] The charge of pla ism made by Palladio against Pietro with regard to a particular invention which Palladio claimed as his own,[2] supports this pattern of Pietro presenting ideas that were current in his time rather than being an innovator.

Pietro's work on fortification was then rather a work-a-day production, like his book on mathematics, which picked up and put together various strands of the period. Significant rather for its presentation of clear illustrations of the structures though desirable in his time, rather than for its fundamental ideas or innovations. But of interest in that a practising architect thought it worthwhile to write such a work.

Giovanni Battista Zanchi and his book

Giovanni Battista Bonadio Di Zanchi da Pesaro[3] was born in 1515 at Pesaro into a family which in the 15th. century had produced many literary names at Venice, from where his father had migrated. In 1543 he held the rank of captain at Pesaro, and three years afterwards he was in Germany with a papal force. He found military employment during the war of Siena and then in that of Carafa (1553-57). With peace he returned to Pesaro. In 1561 he was appointed engineer in Cyprus for two years by the Venetian Senate, at 50 ducats per month. At a later date he worked for a period in Ragusa. Afterwards he was involved in actions against the Turks. A notice puts him alive and in Pesaro in 1586.[4] Maggi called him "uomo ingegnosissimo e di ualore";[5] and Ruscelli wrote of him as "d'auer sempre atteso al mestier dell'arme et insieme alla teorica et alla pratica del fortificare."[6] Zanchi's only published work, Del Modo di Fortificar La Città (1554) appeared at the instigation of Girolamo Ruscelli who read it in manuscript at Venice where Zanchi left it for him when going abroad.[7]

In his treatise Zanchi indicated at a number of points that he considered fortification to require a firmly established rule or method.[8] The realm in which this rule or method was to work, Zanchi delimited firstly by eliminating such problems as the morale or spirit of the defenders, and

1. These forms had of course, been coming into use for many years before (see below) and Pietro received his training at the hands of the generation which developed them. ENCY ITAL states that Pietro's work was in "direct pl ism from Francesco di Giorgio through Peruzzi" but Pietro's work was so dependent on Vitruvius's text, and the forms of structures he showed were so clearly common coin at the time, that this is hardly apt. But the 'disegni' in the Uffizzi Florence No. 3275/3381 attributed to Pietro in many cases certainly do show drawings completely derived from that author. Some equally are reminiscent of Leonardo's drawings, and some of Michaelangelo's. Machines are also shown there in a tradition going back as far as such figures as Taccola. According to MALTESE (1967) p.lxiv Pietro copied Francesco's drawings in these cases c. 1533.

2. PALLADIO (1570) Bk. I, Cap. XIII, p. 15. "mi son nondimeno maggiormente cõfermato in questo mia inuentione, poi che tanto è piacuta à messer Pietro Cataneo,....che l'ha posta in vna sua opera di Architettura, con la quale ha non poco illustrato questa professione". The invention referred to concerned a way of setting out the diminution of the diameter of the column with height. Pietro gave this in Bk. V, Cap. XI of L'Architettura (1567). Vitruvius Bk. III, Cap. II gave the difference in diameter between top and bottom but the way the diameter diminished was not given because he refered to a drawing which did not come down from antiquity. Certainly Pietro gave a rule of the same nature as Palladio's beginning with the first third with an undiminished diameter. and using a spline to get the curve.

3. So he appears in the portrait in his work. Promis preferred the form Giambattista. The title page of his treatise gives Giovambattista, and Ruscelli used this form again in his letter at the end of the treatise.

4. Generally after PROMIS (1874).

5. Della Fortificatione delle Citta f. 26a,(Bk. I Cap. XI and not 2 as given in PROMIS (1874)), 1564 ed.

6. Le imprese illustri (Venetia 1584/3) p. 435.

7. Letter in Zanchi's treatise by Ruscelli p. 62. PROMIS (1874) stated "alle mani sue fosse capitato il ms. consegnato dall'autore ad un amiço comune in Venezia". But Ruscelli wrote (p. 62) that Zanchi "partendosi questi mesi a dietro di Venetia; mi lascio un trattato che egli ha fatto interno à questa delle Fortezze". Zanchi on his return to Venice, Ruscelli explained, gave his permission for its publication.

8. II p. 32; l. 12/14: p. 34; l. 21/23: p. 40; l. 1/3.

treachery, from the scope of his approach;[1,2] and then, having outlined the distinction between sites strong by nature and those strong through human artifice,[3] he eliminated, by and large, the former class as being "too tedious" to discuss in detail.[4] Having thus narrowed his topic down to consideration of general rules about the forms of structures[5] Zanchi then simply presented the pointed bastion system in plan form, through discussion of the regular polygons, with some emphasis on the square,[6] and this formed the focus of his approach.[7]

Zanchi believed strongly that a necessary and very important part of understanding in fortification was to be found elsewhere than in mere practice of itself. More than once he pointed to the use of reason, the need for rule, and a proper foundation in fortification, as contrasted with, and not supplied by military practice or experience.[8] Further, he explained, his treatise was concerned "with all that which it is possible for the human intellect to employ to defend against the force of the enemy",[9] and it was clearly on the plan trace of the fortress that he saw the human intellect acting.[10] Again when he discussed the regular polygons of few sides he allowed himself to get tangled in a very abstract type of discussion on figures of two angles, which is by no means clear.[11] Here the sort of abstract geometrical discussion in which he was involved seemed to take over Zanchi's mind completely as something with its own significance, apart from any application to actual practical problems.

Thus in the general ideas that he expressed, and in the sorts of structures he presented Zanchi was keen both to present and cultivate a type of approach that was intellectual, that is of the mind, and of a very different nature to mere military experience in these same matters.[12]

On the other hand as a practising military man Zanchi never denigrated the value of practice or denied its necessity to the understanding of his subject.[13] He sometimes tended to suggest that the correct methods that were to be practised in the intellect could grow out of actual military practice, but he had to admit that this in fact did not generally occur.[14]

Thus a practising military man like Zanchi in writing about the general fortification style of his time was not content with the lessons of actual experience, but felt a need for a general, and firmly based approach in his whole topic.

1. II p. 31/2: p. 34/36.
2. Such discussion had of course figured in many works such as those of Vegetius and Frontinus which had been published earlier, and Machiavelli had been much concerned with such problems.
3. II p. 37; l. 9/39. 4. II p. 38; l. 40/46.
5. This process of limiting the scope of the discussion to just that area which was handled by Zanchi through the use of the geometric bastion style, may have been a gradual build up simultaneous with the development of his manuscript. The discussion of the strength of a fortress being due to art or nature, is very much clearer than many of Zanchi's other preliminary remarks -- as on treachery and robbery for example. Equally these other preliminary sections eliminating the element of morale from the discussion do form a relatively coherent introduction in themselves. It is possible that while Zanchi was working up his manuscript (and PROMIS (1874) puts its composition after his return from Germany in 1546), he came across Tartaglia's remarks on the same topic and was able to neatly fit a derivative discussion in. The earlier version would then have had the elimination of morale as the preliminary problem and have moved straight on to the discussion of general forms. This would explain the relative coherence of these sections taken alone; the way in which the 'Tartaglian' section does not seem to effect greatly the treatment of other sections; and why it is so much clearer. However this does not take away from the fairly high coherence of the actual finished work. Zanchi himself indicated that he had perhaps not achieved all the clarity of expression that was to be desired, and wrote in his dedication (p. 8) that perhaps later commentators might increase and give better form "a quello ch'io non hauessi ò saputo ò potuto si apertamenti & con facilta esprimere". Thus the relative clarity of Tartaglia's remarks was probably very welcome to him. 6. II p. 39, 1st. sect.
7. The general plans discussed p. 22/28; its parts p. 40/50. See contents II p.31.
8. II p. 33; l. 13/18: p. 40. 9. II p. 36; l. 10/14.
10. This forms the core of the book. See contents II p. 31.
11. II p. 39; l. 13.
12. Noticeably Zanchi did not emphasise geometry and mathematics in this context. although he freely used the pointed bastion trace and the notion of flanking fire as a primary determinant of the trace, the geometric notions at work he presented only tacitly without any discussion. Again see II p.40; l.11→ where mathematics is given a rather secondary role. ("in parte")
13. See the same passages where he points to the need for this approach in contrast to that of mere theory, and others indicated above. 14. II p. 33; l. 6/13.

Giacomo Lanteri, his works and ideas

Giacomo Lanteri, possibly born around 1530, bore the name of an old noble family of Brescia, into which he may have been born illegitimately.[1] In 1557 he took part in the defence of Civitella del Tronto[2] and that same year his Delle Fortezze Secondo Euclide appeared at Venice. In 1559 his Fortificationi di terra appeared.[3] In 1560 Lanteri published a little treatise Della Economica on the organisation and running of a household.[4] His published treatises seem to have gained him some reputation[5] and in 1563 he was receiving a stipend from the King of Spain with the title of Chief Engineer.[6] He was first in charge of the fortifications of Italy and then took over charge of Africa as well.[7] He is quoted as receiving at Naples a "grosso stipendio",[8] and he died there.

Lanteri was quite emphatic as to the usefulness, and indeed, necessity of the use of mathematics, particularly geometry, in fortification. The title of his first work made it very clear that the work centered on design "according to Euclid".[9] The contents of the book equally followed this same pattern to a high degree, being concerned to a very great extent with a limited number of problems all dealt with geometrically.[10] In all these cases Lanteri was not so much concerned with the geometry of the structure in 3 dimensions, but with the geometry of the plan trace alone. Quite explicitly he made this clear when at one point discussion of the casemates is rejected because their form could not be handled in terms of the Euclidian geometry of their plan.[11] The strength of Lanteri's belief in the power of mathematics is indicated by the extreme position he put forward in one place. Which was, that in architecture in general one could design without the orders, using mathematics alone, as one could in any other area;[12] a very radical sentiment for the time, and although put forward somewhat tentatively, without doubt it was meant to be taken seriously.

Lanteri supported his strong emphasis on mathematics by way of a number of points. Firstly, he insisted that the certainty to be found in mathematics made its use in fortification very desirable.[13] He was equally quite clear that the traditional notion of a proof which gave certainly to views, which otherwise , although perhaps commonly accepted, lacking such proof, had to be considered defective.[14]

1. PROMIS (1841)A suggested this date for his birth. The title page of his 1557 work described him as "da Paratico, Bresciano". Paratico was the family seat of the Lanteri's. In Della Economica (Venetia 1560) p. 116/7 in the section addressed to "Signora Lucretia Bona de Lanteri"
Lanteri wrote of "Signor Sigismondo vostro cosorte, & mio cugino", this tends to suggest Giacomo as a legitimate member of the family, but it is hardly conclusive. The suggestion of PROMIS (1841)A about his illegitimacy is supported slightly by his non appearance in the family records, as for example "I diari dei Lantieri de Paratico di Capriolo" in Le cronache bresciane inedite dei secoli XV/XIX ed. Paolo GUERRINI Vol. 2 (Brescia 1927) p. 54/118, comprising a diary from the 1520's on.
2. PROMIS (1841)A.
3. For details of these works see II p. 41 & 49.
4. See BARBIERI (1961) for an analysis of this work of Lanteri's.
5. Otavio ROSSI Elogi historici di Bresciani illustri (Brescia 1620) p. 311 wrote "con queste celebri fatiche d'ingegno, & con molte altre inventioni intorno alle Matematiche, fece chiaro il suo nome per tutta l'Europa", relative to his writings.
6. PROMIS (1841)A.
7. Leonardo COZZANDO Libraria Bresciana nuovamente aperta (Brescia 1694) Pt. I, p. 101.
8. ROSSI, op. cit. p. 312.
9. See II p. 41, t.p.; and also p. 42/47 generally.
10. See II p. 41, contents and texts generally.
11. II p. 47, 1st. sect.
12. II p. 49 2nd. sect.
13. II p. 42; l. 31/39: p. 43; l. 11/16
14. See II p. 43; l. 36/41. See also Lanteri's remarks about those who proceed only by practice (op. cit. p. 23) "Ma questi tali....non fanno renderne altra ragione per vie d'Euclide, che venghi à prouare la loro opinion..." with regard to the angle of the bastion being less than that of the curtains on which it is set.

Lanteri further supported this position by insisting that practice in itself, however effective, was not to be depended on in fortification and that experience was not essential to effective commentary on the art or to solutions of its problems.[1]

The whole of Lanteri's position empahsising Euclid, mathematics, and the weakness of mere practice, interlocked with his views on the cultivation of understanding in general, in architecture. This was not a study for the base he insisted, rather for gentlemen and nobles. Further it was not the sort of knowledge that would enable a nobleman to actually go out and personally labour on construction of a house -- that would be a very blameworthy thing; rather it was the science of the subject which involved just the sort of certainty as was involved in mathematics.[2]

However, although Lanteri's position as found in Delle Fortezze Secondo Euclide is quite clear, when one comes to look at his practice, matters are not quite so simple. This is particularly the case with his discussions of the construction of the regular polygons. In regard to this problem Lanteri set out the principle that what was required was not a construction which allowed setting out of one particular polygon, but rather a general method by which any polygon of any particular number of sides could be set out.[3] Of course there is no known method for this process in accord with the traditional canons of Euclidean geometry: the septagon being intractable for any solution, for example. Yet, Lanteri proported to give such a rule in Delle Fortezze Secondo Euclide, but in fact all he gave there was a method for constructing any regular polygon, once its angle had been discovered. But of course this last is the central problem of the construction of many of the regular polygons, and in this work he completly glossed this over. He simply selected the case of a square to illustrate the general rule, in which case the relevant angle is a right angle which is easy enough to construct, and then went on to show how replicating right angles and equal sides one arrived at a square, the whole discussion suffused with a pseudo profundity by referring to this petition of Euclid, that definition, some other theorem and so on.[4] While furthermore he did not even give a proof that he had arrived at a square.[5]

In Fortificationi di terra Lanteri returned to this same problem. There he did provide a general algorithm for the construction of any regular polygon. The angle of any such polygon can be relatively easily discovered as a proportion of a right angle.[6] Given this Lanteri simply took an arc subtending a right angle; divided it into a number of equal sections equal to the denominator of the fraction of a right angle which gives the angle of the required polygon; and took a number of those parts along the arc equal to

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1. See II p. 43; l. 42/p.44;l.9.
2. See II p. 48; l. 14/23. In this same passage Lanteri remarked "che si deggiano gli huomini tutti intrattenere secondo il grado loro". See also II p. 48 n. 5.
3. See II p. 46; l. 1/8.
4. See II p. 44; l. 23/p. 46 for the nature of the whole discussion.
5. II p. 45; l. 34/35. He in fact stated that his construction gave a true square by the 30th. definition (of Euclid). In the Zamberti tradition this simply defines a square as of right angles and equal sides. Lanteri made no attempt to show that the last side of the square which he arrived at by joining the end of the third side to the beginning of the first, was in fact equal to its opposite number.
6. See II p. 51 n. 1.

the numerator of that fraction.[1]

Of course there is no known method of dividing up an arc into whatever number of equal parts as is required -- if there were one could trisect any angle.[2] Thus Lanteri offended totally against the traditional canons of Euclidean geometry here and the position he expressed in a general way emphasising certainty, proofs, and mathematical science, as necessary to fortification, produced requirements which he could not fulfil, and which he then glossed over in Delle Fortezze Secondo Euclide, or jettisoned in Fortificationi di terra, in favour of mechanical solutions.[3]

It is difficult to doubt that Lanteri's whole approach in Delle Fortezze Secondo Euclide (1557), dependant on mathematics, and denigrating the value of practice, was an attempt to write a work by which he could gain a reputation in a field in which he probably had little personal experience, if any, and that this was at least in part responsible for his particular kind of approach there.[4]

His later work on fortification however, Fortificationi di terra showed a certain shift away from the extreme emphasis of the earlier treatise. It was much more concerned with practical matters, materials and repairs under siege conditions and so on.[5] This shift may have been due, in part, to criticism of his earlier efforts;[6] but equally it tended to complement rather than supersede his earlier treatise by giving discussion of these more practical problems.[7]

But the aim of this later work was probably not so very different from that of the first -- to gain a reputation through writing about, rather than practice in, the art of fortification.

Lanteri indeed seems to have been relatively successful on such lines, for, it was not long after the period of the publication of these works, that he appeared in a position of some importance as an engineer concerned with fortification to the Spanish crown at Naples.[8]

Girolamo Cataneo and his writings

Girolamo Cataneo was probably born sometime after the beginning of the 16th. century.[9] He seems to have been interested in warfare and cultivated

1. Se II p. 51, n. 2.
2. On which see Tartaglia's remark II p. 46, n. 2.
3. Much derided by 16th. century authors. For example see Errard II p. 219, 1st sect.
4. For example Lanteri's geometric proof of the impossibility of defending a round tower because there would always be an area of dead ground ((1557) p. 25/6) seems to be completely redundant in terms of practice and hence completely parasitic on existing practice.
5. See contents II p. 49; and II p. 50; l. 17/23.
6. See (1559) p. 4. "..le lingue serpentine di coloro, che nulla di buono, fuori che biasimare le fatiche altrui sanno fare; mi mordano acerbamente; à i quali (perioche d'essi nõ mi curo) nõ son per rispondere gia mai cosa alcuna...."
7. ibid. "....questa mia secondo fatica, nata dal desiderio di farui utile, et giouamento, uogliate quale ella si sia accettare con quella candidezza d'animo, ch io lo ui porgo..."
8. During the period in which his books were first published Lanteri's associations and familiarity with Brescia and northern Italy seems very strong. He mentioned a good number of individuals of that town at the end of Bk II of his (1557) work as if they were his regular companions; equally his treatise on economics was dedicated to many of the Lanteri's. It is therefore likely that he only later got service with the Spanish crown.
9. PROMIS (1871) put his birth at around the beginning of the century. But he noted Cataneo as teaching at the Castle of Arco around 1530, while Lanteri stated that this was actually in 1542. (See II p. 44 n. 2.) So Promis possibly got his birth a little early.

Mathematics from his youth on.[1] At some time he served Charles V in Lombardy.[2] He died in the 1570's or early 1580's.[3] Details of the sort of life Girolamo led are scarce. Lanteri featured him as the protagonist of his dialogue of his earlier work, teaching fortification through mathematics at Brescia in the 1550's; he also mentioned him as likewise teaching at the Castle of Arco in 1542.[4] In his first work on fortification Girolamo stated that he had taught verbally in the area for many years,[5] which matches Lanteri's picture. Girolamo began publishing with a calendrical work in 1562.[6] 1563 saw the appearance of his mathematical treatment of arrays of soldiers[7] and the next year his first work on fortification was published.[8] Girolamo had no new publications until his more elementary work on fortification appeared in 1571,[9] although his earlier works had appeared in different combinations in later editions in between. His final work on surveying appeared in 1572.[10] All these works appeared at Brescia. It seems likely then that Girolamo spent much of his life in courts and castles propounding mathematical topics,[11] with particular emphasis on the use of mathematics in warfare, much of the time, but especially later in his life, in and around Brescia. This sort of activity he possibly combined with a certain amount of military practice from time to time.[12]

At a number of points Girolamo indicated that he considered there to be two main sources of understanding in practical knowledge. On the one hand experience, and on the other mathematical knowledge.[13] His concern with mathematics, particularly geometry, ran through all his published works.[14] At the same time the sort of geometry he presented was never of a particulary high level. The instructional section to his <u>Opera Nuova de Fortificare</u> for instance contained mainly simple constructions, such as in replicating an angle,[15] discussed at some length, although with nothing like proofs appearing. This pattern is emphasised by Girolamo's discussion of the construction of the regular polygons, where he gave that construction that had earlier been published by Lanteri[16] involving the division of an arc subtending a right angle into the requisite number of equal parts to arrive at the fraction of a right angle to give the angle of the required polygon.[17]

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1. See <u>Formare una quistissime Battaglia</u> (1563) f. (iiia) where Girolamo stated that he had observed captains and had experience of war "for more than 30 years"; and was had experience as much in mathematics as in warfare (II p. 52). Girolamo's birth might then be put at c. 1508 and his beginning in his profession around the age of 20. He would then be sufficiently mature to teach at Arco in 1542.
2. PROMIS (1871).
3. The dedication to the <u>Opere di misure</u> was dated by Girolamo 1572. Marchetti, when he brought out a two volume edition of all Girolamo's works in 1584 implies he was dead by then. See particulary the dedication to the surveying work.
4. II p. 44 & n. 2 5. II p. 53, 1st. sect. 6. <u>Rota perpetua</u> (see II p. 51.) 7. See ibid. 8. II p. 52. 9. <u>Nuovo Ragionamento</u>, see II p. 55. 10. See II p. 56.
11. The section in his surveying work where he discussed the relation of mathematics with other disciplines, a topic rather distant from his subject matter, has a rather pedagogical ring to it. (See II p. 57/59)
12. But this might not have been too extensive after his youth particularly. PROMIS (1871) states that he never errected any fortification or participated in any war.
13. In his work on arrays he quoted his own competency in both these areas as providing the base for the work. (See II p. 52.). The same sentiment is to be found in his <u>Opera Nuoua da Fortification</u> (See p. 53; 1. 23/29.) In his surveying work he wrote of geometry being 'accommodated' to practice. (See II p. 58; 1. 36.)
14. His first two works on calendrical problems and on the formations of arrays were very explicitly mathematical. (See II p. 51, desc.) His main fortification work opened with a section giving elementary geometrical instruction. (See II p. 52/3.) His more elementary work on fortifcation <u>Nuouo Ragionamento</u> started similarly (See II p. 55.). He described his surveying work as concerned with practical geometry. (II p. 56/57.)
15. This is the first operation he explained here (op. cit. f. 3a). The fourth was on drawing a parallel (ibid. f. 9a)
16. See above p. 20. The relationship betwen Lanteri and Girolamo, of pupil to master suggests that this construction was probably derived by Lanteri from Girolamo, rather than the other way round. Girolamo's rather sketchy but relatively clear accoune he gave op. cit. f. 9b/12a.
17. I.e. the pentagon. The angle = 6/5 rt. angles 

Of course this is a non Euclidian construction as noted above,[1] but it does seem to illustrate the kind of 'operative'[2] geometry that Girolamo thought necessary to the practical arts. For example his work on surveying was equally concerned with operations rather than proofs, and it was generally a work on how to calculate quantities, rather than an explantion of why particular calculations were used.[3] Girolamo certainly seemed to think that this type of approach, even though it might offend in some ways, was a legitimate one; If other sciences use the principles of contemplative geometry, how much more licit will it not be, he insisted, for surveying to make use of this discipline, seeing as contemplative geometry grew out of daily practical geometry (in Egypt with the flooding of the Nile); thus to Girolamo it was reasonable for contemplative geometry to 'accommodate' itself to practical geometry.[4] In the face of such an attitude the use of a non-Euclidian construction for the regular polygons was not unreasonable.

But even as Girolamo sought this 'accommodation', with the possible weakening of traditional standards, he simultaneously gave an account of geometry as a very significant discipline because it treated of lines surfaces and solids, which enter into other sciences and arts, but which in geometry are treated in a general way, so that its techniques provide the proofs necessary to such other disciplines as Astronomy, Perspective, and Natural Philosophy.[5]

Girolamo then seemed to want it both ways. Geometry as a very useful discipline because it supplied proofs in a number of areas. But geometry also as an operative discipline which could supply the non provable method for the construction of the regular polygons, and which ought to 'accommodate' in practical areas.[6]

This tendency to emphasise geometry as involving a very sophisticated discipline, and the implication that very important things were being said, while at the same time the actual way geometry was used was pretty low level, and partly in conflict with such claims, is clearly to be found in Girolamo's main fortification work.[7] Again the construction of the regular polygons makes clear the pattern. For, once the quality of provability has been withdrawn from that construction – and this seems to be more reasonable to allow in the context of Girolamo's ideas than it does in the context of Lanteri's approach – its whole rationale tends to disappear. Because, if the division of an arc is allowed into any particular number of equal segments, why is not the whole circle divided up

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1. The rule Girolamo gave here is slightly different form Lanteri's. Girolamo took the number of sides of the figure, subtracted two, and multiplied the result by two to get the sum of the angles, which was then divided by the number of angles to get the value of any angle. That is, in the case of the pentagon ((1564) f.10a.) "....figura di cinque lati; cauarermone due, restaranno tre lati; doppiamo tre lati, sanno sei angoli retti, & la figura di cinque lati, è uguale à sei angoli retti" The general rule was left to the reader to induct form the examples of the triangle square and pentagon. As Girolamo put it "Et per questa medesima regola conosceremo ciascuna figura fatto di linee rette, è quanti angoli retti si agguagliano i suoi angoli." Ibid.
2. Tartaglia's term.
3. He gave for example 10 pages of tables concerned with guaging of barrels. Op. cit. (1572) Bk. II, f. 29a/30b, 40b/43a.
4. See II p. 58/9. 5. Ibid. 6. Ibid.
7. Opere nuoua da fortificare (1564)

to give the verticies of the polygon ? A much easier and more accurate process one would have thought.[1] But of course then one would have had much less of the rather esoteric geometric manipulation in finding the required angle. This same pattern occurs in the general approach of this whole work. After the geometry of the construction of the pointed bastion has been discussed, there is very little geometrical discussion of any kind to be found in the rest of the book, even though the underlying geometry of the trace of the structures illustrated is a significant element in their design,[2] and such designs form the focus of the rest of the treatise.

The picture that eventually emerges of Girolamo Cataneo's life and work is of a figure with a certain background in warfare,[3] who cultivated mathematics at a fairly low level for the pedagogical position it gave him, with an insistence on the value of the mathematical approach in order to give significance to what he taught through the status such a claim could bring. The fortification style of his period could hardly have been more congenial to such predilections.

Maggi and Castriotto and their book

Iacomo[4] Fursto Castriotto was born at Urbino at the beginning of the 16th. century.[5] He studied under Girolamo Ghenga[6] and served under Francesco Maria Duke of Urbino.[7] In 1542 he was serving at Naples.[8] He was invovled in the discussios about the Borgo at Rome in 1548.[9] In 1549 he was in correspondence with Tartaglia, to whom he sent some of his designs and writings.[10] He worked on fortifications at Sermoneto, Anagni, Paliano[11] and Urbino. He took part in the war of Mirandola and served with the Imperial forces in the Val d'Orcia in 1553. He took service then with the French crown and took part in the sieges of Mariemburg (1554), S. Quentin (1556) and Thionville (1558).[12] He was also involved with design work at Calais in 1558.[13] In his service with the French crown he was involved in fortification work at many sites[14] and he died at Calais in 1560 holding the title of General over the fortresses of the Kingdom.[9] His writings were published posthumously in the work complied by Maggi.[15]

Girolamo Maggi d'Anghiari was possibly born around 1523 or a little later. He studied oratory under Pierantonio Ghezzi,[16] and frequented the Universities of Perugia, Pisa and finally Bologna.[17] In Pisa he heard the lectures of Francesco Robertello Professor of Greek and Latin eloquence who taught there from 1543 to 1549. Maggi graduated from Pisa probably in 1546. In 1551 he dedicated his manus-script work Ingegni et invenzioni militari to Duke Cosimo I, and dated it at

1. This is surely true on paper. In setting out a full size fortification Girolamo's techniques might just have been of some advantage, but it is doubtful.
2. This is not explicitly focused on, and there is certainly never any question of geometrical proofs, and even ruler and compass manipulation are missing.
3. That this practical background was never fully dominated by the mathematical approach can be seen in Girolamo's remarks on gunnery and related areas, where nothing like geometric ballistics occurred. See II p. 54/5.
4. This is how he appears in the work with Maggi and not as Jacopo as for example TIRABUSCHI (1791) gives.
5. PROMIS (1841)λ, Della Fortificatione della Città (1564) f. 37a "Urbino patria mia".
6. Ibid. f. 92b. 7. Ibid f. 33b. 8. PROMIS (1841) λ.
9. Delle Fortificatione della Città (1564) f. 89a.
10. See above p. 14 n. 8. 11. Delle Fortificatione della Citta f. 19a
12. PEPPER (1972).
13. Della Fortificatione della Città f. 65b.
14. Ibid. f. 19a. "nella Provincia di Lingua d'Oca, in Prouenza, nel Lionese, in Campagna, in Picardia, in Normandia & ne gli altri luoghi di frontiera"
15. See II p. 59/61 contents & p. 60 n. 1.
16. PROMIS (1862)
17. Variarum lectionum (Venetiis 1564) f. 72b.

Anghiari. In that same year his verses on the war in Flanders appeared at Venice;[1] and in 1552 he was concerned in the defence of Anghiari. His work with Castriotto Della Fortificatione delle Città appeared in 1564. During the Turkish attack on Cyprus in 1570 Maggi was in the service of Venice, and was mentioned for valour. During the siege of Famagusta, however, he was captured by the Turks. He was taken to Constantinople, from where, attempting to escape he was recaptured and strangled in 1572.[2]

During his life time Maggi published a number of works, generally more concerned with his classical studies than with military studies.[3] However these two areas did to some extent overlap and it seems likely that his work on the classical authors aided his shifting towards the field of warfare.[4]

The work that bears the names of Maggi and Castriotto, Delle Fortificatione delle Città (1564) was a compilation made by Maggi after Castriotto's death.[5] In it, interspersed with his own sections of text Maggi published sections of Castriotto's writings and designs (together with some additional material from other writers towards the end of the book).[6] Maggi's text provided the structure of the work within which he used Castriotto's fragments[7] to help to give a sufficiently practical basis to the work, especially in illustrating some particular sites.[8]

Maggi approached the problems of fortification by way of two very different routes. On the one hand he used his familiarity with the classical authors to quote historical incidents of their period, along with their opinions, wherever he though such relevant.[9] On the other hand when he came to the styles of the structures he illustrated and put forward Maggi depended almost entirely on contemporary practice.[10]

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1. Cinque primi canti della guerra di Fiandra (Venezia 1551).
2. Generally from PROMIS (1862)
3. In 1562 his De mundi exustione et die judicii, appeared. Vitae virorum illustrium autoribus in 1563. An edition of Julio Serenio's work De fato libri IX and Variarum Lectionum in that same year. Many of his writings of the same character were published after his death. (See PROMIS (1562).)
4. For example Variarum Lectionum (1564 Venetiis) contained in Bk. I, Cap. I a discussion on whiether the ancients used bombards; and in Bk. II, Cap. X of that same work, entitled, "Quae'nam illa fuerit machina, qua Archimedes memorabilem Hieronis nauem in mare deduxit", Maggi began, "Athenaei Dipnosophistarum libros à doctissimo viro Natale Comitio amico meo, quem Mediolano anno salutis 1550. in patriam reuersum, primum allocutus sum, latinitate donatos, pomeridianis horis cum legerem, incidi in caput 8. libri quinti, ubi ille ex Moschione de Hieronis, celebri naue loquitur..." During the fight against the Turks in Cyprus a contemporary account stated "Fece similmente un istrumento a modo degli antichi, da gettare pietre di gran grossezza molto lontano", although it goes on "ma non s'adopro". Quoted in PROMIS (1562). Some of his other efforts however seem to have been more successful, however. (See ibid.)
5. Castriotto died in 1562. Maggi in his dedication described the book as his own. See II p. 60 n.1.
6. See contents II p. 59/61
7. There is no doubt that Castriotto had been collecting a portfolio of designs along with his thoughts on them, for some years. He had sent material of this nature to Tartaglia in 1548. (See above p.14, n.8) The material Maggi used was probably a late redaction of earlier versions.
8. The whole introductary section of Bk. I was by Maggi, and it was not until Cap. IX that a section by Castriotto appeared, giving plan traces that had already been introduced by Maggi. Cap. IX/XV gave descriptions of fortresses in France by Castriotto. See contents II p. 59/61.
9. The first two chapters of Bk. I were pretty well entirely of discussion from the ancient authors. Throughout the work marginal notes again and agian noted the name of some ancient author whom Maggi was quoting. He equally included a chapter (Bk. II, Cap. XXX) on the fortifications of ancient cities. This continuous reference to the ancient authors carried right through the work , and did not provide simply an introductory framework. For his discussion of bastion systems see contents II p. 59/61. See also II p. 61, [illegible] in which the very beginning of the treatise is a historical account.
10. Maggi mentioned his personal inspection of fortifications in 1550 thus "io già l'anno 1550. uidi a Padoua una cortine ritirata in dentro con bonissimo intendimento" Delle Fortificatione delle Città (1564) f. 8b. This element Castriotto's fragments helped to supply. Maggi also made a good deal of use of contemporary writings from Alberti on. See II p. 63 2rd. sect. for the standard emphasis on form. Cap. V, Bk. I began with a mention of Tartaglia. f. 24a mentioned Lanteri and Girolamo Cataneo. f. 62a mentioned a bastion at Padua built by San Michele in 1550. f. 6a he mentioned the unpublished treatises of Belluzzi.

Maggi, taking these two elements as the basis of his discussions then made very little reference to any fundamental method or self-evident principles as the basis of the art, and mathematics hardly figured at all in his account.[1]

Thus past and present practise rather than 'science' or mathematics was the focus of Maggi's approach to the art, and equally Castriotto's discussions tended to centre on contemporary practice, although some of his ideas, particularly in regard to floating whole forts out to sea, seem rather fantastical and impractical.[2]

But at least on one crucial point, Castriotto took a very different line from Maggi. Castriotto was by no means willing to dismiss completely circular structures, and indeed though them useful in their place. The resultant "minutiae" which remained undefended, he insisted, were only of the lightest importance.[3] Maggi on the other hand emphasised the common viewpoint that the area of dead ground not covered by the defenders guns in such structures could not be accepted, and hence that this form was very undesirable.[4]

Thus Castriotto, much more familiar with practice than Maggi, made a judgement about what was important, from the basis of his experience. While Maggi, essentially a classicist moving into military affairs, used a approach much more typical of the literary tradition, and quoted all sorts of opinions from as many different types of authorities as he could find, and when he came down to the principle of no dead ground could only accept it as self-evidently true.[5]

Domenico Mora and his ideas

Domenica Mora was born in Bologna in 1539.[6] By 1567 when his Tre Quesiti appeared,[7] he clearly had his later treatise Il Soldato well in hand,[8] and had by then achieved a good deal of familiarity with the practice of warfare. In 1570 Mora was made captain of a company of infantry and sent to the garrison of Zante.[9] For some reason Mora soon was forced to leave employment with Venice and his position at Zante,[10] and became involved at Avignon in the religious wars of the time.[11] In 1579 he passed into Poland and was made Colonel of 1400 infantry

1. Castriotto on surveying (Bk. I, Cap. XVI) is something of an exception to this. But here Castriotto was intent on showing an instrument which could be used by anyone with little knowledge of mathematics. f. 37b. Chapter heading. "Come facilmente ogni persona senza cognitione delle mathematiche possa sapere le distantie.." When Maggi wanted to refer to general principals he quoted some authority or other. For example Aristotle -- f.6a/b, on the number of inhabitants of a city needing to be neither too large nor too small; or Vitruvius -- f. 8oa on sites in swamps.
2. He showed whole stone structures including lighthouses being floated out on boats for example f. 84a/b. See Pl. 6.
3. See II p. 62; l. 14/24. 4. II p. 64 2nd. sect.
5. Of course Maggi could not refer to the ancient authors here.
6. PROMIS (1863)8 from information given by Mora in IL Cavalieri.
7. See II p. 65.
8. 1st. ed. 1569. See II p. 67. He noted it as already written in his Tre Quesiti (1567) in the dedication to the "signori Academici Storditi" f. (iiib), and at 60b, 67a.
9. According to his contemporary Filippo Bianchi who knew Mora, he held the title of "governatore". See quote from Bianchi in FANTUZZI (1781/ 4).
10. Promis suggested for some misdemeanour.
11. In 1576 he published Raquisto di Camerato, e Baume, Acome si deva fare una Batteria, A quardare le piccole ville del Contato d'Avignone at Avignon", relative to this period, according to FANTUZZI (1781/94). During the same period he published also Parere sopra l'ordine de guerreggiare la potenza del Turco(Bologna 1572*) (N.U.C.) Mora published a work in Latin at Vilna in 1595* which concerned war against the Turks, it has not been possible to establish the relationship between this and the earlier work on the same topic.

by the king.[1] He was involved in many military actions and sieges in that country. On the death of the king Stephen Bathory, his successor Sigismond continued him in his position but sent him to fortify Transylvannia where he was in 1585.[2] In 1589 he published Il Cavalieri at Vilna, which was concerned with the relative nobility of arms as against letters.[3] Mora possibly died around the end of the century.[4]

Mora in his three main works[5] relative to the soldier's trade, had two main themes. In the first place he was concerned with certain techniques relevant to the trade of war.[6] His approach in these areas was a relatively elementary and practical one, and his works from this point of view were no more than fairly elementary handbooks for the instruction of the unpractised soldier.[7] In their ideas they were not very different from many works of the period.[8]

On the other hand Mora in these same writings demonstrated a high degree of concern with a rather different issue. The relative nobility of arms as against letters, was a topic he returned to again and again,[9] and which became the single topic of Il Cavalieri (1589). Mora was quite clear that he could not accept that soldiers should take second place in precedence to literary men,[10] who equally did not even provide such benefits as those who made possible the construction of machines for the use of men.[11]

But these two strands -- the acquisition of technical skills relevant to warfare, and the nobility and value of that trade -- were not independent in Mora's thought. Part, at least, of his argument for the nobility of arms, was that it was a skilled trade, which required that the skilled 'Cavalier' was to some extent literate,[12] and that literacy in some fairly sophisticated disciplines; and further by virtue of the sort of employment which he undertook the 'Cavalier' acquired knowledge superior to that of the mere literary man.[13]

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1. According to Bianchi. See FANTUZZI (1781/4). 2. Ibid.
3. Dedication dated there. See II p. 69.
4. A last work Dell'inodazione del Tevere a Roma....1598 (Rome 1598*) is accredited to Mora. See PROMIS (1863) on which this is generally based.
5. Tre Quesiti (1567); Il Soldato (1569); and Il Cavalieri (1589). These works were concerned with the soldier's trade in a general way in contrast to Mora's other works more concerned with specific problems.
6. In the Tre Quesiti, the use of artillery, fortification and the formation of arrays, all common topics of published works of his day, were the three main topics. (See II p. 65.) In Il Soldato a good deal of Bk. II concerned the formation of arrays, and Bk. III discussed fortification; Il Cavalieri however did not discuss such topics in detail. (See II p. 67 & 69)
7. See for example Tre Quesiti (1567) f. 10b "Signore, che le ragioni recitate da me per dichiaration del tiro dell'artegilieria sieno filosofiche, nol so: percioche non ho giamai atteso a tali studi: so bene, che queste sono ragioni naturali, & cauate dal'experienza". See also II p. 66, 3rd sect. where the idea of the form of the structure rather than its material, being the important element, is outlined. Here Mora took the very practical position that the crucial element is economy of effort: see ibid. n. 2. In Il Soldato (possibly written before the Tre Quesiti), in the fortification section Mora explained he was only giving a simplified version of Castriotto's ideas. See II p. 68, 2nd sect.
8. The most notable exception here, is in the fortification traces of the Tre Quesiti which have a pattern rather personal to Mora. On the other hand in Il Soldato, the later work in terms of publication at least, Mora was quite content to say he was following another's work in this area. (See last note)
9. This topic was advertised on the title page of the Tre Quesiti although it did not figure as the main subject of one of those 3 questions. A section was however devoted to it at the beginning of the 2nd. question. (See II p. 65). In Il Soldato it was the main topic of Bk. I. (See II p. 67). The title page of Il Cavaliere indicated that this topic was the main one of the book. (See II p. 69)
10. II p. 65/6. 11. See II p. 69 1st. sect. 12. II p. 68; l. 11/16.
13. II p. 69, 2nd. sect. In the subject of 'the sphere' for example; Mora's argument seems to be basically concerned with the grounding of knowledge in practice rather than in the study bound activities of the literary man.

Thus the sort of knowledge that the military man needed in his profession and which generally only the practical men of that profession could provide, was just what Mora dealt with in the Tre Quesiti -- gunnery, fortification and the organisation of battle arrays. Which knowledge because of its value, in turn demonstrated the high status of the military profession.

However, this type of argument had its difficulties because, as Girolamo Muzio (at whose work Il Cavaliere was directed) pointed out, it was the literary men who produced so much work in such disciplines as Mora discussed, that were necessary to the soldier's trade, and therefore precedence ought to go to the producers of that type of work.[1]

Thus Mora could not emphasise any too strongly this sort of literary activity as necessary to the skilled soldier, and mathematics, for instance, found no very great role in his scheme of knowledge for the soldier. Always it was sophisticated intellectual knowledge, plus the practice that the soldier gained, and which was not available to the study bound literary man, that he tended to emphasise so as to uplift the status of his trade.

It is not suprising in this context that Mora made only minor efforts to elaborate any sophisticated approach to fortification, and was willing sometimes to be considered as following another's writings in the area, as his discussions in the area tended to be governed by his concern with the status of the profession he followed.

Carlo Theti and his treatise

Carlo Theti[2] was born in 1529 in the region of Naples to the station of a gentleman. In his youth he became a soldier of Spain and was at the siege of a city called Africa in Barbary at the age of 21.[3] After a certain amount of ill fortune he found a place in the house of Prospero and Pompeo Colonna. Discussions in the Colonna's house, Theti claimed, had done much to help him to develop his ideas on fortification. Prospero Colonna took Theti in his service to Vienna in 1565.[4] While there Theti dedicated his manuscript treatise on fortification to Maximilian and this version was later published at Rome against his wishes in 1569.[5] At the emperor's court Theti was frequently involved on giving advice on fortification matters including such sites as Ujvar, Comorra, Canissa and Vienna. After many years in Vienna Theti left service there and later became advisor to William V elector of Bavaria.[6] Returning to Italy he worked on fortification on Turin, Bergamo and Verona. He died in 1589 at Padua.[7]

Theti's treatise has the appearance of a work published from manuscript material assembled over time, which was never to any great extent organised around specific notions about the nature of his art.[8] His work began with a discussion of sites, not as he explained, in order to define which types of site were the best, but rather to inform the reader as to the advantages and disadvantages of the different types.[9] This rather practical attitude and concern

1. II p. 70 both sections. 2. Tetti or Teti.
3. PROMIS (1874) who prints his internment inscription. This siege is mentioned in the 1589 ed. of his treatise Bk. VII p. 42.
4. Ded. to the 1569 ed. of his treatise. 5. Ded. to the 1575 ed.
6. Ruled from 1579.
7. Based generally on Promis and Maggiorotti.
8. See a seperate discussion on the bibliography and evolution of Theti's treatise II p. 78/80. There is for example no great emphasis on mathematics in the work. Bk. II did include a section on surveying but this was more concerned with a gadget to assist in such operations rather than any mathematical approach; and there Theti wrote "che à quelli che fanno, ò vogliono far profession dell'arte della guerra, li sia necessario sapere vsare fra l'altra cose istrumenti che ui sono necessarie." p. 104, (1575) edition.
9. II p. 73/4.

with specifics strikes the tone of the rest of the book. On the other hand Theti in his opening sections turned to the discussion of the geometry of the trace of the fortification,[1] particularly with regard to the setting out of the pointed bastion.[2] But, while he clearly outlined the notion of flanking fire, he did not do so in the context of the dependence of knowledge on universally true principles, and discussion of the regular polygons, but by reference to the historical development of the form.[3]

Walls and towers were made relatively small according to Theti, before the ancient instruments of attack were discovered. Then, with the development of instruments of attack and finally with the discovery of gunpowder artillery, it became necessary to make the walls better, the towers bigger to contain artillery and more distant to take account of the greater range of artillery as compared to bows.[4] This first stage in Theti's account was largely a response to the possibilities of the employment of artillery in defence. It was only then,[5] according to Theti,[6] that the resistant powers of towers began to be called in account, and round towers replaced the older square ones to cope with this. Then, further experience showed the need for their plan to be determined by flanking fire. But the smallish and hollow structures were not satisfactory, either for mounting artillery, or for making 'retirate'. Equally, one could not remain within them because of the danger of flying stone when battered, and through the shaking, and the smoke produced by the guns within. Thus the older towers developed into large solid masses.[7]

Theti's historical account tended then to separate the development of the plan trace in accord with the needs of flanking fire, whatever weaponry tended to be in use, from the idea of using gunpowder artillery in defence[8] and the resultant need to thicken and fill up structures to provide satisfactory platforms for that use.[9]

Theti followed this pattern, at least in part, because he used this historical account as an introduction to his discussion of the pointed bastion in terms of its plan trace.[10] Hence the development of the trace through earlier forms was dealt with as an independant process. Theti's historical remarks were not therefore intended as simply history in themselves, but rather formed an introduct-

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1. This Theti clearly considered was of great importance because he adduced the fact that one could not choose the desired form on hilly sites as an important disadvantage of such sites. II p. 74, 2nd sect.
2. See II p. 74/5. 3. Ibid. & p. 71, 2nd sect.
4. See ibid. The phrase "non resistendoli alcuna fabrica antica" which appeared in the 1569 edition, was droped in the later more considered version of 1575. "Antica" here, by context, not with the implication of being worn out, but referring to earlier styles of structures.
5. Ibid. "Parue dapoi a quelli che vennero appresso".
6. II p. 74/5.
7. 1575 ed. p. 15. "hora comunemente li baloardi, e le cortine che uengono tra essi, si fanno grandi & terrapeinati affatto in sino al piano della piazza di sopra".
8. I.e. First the use of artillery, then tower development square → round → flanked. The first part of which process was due to the weakness of the towers under attack; while the second was simply a good idea in itself.
9. These historical remarks of Theti make very little of the role of attacking artillery and Theti seemed sometimes to want to supress this leaving out the crucial phrase in the 1575 edition. (See above n. 4.) But this must be considered to have been the generator in the process of tower development square → round → flanked, yet it figures little here. (Of course generally in the passages surrounding these sections, and in the rest of his treatise, the significance of attacking artillery was much mentioned by Theti.)
10. And to go on to discuss such topics as that of the pointedness of the bastion (Cap. II in the 1575 ed.)

ion and support to the discussion of the forms of the trace considered desirable in his day, and the justification of that trace as an intellectual achievment in an independent way.

Theti then did not appeal to mathematics or to a general method, or to universal principals, to support the use of the pointed bastion trace. He rather gave a little piece of history and once this was done could go one to discuss a wide range of topics, and his ideas on them, without being constrained by any too rigid framework. Such a pattern indeed was probably much suited for a presentation manuscript treatise, such as that out of which Theti's published treatise grew.

Theti's treatise then, particularly as it later evolved, had a rather practical tone to it, as he discused this or that problem, this or that actual situation. But this was not the result of Theti emphasising the role of practice or experience, as against theory or mathematics, in fortification. Such an issue did not figure in his work to any significant extent. Rather, because his treatise grew out of his day to day consulting in fortification, probably almost entierly through an intermediate stage of fragmentary manuscript accounts, the finished work reflected that practice. Theti then, who gained preferment at court for an extended period through work in the field of fortification, never became a treatise writer for whom that activity, in an independent way, had a significant role in his life.

Gallaso Alghisi and his treatise

Galasso Alghisi was born possibly in the early 1520's at Carpi.[1] He went to Rome with Antonio da Sangallo and worked with him on the Farnese palace in the time of Pope Paul III (1543/49). During this period he knew Castriotto and engaged in debates in fortification in 1542 and afterwards on the Borgo. In 1549 Alghisi was involved in work on the sanctuary at Loretto. In 1550 in the same town he worked on the Palazzo S. Maria.[2] Later he worked at Macerata on the church of S. Maria delle Verghini, and submitted a project for the Torre di Piazza towards the end of tha decade. After the 1550's he found employment at Ferrara under Ercole II and Alfonso d'Este. He worked during this period on civil works such as the theater in the Palazzo Ducale, and on hydraulic projects such as at Ravenna in 1561. He seems equally to have been involved in work on the fortifications while in Ferrara. He died in 1573. His treatise Delle Fortificationi appeared in 1570.[4]

Alghisi's treatise had a very clear structure and method. In Bk. I, after some general introductary remarks,[5] he quickly moved on to discuss the defects of contemporary approaches to the art.[6] He then outlined in a general way

1. THIEME & BECKER (1907/50) states he was around 50 when he died in 1573, according to an old chronicle of Ferrara. This seems rather late if his opinions were taken seriously in 1542 (see below) as Promis suggests from Marchi's manuscripts.
2. Alghisi discussed foundation problems that occured with this structure in his treatise (1570) p. 325.
3. Delle Fortificationi (1570) p. 359.
4. Based generally on PROMIS (1873); VENTURI (1901/35) XI, III; GR DZ ITAL; DZ BIOG . ITAL; DZ ARC URB. VASARI (1978/81) described him as "uomo di bellisime ingegno" Vol. 6, p. 479.
5. Including a strong emphasis on the power of contemporary modes of attack, including the use of artillery, (II p.82&84); and some discussion on the nature of the architects skill, the need for drawings and the like (II p.83 & 86).
6. Based to a a significant extent on attacks on books already published in the field particularly Maggi and Castriotto's work which featured the 'forbici' which was the base of Alghisi's system. See II p.85, 2nd sect.

the advantages of his system.[1] In Bk. II Alghisi shifted the discussion to a more detailed level, and there, focusing on the plan trace of the pentagon he explained in detail how his system applied to this figure. Then came the core of Alghisi's treatise over 200 pages long in which he discussed, at interminable length, the case of each regular polygon of from 5 to 21 sides and how it appeared in his system, each case in a standard way one after the other.[2]

The trace in each case was defined by a complex geometrical array to give a star shaped fortress with bastions at the points of the star, re-entrant curtains with a solid triangular mass filling up the re-entrant areas.

Two characteristics of this system of Alghisi's are very predominant. In the first place Alghisi attempted to produce a general method, which could be applied to any polygon.[3] But in fact no specific set of rules, or algorithm, can be extracted by induction from Alghisi's many examples.[4] His approach was too <u>ad hoc</u> in practice to allow this. He simply attempted to define as much as possible of his trace from the geometrical network he set up in each case.[5]

The other main characteristid apparent in Alghisi's 'method', is connected with his particular manner of using geometry. In the standard approach of the 16th. century, the faces of the pointed bastions were defined in geometrical fashion by reference to lines of fire of defensive guns. In Alghisi's method the lines of his geometric arrays can not be conceived to relate to any particular physical functions.[6] Those arrays in fact simply provided a network which was so established as to define certain aspects of the trace of the fortress in accord with Alghisi's rough preconceptions as to its proportions and shape within the given star shaped pattern outlined above. The geometric network functioned then as a refining and legitimizing device to bring out the precisely determined trace of the fortress and did not relate to physical constraints.

Thus Alghisi, whose personal career seems to have been concerned more with civil architecture than the military branch, cultivated an approach in the latter area much closer to the approach of civil architecture than that accepted by his contemporaries in fortification. For, in general architecture number, ratios and proportions were conceived to have a certain inherent rightness purely from their

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1. These were mainly detailed aspects of his strucutres, including such things as the greatness of the shoulders of the bastions (p. 26); but also including such qualities as the obtuseness of the angles of the bastions.
2. See II p. 81.
3. That is the star shaped trace as described. Clearly Alghisi's dealing with so many different cases was intended to show how it could be generally applied.
4. In each case Alghisi divided his basic external circle into a number of equal segments equal to the number of bastions in the case under discussion; or, double or treble or 4 times that number of parts. Then he joined up many of these points to get his complex array of lines, of which parts of some, were taken to define the trace of the fortress. But this dividing up process and the joining of particular points on the circumference of the basic circle was not done in any standard manner. It was clearly varied in each case to give proportions to certain members of the fortress in accord with what Alghisi considered them to require. The lengths of the faces of the bastions for instance were arrived at by looking for an intersection or measurment in the array which would give roughly its desired length. See Pl. [7]/[9].
5. The triangular masses in the re-entrants of the fortress had their front faces so defined in the case of the 11 bastion fortress, but not in others, for example.
6. Many of Alghisi's setting out lines went right accros the body of the fortress, and hence are far too long to be conceived as lines of fire, and would have often been blocked by intervening buildings. It is further difficult to see any further referent for them.
7. This sort of effect is probably what Alghisi meant when he critiscised Maggi and Castriotto for not defining bastions purely by their form (See p. 35; l. 4/11) See also his emphasis on designing through a scale drawing (II p. 85/6).

mathematical qualities and functioned just as Alghisi's networks in his 'method',[1] rather than being defined by some clear physical need as in the principle of no dead ground so much a part of fortification in his period.

Vincenzo Locatelli[2]

Vicenzo Locatelli was born at Cremona, probably in 1526 or a little earlier, and followed the soldier's trade from a youth.[3] He spent 3 years with Captain Fra of Modena, at Pesaro and learnt from him a good deal about warfare. Then, anxious to see more of the world he took service and went to Crete. Later he served in France during the wars of religion where he was put in charge of fortifications in Piccardy. After the death of Henry in 1559 he lost favour at court. He later took service with the Spanish crown and worked on fortifications at a number of sites including many in Flanders. Returning to Italy he was made superintendant of the fortifications in Sicily for the Spanish crown in 1574.[4] This does not seem to have lasted long for by the end of 1574 he was living in Bologna in poor health and lacking money, as he complained in his Invito Generale published in 1575.[5]

Locatelli's work Invito Generale was not a fortification treatise in the ordinary sense. It was an attempt to set up a competition among fortification designers,[6] with each depositing a sum of money to compete,[7] and the winner taking all.[8] It further differed from the standard pattern of contemporary writing in this area, in that it suggested that old structures with round and square towers could be defended just as well as those in the contemporary style.[9] In fact Locatelli, while implying that he personally could achieve this, never disclosed just how it was to be done or what he had in mind. The rather skeptical response he got to these sorts of claims seems to have been responsible for Locatelli adding some pages to his original prospectus, including letters trying to establish his good faith.[10]

Locatelli's general ideas however, were probably not so very different

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1. See below sect. II:(7).
2. Or Locadelli. He appeared generally as Vincentio in his Invito Generale.
3. Invito Generale (1575) Sg. B1b."....le molte fotezze, le quali ho ueduto, & sonosi nel corso di trentedui anni, ch'io seguo la militia fabricare...." See II p. 87/8 also. PROMIS (1874) Quotes form his "Discorso sopra la vita che ha tenuto il Capitan Vincenzo Locatelli dalla età di diecisetti anni in qua"(1564) where Locatelli stated that he left Cremona at 17 to go to the wars, and implied that he soon was at the siege of 'Nizza di Provenza' (1543).
4. Based on PROMIS (1874) generally, who prints a source giving further details of Locatelli's military career up to 1564. This comes from a work by Locatelli which may have been published Manifesto ....nel quale si contiene la giustificatione sua contro le oppositioni false, which may have added to it, Discorso sopra l' offesa e la difesa de'luoghi (After ARISI (1702/41))
5. Sg. B2a. There is a slight difficulty about the date of this work because a colophon appears in the middle of the work and it seems the later sections were probably printed after this. In the later section Locatelli explained how he had earlier sent the earlier sections of his proposals to prelates and designers (Sg. E1b.) 6. See II p. 86/7: 87 n. 4ff.
7. The competitors were expected to approach their patrons for the large sum of 2,000 scudi each. Locatelli suggested other arrangments for those who were not able to raise this Sg. D1b/2a.
8. Locatelli set out 11 "quesiti" to provide the framework of the competition. for details of these see II p. 87, 2 n. 3; & 88/9.
9. See the title page (verso) for example II p. 88.
10. He stated Sg. E1a "Non so la causa che muoue qualunque che sia di hauer alcuna scintilla di dubbio, hauendo io publicato il mio inuito , che non debba operar per ogni sorte di vie, per far conoscere quanto dico in esso, che sara gli medemi effetti ho detto. E perche non è in poter di alcuna persona di far credere quello, che altri non vogliono credere......"

from those of his contemporaries. For although, as he tells us, he favoured military matters more than study from a youth, and practised the soldiers trade for many years, he still was clear for the need for general methods[1] and he insisted that at least one of the judges in his proposed fortification competiton should be a skilled mathematician[2].

Locatelli's role in his suggested competition was however slightly ambiguous[3] He was to be one of the judges. In this way he seems to have excluded himself from a chance at the prize money, although it is possible he envisioned the emoluments of the judges to be quite substantial[4] while on the other hand he seems to have considered that he was bound to receive great rewards for his marvelous ideas.[5]

Marc Aurelio da Pasino and his ideas

Marc Aurelio da Pasino was possibly born in the early 1540s or perhaps a little later.[6] He was Ferrarese and studied under Alghisi, in all probability in that city.[7] Pasino probably had a wider education than in Architecture and fortification for he is mentioned as skilled in music, engraving, sculpture and fencing.[8] He worked on the new enceinte of bastions at Sedan for the Duke de Buillon, which was built between 1553 and 1572.[9] As well as working for the Duke de Buillon in the 1570s Pasino seems to have gained commisions from the Prince of Orange in connection with the Flanders wars.[10] His treatise Plusiers poincts

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1. See II p. 88, & 89; l. 4/9.
2. Sg. D.2 a/b for details of the competition administration see II p. 87, n. 4
3. 4 secretaries were to be employed, three for the other three judges and one for Locatelli, Sg. D2.a. See also D.2.b/iia where he describes the judging process with himself involved.
4. As Locatelli set the conditions of the competition it might have been seen as unfair for him to have entered. But he could just have easily framed his suggestions as simply a challenge in which he would have taken on all comers. "Other expenses" were to be deducted from the deposited monies. In the main Inuito Locatelli complained that he had not enough money to perfect and bring to fruition his system. (Sg. B2 a) Locatelli explained there that he wished to do this to aid the church, i.e. to gain employment with it "mia speranza di poter anco un giorno adoprar e la mano, e l'ingegno in seruito della santa fede di Christo" hence his general dedication to the Pope. 5. See II p. 89, 3rd sect.
6. The poet Charles de Naviers Gentleman of Sedan born in 1544, who wrote an introductary verse for Pasino's treatise "tutoyered" him (See II p 91; l. 19) This suggests them as near contemporaries. Alghisi was at Ferrara during the 1560s and 1570s. This would suggest him as a man of some reputation for Pasino to study with in his late teens or early twenties, in the early 1560's. Pasino's treatise published in 1579 has the tone of a young man's work, with little or no mention of actual sites or particular historical incidents of war. Yet it was written with a good deal of authority. An author in his late 30s is consistent with this. Pasino seems to have become interested in and occupied with his subject since a youth L'Architecture de Guerre (1579) p. 4 "la cognoissance de cest art de fortification, & de l'experience que i'en ay acquise dés ma ieuness"
7. Pasino himself mentioned Alghisi with respect, L'Architecture de Guerre (1579) p. 42 & 61/2, and wrote of his "lecons exquises & singulieres", and followed him in praising the forbici. The approach of Pasino in his treatise followed much of Alghisi's approach, including the consideration of Architecture as the basic subject with fortification as a sub-discipline; the need for historical understanding of the genesis of fortification (see II p. 91/92); the workers as the tools of the architect (see II p. 93) (although this comes from Alberti); a belief in the strength of artillery was expressed by them both in the same way. The influence of Alghisi on Pasino then seems to have been fairly strong.
8. Verse by Charles de Naviers "Maurel, di-ie, subtil,/ De qui l'entendement est mille fois gentil;/ Soit que princes le luth de grace musicalle,/ Ou tout autre instrument sous ta chanson vocalle,/ Soit que ta mesme main qui sçait bien ciseller,/ L'ouurage d'un Scopas entreprene tailler,/ Ou prene le pinceau pour seconder Apelle,/ Ou soit qu'vn escrimeur pour combatre l'appelle"
9. Ibid. "Maurel qui mon Sedan imprenable bastis;/ Imprenable desia par sa premiere force,/ Mais par l'enceinte nouueau qui ores le renforce/ Imprenable deux-fois." This suggests Pasino as particularly involved with the later stages. For Sedan's fortifications see CONGAR (1961).
10. L'Architecture de Guerre (1579) p5. from the dedication "où il vous plair a m'employer, quand le recuperay cest heur & faueur d'estre commandé par vostre Excellence....." At this date Pasino still advertised himself as architect to the Duke de Buillon. (See II p. 90.)

de l'Architecture de Guerre was published at Antwerp (in French) in 1579. Pasino's name is sometimes connected with the design of a camp retranché at Antwerp in the early 1580's.[1]

In Pasino's view what required improvment in fortification at his time was not the consideration of the details of structures, sufficient had been published on this already,[2] but rather the general principles and basis of the art required a proper foundation.[3] In order to get to grips with the nature of the art of fortification Pasino considered it first necessary to be clear on the nature of Architecture as a whole.[4] Here Pasino insisted that Architecture was based on geometry, arithmetic and perspective, and attempted to assimilate it to the seven liberal arts on this ground.[5] But Architecture historically had always two branches, the private type concerned with particular buildings to protect against the weather, and the architecture concerned with the protection of private buildings which was the prerogative of the Prince. The later branch was concerned with defence against force, while the former was more concerned with enrichment and embelishment; and in private buildings the architect was able to, and had to, follow after the main features of buildings as developed by the ancients, while in fortification -- defence against force could only be found by art and science alone.[6]

Thus fortification to Pasino was a science whose most fundamental base was geometry.[7] The general principle of ability to withstand artillery governing its practice, even though Pasino would only go so far as to express a

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1. WAUVERMANS (1896), p. 67. Generally, the biography given here is not in accord with one of the few previous biographical accounts by ROCCHI (1908) p. 390/4. However Rocchi seems unreliable here. He stated that Pasino was in service with the Prince of Orange at Antwerp in 1579. Yet Pasino in his preface clearly wrote of hoping to regain favour with the prince in that year. Rocchi stated that the poet Le Blonde confirmed Pasino's authorship of the fortifications of Sedan. Now Jean Le Blonde died around 1550 which is too early for him to confirm Pasino's role here although Pasino did definitely build there as confirmed by Charles de Naviers. Roochi then had Pasino working at Sedan from c. 1550, but this tends to make him rather too old to be the strongly influenced pupil of Alghisi. Thus the biography given here is independent of the whole tissue of fabrication given by Rocchi. If however Pasino's father had worked at Sedan, Pasino growing up at the court there would more naturally have gained familiarity with Charles de Navieres. Having gone back to Italy to train with Alghisi he would have been likely to follow him in some detail. It would then not be suprising that Pasino claimed very much to be an Italian yet wrote his treatise in a relatively fluent French, although this is purely conjecture.

2. II p. 103.

3. p. 3. (Dedication) Pasino explained his treatise was about "quelque poincts remarquables" to improve poor schemes of fortification such as he had seen in the last civil wars. At p. 52 he stated "Et pource que i'ay entamé ce propos, ie ne veux passer oultre sans donner quelques instructions & reigles principales qui puissant, selon mon aduis, seruir de remedes pour estre appliquez generallement à telles fortificationes"(emphasis added). (In the context of bad sites) This emphasis on principles comes out at many places in Pasino's text. (See also for example II p. 93; l. 30/33). A good deal of the early part of his work concentrated on outlining the historical background of the art and its relation to architecture. See contents II p. 90.

4. II p. 91/3 5. II p. 92. 6. II p. 93/5

7. See II p. 101, 2nd. sect. This use of geometry was of course backed up by Pasino in his account of the pointed bastion, defined by flanking fire for which he gave the standard type of historical account (p. 35/6) like that found in Theti. Arithmetic and geometry were, by and large, ignored by Pasino in his later discussions, however.

belief that resisting masses could not withstand it.[1]

To Pasino, this account of fortification was on the one hand connected with the status of architecture and the architect; and on the other had strong implications as to how the architect ought to procede in certain circumstances, particularly those involving hilly sites. Architecture as a whole had been assimilated to high status liberal arts, by Pasino, with their place in the medieval curriculum, in contrast to low status servile or base mechanical arts. Equally the architect was to the workman, as the workman was to his tools, and as the soul was to the body.[2] His activities therefore were of the mind, rather than in manipulating materials, concerned with design 'conceived and imagined in the mind'.[3] As a designer he depended greatly on science and theory and his skills were very different from those used by workers who depended on mere practice.[4]

The architect then, under all circumstances, particularly when dealing with hilly or bad sites, must be true to his art. Neither the expenses that will be incurred in moving from hilly sites, nor the advantages hoped for in attempting to make use of existing enceints,[5] can be allowed to sway him from giving advice in accord with the true principles of his art. For, he cannot "reduce to the rules of art" what nature has made bad and imperfect,[6] and in submitting to old circuits he can only be led astray. The result of any such deviation can only be a loss of reputation to the architect.[7]

Yet this picture of fortification based on mathematics, general principles, rules of the art, high status of the architect, and an activity of design quite distinct and seperate from physical building and the details of actual sites, was not to Pasino's mind so much to be contrasted with practice -- it could indeed only function satisfactorily when accompanied by practice and experience.[8] It was what distinguished good military architecture from mere practice, and gave it the standing he required of it.[9]

Thus Pasino, very much the practising fortification engineer with the Duke de Buillon, and familiar with the events of the Flemish wars, felt a need for a strong basis to his art, if for nothing else but the higher status such a foundation would give to his professional field.[10]

Antonio Lupicini and his work

Antonio Lupicini was born around 1530 or a little before, the son of a bombardier of Florence.[11] He served as a soldier to Cosimo Medici in the war of Siena and was present at the sieges of Montalcino and Monticchiello in 1552, and with peace, returned to Florence.[12]

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1. See II p. 97, 2nd sect.; and also II, p. 97/8 . Here Pasino emphasised the shift from 'vertical' to horizontal defence that arose with the advent of artillery as very important in bringing about the new forms of structures.
2. II p. 93; l. 1/6. 3. II p. 101; l. 27
4. See generally II p. 94/101; & 101/2 where Pasino railled against those claiming the title of Architect without having properly and deeply studied the subject.
5. II p. 98/99. 6. II p. 99; l. 30/3. 7. II p. 99; l. 9/19, & p. 100 1st sect.
8. II p. 91 & 102. 9. See particularly II p. 100, 2nd sect.
10. The picture of Pasino as fencing expert, musical preformer at court, engraver, sculptor, together with the idea that fortification will "spiratuliser les persons gentile" (See II p. 91, verse.) put forward by Charles de Naviers in the introductary verses to Pasino's treatise, places this sort of account of fortification exactly in its right background.
11. His father had the nickname "Il Lupo", hence Lupicini's name, and had defended a tower with balls of wool during the siege of Florence in 1530. See Architecture Militare (1582) p. 26. PROMIS (1874) gives this estimate of his date of birth. 12. Ibid.

He presented a treatise to Cosimo I in 1560 whose subject is not known.[1] In 1578 he published at Florence a treatise on the reform of the calendar at his patron's request.[2] As part of the Medici's aid to the Emperor he was sent to serve under Rudolf II that same year and was involved with proposals with regard to the fortifications of Vienna.[3] Lupicini soon returned to Italy and his treatise concerned with surveying was published at Florence in 1582, at the request of the Duke,[4] in which same year his work Architettura Militare was also published. In 1584 and 1589 he was at Venice working on problems of water control, while in the interim in 1587 he published his Discorsi Militari and a work on water control of the Po, both at Florence.[5] In 1591/3 he was concerned with the protection of Pisa and Florence from flooding and published a work on that topic in 1591.[6] In 1594 Lupicini went as engineer with the Medici's to the aid of the Emperor and was concerned with fortifications in Hungary. Lupicini was back in Florence in 1598 and probably died soon after.[7]

While Lupicini considered mathematics to be a useful tool in practical matters, because of the clarity and certainty which resulted from its use,[8] in fortification he was much more concerned with the details of specific cases and the whole interactive process between attack and defence.[9] He certainly thought that mathematics was of importance in surveying and hence had its role in fortification in this connection,[10] but even here he suggested that a good deal of the activities involved in this technique were concerned more with "a certain kind of practice" than with science.[11]

Lupicini was of course familiar with the geometric type of arguments of fortification common in his period, but he made little of them.[12] Given the overpowering effectivness of attack, Lupicini seemed to say, one had to do ones best in coping with all the multifarious problems of fortification as best one could, rather than hoping to succeed by concentrating on abstract qualities of the geometric trace in idealised form, and so ignoring all the detail problems of actual sites.[13]

Lupicini's interest in mathematics was nevertheless by no means minor, although seemingly more pronounced during the earlier part of his career, and at least in part in response to the desires of his patron.[14]

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1. PROMIS (1874) 2. See II p. 103.
3. PROMIS (1874) printed two letters from Lupicini to the Grand Duke reporting on his doings, from Prague in December of that year.
4. Nuoue Verghe Astronomiche, see II p.103; p. 3 "ordinatomi da V.A.S" This work was partly concerned with altitudes hence the 'Astronomical' of the title. II p.104.
5. See II p. 103. Discorsi sopra i ripari del Pò ed altri fiumi*. RICCARDI (1893).
6. Discorsi sopra i ripari delle inondazioni di Fierenze* (Firenzi). A modern edition is NARRAZIONI Istoriche delle piu considervoli Inondazione dell'Arno... da G. A. (Firenze 1645) p. 91/7.
7. Based generally on PROMIS (1874) 8. See II p. 103/4.
9. His whole treatise Discorsi Militari was set out around seperate discussions of 30 sites. (See II p.107). For the interaction of attack and defense see II p. 105; l. 12/17. For his doubt as to the possibility of general rules see II p. 106; l. 19/24. 10. II p. 106, 3rd. sect.
11. See ibid. See II p. 103 where he supports the use of mathematics in a general way in contrast.
12. See II p. 106, 1st. section.
13. See II p. 106, 2nd. sect. His Architecture Militare was divided generally into 4 discussions each of a different site, (see II p.104/5) in some detail. The regular polygons figured at no point. The Discorse Militare had the same pattern only more so, see II p.107.
14. In both his more mathematical works on the calendar and on surveying he explicitly mentioned the Duke's desire for the works. He stated in Nuoue Verghe Astronomiche (1582) p. 52 "...di Astrologia, io mi riserbo à ragionarne in altra occasione, doue spero di ragionare delle Teorichi de Pianeti". But no such work ever seems to have appeared. Rather he published on specfic practical problems of water control and on exteremly specific site orientated works on attack and defence.

Thus as the son of a bombardier -- one who was involved in a very practical craft -- Lupicini seems to have cultivated mathematics to gain the basic skills in his trade, and to gain a certain reputation and to find employment at court. Yet he remained always the practical and practising engineer, willing to admit the great value of mathematics in a general way, yet in practice allowing it only a relatively minor role here and there, and always remaining more concerned with, and acutely sensitive to, the details of actual problems, with regard to which general rules could only give the most basic assistance, both in fortification and water control.

Jacopo Aconcio [1]

Jacopo Aconcio was born possibly at Ussana in the Val di Sole, at the end of the 15th. century. He studied law as a youth and practised at least for some years.[2] Between 1549 and 1553 he was at the court of Maximilian II in Vienna. He then became secretary to Cardinale Madruzzo, who had been made governor of Milan in 1555. Aconcio's Lutheran sentiments causing trouble for him, in 1557 he fled Milan for Zurich. There he probably wrote his work De Methodo which was published in Basle in 1558.[3] In 1559 Aconcio arrived in England after a short period in Strassburg. In December of that same year he petitioned the Queeen for a privilege for some inventions he had made.[4] This was refused but a little later he was awarded a pension of £60 per year, perhaps in part because of his reputation for understanding fortification.[5] Certainly by 1562 Aconcio could write of his having translated his fortification treatise from Italian into Latin;[6] and in 1564 he was invited to give his opinion on the fortifications of Berwick. In 1562 Aconcio presented a project for land reclamation near London, though the work does not seem to have been very successful.[7] Aconcio probably died in 1566 or shortly afterwards.[8]

It is possible that some years after his death Aconcio's fortification treatise was published. But no copy of this has ever been traced in the modern period, and no manuscripts exist to indicate the nature of his general approach to fortification.[6] However it is clear from his opinions on Berwick that, as one might expect, Aconcio accepted the pointed bastions style of his day.[9] The rather Aristotelean[10] cast of his ideas on method and his lack of

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1. Or Acontius, Aconzio, Aconcio, Concio.
2. See O'MALLEY, Charles D, Jacopo Aconcio (trs. Delio Cantori Rome 1955). At Trent in 1548 for example.
3. See II p. 108.
4. See O'MALLEY (1955) who prints the patent request.
5. Francis Russell Earl of Bedford, with whom Aconcio had been friendly at least since early after his arrival in England, was named to the direction of the works at Berwick 1563. O'MALLEY (1955) prints a memoir of Aconcio's on Berwick. For a discussion of Aconcio's opinions on the work there see MAC IVOR (1965).
6. This work is listed in older works, as for example TIRABOSCHI (1791) p.565 as Ars muniendorum Oppidorum in Latin and Italian at Geneva in 1585. Doubts have been expressed as to whether it was ever actually published (See for example O'MALLEY (1955) p 28, n. 114.) However an anonymous (18th. century ?) bibliography (Essay de Bibliotheque Militaire Bib. Naz. Cent. Fr., Palat 995) lists this work with the additional information that it is in octavo which makes its original existence slightly more likely.
7. See O'MALLEY (1955) p. 49 who prints part of an act of a few years later which stated "whereas the said Jacopo Acontio did win some part therof which was by the violence of the floods shortly after lost; and not being able to recover the same".
8. For Aconcio's other works see KÖHLER (1927); and on the fortification work ibid. p 231 where Aconcio is quoted thus "Interim tamen conscriptum iam dudum a nobis nostrate lingua muniendorum oppidorum artem latinam fecimus. Sed versio novum pene opus fuit."
9. See MAC IVOR (1965). The opinion on Berwick is given in O'MALLEY (1955).
10. See II p. 108. Aconcio did make use of other writers such as Plato, but only to a minor extent.

emphasis on mathematics,[1] perhaps did not support that approach to fortification, but the notion of general rules and a method[2] would have fitted very well with the idealised solutions based on the series of the regular polygons.

Gabriello Busca and his ideas

Gabriello Busca was born into a family of gun founders and bombardiers, probably around 1540.[4] He entered the service of Duke Emmanuel Filiberte (of Savoy) as a bombardier in the early 1570s, when his brother was made head founder and bombardier to the Duke. By 1579 Gabriello was referred to be the Duke as "ingenieur et lieutenant du cappitaine general de notre artillerie".[5] In 1594 Carlo Emanuele I, the then ruler, increased his salary to 1200 scudi. As well as being involved with artillery Gabriel was concerned with the fortifications of Montmeillan and Bourg-in-Bresse, for the Dukes.[6] In 1584 Gabriello published his work Instruttione de'Bombardieri,[7] and the next year Della Espugnatione et Difesa delle Fortezze.[8] In 1589 he was sent to defend Borg-en-Bresse when it came under threat. In the early 1590s he served as a soldier and engineer in the religious wars in Piedmont. In 1595 he took service with Spain and served in Burgundy, and then was named captain of artillery to the state of Milan. Busca published his longest treatise Architettura Militaire from that city in 1601, possibly then in semi-retirment,[9] although in that same year he was involved in work on the canal of Pavia. He probably died soon afterwards.[10]

Busca in his writings frequently mentioned the importance of experience and practice in fortification and gunnery, and indeed emphasised it quite strongly.[11] But he was equally quick to denigrate any dependence on mere practice alone, and any lack in the skilled practitioner, of science, and more particularly mathematics.[12] Yet the contribution of study, (or the use of reason, or science or mathematics -- all to some extent equivalent in being in contrast to practical experience) was to Busca's mind limited, even if necessary, and he always insisted on experience playing a primary role.[13] He distrusted equally any approach, particularly in fortification, that was too distant from the practical activities of warfare and that hence became too idealised. He denied the possibility of making an absolutely impregnable fortress, this he considered was against the nature of things.[14] He attacked Tartaglia

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1. Aconcio did make some mention of mathematics, as for example in discussing universals (De Methodo (1558) p. 36) but this was only a very minor part of his approach. 2. II p. 108.
3. Or Gabrio in the spanish usage which Promis preferred.
4. Gabriello's father Giovanni Antonio was "fonditore per Sua M^{tà} Catolica nello stato di Milano." His brother Francesco was employed as gunfounder and bombardier by Duke Emanuel (of Savoy d. 1580) around 1570. Giuseppe, one of Francesco's sons became a gunfounder also. See PROMIS (1571). Gabreil's date of birth is Promis's reasonable assessment from the given details about him, and his relations biographies
5. Letter printed in PROMIS(1871)A.
6. Architettura Militaire (1601) p. 75 & 181.
7. See II p. 109 8. II p. 111. 9. II p. 114/5. 10. See PROMIS(1871)A.
11. His first work Instruttione de'Bombardieri (1584) was in fact very much concerned with the practical problems of the working gunner, and Busca denied that any mathematical approach was necessary to him, for practice was the important thing even in judging distances. See II p. 110; l. 32/36: 111/112: 115/16.
12. This is particularly true in his Architettura Militaire (1601) (See ff. II p. 115; l. 11/16) but equally at the beginning of the Instruttione de'Bombardieri he implied that this sort of knowledge was necessary to captains, if not to ordinary soldiers. Further in Delle Espugnatione et Difese delle Fortezze (1585) p. 9 Busca stated "...quella forma al forte dare, che l'esperienza, & essa ragione insieme douere esser più gagliarda". The use of reason being equated to science and contrasted with mere practice.
13. See, for example II p. 111, 1st ed. where it is practice with mathematical instruments that Busca thought important to the Military architect in surveying, rather than knowledge of theory. See also p. 112/13.
14. See II p. 116; l. 13/16.

Castriotto, Mora, and Alghisi, for, he claimed, asserting that one could make an invincible fortress on a plain through form alone.[1] He allowed the importance of form but refused to ignore the importance of the material of the structure.[2] He emphasised the contribution of the site to the strength of the fortress.[3] Equally his general approach in his treatises involved a concentration on practical details, without any attempt to produce results heavily dependant on mathematics or any elaborated science.[4]

Mathematics and science therefore in Busca's accounts of his areas of technical knowledge tended to have a low level epistemological function as involving not a great deal more than the role of giving a certain rationallity and orderliness, in the sense of supplying general rules, to knowledge that was highly dependent on practice and experience. But in contrast, such knowledge of the study, Busca conceived to be important to the picture of the military architect he wished to put forward. Thus he followed Vitruvius and emphasised all the sorts of skill that belonged to Architecture in that author's account, and refused to allow the honour of belonging to that profession to those who did not possess the "best science";[5] and in his <u>Architecture Militaire</u> did not emphasise science and mathematics but rather demonstrated his own studies by a great deal of reference to the classical authors.[6]

Thus Busca remained true to his craft background in gunnery, and emphasised the importance of practice, and sought for social status in his profession by reference to the general cultural interests of his day in the classical world instead of depending on mathematics and science.

<u>Eugenio Gentilini</u>

Eugenio Gentilini served as a gunner for many years, particularly at sea. At first with the Order of St. John of Malta and then sometimes with the Duke of Tuscany, but for the most part with Venice.[7]

His little treatise, first published in 1592, was essentially a collection of gunners hints, and descriptions of guns, and the like.[8] The section on fortification was, he explained, the result of discussion with his brother Marino, engineer to the Republic, and was added to make the work more

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1. See <u>II</u> p. 113/4. Challenged, these authors would surely have claimed to have been able to design only reasonably invincible fortresses, not one, completely so, as Busca tried to make them say.
2. See <u>II</u> p. 114, 2nd sect.: p.113, 2nd sect. 3. <u>II</u> p.113 beg.
4. Busca kept well away from geometric ballistics, or involvement in problems of natural and forced motion, though he clearly knew of them (see <u>II</u> p. 109/110.). His remarks on surveying, where he did admit to a certain value in mathematics, he never elaborated to any great extent. He did however show triangles imposed on the landscape as part of his explanation of how to measure distances -- <u>Delle Espugnatione et Diffese delle Fortezza</u> Cap. XXXIII -- but his explanation there was very short and general with little emphasis on mathematical techniques or manipulations. In his final work (<u>Architettura Militare</u> (1601)) he did give the usual diagram illustrating the principle of no dead ground, (p. 126) but it is only quite late on in that work that he mentioned the importance of mathematics to the military architect, and there admitted that he has largely ignored this aspect, and yet never went on to give much more on it. See <u>II</u> p. 118, 3rd sect.
5. <u>II</u> p. 115/6.
6. Incidents and examples from the classical authors, within Busca's approach functioned then as an extension of the limited personal experience of the author, see <u>II</u> p. 112, 2nd. sect.
7. See <u>II</u> p. 119, 1st. sect; & <u>Instruttione di Artiglieri</u> (1598) f. (iia).
8. See <u>II</u> p. 119, desc.; & 3rd. sect., for the sort of skills Gentilini was much concerned with.

complete. Basically Gentilini included this topic because artillery played such an important part in fortification and hence the gunner was considered to need to know something of this area.[1] Gentilini's discussion here concerned with the trace of a length of curtain and its adjacent bastions, then enabled him to give some of his own opinions about the design of the fortification from the point of view of the artillerist, without being too tedious.[2] While Gentilini made some mention of geometry as useful in his art, he only considered this discipline at a very low level, and mainly for its use in elementary surveying for range finding.[3] On this topic he described a gadget to assist in finding distances.[4] Such discussion however was merely part of Gentilini's description of the gunners craft and was given no particular predominance.

Giovanni Scala

Giovanni Scala seems to have flourished at the end of the 16th. century and possibly died c. 1603.[5] His approach to fortification was that very much of the mathematician concerned with manipulative geometry which gave determined solutions considered of value for their inherent geometric qualities rather than through any physical interpretation of the geometry. He seems to have been little concerned with the detailed practical problems of fortification.[6]

Bonaiuto Lorini and his ideas

Bonauito Lorini was born to a noble Florentine family around 1547, possibly. As a young man he became interested in mathematics and warfare and was encouraged by Cosimo I. In order to gain practical experience he went to Flanders around 1566/7. In the next years he gained experience in Flanders and with French and Italian princes until around 1579 he entered the service of Venice.[7]

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1. See II p. 119, 2nd. sect.
2. See II p. 120, 1st. sect for a typical gunners remark on fortification.
3. See II p. 120, 2nd. sect.
4. In the final section of the work as noted II p. 119, desc.
5. In 1603 Scala's redaction of Pomodoro's geometry was re-issued by a new editor.
6. See the description of his writings II p. 120A.
7. PROMIS (1874) put Lanteri's birth rather earlier c. 1540 or a little after. In fact Lanteri's treatise contains a number of dates that do not fully agree. Promis's view seems to have been based on Lanteri's statement "...di ventidue anni della mia età, fui introdotto in questa profession (i.e. military architecture), &.... assai favorito dalla gratia di Cosimo de'Medici" (Delle fortificationi (1596) p.(vi)) which Promis took as indicating the beginning of Lanteri's studies in military engineering. But this ignores Lanteri's remarks about his interest in this field "ne'primi anni della mi giouentii" (II p. 122). It seems possible that Lanteri was referring perhaps to getting his first actual commission in fortification at that age. This then gives Lanteri's date of birth as more in accord with the dates given in the engraved portraits in his treatise (1596 ed. gives hs age as 50; 1609 as 60) The other dates Lanteri gives are these. Delle fortificationi (1596) ed. p. (vi) 16 years in the service of Venice; his experience in fortification 30 years; 1609 ed. p. (iii), service of Princes in Flanders, France, and Italy, 40 years; p. (iv) 30 years service with Venice. A letter of 1595, printed in PROMIS (1874) 30 years since he began to work in Flanders. Letter of 1600 in Due pareri sulla fortificazioni di Udine e Palma Silvia Beretta MANIN & G. L. MANIN (eds.) (Udine 1868) 22 years in the service of Venice (not noted by Promis) In Delle fortifiationi (1609) Lorini stated "del castello d'Anuersa, fatto nel tempo che era là" p. 263. The citadelle at Antwerp was begun in 1567. Military action only recommenced in Flanders in 1566.

In his service for Venice Lanteri gained the position of engineer to the republic and probably worked at Zara.[1] He worked also at Bergamo and on the castle at Brescia, and at Palma. By 1596 Lorini seems to have completed his treatise, and in the following year it was printed and distributed, possibly in single copies, only to individual princes, with different dedications to each specific prince, probably as a result of pressure brought to bear on Lorini by the Grand Duke against its general distribution. Then the next year, for fear the work would be pirated, according to Lorini, it was more widely distributed.[2] In 1609 a new edition appeared with the addition of a 6th. book. Lorini probably died not long after 1611.[3]

To Lorini it was axiomatic that fortification had to have a "demonstrable foundation",[4] and had to be founded on "termini",[5] demonstrable[6] and real,[7] the demonstrations involved to be of the most easy kind,[8] all proceding from first principles.[9] Because, in being a science, like other sciences it had to have certain and demonstrable foundations.[10] It also needed to be open knowledge and not a collection of secrets because before anything could be considered to be established it had to be subject to the process of "conferring and disputing" with others.[11] Its nature moreover could best be understood by comparing it with (the traditionally honourable) science of medicine. The physician treats the patient by reference to the superfluous humour, the fortification engineer must analogously consider the site as a sick body, so that whatever is in excess in the complexion of the site must therfore be mitigated. But the work of the physician is really only a skill or ability, while fortification additionally, is science and art, being based on certain and determined rules.[12]

However, Lorini was forced to admit, and he felt a need to go into this more than once and at length, as it was actually practised fortification did not appear to conform to this pattern too well, and all the many benefits that should have ensued were not as much in evidence as they should have been.[13] The reason for this Lorini insisted was that fortification designers did not follow the correct general rule in their work, which was that defence had to be drawn out of attack and the nature of the site.[14] This

1. Part of Lorini's treatise had a dialogue set in Zara, Delle Fortificationi (1596) p 52.
2. See II p. 121, n. 1.
3. PROMIS (1874) on whom this is generally based except where noted.
4. See II p. 122/3.
5. "termini" in this kind of context can not be got properly into English. It has both the sense of "terms" as in 'technical terms' in English, but also the sense of end points as in English "terminus, termini", in 'tram terminus'. Thus in geometry points, lines and surfaces are particular terms, but they are also stopping (or starting) points of discussion and form the basic units of the discussion which cannot be further broken down and hence are 'termini'. But "termini" are in addition 'ends' in the sense of aims or 'goals', and sometimes when Lorini uses this word this aspect is in evidence. A line as a geometrical object was a "termine reale" but equally as a representation of a line of defensive artillery fire it had a real function or aim or goal, and was thus also a "termine" in this sense. It is difficult to be sure as to how much Lorini intended "termini" in this last sense at any particular time, because he often did not discuss this aspect in detail, while this sense does seem to be required in some passages.
6. II p. 124; l. 15/18. 7. II p. 131; l. 16/18. 8. II p. 130; l. 28/31
9 II p. 130; l. 17/17. 10. II p. 131; l. 9/10. 11. II p. 130; l. 31/43.
12. II p. 132; l. 16, et. seq. 13. II p. 122 & 130; l. 45, et seq.
14. This principle Lorini repeated again and again. II p. 123: 132; l. 2/4: 135; l. 40/3 for example.

rule had a very important function in Lorini's thought. On the one hand it created a basis of fortification in practice and prevented the discipline from becoming too much abstracted from the business of war, an effect that Lorini deplored,[1] as he did also any kind of scholastic discussion in his subject.[2] On the other hand practice and experience then provided a general rule for fortification, in accord with which that discipline as a science could be elaborated. While at the same time the failure of others to follow that same rule, explained why so many different opinions were held by different writers in the field, and why actual structures seemed so often ad hoc.

To Lorini, the experience and observation of the events of sieges and the structures built was not such that it might challenge his assumption that fortification proceeded by way of a general method; the variability of actual practice only indicated that fortification required further explication[3] in order to become as fully 'scientific' as it should be: for, any questioning of such a first principle, would only involve the illegitimate and unrewarding activity of 'scholastic' dispute.[4]

Given these interlocking ideas: that is, fortification as a science based on general rules, and founded on "termini" determinate and real,[5] demonstrable and certain, and legitimized by open debate, which characteristics had to be present because fortification was a science; and the general principal that defense was drawn from the nature of attack and the site which gave a role for practice and explained actual illegitimate variability in fortification as it was practised in his time: Lorini had then a framework within which to expound and further justify certain aspects of his account of the nature of fortification, particularly its basis in geometry and the importance he attached to 'design'[6] in its practice.

Geometry was in Lorini's view not only useful but necessary[7] in his subject because this science produced the most clear and easy demonstrations;[8] but further because without geometry the physical objects at issue could not be

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1. II p.131; l.45, et. seq: 136; l.10/15.
2. He also wrote p. 53, Delle Fortificationi (1596) "Se ne'ragionamenti, ouera dispute, che si sogliono fare, vengon da vna delle due parti, negati i primi principij, per certo l'altra non può, ne debbe disputare, vendendosi da questo, segno manifesto di poca intelligenza; perche nel tratarne saria, come si dice, il voler pestar l'aqua nel mortaio, che doppo vna lunga fatica non si saria altro, che di chiara farla diunir torbida".
3. II p.122/3.
4. Which of course Lorini considered his treatise provided. See II p.136; l.13/14.
5. See above p.41 n.5.
6. "Disegno" in Italian had in the 16th. century very much the wide extension and application of the word 'design' in English. FLORIO (1611) for instance gives "Diségno, a purpose, a designe, a draught, a modell, a plot, a picture, a pourtrait." Thus a 'design' in both English and Italian could be either an actual physical representation -- a drawing, model or the like; or the conception of the object to be constructed, formed in the mind. But one particular use of this term was extemely important for many Italian writers of the renaissance, that was 'design' as a kind of skill, roughly equivalent to what is meant when in English it is said that someone has a good sense of design. Often, and this was very true of Lorini, the skill involved was discussed as if, by and large, it merely involved the drawing techniques by which an object was represented on paper. Thus in discussing the "science of design" (II p.128/9) Lorini sometimes concentrated almost entirely on the need for the technique of perspective to present the design; and similarly he discussed the making of maps as 'design'. (II p.127; l.41/3: 130/1, f.n.1) But "disegno" was much more than this. For example Vasari stated "Uso, adunque, che la scultura e la pittura per il vero sono sorelle, nato di un padre che e il disegno" GR DZ ITAL. And this notion of design as a skill in previsioning or preconceiving an object with all its parts in proper relation before it was ever constructed, or represented was clearly at work in Lorini's mind also. (See II p.127; l.15/20, 'perspective introduces the design'.) Such a skill along with the production of a proper representation and the skill involved there, was extremely significant to the notion of design in the period.
7. II p. 124/5.
8. II p. 125, et seq.

be understood,[1] nor even the objects of nature truly represented,[2] or shown in their true being.[3] Equally geometry, as fundamental to mathematics was crucial to the understanding of nature.

Geometry in fact was fundamental to design and hence the means by which we can discover, and adjust objects in our intellects until they are perfected, as if they were real.[4] In design perspective is necessary to show objects in such a way as they may be truly understood;[5] further it was with this tool that one presented one inventions and their grounds,[6] and communicates ones ideas, without which this could not be done;[7] and lacking this skill one is all too likely to be ousted from command by some (low) mechanic who does possess it.[8] In fact in possessing this science of design one is able to demonstrate ones human ingenuity in imitating nature by making everything perfectly suitable to its function and human use.[9]

Thus to Lorini the use of geometry was necessary not only because of its formal advantages,[10] but also because of its essential role in the conception and transmission of design; in the judgement and adjustment of the design into the most perfect form that human art can discover; and further because only by the means of geometry (and mathematics) can the world and its objects be grasped in their being or properly understood as they truely are.

This system of ideas of Lorini of many interlocking elements, elegantly set out a position about the nature of fortification which Lorinini then considered could bring proper honour to its true practitioners.[11]

Yet even as Lorini put forward this position he could not himself come to accept fully the dependence of his art on general rules demonstrated by clear, open and easy rules and methods. Because such knowledge, of the most noble kind, when possessed by only a few, would not be held to be of much account when possessed by many.[12] Thus Lorini finally insisted that understanding in fortification, fundamentally rested on knowledge gained through experience, such as his own gained with many years labour and contention, of how defence rested on the form of the site and the nature of the attack practised by the enemy.[13] The stronger position he elaborated in parts, at many places in his treatise, seemingly tending to imply that the sort of knowledge he possessed, once spread abroad through his treatise, was too easily to be picked up by others, so that he would no longer be able to take advantage of his own personal monopoly in the skill which he had with so much toil acquired; and his treatise with much emphasis on the principle that defence is drawn from attack and the nature of the site, remained a very practical one[14] despite the strong position Lorini expressed about the nature of fortification at the level of theory.

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1. II p. 125; l. 23. 2. Ibid. & l. 15/16. 3. Ibid l. 20.
4. Ibid. l. 17/21. 5. II p. 127; l. 25/6. 6. Ibid. l. 37/8.
7. II p. 127/8. 8. II p. 129; l. 23 et. seq.
9. II p. 127; l. 26/30: 123, 2nd. sect.
10. Lorini wrote of the "formal perfection" of mathematics II p. 133; l. 25.
11. II 123; l. 30 et. seq. & 128; l. 41/44: see also p. 136, 2nd. sect.
12. II p. 135/6.
13. See letter quoted II p. 121, n. 1. and texts quoted.
14. The geometry of the regular polygons was only very sketchily dealt with in one diagram, for example.

Giovanni Battista Belluzzi[1]

Born in 1506 in San Marino Belluzzi studied the humanities until at 18 he went to Bologna to learn the wool trade.[2] After 2 years he returned to San Marino, and for a period was occupied in trade there.[3] In 1535 he went to Rome and found favour there with Ascania Colonna, with whom Belluzzi's brother in law, by his first wife, had been in service.[4] Ascanio offered him "a good place" with the imperial army preparing against the Turks, but Belluzzi turned the offer down in the hope of something better.[5] At the end of 1535 Belluzzi married Guilia daughter of the architect Girolamo Genga.[6] Through this connection he became attached to the administration of the Imperial buildings and at the end of 1537 he went to Pesaro to administer construction there and "began to design a little" taught by his brother in law Bartholomeo Genga.[7] In 1539 he made "uno modello de la casa di maestro Cesare", which was the first he ever made, and went with Bartholomeo to Bologna to take the measure of the face of the church of S. Petronio.[8] In 1540 he worked on a commission for a house in Iesi.[9] In 1542 Belluzzi entered into the pay of the Medici's. In 1544 he was involved with the fortificatios of Pistoia. Belluzzi was concerned with fortification at many sites during the later 1540's, at Pisa, Castrocaro, Borgo San Sepulcro, Florence and the new city of Portoferraio. Taking part as an engineer in the war of Siena, he was killed in 1554.[10] Only long after his death, that is in 1598, was the treatise published under his name which contained in part some of his writings.[11]

In Belluzzi's view both experience in warfare, and knowledge of mathematics and the cultivation of "speculation", were necessary to the fortification designer.[12] The first because only through this experience could he learn how particular sites might be attacked, the abilty of being able to take advantage of any site, being in his view central to the art.[13] Mathematics on the other hand he considered necessary because one had both to be able to survey sites in accord with the above principle, and because structures had to be made up of lines and angles.[14] Further when considering costs, materials and

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1. Il San Marino as he was often known. His name is given variously as Belici Bellucci, or the like. The Belluzzi family was an old and powerful one in San Marino. Se EGIDI (1907) p. 10/11.
2. VASARI (1878/81) Vol. VI, p. 330.
3. VASARI ibid. But from his diary (see below n. 4) it would seem more likely that it was the grain trade, as Egidi remarked p. 11.
4. Belluzzi's diary f.1a/b. EGIDI (1907). Egidi published Belluzzi's diary covering the years 1535/1541 which had previously been wrongly filed (Promis seems to have known of this work but never saw it). Edigio discovered the author of this manuscript was Belluzzi by collating a statments in the diary where the author wrote of his father being made captain of San Marino in 1539, with the registers of the republic. The father of the author then appeared as Bartolo di Simone Belluzzi. Similarities with the accepted biographical information, particularly the author's relationship to Genga, increased the probability of the author being Giovanni Battista Belluzzi, but Egidi was finally able to confirm the authorship when he found that the list of mourners at the funeral of Francesco Maria I della Rovere, had our Belluzzi's name in it, and against it a little mark, which, when Egidio was aware of the possible attribution, he realised for the first time read "io". The attribution thus seems definite.
5. Diary f. 12a. 6. Ibid. f. 30a. 7. Ibid f. 53b & 66b.
8. Ibid f. 109a; 120a/b. 9. Ibid f. 133b. 10. AYALA (1873) p. 297.
11. For its description see II p. 137. Belluzzi's Fortificationi di terra remains unpublished. In the m.s. Bib. Naz Fierenze Cl. XIX cod. 18. Bernardo Puccini explained "Il Cap^{no}. Gio: Batista Bellucci da San marino haueua molt' innanzi la guerra di Siena dato principio, a un'opera di fortificatione, e di gia uicin'al fine l'haueua condotta, quando per andar'à tal guerra me la lasciò..." dated Fiorenze XVI Nov. M.D.LVIII. (A m.s. of Puccini's on surveying is extant see bib.) Belluzzi's writings circulated in m.s. and were well known in the earlier period, before the publication of 1598. See for example MAGGI (1564) f. 6a where they are mentioned with respect.
12. II p. 138; l. 39 et. seq. 13. II p. 138; l. 5/10. 14. Ibid. 10/25.

labour one had to know number.[1] The activity of speculation included an understanding of geometry by which structures were considered.[2] Speculation was necessary because only in this way could one forsee how ones structure might function in practice and take account of all the things that might occur.[3] Such speculation however had always to proceed hand in hand with practice, for neither speculation without practice, nor practice without speculation were of any avail, even though the achievement of skill in both areas was hard of acquisition.[4] Having such skills however one was then able to build anew in accord with the models of the regular polygons matching them to the site and the resources available.[5]

In Belluzzi's view then a nice balance had always to be kept between theory and practice in one was to achieve success in fortification design, while the relevant knowledge remained always very suitable to princes and gentlemen who wished to command.[6]

Francesco de Marchi and his treatise.

Franchesco de Marchi was born in 1504[7] into a family of wood engravers (or carvers).[8] He probably received little formal education and served from a youth in the military.[9] He was present at the siege of Florence in 1530.[10] He found service with the Medici's in 1533.[11] In 1535[12] Marchi moved to and settled in Rome where he lived until 1551.[13] He took part in the debates on the Borgo with many other engineers.[14] During this period he began to assemble his fortification designs[15] and had a work with 30 designs printed to give a small number of presentation copies.[16] In 1551 the Pope and Charles V threatened war on Ottavio Farnese, who, fleeing to Parma took Marchi with him, and in 1552 Marchi became commisioner of artillery there; he also produced designs for the fortification of the same city during this period. In 1559 he followed Margeret of Austria to the Low countries and acted as advisor on fortifications to her there. When Margeret left the Low countries in 1568 Marchi returned with her to Italy and died in Aquila in 1574.[17,18] In 1599 the more developed form of Marchi's treatise was published.[19]

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1. II p. 138; l. 24/27. 2. II p. 140; l. 16/26. 3. II p. 139; l. 20/28.
4. II p. 140; l. 31 et. seq. 5. II p. 141, 3rd. sect. 6. II p. 139; l. 28/34.
7. PROMIS (1863)B prints his grave inscription giving his date of death as 15th. Feb. 1576 and his age as 72.
8. MARINI (1810).
9. ENC ITAL states he was almost illiterate still at the age of 32. VENTURI, G. B., Memoria intorno alla vita ed alle opera del Capitono Francesco Marchi (Modena 1816) suggests he was entirely an autodidact.
10. Marchi mentions the tower armed with balls of wool. (See II p. 145, 2nd sect.)
11. PROMIS (1863)B.
12. Autumn 1534 according to Promis.
13. VENTURI, op. cit. p. 5. Magaret of Austria becoming a widow on the death of Alessandro de Medici she married Ottavio Farnese in 1538 and Marchi entered the Casa Farnese.
14. PROMIS (1863)B.
15. Plate No I of Della Architetture Militare states that the work was begun in 1546; and f. 44b Marchi stated "Io haueva la maggior parte Dell'opera mia in ordine" in 1545.
16. PROMIS (1863)B quotes a ms. where Marchi stated that he had only 3 copies presented and where he complained the printer produced more than the 3 copies required. One of the presentation copies was given by Marchi to Philip of Spain at Greenwich when he married Mary Tudor in 1554 (ibid.)
17. ibid.
18. Other works relevant to Marchi's life not available for consultation here include Cento lettere del Capitano Francesco Marchi (Parma 1864)* and MAGGIOROTTI, L. A. "Dizionarietto degli ingegnieri militari italian" Esercito e Naziona (1933)*
19. For the build up of the treatise and its relationship to the Mss. from Marchi see VENTURI, op. cit. and PROMIS (1863)B generally.

Marchi's thinking on fortification clearly revolved around particular designs and the many different solutions that could be presented under different circumstances.[1] He did however in his treatise give a certain amount of general introductory discussion[2] and in one long section attempted to set out his views on the nature of architecture in general and in military architecture in particular.[3] There he emphasised that both theory and practice were necessary to the art, practice being central to skill in designing which cannot proceed by reference to this alone. This contention Marchi set in the background of general remarks on the nature of man's relationship with truth, whose relevance is not altogether clear.[5] But Marchi discussed also the relationship between universals as general rules, and sensations, in man, in an attempt to connect together general rules with the sensations which are to be found in experience. So connecting theory and practice and showing the need for both, if albeit only in a very loose way in terms of the particular discipline of fortification.[6]

The key to Marchi's attitude in such general remarks seems to have been very much the idea of Vitruvius that building is born of practice and discussion.[7] Thus in presenting a large number of designs Marchi felt the need to add some general discussion also. But the result was only that he gave some general and hence vague remarks, whose application in detail he was not forced to elaborate on leaving him free to present his designs very much independently in their own terms,[8] while at the same time giving the impression that his technique had been set on a secure and sufficiently dignified basis.[9]

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1. Marchi's treatise was built around different designs, each with a small section of text. See contents II p. 142/3. Also II p. 143 where he stated that the goal of his treatise was to show his designs.
2. Della Architettura Militare (1599) Bk. I & II.
3. See II p. 146/51. Bk. II, Cap. XXXVI of his treatise entitled "Dechiaratione che cosa sia Architetto & Architettura". Marchi followed after BARBARO (1556) largely in this section. See II p. 146, n. 2, et seq.
4. II p. 145, 3rd. sect. 5. II p. 146/7.
6. II p. 148/9. 7. II p. 151; l. 23/4.
8. Which centrally involved the manipulation of lines of fire on the plan. The whole pattern of the evolution of his treatise centering around the designs, and the tendency of his other remarks to be rather isolated notes tended to mitigate against there being any strong argument at the level of general ideas behind his work.
9. In these general discussions, Marchi made a good many references to the ancient authors and to events they described, probably from this kind of motive.

I:(ii): The Indigenous German Tradition

Outline of the tradition

The German writers considered here are: Albrect Dürer whose treatise on fortification was the first specialised work published in the field: appearing in 1527 it had a rather transitional character. Graf Reinhard von Solms-Lich, who published a dialogue on the subject of fortification in 1535. Walter Herman Ryff who published two compendious volumes as commentary on and extension of Vitruvius during 1547/48, the first of which contained discussion of fortification. Leonard Fronsperger who published many works on topics related to many aspects of warfare in the 1550s and 1560s, which includ-ed sections on fortification. These last writers all having an approach some-what in common, and leaning heavily on predecessors. Finally Danile Specklin who was the first to publish a work in German dealing clearly with and leaning heavily on the pointed bastion trace: a work memorable particularly for its very fine illustrations.

Albrecht Dürer, his ideas on fortification and their background.

(i) Dürer's career

Albrect Dürer was born in 1471 to a father of the same name, a goldsmith of Nüremberg.[3] As a youth Durer attended the "Lateinschule" in St. Lorenz[4] for a short while before being set to his father's trade. But after acquiring the basic skill of that profession Dürer found himself more drawn towards painting. His father therefore apprenticed him to the well known Nuremberg painter Michael Wohlgemuth in 1586 for 3 years. In early 1590, Dürer having completed his apprenticeship set out on his 'Wanderjahre,' and only returned to Nurnberg in the spring of 1594.[5] In that same year Durer was married, and in the autumn set out for Italy.[6] Returning to Nüremberg in the spring of 1595, Dürer entered a period of immense productivity in painting, engraving and and wood carving, and as a result obtained a wide reputation.[7] In 1505/7 Dürer again visited Italy, particularly Venice where he seems to have cut something of a figure.[8] Before returning to Nuremberg he bough a copy of Tacinus'

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1. The 'indigenous' German tradition to make clear that we are not concerned here with Italians such as Carlo Theti working at the Emperor's court.
2. Among other possible works as candidates for inclusion here, most have too little to say of particular reference to fortification JAHNS (1889) lists Institutiones architecturae militaris, BRULTORF, Sigismund Elias, Praeses Henricus Rideman (Rostochii 1574) In fact this is clearly a 17th. century work which makes much mention of the writers of that period such as Dogens, Frytag, Goldmann and others. 1574 should in all probability read 1674 as B.M. cat. suggests.
3. Dürers family chronical. See RUPPRICH, Hans Dürer schriflichen nachlass (3 vol. Berlin 1956/69) Vol. I p 29.
4. D.S.B.
5. Family chronicle RUPPRICH (op. cit.) p. 30/1. For an outline of Dürer's itinerary, much of it in Germany, see PANOFSKY, Erwin: The Life and Art of Dürer (Princeton 1955) p. 5/6.
6. Ibid p. 8/9
7. Ibid.
8. His letters to his friend Willebald Pirckheimer from Venice tell a good deal about his activities there. See RUPPRICH (op. cit.) Vol. I p. 41/59. (CONWAY, William M: The Writings of Albracht Dürer (London 1958) p. 47/59 gives English translations of these) On the 7th. Feb. 1606 Durer wrote "Aber Sambelling (Giovanni Bellini) der hatt mich vill czentillone fast ser globt." On the 18th. of August "Jch pynn ein zentilam zu Fendig worden"; and on 13th. Oct. "Hÿ pin jch ein her, doheim ein schmarotzer etc". In the same letter he wrote about his having no success with the dancing master he went to. However the painters guild at Venice were not so happy with his presence for on the 2nd. April he wrote "Awch wist, daz mir dy moller fast abholt hÿ sind. Sy haben mich 3 moll vür dÿ herenn genüt, vnd mus 4 fl. jn schull geben." Just before he left Venice Durer seems to have been offered a post at 200 ducats to induce him to remain there. He also noted himself that in 1507/8 he had paid off many debts with what he had earned at Venice (See CONWAY (op. cit.) p. 59/60).

Euclid of 1505.[1] In the period after his return from Venice Dürer began to work out on paper his ideas on method, particularly with regard to painting.[2] In 1515 Durer received a pension from Maximilian of 100 guilders in reward for commissions he had undertaken for the Emperor and as a permanent stipend.[3] During his attempts to gain some such reward Durer made recourse to Johann Stabius, court astronomer to Maximilian. For Stabius, around this time Dürer, produced star charts and a fine perspective view of the globe.[4] It was in part in order to get his pension confirmed by Charles V on his accession, that Dürer travelled to the Low Countries in 1520.[5] During this trip he met Erasmus and Nicolas Kratzer.[6] In November 1520 Durer had his pension confirmed, but only in July 1521 did he depart for Nuremberg.[7] In 1525 Durer published his Unterweysung der messung,[8] which outlined ruler and compass geometric techniques for use in many areas, this work having evolved as a result of his concern to put painting on a firm foundation.[9]

However earlier, in preperation for the Nuremberg Reichstag of 1522 a committee of experts was set up to consider the problems of defence against the Turks. On this committee sat Durer, his friend Wilibald Pirckheimer and Johann Tscherte.[10] Durer, as a result became involved in the detailed problems of fortification and his Beftestigungslehre appeared at Nüremberg in

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1. D.S.B. CONWAY (op. cit.) p. 60 notes Durer's endorsment on the book saying he bought it in 1507. WAETZOLD, William; Durer and his times (London 1955) p. 208 gives 1505 but this seems to be an error.
2. D.S.B. The use of canons of proportion can be distinguished in Durer's drawings from at least 1500 on. (ibid.)
3. CONWAY (op. cit.) p. 83 prints the privilege
4. See STECK, Max: Durer and his world (London 1964) p. 43 & 96. WAETZOLD (1955) p. 211 who suggests it was the first such map.
5. Durer's diary of this journey gives many details of his itinerary and his activities there. He stayed just under a year. For an English version see GORIS, J.A., & MARLIER, G: Albrect Dürer, Diary of his journey to the Netherlands (London 1971).
6. See his diary August 1521, op. cit. p. 59 & 60. Nicolas Kratzer, astronomer to the English King, wrote to Durer in 1524 inquiring about measuring instruments they discussed at this time. RUPPRICH (op. cit.) Vol. I p. 111. CONWAY (op. cit.) p. 28 gives an English version of the letter.
7. Diary, op. cit. p. 72 & 103. Durer's attempt to get his pension confirmed included his seeking of patronage from Margaret of Austria, daughter of the Emperor (Maximilian I) and he recorded in his diary "Jtem hab der frau Margareth, des Kaysers schuester (sic), geschenckt ein ganczen truck all meines dings, und hab ihr zwey matery auff pergament geriessen, mit ganczem fleiss und grosser mühe, das schlag ich an auff 30 gulden. Und ich hab jhrem arczt, dem docter, müssen ein hauss auffreysen, darnach er eines bauen hat wollen. Davon zu machen, wolt ich auch unter 10 gulden nit gern nehmen." RUPPRICH (op. cit.) Vol. I p 158. English version in Diary (op. cit.) p. 68. Among the people Durer met on this journey was Hans Poppenreuyter of Malines who became gunfounder to Charles V in 1520 (BIOG NAT DE BELG) Diary (op. cit.) p. 95. "I went also to Poppenreuter the gunmaker's house, and found wonderful things there". Amongst his sketches from the journey is one of a mortar. (ibid. Ill. no. 25.)
8. See II p. 156.
9. See for example II p. 156/7. See also facsimilie ed. of Unterweysung der Messung (Zurich 1966), commentary by PAPESCH, Christine, p. 183 (in the English verson p. 201)
10. See JAEGGLI (1971) p. 109. Willibald Pirckheimer was of course Durer's intimate friend who had studied much from a youth and was widely read. Johan Tscherte served Maximilian and then Ferdinand I as advisor. He was selected for this committee due to his experience and knowledge of warfare and fortification. In 1528 he was made Baumeister for Lower Austria (ALL DEUT BIOG) A letter from Tscherte to Durer, probably from this period shows them discussing elementary geometrical problems. Tscherte wrote, "Hiemit schikh jch ew die proposicion mit dem trianlg dreyer vngleicher syg. En vnd jch nechten von euch haym kam, het jch sy vnnder wegen funnden. Aber aus ainem quadrat ainen triangl, der in gleicher continentz zu finnden, ist chunstlich. Versich mich, jr wisst sein wol. Die kugl sol sich nit verpergen. So balld jch der muss hab, wil jch suchen, was jch aus-richt." A construction then follows showing how to draw a rectangle equal in area to a given scalene triangle. RUPPRICH (op. cit) Vol. I p. 95. (CONWAY (op. cit.) p. 29 for a translation).

1527.[1] Dürer's third published work, on human proportions was just going through the press when he died in 1528.[2]

(ii) Dürer and method.

Dürer could not accept that mere skilful practise in the arts could ever be satisfactory in itself.[3] He felt there had to be a true ground (or method) underlying any satisfactory work.[4] For many years he searched for a method[5] in painting. He wrote how when young he had seen figures drawn by Jacopo de'Barbari by means of an underlying method, which, unable to obtain, he himself set out to discover by reading such authors as Vitruvius.[6] Again from Venice in 1506 Dürer wrote of wanting to go to Bologna to learn some secrets of perspective that a man there was willing to teach him.[7]

Dürer was quite clear that geometry provided just such a ground as was required, particularly in painting. He suggested that there was no single proportion best for the human body, but, he admitted, if in such a field "a man can prove his theory by Geometry and manifest forth its fundamental truth, him must all the world believe, for so one is constrained."[8] He equally suggested that his geometrical methods gave access to the truth about objects.[9]

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1. See II p. 157/8 The connection here is not documented, but Dürer appears to have shown little interest in details of fortification before this period. His 'theoretical' writings dating from the first decade of the century do not deal with this topic. As CONWAY (op. cit.) put it (p. 263) "The Theory of Fortification was not the outcome of long continued labour, in the sense that the Books of Human Proportions were. Its paragraphs were not written and corrected and re-written. They were apparently jotted down at odd times, and then transcribed, after one revision, into the printers copy." WAETZOLD, W: Dürers Befestigungslehre (Berlin 1917) p. 13. tried to make something of Durer's earlier drawings of sieges and defensive structures. (Followed by RUPPRICH (op. cit.) Vol. III p. 371) But these indicate hardly more than the painters general interest in many subjects. In his Diary of the Netherlands journey the only mentions of the subject seem to be 18. 11. 1520 "Niemägen...hat...ein whol gelegen schloss"; and 20. 11. 1520. "Pusch....hat ein aussbündige schone kirchen und uber fest". RUPPRICH (op. cit.) Vol. I, p. 161. Thus fortification seems to have been a late interest of Durer's.
2. Von Menschlicher Proportion (Nurnberg 1528). D.S.B.
3. See II p. 156/7. Of course here, in the Unterweysung der Messung, Durer referred specifically to painters, but the range of practices to which he suggested the treatise applied, and the range of topics dealt with in it (see *ibid.*) indicate that he felt this to be the case in many applied arts.
4. Ibid. Durer saw the Unterweysung der Messung as part of the ground for Von Menschlicher Proportion, for in the prefact to that work (1528 ed.) he wrote. "Damit auch dass mein vnderrichtung destpass verstanden mög werden/ hab ich hieuor ein puch der messung....ausslassen geen..."
5. "Method" was not a term Dürer used, rather he referred to "grundt" (see II p. 156) But by this term Dürer meant more than just a firm foundation. He sought a preliminary well established system which predetermined actual activity with regard to a particular task in a particular field.
6. "Jdoch so ich keinen find, der do etwas beschriben hett van menschlicher mas zw machen, dan einen man Jacobus genent, van Vendig geporn, ein liblicher moler. Der weis mir man vnd weib, dÿ er aus der mas gemacht het, ...vnd wen ichs hett, so wolt jch ims zw eren jn trug pringen, geimeinen nutz zw gut. Aber jch was zw der selben tzeit noch jung......(but) diser forgemelt Jacobus seinen grunt nit klerlich an tzeigen, das merkett ich woll an jm. Doch nam ich mein eÿgen ding für mych vnd las den Fitrusium....." RUPPRICHT (op. cit.) Vol. I p 102. This was written in 1523 by Dürer as a draft of a dedication of his work on human proportions, addressed to Willibald Pirckheimer. On his Netherlands trip in 1520/1 Durer was still trying to find out the secrets of this Jacopo, who had died in 1515, for he requested Lady Margaret that she give him a book written by that same Jacopo, which she possessed. But she refused saying she had promised it to her own painter. See Diary (op. cit.) p. 96.
7. "Dornoch wurd jch gen Polonia reiten vnder kunst willen jn heimlicher perspectiua, dy mich einer leren will", letter to Pirckheimer 13 Oct 1506. RUPPRICHT (op. cit.) Vol. I p. 59.
8. Trs. after CONWAY (op. cit.) p 245 with slight alterations. This is from the excursus at the end of Bk. 3 of Von Menschlicher Proportion, added by the editors. The full passage from the 1528 ed. Sg. Tiib "Aber vnmöglich bedunckt mich so einer spricht er wisse die beste mass inn menschlicher gestalt anzuzeygen/ dann die lügen ist in vnser erkantnus/ vnd steckt die finsternus so hart in vns das auch vnser nach dappen felt/ welcher aber durch die Geometria sein ding beweyst/ vnd die gründlichen warheyt anzeygt/ dem sol alle welt glauben/ dann da ist man gefangen/ vnd is billich ein solcher als von Got begabt für ein meyster in solchem zuhalten/ vnd der selben vrsachen jrer beweysung sind mit begirden zu hören..."
9. See II p. 157; l. 18/23.

This foundation for the arts, particularly in painting, which Dürer sought, and which he conceived could not be found in mere skilful practice, he believed to be something that ancients had possessed,[1] and it was therefore to their written works that he turned for guidance.[2] His view of method then tended willy-nilly to become that of one which was written, erudite and quasi literary.[3] Which instruction, he did not wish to keep secret but rather considered should be published forth for the benefit of all.[4]

Dürer's view of this kind of theoretical work was then one of the cultivation of ideas in a type of activity, both socially and in terms of its content, very different to the craft practices in which he had trained as a youth, grown up with, and sometimes fallen foul of.[5]

Joachim Camerarius, Dürer's friend, who after his death published a Latin version of his work on human proportions, saw Dürer very much in these terms as a literate and highly skilled searcher after rules or method, in contrast to one with a skill stemming from mere practice, along the lines of others of his time. In his preface Camerarius wrote of Dürer

> Letters, it is true, he had not cultivated, but the great sciences of Physics and Mathematics, which are perpetuated by letters, he had almost entirely mastered. He not only understood principles and knew how to apply them in practice but was able to set them forth in words. This is proved by his Geometrical treatises, wherin I see nothing omitted, except what he judged to be beyond the scope of his work....

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1. He sent a draft for the dedication to his book on human proportions to Pirckheimer on 18th. Oct. 1523 which included "vnd vnder anderm ich fragte, ob avch pücher ferhanden wern, dy do fan der gestalt der menschlichen glidmas lerten machen, fernem jch van ewch, sy weren gewest, aber pey vns nit entgegenn" RUPPRICH (op. cit.) Vol. I p. 105. (CONWAY (op. cit) p. 227 gives: "When, amongst other things, I enquired of you whether there were any books which treat of the manner in which the human body should be depicted, you answered me that, though without doubt there had been such, they have not come down to us".) He also wrote in the dedication to the <u>Unterweysung der Messung</u> "In was eren vnd wirden aber dise künst bey den Kreichen vnd Römern gewestist/ zeygen die alten bücher gnugsam an/ Wie woll sie nachfolgent gar verlosen...." (Sg. Aib (1525 ed.)) The art is geometrical drawing of course.
2. See above p.49, n.6. Much of the discussion in the <u>Unterweisung der Messung</u> was in direct descent from Vitruvius, as for example on sundials. Durer's dependence on Vitruvius is well recognised. See for example PAPESCH (op. cit.) p. 203.
3. In the dedication to the <u>Menschlicher Proportion</u> (1528) Sg. Aiib. "Ich will auch mit diser meiner vnderricht allein von den eussern linien der form vnd pilder....schreiben/ aber von den innerlichen dingen gar nit. Wie alt nun dise kunst sey/ wer sy erstlich befunden hab/ in was ansehen vnd wirden sy etwan pey den Kriechen vnnd Römern gewest sey/ wie auch ein gutter maler oder werckman geschickt soll sein/ dauon ist yetz on not zu schreiben/ wer aber des wissens zuhaben begert/ der lese Plinium vnd Vitruuium/ so wirdt er derhalb gnugsame underricht empfahen." (CONWAY (op. cit.) trs. p.231.)
4. See his remarks about Jacob de'Barberi's method above p. 49, n. 6.
5. PANOFSKY (op. cit.) p. 7, in writing about Durer's relationship to his wife outlined this general contrast quite clearly, (allowing for the art historian's exageration) when he wrote, "Agnes Frey thought that the man she had married was a painter in the late medieval sense, an honest craftsman who produced pictures as a tailor made coats and suits; but to her misfortune her husband discovered that art was both a divine gift and an intellectual achievment requring humanistic learning, a knowledge of mathematics and the general attainments of a 'liberal culture'." See Durer's own remarks about his social positon and his attempts to learn the social graces above, p.47, n.8 ; and his conflict with the monopoly of the Venetian painters. Durer's circle of acquaintences including Erasmus, Nicola Kratzer, Johan Stabius as well as his old friend Willibald Pirckheimer, indicates the type of society he came to mix in. Further, it was for example his very skill in manipulative geometrical techniques that enabled him to do favours for Stabius when petition ng the Emperor. (See above p.48 & n.4.) Equally in the same sort of context he produced drawings for a house for Margaret of Austria's physician. (See above p.45, n.7.). Further, according to WAETZOLD (1955) p. 60 "Dürer, as Erasmus noted with astonishment was capable of holding his own in conversation with learned friends and was conversant with the religious, philosophical, mathematical and astrological literature of the time" (But note ff. the level of mathematical discussion indicated by Tscherte's letter quoted above p. 48., n. 10.)

and that

> .....Andrea Mantegna, who became famous at Mantua by reducing painting tp some severity of law....(when) lying ill at Mantua he heard that Albrecht was in Italy and had him summoned to his side at once, in order that he might fortiy his (Albrecht's) facility and certainty of hand with scientific knowledge and principles...[1]

Yet when Dürer came to deal with the problem of human proportions in detail, his actual approach did not manifest the type of pattern he tended to outline in some of his more general remarks, except in a rather weakened form. He could not accept the use of a single 'cannon' or 'method' which would define one particular ideal type of human body, he explained himself;[2] and in his published treatise on the subject gave merely instructions on how to draw a fat man and a thin man, a fat woman and a thin woman, and so on, without either a geometrical (or numerical) approach focusing around a single ideal type, or a system which would have integrated his seperate types into a unified whole.[3]

Thus Dürer in the face of a specific task could not ignore the multitude of variations found in nature in favour of an over rigid and unitary geometrical approach, or method, despite his tendency to suggest he favoured such a system, and geometry tended to remain for him a useful tool merely to bring out particular variations, rather than the organiser which could subsume them under a single pattern.[4]

(iii) Dürer and his approach to fortification

In his treatise on fortification[5] Dürer manifested much the same approach as can be detected in his writings more closely associated with painting. He provided no (unitary) theory of fortification. He rather tended to put forward specific solutions to specific problems,[6] and even sometimes alternative solutions to the same problem, with no very articulated system integrating them together, each type of solution to be taken up where it was conceived most useful.

To some extent these different solutions were based on geometry, but only in the weak sense of their plan's (particularly) being drawn using ruler and compasses; and their actual geometry was often presented without reference to any clearly specified physical needs, as for example the projection of his first type of bastion into the ditch, which Durer explained needed to project merely a 'reasonable' distance into the fosse in the way he indicated.[7]

On the other hand in the case of his first situation, once the overall plan had been indicated Durer did use geometrical diagrams to give a regular diminution of the thickness of certain of the internal walls of his

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1. Trs CONWAY (op. cit.) p. 137 & 139, whose language is perhaps a little over modern. The oringinal Latin from Geometrae de Symetria partium in rectis formis humanorum corporum (Norimbergae 1532) Sg. Aiia & Aiiia, reads "Litterarum quidem studia non attigerat, sed quae illis tamen traduntur, max. naturalium et mathematicarum rerum scientiae, fere didicerat. Lqz is praecipua vt intelligebat et re explicare nouerat, ita et oratione sciebat declarare. Testãtur hoc scripta eius Geometrica, in quib. quid de illa scientia possit requiri, quatenus quidem tractandam sibi iudicauit, nõ video....Andreas Montegna qui Mantuae floruit reuocando ad seueritam quandã et legẽ picturã..... Mantua decumberet et Albertum in Italia esse audiuisset, curauit celeriter ad se accersi. Instructurus facilitatem eius et certitudinem manus rerum cognitione et arte...."
2. See above p. 49 & n. 8.
3. See Von Menschlicher Proportion (Nürenberg 1528) generally.
4. Interpretations of Durer's ideas on 'theory' not totally unlike what is given here can be found in a number of places. Particularly in PAPESCH (op. cit.); and also Max Steck's works. Unfortunately these authors tend to treat ideas as functioning in a rather autonomous realm and the detailed relationships between practice, method and the status accredited to certain types of knowledge by the surrounding society seem not to have been explored in any detail.
5. See II p. 157/9.
6. See contents ibid. The main problems Durer dealt with were the reinforcing of the angle of a town wall, with a bastion in 3 different ways, the last a relatively cheaper version than the first two. The provision of a Royal fortress on a plain de nuovo. A blockhouse. The modification of an old town wall in the context of the use of artillery.
7. See II p. 162; l. 1. On the other hand the orientation of the square fortress in a plain was set by reference to the winds in Vitruvian fashion. See II p. 162.

bastion, both in relation to each other, and in each individually as it rose in height.[1] Thus here Dürer used geometry as a minor tool once he had fixed his overall layout in terms of the particular problem with which he was dealing.

In contrast in the case of a prince's stronghold set in a plain Dürer fixed on the simple square as the most suitable shape.[2] Yet in the case of the blockhouse he preferred to organise the structure in a circular and annular form.[3]

Thus geometry was used by Dürer in different cases in rather different ways and his approach to each particular problem remained distinct and different, if not to say completely <u>ad hoc</u>.[4]

Yet at the same time there were general principles at work in the different solutions Dürer put forward. He stated generally that walls should not be vertical because of the vulnerability of such a profile to artillery and this is a feature of all his solutions.[5] Equally he was clearly always at pains to provide heavy solid structures and to organise them so as to contain or support defensive artillery, to harass any assault force.[6] In the case of the stronghold in a plain the preferred geometric shape of a square was relatively closely linked to the use of defensive artillery firing from his heavy 'bastions' along the ditches, to flank the assaulting troops,[7] -- a principle that was of course to become so dominant amongst later, particularly Italian, writers on fortification. But this principle was never used by Dürer consistently enough to create a particular system that can be associated with his name. Dürer's ideas on fortification were thus more a groping towards a system or method in accord with his general ideas,[8] than any definite expression of such an approach; and he tended to be too concerned with the details of particular situations or problems, to employ a general overal method.[9]

On the other hand in one respect Dürer's insistence on a proper ground or method in the arts, distinct from mere skill in practice, was reflected in his views on fortification. He did not take as a basic determining factor in his designs the possible costs of his structures or their probably relationship to the resources available.[10] He meditated on the problems of fortification of his time as he saw them, adduced some general principles as guides and then attempted to elucidate the optimum solutions in terms of those principles, ignoring the practical cost of building. He thus provided, he suggested,

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1. See sg. Aiiib/Aivb, op. cit. 2. <u>II</u> p. 162/3.
3. See the drawings in Dürer's treatise.
4. In the 3 discussions Dürer gave on a bastion at the angle of a town wall there was a certain similarity in their general shape and profile; and the third case was rather a scaled down version of the first. But within this framework, this holds true.
5. See <u>II</u> p. 159/60.
6. Dürer equally made clear that he considered the power of attacking artillery a very significant factor for the fortification designer. Ibid. He gave a general emphasis to the importance of defending artillery at other points. See <u>II</u> p. 161; l. 24/27 where he stated the spacing of his 'bastions' was to relate to the range of the defensive guns; & <u>II</u> p. 162; l. 33/8.
7. These are clearly indicated on his plan at Sg. Diiia (op. cit.) at the corners of a number of layers of ditches and at their mid points also in some cases. (Referred to as "streychweeren".)
8. As for example in his use of such general principles as indicated and his attempts to bring geometry to bear in different ways.
9. His contention that the inner core of the "schloss" or fortress on a plain should be designed according to Vitruvius (see <u>II</u> p.163, 1st sect) was again the use of a disparate element in contrast to his approach in other places. Equally in the same example when he had the basic trace set out in accord with defensive needs (see <u>II</u> p.161; l.23/30) he then went on at a good deal of length about "town planning" considerations. (Sg. Diiib/Eia.) Such topics he seemed to pick up as they came to hand, if he felt he could say anything interesting about them.
10. <u>II</u> p. 160/61.

solutions from which other could take as much as they found useful.[1]

Durer's ideas in this area were therefore rather a personal blend between his search for method and his sense of the needs of specific cases like his work in other areas.[2] He seems as a result never to have fully escaped his craft background to a condition where he could rigorously cultivate any such general mathematical methods in the arts, separate from the details of practice, and in part at least his approach to fortification seems to have been determined by this.[3,4]

Graf Reinhard von Solms-Lich and his dialogue on fortification

Reinhard von Solms-Lich was born into the family of the counts of Solms in 1491.[5] The details of his early life are obscure but the predominant influences on him during his youth seem to have been that of his father, and of the artillery master at Solms, while it is possible that he attended university also. In 1517 Reinhard was at the Emperor's court, and showed skill and practice with artillery during this period.[6] In the earlier part of his career Reinhard served with the Elector of Bavaria.[7] In 1535 his dialogue on fortification was published though not widely distributed;[8] and then in 1539 he was involved in strengthening the defences of Ingolstadt with the title of "baumeister".[9] In 1545 Reinhard was charged with organising the Emperor's command train in France,[10] and from that period on served Charles V and his successors.[7] In 1554 he was named as "Field-marshall" by the emperor. Reinhard died in 1562.[5,11]

1. See II p. 159, 1st. sect: & p. 163, 2nd. sect, where he denied that fortification could be similar in all places.
2. E.g. in his work on human proportions
3. Durer's continuing practice as painter and engraver on which his fame (and income) rested must have tended to mitigate against any such effect.
4. Earlier interpretations of Durer's fortification ideas have taken a rather different view, largely because their authors have tended to be interested in rather different aspects of his work. IMHOF, G. V., Albrecht Durer in seiner Bedeutung für die modern Befestigungskunst (Nördlingen 1871) because he was more interested in Durer as a forrunner of certain developments in fortificatiln such as the polygonal trace. RATHEAU, A, Instruction sur la fortification (Paris 1870) like ZASTROW (1839) tended to be interested in Durer as a forrunner of Montelambert. WAETZOLD (1917) approached Durer's work as a "mathematisch gerichteten Phantasie" (op. cit. p. 9.))Followed by RUPPRICH (op. cit) Vol. III p. 372.), whereas in fact it was not that strongly mathematical, especially in comparison with later Italian writers; and it was not so much "Phantasie" as an ideal approach (cf. Corbusier's skyscrapers of the 30's), and indicated as such. (An aspect that tended to tie up with Durer's approach in many paintings and engravings.) WAETZOLD (1955) p. 220/226 is slightly more balanced. This author also tended to make over much of Durer's town planning". as does JAEGGLI (1971) p. 117/20, where in fact Durer's ideas in this area were an appendage to his ideas on a royal fortress, rather than a central organising framework of the fortification. None of these authors then really came to grips with the problem of Durer's method in the area of fortification.
5. JAHNS (1889) p. 510.
6. ULHORN, Fredrich, Reinhard Graf zu Solms (Marburg 1952) p. 15/19.
7. ALGEM DEUT BIOG (under Solms).
8. See II p. 164 & n. 1.
9. SOLMS-LAUBACH, Rudolf Graf zu, Geshcicte des Grafen und Fürstenhauses Solms (Frankfurt am Main 1865) p. 189 & ALGEM DEUT BIOG, WAETZOLD (1917) p. 61/2 discussed Reinhard's work at Ingolstadt as influenced by Durer's treatise. The same author (1955) p. 225 wrote "The new fortifications of Ingolstadt, built in 1539 by Reinhardt Graf su Solms, with their earthworks and masonary bastions were almost certainly influenced by Durer's theories". For a discussion of this view see below p. 56, n. 1.
10. SOLMS-LAUBACH (op. cit.) p. 184.
11. Reinhard composed an encyclopaedic work on warfare of which at least parts were published before his death, although probably only in a few copies. See JAHNS (1889) p. 510/11. After his death his work Beschreibung Vom Vrsprung anfang vnd Herkomen des Adels (Franckfurt am Mayn 1563) was published.

Reinhard's view of the process by which sound fortifications came to be built was dominated by his insistence that experience was the crucial element in the process.[1] The title of his dialogue and its general structure made this clear. In his text the young relatively inexperienced "bawmeyster" was portrayed as receiving instruction from the old experienced warrior, and Reinhard was quite explicit that this should be the case.[2] Experience here, in the first place, was not that which concerned building itself. It was experience of warfare and the needs of that practice, and the knowledge that arose from this experience, which Reinhard tended to contrast with the poorer ability of the ignorant "bawmeyster".[3] But this was not to exclude experience and skill in building; rather, that experience was absolutely necessary, but it had to work within the framework of practical knowledge of warfare.[4] This knowledge of building Reinhard tended to see as, almost necessarily, being acquired through practical experience;[5] and equally as a personal possession, that was often not disseminated as much as was desirable, and which as a result tended to go to the grave with the individual that possessed it.[6] Its acquisition in Reinhard's view was best achieved through examination of existing work, and involvment in actual construction projects, although general discussion could be worthwhile in order to bring out some of the skills involved and the important points that needed to be made.[7]

Beyond these general ideas however Reinhard tended not to be very forthcoming about the precise nature of the building skills involved. At least in part this seems to have been because he conceived that particular cases had to be handled each in its own particular way.[8] On the other hand, he did indicate a number of general principles that had always to be kept in view. Firstly, everything had to be done at a reasonable cost,[9] this Reinhard continually emphasised, and in accord with the needs and resources of the patron.[10] Equally the understanding of the significance and performance of artillery was to Reinhard a general and crucial aspect of design.[11] This

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1. For a general description of the work see II p.164.
2. See II p.168;1.8/14 where Reinhard sets out the pattern.
This emphasis on experience ran throughout the work in a similar manner both explicitly and implicitly.
3. Again the main protagonist of the dialogue was an "alten erfarnen krieggsmans". See *ibid.* Reinhard made it clear that a crucial element here was the experience of the way artillery performed and adaption to it and for it.
4. Michel Ott the main protagonist of the dialogue was described in the title as a "ba meyster" as well as an "alten erfarned kriegsman". Reinhard equally emphasised thus his knowledge of building, as part of his qualification for his role in the work. (See II p.168;1.3/6.) The need for experienced building masters, pure and simple, Reinhard continually emphasised (See II p.166/7.). Equally he allowed to Hans Willing the junior partner in the dialogue, although somewhat inexperienced, useful knowledge which had accrued to him in serving a "ba meyster" (see II p.168→); and the structure of the dialogue was to build on his rudimentary knowledge of the trade in order to improve it through the council of one more familiar with the actual practice of warfare. (Stated explicitly II p.168;1.17/24; seen in action II p.169/70.)
5. II p.173, 2nd sect; & 169/70. 6. II p.166;1.5 et. seq. 7. II p.166;1.17/26.
8. II p.167;1.10/24.
9. See II p.167;1.29/7 See also f. Va (op. cit) "missrathen/ vnnd deinen herrn der vnnütz kosten reuen...."; f. Xb, "ist es keyn kunst dass eyner mit eym überentzigē kostē eyn starck werek macht...."
10. II p.169/70. The notion of the lord's resources is not specifically outlined by Reinhard. But the notion is clearly present that there is some suitable 'scale' of building for him and this must surely be taken to relate to his material resources at least to some extent, as well as also (in all probability) to his position in the social/political hierarchy, given Reinhard's picture of society. (On which see below p.56.)
11. II p.172, 1st sect ; also f. IXa "Nun bedenck wilt du eyn guten baw machen/ so must du der Artolorei dienen die im bau ist".

general idea about the importance of artillery was then further emphasised by Reinhard, when he insisted that a defensible structure was one that had the ability to flank itself.[1] In the field of the particular skills that the "bawmeyster" needed to possess, only one general aspect was made anyway clear by Reinhard. That was that he had to be able to survey sites and produce scale drawings of the proposed structure.[2] Within this rather general framework, however, the best responses to particular problems and situations, which formed the basis of good council in the field, and skill in building, which was only acquired by experience, was the ground of all true art in the field of the production of defensive structures.[3]

The position of the "baumeyster" in the construction process Reinhard made clear in a number of aspects. He was to a great extent an organiser and supervisor of the work, merely, standing in as a substitute for the lord to see that everything was done diligently and properly.[4] On the other hand he was equally expected to offer advice to the lord, although fairly clearly it was counsel he was conceived as supplying, with the ultimate decisions, even on matters of detail, lying with the lord.[5] The lord, generally being expected to have a certain amount of familiarity with warfare and hence being able to exercise properly this function, when properly advised.[6]

But Reinhard conceived there to be an activity of design which did not coincide with the activities of the "baumeyster". The "bau angebar" was an individual who advised on the proportions and measurments of the structure and its layout.[7] As such he did not fit very well into Reinhard's general scheme of things, but presumably his skills were conceived by Reinhard to arise from the same sources of experience in warfare and building.[8] The "bau angebar" then seems to have been not so much an individual who practised this as his profession but rather one who undertook a certain kind of activity which might be undertaken by different types of persons. The good "baumeyster" given Reinhard's general account of his activities should have been able to do this well.[9] Equally the good councilar and skilled warman, familiar with building, was pictured by Reinhard as being accomplished in this sort of activity. Thus we have rather an emerging role for a particular kind of individual, which role in Reinhard's account was fulfilled on different occasions by those whose primary roles were of a different nature.[10]

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1. See II p. 170/71.
2. See II p. 167; 1. 38/46: p. 165; 1. 29/35. Reinhard in no way attempted to emphasise mathematics as a kind of esoteric skill necessary to this task. It seems likely that he considered the skills involved would arise naturally in the course of apprenticeship and practice. The greatest emphasis he ever gave to mathematics was in fact in taking off quantities. See contents II p. 164 (Part II).
3. See texts noted above generally.
4. II p. 174, 2nd sect.
5. See II p. 169, 2nd sect.; 173, 3rd sect.; 167; 1. 15/25; 165, beg. although in dedications there tends to be a good deal of exageration of the skills of the person addressed.
6. This point is not specifically expressed by Reinhard, but it is difficult to conceive that this was not part of his viewpoint given the emphasis he put on the high degree of involvement by the lord in the details of the building, along with his emphasis on war-wise men as councillors.
7. See II p. 173/4 ; also f. VIIIb (op. cit.) "eyn baumeyster vnd eyn angeber des bawes seind weit von eynander als du horen solt..."
8. Because he gave no other account of the basis of such skills.
9. See above generally. A "baumeyster" was supposed to be able to design in some sense and had to produce drawings. The root of "angeber" is concerned with giving information, thus he was conceived as something of an adviser or councillor like Michael Ott.
10. This notion is introduced rather late into the text and hence perhaps reflected rather more second thoughts on the part of Reinhard, more in accord with the coming practice, than with his traditional picture (see below). Walter Herman Ryff (see below) in giving a redaction of Reinhard's text equated "bau angeber" with "architect", which was not a term Reinhard used.

The general picture then that Reinhard gave of the creation of satisfactory defensive structures, setting aside his account of the "bau angeber" who was suplementary to the main pattern, was of a very traditional cast. It was of individuals training in a craft by apprenticeship and acquiring skills through personal experience in their trade; it was of the lord (or patron) surrounded by advisers, whose practice in warfare allowed them to advise the lord, who by virtue of his role would be able to decide what best he needed in a structure and hence how best to get his "baumeyster" to organise the necessary building.

Just such a picture as to be highly consistent with the pattern of society Reinhard outlined in his work on the origins of the nobility.[1] A society where the lord, who could not practise trade, required the services of his subjects for his support, including that given by different types of tradesmen. A society where an important activity of the lord was the tourney, and the proper behaviour of the knight was an important part of the lord's knowledge; where the lord was essentially one practised in and knowledgeable about war; where the whole society was hierarchical both in terms of the different styles of living of different groups, and in terms of the sorts of knowledge the different groups possessed. Each finding their own skill through the continual practice in their own particualar roles.

Only the intrusion of the "bau angeber" with his not altogether clear position indicated any tendency for Reinhard to see things otherwise than in terms of the stereotype of the traditional feudal hierarchy, and the function of tradesmen within it: and it was this picture that dominated his dialogue on fortification.[2,3]

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1. See above p. 53, n. 11, for the edition of this work. f. Ib "...gross Volck/ solt vnd mûst vnerhalten werden/....als durch leibs notturfft/....Schmidt/ Schlosser/ Wagner/ Zimmerleuth van alles was man nuh nottůrfftig were..... dann sie befůnden die nottůrfft/ dass sie selbs bedencken....in den Stătten vnnd gelegen orten zu einem jeden handwerck plătz vergenom̃en vnd geordnet... so ordneten sie dann ein Person von ihrem handtwerck darzů der sich dessen verstundt/ vnnd in Regiment zuhalten vnd anzustellen wuste." f. IIIb "Zum ersten ist dem Adel alle Handthierung/ als Kauffen vnd verkauffen/ auch alles was Wůscherey/ oder wider den gemeynen nussen ist/ verbotten." Of the 20 folios of the work the last 13 were generally concerned with tourneys and the proper behaviour of the knight. Cf. some typical medieval ideas discussed below p.276/7.
2. In view of Reinhard's general position, the whole idea of his being influenced by Důrer is rather odd.(See above p. 53, n.9.) These two writers expressed radically different general approaches to fortification. Limited structures at a reasonable cost, in accord with particular needs, were Reinhard's ideals. Dűrer emphasised idealised structures of fairly massive proportions, for which the resources had to be found if one was to be safely protected. Reinhard emphasised quite strongly the notion of flanking fire, while Dűrer only made use of it in part. Dűrer emphasised the use of stone, while Reinhard favoured earth banks much more. The works at Ingolstadt seem to have been earth banks with not overmassive masonry casemates at some points to house flanking guns, (See WAETZOLD (1917) Illus, following p. 64 &68.) closer to Reinhard's ideas than Dűrer's. Of course Dűrer emphasised the need to take account of artillery both defensive and offensive, and Reinhard did likewise later. But Dűrer's personal experience of warfare was clearly fairly limited, and it is hard not to conclude that his discussions with Pirckheimer and Tscherte, and on the Reichstag committee of 1522 were the source of a good deal of his ideas about what the general problems were, in the field of fortification in his period. Both Reinhard and Dűrer were surely reflecting the consensus of contemporary opinion here, rather than Dűrer expressing some marvellous new truth which Reinhard followed.
3. This is not to suggest that Reinhard held completely, or merely, traditional views. Hans Willig the less experienced figure of the dialogue tended to express the greater preference for the older types of structures and more traditional attitudes to building, while Michael Ott often was involved in shifting his pupil more towards the coming pattern with emphasis on the importance of defensive fire (although without any pedantic worry about miniscule areas where this might not function). Yet the significant role given to experience in the whole dialogue, and the way its lessons were given by considering existing structures was very different from the 'demonstrative' knowledge of the later Italian writers. Thus it was in tending to shift from a traditional pattern that Reinhard informs us as to the nature of that traditional pattern. Most significantly in attacking his pupil's view on the value of the lessons of the castle of Milan, it was in no way central to Michael Ott's view that it was not a defensible structure. Rather, such a model reduced in accord with Hans Willig's patron's needs, could not satisfactorily contain artillery and would be weak.

Walter Herman Ryff and his writings

Between 1538, and 1548 when he died Walter Herman Ryff published over 30 different works, mainly on medical, and medically related topics, generally in the form of redactions from earlier authors.[1] But not content with studying and publishing on medical subjects, Ryff also took an interest in the mathematical arts[2] and in 1547 published Der Gantzen Architectur[3] and in 1548 Vitruvius Teutsch. These two works Ryff intended as a contribution to the mathematical arts, organised around the well known work of Vitruvius, which Ryff wished to make known to the German speaker.[4] But, Ryff explained, Vitruvius was not always clear and had written before certain discoveries, particularly in the fields of fortification and gunnery.[5] To fill in such gaps Ryff in Bk. II of Der Gantzen Architectur for example, dealt with geometric ballistics, fortification and troop arrays, all subjects with a mathematical ground.[6] In this section Ryff depended heavily on the earlier work of Reinhard,[7] and on Tartaglia's writings,[8] but also in the section on fortification on the ideas of many of the ancient authors.[9] But although Ryff leant heavily on earlier writers he was not merely a compilator who simply assembled the views of others uncritically. In his redaction of Reinhard's dialogue for example, while at many places he simply repeated that earlier writer's ideas or words exactly, on the other hand he continually inserted remarks as to how all the things he was discussing rested on the true grounds of the mathematical arts,[10] thereby changing the emphasis of the original text in a significant way.[11]

Again Ryff's whole project, built around the Vitruvian text, was no mere repetition of that text. By presenting material with a strongly mathematical base as supplementary to Vitruvius he made clear a view that architecture was very much more mathematical than Vitruvius had presented it as.[12]

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1. Apart from the large number of works he published Ryff's biography remains obscure (see BENZING (1959)). He seems to have been born in 1500 in Strassburg. (RÖTTINGER, Heinrich, Die holzschnitte zur architecktur und zum Vitruvius Teutsch (Strassburg 1914) p. 9.) Reinhard eventually referred to him as the Doctor of Nürmberg (2nd. ed. Eyn Gesprech Sg.Aijb) in which town some of his later works were published, including those considered here. He may have trained as an apothecary (BENZING (1959) and certainly he considered himself to belong to the medical profession (see II p.177; l.30/3). His publications tended to be rather handbooks than works directed towards members of the medical profession, and went through many editions before and after his death. Von Weibern und Geburten der Kinder des Albertus Magnus ran to 33 editions; Kurzes Handbuchlein und Experiment vieler Arzneien to 38. (See BENZING (1959))
2. See II p.177; l. 34/40. Mathematical arts in the sense of arts that employed mathematics.
3. See II p.175/6, for the nature of the former. Vitruvius Teusch was also published at Nurnberg; for later editions see BENZING (1969).
4. The two works had pretty well identical dedications. See II p.176/7.
5. Ibid.
6. See contents II p. 176.
7. Eyn Gesprech,
8. Nova Scientia & Quesiti et Inventioni.
9. Ryff was clearly also familiar with Durer's treatise in this area. His text ocassionally hinted at this II p.178 & n.1 But more definitely one of his illustrations, f. XXIIb, Fortification sect., 2nd. foliation, is clearly after Dûrer.
10. See e.g. II p. 180, 1st. sect. He also wrote (op. cit.) f. Ia, that all young workers should get help not only from him but also "nach der lehr Platonis vnd Christi selber".
11. See above for discussion on Reinhard in whom references to mathematics as central to the art were almost non-existent. JAHNS (1889) p. 800 said of Ryff's version in comparison to Rheinhard's that "Und in der Tat, jener Dialog folgt nun fast Wort für Wort --ein Plagiat....." his "fast" concealing the very significant differences between the two versions.
12. See II p.177; l. 11/21 for Ryff's outline of this position and his explanation that the new material was necessary because of gradual progress since Vitruvius' time, as well as the discovery of artillery which brought about the need for ballistics and new approaches in fortification. Ryff gave an extensive section on perspective in Der Gantzen Architecture as well as sections in some detail on surveying and on weighing and measuring, which disciplines were prefigured in Vitruvius but by no means emphasised in detail the way they appeared in Ryff's work.

Thus in general in the arts, as well in his section after Reinhard; Ryff promulgated his view about the value and importance of mathematics.

Ryff's compilation further reflected his own personal point of view, in his choosing to present commentary on fortification in that form of assembled views from different authors. For thus Ryff presented a particular picture of that art. On the one hand in the section after Reinhard's dialogue there was a tendency to emphasise such structures as the castle of Milan;[1] on the other hand the importance of banks and flanking fire was suggested;[2] while in the section after Tartaglia one found the geometry of the trace emphasised;[3] and then one was told that if one wanted to build castles in the traditional manner, one had Vitruvius to refer to.[4] Thus by assembling the views of earlier writers Ryff tended to present different views that seem to be not altogether in agreement. But this is only to insist that Ryff should have had some specific 'system' of fortification;[5] while in fact he chose to present a number of different approaches,[6] which the reader could learn from and apply, to the best of his own personal ability; those aspects of the different approaches being used where necessary and relevant.[7] Ryff however did implicitly present a "method". This was the search for and use of the best mathematical tools, each with its own specific function, relevant to a problem or part of a problem;[8] and by this means found the 'ground' for a correct approach, amongst all the multiplicity of difficulties involved in actual practical problems, and the possible responses to them, in the arts in general and fortification in particular.[9]

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1. See II p. 179; l. 15/23. This view comes from the junior partner in the dialogue who needs to be corrected. However the impression is still given that such a structure is very much worthy of consideration as a powerful one.
2. See II p. 170/1 for Reinhard's version, and p. 110, n 4 for Ryff's version of the beginning of this section.
3. II p. 180/2. 4. II p. 182, 2nd sect.
5. It is equally to insist that Ryff should not have used the same type of approach that was so common in the medieval period in contemplative knowledge.
6. And there is after all no inherent reason that the best system for the protection of a large urban area, should be in some sense, a scaled up version of the structure best suited to house a small garrison in an isolated fort.
7. Ryff was not very explicit about this. However this sort of view tends to be implicit in Reinhard, whom Ryff followed in many ways so closely, and reflects what can be got out of Reinhard's text. Ryff's approach may perhaps have reflected Vitruvius's idea about architecture that "Ea nascitur ex fabrica, & ratocinatione" Bk. I, Cap. I. (This was the contemporary reading; GRANGER (1931) suggests that there was a certain amount of misinterpretation here.)
8. This is implicit in Ryff's whole approach, and is outlined in his dedication, see II p. 176/7.
9. There is one difficulty here in explaining why Ryff made little use of Durer's treatise on fortification whose work he knew (see above p. 57, n. 9.). It was possibly because it was the foreign texts, not available to the German reader that Ryff wished to present (see II p. 176). But he gave Reinhard's text which was in German; however this was not widely available (see II p. 164, n. 1) so perhaps in part this was the sort of reason he ignored Durer's text largely. But additionally both Reinhard and Tartaglia and the ancient authors tended to provide apopthgems, principles and considerations of a very general nature, and not to provide specific solutions with detailed drawings as Durer did. Ryff's approach was to provide discussion at the general level rather than giving specific forms -- and noticeably he did not give any illustration of Turin to go with Tartaglia's remarks -- or detailed solutions. Probably then Ryff found Durer's writing on fortification too specific and yet not sufficiently dependent on mathematics, as well as being very readily available to the German reader, particularly at Nurnberg, an hence ommitted it. Generally in fact Dürer's work does not figure strongly in Ryff's mathematical writings where one might expect to find it.

Leonard Fronsperger and his writings

Leonard Fronsperger's early years remain obscure,[1] but in 1535 he was involved in the siege of Marseilles. In 1541/2 at Ofen and Pest. In 1552 he was in charge of a siege train in France for the Emperor and later rose to the rank of "Feldsgerichtsschutheissen"; and then "Kaiserl. Provisioner" in the Emperor's service. He died in 1575.[2]

Fronsperger published a number of works in the 1550s and 1560s, relating to many aspects of warfare, culminating in his massive compilation, known as his Kriegsbuch (Pt. I, 1571; Pts. II & III 1573) containing much from his earlier publications which in their turn leant heavily on earlier writers.[3]

In the midst of all the writings that were to form parts of the Kriegsbuch, Fronsperger included at a number of points, sections on fortification. In these sections he depended heavily on Reinhard and Ryff, whom he openly acknowledged in this.[4] In the Kriegsbuch Fronspergers ideas then were made up of a great many strands, leaving the reader with no single clear picture of the optimum type of fortification.[5] Equally he gave no clear plans or illustrations of structures,[6] except in the case of field fortifications; and here he presented one with a sinuous trace;[7] one, a square defended by roundels at the corners;[8] and one with something of a tenaille type trace with some flanking.[9] Thus Fronsperger in no way attempted to put forward any system in fortification. He rather provided general discussion from many points of view without going into any too great detail of what structures ought to be like. The reader could thus, when he had put before him many (informed) opinions, adjudge and choose what was suitable to his own particular needs.[10]

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1. NEU DEUT BIOG.
2. After JAHNS (1889) p. 548.
3. See II p. 185 . Fronsperger also published Baw Ordnung much concerned with practical aspects of building in general in 1564 at Franckfurt am Main; and a little treatise on ethics in the same period at the same place.
4. f. XXIIb. See texts also.
5. He acknowledged Vitruvius for instance Bk. II f. XXIIa "viel erfahren Vitrunius welcher aller Gebäw vnd Baumeister ein Vatter vnnd vrsprung ist" He equally had Ryff's remarks after Tartaglia -- Pt. II f. XXVb (Ryff II p. 180/1). In Pt. I f. CLXVIb he wrote "Alle hohe Thürn vnd Gebäw sol man in einem Schloss oder Besatzung abhenden" (This is from the section taken from his earlier Feurwerksbuch); and yet he repeated Ryff's remarks about going to Vitruvius when towers, gates, etc. for a castle are needed. Pt. II f. XXXb. (After Ryff II p. 182) (One therefore can not see Fronsperger's views as simply developing here, for it is in the later works he mentions the old forms , while the earlier says to omit them. And in Pt. I CLXIIIIa he wrote of round and square towers. See II p. 184, but ext. from the Feurwercksbuch book which is exactly repeated there.
6. Many of his wood cuts show cases of round squat towers, Other clearly invovled the pointed bastion, but its trace is never clear, and only the initiated could have recognised what was going on. One illustration was repeated at a number of places (Pt. II, f. XLVIa, f. CXLVIa; Pt. III, f. XCVIa XCVIIIa, CXXVIa) which shows a regular square fort with low banks, although not using the pointed bastion. These however are all more illustrative than informative.
7. After, Pt. III f. CXXVII; f. LXXVI "Von den Gewelbdten runden Schlangen Schantzen. Ob man sich vor vberfal in Feindts nötten oder gefahr zubesorgen hat".
8. After Pt. III f. CXXXIX, f. LXXVIIIb "Diss Muster oder Exempel der auffgeworffner Schantzen..."
9. After Pt III, f. CXXX, f. LXXXa "Erklarung der Stern oder Ecten Schantzen mit ihren Streichwehren."
10. This is inferential, as with Ryff, but unless one takes something like this point of view Fronsperger's whole effort seems to become contradictory to the degree of being completely nonsensical.

Daniel Specklin and his treatise

Daniel Specklin[1] was born in Strassburg in 1536, son of one or other of two brothers, Daniel a silk embroiderer, or Rudolf a wood engraver (or carver). However, Daniel learnt both these trades, and then aged 16 (in 1552) took to the life of a wandering craftsman.[2] During the next 9 years he visited and worked in many parts of Europe.[3] Then in Vienna in 1561 by virtue of his skill as a designer, he came to the notice of Hermann Schallantzer, engineer to the Emperor, with whom he found service and began his career in building.[4] Returning to Strassburg in 1564, Specklin there engraved a plan of the town but the authorities, fearing it might fall into the hands of their enemies ordered it confiscated The resultant controversy[5] resulted in Specklin's moving to Dusseldorf, and in 1567 he held the position of engineer there. But, unsatisfied, he returned to Vienna and took service with Lazarus von Schwendi, for whom he produced many plans, and with whom he served in Transylvania in that same year.[6] In 1569 Specklin returned to Vienna at the behest of Carlo Theti one of the successors to Schallanzer. Specklin worked on fortifications in Hungary and then was named to the Military Academy of Maximillian II and to his collection of Roman antiquities. In 1570 Specklin was again in Alsace and in 1572 held the post of bailiff to Simeon von Fleckenstein. From 1573 to 1575 Specklin was involved in making a map of Alsace. In 1576 he was concerned with drawing up plans for Ingolstadt, and sat on a congress of engineers at Ratisbon presided over by Lazarus von Schwendi. In 1577 Strassburg finally named Specklin as town architect.[7] For the rest of his life Specklin was continually involved in many building projects, civil as well as military, at Strassburg; and at sites such as that of the castle of Lichtenberg which was largely rebuilt between 1575 and 1580, and for example at Ensisheim.[8]

In 1587 Specklin addressed a letter to the magistrates of Strassburg about three works of his: one a treatise on fortification; the second a work on the improvement of the fortifications of Strassburg; and the third a chronicle of the history of the buildings of Strassburg.[9]

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1. Or Speckle or Speckell or Speckel. See Fragments des anciennes chroniques d'Alsace Vol, II, "Les Collectanées de Daniel Specklin" ed. Rodolphe REUSS (Strasbourg 1890) p. 4.
2. Ibid. p. 5.
3 Including north Germany, Poland, Hungary. In his treatise he stated that he was at Vienna in 1555 (1st. ed. f. 35a) and at Antwerp in 1560 (see f. 17b).
4. REUSS (1890). JAHNS (1889) p. 822/3, in contrast wrote "widemete er (i.e. Specklin) sich fruhzeitig der Geometrie und Baukunst und durchwanderte als Lehrling und Gesell zu seiner Ausbildung....Im j. 1554...wie er selbst erzahlt, bei dem Bau der Feste Comorn beschäftig." However what Specklin wrote on Comar was "ich bin in meiner jugent vor 34. jahren do bey diesem bau gewesen"; and REUSS (1890), who based his account on Wencker, the 17th. century archivist and chronicler, quotes that author as stating of Specklin c. 1560 "Allow er seir anfang in der baukunst genommen". Jahn's emphasis on Specklin's studying building and geometry as a youth then seems to be a product of this historian's imagination, although one may presume that Specklin's first trades may have involved a good deal of 'design', and Specklin did evidence interest in fortifications before 1561, as at Antwerp in 1560, as well as at Comar. But his involvement in actual building must be put at only this later date, while previously he had been building up his personal drawing skills, presumably, not doing geometry.
5. REUSS (1890) p. 5/6. Specklin requested the authorities to take an interest in this plan, whereupon, they demanded he give up the sheets already completed against reasonable damages because they feared it might serve their enemies. At this period Specklin continued to work at his original trades.
6. KERN, Georg, Bilder aus der Geschichte des Alsass (Strassburg 1900) p. 4.
7. This was apparently a new post "Daniel Specklin der Stadt Strassburg ersten bauwmeister, dieses bestallet, war in der jugend ein seidensticker" is found against 1577 in "Les Chroniques Strasbourgeoises" Fragments des anciennes chroniques d'Alsace No. III (1892) p. 167.
8. For details see KERN (1900) p. 17/25.
9. REUSS (1890) p. 9. The magistrates were not over impressed by Specklin's attempt at history. A report described it as "ein farrago aus alten historien" and pointed out the need for correction of Specklin's grammer. (Ibid. p. 12.) During this period of his life Specklin was involved in a good deal of antagonism with some of the magistrates of Strassbourg. (Ibid. p. 8)

In 1589 Specklin's Architectura Von Vestungen was published and he died in October of that year.[1]

In a general way Specklin drew heavily on Vitruvius in his account of the fortification designer's craft.[2] But deviated from the Vitruvian position by emphasising the Architect's need to be familiar with many crafts and their practices,[3] and on the other hand, by emphasising the need for mathematics.[4] Yet while Specklin tended to make mathematics in this context sound like a very esoteric and fundamental tool,[5] that discipline as it appeared in his treatise was no very sophisticated tool of analysis or construction.[6]

On the other hand Specklin's treatise clearly manifested his immense skill and inventiveness as a draughtsman,[7] and that it was this type of rather practical craft that was the core of his personal 'mathematics'.[8] In one engraving he made clear his technique involving the determination of a great many features of the trace of the structure purely by reference to the geometric coincidences of lines within the drawing; physical interpretation of these features being of little account.[9] His most beautiful and elaborate

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1. "Les Chroniques Strasbourgeoises" Fragments Des Anciennes Chroniques d'Alsace No. III (1892), p. 44 (1589)"Es starb diss jahr 18 oct. herr Daniel Speckel disser Statt baumeister, ein berühmter baumeister und ein fleissiger beschriber disser stadt, im 53 jahr seines alters; sein contrafactur is bey dem anfang zuo sehen".
2. Architectura von Vestungen 1st. ed. Cap. I f. 1a/2b. He gave importance of health factors in the selection of the site (see II p.191; l.17/21), and discussed the significance of the orientation of the structure in the context of the prevailing winds. (Op. cit. f. 1a/b.) The architect as a result had to know something of Physic and Astronomy Specklin explained. He equally tended to see the architect as familar with a large number of disciplines.
3. See II p. 190, 3rd sect. et. seq. Vitruvius did of course discuss machines, but tended to be more concerned with the theory of machines, while Specklin focused on craft practice. Again while Vitrivius gave a good deal of discussion on material Specklin tended to consider such knowledge more practically and to give it a more central role. (Ibid.)
4. Vitrivius of course did not ignore mathematics. In pointing to its usefulness in surveying sites for example, Specklin was quite in accord with Vitruvius (see II p191; l.35 et. seq. & Vitrivius Bk. I, Cap. i, sect. 4). But mathematics was mentioned as but one among many disciplines in Vitruvius, while Specklin emphasised it centrally. See II p. 191; l. 12 et. seq. ; and of course Specklin differed from Vitruvius in emphasising the importance of artillery.
5. He mentioned astronomy for the finding of directions in order to orientate the structure relative to the winds for example (f. 1a in the passage following II p.191; l. 34.) He then gave a rather Platonic emphasis to the use of the compass II p. 192, 2nd sect.
6. In his remarks on surveying and setting out for example Specklin very rapidly turned to very practical details (see II p. 193, 2nd & 3rd sect). To set out the regular polygons he simply gave the radius of the circumscribing circle for each polygon when its side was 1000 ft. The compass which he described using also tended to reduce 'geometrical' activities to mechanical ones. See II p. 192, 2nd sect. His attempts to make very crude craft practise into sophisticated mathematics is best seen in his attempts to connect harmony with the 'true ring' of a material. (See II p. 191/2.)
7. See for example his plates nos. 10. 11, 12, and 8, l, n, m, Nothing of comparable quality can be found in the other published treatises of the period certainly in those previous to his work, with the possible exception of Alghisi's book: yet Specklin's engravings are far superior in technique to Alghisi's in their use of shadow techniques and perspective presentations. There does of course always remain the problem of the contribution of the engraver, if Specklin did not do this work himself. But the engraver can not work on what is not given to him, and the subjects are so specialised that it is very difficult to conceive that anybody but the individual familiar with the specialized art, could do more than help to elaborate and clarify what was in the oringinals from which the engraver must have worked. [26]/[31]
8. Drawing, particularly using perspective techniques being so often considered as part of mathematics in this type of context. Many sections of Specklin's text are presented simply as an elucidation and further clarification of what is first presented in one of the plates.
9. No. 7. Ut. half. While some of the lines here may be considered to relate to the lines of fire of the defending guns, it is hard to see how, for example, the determination of the line of the foot of the glacis could reasonably be so accounted for. [25]

designs then involved a geometric elaboration of the pointed bastion trace, along with a consummate skill in the presentation of the results.[1] While at the same time, his very practical approach, directed towards actual tasks to be done,[2] existing structures, actual sites,[3] and the trade practices relevant to building,[4] helped to restrain his geometrical approach from degenerating into a mere intellectual game.[5]

Thus in his personal life and in the treatise he assembled, Specklin continually remained intensely in touch with practice while basing his achievements on design involving high degrees of skill or draughtsmanship.[6]

But clearly however great Specklin's abilities they were never in themselves quite sufficient to stand independently and to give him the position he desired.[7] Thus in his treatise he attempted to underpin his approach by an insistence on it as being fundamentally dependent on mathematics; and by, Vitruvian fashion, emphasising the wide range of skills necessary to the architect. While in his efforts at history he attempted to enter the world of the learned.

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1. Pl. 29/31.
2. See for example on setting out II p. 193, 2nd & 3rd sect.
3. Antuerp, Comar and Valetto for example figured prominently in his discussions. Much of Pt. II of his treatise was confined to discussion of particular sites, especially of castles on crags, as Specklin explained was his intention here. See II p. 190; 1. 30 et. seq.
4. II p. 190, 2nd sect.
5. As Alghisi's did, or nearly did.
6. In his biography his skill in design continually comes out, with his employment with Schallanter, and Schwendi for example. It is also not unlikely that Theti called for him due to his skills as a draughtsman rather than a designer, for presumably Theti was going to remain the designer. His work on plans and maps as at Strassbourg and for Alsace follow the same pattern. His basic trades both involving delicate design must have been of great aid to him here.
7. There are a number of hints that Specklin's life was not altogether a happy and satisfying one. Firstly, while he seemed to be able to gain employment with various people in many positions, he never seemed to stay long in any one situation, and even after becoming architect to Strassbourg he still seemed to work in many places. (For greater details on his movements see above quoted sources.) His emphasis in the dedication of his treatise on the criticism he suggested Italians were always making about German workers (see II p.188/9.) tends to suggest that Specklin did not feel his position and efforts were sufficiently appreciated. His account of construction at Antuerp and his talks with Master Franz, with its emphasis on the technical skill of the architect as against the knowledge of councilers who were merely war wise (see II p. 193/194.) tends to suggest that he felt the need to insist on the value of his own particular skill, which in his environment was not always sufficiently attended to, in his view. His relatively humble background seems to have been something his contemporaries were not too willing to ignore. (See above quote p.60, n.7.) The enmities which he seems to have made in the last years of his life among the magistrates of Strassburg again suggest tensions in his position. Finally his attempt at a chronical and hope for approval from the magistrates of his city tends to indicate a dissatisfaction with his social position.

(iii): The International Tradition

Outline of the tradition

Towards the end of the 16th. century and especially during its last decade original fortification treatises began to be published in countries other than Italy and Germany, by native authors in their own languages.

Within this group is the slight work by the English author Paul Ive (1589); a treatise by the Dutch mathematical practitioner Simon Stevin (1594); an introductory work much concerned with the general use of mathematics in practice by the Frenchman Claude Flamand (1597); a treatise much concerned with drawing techniques in fortification design by his compatriot Ambroise Bachot (1598);[1] two works introducing the Spanish reader to the art, one by Cristobal da Rojas (1598); the other by Diego Gonzales de Medina Barba (1599); and finally a treatise that was to become a classic on the art by the Frenchman Jean Errard (Bar-le-Duc) (1600).[2]

Paul Ive

Paul Ive became familiar with contemporary fortification in the Low countries in the early 1570s.[3] In 1584 he was concerned with the harbour works at Dover, and his treatise was published in 1589. From this time on until his death in 1604[4] Ive was much employed by the English crown on harbour and fortification work. He apparently had a reasonable amount of education,[5] and published a translation of a French work on warfare in the same year as saw the publication of his fortification work.[6] There is no doubt that Ive leant heavily on the Italian treatises for certain sections of his work, particularly in those sections dealing with the preferred trace.[7] But even though he presented such material in much the same way as it was found in many of these Italian works Ive tended to consider the practical problems posed by particular sites as more important[8] and denigrated any too 'academic' an approach, considering the knowledge of experienced builders and warleaders as of significant importance in applying any preconceived design.[9] Ive was equally just as much concerned with modifications to older structures to make them function satisfactorily under contemporary conditions,[10] as with building anew. In both his experience and thought, then, fortification tended to remain always a practical matter to Ive and not an abstract geometric activity.

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1. Bachot published in 1587 an earlier and slighter version of his treatise that appeared in 1598. Because of its probable original rarity, its details not being available for analysis together with its less definitive nature, it has been ignored in the analysis of this writer given here.
2. Among other works not included for analysis here is Jacques Perret's Des fortifications, et artifices d'architecture (Paris 1594) which with regard to fortification only presented particular designs.
3. Dedication The Practise of fortification (London 1589) Sg. Aa 2a "the practise of fortification, hauing had sight therein since the view taken by the Marques. Vitell, for the oppressing of the Lowe Countries, with the yoke of Citadels." See also II p.195, 3rd sect. Chiappino Vitelli may have died in 1575 GR. DZ. IT. (BIOG UNIV states sometime after 1576.)
4. BIDDLE (1972). In the channel Islands 1593/5 & 1600. At Portsmouth 1595/6. On the Cinque Ports' defences 1596/9. 1599 on Pendennis. 1601/2 at Kinsale and Cork, in Ireland, where he died.
5. D.N.B. He seems to have been registered at Cambridge in 1560, though he never matriculated.
6. Instructions for the warres (London 1589) of "Monsieur William de Bellay".
7. See II p.195, 2nd sect. where he makes a typical point. His account of the pointed bastion (Cap. 3 ff.) took the standard Italian form. BIDDLE (1972) has pointed out the similarity of one of Ive's main illustrations to diagrams of Girolamo Cataneo, and other like derivations.
8. II p. 195, 2nd sect. 9. Ibid. 4th sect.
10. Ibid. 5th sect. His Cap. 5 dealt with this topic.

Simon Stevin, his ideas on method, and approach to fortification

Simon Stevin of Bruges was very probably born in 1548.[1] His early life remains obscure but by 1577 he was occupying a position in the finacial adminstration of his city. He settled in Leyden in 1581. In 1582 his tables of interest, the first of the many works he published, appeared. In 1583 he matriculated at Leyden. In the following 10 years Stevin was much engaged in engineering projects, particularly in connection with water managment and related topics.[2] Mill construction occupied him on a number of occasions and he attempted a sophisticated mathematical analysis of some of the problems involved to effect improvments.[3] In 1594 Stevin published his work on fortification Der Sterctenbouwing.[4] Around this time Stevin must have entered into service with the young Stadtholder Prince Maurice, as tutor and advisor, and engineer to the army.[5] In 1598/9 Stevin was involved in consultations on the fortifications of Hàderuijk.[6] In 1605/8 Stevin's Wisconstighe Ghedachtenissen appeared containing discussions on a large number of topics involving the use of mathematics, which he composed as a result of his studies with and for Prince Maurice.[7] At the end of the first decade of the 17th. century Stevin was involved in consultations on the fortifications of Flushing. He was undoubtedly at the siege of Julich in 1610.[8] In 1617 Stevin published Castrametatio and Nieuwe Maniere van Sterckebou, door Spilsluysen together.[9] In 1619 he was involved with designs for the new castle at Batavia. Stevin died in 1620.[10]

Simon Stevin composed a very large number of works involving the use of mathematics in many areas.[11] At least in one place he expressed the view that in such work there was a general method involved, which definitely owed little to the Aristotelians, was perhaps nearer to Ramus' position, but which particularly owed a great deal to Euclid.[12] In this Stevin made little of the

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1. Biographical information generally on Stevin is found in DIJKSTERHUIS (1970); STEVIN (1955/66) Vol. I p. 3/34; on his military activities, ibid. Vol. IV p. 3/27. D.S.B.
2. See STEVIN (1955/66) Vol. V p. 9/38 ff.
3. Ibid p. 325/413. Stevin seems to have run into a good deal of trouble on occasion with his construction of mills, in terms of performance. (See ibid. p. 324/327.) In this period he was in partnership with Johan Cornets de Groot (ibid p. 13) with whom he carried out experiments on falling bodies. See Weeghconst (Leyden 1586) Pt. III p. 66.
4. II p. 197.
5. The way in which Stevin found this position, the actual period when he came into contact with, and to serve Prince Maurice and the detailed nature of his activities in this context, remain obscure. (See Dijksterhuis (1970) p. 6.) c. 1593 he was employed by the army as "affteeckener der Quarteiren" but only in 1604 was his title confirmed as "Quartermaster to mark out the Quarters" (STEVIN (1955/66) Vol. IV, p. 17.)
6. STEVIN (1955/66) Vol. IV p. 18.
7. See STEVIN (1955/66) Vol. I p. 28/30 for contents, and II p. 200, 3rd. sect. & 201, 3rd. sect.
8. STEVIN (1955/66) Vol. IV p. 20/1.
9. At Rotterdam.
10. Probably somewhat dissatisfied with his lack of success as a military engineer his son Hendrick says he petitioned the States General for the establishment of an office of superintendant of the fortifications for which he recommended himself. His request was rejected. He petitioned for an increase in salary in 1520, and again was rejected. See STEVIN (1955/66) Vol. I p. 12.
11. For bibliography of his works see STEVIN (1955/66) Vol. I p. 25/34 & VAN DE VELD (1948) Among his published works were the many topics of the Wisconstighe Ghedachtenissen, including astronomy, perspective, navigation, surveying, the overturning moments of ships, and the forces on bits and bridles. Amongst his unpublished manuscripts were notes on music STEVIN (1955/66) Vol. V p. 416/64; and on forming regular arrays of pikemen, ibid. Vol. IV p. 479/517; and of course he published separately on fortification. See II p. 197/8 for his emphasis on the value of geometry in this context. The most notable ommision in Stevin's mathematical studies is with regard to ballistics and the free fall of bodies (although he mentioned experiments in this last area -- see above n. 3). That both these topics are missing, the first particularly glaringly so in the context of Stevin's military/mathematical work with Maurice, suggests something about the sorts of problems involved in these areas was very uncongenial to Stevin.
12. II p. 198, 1st sect.

distinction between contemplative or speculative knowledge, and practical knowledge, but rather emphasised the difference between practice or experience and theory.[1] Indeed in explaining the basic nature of astronomy he made use of the analogy of making a map to explain his picture of how knowledge of the heavens was gained.[2] Theory, Stevin felt, using mathematical methods, had not only the value of certainty,[3] and gave a reasoned understanding,[4] but also was the quickest and surest route to knowledge, and made up for defects in the amount of empirical information available at any time.[5] But although he conceived of theory as predominating over practice,[6] Stevin insisted that theory should never lose sight of the ends of practice.[7]

Yet in his own writings, while Stevin was very frequently concerned with very practical topics and directed his theories towards them, often his theories, while grounded in practical experience became, or involved, mathematical solutions which had little or no application to practice, but which Stevin considered valuable simply because he conceived the mathematical treatment to be inherently useful.[8] In part this tendency of Stevin's seems to have been a response to theories as, so to speak, idealisations which often had to be modified in the face of the awkward details of the natural world, after the general pattern had been established by theory;[9] and equally with the idea that he sometimes expressed, that his theories might have to be altered in detail as experience increased.[10]

In his main treatise on fortification Stevin made clear that, in his view, theory in the form of mathematical methods using "sight-lines"

1. II p. 196, all sects. In his texts on astronomy his first book was based on "ervarings dachtafels" or empirical ephemerides; the second was in contrast mathematical. See II p. 201, 2nd. sect.
2. II p. 210, 1st. sect. 3. II p. 196, 3rd. sect. 4. II p. 201, 3rd. sect.
5. II p. 200, last sect. 6. II p. 198, 2nd. sect. 7. II p. 196, 2nd. sect.
8. In the "vlietende Topswaerheyt" (floating top heavyness) STEVIN (1955/66) Vol. I p. 566/73, he admitted that his method of assessing if a boat would overturn was impractical, but gave it all the same "Maer want die soucking der swaerheyts middelpunten van soo veel verscheyden stoffen als ghemeenlick in een schip sijn te moeyelick soude vallen, soo en dienet niet om im sulck voorbeelt hem daer me te behelpen. Nochtans insiende dat kennis der oirsaken van topswaerheyt, en der ghestalt eens vlietende lichaems int water elders can te pas commen; Oock me dat deghene die moeyte mocht doen van dat te soucken, hier me geholpen can worden, soo hab ick dit by ghedachtnis ghestelt alsboven. (p. 572, op. cit.) Again in his writing on perspective he admitted that views with the glass (on to which the object was conceived to be projected) at an angle to the floor were seldom required ("selden begheert te vvorden"), yet were necessary to perfect knowledge in the art ("tot volcommen kennis der heele verschaeuwing"). (Op. cit. Vol. IIB p. 805.) In music he equally seems to have proceeded mathematically, and did not take full account of the fact that the nice mathematical ratios he put forward would produce discords. See STEVIN (1955/66) Vol. V p. 413/464, ff. p. 420.
9. He took this position very clearly in Der Ebbenvloet STEVIN (1955/66) Vol. III p. 329/57. " Maer op dat alle dese ongheregheltheden, ons niet en verhinderen om te begrijpen de groote ghemeene eygenschap van ebbe en vloet, die wy spieglingsche wijse voornemen te beschrijven, soo begheeren wy hier boven toghelaten te worden, den Ertcloot heel met water bedeckt te sijn, sonder wint of yet dat an ebbe en vloet hinder gheeft, om daer na vande ghedaente der beletselen onderscheydelicher te meughen spreken..." Op. cit. p 334.
10. See De Havenvinding STEVIN (1955/66) Vo. III p. 419/475, p. 432"....(if) by aldien namals deur nauwer en seker der ervaringhen...befonden weerden... dat ons sulcx van t'voornemen deser ondersoucking niet en behoort af te keeren, maer veeleer daer toe te trecken, als allen ex gerakende tot meerder en seckerder kennis eens handels ghesticht op sulcken gront als vooren verclaert is." See also a not dissimilar notion, which seems to run through Stevin's astronomical text, where he uses the "empirical ephemeredes", although he knows they are not fully accurate, due to lack of sufficient observers (ibid. p. 55).

(sichtstralen) was the only basis for the true art.[1] The general approach of the treatise involved the discussion of the (idealised) regular fortresses with the case of the hexagon being chosen for discussion to indicate the general method involved; later sections then dealt with discussion of various aspects of the fortress that might justifiably be handled differently, or about which this might be thought so; while the final chapter considered the problems of irregular and actual sites, and their advantages and disadvantages in the context of the ideal solutions.[2] In many ways Stevin's remarks were very practical as for example in explaining how to set out a fortress with ropes and stakes. Yet in just this context he indulged in a demonstration of sophisticated mathematical manipulation wholly irrelevant to the practical problem as he had set it up. For, here he explained how to work out the length of the rope needed to set out the circumscribing circle of a pentagon with a side of 1000ft, using mathematical tables to an incredible degree of accuracy.[3]

Thus the theoretical approach through mathematics, the primary use of idealised solutions modified by the exigencies of actual practice, and the tendency to allow mathematical manipulation to become an end in itself even while in close contact with actual problems and experience was maintained, which was typical of Stevin's approach in many other areas, was equally to be found in his writing on fortification. The approach of his contemporaries and of earlier writers in the field, which concentrated on the ideal trace of the regular polygons, enabling his general approach to function satisfactorily in this particular area, which could then become almost a paradigm for 'method'.[4]

Claude Flamand

Claude Flamand was born in Savoy in 1570.[5] He had little or no formal schooling and probably practised the trade of war from his youth, giving particular attention to the mathematical disciplines relative to his trade and cultivating them through discussion.[6] A convert to protestantism,

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1. Sterctenbouwring See II p.197 last sect. This passage comes from the dedication and hence before the beginning of the main text, which itself starts with definitions. Thus Stevin saw this assumption as setting up the framework for his remarks even before he could come to consider the proper terms to be used.
2. See II p.197. In Nieuwe Maniere van Sterctebou door Spilsluysen (Rotterdam 1617) Stevin followed the same pattern which he explicitly outlined. (p.1)
3. See II p.199, 3rd sect. The fraction Stevin gave was ludicrously over precise under any circumstances. The use of a rope, a very elastic filament, simply compounds the problem.
4. Stevin as a writer on many areas of applied mathematics deserves a great deal more attention than it has been possible to give him here. Only a thourough study of his many published works and extant mss. would enable clarification of those aspects of his work outlined here to the degree desirable. The standard work on Stevin DIJKSTERHUIS (1940) gives a great deal of detail and analysis of Stevin's work in many different areas, but unfortunately does little to bring out similarities (and differences) in Stevin's different areas of work, and to elucidate such ideas as his views on method. BRIALMONT, Alexis "Oeuvres Militaires de Simon Stevin" in STEICHEN, M, Mémoire sur la vie et les travaux de Simon Stevin (Bruxelles 1846) discusses the relation of Stevin's ideas on fortification to those of earlier writers, attempting to make Stevin more original that is warranted.
5. BALTEAU states c 1570. But the portrait in the title page of his Les Mathematics et Geometrie (Montbeliart 1611) has the date 1570 explicitly.
6. See II p.204, 2nd sect. See also following this section "Priant les Lecteurs & amateurs des sciences prendre de bonne part, & mexcuser, si ie n'ay approprié les mots & termes, comme ils doiuent estre n'ayant eu la commodité, ny le temps de les mieux attenser pour plusieurs occasions contraires qui me sont suruenues, & d'autant aussi que ie ne suis iamais esté à l'Escole en lieu qui soit pour apprendre les lettres....."

as a result he emigrated to Montbéliard and found service there with the Duke of Würtemberg as architect and engineer.[1] In 1597 he published La Guide des Fortifications et Conduitte Militaire at Montbeliard.[2] Flamand fortified the outlying areas of the town and the northern section of the Castle at Montbéliard; he enlarged the markets and worked on the Pont de Gray. In 1601/3 he worked on the fortifications of Besançon. He drew up plans for a foundry at Audincourt in 1618 and also worked at Verdun-sur-le-Doub. He was reputed to be designer, sculpter, and clockmaker. He died in 1526.[1]

While the subject of fortification figured predominantly in the title of Flamand's treatise, this topic only took up a relatively small portion of the whole work. The designs presented in it were of a relatively sketchy nature, and in no way remarkable. The treatment was equally of an introductory nature which explained in simple terms the way to lay out fortifications on the basis of the pointed bastion.[3] Flamand's treatise was indeed more an elementary mathematics text book with a certain emphasis on the practical application of mathematics, rather than a work whose major focus was fortification.[4] Flamand himself made clear that it was the practical usefulness of mathematics that concerned him,[5] and he thus presented fortification as a very significant example of where such usefulness was patently demonstrated.[6,7]

Ambroise Bachot

Ambroise Bachot was possibly born sometime around mid century, or a little after. He trained for the art of war from a young age and possibly as a painter, or draughtsman and engraver also.[8] With Agostino Ramelli, Bachot gained a good deal of his knowledge of fortifications and machines, probably serving as an apprentice in Ramelli's household.[9] When Ramelli came to publish his machine book Diverse et Artificiose Machine (Paris 1588), he complained biterly about "alcuni domestichi" who had stolen and published many of his "Disegni".[10] Undoubtedly he was referring to Bachot here and La Timon which Bachot had published at Paris in 1587*.[11] In 1590 Bachot was brought to Melun by Jaquel le Roy, sieur de la Grange, and put in charge of fortifications there.[12] In 1598 Bachot published La Gouvernail a much enlarged version of his earlier work, particularly with regard to the fortification designs.[13]

In this treatise Bachot published many illustrations of

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1. BALTEAU.
2. See II p. 202.
3. For a general description of the work see ibid.
4. Later editions of this work actually droped the fortification and general military discussion, further emphasising the patern. See II p 202, n.1.
5. See II p 203/4.
6. Ibid.
7. Claude's son Jean b. 1597, trained by his father, served with Prince Maurice of Nassau as military engineer in the low countries in 1623/5. BALTEAU.
8. Le Gouvernail (1598) p. (iii) "ayãt este presche des l'enfance par mes peres, de mettre peine a trãsformer ma langue en bras en mains affin d'estre capable de porter au service de mon Roy la pique ou le pistolet...."; (p. 1) Ie n'ay cessé quand l'occasion s'est presentee...de frequenter la guerre...... Ce qu'ayant ansi continue par longues annees......" For Bachot's relationship to Ramelli see GNUDI (1976) & below) a date of birth 1550 / 1560 is not unlikely. GNUDI,(1976) suggested Bachot acted as Ramelli's engraver. His drawing skills make some such training probably. (See also GNUDI, M.T. "Agostino Ramelli and Ambroise Bachot" Tech & Cult (1974) 614/25. Bachot wrote of being with Ramelli at the siege of la Rochelle in 1571 and dated his apprenticeship from then. (Ibid.)
9. Bachot himself wrote in La Gouvernail p. (iii) "Je la tiens de la longue & familiere conuersation de ce nouuel Archimede, le Capitaine Augustin Ramelly" GNUDI (1976) quotes from La Timon passages further confirming their relationship. See also below
10. p (xxvii)
11. See GNUDI (1976)
12. Ibid n. 23.
13. For details of the work see II p. 207/8.

fortifications, and of machines, many of which related to warfare. In his relatively short text however, Bachot gave no discussion on the machines, and made clear that it was not so much particular designs he wished to put forward, rather what he considered the best way of representing fortifications in "perspective".[1] Perspective, not like that of the painter's based on a vanishing point, but rather an orthogonal technique from which dimensions could be measured off wherever necessary.[2] Only this, he suggested, gave a true and firm basis to the art of fortification.[3]

Now in his machine drawings Bachot undoubtedly followed his master Ramelli very closely both in style of presentation and in content.[4] In contrast in his fortification designs, Bachot, while he may have used Ramelli's ideas as to the most useful forms of structures, used a style of presentation which Ramelli took strong exception to, thus

> ...io hauendone ueduto qualche particolari designi stampati, <u>molto sproportionati</u> & molto lontani daquella purità naturale con laquale io gli haueuo composti...Disegni, a me sottratti, & dal loro trasformati & cangiate in tutto dalla loro propria essenza come si uede nelle lor impressioni...[5]

Which same designs Bachot put forward as a fundamental contribution to the art of fortification in virtue of the particular mode of representation they illustrated, and which were thus clearly Bachot's own. The break with his master's teachings then allowing him to make what he considered a particularly valuable, personal contribution to the art.

<u>Christobal da Rojas</u>

Christobal da Rojas, probably born in 1555, may have attended the University of Toledo and studied under Alonso Cedillo, in his youth.[6] He trained as an architect under Juan de Herrara and worked as his assistant on the Escorial, which building was finished in 1584. Rojas then moved to Seville where he worked on a number of architectural commisions.[7] In 1588 he obtained the title "maestro cantero" over the works of Pampalona, and in 1589 at Madrid solicited unsuccessfully for the place of Engineer.[8] In 1590 he was involved with the fortifications of Cadiz[9] and in the following years worked on fortifications in Britany with the Spanish.[10] A few years later he received the title of "Ingeniero" and in 1597 the honorary rank of Captain,[11] under which title his treatise <u>Teorica y Pratica de fortification</u> was published in 1598.[12] From this period until 1607 he read on fortification in the Royal Academy of Mathematics in Madrid and for the rest of his life until his death in 1614 he advised on the fortifications of many sites in Spain for the crown.[13]

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1. <u>II</u> p. 210; l. 9/16.
2. <u>II</u> p. 209; l. 37/44.
3. <u>II</u> p. 209; l. 5/14.
4. It was this similarity and the discovery of <u>La Timon</u> which led Gnudi to point out that it was Bachot that Ramelli accused of stealing his "disegni".
5. Op. cit. p. (xxxvii/viii), emphasis added. Ramelli complained that his machine drawings had been changed also, but on these said "a quegli hor' agguingendo & dimmuendo alcune inutile minuzie...et hor strauolgendoli, ouer in altra parte distornandoli, per coprire i furti loro." The language of Ramelli about the fortification drawings is in fact just how perspective and true representation were discussed in the period. That he could state that one could see the defects in the printed copies when his originals were not available for comparison indicates that it was the mode of presentation he took exception to, also. He also explained that he wished to disclaim responsibility for these drawings for this same reason. There may have been a basic disagreement on this point which helped to lead to the rupture between Ramelli and Bachot.
6. MARIATEGUI, D Eduardo de <u>El Capitan Cristóbal de Rojas</u> (Madrid 1880) p. 12/13.
7. ibid p. 13/4.
8. Ibid p. 18/9.
9. Ibid. p. 20
10. Ibid. p. 29/30.
11. Ibid. p. 41 & 59.
12. See <u>II</u> p. 212.
13. ENC UNIV ILL EUR AMR. For the Royal Academy of Mathematics at Madrid see below p. 319, III:(4):(d). In 1607 Rojas published a slight work <u>Cinco Discursos Militares</u> (Madrid).

Rojas'[1] treatise, composed in connection with his lectures in the Royal Academy[1] was very much a textbook on the subject of fortification to inform the Spanish reader (or listener) about the nature of the art as it was understood at the time.[2] Yet the work was also, in part, an elementary introduction to the mathematics, mainly geometrical, relevant to fortification and building, necessary to the soldier cum engineer.[3] The presentation of such material was however relatively elementary, and although Rojas gave emphasis to such knowledge as necessary to his subject he considered it to be of value only when accompaied by a good familiarity with practice.[4]

Within this framework Rojas then presented designs of fortresses much as they had been popularised by the earlier Italian writers. He did not however slavishly follow those writers but took the later 16th. century view that the defence should be setout by reference to musketry range rather than in accord with full scale artillery performance.[5]

In general then Rojas was content to follow and reflect contemporary practice and theory in the art, and was little concerned to justify in any general way the foundations of that type of knowedge. Indeed at one point he either misunderstood, or more probably felt free to transform, the traditional distinction between places strong by art or by nature,. and explained tha a castle was strong "por artificio" when it could easily be supported by nearby friendly places.[6]

The content of contemporary fortification practice, in terms of the forms of structures, together with some necessary mathematics, seems to have been of more concern to Rojas than any justification of the art, much in accord with the needs of his students in the Royal Academy, one presumes.[7]

Diego Gonzales de Medina y Barba

Diego Gonzales de Medina y Barba, a native of Burgos and member of an illustrious family remains a shadowy figure.[8] He possibly studied in the artillery school of his native town as a youth,[9] and seems to have served the Spanish crown in a military role.[10] His treatise Examine de Fortification was published in 1599.[11]

Gonzales de Medina's treatise was clearly not intended for too

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1. MARIATEGUI (1880) p. 114.
2. As MARIATEGUI (1880) put it (p. 122) "El libro resulta, sin embargo, casuista, pues su autor, siguiendo las huellas de muchos escritores de su tiempo, con el afan de reducir á un corto número di preceptos la prática de la fortification".
3. With a section on elementary geometrical constructions, mensuration, surveying, dialling (part of the Vitruvian tradition) and a few remarks on setting out of arrays of soldiers. See contents II p. 112.
4. The geometry presented by Rojas was generally not concerned with proofs for example. See II p. 213, 2nd, where he suquest the "mechanical" knowledge of his treatise will be sufficient.
5. II p. 214, 3rd sect. 6. II p. 214, 2nd sect.
7. Rojas later work (see II p. 212, n. 1), apparantly a summary of the views he gave in the Royal Academy, may have been more concerned with these aspects, According to MARIATEGUI (1880) p. 183 "es un libro de propagando, escrito más bien para los soldados que para los ingenieros".
8. APARICI Y GARCIA, J, "De las biografías de los Ingenieros que esistieiron en Espana en el Siglo XVI" Memorial de Ingenieros (1851) does not include him among the 63 engineers he gives biographical notes relative to. A laudatory verse at the beginning of his treatise indicates his general background.
9. Suggested by ENG UNI ILL LIB AMER.
10. Examen de Fortificacion (1599) p.(v/vii) "...escriuiendo lo que dello con esperiencia y estudios he alcançando...suplico acepte este pequeno seruicio entre los q tengo hechos, y espero de hazer...." from the dedication to the crown.
11. II p. 215/16.

specialised an audience, but rather attempted to give a clear account of contemporary fortification.[1] Its dialogue form presented the Spañish reader with an explanation of various aspects of the art, in an order, reflecting to some extent, the actual business of creating a fortress, and this practical note was maintained throughout.[2] By and large, the work tended to present the sorts of points made by the earlier Italian treatise writers without supporting argument, and as established fact:[3] the dialogue form served then not as a method of presenting an argument, but rather to carry the reader along, and as a way of introducing each new topic without having to establish connections with foregoing sections.[4] Gonzales da Medina's text was then largely didactic and non argumentative; it did not consider the foundations of the art;[5] it presented established opinions; and gave solutions to many of the sorts of problems that might arise on different occasions.[6] It was thus basically a textbook in Spanish for the relatively uninitiated and unscholarly, which propounded the contemporary art in its details, rather than any attempt to say anything fundamentally new therein.

Jean Errard and his work

Jean Errard was born at Bar-le-Duc in 1554 into an old noble Lorraine family.[7] In his youth Errard seems to have travelled in Italy studying mathematics, perhaps especially in its more practical branches.[8] On his return he entered the service of Charles III Duc de Lorraine, and in 1583 received 200 francs to support the publication of certain of his works. The next year his Le Premier liure des instruments mathematiques mécaniques* appeared at Nancy.[9] Some years later Errard entered the service of Charlotte de la Marck, princess de Bouillon. Then, involved in the siege of Jametz from 1588, when it fell in 1589, Errard entered the service of the French crown as "ingénieur ordinaire". In 1591 Errard received a privelege to coin gold money.[10] In 1594 he published his work Geometrie et Pratique Generale,[11] and Refutation de quelques propositions du liure de M del'Escale.[12]* For the next years Errard

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1. He stated (op. cit. p. viii) that he wrote because understanding of the topic was "muy necessario su conocimiento a los ministros del gouierno de la guerra..."
2. See II p. 215/16 for contents. After some very general introductary remarks focusing on the nature and desirability of defence, came the choice of the site, the best general form to be used, the details of the form, producing the plan, and after a little, the setting out on site. Discussion of many detailed, practical problems then comprised the remaining and major part of the work.
3. See II p. 216. At pages 13/16 Gonzales de Medina explained that the triangle and square were defective forms because of the pointedness of the bastion, and that the pentagon was the most desirable form. (The higher polygons requiring too much guard.)
4. The dialogue was between a "Prince" and a "Master of the trade". The prince, particularly in the later longer section of details, simply introduced each topic at his whim and the master continued until he had said all that was necessary, and then a new topic was proceeded to, as a rule.
5. Gonzales De Medina came nearest to discussing such topics in a very occasional remark like (op. cit. p. 5) fortification "no cõsiste menos en la teorica, y saberlo, que en la platica."
6. As in its later sections.
7. LALLEMENEND & BOINETTE (1884) p. 12. His father was notary of Bar.
8. Ibid. p. 15/16. Rather Italian idioms in his language support this. He was thus possibly referring to his won experience at II p. 216 He received a privilege in 1594 for his works "Mathematiques, scauoir la Geometrie, la Fortification, lart de Nauigation, & la Mapemonde de nouuelle reduction". (According to the privilege at the end of the 1604 Paris ed.).
9. Ibid. p. 16/17. 10. BALTEAU 11. II p. 216 & n.3.
12. At Paris. Scalier had claimed to hve squared the circle and was attacked by others as well as by Errard. LALLEMENT & BOINETTE (1884) p. 117.

was employed on fortification works at a number of sites.[1] In 1598 he published a translation of part of Euclid,[2] and he was ennobled in 1599.[3] The next year his treatise La fortification demônstre et reduicte en Art,[4] appeared. For the rest of his life Errard continued to gain commissions from the French crown, and died in 1610.[5]

In Jean Errard's view thoery and practice were both necessary to fortification.[6] Yet the Art of fortification he considered to consist essentially in geometrical manipulations on paper (of the plan of the fortress), together with true and certain demonstrations.[7] By Art Errard made clear, that he meant a practical science (in contrast to any contemplative science), that is an activity based on that very quality of true demonstration, which was to replace the merely "mechanical" approach of his predecessors.[8] Of course certain more practical topics, such as the events of sieges, the particular difficulties and advantages of different sites, the best materials and the nature of the different members of the fortress, were of significance in fortification: but these were topics that were 'indifferent' and not of the "substance and essence" of the Art.[9] Mathematics and more particularly geometry was of course the discipline through which these qualities of certainty and demonstrability were achieved, and, Errard was quite explicit, the notion of defence by flanking fire and the principle of no dead ground gave the basis to this use of mathematics.[10]

But the fundamental basis of the Art of fortification in geometry did not arise from this reason alone. Geometry in itself Errard felt was a discipline, very worthy to be cultivated by "gentlemen", and a subject which "la Noblesse" (of France) ought to cultivate.[11] It was not only very useful in peace and war, but contained a great deal of beauty and rarity, and even the creator of the universe had not disdained to use it in the creation of the world. Those then, who god had designated to have authority in this world, ought equally, surely, to show themselves as lovers of this science. And, happily, this same science was just of such a nature as to be a suitable tool by means of which the fortification designer could communicate his conceptions (along with certain demonstration) to the prince his patron:[12] and which gave good results in practical matters, not only in the invention of machines,

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1. 1595 Sedan. 1596 Calais, 1596 Amiens, 1597 Montreuil-sur-Mer, 1597 Guines. (See BALTEAU.)
2. II p. 217 & n. 2
3. BALTEAU.
4. See II p. 218.
5. See both works noted above for details of sites and dates.
6. See II p. 219, 1st sect.
7. II p. 221, 2nd sect.
8. See II p. 219/20 ; that he felt it necessary to add this note to the 2nd. edition to clarify this point shows how deeply it was embeded in his thinking.
9. II p. 221, 2nd sect. This was of course a move equivalent to that made by the Italians in differentiating between structures strong by nature and by art, and considering only the latter. Errard did not try to justify this, rather accepted it as given, and by definition included only the latter cases in the Art of fortification.
10. II p. 221, 2nd sect.
11. II p. 216/17. These texts were published by Errard before his work on fortification.
12. II p. 220, 3rd sect.

but in rationally constraining the designer in the process of conceiving the desired object, before its actual construction was undertaken.[1]

Thus geometry was the fundamental ground of fortification[2] to Errard, not so much through some happy accident, but because of the very nature and texture of the world.[3] Indeed his cultivation of this branch of practical mathematics which was concerned with merely the art of defence, was probably a response to opportunities for employment and patronage, and given his attitudes he might just as easily have taken the same position in many other areas.[4]

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1. II p.221, 1st sect.
2. Errard however should not be considered to have conceived fortification as merely a branch of geometry, and to have handled the topic implicitly as if it was not a seperate (practical) science, or Art; nor to have implicitly ignored the contribution of practice, by emphasising so strongly the mathematical elements, despite his own remarks. In fact rather idiosyncratically he included among the "irregular figures", the regular polygons of from 3 to 5 sides (see contents II p.218), because the resultant bastions were too pointed. Thus a rather practical point determined one of his basic concepts in the Art. From this one can see how he could conceive fortification to be a distinct (practical) science even while he insisted on its fundamental basis in geometry.
3. In both its social and physical aspects
4. For the list of areas for which Errard was granted a priviledge in 1594 see above p.70, n. 8.

PART I:(2):16th. century fortification as a discipline: Common assumptions and individual responses of the treatise writers.

(i): The relationship between the different traditions, and their description.

The dominant tradition[1] in the published works on fortification in the 16th. century undoubtedly was that collection of ideas expressed in the many Italian treatises. Indeed, the International writers did little more than recount those same ideas in their own languages. In contrast the German writers put forward a very different approach to the art, at many places. The first of this group, Durer, was actually closer to a direct line of development culminating in the dominant tradition, than some of his later compatriots. Specklin on the other hand, the last of this same group, while he manifested some signs of being rooted in the German tradition, in a great many ways expressed the views of the dominant tradition. He was thus in some ways as much a member of the International group in publishing for the first time an original work in German, in line with the ideas of the dominant tradition.

Thus the published writings on fortification of the 16th. century show a dominant, mainly Italian tradition, with a—very much weaker—competing German tradition. Which last tradition by the last decade of the century had become defunct, leaving the ideas of the Italian writers in sole possession of the field, as original works based on those ideas, in nearly every language of the heart-lands of western Europe, came to be published.[2]

The description of the dominant tradition then depends basically on a recording of the views of the Italian treatists. However, the views of the international writers particularly, and the Germans occasionally, help to demonstrate the nature and range of those ideas where these writers expressed views most in common with those of the Italians.

This dominant tradition is described in terms of three areas: Theory, Practice, and Values: the first two, theory and practice, being basic catagories of the treatises themselves: the third, the realm of values, being concerned with the treatise writers' views as to the significance of their art in terms of the social hierarchy of the time, and their beliefs and commitments with regard to desirable ways of proceeding in their area: both, to a greater or lesser extent, explicit or implicit in their writings.

This description is then clarified by examination of the views of the German writers as contrasting with those of the Italians.

A brief examination of the International writers as a particular kind of expression of the dominant tradition then suggests that some shift of emphasis occured when the dominant tradition of the Italian authors was accepted and expressed by the International writers.

1. The classification used up to this point of the Italian, German, and International traditions, was based broadly on language and nationality of the treatise writer (and his treatise). The notion of the dominant tradition, that is, of that set of ideas which was and became the commonly accepted view of the subject in the 16th. century, complements and overlaps the earlier classification and is used in conjunction with it. Usage makes its meaning clear.
2. French, Spanish, Dutch, with the minor work of Ive in English. The German work of Specklin. This pattern should not be taken to imply that the relationships of the different traditions given here proceeded in some isolated realm of treatise writing. In fact the relationships that were expressed in the published treatises were undoubtedly a reflection of the influence of the Italian fortification engineers who practised all over Europe during this period.

Description of the ideas of the 16th. century treatises within this framework then allows an overall consideration of the the ways in which the ideas of the dominant tradition came to be accepted, in a general way, as evidenced by the published writings of the individuals involved.

I:(2):(ii): The dominant tradition.

(i): The nature and function of theory.

(a): The general requirements of fortification as a discipline according to the treatise writers.

Almost universally the 16th. century fortification treatise writers distinguished between practice or experience, and theory or science, as very different yet essential contributors to their art, as in the (practical) arts in general[1] Not infrequently they made a similar contrast in a rather weaker form, by quoting Vitruvius to the effect that Architecture consists in construction and discourse[2] The notion in fact, that in the mind, and in the realm of ideas, was to be found the primary basis of fortification, was a common view

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1. Tartaglia (II p.21; 1.8/9) distinguished, in a general context, between "theory or speculation", and "practice". Pietro Cataneo (II p.28;1.23/4) between an Architect being "scientific" (sic) and, ingenious or skillful. Zanchi (II p.33;1.14/20) between "practice" and "doctrines" "demonstrated". Lanteri (II p.50;1.19/21) between "practice" and "geometry". Girolamo Cataneo (II p.52;1.10/13) between "experience in person" and "the mathematical disciplines" in putting soldiers into arrays. (II p.53;1.35/7) between "the mathematical disciplines" and "experience"; (II p.55) between "practice" and "theory", in his title. Theti (II p.75;1.30/2) between "art" and experience, (Cf. Errard II p.219/20 on "art" and "science") Alghisi (II p.82;1.30) "theory and practice". Pasino (II p.91; 1.5/6) "science and practice". See also II p.100. Acconcio (II p.108) on method in general, between, "art or science" as against application, and "art" against "practice". Busca (II p.110;1.22/3) in gunnery between "science" and "labour". (II p.115; 1.14/15) "rough practice" and "the best science". Lorini (II p.122;1.3/11) "mathematics" and "practice"; (II p.130;1.6) "practice and science". Belluzzi (II p.139;1.9/11) what is taught by the business of war and "mathematics". Marchi (II p.145; 1.28/9) "theory" and "practice and experience". Durer (II p.156/7) criticised painters who had skill in practice but no "recht grundt". Specklin (II p.190; 1.44/5), of 3 things necessary to a builder gave as two, knowledge of "mathematics" and of the "mechanical arts". Ive (II p.195;1.31/3) favoured the opinions of a soldier of experience over those of a "geometrician". Stevin (II p.196; 1.16/18) distinguished in the arts generally between "theory and practice"; (II p.198;1.14/16) in fortification between "theory" and "practice". Flamand (II p.204;1.33/5) "experience and practice" and "mathematics and geometry". Bachot (II p.211;1.12) "theory and practice". Rojas (II p.212) in his title, "theory and practice"; (see also II p.213/14). Errard (II p.219;1.1/3), the definitive statement, "practice being as blind without theory, as theory is one armed without practice.....". Some individuals reduced the contribution of one or the other factor to almost zero. Lanteri, for example, in depending almost completely on Euclid (in his first work); while Gian Tommaso Scala was very sceptical of any kind of learned approach, see II p.152/5. In some writers the distinction was more implicit than in others.

2. Lanteri II p.50;1.27/8. Busca II p.117;1.3/4. Marchi (II p.151;1.23/4) "Discourse is the father of architecture". For Vitruvius' remarks see II p.50, n.2. Vitruvius is usually taken to be saying in such passages that architecture is based on theory and practice. LEWIS & SHORT for example give "ratiocinatione"="theory", as a particular usage in architecture; and Vitruvius himself wrote (Bk. I.I.I.) "Ratiocinatio autem est, quae res fabricatas sollertiae ac rationis proportione demonstrare atque explicare potest." But the treatise writers did use the weaker term "discourse" as equivalent to "ratiocinatione". In fact Vitruvius included in the knowledge of the architect, philosophy, law, letters and history (Bk. I. I. 3/5). These were then part of Vitruvius' theory. But to the 16th. century treatise writers they were discourse. Theory to them was more like science, and particularly mathematics (see below generally). Hence we have here a subtle shifting in the emphasis of the usage; and while the 16th. century treatise writers seem to be simply parroting Vitruvius, the way they used "discorso" for "ratiocinatione" indicates that they were in fact 'hardening-up' a position in terms of their own predilections, 'theory' becoming a more precise term.

among the treatise writers: perhaps most strongly put by Zanchi when he wrote that his treatise was essentially concerned with all that which it was "possible for the human intelligence to employ" to defend against "the force of the enemy".[1] But most characteristically the treatise writers were much more specific as to what was required in fortification over and above simply what was implied by discussion, or power of the intellect, or bare skill. They insisted that what was necessary in fortification, as in the other (practical) arts, was the employment of true rules or method.[2] Method, as such, had essentially to be general: that is, to be potentially able to operate over a wide range of cases, which, in fortification, meant generally to be able to handle all sorts of different sites.[3] Too much "diversity" with regard to solutions for different places, indicating, as Lorini gave the reader to understand, that fortification had no "demonstrable foundation", or "rules" that would "reduce it to its best end".[4] Equally, as Zanchi indicated, if ones approach (or method) involved the discussion of the advantages and disadvantages of all sorts of "forms", or sites, this would be "not only the most tedious, but perhaps even impossible."[5] Generality and method were therefore, to a greater or lessor extent, highly desirable if not absolutely necessary characteristics of any true art of

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1. "forze de nemici" (II p.36;l.13/14). See also Tartaglia (II p.14;l.1/2) for whom the key notion was "lo ingegno humano". Pasino (II p.91;l.20/3,& n.5). This may seem a rather obvious and trite idea, even almost necessary. For, one is inclined to argue, if a structure is going to be made, the more effectively someone thinks about how it ought to be done the better it is bound to be. Yet Zanchi previously (II p.31/2) felt it necessary to argue against the view that the spirit of the defenders was the crucial aspect of defence, so as to preclude any contention that such ingenuity might be largely irrelevant. Moreover there is no a priori reason that human intellect or ingenuity is primary in constructing structures for defence. The sheer mass of material employed may be the crucial element, with human skill and ability in the sphere of the intellect counting for little against ability to marshal physical resources. Of course there may be skill in that activity, but this was not what the treatise writers were thinking about.
2. Zanchi (II p.33;l.21) "regole & modi intendea"; (II p.34;l.21/22) "certo modo, & universal regola"; also II p.40;l.1/4. Lanteri (II p.42;l.38 & p.50;l.4) "l'ordine". Girolamo Cataneo (II p.56;l.10/13) on sciences taught "con dritto ordine". Castriotto (II p.63;l.6/7) "riparatione" could be carried on without "rispetto d'ordine, o regola de detta Architettura" (i.e. fortification). Poem to Alghisi (II p.82;l.33) "regola firma". Alghisi himself (II p.86;l.22) "ragione". Locatelli (II p.89;l.6) in general, "regola & ordine". Acconcio (II p.108;l.4) "methodo" on which subject he was of course writing. Busca (II p.116;l.29) "la ragioni"; (II p.118;l.27/8) "le regole & misure". Lorini (II p.123;l.12) "le regole". For Durer's remarks on painters see above Biog p.49. Stevin (II p.198;l.5) "method". Stevin stated his fortification treatise was written to show a method (II p.198,n.4). Context gives the extent, strong or weak, to which such words and phrases have to be equated with 'method'. The orders of architecture were probably always very much in the treatise writers minds as an example of method: see, for example Pasino II p.94. For one of the few dissenting voices, see Lupicini (II p.106;l.19/30) who doubted the possibility of general rules; Lorini (II p.135;l.40/5) who doubted if it were possible to teach perfectly in fortification with general rules, as was done in other sciences.
3. See Zanchi as indicated in above note on the need for a "universal" rule, for example. In fact the treatise writers did not often in any very direct way point out this need for a 'general' method, although this was clearly implicit in a great many of their discussions, and was an assumption of nearly all the treatise writers. (See, for example Pasino II p.93;l.32/43). Further any call for (true) rules, or a (correct) method, such as was so often made, tended by its very nature to imply that a number of different cases should be handled by some general device. It might then be considered that this was something inherently necessary simply because they were concerned with design. But what could have been called for might have been not a "universal" method, but a very wide range of rules, all relevant to different sites and problems. Further, see Lanteri (II p.46;l.1/8) on the need for a general rule for the construction of the regular polygons. For the way he offended against some of his other favourite qualities in order to achieve this see Biog. (above p.20). See also Errard (II p.220;l.8/23). Lorini (II p.132;l.2/10). There is no doubt also that the 'method' the treatise writers put forward was a very general method. (See below generally.)
4. II p.122;l.18/123;l.14.
5. II p.38/9. See also Gentilini (II p.120;l.1/5) for a similar sentiment.

fortification, in the treatise writers' minds. These qualities indeed provided the very basis of theory.

However, when the treatise writers were concerned with that aspect of their art which contrasted with practice or experience, the term that most frequently came to their pens, was 'science' rather than 'theory'. But this term tended to have a number of rather different, though related meanings. Firstly, it was sometimes used almost entirely for its positive connotations to indicate something of value, or some activity undertaken properly: as for example when Gian Tommaso Scala wrote of the "science of the soldier" and equated it (in part) merely with courage.[1] In a similar but more precise sense it was often used in connection with any activity undertaken in good order, properly and according to the true needs of the business, particularly with regard to any written intellectual activity: at this level a "science" was a discipline which could be compared to, or contrasted with, "letters", or "sacred literature".[2] But, perhaps most frequently, the term 'science' was used by the treatise writers in reference to any activity or discipline which could equally be designated as an 'art', especially in so far as it was undertaken with good order and method as a result of its being handled through intellectual processes in the mind.[3] 'Art' in this usage had particular reference to the seven liberal arts.[4] In this sense the treatise writers continually referred to fortification as a 'science' or 'art'.[5] Yet where they attempted to make clear what such a 'science' or 'art' amounted to, they continually referred merely to the subjects of the <u>quadrivium</u>, and not to those of the <u>trivium</u>: or to other 'sciences' or 'arts' which were similarly mathematical or mathematically based.[6] Thus, in its most specific and characteristic sense 'a science' in the fortification treatise writers vocabulary, designated a mathematically based discipline, or the mathematical disciplines themselves.[7] Which disciplines by the end of the century the treatise writers could refer to as "the true and only sciences" or the like.[8]

The treatise writers explicitly and directly at many points emphasised the value of, if not the absolute necessity for, the use of mathematics, and particularly geometry, in fortification[9] (albeit there was

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1. II p.153;1.12/19. See also della Valle II p.2;1.1 & n.1 on this type of traditional usage. Pasino (II p.102;1.14) on the "science of the soldier which is natural".
2. Lorini II p.123;1.33/5. Valle II p.4.
3. See Pietro Cataneo (II p.28;1.16/20) on architecture. Lorini, ibid. Girolamo Cataneo (II p.58;1.15/20) where "natural philosophy" (sic) and mechanics are referred to as "sciences".
4. Girolamo Cataneo (II p.56;1.10) Pasino (II p.92).
Sometimes however science was contrasted with art, as for example Lorini (II p.133;1.15/33); Errard (II p.219/20). There tended in fact to be a continuum of meaning: Discourse-Theory-Science-Art-Practice, in which each term tended to be synonymous with the terms on its either side.
5. Girolamo Cataneo (II p.55), title: fortification= a science. Lupicini (II p.105;1.8/9) "art of fortification". Lorini (II p.124;1.15/17) "science of fortification"; and (II p.131;1.15). Belluzzi (II p.141 1.12). Errard (II p.219;1.34) "science"; (II p.220;18) "art".
6. Tartaglia (II p.7/8). Pasino (II p.92).
7. The mathematical sciences, or disciplines, were those 'sciences' the most frequently mentioned by the treatise writers and gave them the paradigmatic use of that term. See Tartaglia, ibid. Lupicini (II p.107;1.3/4) "the science of the mathematical disciplines". The treatise writers often in fact tended to conflate the mathematical sciences with the mathematically based sciences, confusing, to the modern mind, the difference between 'pure' and 'applied' maths. On which see below.
8. Errard (II p.217;1.5/6). Flamand (II p.203;1.40/5). Lorini (II p.133;1.25/6) "pure sono scienze".
9. Pietro Cataneo (II p.10;1.7/11); (Ibid. 1.19/20) "Arithmetic and geometry the base and foundation of Architecture." Zanchi (II p.40;1.10/18). Pasino (II p.92;1.7/12). Lorini (II p.124;1.38/41). Belluzzi (II p.138;1.10/27). Gian Tommaso Scala (II p.153;1.2/5), who, in attacking any too theoretical approach in fortification, included in the "soldiers geometry", courage, showing how deeply this idea was entrenched in fortification. Specklin (II p.190;1.40/5). Stevin (II p.197/8) who defined a proper fortress as one mathematically produced. Flamand (II p.204;1.34/45). Bachot (II p.209;1.5/10). Rojas (II p.213;1.11/15). Errard (II p.220;1.30/4). Lanteri (II p.42;1.31/39). Girolamo Cataneo (II p.53;1.23/4). Alghisi (II p.84;1.21/6).

a good deal of variation in different authors views on the extent of the contribution that could be expected from these disciplines).[1] This use of mathematics was much to be desired because, as Tartaglia said, "truth is more touched in mathematics than in any other liberal art".[2] Mathematics was considered by the treatise writers to be needed in fortification, above all, because it gave certainty and demonstrability to the subject. Its use being necessary, according to Lanteri, because the writer wanted to put forward "things certain and not false", and mathematics was "the study--excepting sacred letters--most certain of all".[3] Geometry, as Errard put it, being necessary in fortification in contrast to any merely "mechanical" approach, because it gave to everything "infallible assurance".[4] But this certainty was not something anyone was required to take on trust: stemming from mathematics it was demonstrable, and made fortification an art demonstrated. Demonstrated further in a clear and easy way plain for all to see.[5] Certainty and demonstrability, inherent in mathematics, were then carried over into fortification, in the treatise writers view, through the use of mathematics in the art. A process they plainly believed, the value of which not even the most foolish would want to challenge.[6]

Thus, in its strong form, what the 16th. century fortification treatise writers believed was, that in the art or science of fortification, what was required in addition to any mere practice and experience was a theoretical component which was handled through discourse; which gave the very quality of science to fortification through involving the application of a general method, or true set of rules, to the subject; and which, through being dependent on those most characteristic of sciences, the mathematical disciplines, brought the great qualities of certainty and demonstrability to the art.

I:(2):(ii):(1):(b): The wider justification of the basis of fortification mathematics

Mathematics in addition to providing a basis on which fortification might become a (true) 'art' or 'science', in the treatise writers' minds, was a desirable foundation for the subject for a number of wider reasons. Great utility flowed from the use of mathematics, and particularly geometry, they frequently pointed out. Its application in many practical fields led to extremely useful results.[7] In fortification itself mathematics served to "number and measure" the

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1. Described below. 2. II p. 8; l. 30/33. 3. II p.43; l.11/13; p.42; l.31/4.
4. II p.219; l.14. See also Pietro Cataneo (II p.30; l.9/11). Lorini (II p.131; l.11/12) where the assumption is made that for something to be a science it must have its foundations certain and demonstrable; & II p.133; l.23/8.
5. Errard's title: "la Fortification demonstree...." (II p.218). For the value that in the period was attached to this quality of demonstrability see for example Dürer above p.49. See also Zanchi's contention that this quality must underlie fortification structures II p.32; l.13/15. Lupicini (II p.104; l.1/5) on mathemactics in general, and the connection between certainty and the "clear and manifest qualities of the operations of mathematics (although Lupicini did not emphasise the use of mathematics in fortification to any great extent). Lanteri (II p.43; l.34/41) "science.... renders everything clear with proof". Lorini (II p.122; l.18/23) on the need for a "demonstrable foundation" in fortification; (II p.123; l.11) easy demonstrations"; (II p.125; l.11/13) "clear and easy demonstrations". For Errard's view see above p.71.
6. The treatise writers were of course much less in agreement as to the extent which this could occur. But the above cited passages show how some individuals tended to emphasise the desirability of the result, in order one feels, to gloss over the problem as to how far it could be achieved.
7. Tartaglia (II p.9/11). Lanteri (II p.47; l.45/6) "the study of mathematics so much to every human condition necessary". Pasino (II p.92; l.25/30), in the other mechanical arts as well as in architecture. Lorini (II p.125; l.3/6) even "shoemakers" and the other "baser trades" had need of it; (II p.127; l.21/4). Flamand (II p.203/4) "Mathematics and geometry, as the support of human life". Stevin (II p.196; l.1/10). See the title of Giovanni Scala's work to indicate the wide range of subjects in which he considered practical geometry to be of use (II p.120A). Durer (II p.167; l.28/36), similarly.

fortress, indeed to produce the very design of the fortress.[1] It was the basis of surveying which enabled the nature of the site to be represented, and the structure set out on it.[2] The use of perspective, with its mathematical basis, was fundamental to the presentation of the design.[3] Its clear utility was then an important factor in the use of mathematics in fortification, in the treatise writers' view.

But further, the use of mathematics, because of the quality of demonstrability--so clearly manifested by Euclidian geometry--which ensued, gave to design a very important kind of 'rationality'.[4] The basis of their designs in mathematics, and the expression of those designs by means of mathematical techniques, the treatise writers considered, resulted in their concepts being brought forth in a clear and unambiguous way, most fully in accord with the demands of reason, because these results were then demonstrable.[5] Such a process further enabled the designer to judge, assess and adjust his design in reasoned manner so as to achieve a fully understood result.[6] The quality of demonstrability additionally meant that the reasons relevant to any design could be publicly argued through with other experts.[7] Different views could be brought to bear which would not be merely a matter of opinion but which could be resolved by argument so as to arrive at a consensus. Further, and perhaps most importantly, such argument could take place in front of the relevant patron, prince, or client, who could, even though he did not possess the full specialised knowledge of the expert, follow the arguments of the protagonists, and in ajudicating make reasoned judgements about what was to be done: thus maintaining control of the whole business of design while at the same time making use of the skills of his experts.[8] The demonstrability and clear presentation which stemmed from the mathematical basis of fortification, making all this possible.

But more general views were at work which tended to support the desirability of the mathematical basis of fortification. Many treatise writers tended to assimilate their discipline, and other arts, to contemplative (or speculative) mathematics, particularly geometry: and to suggest that the qualities that were conceived to give value to that kind of study were equally to be found in the use of geometry in practical matters, and in fortification. Such practical knowledge could be "pleasing", "delightful", "beautiful and rare";

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1. Zanchi (II p.40;1.10/14) Pietro Cataneo (II p.30;1.1/6). Alghisi (II p.86;1.24/33) Errard (II p.221;1.1/20).
2. For example: Pietro Cataneo (II p.28;1.33/40). Zanchi (II p.40;1.14/16). Girolamo Cataneo (II p.58;1.16/24). Lupicini (II p.106;1.31/40), in artillery. Busca (II p.111;1.1/15). Lorini (II p.129;1.1/15) Belluzzi (II p.138;1.8/21). Marchi (II p.143;1.13/15). This point was made by nearly every treatise writer.
3. Pietro Cataneo, ibid. Zanchi, ibid. Alghisi, ibid. Lorini (II p.127;1.12/16). Bachot (II p.209;1.11/14) and Busca (II p.117) who both did not accept the use of vanishing point perspective.
4. The treatise writers did not use any such term. But their whole notion of doing things by rule and reason, and their insistence that fortification was a science, so common in their discussions, make some such description necessary.
5. Pietro Cataneo (II p.28/9): the architect, not knowing perspective, "will never be able to show through design his concepts as an excellent designer should be able". See Zanchi (II p.40;1.16/19) on models "to make clear the idea of ones intellect to everyone". Lanteri (II p.47;1.24/1) who argued against those who did not make their models mathematically. Pasino (II p.101;1.19/28) the plan geometrically organised "so that it truly reflects the first design imagined and conceived in the mind".
6. Lorini (II p.125;1.15/23). 7. Lorini (II p.130;1.16/43).
8. Lorini (II p.130,1.28 et seq). Giovanni BOTERO (1589). explained the matter thus: the prince "deue hauer piena notitia delle cose militari...e delle scienze che sono quasi ministre dell'arte militare; della Geometria, Architettura, e di tutto ciò, che si appartiene alle mechaniche..... Non voglio però, ch'gli attenda à queste cose, come ingegniero ò artifice: ma come Prencipe; cio è che n'habbia tanta notitia, che sappia discernere il uero, dal falso, e l'buon dal reo; e di molte cose proposte sappia sceglierne la migliore: perche l'ufficio suo non è di fabricar ponti, e machine da guerra; non di gittare, ò maneggiare arteglierie; non di disegnare, ò edificar fortezza: ma di seruirsi guidiciosamente di quei, che fanno professione di tutte queste cose." (p. 50/1)

could partake of "worthyness", and "spiritualize gentle persons".[1] Sometimes the treatise writers would use the term "speculative" or "contemplative", about an aspect of fortification, further confusing the traditional distinction.[2] This process both brought status to the study of fortification, and helped to justify its mathematical nature.

But the treatise writers also pointed to remarks about mathematics made by the ancient authors to support their contentions as to the utility of these disciplines, and their inherently worthy nature, in order to support their view of the importance of the use of mathematics in fortification. Not suprisingly Plato often figured in this sort of context.[3] Yet Girolamo Cataneo pointed to Aristotle as the author (albeit as one among many others) who showed how geometry belonged in many disciplines.[4] Archimedes also, not unexpectedly, was considered an important example, particularly with regard to the usefulness of mathematics in mechanics.[5] However the views of the treatise writers were not so much the result of the influence of one or other ancient author, but rather, any particular writer that came to hand, so to speak, was quoted when such support was felt necessary or desirable.[6] Nevertheless Euclid was probably the one ancient author who supplied the treatise writers with more key ideas than any other (leaving aside Vitruvius[7]). The notions of certainty and demonstrability, of unambiguous expression, of basing everything on clear first principles, and proceeding by easy steps to the conclusion, manifest in the Euclidian presentation of geometry, being the very qualities the treatise writers sought in a science, and in the art of fortification. Their 'method' in knowledge was then, to a great extent, simply Euclidian.[8] Reference to many of the ancient authors was thus used sometimes by the treatise writers to justify the mathematical basis of fortification, and their use of Euclidian method with its roots in contemplative knowledge gave added force to their approach.

Reference to the ancient authors equally helped to set the tone for remarks that were sometimes made about the desirablity of the mathematical approach because of either, the inherent epistemological power of mathematics,

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1. For Tartaglia's tendency to conflate speculative knowledge and practical knowledge, generally, see Biog. p.11 and citations . there. Lanteri (II p.42;1.13) "delight" in Euclid. (II p.43;1.29/21) "enjoyment". (II p.91;1.16/18) verse to Pasino. Pasino (II p.92;1.21/2) architecture founded on Geometry, Arithmetic, and perspective "participates in the liberality and worthyness of its three mothers". Lupicini (II p.103;1.11/12) mathematics "not only delightful, but the most useful". Lorini (II p.126;1.11) "pleasure". Marchi (II p.143; 1.4) "pleasing". Flamand (II p.203;1.1) "pleasure". Errard (II p.217;1.2) "beautiful and rare".
2. Belluzzi (II p.139;1.20 →). See also Tartaglia for the use of the locution "speculative practice" Biog. p 11 . But see Errard (II p.219;1.26→) who in the second edition of his fortification treatise felt compelled to clarify his use of the terms 'art' and 'science' in fortification, and made quite clear the traditional distinction.
3. For example Pasino (II p.92;n.3). Errard (II p.219;1.18/19). Marchi (II p.150;1.3/4) who quoted Plato in support of the value of mathematics in the arts generally. Lanteri (II p. 47/8) referred to Platonic ideas to support the contention that the circular form as the best one for a fortress, but very quickly explained that this had already been proved on the standard grounds that it gave less pointed bastions.
4. See II p.68;1.25. He gave here Astronomy, perspective (sic), mechanics, and natural philosophy.
5. Pasino (II p.95;1.33/5) for example.
6. See for example the way Tartaglia quotes Cicero in support of his views on the status of practical knowledge.
7. On Vitruvius see sect. II:(7).
8. Stevin (II p.198;1.9) openly acknowledged such a debt. See also Marchi (II p.147) who attempted to set up a model of knowledge on Euclidian lines. See also Girolamo Cataneo (II p.66,1.4) on the importance of Euclid, and (II p.56;1.10→) on the sciences or arts based on first principles. Lanteri (II p.44;1.17). Lorini (II p.130;1.12/17). Bachot (II p.211;1.5/13). ERRARD (1604 Paris) p. 3, began Bk I of his treatise with a short paragraph saying he did not need to discuss definitions because the terms of his science were commonly known, and then gave as the heading of his next section "Les axiomes, qui sont sentences communes, n'ayans besoin d'aucune demonstration", in reflection of the Euclidian pattern.

or because of the fundamental underlying mathematical nature of the world.[1] Mathematics, it came to be felt by the treatise writers, entered into the very essence of things and without it, as Lorini put it, "it would be impossible to show anything in its (true) being"; while by its means all things could be "represented truly".[2] This inherent power of mathematics and the particular ability of the subject to handle the physical world, implied then that representation through mathematical perspective, the use of mathematical techniques in surveying, and the mathematical treatment of the body of the fortress itself, were almost necessary characteristics of the true art of fortification.

Yet the predominant factor in this relationship of mathematics to the world, of the treatises, was not so much any Platonic or neo-Platonic view. Rather the conception of the anthropomorphic Judeo-Christian deity, of the treatise writers, was the more important influence. God, in designing and creating the world perforce made use of mathematics. Man on earth, as a result, faced with an underlying mathematical reality had to use mathematics to grasp that reality. Equally man, made in the image of the creator, had therefore in design to follow a similar mathematical process, albeit in his own poor and imperfect way. But mathematics was equally the method by which god governed the world, the prince then as a governer in the world in his own small way, had perforce similarly to make use of mathematical knowledge in governing his estate.[3] The treatise writers in emphasising the use of mathematics in fortification then felt, to a greater or lesser extent, that they were only conforming to this general pattern and cultivating the most effective tool on earth that could be conceived, in order to handle the problems of their art.

Thus a wide range of views on mathematics: it utility; its ability to provide a tool of evaluation, communication and control; its nature as contemplative knowledge; its valuation by the ancient authors and the particular value of the form of its expression as found in Euclid; its power to grasp the world; and its role in the relationships between God, man and the world, helped to justify its use in fortification. To some extent these latter ideas being more clearly expressed towards the end of the century, but appearing in various ways in a rather inchoate form in earlier writers.

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1. These two points of course tended to fuse together. See Girolamo Cataneo (II p.57/58) on the general power of mathematics in many areas. See also Marchi's Euclidian model knowledge which allowed one "to get to the heart of things". (Cited in n.8, p.79 above). Lanteri's view (II p.49; l.20/21) that anything could be designed using mathematics alone.

2. II p.125; l.24 & 15, who also conceived of the world as made up of simple mathematically defined bodies and that the foundation of mathematics was the "main cause of arriving at all the most secret understandings of nature". See also II p.127; l.26/7.

3. The full blown view appears in Errard (II p.217; l.19/38). Tartaglia pointed to the fact that the painter had to follow God in representing the human figure through mathematics. The notion of the creator of the world using patterns that had to be followed by the designer was expressed by Lanteri (II p.47/48) although not very strongly; and (see above n.1) suggested everything could be designed by mathematics. Lorini (II p.123; l.23) emphasised the need to follow nature as created by God. The poem to Pasino (II p.91) gave Geometry and Perspective as inventions of God. The christian view of man as made in the image of god, something missing in the classical accounts, must undoubtedly have assisted the analogies between man and God in design, and between prince and god in government. Which last was further supported by the political idea of the divine endorsement of rulers. The assumption that God acted through the use of mathematics was not so much a deeply held independent philosophical view of the treatise writers. Their style of discussion continually indicated that it was the effectiveness of mathematics in practical matters that was of most significance to them, and this justified their mathematical view of the world to them. Their view on God, the world and design then tended to be circular, but it formed to them a very coherent package. Thus the role of practical mathematics, and of the christain view of the world in the analogy between God and man in this pattern, means that Plato's ideas can not be considered as primary here. Although in so far as those ideas were influential they must have helped to support the pattern. The notion of the problem of fortification being essentially a thing of the intellect also undoubtedly helped the man God analogy.

I:(2):(ii):(1):(c): The application of mathematics in fortification and the nature of the resultant discipline.

The 16th. century fortification treatise writers made a basic distinction between "ripapare" (or "riparatione") and fortification. The former involved repairs, the 'tinkering' with, and improvment of, existing sites and structures. While the latter was concerned with important sites, and large schemes on sites lacking many natural advantages.[1] Thus, while from time to time advice was given on how to modify older structures in order to put them into a satisfactory condition,[2] the central core of the true art of fortification, was always fortification in this sense of an activity distinguished from mere "riparare". In which last process, as Castriotto explained "it is legitimate to be aided by ingenuity.....without regard to the method or rule of the said Architecture...." (that is, military architecture)[3] that is, that method or rule that made fortification a true art or science.

The treatise writers therefore, in the 'theoretical' part of fortification, were primarily concerned with structures in an abstract way divorced from the problems of existing works, or the peculiarities of particular sites. They almost universally further insisted that the essential function of design was the consideration of the form of the structure, in contrast to its material aspect.[4] They focused here almost entirely on the plan trace of the fortress which was the "foundation" on which the structure was raised.[5] Tartaglia was the first to outline in print the rationale behind this approach. He distinguished between structures strong by art or by nature, and considered only those of the first kind worthy of discussion.[6] Amongst those strong through human skill or art he distinguished those strong in virtue of their form, and those strong in virtue of their material mass, which latter class he equally did not consider of any real interest:[7] they did not display human art or skill Tartaglia insisted. For, as Domenico Mora put it, "any simple man" could fortify a place, given sufficient time and money, using "immeasurably thick walls".[8] This set of

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1. See Theti (II p.77) for this account. Also Castriotto (II p.62;1.41→) and Locatelli (II p.88;1.25/6) who both gave the tripartite distinction between, riparare, fortificare, edificare.
2. THETI (1569) f. 30a. Pasino (II p.100;1.1/2) argued strongly against "submitting to old circuits". 3. Above citation.
4. Tartaglia (II p.14/16). Zanchi (II p.18;1.23). Lanteri (II p.44;1.10/13) implicitly. Maggi & Castriotto (II p.63;1.31→). Mora (II p. 66;1.17→). Alghisi (II p.84;1.25/6) implicitly. This in not to suggest that material was never discussed. The problem of whether to use earth or stone as the best resisting material was often discussed. A well known m.s. of Belluzzi's on earth fortifications is extant, for example (See I p.44,n.11); one of Lanteri's published works was on this topic; (See II p. 49/50); Pasino made a good deal of the use of earth as against stone also. (See II p.90 contents). But this topic was generally considered a more minor one as Busca insisted (II p.114;1.14/15). It was equally only discussed in the context of the form previously determined to be desireable in itself, and not as a determining factor of form.
5. Tartaglia (II p.19;1.1/4). Lanteri (II p.41;1.1/12), everything according to this author having to be done by Euclid. Poem to Pasino (II p.91;1.13/16). Pasino (II p.101;1.19/20). "the plan which is the main foundation". Busca (II p.117;1.20/21) "pianta, o radice". Stevin (II p.198;1.28), but see later (II p.198/9): consideration of height and depth very important. Flamand (II p.204;1.36/45). Rojas (II p.213;1.20/1) "plans and foundations". Errard (II p.221;1.13/20) explicitly defined fortification as such, as had Stevin (II p.197/8). There is no doubt that there was a tendency here of the treatise writers to conflate the foundation of a fortress, as that physical part of the structure, with the primary basis of design as a "foundation". The significance of the plan is of course evidenced by the great numbers that were presented in the treatises generally, particularly as in such a work as Marchi's.
6. II p.15;1.20/23 7. II p.15;1.32/3. 8. II p. 66;1.26/33.

distinctions and general attitude was frequently repeated in the treatises.[1] Its primary effect was to encourage concentration on the plan trace of the fortress in design, and hence to make fortification a mathematical art, by virtue of making the geometrical manipulation of this trace central to design.[2]

The basic constraint that was then applied to the plan trace of the fortress was the proper functioning of the defensive artillery in accord with the notion of flanking fire and the principle of no dead ground.[3] Such other considerations as the desirability of the bastions not being too pointed, the need for sufficient space within the bastions,[4] then functioned as further constraints on the geometry of the trace. Distance between bastions was determined in accord with the "length of defence" which was set in accord with the range of the defensive artillery that was to be used.[5] Considerations of this nature then allowed the treatise writers to demonstrate certain conclusions as necessarily holding in fortification: that the nearer the basic polygon of a fortress approached the circle, the better the fortress was, due to the lesser pointedness of the bastions, was a favourite one.[6]

Thus a few relatively simple considerations defined the basic trace of the fortress. Its details were then filled in, in accord with more detailed needs, while the geometrical manipulation of the plan trace remained the primary manifestation of fortification as a mathematical science.

The general mathematical theory of fortification which grew out of this treatment then involved the application of the above design criteria to the series of the regular polygons.[7] A general rule for the construction of any member of this series was often given which further emphasised the mathematical nature of the discipline, and the generality of the method which was employed in it.[8] The discussion of the geometrical qualities of these idealised forms then took place in a completely abstract manner divorced from any concern about the peculiarities of particular sites and as if the sheet of paper represented a flat featureless plain, to form the theoretical core of fortification as an art.

This method of design was however not always rigorously adhered to. Alghisi in particular produced designs in which geometrical relations within the plan trace were significant determinants of the layout of the fortress, yet which had no corresponding physical interpretation[9] as provided generally by the notion of flanking fire. Specklin also produced complex traces whose geometrical relationships in parts were not so physically determined.[10] A not dissimilar tendency was shown earlier by Zanchi, who, when considering the

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1. As by Mora, Zanchi, Alghisi, Busca, ibid. But compare the rather odd account Rojas gave of places strong "por artificio" (II p.214;1.13/30).
2. For further consideration of the role and nature of this argument see II p.23/6.
3. This is sufficiently recognised so as not to need detailed documentation here. But see for example Theti's historical account (II p.74/5).
4. Lanteri (II p.48;1.10/13). Maggi and Castriotto (II p.62;1.7/10). Gentilini (II p.120;1.10/13). See also Theti (II p.75;1.19/23), Lupicini as in n. 6 below.
5. This is again sufficiently well recognised so as not to need documentation here. The topic was discussed at great length by many authors. See however Theti's historical account as noted above and Rojas as to how the hand gun in his time had taken over the primary role here. (II p.214;1.23/5)
6. Zanchi (II p.39;1.23/27). Lanteri (II p. 47/8). Alghisi (II p.85;1.15/18). Lupicini (II p.106;1.1/10). Marchi (II p.144;1.33/6) on more spaciousness, another favourite reason for favouring the circle.
7. Zanchi (II p.39;1.9/10) discussed the square as representing all the others. See Busca (II p.113;1.23/30). Belluzzi (II p.141;1.25→) for example. Alghisi's whole method of presentation involved the separate treatment of the fortresses from 5 to 21 sides. Examination of the contents of the various treatises will show how common was discussion which focussed on this series.
8. See Lanteri (II p.46;1.6/21) for his insistence on the need for a general rule for the polygons, which rule was not in accord with traditional Euclidian standards.
9. Different parts of the fortress were governed by their lining up right across the body of the fortress, for example. See Biog . But see below for a discussion of the relationship between fortification and general architecture.
10. See Pl. 23 . Busca reproduced one of Specklin's designs with this quality. 31

series of the regular polygons made some remarks about the "example" of 2 sides.[1] In such cases certain aspects of method appear to have taken on a value in themselves, irrespective of whether results could be directly related to practice or not. Thus once the original theoretical treatment had been set up, discussion and elaboration could take place in terms of the accepted geometrical approach without any reference to the sorts of practical consideration that had determined that treatment in the first place. The general mathematical treatment at work, to a great extent, making this possible.[2]

However such tendencies were not very pronounced in the 16th. century treatises, and the standard technique of design was followed almost universally.[3] Nevertheless two alternative ideas were not infrequently discussed which, like the more favoured approach, related directly to the problem of the plan form, and yet which were to some extent in competition with the accepted technique. Firstly the idea expressed by Tartagli that the plan should be designed so that the enemy shot struck the fortress walls at an angle in order to minimise damage,[4] came up relatively frequently. Particularly in the form sometimes known as that of the "forbici".[5] This device however never found any kind of universal acceptance, despite some authors, particularly Alghisi, making much of it.[6] A very different point was often discussed which was concerned with the contention that the round form, in towers, was the strongest, because the impacts on its external face would tend to force the stones together. Round towers (or bastions) were however almost universally dismissed in favour of the pointed bastion form which eliminated all dead ground.[7] One lone voice however, spoke out against this accepted view. The very practical and experienced engineer Castriotto insisted that the "minutae left undefended" when round bulwarks were employed were of the "lightest importance", and that such forms defended "sufficiently".[8] But his opinion made to headway against the accepted view.

Thus it was the notion of the primary role of defensive fire in design, with the related, and in principle very simple, mathematical treatment that went along with it, that held pretty well entirely unchallenged sway among the 16th. century treatise writers.[9]

The resultant discipline of fortification, at the theoretical level, tended to be justificatory rather than normative; that is statements put forward

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1. II p. 39; l. 13.
2. Development of design in contrast took place in a way consistent with the standard technique when ravelins and other outworks came to be equally determined by lines of defensive fire. As in Marchi's designs for example.
3. The use of a trace defined purely by defensive fire which dispensed with the pointed bastion being the one approach distinct from the most common method which used that form, which was widely accepted. See Pl. [2], [5].
4. II p. 17; l. 27/36.
5. Or scissors. Only in the later editions of the Quesiti et Inventioni did Tartaglia expound the forbici to cope with this condition.
6. Alghisi's designs were based on this device although he introduced triangular masses filling in the re-entrant space, rather negating Tartaglia's point. Alghisi claimed to have invented this device. It involved very deep structures (on plan) and this was probably one of the reasons that it lacked greater popularity, even though Alghisi attempted to stave off any such criticism. (II p. 85; l. 25→)
7. Maggi (II p. 64; l. 11/17). Theti (II p. 72; l. 15/21). Pasino (II p. 97; l. 21→). BOUVELLES (1547) put forward this view as a substantive point in his practical geometry.
8. II p. 62; l. 18/24. Maggi, the compiler of the work that bore both his and Castriotto's name, less experienced in fortification and more a general humanist who came to warfare through the study of the ancient texts on machines and the like, was the one to insist in the combined work, that the general principle of no dead ground had to be adhered to, so eliminating round forms. See above p. 25/6
Of course Castriott spent much of his working career in France, where presumably the 'common sense' of the business was less well established. (Biog.)
9. Locatelli's challenge (see II p. 86/7 T.p.) to the established view, insisting that old fashioned structures could be defended just as well as those in the modern style seems to have been not so much ignored, as never to have been taken seriously. (See above Biog)

were generally required to be supported by arguments, using elaborated intellectual concepts; and statements of a purely assertive nature on the lines of 'it is done thus' or 'we do it this way' with the implication, more or less explicit, that practice had been found to justify the relevant action, were not favoured.[1]

As a result the discipline tended to be a-historical, and dependant on arguments that any individual could recapitulate and test for truth, no matter what the state of his knowledge of the business was, and no matter what as a matter of fact had been found to be satisfactory in the past.[2] Except that is, with regard to the power of artillery, which basic fact the treatise writers insisted, had to be understood by the reader, and preferably through personal experience.[3] That power which, they insisted, made it necessary that the design techniques they favoured, based on a primary concern with defensive fire, should be accepted.[4] Which insistence was itself fundamental to the justification they felt it necessary to put forward for the techniques they favoured, with their basis in mathematics, further illustrating the same tendency.

This a-historical approach and fundamental appeal to mathematics as a body of a priori truths let to fortification becoming a discipline with a method, as opposed to a subject matter, very different from that of general architecture.[5] In this latter, as Pasino explained, one had ones lessons written before you--in the form of the orders: while in fortification one had search in the intellect (using the tool of mathematics) in order to find out what was best to be done.[6] In this way fortification became, in contrast to the general architecture of the period, in modern terms, more engineering than art.[7]

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1. This of course being largely dependant on the mathematical treatment so ~~strongly favoured. But for this tendency more generally in action see Theti~~ (II p. 75; 1.19/23) where the form of a syllogism is reflected. (What about needles?).
2. Certainly on many occasions the treatise writes would appeal to actual incidents of war or existing structures, or to incidents described by the ancient authors. But such references in no way defined the theoretical core of their art.
3. See below p. 87.
4. See however Pasino (II p. 97; 1.33/5) where he used a normative form on this point. But previously he had given the justificatory arguments dependant on the principle of no dead ground. (See II p. 90 contents.)
5. Lanteri II p. 49; l. 9/21. Pasino II p. 96; 1/9.
6. II p. 95/6.
7. This is not to deny that aesthetic consideration were not at work in renaissance fortification for quite plainly they were. For example an anonymous m.s. in the Vatican states "le mura delle Fortezze moderne le sensdono (sic) piu tosto piu belle che forti...." (Codex Urb. Lat. 821 Modo di fortificare.... fol. 43/122b. Redaction dated 1613. f. 62b.) Clearly it was not the ornamentation of the walls that was considered beautiful, but their mathematical form. This treatise makes this clear because just previously the author had explained that the walls of modern fortifications did not have to be thick because it was the earth behind them that resisted the violent blows of the artillery. Clearly the "walls of the fortress", he conceived as the thin masonry skin which faced the earth. That skin which followed the geometric trace and which in the design was an infinitely thin geometric line. Some representations of towns from the same general period, as for example in some of SPEED'S maps, in fact show a bastion trace by means of thin skin without infill behind, and indicate that this was a not uncommon way of conceiving the walls. The beauty then was in the geometric trace. There is no doubt that 16th. century designers were fascinated by the aesthetic aspects of this geometry. For example Alghisi's designs show a very strong concern with symmetry, simplicity and coherence in the geometric pattern. While Marchi seemed to be fascinated with complexity, overdetermination, and multiplicity of variation. This beauty was however almost entirely confined to the design on paper, for as HALE (1977) points out, contemporaries could not view this plan in the actual structure. But while there is no doubt that the 16th. century fortification writers did tend to be fascinated by this aesthetic aspect of design to some extent or other, any such effect must be viewed more as something that grew out of mathematical design, rather than as a determinant of it. (In contrast to general architecture.) The published treatises in fact put little emphasis on beauty in their art, and rather emphasised utility and robustness, which they contrasted with the ornaments of architecture. See Belluzzi (II p. 140; 1.11/12). Pasino (II p. 94; 1.6/8). Castriotto (p. 64, 3rd. sect.)

I:(i):(ii):(i):(d): Summary: The nature of 16th. century fortification as a theoretical discipline.

In its theoretical aspects 16th. century fortification was conceived to be dependant on a general method which made it a certain and demonstrable science because it was based in mathematics; which foundation was conceived to be desirable because of the utility, clarity of expression, communicability, and possibility of control that that discipline was thought to bring to the art. Mathematics in itself being conceived as a desirable kind of study because of its value as contemplative knowledge; because of its valuation and important development in the ancient authors; and because of its inherent epistemological power, and role in relating God, man and the world. The application of mathematics to fortification was achieved through concentration of the form of the plan trace of the fortress as the primary aspect of design, and the treatment of that trace as a function of the needs of defensive weaponry: the general nature of the discipline being manifested through the treatment of the series of the regular polygons as idealised examples handled in a context free manner in accord with the universal propositions of mathematics. The resultant discipline was then distinct in method from general architecture through its dependence on universal and immediate arguments, free from historical roots or paradigmatic examples, except in so far as it necessarily had its own roots in the needs of its own period.

I:(2):(ii):(2): The contribution of practice and its relation to theory
(a): The varied individual responses

While the 16th. century treatise writers were almost universally in agreement that both theory and practice contributed to the art of fortification, they diverged widely in their views as to the relative importance of these different aspects of their art.

At one extreme, Lanteri in his Delle fortezze secondo Euclid (1557), presented an almost entirely 'theoretical' approach to the art, the great majority of that work being based on Euclidian demonstrations.[1] At the other extreme Gian Tommaso Scala in some of the fragments of his writings that were published, rejected almost completely any such theoretical approach.[2]

Most of the treatise writers however took a position somewhere between these two extremes. Somewhat similar to Lanteri in emphasis, although they never followed him at his most extreme,[3] were: Girolamo Cataneo, who began his Opera Nuova de Fortificare (1564) with a section of elementary geometrical instruction;[4] Alghisi, whose treatise was organised around the presentation of the designs of fortresses for a great many of the regular polygons, according to his system;[5] and Pasino, who, while he agreed that practice could be a useful aid in certain situations, refused to accept anything but the very real necessity of theory.[6] Zanchi held views not dissimilar to these writers but sometimes seemed to consider theory as really a substitute for practice.[7] Tartaglia, Stevin, Giovanni Scala, Errard, all in various ways had a mathematical approach but by no means ignored practice.[8] More concerned to hold a balance between theory and practice in the art were Belluzzi[9] and Lorini,[10] for example. While Pietro Cataneo with his Vitruvian emphasis on such problems as the selection of the site, yet with a strong idealizing tendency in his presentation, manifested his own kind of balance.[11] Theti took a position which emphasised practice somewhat more than most of these writers perhaps.[12] On the other hand Maggi and Castriotto, Marchi, and Specklin in part,[13] based their treatises to a great extent on specific solutions to particular sites, actual or imaginary, and hence tended to emphasise the practical responses to such problems more strongly. Gentilini, Busca, Lupicini and Ive,[14] were all much more authors of elementary handbooks which tended to focus on the introduction of the beginner to the practice of the art.

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1. See II p.41 contents. For example, he demonstrated through a Euclidian style proof the fact that given a round tower there must exist an area of dead ground. (So long as the curtains are not re-entrant.)
2. II p.154; l.20/26.
3. In his later work Fortification di terra (1559) Lanteri was much more concerned with practice and there seemed to suggest that long practice might be a substitute for knowledge of geometry (II p.50; l.19/21).
4. II p.52 contents. See also his tendency to eliminate from the core of the art, such Vitruvian considerations as healthyness of sites (II p.53/4).
5. II p.91/2 contents. See II p.85; l.1/6 also.
6. II p.100; l.8/30. Girolamo Cataneo and Lanteri, Alghisi and Pasino, were of course as masters to pupils.
7. II p.33; l.7/10.
8. See the analysis of each of these authors as individuals and their texts.
9. II p.138
10. II p.122/3
11. See also II p.28; l.23/6
12. See II p.70/1 contents & II p.73/4.
13. See II p.59/61, contents. II p.142/3, contents. II p.187, contents.
14. See analysis of these figures as individuals.

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Thus the treatise writers expressed a wide range of views on a continuous spectrum from one extreme to the other, in regard to the relative importance of theory as against the contribution of practice.[1] Yet universally they all presented paradigmatic designs based on the pointed bastion trace as the core of fortification.[2] Practice or experience functioned then not to influence the nature of the accepted design techniques based on the notion of flanking fire and the principle of no dead ground, and its most characteristic expression in the pointed bastion trace. Rather, experience helped to provide skill in the handling of particular sites, and their individual advantages and disadvantages, in dealing with the buildings that cluttered them, and the existing defensive structures, and the relationship of the site to the surrounding terrain, through the application of that basic technique of design. Lupicini, for example, in his treatises in a very 'practical' vein, presented almost nothing but, different sites and the way the pointed bastion trace was applied to them.[3] Experience or practice, the treatise writers were clear, was necessary in order for such a task to be undertaken satisfactorily,[4] so that when they emphasised this aspect of the art, it was to a great extent, this type of activity they intended to draw attention to.

Experience however had another important function in nearly all the treatise writers' minds. It was necessary in order that the immense power of contemporary artillery and the inability of any material to withstand it, should be understood. Such an understanding being necessary, of course, because it was the basis of these writers' contention that such weaponry made the use of their approach based on defensive fire necessary in fortification. However understanding of artillery was further necessary because the range of the defensive guns determined the primary dimension of the length of defence, of the fortress. Experience, the treatise writers concurred, was a necessary teacher here.[5]

Experience was also conceived sometimes to teach a wider but related point by indicating that "defence had to be drawn out of attack", or had to "conform" to attack.[6] Here the general nature of contemporary warfare and the kind of attack the fortress had to withstand were considered important: and rather in contrast to the many passages where offensive artillery was noted for its primary causal role in contemporary fortification, in this context, the mine, the sap, and sometimes "the spade" were indicated as important factors that had to be understood and recognized for the threat they contained, in order to produce a satisfactory fortification.[7]

Now all these ways by which experience or practice were conceived to contribute to the art of fortification were related primarily to the use and manipulation of the pointed bastion trace. In contrast, within the basic

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1. This should not be read in any too precise way. While it is indubitable that the treatise writers expressed a wide range of views on this point, the particular placement of any one individual on the spectrum is somewhat problematic sometimes and is in no way precise. But the generalisation holds.
2. Even Castriotto, who at one point accepted the usefulness of round towers, more generally followed standard practice. Even Gian Tommaso Scala accepted this, see II p.154; 1.36/8.
3. See II p.104 & 107 contents
4. See for example Castriotto II p.63 . Pasino II p.95 in attacking this view. Also his grudging acceptance of this idea II p.100; 1.12/17. Lorini II p.123; 1.6/9. Belluzzi II p.138; 1.29/30. The need for the fortress to conform to the site was very commonly expressed. See for example . . Mora II p.66; 1.43/4 Marchi II p.144; 1.37/9.
5. See Girolamo Cataneo (II p.54/55) for example. Lorini (II p.124; 1.35/7) Marchi (II p.144; 1.6/18). For general attitudes to artillery and its relation to fortification see Tartaglia (II p.9; 1.20/23) & (II p.18; 1.7/10). Pietro Cataneo (II p.29; 1.13/15). Zanchi (II p.36; 1.33/40). Maggi (II p.62; 1.11/13). Theti (II p.71/2) gave the most detailed historical account. Alghisi (II p.82; 1.8/11 & p.84). Pasino (II p.96; 1.30 → & p.97). Lupicini (II p.106; 1.1/7). Gian Tommaso Scala (II p154; 1.5/9). For the length of defence see above, p. 82.
6. Lorini II p123; 1.7.
7. See citations in n 4 above.

framework so given many details had to be clarified and determined. A good deal of the treatises in fact, particularly the more compendious works, were extensively concerned with just such matters. The thickness of the parapet, the dimensions of the fosse, cavaliers, the positions and layout of the casemates, and the like were topics which provided the 'bread and butter' discussion of most of these volumes.[1] Here again however it was generally form that was primarily at issue: and idealised geometric forms as in the basic trace not being readily applicable to such problems, undoubtedly 'experience' and 'practice' were of the greatest importance.[2] So even here the treatise writers were primarily concerned with form and only rarely discussed building methods and the use of materials in any great detail, or as primary determinant with regard to such detail problems.[3] The use of earth as against stone (faced) structures it is true, was a common and important topic, yet this problem was equally always discussed in terms of the need to fill out the independently predetermined trace.[4]

Thus when the treatise writers emphasised the importance of practice or experience as against the role of theory or science, they never meant to attack the central assumptions or the method of the theoretical part of their art. Rather, they sought to draw attention to such problems as "the recognition of the site", the skills of adjusting to particular sites, the understanding of artillery, and the need to design and adjust the structure in all its details. All this with primary reference to form, and with little consideration of the building crafts involved and their operations, or other practices of like nature,[5] except as lesser afterthoughts.[6]

I:(2):(ii):(b): The problem of the site

Design, in the face of the peculiarities and difficulties of specific sites was sometimes handled in the treatises under the general notion of irregular figures. In such cases the resultant trace was often conceived as an unfortunate if necessary deviation from one of the regular polygons. Results arrived at from theoretical discussion, as for example that the angle of the bastion was always less than the angle of the curtains on which it was set, could then be conceived to clarify somewhat the needs of the irregular figures. But irregular figures were also handled in a more abstract way sometimes by reference to the 'less regular' geometric figures such as the rectangle, oval and trapezium.[7] However, most frequently irregular figures were distinguished as such merely by way of their contrast to the regular polygons,

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1. See contents of specific works, as for example Theti's 1575 edition II p. 72/3.
2. This is such a general assumption of the type of discussion so common in the treatises that it is difficult to support by any apt specific quotations. A cursory glance at even a few of the treatises however makes the point clear.
3. The contrast is with modern 'engineering' techniques of design, which depend so much on characteristics of materials to determine form. However this is a question of degree, and in some sorts of details, such as the thickness of the parapet for example, the resisting force of the material did tend to frequently function as an important determinant of design.
4. As noted above p. 81, n. 4. . Peitro Cataneo following Vitruvius gave a section on materials, and some discussion certainly was given from time to time on this subject, but it was never of central importance, and again it is a question of degree.
5. See for example Alghisi (II p. 83; 1.23/5). See Lorini (II p. 136; 1. 31/2) who gave a grudging acceptance of such knowledge as part of the profession: "at least not to be there ignorant". Cf however Specklin II p. 190/1.
6. See for example Alghisi (II p. 82, Bk. III). Lanteri gave a good deal of detail on materials and construction in his later treatise, but he had of course given the most highly 'theoretical' account in his earlier work.
7. The division is made most explicitly by Errard, who in Bk II discussed the regular polygonal fortresses, and who then went on to discussin Bk. III "des Places irreguliers". His notion of irregular was however a theoretically determined one, for, as well as discussing there the rectangle and an oval, he also included the triangle, square and pentagon: these last being 'irregular' because their bastions cam out too pointed. See also the m.s. of WAYMOUTH where geometrically regular traces with semi-circular bulwarks were described as "irregular". [31], [36]

and were discussed separately in terms of the problems that resulted from each particular kind of site and the possible responses to them. It remained basically then a matter of 'ingenuity', or skill, to design their enceints, in accord with the notion of flanking fire, in the best possible manner.[1] The resultant trace, determined to a great extent, by the need to make the bastions as obtuse as possible; and to hold the length of defence to its optimum dimension, in accord with the range of the defending artillery, often involved the 'regularization' of the line of an old enceinte.[2] This process therefore tended to imply that what the designer sought was the best possible approximation to one of the regular polygons. However, any direct attempt to fulfil those same demands, equally led to the same result, without any reference to the regular polygons, and by and large each site tended to be dealt with in an <u>ad hoc</u> manner through diligent manipulation of the fortress trace in accord with the accepted design techniques.[3]

However, with regard to individual sites the treatise writers did not consider their techniques of design as involving a method that should, or could, be applied indiscriminately to each and every site that might be favoured as a candidate for a defensive structure. The selection of sites, not so much in terms of the healthyness of their air, or the availibility of good water, and the like, in the Vitruvian tradition, but with regard to defensibility under conditions of contemporary warfare, and especially with regard to what particular form could, or could not be given to a fortress on any specific type of site, was a common topic of discussion. Frequently, lists of advantages and disadvantages of different types of sites were given, and the author often in fact left the reader to judge which were best, or claimed to do so.[4] Now in this type of discussion a point that came up again and again was that constrained or hilly sites generally had the disadvantage that one could not chose for them the most desirable form.[5] In such cases it might not be possible to make the fortress as capacious as was desired; or, to achieve that figure that gave the greatest capacity for a given length of enceinte; or to prevent the bastions from becoming too pointed,[6] for example.

To the treatise writers the fact that certain types of sites posed problems to the design techniques they employed in no way indicated any defect or limitation of those techniques. Rather, they would insist, nature was at fault in such cases. Pasino, for example, wrote of "the impossibility of reducing to the rules of the art that which nature had produced bad and

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1. As for example in Marchi's many designs. See also Lupicini
2. Pl. 112, 131, 133.
3. There was of course a tendency to suggest that the problem of irregular sites was to regularise them into a regular polygon, as Errard's diagram shows. However this was only very rarely achieved in structures actually built. The sort of process actually involved is nicely illustrated by a m.s. in the Royal Society of Antiquaries (London) library (m.s. Vol. 824). This is a work produced by an Englishman who went to study fortification under Italian engineers, probably at a rather later date (17th. century ?). It bears the appearance of a 'project' book perhaps produced to show that the student had acquired the requisite skills, and also as a means by which he might demonstrate his skills to possible employers or patrons. It is almost entirely composed of specimen traces, the first few of regular fortresses. The remaining designs however include many purely concerned with regularisation of old enceints, as much as seemed reasonable, but without producing regular polygons, Such a kind of activity one must assume was part of the 16th. century designers training. Pasino expressed the general attitude to this problem. See II p.98; 1.5/13.
4. See for example Theti (II p.13/4) who insisted that designers did (wrongly) tend to build indiscriminately with regard to sites. But Zanchi had already discussed sites from this point of view. See below n. 5. Stevin did this at length, see contents II p.197.
5. Zanchi (II p.37; 1.29/33). Theti (II p.74; 1.5/9). Stevin (II p.200; 1.4/9). The same point was made more, or less, implicitly by others. See for example Marchi (II p.144; 1.29/33) and other citations below.
6. Stevin, Theti ibid.

imperfect."[1] The idea that such sites were only 'imperfect' in respect to the design techniques that they favoured, never seems to have been entertained by the treatise writers. Nor the idea that the elaboration and justification of those techniques took place in an abstract, context free fashion on a design sheet which could only be equated to a flat featureless site -- a type of site they could only hope to design for in a small proportion of cases -- and that therefore it was not suprising that those techniques were not altogether suitable to awkward hilly sites.

A similar attitude appeared, particularly in those writers who emphasised theory to the greatest extent, in discussions as to whether it was better to attempt to modify and ameliorate existing, rather unsatisfactory sites, or on the contery better to move to a new and more favourable place, despite the rather heavy costs that might be involved. The tendency was here generally to insist on the necessity of the move no matter how heavy the cost.[2] Similarly sites without the encumbrance of existing defences, or even any kind of building whatsoever, tended to be considered the most suitable to the construction of an impregnable fortress because of the opportunity such a site gave to the designer to manipulate the form of the fortress to the greatest extent in accord with his (preconceived) desires.[3]

Thus the treatise writers, even as they admitted that often awkward and cluttered sites had to be dealt with, tended always to favour those sites that were susceptible to treatment to the greatest extent in terms of their theoretical approach: to consider theory as the arbiter of what was or was not a favourable site: and to attribute fault, if fault had to be attributed, to anything, even the problem to which they preported to give answers,[4] rather than accept that their basic design technique, based on the notion of flanking fire, could be at fault.

I: (2):(ii):(c): The environment and practice

The basic problem of fortification, to which the treatise writers addressed themselves in order to elaborate the nature of their art, was the provision of a protective barrier around an urban area.[5] The key notion of the titles of many treatises was in fact:'the fortification of the city'.[5] In this the treatise writers undoubtedly followed an attitude of the period, emphasised particularly in Italy, which attributed to the city high value and significance,[6] and on occasion they explicitly made the same point themselves.[7] They thus posed

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1. II p.99;1.30/33
2. Pasion (II p.98/99) was perhaps the most extreme exponent of this view. But see also Girolamo Cataneo (II p.54; 1.20/24).
3. Busca (II p.118;1.27/32). Belluzzi (II p.141; 1.20/39).
4. That is, how to fortify a place. They were rather like the individual in the humorous anecdote who when asked to give direction to a particular place, replied "If I were you, I wouldn't start from here." In like fashion the treatise writers when asked how to fortify a 'bad' site, tended to answer "I wouldn't build there at all". This is not to suggest that some sites were not more suitable to defensive structures than others, in a general way. Rather that the theory of fortification favoured was an additional significant determinant of good and bad sites, instead of its relative inapplicability to certain sites being evidence of certain limitations of theory.
5. Valle (II p.11, t.p.). Tartaglia (II p.12) title to Bk. VI of the Quesiti et Inventioni. Zanchi (II p.31, t.p.) Lanteri (II p.41, t.p.), "delle fortezze" & "le piante delle Citta". See also (II p.42; 1.36/9). Maggi & Castriotto (II p.59, t.p.). Lorini (II p.121, t.p.).(But castles were sometimes listed here also.)
6. As evidenced by the title of Giovanni Botero's very well know treatise Dalla Ragion di Stato.....con...cause della Grandezza, e Magnifcanza delle Citta (Venice 1589). See also ROSENAU (1959). Renaissance Italy was of course very much a collection of 'city states'.
7. See Pietro Cataneo (II p.29; 1.23/8). Maggi (II p.61; 1.26/8). Mora (II p.69; 1.14).

as central to the art of fortification the problem of creating a defensive barrier with a specialised function[1] quite divorced from the need to provide habitation--in contrast to the medieval castle complex, for example. This was made explicit and clear by the treatise writers when they distinguished between "building", "fortification" and "repair".[2] Defined in this way the requisite single function structure was undoubtedly more susceptible to theoretical treatment by means of reference to the single notion of flanking fire, in virtue of the lack of other needs which might have clashed with the purely defensive function.[3] But the design techniques that were promulgated by the treatise writers tended to produce solutions that were acceptable just because the central problem of the art was conceived to be the fortification of an important city. The conclusion that the nearer a fortress approached a circle the more perfect it was--a result drawn from theory[4]--which implied that the larger it was the better it was,[5] was highly consistent with the fortification of an important city having a central role in the art.

In addition however, and perhaps more importantly, the inevitable conclusion (given the theory) that the largest fortress was the most perfect, was acceptable only because of the approach of the treatise writers to design. Because, they not only discussed, <u>the problem of fortification</u>, in a context free way with regard to sites, they equally refused in theoretical discussion to allow cost any primary role in determining the most perfect structure, and of course cost and size must to some extent be considered to be related. Thus in accord with their preconceptions about method, which had to have the most general nature, the treatise writers addressed the problem: not of how to design the best fortress of the sort of size that might be most frequently employed; not the problem of a fortress of a cost that most of their clients might be expected to be able to support: but the problem of the most perfect fortress, without regard to consideration of either cost or size.[6] This of course being but a reflection of their 'idealising' approach to design. The theoretical result that the best fortresses were of such a size that only very infrequently, or not at all, would anyone wish to build one, was not then considered to be any detriment to theory. For, such practical consideration as the particular size and actual cost of the fortress were not conceived to be considerations that should influence the basic nature of theory.

That however small forts were needed not infrequently, was widely recognised, and it was admitted that the polygons of only a few sides then had to be used even though they were rather imperfect. But if the fort was of a small size, then it could hardly have any great significance; and

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1. See the way Zanchi (II p.31|2 & 34|6) excluded many other kinds of consideration at the start.
2. See above p. 81 & n. 1, ibid.
3. Medieval castles in developing vertically gave inhabitable space as well as increasing the difficult of escalade. (Consider Connisbourough for example). Given the treatise writers commitment to flanking fire, any such equivalent need might have caused difficulties; and certainly would have increased the complexity of structures.
4. See above p.82.
5. Because the length of defense was held constant.
6. See for example Alghisi <u>II</u> p. 85; l. 25/38.

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if in fact the fort should be of importance the device of reducing the length of defence below its theoretical optimum, could always be employed.

Thus the actual problems that defensive needs threw up and the particular economic environment in which the treatise writers might have had to work had little influence on the treatise writers at their most theoretical, and practice could do little to influence the world of ideal theory.[1]

I:(2):(ii):(2):(d): Summary: the separation of theory and practice

While practice as an activity in contrast to theory or science, was very variably emphasised by different treatise writers, its contribution to the art remained always limited and determined by accepted theory. Practice served to indicate why concentration on form in design had to be adhered to by giving familiarity with the power of artillery; helped to give skill in adapting the trace to particular circumstances; was influential after the general outline of the trace had been determined: but it was not conceived as something that might influence accepted theory in any fundamental way. The difficulties of practical application of the standard design techniques to certain kinds of sites did not weigh against the acceptability of theory as it stood; nor did consderations of cost or size of structure influence the acceptability of that approach. Application always tended to be an attempt to put into practice what previously theory had given insight and justification to.

Thus practice, while conceived by the treatise writers often as merely the opposite pole to theory, had in fact a rather one-sided relationship to theory. Once the demonstrative theoretical system had been set up--and here it was agreed that practice had an important role--but from then on, once the basis of design in flanking fire had been established, practice could do nothing to alter basic theory, it could only proceed within that given framework. Thus was the notion of flanking fire able to remain the unviolatable principle and foundation of all understanding of the art.

But this result was wholly consistent with the treatise writers' views with regard to method: their high valuation of a demonstrable system; their belief in the great value of Euclid and his techniques; and their desire for certainty. Taken together these views formed a pattern which was equally manifested in their approach to the relationship between theory and practice:

Euclidian geometry began with self-evident truths and through the method of deduction went on to elucidate further truths that had to be considered indubitably established because of their basis in such principles and necessary deduction from them. Fortification began with the evident (to anyone who looked), and undeniable truth of the power of contemporary artillery and inability of any material to resist it.[3] From this it was equally self-evident to the treatise writers that defence was only possible through the use of flanking fire. Once this basic 'petition'[2] was accepted, demonstrably certain results could be obtained in the theoretical part of fortification: with exactly that degree of certainty and rigor that was achieved in a Euclidian proof. If practice had been conceived to be potentially able to modify this basic pattern the nature of fortification as a demonstrable art would have been demolished. If the principle of the basis of design in the needs of defensive fire had been conceived as even potentially

1. The treatise writers views on the city were of course ideals.
2. The term used in 16th. century Euclids. See Tartaglia for example.
3. The 'ideal' nature of the treatise writers approach to design greatly aided in making this undesirable. As with size and cost they did not make reference to practical conditions, in terms of any particular number of guns for any particular time, the fortress might be expected to withstand. Allowing as many guns as one like for as long as one liked as close as one liked, of course no material could withstand such weaponry. See also Alghisi II p. 84 when the most extreme of example of water on stone is adduced to support an extremely idealised view.

subject to challenge through experience, even if it had remained as a not unreasonable and sometimes useful approach, the art would have lost its demonstrable certainty. Thus the treatise writers, because of their particular preoccupations with a certain view of method could allow practice no such power to challenge theory and it could only function in a subsidiary role within the given theoretical framework. The notion of the inviolable necessity of designing through concentrating on flanking fire thus became both the substantive and formal lynch-pin of the relationship between theory and practice, and as a result, of the very art of fortification itself.

I:(2):(ii):(3): The realm of values

(a): The social value of understanding in fortification and the dignity of the Architect

The nobility of the soldier's trade was a standard topic of debate in the 16th. century, particularly in the form of the question as to which was more honourable: arms or letters. Military Architecture, as the treatise writers often liked to term their profession, not infrequently played a significant part in such debate.[1]

At one extreme Gian Tommaso Scala railed against too great an elevation of the Architect over the experienced soldier;[2] and equally was dismissive of any too bookish knowledge giving the literary man any such position.[3] Rather differently, in the debate between Mora and Mutio Justinopolis, both contestants attempted to assimilate knowledge in fortification, as one of the number of the (very worthy) mathematical sciences, to the particular profession which they personally supported. The soldier, according to Mora, was the true possessor of such military arts, and in fact in many sciences corrected the errors of the literary man.[4] On the other hand, according to Mutio Justinopolis, such literary arts were obviously the creation of literary men.[5]

The nature and value of the knowledge which constituted the art of fortification was thus of a certain significance in the debates between different groups within 16th. century society.

The treatise writers however were most concerned to emphasise an independent inherent 'goodness' in their knowledge. This they did in one way by emphasising its right to the designation as 'science': and not infrequently they then associated the term 'science' with 'virtue', although without ever being very specific about how 'science' related to 'virtue', or vice versa.[6] Equally they wrote frequently of the nobleness of their knowledge; of its worth and dignity; and of the honour of the Architect.[7] On occasion they would fulminate violently against those who, lacking true knowledge of the art, would attempt to usurp the worthy and honourable title of Architect. One had to beware, at all costs, of these "scum", Pasino explained.[8] On the other hand in Lanteri's view true knowledge in the art was comparable to "beautiful stones and pearls of great value" which, in the hands of the ignorant could be ruined, instead of, as when treated by the expert, being made to appear with all its potential beauty.[9]

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1. See for example Valle (II p. 3/4). Mora (II p.65/6 & 69). Locatelli (II p.87/8).
2. II p.152. 3. II p.154; 1.20 →
4. See n 1 above
5. II p.70
6. Lanteri (II p. 49; 1. 5). Mora (II p.67; 1.5/6). Pasino (II p.95; 1. 39). Marchi (II p.146; 1.18/19). Lanteri (II p. 48; 1. 24) wrote of the possessors of such knowledge as "virtuosi". Giovanni Scala's treatise used this same designation about those to whom the work was addressed. (See II p.120A title.) The association between 'science' and 'virtue' was clearly a stock one.
7. Pietro Cataneo (II p.28; 1.4) "nobility"; (II p. 30; 1.10) "honour" to the Architect through Arithmetic and Geometry. (II p 59; 1.13) "the noble science of" Girolamo Cataneo. Zanchi (II p.33; 1.35) fortification a "noble" topic. Alghisi (II p.83; 1.18/9) Architecture "for its dignity worthy of honour". Pasino (II p.92; 1.22) "liberality and worthyness" of Architecture. Lorini (II p.123; 1.30/1) arts "noble" and "profitable"; Belluzzi II p. 138/9 "worthy and useful art". Castriotto (II p. 62; 1. 39) fortification a "noble practice".
8. II p. 101/2 . See also Lorini (II p.136; 1.24/7) "adorned with the title of Military Engineer". Mora (II p. 65/6) although the context is a little different.
9. II p. 47; 1. 20/46.

This very worthy nature of knowledge in fortification, was supported in a number of ways. Firstly, the use of mathematics in general and geometry in particular gave honour to the subject and its practitioners, it was suggested: such studies possessing a nobility in themselves.[1] But it was not only expert practitioners who received honour in understanding this subject: knowledge of defence would "spiritualise gentle persons" according to the verse to Pasino.[2] Castriotto's results, were worthy of being seen by "every gentle spirit", according to Mora.[3] The nature of the underlying notion was indicated by Tartaglia when he explained that Geometry was "pure nourishment" for the "vita intellectuale".[4] Errard further emphasised the suitability of such knowledge to, even almost necessity for, men of quality, and to those with high political responsibility.[5] Castriotto likewise insisted that "the great" ought to possess the sort of knowledge he cultivated.[6]

This pattern was additionaly emphasised by those writers who followed Alberti, such as Alghisi and Pasino, through the description of the relationship between the Architect and the operatives who followed his designs, as similar to the relationship between those same operatives and their tools, which, Pasino suggested, was like that between the soul and the body.[7] Alghisi further insisted that the knowledge of the Architect was not like that of any simple man or soldier, but rather was something a great deal more.[8] Lorini, while he suggested that geometry was necessary in even "the baser" trades, insisted it was all the more necessary in "works royal and more worthy".[9] Understanding of design, he also argued, was not the work of "mechanics", or "men of low condition", for if anyone in command lacked this, he would find himself having to be commanded by a mechanic.[10] Work in the actual manual arts being of course something no noble should even dream of undertaking--that would be very blameworthy, as Lanteri put it.[11]

The value of the art was also sometimes supported by reference to the many learned disciplines Vitruvius had suggested as necessary to the Architect.[12] Or to the long toil and study, and even danger that was necessary to the aquisition of expertise in the (true) military arts, and in fortification.[13]

Generally then, understanding in the art of fortification, based on mathematics and acquired with long study, was contrasted with the operations of mechanics and those of the baser trades; and was seen as very suitable to be cultivated by 'gentle spirits'. Being useful to those who governed, it was not only suitable to them but moreover necessary. This noble study with the dignity and worthyness inherent in it brought these same qualities to expert practitions in the art.[14]

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1. See citations above p.79; n.1 . This was part of the whole pattern whereby attempts were made to assimilate practical mathematics to contemplative knowledge.
2. II p.91; l.17/18. 3. II p.68; l.26/28. 4. II p.8: l.37. 5. II p.216/17.
6. II p.62; l.32/3. 7. II p.93: l.1/6. 8. II p.83; l.22/8. Cf Alberti below p.185.
9. II p.125; l.3/10 10. II p.129; l.5/36. 11. II p.48; l.4/26.
12. See Lanteri ibid. l. 30→. for example. Pietro Cataneo II p.28; l.16→
13. See for example Busca (II p.115: l.22→). Mora (II p.67/8). Zanchi (II p.32; l 33→).
14. The importance of this to the treatise writers can be seen by Lorini's insistence (II p.135; l.46→) that fortification could not be based merely on general rules because the "nobility" in it "through being possessed by a few, would not be of much account when understood by many". This attitude tending to be in tension with the call for method based in simple geometry (see Lorini II p.130; l.19/20 for example) understandable to all. This last demand being equally in tension with the emphasis on long study. Thus the desire to support the nobility of the subject sometimes over-rode the call for a simple demonstrable method.

Its mathematical basis making it suitable to a certain superior level of society, its study was made all the more dignified and noble by being suitable for such a group.[1]

I:(2):(ii):(3):(b): Ideological commitments at work

At the level of fundamental theory the treatise writers generally attempted to present their ideas in the form of statements, either: self evidently true, or deduced from such principles; or obviously true to anyone who had the least knowlege of the business: that is in the form of 'such and such is the case, and is necessarily so', often with the implication that the empirical evidence demonstrated this to be the case. On the other hand on occasion they indicated, sometimes quite plainly, sometimes more tacitly, that things might not always be quite so simple. In such cases it is clear they were concerned with statements about what ought to be; what could be, what truly was the case, although the relevant evidence might not be fully available; about the optimum ways to proceed: in short statments of belief and judgement which indicated their commitments to particular values.

On the fundamental problem of method Zanchi made it clear that he was responding purely to a belief that successful fortificataion could only arise by way of method. The successful structures of the past and present he insisted, had to have had "each one a rule and foundation through great study and demonstrated doctrines" because such was necessary to give perfection to their strength. He then had to go on and explain why not even one such rule had in fact been handed down from the ancient world.[2] Lanteri expressed the same sort of assumption when he criticised contemporary architects for not proceeding by number, contrary to the ways of the ancient "eccellenti".[3] Lorini equally made clear that rule and method in fortification were not what one saw when one examined contemporary procedures. But contemporary procedures had then to be at fault, because the true art had necessarily to proceed in such a way.[4]

Thus belief in the need for method was concerned with what ought to be rather than what the empirical evidence demonstrated: and in fact this attitude was implicit in nearly all the 16th. century treatises, despite the attempts of their authors to make method seem necessary, as some kind of established fact.[5]

Similarly, with regard to mathematics, Lanteri admitted at one point, that his belief in the great power of these disciplines in design was only a (reasonable) belief, and in fact that his belief ran contary to accepted practice in general architecture. Any strong emphasis on his view, he agreed, implied one could have architecture without the orders, nevertheless he believed

1. Fortification differed greatly from general architecture in this, for that study was often conceived to gain its worth and dignity from beauty. Fortification being concerned with force, this could not be so, thus mathematics took over the function of providing worth and dignity. The kind of argument indicated here was of course circular, but at this level this was of little significance.
2. II p.32; l. 11/14. Vitruvius of course gave no such rules for fortification and he was the major source of detailed knowledge of the building of 'past' times.
3. II p.47; l. 21/4. Lanteri did not so much assume here that the ancients had a method in fortification. But seeing as they proceeded "by number" in building generally (in his view), one therefore had to proceed in this way in fortification.
4. Lorini II p. 122; l. 18 →, & p. 130; l. 43 →.
5. See above sect. I:(2):(ii):(1):(a).

that: with mathematics alone--and without any other science, "one could design a city, or any other thing".[1] This type of attitude was also at work in many of the other treatises, although perhaps not so strongly.[2]

On the crucial contention that the power of contemporary artillary meant that it could not be resisted by any material, Pasino put that he did not know if even the very great walls of Babylon could have withstood it.[3] Mora further gave the game away with respect to any absolute necessity of proceeding in design by way of form alone when he admitted "without any doubt any simple man" could fortify (successfully) with walls of "immeasurable greatness".[4] Of course the treatise writers insisted that such would not demonstrate any skill. Yet this was purely an assumption of how best skill could be demonstrated. They simply assumed that skill was best manifested through the manipulation of form, and ignored such possibilities as the judicious selection of the material and the working of it, by and large. Having assumed that form was the critical aspect of design they then simply concentrated on it almost exclusively as the primary determinant of the fortress, and insisted that its manipulation was the only way in which the designer could demonstrate his skill. Their attempts thus to support their approach by suggesting that only in this way could the designer demonstrate his skill were then completely circular.[5]

Further the contention that the designer should be able to rationally expound and demonstrate why his design would function effectively, rather than merely being required to produce an object that actually did function satisfactorily in practice, which was what was involved in the requirement that one should be able to recognise the designer's "ingenuity" or "subtlety" in his design,[6] was a commitment to a desirable state of affairs, by no means necessary. After all, one does not expect the surgeon or physician to be able to fully explain to one why his treatment will work. To a great extent one goes to him for his expertise and hopes he will achieve a satisfactory cure, because he had done so in other cases in the past: not because one understands why his cure works.[7]

Now the biological/medical analogy was a common enough one in 16th. century fortification. Both in relating the parts of the fortress to the human body,[8] and where the physcian treating the body was compared to the fortification designer treating the site.[9] Lorini used this last analogy with medicine to explain why such diversity in opinions and structures in fortification

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1. II p.49; 1.9/21.
2. It appeared most frequently in the form of the belief in the general power of mathematics, and its utility. For, even if mathematics was found to be useful in many other areas, where was the guarantee that this was to be the case in fortification. (The general problem of induction. Compare naval architecture below sect. II:(1) .)
3. II p.97; 1.13/20. See also Alghisi II p.94 & n 3.
4. II p.66; 1.26/32. This of course implicitly denying the contention that no material could resist contemporary artillery.
5. In other words they tended to put forward as the basic criterion of success in design, the manipulation of form. On this assumption the architects skill could only be demonstrated in that way, so that this second contention could in no way support their basic assumption. For more detailed and formal consideration of the Tartaglian argument on form which is considered here and below see II p.23/26.
6. See Tartaglia (II p.14/16).
7. His suggestion that one should take such and such a medicine, for example, because it has been found to favourably affect ones complaint in previous cases, although why this should be so has not yet been discovered, is quite a sufficient explanation, if one requires one. And here simply the criterion 'it works' is considered satisfactory, without their existing any demonstrable reason why it works. Thus demonstration can not be considered a necessary condition of success in a practical task.
8. A well known drawing of Franceso di Giorgio showed a fortress overlaid by a human body, for example.
9. Pasino II p.96; 1.9 →, for example.

did exist.[1] But, he then went on to argue, fortification is not merely a skill (facolta), like medicine, but "science" and "art" because of its demonstrable quality: that this was desirable was thus not inherently necessary but rather an assumption about what was desirable.

Thus alternative approaches, such as suggested by the medical analogy, were available to and in the minds of the treatise writers.[2] But they chose to cultivate demonstrability in design. The assumption of the desirablity of such demonstrability, together with the assumption of the desirability of concentrating on form in design, with its mathematical treatment, then provided them with mutually supporting ideas. Their commitment then was given to a whole package of ideas--the overwhelming force of contemporary artillery: the impossibility of material resisting such force: the need to design through concentration on form (by way of the notion of flanking fire): the need for demonstrability in design--each of which individually involved a high degree of commitment, but which taken together mutually supported each other so well, that one seemed to have an inescapable and undeniably necessary result.

Thus while the 16th. century Italian treatise writers favoured the exposition of their basic ideas as necessarily demonstrated, those ideas in fact involved strong commitments in many areas.

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1. [] p.132;1.16→. Lorini clearly considered medicine to be a very worthwhile and truly established discipline. However doctors were not always successful in treating patients, he argued, hence there was equally a diversity of opinions and structures to be found in fortification.
2. Even here however they could always point to the theory of humours, as they did, to support the need for a theoretical approach. But medicine was not demonstrable in anything like the way that geometrical fortification was.
3. This occured in other areas not dealt with here, as for example, the social implications of particular appraoches, which should be obvious by now.

Dürer, in a number of ways expressed attitudes about the way work in the arts ought to be undertaken, similar to those expressed more strongly and explicitly in the later Italian fortification treatises, particularly with regard to the desirability of method and the value of the use of mathematics.[1]

On the other hand in his fortification treatise--the first published work in this genre--his approach did not represent any very full expression of those ideas. In essence his views and approaches were in some ways similar to, and in others rather different from those of the later Italian writers. In the Befestigungslehere Dürer in fact presented a series of particular solutions to a number of rather different problems: the provision of a bastion to strengthen the angle of an existing town wall; a smaller version of the same; the provision of a lord's residence with surrounding town on a plane; a round fort or blockhouse;[2] the modification and strengthening of an old town wall: separate solutions rather than any integrated method as provided by the later Italian writers.[3] These separate solutions all dealt with in a rather ad hoc piece-meal fashion. He equally differed from these later writers, of course, in concentrating to a great extent on providing heavy defensive masses protecting defending artillery. In following this principle, and his other general point that walls ought to be battered rather than vertical to withstand artillery he did to some extent have a general method, but so loose, that experience in putting it into execution tended to become much more important than in the later dominant tradition.[4]

On the other hand, in other ways, Durer's approach was much more like that of the later dominant writers. Firstly he followed the approach of 'idealised' design in a cost free context. He indeed made remarks very similar to those of later treatise writers in insisting that the client simply had to follow his idealised designs for his safety, even though they cost very dear.[5] He equally, just like the later writers, used the argument of the power of artillery to justify his design techniques.[6] He also to some extent favoured mathematical techniques in design: and in the case of the strong prince's residence on a plane, used the abstract geometrical shape of the square, in such a way that it was related to the use of flanking fire along its ditches.[7]

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1. See Biog.(b). 2. See II p.158 contents.
3. That is like the use of the series of the regular polygons all handled by reference to the needs of defensive fire and the principle of no dead ground.
4. See II p.163; 1.16/26. The Italians of course often made similar remarks, but with their stronger method such remarks tended to have much less force. Dürer's use of bastions like the ones he first described, in the ditches of the kings residence and town, to some extent tended to provide an overall method, however.
5. II p.160; 1.46 →. 6. II p.159; 1.30/33.
7. 'Related to' rather than determined by as in the case of the Italians. For a section where Dürer clearly mentions this type of fire and the notion of determining the distance between strong points by reference to the range of the defending guns just like these later writers, see II p.161; 1.24/28. On the other hand the layout of the defensive guns around the whole circular periphery of his 'bastions' meant that this type of fire in Dürer's designs was only one particular case of the total fire provided. Dürer in fact seemed to be using the general principle of providing fire to make the whole of the bottom of the fosse a 'killing ground', not that of flanking fire specifically. In the case of this last problem Dürer, like the Italians handled the town in an 'idealised' fashion, but unlike them his designs focused principally around the princes residence or castle, a point which some commentators have tried to gloss over in order to emphasise Durer's contribution to town planning. See Biog. (c). See ibid. for further details on these points. Dürer has often been rather hard done by, by later commentators. WAETZOLD (1917), for example, saw his designs as fantastical because of their high costs particularly. But this idealisation was equally present in the later dominant writers, whose ideal solution approached a circle and hence was infinitely large--that surely was fantastic. There is no reason why scaled down versions of Dürer's designs should not be considered characteristic of his 'method' and hence much more practical, just like the 'more imperfect' solutions of the Italians.

But these elements in Dürer's thought, were never fused into an interlocking intellectual system and generalised to give a theory of the art, and his approach always remained piecemeal and related to specific problems.[1]

The German writers who published after Durer: Reinhard, Ryff and Fronsperger[2] formed a group whose ideas, set against the course that 16th. century fortification did happen to take, were not a progression from Durer's position but rather a degeneration in the sense that they were closest to Durer's view where he differed most from the later Italians.

The approach of these writers to the topic of fortification, and of Ryff and Fronsperger particularly, to writing about the art, was very different from that of the Italians. These last two in fact produced very compendious works in which fortification was included as but one topic among many: and the subject itself was handled by assembling the views of earlier commentators, or their actual texts, in the form of a compilation. In this both Ryff and Fronsperger leant heavily on Reinhard, (and ignored Durer almost entirely).

Reinhard in his dialogue, as its title indicated,[3] put great weight on the value of experience, both in warfare and in building, as the ground of knowledge in fortification.[4] The purpose of his work, he explained, was at least in part, to expound the knowledge of experienced builders in order to preserve their skill lest their expertise be carried over into death undisclosed.[5] In his early sections Reinhard focused his discussion around the specific structure of the castle of Milan, indicating that one needed to learn through examination of particular structures already created, in order to profit by the experience of others in building.[6] The lessons of such examples had then, in Reinhard's view, to be followed only so far as was possible within the constraints posed by the individual patron's needs and resources.[7] In all this he was in great contrast to the Italian writers with their emphasis on a general, intellectually determined method,[8] and their consideration of design in an idealised way. On the other hand in a very important section he insisted on the importance of defensive flanking fire in defending a structure,[9] just like the Italian writers. Nevertheless the general tenor of his work was to imply that many different kinds of structures, different sorts of general considerations relevant to design and the multifarious conditions of actual warfare had to be considered in any discussion on fortification.[10] Again, like the Italian writers he emphasised the importance of understanding the power of artillery and its role in attack,[11] but it was the actual detailed effects of particular guns on particular thicknesses of walls, that he considered the designer should know.[12]

In so far as Reinhard had a general method, it tended to be a collection of general apophthegms[13] and the insistence on taking good council before building. But it involved also good surveying of the site, and elementary mathematics as he demonstrated in the taking off of quantities. However this last element was balanced by a good deal of rather discursive treatment of a varied collection of topics relating to materials and construction.[14]

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1. For details of these writers views which are merely summarised in this section see the relevant Biog. sections where fuller citations are given.
2. See Biogs. JAHNS (1890) described them as representing an encyclopaedic tendency but this was rather over simple and distorting.
3. See II p.164/5, title and description.
4. II p.166; l.18/25.
5. II p.166; l.5/10.
6. II p.169; l.6 →.
7. II p.164; l.79 for example.
8. See II p.172; l.19/21 for his denial of the possibility of a general method.
9. II p.170/71 But only in a general way, and it is impossible to establish if he was thinking in terms of the pointed bastion or not.
10. See II p.167; l.38 →, for example.
11. II p.172; l.34/9.
12. II p.172; l 4/8.
13. II p.172; l.40 →, for example.
14. See contents II p.164/5.

In sum Reinhard's dialogue was a collection of much practical advice on many diverse practical problems.

Ryff, in assembling sections from different writers, included one following very closely after Reinhard, and one which equally followed Bk. VI of Tartaglia's Quesiti et Inventioni almost exactly. He thus presented the reader with a good deal of information about all sorts of different problems, and how they might be approached in terms of the different principles that might be used, in much the same pattern that Reinhard manifested. He thus equally put forward no general method, but on the other hand he emphasised mathematics more than Reinhard had, modifying that writer's dialogue to that end in places. In this he follwed the general pattern of his rather mathematical commentary on Vitruvius of which fortification was but one (albeit important) part among a number.[1]

Fronsperger's remarks on fortification followed much the same pattern as that of these two earlier writers, who he avowedly admitted to leaning on. In his case however, in contrast to the position with Reinhard and Ryff, he provided clear graphical evidence about the sorts of structures he was thinking of, although only for field fortification (these German writers being very poor in graphical presentation in contrast to the Italians). Fronsperger showed a protected camp in one case defended by a sinuous trace; in another as a square [19] with rondels at the corners; and a third with a zig-zag trace related in parts [20] to flanking fire. Thus Fronsperger like his earlier compatriots Reinhard and [21] Ryff, refused to provide any general method: neither insisting on the determination of the trace by reference to flanking fire, nor the use of the pointed bastion, whose form was roughly indicated in some almost purely decorative illustrations in his work.[2]

In contrast Specklin was in many ways a representative of the dominant tradition and much closer in approach to the Italian writers. His many magnificant illustrations showed him designing in accord with the method of the pointed bastion, and attempting to elaborate that technique. In one plan he demonstrated how to design a fortress including an extension of the geometrical approach to include the trace of the counterscarpe. He equally tended to emphasise the use of mathematics.[3] On the other hand he emphasied knowledge of the building trades to a much greater extent than was the case in nearly all the Italian treatises, including an attempt in a rather crude way to bring materials under the scope of mathematics.[4] Again the amount of space and attention he gave to hilly castle sites and responses to them through the use of the pointed bastion trace, was rather greater than that of most of the Italian treatises. His use of geometry also tended to be much more a practice

1. See Biog. for details.
2. These German writers did not give plan traces in their texts, or many clear illustrations showing what structures might look like. Reinhard had only a section and orthogonal projection, of a bank. Ryff's whole work was full of many illustration, but most of them were mainly decorative. However he did give a nice picture of the castle of Milan. At other points he showed bulwarks or [16] rondels much like Durer's, and in one of his clearer efforts he plainly gave [118] a Durer like solution, even though he did not lean heavily on Dürer in his [22] [23] text. Fronspergers illustrations were much like those of Ryff's work with an important decorative function, with the addition of the engravings of field fortifications, and those showing bastions or regular banks. The Italians nearly always treated the subject of field fortification in accord with their general theory of fortification, although applying their techniques somewhat more sketchily. [4]
3. II p.190; I 40/45.
4. II p.190/2.

of manipulation within the design sheet, than an attempt to ape Euclidian proofs, as was done by so many, particularly the more extreme, of the Italians.[1] Specklin's relationship to the earlier German writer can be seen in his description of the events surrounding the building of Antwerp citadelle where he recounted his discussions with Master Franz about the earlier urban enceinte there. This enceinte Specklin emphasised was faulty in design because the advice of experienced war councilers and the opinions of the Emperor himself had been followed rather than that of the specialist in building, Master Franz. Thus he denigrated the advice of the warwise, against that of the specialist builder, in contrast to Reinhard, Ryff and Fronsperger, although, perhaps somewhat accidently, he stressed the skill of the master mason, (Master Franz) not unlike them.[2]

Thus the German writers, particularly where they differed most from the Italians, and particularly those who differed most from the Italians, emphasised a distinctly different pattern with regard to the understanding of, and writing about fortification, and of the process by which design ought to proceed.

Where the Italians stressed the need for a general method, the Germans stressed the value of particular examples and the need to consider individual cases: where the Italians stressed the value of theory and science, the Germans emphasised the value of experience in warfare and building: where the Italians stressed the central role of mathematics in fortification, the Germans favoured its use as a tool for specific tasks: where the Italians stressed the value of universal, immediate and certain demonstrability, the Germans presented the views of many authors: where the Italians stressed the public nature of demonstrability, the Germans emphasised the personal quality of knowledge. Where the Italians produced idealised design techniques, the Germans emphasised the importance of the patron's needs and resources: where the Italians emphasised defence of the urban area, the Germans considered the problem of the Prince's residence: where the Italians focused on form in design, the Germans gave weight to the need to consider materials.[3] Where the Italians emphasised the value of Speculative knowledge, the Germans paid heed to the understanding of the building trades. Where the Italians insisted on the need to defend by flanking fire, the Germans accepted the possibility of its use on occasion.

Yet on one point were the Italians and the Germans in almost entire agreement: the importance of contemporary artillery and the need to take account of this when considering the problems of permanent structures for defence.[4]

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1. See Biog. for details.
2. II p 193/4
3. This is very much one of degree, as with so many of the other contrasts noted here, and as was the case with the different design approaches as a whole.
4. See Fronsperger II p. 183; 1.115.

I:(2):(iv): The International acceptance of the approach of the Italian treatises

The fortification treatises published towards the very end of the 16th. century in a number of other languages apart frm Italian clearly involved the almost total acceptance of the approach of the Italian writers. The idealised solutions they presented, determined by the pointed bastion trace, were of precisely the nature that the Italian writers favoured.

Equally, the justificatory background these international writers presented owed a great deal to the same ideas that were expressed by the Italian writers. However, the relationship between that justificatory background and the preferred solutions in terms of structures, showed signs of having changed slightly in emphasis as those ideas were disseminated. Whereas, in the Italian treatises, justificatory remarks were concerned with supporting the types of solutions that were put forward, in the international treatises the solutions of the Italian writers tended to be accepted independently in themselves as representing the best solutions of common practice, while the justificatory background could be modified or used in particular ways to suit the author's own personal predilections.

In a way this was by no means suprising because these international writers often suggested that their primary purpose was to put into their own particular language, for the first time, accounts of contempory fortification as an art, and the literature of the subject was enshrined in the great number of Italian publications on the subject.[1] The detail solutions given by those Italian treatises were then the parts most likely to be of interest to the reader who wished to know about the substance of the Italian's ideas on fortification. The justificatory background was then more open to modification and shifts in emphasis, in the hands of these international writers.

In this context Specklin must be considered one of the international group for he had the avowed aim of presenting contemporary ideas in fortification to the German reader for the first time.[2] In his account he then emphasised the role of geometrical drawing, rather than of Euclidian geometry, and used this as a major justificatory device.[3]

Paul Ive on the other hand expounded the theory of the pointed bastion in standard geometric fashion,[4] but then insisted on the value of the advice of the experienced soldier against that of the "Geometrician" (or mason).[5]

Stevin felt that the basis of design in fortification in defensive fire was so clearly established that he could define the subject as the mathematical manipulation of lines of defensive fire, without giving any specific arguments to support this, by and large.[6] He was then able to see fortification as a subject where he could demonstrate method in operation,[7] while simultaneously

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1. Specklin (see below n.2). Stevin Op. cit. (1594) f.(ib) where he further expounded his favourite theme that the Dutch language was superior to others in expressive power and clarity.
2. II p.189.
3. II p.192
4. See II p.195; l.10/11 for typical geometrical discussion; IVE (1589) p.9, for the standard pointed bastion diagram.
5. II p.195; l.31/4.
6. II p.197/8.
7. II p.198; n.4.

he used the topic to demonstrate his mathematical expertise at work.[1] Within the context of his general mathematical work fortification thus tended to become for Stevin, simply one subject among many that demonstrated the usefulness and power of mathematics, and the need to apply these disciplines in many areas of knowledge.

Claude Flamand to some extent used the topic of fortification as one which demonstrated the value of mathematical knowledge, and helped him to disseminate such knowledge.[2]

Ambroise Bachot very differently took up one aspect of the art-- the presentation of the design through perspectives techniques, and developed this topic in what he considered was a new and more rigorous way.[3]

Christobal da Rojas, while he wrote a fairly common place account of the art, at one place put forward the rather odd proposition that the difference between sites strong by nature and those strong by art ("artificio"), was that the latter were in such places that they could be reinforced by friendly forces when necessary, completly demolishing the traditional justificatory function of this distinction.[4]

Jean Errard like Stevin, defined fortification as the geometric manipulation of lines of defensive fire.[5] He equally took the opportunity, not to repeat the sort of justificatory discussion along Italian lines, but to make that background more rigorous in its own terms by making it more consistent with its own avowed aims, as in dispensing with "mechanical" solutions,[6] for example, and also in presenting the material in a form closer to the Euclidian model. He equally felt free to make a distinction between regular and irregular figures which was dominated by contemporary theory.[7]

This pattern, while rather tentative, and relevant to only a relatively small group of individuals can not be given too much emphasis. However, these responses ought to be contrasted with that of Lorini who published at around the same period, and who felt it necessary to argue more than once and at some length that there could and should be 'a method' in fortification, and that the discipline was truly 'a science', in contrast to the International writers who tended to simply accept such points.

The emergence of many original works in many other languages in addition to Italian, which put forward detailed solutions in fortification similar to those of the Italian writers, marked therefore the acceptance of the art of fortification at the level of the textbook or treatise, after the Italian pattern, in more than one way. The acceptance not just of the substantive ideas of those works, but also of those ideas as having not so much become demonstrated, but as having become solutions that could not be questioned because they were so much in accord with both common sense and the opinions of specialists in the subject. From then on, the justificatory background, which could be developed in its own terms or used for particular purposes,[8] and the solutions within the accepted framework of the discipline.(in

1. II p.199; 1.28/41.
2. His book was really a mathematics text book in many ways and in the second edition appeared as such without the fortification section. See II p.203 where the typical package about the nature of mathematics, its virtue and power, of the treatise writers, was at work about mathematics in general. II p.205; 1.21 and seq. where Flamand pushes his mathematical ideology in a general way.
3. Biog.
4. II p.214; 1.13/20.
5. II p.221; 1.13/20.
6. II p.219; 1.9.
7. See above p.72; n.2.
8. That is, for example, as part of, and support of a mathematical view of the world.

other words the art of fortification in itself, as it had come to be) were free to be developed in their own ways.[1] Thus the justificatory background had served its purpose even as Lorini continued to argue in favour of the accepted design techniques in the traditional way.

I:(2):(v): The acceptance of the ideas of the treatise writers in the dominant tradition in the later 16th. century: Inevitability or choice?

The core of the dominant tradition in the 16th. century treatises on fortification comprised an interlocking system of ideas, attitudes and beliefs: about the need for theory and method in the science; the value and usefulness of a general, and particularly mathematical approach to the subject; the value and nobleness of mathematics and its suitability and usefulness to those of a certain (gentle) station in life; the acceptability of idealised design techniques and the need to design through concentration on form in accord with the requirements of defensive artillery; the immense power of artillery and the inability of material to resist it.

The 'empirical' judgement therefore with regard to the irresistable force of artillery was at least, just as much an essential, indeed critical, part of this system of beliefs, as it was any simple response to the observed effects of artillery. The evidence of the published treatises of the dominant tradition then suggests that the reasons for these treatise writers holding such a view were at least as much concerned with their wider preoccupations about the nature of theory, as with any mere empirical observation of events. Their observations must then be considered to have been 'theory loaded'. But not 'theory loaded' merely in the familiar sense of (for example) influencing them to take note of events which supported their views, and to ignore as anomalies those that refuted them when they could not be explained away in one way or another. The treatise writers' view on the power of artillery and the possible response to it, was in fact 'theory loaded' in a wider sense. The desire, in the dominant tradition, for a general idealised theory or method in the art, led to any reasonable effectiveness of artillery being able to function as a justification of their view of this weaponry. For, in idealised design it was not any particular amount of artillery that was considered, just artillery: given then some reasonable effectivness of artillery on occasion, what had to be designed for was artillery in (roughly) as great amount as might possibly be met with, not in a practical sense, but in an idealised sense in accord with the approach of the treatise writers to design. Thus what had to be withstood was as much artillery as one might care to conceive: and of course no material could resist artillery so conceived if it was to any extent effective. Hence any observation that favoured this last assumption, given the attitudes of the treatise writers to theory, did support their contention that artillery was irresistible and hence that design had to proceed by reference to flanking fire.[2] Similarly, this same attitude to theory of the treatise writers, made it impossible for them to consider that fortification

1. As in the 17th. century systems such as those of Pagan, Von Coehoorn and Vauban.
2. See Busca (II p.113; 1.3118) who argued against those who, he insisted, contended that one could make an impregnable fortress on a plane through form alone. Impregnable against what precisely was never defined.

solutions could be handled in an ad hoc way according to situation to resist this or that amount of artillery, or in this or that way. So again any observation of some reasonable effectivness of artillery on one occasion was conceived as a support for the contention that design techniques had to respond to such a threat on every occasion, simply as a result of the treatise writers attitudes to theory, and supported their contention that those techniques were a necessary response to the power of that weaponry.[1] In this wider sense then the views of the treatise writers in the dominant tradition on artillery, and the rational response to it in design, were highly theory loaded in terms of the way observation was conceived to function.

The evidence from the German writers albeit somewhat tentative perhaps and from a relatively few treatises of perhaps a somewhat earlier date than many of the Italian works, is however essentially clear with regard to this issue and shows that there was no kind of necessity in the response of the dominant writers. These German writers took a view of artillery substantially the same as that of the Italians and yet conceived that fortification ought to be approached in a rather different, though not diametrically opposite way. The difference between the two approaches being fundamentally about the problem of whether any such 'fact' as that artillery had become immensely or irresistibly powerful, could or should lead to a certain kind of 'method' in the 'art'. This difference was in fact about how such a technological problem could or should be approached. Whether, as in the Italian view, with a method as they proposed, because artillery was immensely powerful--although Pasino addmitted he only believed it could not be resisted by such and such a sort of structure: and therefore no material could resist it--although Mora admitted even a simple man could use it in this way: so that design on the principle of no dead ground was necessary-- and although Castriotto on occasion admitted that the minutiae left undefended through the use of round towers were only of the lightest importance. Or whether as the Germans did, by concentrating much more on particular problems, the actual effectivness of artillery,[2] and the needs of the patron, using such notions as that of flanking fire when useful, but by no means building one such principle into a total architectonic system. Both views involving very similar views as to the contemporary strength of artillery.

Thus the view of the dominant tradition that it was necessary to approach design in fortification through concentration on the needs of defensive fire because of the power of contemporary artillery, when viewed as part of the system of ideas to which it belonged, is found to have been a response to a great extent to the particular preconceptions of its protagonists on a wide range of issues, and especially with regard to the nature of their knowledge. Equally when considered against the views of the aborting and more minor German tradition, that same contention is seen not to have been the only alternative but again a response to those same preconceptions.

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1. These two pressures though similar in many ways and leading to the same result were in fact different in substance. In the first case one generalised over artillery and hence design had to respond to its (theoretically) infinite power. In the second one generalised over sites and any effectiveness in one case results in one considering ones design techniques must respond to its power in the case of every site.
2. See Reinhard (II p.172; 1.4/8). This is one of the most suggestive passages in the whole literature of the period. It suggests a whole mode of design that simply never was followed, at least in the treatises, and involved just the sort of question to which a modern designer centrally addresses himself.

Thus the acceptance of the dominant view can not be seen to have been an 'inevitable' response to some 'objective' quality of contemporary weapons of attack, but was to a great extent a choice, in response to certain epistemological evaluations.

However, any such contrast between necessity and choice, forced into prominence as it is by the treatise writers themselves, is a notoriously troublesome one in history. Further, it might also be considered that the approach of the dominant tradition was a response to the threat of artillery in some weaker sense than the treatise writers propounded, as for example having been the only reasonable response that might have been made under contemporary conditions. However what is a 'reasonable' response under a particular set of conditions may vary widely from period to period, and from culture to culture. It was furthermore just the point the treatise writers were arguing about. Thus this notion can not be used in any <u>a priori</u> fashion here to give an answer to such questions, but requires its own historical description. Thus the wider background to the ideas of the dominant tradition, social, physical and intellectual, must be examined, within their contemporary milieu, and in their historical genesis, before a fuller description of the responses, as found in the published treatises, can be given.

Nevertheless what can be catagorically asserted at this stage from the evidence of the printed treatises, is this: One, the fortification treatise writers[1] of the second half of the 16th. century promulgated a particular kind of approach to design in their art, to a great extent only as a result of their particular preoccupations with a wide range of assumptions about the qualities to be expected in, and the value of, any such art. Two: that statments about the irresistible power of artillery were highly 'theory loaded' in the sense of tending to distort the evidence, in the sort of context in which the treatise writers worked, and their testimony in such a context, and of others in like position, must be considered at least partially untrustworthy and tainted with special pleading.[2] Three: that statements about the irresistability of artillery and the sorts of responses that can be made to it are more generally 'theory loaded' in the sense of involving assumptions about how technology does or should function (by theory or piecemeal, for example), and therefore can not function as neutral descriptions of circumstances against which to assess the nature of the responses made. Fourthly, finally, substantively, and most generally, that the <u>art</u> of fortification as it was accepted in the second half of the 16th. century, was in no way <u>merely</u> a response to effective offensive artillery.

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1. From here on, when the treatise writers are referred to collectively what is to be understood is the writers of the dominant tradition and their ideas, even if the modifier is missing.
2. It might be contended here that the German writers, who took a different approach to the Italians, can then be considered to be more reliable on this point; that because they expressed here views similar to those of the Italians, the views of those Italians can then be considered reliable. But to some extent the Germans were responding to the same pressures as the Italians (Dürer for example, particularly), and the annunciation of this same view equally gave them a clear cut background principle to the ideas they developed in a rather different fashion, and helped to provide a justification for their composing their works. They thus equally tended to 'idealise' on this point like the Italians, and hence are likely to have also exaggerated somewhat.

PART II: The development of the practical mathematical sciences of the renaissance (1): Naval architecture and shipbuilding

Rules for the construction of ships[1] were set down in writing in the early 15th. century at Venice.[2] They show a distinct pattern and illustrate something of how ships were produced to a particular design during this period.

To a very great extent these rules of construction comprised no more than a collection of discrete pieces of information. On the one hand a quite separate set of rules was given for each type of ship. The mid-century text, for example, gave the most complete set of rules for a "galia sottil", and a "fusta"; while less detailed rules were given for a slightly larger "galia sottil", and an alternative set of rules for another "galia sottil", and for a "galia grosa", as well as for two smaller types of "fusta"; and the general dimensions were given for round ships of various sizes.[3] But equally within each set of instructions for any particular vessel, most characteristically what was given was a list of independent statements of the form 'this dimension (or member) is of such-and-such a length'.

Almost entirely, all these statements were purely normative then, with no attempt to give any underlying reasons for the information expressed: the general implication being that this is what has been done in other cases and is what has been found to work satisfactorily. Not unexpectedly these instructions contained many technical (today obscure) terms, relating often to particular members of the ship, but also to key points in the design; the impostura being the point where the line of the deck cut the stem or sternpost, while every fifth frame whose shape was independently determined, seems to have been distinguished as having a "corbe di onza".[4] The shapes of different parts of the vessel, especially the more important ones like the main sections and the stem and sternpost were given by way of a large number of dimensions.[5]

On the other hand once the key sections had been determined, in the mid-century treatise, a simple geometrical device was used to give the adjustment of the intermediate frames to gave a sweet curve or curves.[6] Additionally the discussion of masts and yards in this treatise gave general rules about the relation between beam and mast, yards and rigging, in different sized ships.[7]

Thus to some extent general rules and devices were at work in these early 15th. century instructions. But by and large these compilations were to a great extent merely collections of individual normative pieces of information. Undoubtedly they had their roots in the practice of the shipwrights of the time and illustrate the dependance of the design of a new

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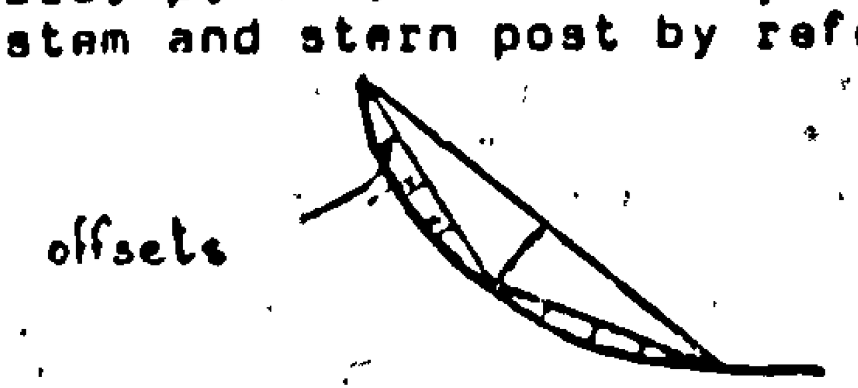
1. 'Ships' is used here and below as a general term to indicate all sea-going vessels and should not be taken to imply any contrast with galleys, as sometimes occurs.
2. JAL(1840) Memorial 5 prints a good deal of a treatise with translation: Fabbrica di galere from the first 30 years of the 15th. century. ANDERSON(1925) published the rules of Giorgio Timbotta of about 1445 with translation. LANE (1966)"Naval Architecture" gives the best discussion of these treatises, along with later rules discussed below, and dates the Fabbrica di galere as c. 1410.
3. Op. cit.
4. These terms are from the mid-century text. See ANDERSON (1925) p. 143 & 150/1.
5. Ibid. p. 147. Sections by half beams at one half and one foot intervals. The stem and stern post by reference to an isosceles triangle with off sets.



6. ANDERSON (1925) p. 153/4. The earlier Fabbrica di galere gives some measures of heights and widths of the "tail frames" and the frames 18ft. before and abaft the midship section. For a discussion of these techniques see LANE (1966) p. 167.
7. ANDERSON (1925) p. 153/4.

ship on past experience with particular vessels both in construction and performance.[1]

In strong contrast during the earlier 16th. century Vettor Fausto, a much travelled humanist, who from 1519 performed the duties of public lecturer on Greek eloquence at Venice for six years, and who had published a restored text and translation of the Mechanica of Aristotle, became preoccupied with the problem of ship design, particularly of galleys. He considered that the restoration of knowledge which had occured in so many areas could similarly take place in shipbuilding and hoped to set the art on a new footing through the study of the techniques of the classical world, and by the application of mathematics and mechanics.[2] In 1525/6 Fausto presented to the authorities at Venice a model of a quinquereme whose basis he claimed ha had found in the Greek authors, although he asserted also that he had consulted seamen of many nations in his studies.[3] In 1529 a galley to his design was launched and in a test against a light galley it was considered something of a success. However, no further galleys to his design were built, perhaps because of the great cost involved, but also perhaps because the version built gave little protection of the rowers, who suffered so much under bad weather conditions that the boat gained the reputation of a "charnel house".[4]

Fausto however continued to work at the Arsenal with apparently some fair degree of success particularly in less ambitious projects more concerned with modifying older practices. Less happily however he began work on a galleon around mid-century, which, not finished until after his death, on launching in 1570 was little used after its first voyage for fear it would capsize.[5]

Fausto's influence on Naval Architecture at Venice, despite his hopes, was not great, altnough towards the end of the century a pupil of his was influential in pointing to Fausto's achievement with his quinquereme, and the authorities, anxious to improve the speed of their war galleys turned for advice to Galileo Galilei.[6]

The continuity of design practice at Venice closely linked with the trade of shipwrighting, against any such influence as that of Fausto is seen in the set of extant rules of Pre Theodoro di Nocolò who in 1544 was made one of the dozen construction chiefs at the Arsenal there, for the construction of various types of vessels.[7] The nature of these rules and their general

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1. The Fabbrica di galere referred to a galley of Theodoro Baxon who, of Greek extraction, apparently was one of the ablest galley builders in the Arsenal at beginning of the 15th. century. See LANE (1966) p. 164. Timbotta on the other hand seems to have been a merchant interested in many areas with a mathematical content. See ANDERSON (1925).
2. This section is based generally on LANE (1934), p. 64/71 who gives the detailed sources. On the renewal of knowledge in shipbuilding and the use of the ancient authors see Fausto's letter to Rhamnusius in Epistolae Clarorum Virorum (Coloniae Agrippinae 1586) where this is generally implied as Lane states, particularly by reference to Vitruvius and Archimedes (p. 131). See also ibid. Fausto to Andrae Naugerius, p. 173 on the value of ancient knowledge in the arts.
3. "Il modello de la qual galia havendolo facto de mia man secondo le misure ritrovate in libri greci antiquissimi" from Fausto's petition to the Senate, printed in FINCATI (1881) p. 50/53, where his discussions with seamen are also mentioned.
4. See LANE (1934) as noted above. FINCATI (1881) p. 57 gives a quotation as to the reputation of Fausto's galley from a later source.
5. For this last see LANE(1934) p. 69. The first great galleon was built for the signoria of Venice between 1526 and 1530. When in 1547 it was broken up, the senate ordered its measurements to be taken because of its success. Two new galleons were then ordered. One, built by Giovanni Maria Spiazza was equally unsuccessful and his vessel capsized on its maiden voyage. Fausto's galleon was begun about mid century. LANE (1966) p. 181/3.
6. LANE (1934) p. 71.
7. For this section see LANE (1966) where the whole matter is very thoroughly discussed.

approach being exactly the same as those of the early 15th. century treatises. However Theodoro's instructions show that probably a gradual, albeit slight, evolution had occured since the earlier period. The number of dimensions given, had for example, been reduced and somewhat simplified: the mid section of a galleon was now divided into equal sections between the first deck and the keel to give the positions where the half-beams were given: as against having the half-beams given at ½ft. and 1ft. intervals. Undoubtedy, as Lane remarks, this must have facilitated the design of ships to a somewhat different size, to the same proportions. Equally, while the earliest treatise Fabbrica di galere gave dimensions for a number of different sections, Theodoro's treatise mentioned four devices by which, once the key frames had been set out, the intermediate frames could be set out from these to give sweet curves.[1]

A later treatise of 1593 Visione di Drachio had much the same nature and mentioned these four adjusting devices.[2] Undoubtedly therefore methods of design based very much on the actual practice of shipbuilding continued to predominate at Venice although to some extent the approach tended to become less 'piecemeal' and more general in involving rules that could to some extent be applied to different sizes of ships.

The first published work to discuss shipbuilding in any detail seems to have been Instrucion Nauthica (1587) by Diego Garcia de Palacio.[3] While some of Palacio's remarks tended to suggest he favoured a search for more general intellectual understanding of the art of shipbuilding,[4] he admitted that he had to take a less learned approach.[5] The resultant information he provided was actually very much along the same lines as that contained in the manuscript construction rules of the Venetian shipwrights. He treated different types of vessels as indepenoent cases, like them for example.[6] He equally gave three sections down the length of the ship with elevations to determine the relevant shapes. However the information in these 'drawings' although they were covered over with a good many numbers, was not as detailed as in the Venetian rules and in fact is somewhat hard to decipher.[7] [40], [41]

The later Spanish treatise by Tomé Cano, Arte Para Fabricar naos de Guerra, y merchante (1611 Seville)[8] showed a not dissimilar pattern calling

1. LANE (1966) p. 166/7 & 171. Timbotta's mid 15th. century treatise mentioned 3.
2. Ibid.
3. Palacio, a lawyer, was sent to America by the council of the Indies and in 1573 was in Guatemala. In 1579 he gained an offical position in the court of Mexico where his treatise was published. In 1587 he was named as captain-general of a squadron sent against the English pirates. ENC UN ILL EURO AM. He published also Dialogos Militares (Mexico 1583) with sections on gunnery after Tartaglia, and on arrays. The privilege of Instrucion Nauthica noted the work as "importante y necessaria para el buen vso del mare". The Dialogos Militares had its privilege similarly granted because it was considered very useful and necessary by the cleric, and by the military man who considered it and whose opinions were given in the work.
4. Op. cit. f. 88b. "Y assi como de medio tan artificioso, y vtil se sacara que el tratar dela nauegacion, y de la fabrica, y gouierno de los nauios, es materia digna para q̃ qualquier buẽ ingenio, y hõbre sabio, se exercite enella: pues tiene subtilezas de naturaleza de industria, y de buena arte, y fu traujo podra ser muy prouechoso à la republica: porq̃ assi como en las artes humanas, para cõseguir sus fines ay mezcla de cosas naturales......"
5. Ibid. f. 89b. "....pero porque no confundamos los entendimientos de los que no saben philosophia, ni letras, que es para quien mas principalmente deuemos trabajar, por ser tales los que à los mas comun, professan esta arte, tratare como he prometido arriba, dela nao, y sus partes, y personas, y oficios, por el modo mas claro que pudiere....."
6. Ibid. f. 94b. "....cierta manera, y forma en nauios mayores, ò ð menor porte: y para que enla fabrica, por otro exẽple de menor capacidad nos muestre v.m. otro modelo...." 7. Ibid. f. 96a/97a.
8. Modern ed. CANO (1964). Tomé Cano was born in Tenerife in 1545. He began voyaging as a youth and during his life travelled much between Spain and the Indies. A document of 1578 referred to him as "piloto de la Carrera de Indias" which title he seems to have achieved around 1569. In 1582 he was one the the group of pilots wh examined the Portugese Diego Fernandoz. Ibid. p. 11/20.

for method in the art, yet leaning heavily on experience.[1] But Cano did not even give any detailed dimensions or setting out of sections as had Palacio, rather he was concerned more to give general advice.[2]

The Italian treatise of this period, Nautica Mediterranea by Bartolomeo Crescentio[3] was similar. While Crescentio emphasised the power of geometry in a general way,[4] the need for theory and practice,[5] and the basis of the vessel in its form,[6] yet in his section on shipbuilding he did little more than repeat the type of information of the shipwright's rules, in a good deal less detail.[7]

In contrast to this rather practical type of approach to shipbuilding that continued to be in evidence throughout the late 16th. century and into the 17th., another type of approach, somewhat closer to Vettore Fausto's ideal perhaps, was also cultivated. The Portugese cleric Fernando Olivera, who published Arte da guerra da mar* in 1555, somewhat later composed a treatise on shipbuilding.[8] Of which work he wrote:

> este liuro da fabrica das naos: no qual ponho esta arte en regras, & preceptos ordenados & claros....[9]

Concerning 'arts', Oliveira suggested

> Arte digo que he, doutrina de palaura, ou de exepro, fundada em boa rezão, & confirmada per experiencia.[10]

Oliveira quoted much from the ancient authors and for example used Vitruvius to insist on the need to relate all parts of the ship to a module in order that its proportions might be correct:

> A esta parte chama Vitruuio nos sues edificios per sua lingua latina rata pars, que quer dizer na nossa portuguesa, certa parte. A este se hão de referir, & proporcioner todas as outras partes, como no corpo humano se referem na cabeça todos os outros mimbros.[11]

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1. CANO (1964) p. 32. "....aviendo determinado de tratar y de poner en práctica la regla, cuenta y medida de las que deven tener las naos para su buena proporción...." (p. 61) "....las medias le convien en para su beuna y perfecta fábric..... es cosa necessarissima que el fabricador o maestro de ella sea aritmetio y sepa archear naos....." (p. 42) ".....de no ser hechos ni fabricados los nauios con el deuido cuydado, orden, trabazón, fortaleza, cuenta, regla y medida que es necessaria y conueniente.....considerando los siniestros y mirando las faltas de las naos....segun la experiencia adquirida en el largo tiempo......"
2. As for example a rule about masts. p. 72. "El árbol major de la nao que tuiviere doze codos de manga, a de tener de largo dos mangas y media de la nao..."
3. 1st. ed 1602. Crescentio (or Crescenzio), born in the second half of the 16th. century sailed for many years as an officer on the papal galleys. In 1591 he composed Proteo militare on nautical instruments. This work, and other relating to navigation, along with the section on shipbuilding were published in his Nautica Mediterranea. ENC ITAL.
4. CRESCENTIO (1607). p. (iii). "LA via inuentrice.....che Platone cercò per trouare IDDIO, fù il venire dalle specie al Genere....trouorono gli Antichi tutte l'altre scienze, & il modo, che egli tenne in mostrare a'mortali che IDDIO è il motore del tutto, & che tutte le cose pendono dallo stesso DIO, lo rappresentò sotto l'ombra delle Figura sferica, nella Geometria di tutte l'altre più nobile & perfetta, per la forma, & somiglianza (figures)....p. (vii). narra Vitruio, di quel Filosofo, che arriuato con la naufraga Naue nella spiaggia de Rodi, & scoprendo alcune linee Geometriche che nell'arena descritte dicesse: Rallegrateui, ò Compagni, che anchora qua vestigio di gli huomini si troua."; p. 1. (2nd. pagination) "....perche la Geometria di Platone con le Mecaniche d'Archimede, & l'arte con l'vso di quelle congiunse, al pari d'Archita, di Leonte, d'Eudosso, di Aristotle, & dello stesso Archimede fu riputato. Essendo che le contemplationi dell'animo, & quella intelligenza & quanto quell'vso, à che esse l'hanno applicate, è più necessario all'humano essercitio......"
5. Ibid. p. 2. "Ci applicassimo dunque, oltre che la natura, & genio là ci inchinauano, & alle discipline Militari, & all'arte di Nauigar insieme, non perdonando alla istesso vita, non che à robba, per intender con la Teorica, & Practica........"
6. Ibid. p. 9. "Così la natura della Galea nasce dalla forma....."
7. Crescentio writing in the Neapolitan tradition only mentioned 2 of the 4 ways of adjusting the frames, as against the fuller treatment of the Venetian rules. See LANE (1966) p. 171.
8. LOPES DE MENDONÇA (1898) Liuro da fabrica das naos which treatise mentions the death of John III in 1557. Oliveira, born 1507, published a Portugese grammer in 1536. He travelled and lived in many areas of Europe including Italy, France and England. Op. cit. p. 1/86. He probably died after 1581. GR ENC PORT BRAZ.
9. LOPES DE MENDONÇA (1898) p. 149.
10. Ibid. p. 172. See also p. 171. "...por que arte he doutrina tirada do uso, & pratica dos boc officiaes...."
11. Ibid. p. 178.

In his actual setting out of the ship Oliviera used simple arcs of circles to determine the sections of different types of ships, and the shape of the stem. He also illustrated very clearly a geometrical reduction device for producing sweet curves as found in Timbotta's rules.[1] [42], [43]

Rather differently John Taisnier gave some remarks on ship design in his Opusculum perpetua (Coloniae 1562). Richard Eden in his translation of Taisner's work expressed them thus:

> Of the ryght and due proportion of what so euer shyppe.
> IN the framyng of any maner of shyppe, the proportion of length, breadth heyght and deapth, ought most cheefely to be exactly obserued, lest the ignorance and negligence of these consyderations, shoulde hynder the swyfte course, and cause daunger of shypwracke. The due proportion therefore of shyppes is, that fyrste the longitude or length of the shyppe or vessell what so euer it be, more or less, ought to be diuided into . 300. equall partes...Of the whiche partes. 30. must be assigned to the heyght or deapth, for the tenth part of ẏ whole requisite longitude or length and to the latitude or breadth shall corresponde the partes of the sayde longitude .50. or the syxth part of the longitude...And this proportion of Shyppes or other saylyng vesselles, of whatsoeuer shape or frame, is most conuenient, and no lesse necessary: As for Scafes, Shyppes of burden, Galleis, double, triple, or quadruple.....Also for Foystes, Pinaces, Brigantines, Espions and such lyke.[2,3]

In 1569 as ordinance was published at Lisbon suggesting the possibility of calculating the burden of a vessel before it was launched and there may have beeen connections between this and Oliviera's work.[4] The first time however, any such general rule was established was in 1582 when Mathew Baker, after some trials with an actual vessel, produced a formula which formed the basis of later developments in this field.[5] Drawings that Mathew Baker produced around 1586, show a draught of a ship with a cross-section produced by joining up a number of arcs of circles, and the stem defined by a single arc.[6] One draft was endorsed to the effect that weight and capacity are proportional to the cube of linear measurments, and that the same draught could be used for ships of different burdens, using the different scales given.[7]

Not long before William Bourne in his Treasure for trauellers (London 1578)[8] had discussed something of the problems relating to shipbuilding.

1. Op. cit. p. 179, 184, 189; 195, 199, 200.
2. A very necessarie and profitable Booke concerning Nauigation (London 1579 ?). Sg. Avib. In his dedication Eden wrote Sg. (**) 2b. "I haue euer loued and honoured men of singular vertue or qualitie, in what so euer laudable Art or Science, euen of those whereof I mee selfe haue little knowledge, as are Geometrie, Astronomie, Architecture, Musicke, Payntyng, feates of Armes, inuentions of Ingens and such lyke." Eden published a translation of Munster's Cosmography in 1553.
3. Taisnier, a Belgian, was born in 1509, entered the church and became preceptor to the pages of Charles V. He travelled widely in Europe and Asia; taught privately and publicly in many cities in Italy until 1558 when he retired to Cologne. His treatise was very derivative. NOU BIOG GEN. He also published Opus Mathematicum...Omnibus Matheseos, Cheiromantiae, Philosophiae & Medicinae (Coloniae Agrippinae 1583) much concerned with palmistry. (1st published 1562.)
4. See NILSSON (1936) p.239 & 248, who gives a reference to his Regras sobre Arqueacões (Lisbon 1926)*.
5. Ibid. Mathew Baker, born 1530, served his time with his father James who was an important shipwright under Henry VIII. Mathew was made master shipwright to the crown in 1572--the first to receive this title. He was made first master of the Shipwrights company when it was given its first charter in 1605 by the crown. ABELL (1948) p. 36/9.
6. Ibid. Pl. VI & VIII
7. BOOKER (1963) Pl. 5. The scales varied in proportion between the smallest and the largest by a factor of 2.2 to give burdens of 100 and 1000 tons, which seems rather a wide variation for one set of lines. ABELL (1948) P. 39 suggests that Mathew Baker's drawings were "the first known attempts to set down on paper the form of the ship". BOOKER (1963) Pl. 5 suggests that Mathew Baker's drawings formed rather an instructional text book, and were not typical of the drawings produced in ordinary shipbuilding.
8. " the fyrste (Book) is Geometrie perspectiue, the second Booke is appertaynyng vnto Cosmographie, the thirde Booke is Geometrie general, the fourth Booke is Statick, and the fyfth and last Booke is appertayning vnto natural Philosophy Sg. *iib.

In Bk. III he wrote on:

> ...how to buylde shippes for to make them of what tonnage or burthen that you lyste....

and stated that:

> I doe know that there is but few Naupergers or Ship carpenters that can do it: for that they do lack for the most parte of them the extractions of Cubicke rootes.[1]

In Bk. IV he wrote on:

> The arte of Staticke or waight shewing vnto ou howe you may knowe the wayght of any Shyppe that swymmeth vpon the water...

and explained one method to solve this problem, that,

> .....any Noble manne, or Gentleman may doe it at home in hys Chamber, that hath any knowledge in the mathematical Sciences....[2,3]

Thomas Digges in Stratioticos (London 1579) listed as one of his works, "begun by the Authour hereafter to be published":

> A brief Treatise of Architecture Nauticall, where in is deliuered Rules infallible vpon anye one forme or Modell of Excellencie founde, to buylde Shyppes for all burthens to lyke perfection and propertie to the Patterne...

George Waymouth around the end of the century indicated a picture of the state of Naval Architecture not to his satisfaction[5] when he wrote

> The Shipwrights of England & of Christendom build Ships only by uncertayn traditionall Precepts (& observations), & (chiefly) by (ye) deceiving ayme of there Ey, whence for want of skill to work by such proportiones as in Art (is) are required, & (is) are ever certayne, I have found these defects. 1. No Shipwright is able to make two Ships alyke in proportion nor quallities; to build a Ship certainly to any desired burden; nor to propose to himself how much water his Ship shall draw, untill there bee triall made therof.[7]

And went on to claim

> My study thes twenty yeares in y Mathematicks hath been cheefly directed to ye mending of these defects: I have during this tyme applied my self to know ye seurall ways of building, & ye secrets of ye best Shipwrights in England & Christendom; & have lykewise observed y (severall) working of Ships in ye Sea in all y voyages I have been. By these helps I have demonstratiuely gayned ye science of making of Ships perfect in Art, which of necessity must bee wrought by a differing way from all ye Shipwrights in y world/ And which shall ever bee built to any desired burden certayn.[8]

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1. f. 1b & 14a

2. f. 1a & 6b. This involved geting a carpenter to take the mouldings of the vessel; making a scale mould and filling it with water. Of course the carpenter did most of the critical work, but the mathematics was needed to arrive at the burden from the qualtity of water in the mould.

3. In 1562 Bourne appeared on the list of the Jurats of Gravesend. He seems to have been an inn keeper because in 1571 he was amerced for selling beer and ale out of less than quart pots. He served as a gunner at Tilbury and Gravsend. His Regiment for the Sea, owing a good deal to Cortes was published in 1574; The arte of Shooting in great Ordnance in 1578. He wrote variously in many areas of the practical mathematical sciences. TAYLOR (1954) & DNB.

4. p. (xv), No extant m.s. of this work is known. Ibid.

5. Defects of the English shipbuilding B.M. Harley 309 No. 25, f. 68/9. The Jewell of Artes (1604) B.M. Add. 19889. Dedicated to James I. This is a compendium of writings in a number of areas. On navigational instruments, shipbuilding, gunnery and fortification for example. TAYLOR (1954) tries to suggest it may have been writen by the instrument maker Charles Whilwell. While this might be true of the navigational sections it seems highly unlikely for the others. The Defects is in the form of a prospectus for a work and is thus presumably anterior to the fuller account of shipbuilding given in the Jewell.

6. Parenthesis represent words crossed out in the draft.

7. Defects. His second defect was concerned with "furring" and the need to eliminate it. That is thickening up the planking to give greater stability when the ship was found too tender on launching. See ABEL (1948) p. 30 who refers to this as "girdling".

8. Defects .

In his Jeuell of Artes Waymouth repeated very much the same sentiments, insisting that the

> ...best and most skillfull Shippwrights in this realme......pretend to builde by an Arithmeticall, and geometrical proportion: when in deed, they keepe no due proportion at all, for the rules of Arithmeticke, and geometrie are certaine......be cause they trust rathere to theire Judgment, then to their Arte, and to there eye, then to their skale and compasse.....[1]

The substantive part of the naval architecture section of this work of Waymouth's comprised not a great deal more than a fair number of geometrical cross-sections of vessels defined by means of a number of circular arcs linked together in apparently complex patterns.[2] 44/47

Simon Stevin in his Wisconstighe Ghedachtenissen gave a section relevant to Naval Architecture concerned with the overturning moments in ships. He proposed a mathematical method of calculating such moments. However, as he admitted himself, the actual calculations involved were so cumbersome and difficult, if not impossible, that his method was not of any real practical use. But he gave it all the same as of some 'theoretical' interest.[3]

A later work by the Englishman Robert Dudley Dell'Arcano Del Mare (Firenze 1646) had a detailed section on Naval Architecture[4] which indicated the setting out of sections by means of arcs of circles.

The book on this topic opened[5]

> L'Architettura Nautica, sopra le quale si discorre in questo Libro....in sette diuerse simetrie......E perche le parole non combattono, però si produrrà in effetto quanto si è promesso, & in atto practico, dimonstrando il modo come i valenti maestri (i quali intendino qualche cose della Matematica ancora) posseino fabbricare in simetria i vascelli del Cap. seguente......

Dudley, who had settled at Florence in 1607, gave as his first design a "galeone riformato" the same he claimed as that to which he had had a ship built for a voyage he made to the indies in 1594.[6] Dudley gave designs for seven different ships and defined their sections by means of circles, showing in one

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1. f. 135/6. The same sentiments were expressed in a m.s. by Escalante de Mendoza of 1571 who stated that it was not uncommon that "algunes naos se trazaron para pequeñas y después salieron grandes, y otros para grandes salieran después mas pequeñas", and "todo los palos y maderos que en elle se fueren poneindo han de ir por su quenta y razón.... y como el buen arquitecto...la mesme quenta y geometria conviene". Quoted in ARTINANO Y DE GALDACANO (1920) p. 113 & 115.
2. George Waymouth's biography is rather obscure at many points. His remarks c. 1600 about studying mathematics for twenty years suggest he may have studied under Dee who still taught in navigation up to 1583, as a young man. Waymouth's treatment of a number of mathematical disciplines in the Jeuell is just the sort of program in maths that Dee suggested in his preface to Euclid. In 1602 Waymouth made a voyage in search of the N.W. passage (D.N.B.) (The last pupil of Dee in navigation John Davis was selected for a similar search in 1585. It is perhaps more likely, although still only a possibility, that Waymouth therefore served under Davis.) Waymouth's Jeuell of Artes of 1604 involved a plea to the king for employment. In 1605 he made a voyage of discovery and trade to N. America. (D.N.B.). In 1610 he went with an expedition to the siege of Julich about which he wrote a journal account. (B.M. Rroyal 17BXXXII). He seems to have been still alive in 1620 because the journal apparently bears his signature with this date in the margin. (D.N.B. suggested he died soon after 1607.)
3. See above p.65, n. 8. 4. Bk. IV. 5. p. 1/2, op. cit.
6. p. 2. "La prima simetria......E dell'istessa simetria l'Autore ne fece fare vno... nel quale egli andò Generale nel'Indie nel 1594...."

plate (Fig. 4, Cap. 4.) how the sections varied down the length of the ship by way of little geometrical diagrams.[1]

Thus during the period of the 16th. century and into the 17th., attempts were made in Naval Architecture to establish general methods of design with a mathematical basis. Design not primarily determined by actual practice, but which through an intellectual process would produce results that could be determined before building took place. However the process proved to a great extent intractable.[2] The design and construction of ships remained very much a craft practice[3] even though gradually and tentatively during the period certain general rules and geometrical techniques came to be used more and more as aids within the design process, while never fundamentally altering the nature of an art in which practice counted for so much.

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1. Robert Dudley, who settled in Florence c. 1606, had been interested in navigation and mathematics from a youth. An "Azimuthall Dyall" of his invention of 1598 is extant. (TAYLOR (1954) and D.N.B.) CHARNOCK. (1800/02) Vol. 2 p. 176/7 was rather scathing about the practical utility of Dudley's results, and, concerning the improvment of Naval Architecture wrote "the proposal of Sir Robert Dudley appears to have been the most important: not indeed on account of its general utility, for vessels constructed according to the intention of this noble person, must, from their form, have been totally unfit for any navigation than that of the Mediterranean". ABEL (1948) p.34 suggested that some of the view of ships given by Dudley are not unlike the profiles of Elizabethan ships and his methods were similar to those of later Tudor times.
2. CHAPMAN in his very well known later treatise of 1768 wrote "...le grand nombre de différents especes de Batimens dont on se sert seulement en Europe: cette variété infinie semblera prouvera au contraire que tant ceux qui construisent les Vaisseaux, que ceux qui les gréent, n'ont pu encore trouver leur vraie forme, ni la meillieure de les gréer, & en général, & pour chaque espece de Bâtiment en particular" (French trs. <u>Traite de la Construction des Vaisseaux</u> (Paris 1781) p. ix)
3. Fuller in <u>The History of the Worthies of England</u> (1662)* wrote "I am credibly informed that the Mystery of Shipwrights for some descents hath been preserved successfully in Families, of whom the Petts about Chatham are of singular regard." Quoted in ABEL (1948) p. 29.

Part II : (l) : The Art of Dialling

At the end of the 15th. century Bonet de Lates published Annuli astronomici a work describing an astronomical instrument which, among other things, enabled one to tell the time by night and day by reference to the heavenly bodies.[1]

In his introductory section Bonet wrote

> NOn est gloria/ sicut gloria notitiã habent dei.nec est exaltatio super exaltationẽ sapientis operationes suas. nam vt ait hieremias propheta capitulo 9. Non glorietur sapiẽs in sapiẽtia sua....Eius aũt noticia acquirit per scientiã stellarũ.....Nam cũ homo corpora celestia/ et motũ accessus et recessus octaue sphere.....non aũt de sole (qui est candela celi et gubernator mundi)....quoddã paruũ instrumentũ adinueni per qđ astro in firmamẽto fixorũ aliorũq dei operũ celestiũ facili quodaz viatico notitia haberi poterit: quod profecto tue etiã non displicere beatitudini michi facile persuasi: ipsumq ad formam annuli/ formandum censui. Tum quia anulus huiusmodi magnorũ dominorũ et altissimos virorum ornamentum manuum nobile est.....annuls erit illi figura ante oculos cum quo solẽ et lunã et alia corpora celestia cosiderabit. et tũc habebit de deo perfectã notitiã....videtur enĩ mihi compositio istius annuli multo facilor astrolabii compositione: et quadrati israelis/ et aliorũ instrumentorũ astrologie/ & minus tediosa. maxime quia est ornametũ nobile/ ac semper visibile in manib: ad sciendum necessaria. & est instrumetũ nouũ. ideo adaperire debeo suos vsus et vtilitate: quia plures sunt.

One of the earliest works on dialling proper was that by Peter Apian, Ein Kunstlich Instrument oder Sonnen vr (Landsschut 1524*) published in the same year as his well known Cosmography.[2]

With similar interests was Sebastian Münster who similarly published on dialling at a relatively early date, but was perhaps better known for his work in the field of Geography.[3] In his Rudimenta Mathematica (Basileae 1551) whose first book had a good deal on surveying and whose second was a later version of his work on dialling, Munster explained:

> Sunt quoque omnes ingeniosi artifices eò in sua artes perfectiores, quo magis haec matheseos callent principia, id quod usu didicerunt pictores, lapicidae fabri legnarij & metallarij, architecti, & quicunque tandem in suis operationibus utuntur regulis, circinis & gnomonibus, sine quorum adminiculo multa artificia perfici ne querunt.[4]

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1. There is some doubt about the date of the 1st. ed. used here. BIOG UNIV suggests 1493 at Rome, which date B.M. catalogue gives. BIB NAT CAT PRS suggests c. 1498 at Rome. Definitely, however a further edition of Bonet's work was issued with Sacrobosco on the sphere, and with a section on Euclid, at Paris 1500, and many other editions in this format followed. There were mere 7 sides to Bonet's text in the first edition. It was divided into 33 very short chapters. Cap. 7 was "ad sciendum quot sont hore de horis 12"; Cap. 8 the same of 24; Cap 9 "ad sciendum quot sunt hore ab ortu solis; Cap. 27 "ad sciendum quot sunt hore di note." Bonet de Lates was a jew by birth, a physician and astronomer from Provence. He gained a reputation at Rome in the later 15th. century. (BIOG UNIV)
2. Apian or Apianus was born in 1495. He studied mathematics and astronomy at Leipzig and Vienna. His Cosmography, in discussing surveying briefly, was one of the earlier published works to touch on this subject. As a result of Apian's success with this and other works he became professor of mathematics as the University of Ingolstad where he remained until his death in 1552, having been knighted by Charles V. (D.S.B.) The part equivalent to the "Sonnen instrument gerendt theorica" of the dialling work was included in a Latin version in his Cosmography of 1524. (ORTROY (1920)) Among Apian's other published works were Eyn Newe Unnd wolgegrundte vnderweysung aller Kauffmanss Rechnung (Ingolstadt 1527) Quadrans Apiani Astronomicvs (Ingolstadt 1532). Folivm Popvli (Ingolstadii 1533). The short section in Dürer's Underweysung der messung (1525) on this same topic was another early contribution. Dürer began there (Sq. iiiib/Kia) "Es ist auch den steinmetzen/ maleren/ vnd schreyneren nutz das sie an die thurn hauser vnd gemeur ein gemeine sonne or konnen aufrichten/ des halben will ich nach folget ein wenig angang anzeygen/ so vil fur der gemeinen man not ist...."
3. Born 1489, Munster studied at Heidleberg and entered the Minorite order at 16. He early mastered Hebrew and Greek and during his early years was much concerned with publication in Hebrew. He was elected to the chair of Hebrew at Basle in 1527. In 1540 he published a Latin translation of Ptolemy's Geography, and his largest work in this field, Cosmography in 1544. (D.S.B. which work does not deem it worthy of mention that Munster was also one of the earlier publishers on dialling and on surveying.) His Composito horologiorum appeared at Basle in 1531.
4. Op. cit. p(iii).

and further added

> LICET Geometria proprie sit mensuratio terrae; tamen ut est una ex disciplinis mathematicis, capitur generaliter pro mensuratione cuiscunq rei, terre...... & circulatiõibus horariorum solarium....[1,2]

In contrast to the geometrical emphasis of such authors, the little work that Jacob Kobel published in 1532. Eyn Künstliche Sonn Uhr inn eynes yeden menschen Lincken handt, (Meyntz) was very different. In this book Köbel discussed how, by holding a small stick in ones hand one could tell the time by the shadow of the stick on the different fingers, similarly as with an ordinary sundial. Kobel explained the usefulness of his device thus

> Dieweyl aber die dselbigen Sonn vhren vnnd Instrument/ nit eynem yecklichen menschen/ vnd sonderlich den Leyen zů brauchen erkannt seyn/ Hab ich Jacob Köbel Statschreyber zů Oppenheym/ vmb fleyssiger bit willen vieler meyner gůtten freündt vnd gesellen/ disse Sonn vhr/ die vonn Natur in des menschen lincken handt erscheynt/ den selbigen/ auch der Ackerleütten/ Weingart arbeyttern/ Botten lauffern/ Keyttenden vnd gehn den/ die sich der Compass vñ anderer Instrumentẽ nit verstehn/ od bey in haben/ noch sich gebrauch mögen odder willen....[3,4]

During the same period the Frenchman Oronce Fine published his De Solaribus Horologiis et Quadrantibus as part of his Protomathesis (Paris 1531/2). In his general dedication of this last work he explained the significance of mathematics thus:

> Quales sunt ueteres illae, fideles, ac diuinae artes: quae solae Mathematicae, hoc est, uerae disciplinae, haud immeritò uocitantur. Sunt einem Mathematicae, mediae inter naturalem seu Physicam auscultationẽ, & supernaturalum siue Metaphysicam....Primum quoq certitudinis gradum, inter omnes liberalioris Philosophiae disciplinas obtinent....Adeò quidem ut solae Mathematicae, medium inter intellectilia sensiliaq locum adeptae, purae, certae, inuiolabiles, ac stabilis semper essentiae, ab quouis censendae sint erudito: quarum excellens decor, ordo, rationem firmitudo, ac inspectionum stabilitas, ad uniuersorum scientiam uiam praebet, & eruditionem. Quod animaduertens Marcus Procli discipulus, caeteras artes Mathematicis similes exoptauit. Plato insuper multa scrutatu difficilia de deo, Mathematicarũ praesidio plus caeteris Philosophis dogmata cõsequutas: ab ipis uoluit & sciẽde modũ, & discendi fore primordiũ.[5]

and then went on at the beginning of the section on dialling to explain the need for this art and its usefulness thus:

> .....ut multiformia totiesq promissa solariũ horologiorum, quadrãtũmue discrimina, primũ delineare, dein singolorũ incundã admodũ doceamus elicere comõditatẽ: ut ex illo totius Vniuersi regulato ac indefesso motu, fructũ aliquẽ primarium decerpamus....cum vix aliquid in rerũ offendatur natura, quod suis horis & tẽporũ non absoluatur interuallis.[6,7]

1. Op. cit. p. 1.
2. Gemma Frisus can be grouped with Appian and Munster for his interests and SCULTETUS (1572) stated (Sg. X iiiia) that Gemma had aided the subject of dialling a good deal with his Annulo astronomico.
3. Op. cit. Sg. Aiia/b. "Keyttenden"?=fishermen?. Description of the similar use of the hand as a sundial is found in the m.s. of Nicolas Kratzer. (GATTY (1900) p. 22. Thus Dürer, Kratzer, Köbel, appear as contemporaries with similar interests.
4. Jacob Köbel, born 1460, the son of a goldsmith and engraver entered the University of Heidelberg in 1480 and gained his bachelors degree in Arts in 1481. He then seems to have been in the book trade and studied law in which subject he took his bachelors degree in 1491. He may then have gone to Cracow to study mathematics contemporary with Copernicus. In 1494 he was in Oppenheim with many interests, book editor publisher and writer, draughtsman and wood engraver among others. He published many works from 1499 to 1532, at first those of others, but then his own including a treatise on gauging in 1515, and on surveying in 1522. He died in 1533. (ALLG DEUT BIOG & BENZING(1962) who does not mention the Cracow period.) 5. f. (iia). 6. f. 158a.
7. Oronce Fine, "sieur de Champrouet", was born in 1494, the son of Francois, physician and accomplished mathematician. He studied at the College of Navarre in Paris and was much attracted to mathematics. Imprisoned for political reasons, and for horoscope casting, in 1518, and he was again in prison in 1524. He was then brought to the attention of Francis I on campaign in Piedmont and worked on the fortifications of Milan. The king also consulted him at the siege of Padua (1525). Captured, Fine refused a post at the University of Padua, Francis rewarded him by naming him to a chair of mathematics at Paris. (He was the first to hold such a title.) Fine had edited an Arithmetic published in 1519. His publications included Epistre exhorative touchant la perfection...des liberaulx mathematiques (Paris 1532)*, works on geography and astronomy, with an astrological emphasis, as well as in mathematics, (including on the squaring of the circle). He died in 1555. BALTEAU.

The German Johannes Dryander published a work on astronomical rings in 1537:[1] and a little vernacular treatise on sundials[2] in 1543 in which he explained that Durer's earlier account of the topic had been too short and unclear.[3,4]

In 1557 Giovan Battista Vimercato published his Dialogo della descrittione theorica et practica de gli horologi solari*.[5] The printer of the 1565 Ferrara edition in an introductary dedication explained that it was published "à commun beneficio de gli huomini studiosi";[6] and assured the dedicatee (Alfonso d'Este) that he believed that worthy gentleman,

> .....giudiciosamente si diletti non pur di questa nobil professione, ma si mostra ancho molto intendente d'ogni lodeuole & virtuoso artificio, in cui l'humana industria honestamente essercitare si possa.[7]

Vimercato himself began

> NON Ad altro fine (studiosissimi Lettori) ha voluto l'omnipotente IDDIO creare questa Machina mondiale, piena & distinta di tante uarie et diuerse creature, sì coporali, quanto spirituali, se non per manifestare la sua infinità bonta in essa.....(through the) bellezza & perfettione del uniuerso &c. Et perche fra l'altre creature: l'huome è il più nobile, fatto a imagine & similitudine del suo creatore: in lui anchora piu che in l'altre si manifesta la sua bontà infinita.....Bisogna dunque dire l'uniuerso con tutte le cose che in esso si contegono esser fatto per il corpo de l'huomo, & perche il corpo è fatto per l'anima concludendo diffiniremo ogni cosa essere stata fatta principalmente da Dio per l'anima, massime intellectiua: accio che per la cognitione d'esse cose naturali & uisibili, si leui in alto alla contemplatione delle sopranaturali......Et se fra essi (heavenly) orbi poisara alcuno qual piu potentemente ne i suoi effetti possa dimostrare del suo uniuersal motore & creatore l'immensa gloria & infinita potenza, qual può esser maggior del Sole? il qual come Capitaneo & generale gouernator dell' intentione della prima causa, non solo come candela accesa illumina il Cielo, & la terra, ma ancora da il uigore & la virtù maggiore a tutti gli altri orbi......(so that) nobilmente & eroicamente al suo desiderato sine appropinquarsi, co lieto uiso & animo giocondo gli presento, l'artificiose & ingegnose ragione della descrittione de gli horologi Solari nelle cui cognitioni nō poco ancora risplende le gran potenza & sapienza del summo Architettor di questa gran fabrica.[8,9]

The Frenchman Jean Bullant in his Petit Traicte di Geometrie et d' Horologiorgaphie pratique of 1564[10] sounded a much more practical note.[11] In an introductory section he explained:

> ....pour autant que par-cy deuant i'ay osé entreprendre ce peu, que mon debile & petit entendement a sceu pratiquer, touchant la fabrique & composition di diuers quadrās & horologes solares. Et par ce que le tout despend du premier degré des belles disciplines & noble science de Geometrie: il m'a semblé n'estre hors de propos de pratiquer ce petit traicté, contenant plusiers reigles & inuentions Geometriques, sans parler de leurs speculations & theoriques, ainsi qu'a faict Euclide. Pour autāt qu'elles ne peuuēt estre si familieres aux artisans, comme elles sont aux gens doctes, & plus curieux. Ie produiray donc tant seulement certaines reigles & simples demonstrations & diuisions de lignes par moy pratiquees, comme reduire la superficie ronde à la superficie carre, au plus iuste que m'a esté possible. Et plusieurs manier

1. Annulorum trium diversi generis instrumentorum astronomicorum (Marpurg 1537).
2. Sonnawern allerhandt Kunstlich zu machen (Marpurg 1543).
4. Born in 1500 Dryander attended a Latin school in his youth and then went to the University of Erfurt in 1518. Afterwards he studied at Bruges and probably at Paris in 1528/33. He concentrated on mathematics and Astronomy and Anatomy. In 1535 he was professor of Medicine and Mathematics at Marburg. In 1548 he held the post of Rector there and continued in this post till his death in 1560. He published a number of works on anatomy in the 1530's, as well as in astronomy, and continued to contribute to both these fields. (NEUE DEU BIOG)
3. "Albertus Dürer in seinem büch/ so er schreibt für die Maler und Bildhauer/ ist aber zukurtz vnd vnuerstendig angezeygt..."
5. At Venice. On the authority of RICCARDI (1893), who had not seen a copy himself. The existence of the first edition noted is perhaps somewhat doubtful. There were two editions in 1565, one at Ferrara, with the same title, the other other Diologo de gli horologi solari (Vinegia) edited by Thomaso Poracchi.
6. Op. cit. p. (iii). 7. Ibid. p. (iv). 8. Ibid. p. (v/vi).
9. The 1565 Venice ed. p. (v) described the author as "Reuerendo & sommamente uirtuoso Padre Don GIO. BATTISTA VIMERCATO nobile Milanese, & Monaco di Certosa d'essemplar bonità di molta scientia, & di singolare acutezza di spirito eleuato: il quale non solamente con molta dottrina, ma anchora (qual ch'è dificle a fare, con facilita & chiarezza ha descritto con ragion theorica il modo di fabricare, non pur gli horiuoli con l'hore communi astronomiche, & antiche planetaria....ma in che modo le medesime ragioni si possano cauar dalla speculatiua per operationi prattica, con l'ombre de gli stile. .."
10. At Paris.
11. The second part of Vimercato's treatise was more practical in tone and more on the lines of Bullant's general approach.

de lignes courbes reduictes en lignes droictes & autre figures delectables qui puorront bien aiseement tumber en l'intelligence & prouffit des artisants.[1]

Bullant then presented a verse

SVr touts les arts que sont dicts liberaux,
Seruants à tous, tant doctes que ruraux,
Le principal apres l'Arithmetique
Est le sçauoir appellé Geometrique,
Pour paruenir à ceux qui sont plus hauts.

Touts artisans & gens Mercuriaux
Quis ont desir trouuer secrets nouueux,
De mesurer faut qu'ayent pratique
Sur touts les arts.
Dieu ha creé les corps, & animaux,
Depuis le ciel iusques aux mineraux,
Per nombre, pois, & mesure harmonique.
Heureuz est donc qui tel sçauoir explique,
Et qui entend secrets si generaux,
Sur touts les arts.[2,3]

During the same period in which Vimercato and Bullant published in the vernacular, Federico Commandino, as part of his activities of editing, translating and commentating on, and publishing ancient Greek texts on mathematics, gave to the public works relevant to the problems of dialling. Hearing that interested persons had difficulty with the text of Ptolemy's Planisphere, he published an edition of this work with commentary in 1558. Then in 1562 he published a latin version of Ptolemy's Analemmante with commentary and additions concerned with dialling.[4,5]

When Giovanni Battista Benedetti came to publish his De Gnomonum umbrarumq" Solarium usu (Augustae Tavrinorum 1574) he expressed the common attitude to mathematics by stating of this study

In quibus ueritatis intellegibilium uestigia refulgent, & ordo ille mirabilis atque exactissima mensura comprehenduntur quibus tota mundi machina gubernatur, omnium natura parens perspetua rerum commutatione pulcherrimas imprimit formas, & hominum diuina mentis suauissima rerum multiplicum contemplatione mirum immodum recreantur.....[6]

and that

....si que autem sunt disciplinae quae speculationis excellentia, tractationis incunditate, aut usus utilitate praestent, hae profecto sunt mathematice, per quas & diuinas operationes intelligimus, & praestantissum rerum opificem emulamur, dum sicut ille naturalium nos artificialium rerum authores efficimur.[6,7]

Herman Witekind in his Conformatio Horologiorum Sciotericorum in superficiebus Planis utcunque sites (Heidelbergae 1576) insisted on the need for a timekeeper such as provided by the sundial, thus:

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1. p. 3.
2. p. 4. This verse appeared earlier in Charles de Bouelles' Geometrie pratique (Paris 1547) after a dedication to Oronce Fine dated 1542. The idea of God creating the world by number, weight and measure was much quoted in the renaissance, especially in the 16th. century, it came from the Book of Wisdom Cap. XI, Ver. 22.
3. After a voyage to study in Rome c. 1540, Bullant became architect on the castle of Ecouen. In 1557/9 he was "controller des batiments du Roi" and later became architect to Catherine de Medici and was in the service of Henry II. He died in 1578. DZ ENC ARCH URB. Bullant published also on architecture and perspective on which see below
4. Liber de Analemmate (Romae 1562).
5. Born 1509 Federico Commandino studied Latin and Greek as a youth. He was taught mathematics by the tutor of one of the sons of the Orsini who had fled to Urbino, Commandino's home town, after the sack of Rome in 1527. In 1534 Commandino went to the University of Padua and there studied Philosophy and Medicine for 10 years, although he took his medical degree at Ferrara. Most of Commandino's published works were commentaries on the anceint mathematical texts. He died in 1575. (D.S.B)
6. Op. cit. f. (iia). 7. Ibid. f. (iiib).
8. Benedetti, born 1530, of patrician status, studied Euclid under Tartaglia. Published his geometry using a fixed compass opening at Venice in 1553. In 1558 he went to Parma and remained as court mathematician there for around 8 years. In 1559/60 he lectured on Aristotle at Rome. In 1567 he went to Turin to serve the Duke. In 1585 his Diversarum speculationum mathematicarum on many diverse problems in mathematics, including perspective, was published. He died in 1590. (D.S.B)

EVIDENS vtilitas est, & commoditas publice & priuatim in distinctione illa visibili atq; audibili [illegible], vel diei ciuilis, in partes vicenas quaternas, quas horas vocamus: quae indicant nobis quando, & metiuntur quàmdiu quoq; agatur, agendumq; sit: quando in Ecclesiam, in Scholam, in curiam ad nuptias, ad funus conueniendum, rursuque inde discendum: quando opere in agro, in officina in coeptando atq; intermittendae: quando & quo ad corpus cibo, potu, somno, quiete, lusu, lotione curandum reficiendumque. In quibus sanè omnibus deformis existerat in aequalitas & barbarica confusio...[1,2,3]

When Christoph Clavius came to publish his treatise on dialling, in which he summed up nearly everything that had been done in the subject up to then,[4] he also set out many of the attitudes that were commonly expressed about the art. On the same lines as Witekind he insisted on the need for regular time keeping.

DE necessitate vero horologiorum non est, quod multa verba faciam. Neminem siquidem latere arbitore, quam miserum, & infelix foret genus humanaum, si horarum distinctionem nullam haberet.....Nam horarum discrimine singuli suos labores.....id ipsum omnes propemodum agricolae, ac solitarij homines, qui cum horologia non habeant, neq; vero eis sine magno incommodo....[5,6]

While in his preface he had explained:

INTER artes & disciplinas omnes, quas rerum auctor Deus, tanquam infinitae suae sapientae, potentiae ac majestatis argumenta quaedam hominum generi communicauit, non in postremis censendae videnteur eae, quas veteres Philosophi Mathematicas appellarunt. Cum einem ipsae sint ita exploratae, vt nihil probabile admittant, sed illustribus omnia argumentis, necessarijsq demonstrent.....Quod ipsum si commune est Mathematicis omnibus disciplinis, quanto id erit magis Astronomiae proprium, quae considerat caelestes illos orbes, quos Dei manus mirabili artificio architectat est....[7]

But Clavius, as his title indicated, did not intend in his treatise to instruct merely in the art of creating dials to tell the time. Rather he wanted to demonstrate everything that could be discovered from the shadow of the sun and, of course, all most firmly:

QVONIAM ea omnia, quae per Gnomonis vmbrã, lucente Sole, cognosci possunt, exquisitis rationibus in hac nostra Gnomonica, hoc est, demonstrationibus Geometricis firmissimis ijsq; quo ed eius fieri poterit clarissimis, describere (Deo Optimo Maximo bene viuante) instituimas, quod pauci admodum

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1. Op. cit. Sg. A3a.
2. Witekind, born 1522, studied at Frankfurt-an-der-Oder and Wittenberg. ALG DEU BIOG.
3. Thomas Fale seems to have been the first writer to publish on this topic in English with his Horologiographia. The Art of Dialling (London 1593). Fale followed Witeking very closely at many places. He expressed the same sentiment "Concerning the profite of this Art, daily experience teacheth how needful it is in a well ordered Common-wealth, seeing nothing can be done in due and conuenient season, where this Science is neglected: for the diuision of the day into certaine parts or hours (which this Art teacheth) doth limit and allot to each action his due time. This Art being then so ancient, and the vse so necessary......" f. (iib/iiia). On this same point BIGOURDAN (1922) p. 1, stated "au XVIe sciecle, l'auteur d'un traite des cadrans solaires pretendait qu'il n'est pas plus possible de se passer de cadran que de boire et de manger."
4. See GATTY (1900) p. 23. Gnonomicus Non solum horologiorum salariũ, sed aliarum quoq rerum, quae ex gnonomis umbra cognosci possunt, descriptiones Geometrice demonstrantur (Rome 1581)
5. Op. cit. p. 2.
6. Francesco Maurolico, born 1494, son of the master of the Mint at Messina, was ordained in 1521 and later became a Benedictine. His patrons included Charles' V viceroy of Sicily, and he gave lectures at the University of Messina, his interests were in mathematics and astronomy, and he was put in charge of the fortifications at Messina. (D.S.B.) In his Opuscula Mathematica (Venitijs 1575) he gave a book (p.161/285) on dialling (dated at its end 1553). Maurolico stated similarly (p. 161) INTER Mathematicas speculationes Illustriss. princeps, Gnomica, quae lineas tractat horarias, haud insimo loco ponenda est: cum sit tam iucunda scitu, quàm usui non commoda solùm, sed etiam necessaria."
7. Op. cit. p. (v). Andreas Schöner, born 1528 at Nürnberg, publisher on astronomical matters, in his Gnomonica (Noribergae 1562) f. (iva) wrote "Nam quod genus doctrinae, quae artium studia sunt, quae perinde ut Mathemata cum labore discendi quandam uoloptatem & delectatione consociatam habent...Mathematis....Quia einem ueras, certas, & minimine fallaces demonstrationes habent, & certitudo quasi quaedam peculiaris horum praerogatua est....Mathematice.....uerum etiam uitae hominum maximopere utilias ac necessaria."

ante nos fecerunt.....[1,2,3]

Finally may be mentioned Adriaen Metius who in his Doctrinae Sphaericae (Francofurti 1598) had a short section on dialling. Adriaen Metius was a son of Adriaen Anthonisz who was a cartographer and military engineer for the States of Holland, and Burgomaster of Alkmaar several times between 1582 and 1601. Anthonisz built fortification in the war against Spain, drew plans of cities and military works, and wrote on sundials and astronomical problems. His son Adriaen Metius went to the Latin school at Alkmaar and entered the recently founded Franeker University in 1589. In 1594 he went to the University of Leiden. He worked under Tycho at Hven, then went to Rostock and at Jena gave his first lectures. Returning to the Netherlands he assisted his father in military engineering until he became in 1598 extraordinary professor at Franeker. In 1600 he became ordinary professor of mathematics, surveying, navigation, military engineering and astronomy there. His lectures were attended by an international audience, including in 1527, Descartes.[4]

A great many other works were published during the 16th. century on dialling, mainly in Latin, but with a number in the vernacular.[5] However the above considered writers serve to make clear the basic attitudes to the art of the period.

On the one hand the art of dialling was concerned with the relatively simple practical task of telling the time by means of the shadow of the sun in accord with the regular movements of the heavens. This task was considered to be a very useful one to be able to accomplish, and indeed almost necessary. Affairs when so organised by the clock, even that of the labourer in the field, could occur at their due time, with a general regularity in accord with the movements of the heavens: and this was considered to be a very desirable result.[6]

1. The beginning of the main text (Op. cit. p.1).
2. Christoph Clavius was born 1537 Bamber, and entered the Jesuit order at Rome in 1555. He later studied at the University of Coimbra. He began teaching mathematics at the Collegio Romano in Rome in 1565 while still a 3rd, year theology student, and for all but 2 of the next 47 years was a member of the faculty there as professor or scriptor. His main work on Euclid appeared in 1574. He published Geometria practica in 1604 at Rome. (D.S.B. which work manages to ignore Clavius' work in dialling.)
3. This type of attempt to give all sorts of information on the dial as well as to simple get the time of day from the shadow of the sun, by means of the so called "furniture" lines to give the day of the year, height of the sun, times of sun set and sun rise, azimuth of the sun and even feast days, was not uncommon. (See MAYALL (1938).) and led to very complicated diagrams. In such writers as Bartolomeo Scultatis, as in his Gnomonice de solaris (in a peculiar mixture of German and Latin) (Gorlitz 1572) this involved extremely complicated diagrams, as was equally the case in Schorner's work, about which Fale wrote that the author "wandreth in a wildernes of lines, that a man know not where to begin, or where to end." FALE (1593) f.(iiia). [50] [51]
4. This is the account of D.S.B. TARDY (1947) gives an edition of the work not of 1592. Later works by Metius also included sections on this topic.
5. Including Giovanni Padovani's De compositione, & usu multiformium Horologiorum Solarium (Venetijs 1582). (1st. ed. 1570 RICCARDI (1893)) F. Cherubino Sandolino's Thaumalemma Cherubicum Catholicum (Venetiis 1598). Giovanni Paolo Gallucci De Fabrica, et usu Novi Horologij Solaris (Venetiis 1592), one of a number of works by this author on this topic. Elie Vinet's Le Manière de fere les solaires (Poictiers 1564*). (BIB NAT CAT). Giulio Capilupi Fabrica et uso di alcuni stromenti horarii universali (Roma 1590*) (RICCARDI (1893)). Levinus Hulsius Descriptio Viatorii et compassi sive Horologii solaris (Nürnberg 1597*) (ZINNER (1964)). Valentino Pini's Fabrica de gl'horologi solari (Venetia 1598*) (N.U.C.). (J. Froelich) Ein wohlgegründs kunstreichs Summari Büchlin, aller Sonnen Vhr (Strassburg 1544*) (ZINNER (1964)). Johann Konrad Ulmer's De horologiis sciotericis (Nürnberg 1556*) (Ibid.). Martin Helwig's Von allerlei Stundenzeigern (Breslau 1570*) (Ibid.). TARDY (1947) gives an edition of Marco aurelio cb el Relox de principes which work is not concerned with dialling at all.
6. In order to facilitate this result not only were such devices as Köbel's stick in the hand put forward, but portable dials and those for use at different latitudes were developed. (See MAYALL (1938) and the works by Gallucci Della Fabrica et uso del novo Horologio universale ad ogni latitudine (Venetia 1590); & Nova fabricandi horaria mobilia, & permenentia (Venitiis 1596). See also GATTY (1900) p. 23 & her section on portable dials p. 185/199.)

Dials however were equally thought to be useful because of their ability to aid in the specialised time telling needed in astrology.[1]

In contrast to these more utilitarian consideration however, the art of dialling was often conceived to be more a subject which in its own right was worth studying. That is it was treated more as contemplative knowledge. Clavius for example was much more anxious to show everything in the art that could be demonstrated, rather than with the use that any such knowledge might be put to.[2] In this sort of context the pleasure and delight that could be got in this art, partiularly because of its mathematical basis was often emphasised. In this same sort of less practical vein dialling was often conceived to be important in bringing one into relation with, and understanding of, God's creation: the machine of the world as Vimercato referred to it,[3] and this type of reaction was in evidence from Bonet de Lates on.[4] A process, Vimercato insisted made all the more to be desired because man, created in the image of God, was distinguished (from the animals) by his spirit or intellect, and hence could follow the equivalent actions of God in his creation of the world. [5]

But most generally the dialling treatise writers were keen to emphasise the mathematical nature of their art, and the desirability of this state of affairs. The mathematical disciplines they contended were of great value and usefulness, particularly in the certainty and firmness of their results. But equally the mathematical nature of dialling helped to elucidate

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1. A dial was apparently made by Jean Bullant on a pillar for Catherine de Medici for the study of astrology. (GATTY (1900) p.72) During the renaissance the use of equal hours had long been the norm. Astrology however required the use of planetary, unequal, hours and this was catered for, as for example in Oronce Fine's De duodecim ceoli domicilus & horis inaequalibus (Lutetiae 1553). See also FINDLAY (1927). The use of equal hours in day to day matters began to become common in the middle ages c. mid 14th. century. (See KÖRBER (1965) p. 17; FINDLAY (1927); BILFINGER (1892). There seems to have been some connection between the introduction of equal hours and the use of mechanical clocks which appears to have equally started to become more common around this time. But this can hardly have been a clear-cut causal connection as the Encylopædia Britannica (1969 ed.) implies. FINDLAY (1927) suggested the introduction of striking clocks was the crucial element. It is difficult to conceive that the introduction of both mechanical clocks and equal hour sundials may not have been both to some extent a response to the same forces. KORBER(1965) tries to associate this change with early capitalism. But this is hardly tenable. Mechanical hours may have been one of the factors that assisted the eventual development of say, factory production, but this only makes this type of time keeping a predisposing factor. In the medieval period, and in the renaissance and after, most economic acitivity must have been linked with natural time varying with the season, rather than with any mechanical time. The attitudes of the 16th. century dialling treatise writers on this point are quite clear. They commonly described how the ancient world used unequal hours as rather a curiosity and accepted the use of equal hours in their time as the most common method of time keeping, but without ever feeling apparently, that this method had to be insisted on. They were quite ready to design for unequal hours when required for use in astrology. To them both systems represented the regular movements of the heavens, which formed their basic 'clock', how that regularity was set out in actual hours was not an important issue to them, and only a somewhat arbitary matter. That these rathe urban, bourgeoise, and status seeking figures so rarely, if at all argued about any kind of inescapable inevitability in the use of equal hours, makes it highly unlikely that there was any rising economic group in which this was felt to be of significance. The early introduction of the polar gnomon from the Arabs seems equally not tc have been of any crucial significance here also, although it does make the use of equal hours somewhat easier perhaps. See KORBER ( ). However more detailed work than is possible here is needed to fully substantiate and elucidate such points, and the central attitudes of the dialling treatise writers are not effected by them.
2. Whether the work was writen in the vernacular or in Latin tended to reflect this distinction.
3. As Benedetti also refered to it. See above generally.
4. Notably Bonet de Lates and Vimercato among others, referred to the sun as the light (candela) and governor of the world. A priori one might consider that this type of view would only fit with heliocentricism, but such authors seemed quite happy to make use of this type of attitude along with geocentrecism. Thus the expression of this type of view along with heliocentrecism can not be taken to count for a great deal in itself.

the relationship of God, man and the world in their subject. God's astronomical creation was essentially mathematical, as had been demonstrated by the ancients. Hence man made in the image of God, in his intellect, could grasp God's creation through its mathematical behaviour.

But equally as Bullant argued, the world of terra firma was made up of number, weight and harmonic measure, almost, he seemed to say, for the benefit of artisans, so that they might mathematically manipulate the objects of this world. While simultaneously that same use of mathematics, particularly when the subject was considered more on the lines of contemplative knowledge, made it such that the art was a fit subject for study by princes, as Thomas Fale put it.[1]

Thus there were many interweaving strands of ideas behind the art of dialling as found in the 16th. century treatises. In the actual construction of dials it has been suggested that in the earlier period "dial makers vied with each other for supremacy, kept their methods secret, shrouded them in mystery and construction became a lucrative occupation" but that later "the art of designing and constructing dials accurately was no longer confined to the craftsman"[2] as mathematicians and astronomers entered the field.

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1. FALE (1593) f. (iia) THE Arts Mathematicall (gentle Reader) in regard of their antiquitie and excellencie may be compared with any other of the liberall Sciences whatsoever. And the very name importeth, that in olde time these of all other were esteemed worthie to be taught, being called for their excellencie Mathemata, that is, Sciences meete to be learned. These be Arithmeticke, Geometrie and Astronomie, from which this Art of Dialling taketh his beginning: a knowledge also ancient and necessarie, and therefore practised by Princes and famous men of former ages". Following Witekind. Thomas Fale was a Cambridge mathematician. MAYALL (1938) suggests that dials were often conceived to be fit gifts for princes, also.
2. MAYALL (1938) p. 17/18.

Perspective in the sense of a technique of representation on a flat surface, seems to have been first discussed in detail by Alberti around mid 15th. century in his Della Pittura.[1]

In his dedication Alberti made clear his view that in the contemporary search for the "optime et divine arti e scientie" similar to those possessed by the ancients, what was often required was the difficult task of inventing quite independantly new results, because:

> Confessoti, si a quelli antiqui, avendo quale aveano chopia da chi imparare et immitarli meno era difficile salire in cognitione di quelle supreme arti, quali oggi annoi sono fatichosissime, ma quinci tanto più el nostro nome più debba essere maggiore, se noi sanza preceptori, sanza exemplo alchuno truoviamo arti et scientie non udite et mai vedute.[2]

In the case of perspective Alberti was clear that this was achieved through a basis in mathematics. He explained that in

> ......questa mia operetta di pictura, quale a tuo nome feci in lingua toscana. Vederai tre libri; el primo tutto mathematico, dalle radici entro dalla natura fa sorgiere queste leggiadra et nobilissima arte.[3]

and that

> Piacemi il pictore sia dotto in quanto et possa in tutte l'arti liberali; ma imprima desidero sappia geometria. Piacemi la sententia di Panfilo antiquo et nobilissimo pictore, dal quale i giovani nobili cominciarono ad imparare dipingere. Stimava, niuno pictore potere bene dipingere, se non sapra molta geometra. I nostri driozzamenti, dai quali si exprime tutta la perfetta absoluta arte di dipingere, saranno intesa facile dal geometria, ma a chi sia igniorante in geometria, nè intendera quelle, nè alcuni altra ragione di dipingere: pertanto affermo sia necessario al pictore inprendere geometria.[4]

In his first book Alberti further explained that he intended to give only

> ....i primi dirozzamenti del'arti et per questo cosi li chiamo dirozzamenti quali ad i pittori non eruditj dieno i primi fundamenti a ben dipingere.[5]

Concerning the actual practice of painting Alberti suggested

> ......ciascuno pictore, quando sè stesso da quello dipignie, se pone a lunghe, dutto dalla natura, quasi come ivi cerchi la punta et angolo della piramide, onde intenda le cose dipinte meglio remirarsi.[6]

Here Alberti gave the game away completely with regard to renaissance perspective. He suggested that there was something inherent in the nature of things which led the painter to view an object from one particular viewpoint: further, from which point, he could get the true or best, understanding or view, of it.[7] In fact there seems to be no a priori reason why this should be the case, or why, as implicitly tends to follow, and object should be represented, or is best represented, as if seen from one particular view point, i.e. with a single vanishing point. It is extremely doubtful that before this period the single vanishing point in representation was consistently and common used either in the classical world, or in medieval art.[8] Cennino Cennini, in his late medieval

1. Later published in Latin and Italian versions.
2. ALBERTI (1877) p. 47/9. 3. Ibid. p. 48. 4. Ibid. p. 145.
5. Ibid. p. 85/7. (Alberti had just explained that, in contrast, he usually instructed his friends "prolisso con certe demonstrationi geometrice".
6. Ibid. p. 69. "dutto dalla natura" is slightly problematic. Spencer ALBERTI (1956) p. 51, gives "endowed with his natural instinct". But "dutto" is from ducire, to lead or conduct, and the sense would seem to be just as much of the painter being 'led by nature' where nature is the natural world, or more precisely here those aspects of the natural world which the painter experiences when observing some scene. However the basic notion is the same, whether primarily being conceived in the painter or in the world, of some inherent quality leading to the given result. 7. See last quote.
8. There is a certain amount of disagreement on this point. RICHTER (1937) & (1970) and EDGERTON (1976), for example, are of the view that the painter did not use such a technique in the ancient world. WHITE (1967) had rather the view that the single vanishing point technique was then known. Certainly, examples of works from the classical period show convergencies of different objects to different points, although the geometry of the problem was clearly expressed in Euclid. RICHTER (1937) considered the point that Vitruvius seems to suggest the use of a single vanishing point, and concluded that he meant something much looser, and argued that "the convergence of receding parallel lines was envisaged by the ancient philosophers.... as a phenomena of appearance for a single object " only. EDGERTON (1966) suggested that Alberti's method was an adaption of an old workshop practice ingeniously combined with optical theory of Euclidean proportions. (p. 368).

text on painting for example, implied simply that each building should be put in to a particular scheme.[1] Thus by indicating that he conceived the use of the single eye point to be in the nature of things, Alberti showed how arbitary an assumption it was, and indeed a very artificial one.[2]

On the other hand given the demand for a single eye point/vanishing point, the visual cone of rays did become an object suseptable to analysis by use of the abstract and universal principles of Euclidian geometry, just as Alberti wished. A result which would have been almost impossible to achieve if multiple eye points had been continued to be favoured.[3]

Painting, as he described it, with this kind of geometrical base, Alberti was able to consider to be a very worthy and gentlemanly occupation. Of himself he stated

> Sia qui licito confessare di me stesso: io se mai per mio piacere mi do a dipingiere qual cosa fo no raro--quando d'all'altre mie maggiore faccende io truovo otio ivi--con tanta voluptà sto fermo al lavoro chè spesso mi marvaglio cosi avere passete tre o quattro ore.[4]

He also said generally that

> ....l'arte del dipigniere sempre fu ad i liberali ingegni et a li animi nobili dignissima.[5]

and that

> ......la pictura sia optimo et antiquissimo ornatamento delle cose, degnia ad i liberi huomini......[6]

To Alberti it was then not unreasonable to compare man the painter, to a god, for as he wrote of the painter Zeuxis, in

> ...dipingniendo animali se porgiesse quasi uno iddio...[7]

and that

> ......in se tiene queste lode la pictura che qual sia pictore maestro vedra le sue opere essere adorate et sentira sè quasi giudicato un altro iddio.[8]

Thus according to Alberti the painter should be interested in the liberal arts, but especially in geometry; he was a member of and practitioner in a very worthy profession; he might be compared to god in some ways and his products were worthy of dignified consideration; and of course the basis of painting was in the true geometrical technique of perspective using a single eye point, which precise point made possible a true geometrical approach.[9]

1. CENNINI (1932/3) Cap. LXXXVII Vol. I p. 55. Whether he may have meant such schemes to apply to a whole painting or not, is not really clear, but the problem is considered only worth the briefest passing mention in his quite long text.
2. It led of course to the theoretical result that there was a particular point from which the representation ought to be viewed, an extremely artificial and constrained result. But Alberti went on to make this consideration a criterion for 'true' representation "Et sappia che cosa niuna dipinta mai parra pari alle vere, dove non sia certa distantia a vederle." (Op. cit. p. 81). Similarly Brunelleschi's earlier, well known experiments, involved a fairly complicated set up of the representation and his mirror precisely to constrain vision in this very artificial way by making the observer look through the pin-hole in the back of his painting. That everyday vision is much more complicated than this can be seen by such cases as where ordinary objects are photographed from unusual angles and are then extremely difficult to recognise because the eye is under precisely this kind of very artificial constraint, yet which can be seen to be what they are from just this view point when they have already been seen from others.
3. A geometrical relationship could of course be set up between multiple eye points, but it would tend to be rather artificial and arbitrary one feels; and by adhering to the single eye point any argument, which might have occured, as to the relationship of the different eye points was totally eliminated so that the universal abstract principles of Euclidian geometry could be applied to give an 'objective' mode of representation.
4. ALBERIT (1877) p. 97. 5. Ibid. 6. Ibid. p. 99. 7. Ibid. p. 91. 8. Ibid.
9. This point Alberti supported however, not by reference to the worthyness of mathematics, but by whatever he could find in the ancient authors in support of his view. On which compare the remark quoted in BURFORD (1972), by Plutarch, "It does not necessarily follow that if a work is delightful because of its gracefulness the man who made it is worthy of our serious regard...No one, no gifted young man, upon seeing the Zeus of Pheidias at Olympia or the Hera of Polykleitos at Argos ever actually wanted to be Pheidas or Polykleitos." (Pericles II.1.) CENNINI (1932/3) Vol. I p. 3, in contrast to Alberti, wrote of the individual undergoing apprenticship "stando in servitu per venire a perfezion di cio".

Piero della Francesca in his treatise on perspective[1] gave essentially only discussion of the geometry of the relationships between the eye and the scene and the way in which this could determine the representation of that scene on a flat sheet, once the assumption of the single eye point had been granted. In fact he defined perspective as that aspect of painting that could be demonstrated by geometry:

> ....in opera essa prospectiva.....tractaremo de quella parte (of painting) che con line angoli et proportioni se po demostrare, dicendo de puncti, linee, superficie et de corpi.[2]

Piero then went on to give as a crucial part of the art, the distance of the eye, which, only when taken as a fixed (single) point could give him that very quality of demonstrability. The form of the object, which was then represented, he insisted, was the only means by which the object could be understood.[3] Piero later went on to attack those who attempted to controvert this type of approach, as by appeal to apparent distance as perceived, insisting that anything involving this last type of consideration would be no true science:

> Per levare via l'errore ad alchuni, che non sono molti periti in questa scienza, quali dicono che molte volte nel dividere loro il piano degradato a bracci, li vene magiore lo scurto che non fa quello che non è scurto; et questo adviene per non intendere la distantia che vole essere de l'occhio al termine dove si pongono le cose, nè quanto l'occhio può in sè ampliare l'angòlo con li suoi raggi; si che stanno in dubitatione la prospectiva non essere vera scientia, guidicando il falso per ingnoranza.[4]

At the beginning of Bk. III of his treatise Piero summed up his ideas and showed them to be merely assumptions about what was the crucial aspect of vision, constrained to a great extent merely by the need for demonstrability.

> Molti dipintori biasimano la prospectiva, perchè non intendano la forza de le linee et degli angoli, che da essa se producano.....Perho me pare de dovere mostrare ~~quanto questa scientia~~ sia necessaria alla pictura. Dico che la prospectiva sona nel nome suo commo dire cose vedute da lungi, rapresentate socto certi dati termini con proportione, secondo la quantità de le distantie loro, senza de la quale non se po alcuna cosa degradare giustamente. Et perchè la pictura non e sè non dimostrationi di superficei et de corpi degradati o acresciuti nel termine, posti secondo che le cose vere vedute da l'occhio socte diversi angoli....però dico essere necessaria la prospectiva la quale discerne tucte le quantità proportionalmente commo vera scientia, dimostrando il degradare et acrescere de omni quantità per forza de linee.[5]

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1. De Prospectiva pingendi. Italian version FRANCESCA(1942).
2. Op. cit. p. 64.
3. After the last passage he explained the 5 parts of the art "...dico l'ochio essere la prima parte, perchè gli è quello in cui s'apresentano tucte le cose vedute socto diversi angoli....La secondo è la forma de la cosa, perhò che senza quella l'inteletto non poria giudicare nè l'ochio comprendare essa cosa. La terza è la distantia da l'ochio a la cosa, perchè, se non ci fusse la distantia, serià la cosa con l'ochio contingente ouera contigua, e quando la cosa fusse magiore de l'ochio, non saria capica a receverla." (Op. cit. p. 64.) The first point is simply an assumption about what aspect of vision is of primary significance. The third, that the eye must be some distance from the object for it to be seen in no way supports any contention that the eye has to have one particular point of vision
4. Op. cit. p. 96/7. Again it is only the assumption that the angle of the rays is the crucial aspect of vision that makes the argument work.
5. Ibid. p. 128/9. Just a pure set of assumptions. What force is in the lines and angles, but their demonstrability. Emphasis added. There was of course a certain shift in the sense of 'demonstrate' between its two meanings and a certain ambiguity in both cases.

Luca Pacioli in his Divina Proportione,[1] while he was primarily concerned with desirable ratios, and the regular geometric solids, made clear his attitude to the value of mathematics and perspective. He explained he added drawings to his treatise because

> .....doue ñ e ordiē semꝑ. sia cōfusiōe, ꝑo a piu pieno ītelligētia de ꝗsto nōro cōpēdio, ꝑ saper retrouare tutte le ꝑprie figure ī ꝑpectiuo aspecto.....ꝗlla tal figura sira del dicō corpo fcō ī piano cō tutta ꝑfectōe de ꝑspectua cōmo fa el nr̄o Liōardo vīci.[2]

Pacioli also insisted on the importance of vision, quoting with approval the view that:

> ..lochio esser la prima porta ꝑ la qual lointellecto intende....[3]

and argued against omitting perspective from a primary place amongst the mathematical sciences, which,

> ......al ꝑposito nostro per scientie e discipline mathematici seītēdano. Arithmetica. Geometria. Astrologia. Musica. Prospectiua. Architecture. e Cosmographia. e qualūcaltra de queste dependēte.

although he addmitted that:

> ......cōmunamente per li suaui. le quatro prime se prēdano. cioe Arithmetica. Geometrie. Astronomia e Musica. e laltre sienno dette subalternate.

yet countered:

> Ma el nostro iudicio benche imbecille & basso sia e tre o cinque ne cōstregni. cioe Arithmetica. Geometria. e Astronomie excludendo la mucicā da dicte per tante ragioni quante loro dale .5. La prospetiua e per tante ragioni quella agiōgendo a le dicte quatro per quante quelli ale dicte nostre.3.la musicā.[4]

Pacioli was equally insistent about the general value and utility of these same mathematical sciences.[5] He explained that:

> ......che la diffensione de le grādi e piccole republiche per altro nome arte militare appellata non espossibile sença la notitia de Geometra . Arithmetica e Proportione egregiamente poterse con honore e vtile exercitare. ......Se ben se quanda generalmente tutta sua artegliarire prendise qual volglia commo bastioni e altri repari bombarde bricolet trabochi Mangani Rohonsee Baliste Catipulte Arieti Testudini Grelli Gatti. con tutte altre innumerabili machine ingengi e instrumenti sempre con força de numeri mensura e lor proportioni se trouarono fabricati e formatī. Che altro sonno Rocche. Torri Reuelini. Muri. Antemuri. Fossi. Turrione Merli. Mantelecti. e altri forteççe nelle terri cita e castelli che tutta geometria e proportioni con debitī liuellie archipendoli librati e asettate?[6,7]

and in more general terms:

> Conciosia che dicte mathematici siēno fondamento e scala de preuenire a la notitia de ciascun altra sciētia per e ser loro nel primo grado de la certeçça affermandolo el pħo cosi dicendo Mathematice. n. scientie sunt in primo gradu certitudinis & naturales sequuntur eas. Sonno cōmo edicto le scīce mathematici discipline nel primo grado de la certeçça a loro sequitano tutte le naturali. E sença lor notitia sia impossible alcunaltra bene intendere e nella sapientia ancora e scripto.q. omnia consistunt in numero pondere & mensura cioe che tutto cioche per lo vniuerso inferiore e superiore si squaterno quello de necessita al numero peso e mensura sia soctoposto. E in queste tre cose laurelio Augustino in deci dei dici

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1. 1509. The 1st. pt. written generally 1496/7 (D.S.B.) although the dedication to Ludovico Sforza mentions the date 1498. PACIOLI (1956) m.s. version dated Milan 14th. 1498. The precise relationship between Pacioli and Piero della Francesca and how much of this work should be attributed to whom, is not of significance here. 2. f. 22a. 3. f. 1b.
4. I. e. the reasons for including or excluding music apply equally to perspective and neither or both should be given in the basic sciences. For, Pacioli went on to argue, if music had the beauty of harmony, "una .līgiadra figura con suoi debet liniamenti ben disposta.....non la giudichi cosa piu presto diuina che humana?" These passages ar all from f. 3a. As to "il sauvi" Pacioli mentions Aristotle, Plato, Isidore and Boetius.
5. In his general dedication Pacioli began (f. (iia)) "CVm in his disciplinis: quas graeci Mathematicas appellant non minus vtilitati: quam voluptatis insit"; and f. 1b. urote of the "...necessarie scientie e dignissime discipline mathematici".
6. f. 2a. See also f. 1b"...tutte le prelibate scientie (i.e. maths) e discipline e da quello ogni altra speculatiua opatione scientifica practica e mecanica deriua Sença la qui notitia e ꝑsuposito non e possible alcuna cosa fra le humane bene intendere opere cōmo se dimostra." . PACIOLI (1956) p. 6. gives "e discipline: e da quello ogni altra speculativa operatione scientifica pratica e mecanica deriva......intendere e opere......"
7. According to Biggiogero PACIOLI (1956) p. 226, Gian Giacomo Trivulzio requested Pacioli's collaboration on military studies. This Trivulzio (b. 1541) of the celebrated Milan family of that name is described as "la personalita piu spiccata di tutte la sua famiglia, per la gloria militare che s'acquisito in numerose campagne" (ENC ITAL).

el summo opefici summamente esser laudato per che in quelle fecit stare ea qua non erant.[1]

His whole subject, and the representations of Leonardo in perspective, Pacioli insisted were:

......ñ de vil materia.....ma de ptioso metallo e fine gemme meritarieno esser ornati.....[2]

Leonardo himself, in a well known passage, described how the painter was somewhat analogous to God when he depicted objects:

La deità, che'a la scientia del pittore, fa che la mente del pittore si transmutta in una similitudine di mente diuina, imperoche con libera potesta discorre alla generatione di diuerse essentie de uarij animali, piante, frutti, paesi, compagne, ruine di monti......[3]

He also placed perspective in a high place among the mathematical sciences

Delle matemitiche, e qual son primieve e qual derivative. 2 sono le scienze matematiche, delle quali la prima è ll'arissmetrica. La seconda è geometria ......E più i natura non se ne trova. Adunque queste abraciano tutte le co(se) dell'universo......Sequita la prosspettiva, prima figliola della geometria, la quale disscendi, della geometria, in quanto che ll'ufitio suo s'asstende in nelle linie visuali, che ss'astendano infra l'obbietto e ll' ochio....Di questa nasscie l'astronomia, perchè mediante la linia visuale si misura nelli strolabi l'alleze e magnitudine de'corpi celesti....E questa prima p(r)osspettiva......è da essere di gran lu(n)ga prepossta alla musica......[4]

In general, of the mathematical sciences, he wrote:

Le sscienze matematiche son dette quelle, che media li sensi sono in primo grado di certeza. E sson solamente 2, delle quali la prima è arissmetrica, la second geometrie....Di questi nassci la prospettiva.....[5]

In the Libro de pittur he wrote:

Nissuna humana investigatione si po dimandare vera scientia, se essa non passa per le matematiche dimostrationi....[6]

and

...le vere scientie son quelle, che la sperientia ha fatto penetrare per li sensi e posto silentio alla lingua de'litiganti e che non parce di sogno li suoi inuestigator: sempre sopra li primi veri e noti principij procede successivamente e con vere sequentie insino al fine, come si dinota nelle prime mathematiche, cioè numero e misura, detta arithmeticha e geometria....[7]

Quella scientià e più utile, della quale il suo frutto è più communicabile, e cosi per contrario è meno utile ch'è meno communicabile.[8]

....se tu dirai tali scientie vere e note essere di spetie di meccaniche, imperochè, non si possono finire se nò manualmente, io dirò il medesimo di tutte l'arti, che passano per le mani delle scrittori....l'astrologia e l'altre passano per le manuali operationi; ma prima sono mentali, com'è la pittura...[9]

.....tal proportione è da l'opere delli huomini a'quelle della natura, qual è quella, che'è dal homo a dio. Adonque è più degna cosa l'imitare le cose di natura, che sono le vere similitudini in fatto, che con parole imitare...[10]

With regard to the dignity of the art of painting Leonardo contrasted the sculpter toiling away and sweating as he chipped away in a cloud of dust, with the painter sitting at ease in front of his work, well dressed, with perhaps sweet music playing or someone reading to him.[11]

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1. f. 2a. See also f. 1b. ".....afferma ar (Aristotle) e Averois le nostre mathematici sonno verissime e nel primo grado de la certeça....."
2. f. 22a.
3. LUDWIG (1882). 181 I, Sect.68.
4. LEONARDO (1974) Madrid codex II f. 62 recto. A slightly different version is found at f. 67 recto.
5. Ibid. f. 66 recto. Cf. "......le cosi grandi, delle matematiche, la certezza. della dimostratione inalza. piu. preclaramente l'ingegni dell'inuestigati; la prospectiva adunque a da esser preposta. a tutte le trallazioni. e discipline. vmane...."
6. DA VINCI (1970) vol. I p. 31/2."Quelli che s'inamorã di pratica saza sciẽtia, so come 'l nochiere che ẽtra navilio sanza timone o bussola...." (Ibid. p. 119).
7. Ibid. p. 34. 8. Ibid. p. 35. 9. Ibid. p. 34.
10. Ibid. p. 35. 11. Ibid. p. 91.

Among the early texts published on perspective were Viator's De Artificali Perspectiva (Toul 1505),[1] and the section in Dürer's Underweysung der messung.[2] Hieronymus Rodler published Eyn schön nützlich büchlin vnd vnderweisung der kunst der Messens in 1531.[3]

In 1560 Jean Cousin published his Livre de Perspective (Paris). In his preface he wrote:

> En ce liure est contenu la source & origine de l'art & pratique de Perspectiue, lequel consiste en trois especes: C'est à sçauoir en plattes formes Geometrialles, en superficies Perspectiues, extraites & tirees des Geometrialles. Puis en corps solides, prenãts leurs origines des superficies Perspectiues, auec la pratique de certains poincts Accidentaux, engendrez de la nature des oeuures que voulez feindre: & aussi en Reigles generalles de n'errer audit Art, & n'y faire faute.[4]

Daniel Barbaro published La Pratica della Perspettiva at Venice in 1568. In his dedication Barbaro wrote:[5]

> ...io dia in luce vno trattato della practica della Perspettiua, che gia molto tempo ordinai per mio piacere, & poi a commune vtilità ridussi a quella perfettione, che'io seppi & potei. Grande fu il diletto nostro ne gli studi delle mathematiche da primi anni, & ci pareua che quel piacere, che prendeuamo di quelle, fosse la maggior vtilità, che se ne potesse pigliare. Ma procedendo piu oltre, quel piacere.....è state aperta la strada ad altissime et sottilissime speculatione: delche ben mille fiate ne hauemo ringratiato la bontà diuina, che ci ha condotto di lume in lume a consentire con qualche ragioneuole discorso alle piu secrete cognitioni....a mi satisfarà, che noi ci seruiamo di quelle discipline per ancille di vna nobilissima, e prestantissima cognitione, & che il piu de gli huomini si serua alle arti, allequali si danno per sostenimento della uita....

In his preface Barbaro went on to explain that we can read that the ancients produced many beautiful works made with this art of perspective, but

> .....in che modo, & con quali precetti si reggessero, niuno (che io sappia) ne gli scritti suoi ne ha lasciato memoria. Se forse non uogliamo chiamare precetti, & regole, alcune pratiche leggieri poste senza ordine, & fondamento, & esplicate rozzamente......I Pittori de i nostri tempi altrimenti celebri, & di gran nome, si lasciano condurre da una semplice pratica, & nella tauole loro non dimostrano sopra questa parte cosa degna di nota commendatione...Perche adunque la ragione, & l'uso di tale arte non è meno piaceuole, & di diletto, che necessario, & chi giouamento....Giouanni Zamberti mi ha fatto aggiungnere alle regole sue non poco studio, & fatica, accioche io potessi con precetti, & ragione di mathematica prouare questa cose....Perspettiua, che tra le arti, che con qualche essercitio, & opera si uogliono dimostrare niuna è che habbia piu certi, & sicuri termini...[6]

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1. For discussion see BRION-GUERRY (1962)
2. See Biog. for Durer, and INVINS (1938) for comparison of Durer, Viator and Alberti.
3. Rodler praised Durer but said his explanations were not clear enough. (Zu dem leser).
4. Sg. Aiib. Jean Cousin (la pere), born c. 1490?, qualified as a painter. He worked as a geometrician (surveyor) at Sens his birth place in the late 1520's. He was involved in a scheme for the enceinte of the market town of Courgenay in 1530. In 1541 he was referred to as "master painter" and "bourgeois" of Paris He was cited by Vasari with praise. He died c. 1560/1. (BALTEAU) His book showed perspective treatments of a good many architectural features and some buildings, but was also concerned with the regular solids. Some of his more elaborate illustrations have the appearance of what today might be exercises in mechanical drawing, showing annular rings under varying views, related by projection techniques, in one case, and a sphere was dealt with in another. [54] [53]
5. p. 2. To Matheo Macigni.
6. Op. cit. p. 3/4. Daniel Barbaro, born 1514 at Venice, studied at Padua where his interests seem to have been mainly mathematics, astronomy and aristoteleanism. In 1545 he was put in charge of the construction of a botanical garden at Padua by the Venetian authorities. From then on he held a number of posts for Venice including ambassadorships abroad. In 1550 he was made Patriarch of Aquila. In connection with the council of Trent, in 1562 with 3 other bishops he worked on the problem of the reform of the calender. He died in 1570. In 1542 he published for the first time on Porphyry* in 1544 on Aristotle*; 1545 Compendium scientiae naturalis*. In 1557 Girolamo Ruscelli published an earlier m.s. of Barbaro's on Eloquence. In 1556 his edition of Vitruvius appeared, and in 1568 his work on perspective (DZ BIOG ITAL). This last work is quite compendious. A good deal of it is concerned with views of regular solids. Other sections are [54] [55] reminiscent of Durer, with these solids developed on a flat sheet. He also showed the proportions of a human head after Durer. He also showed complex geometrical objects such as a 'spiked' sphere, and a similar annulus. He showed a number of buildings in perspective and also a set of astronomical rings for telling the time by the sun. A final very short section showed "inuentione de Iacomo Castriotto" for measuring the scarp of walls. (Some authorities give 1569 for the date of his work on perspective, but this seems to be an error.)

Hans Lencker published a work on perspective in 1567* and then Perspecitva Hierinnen auffs kürtzte beschrieben (Nürmberg 1571). In the forward to this last work he began

> Es lob vn Ehr Gott dem allmechtigen/ von welchem allein alle gute gaben vnnd kunst herkommen/ und jren vrsprung haben.....Hab ich erstenmals den 25 October des 67. Jars/ ein kliens Tracterlein von diser kunst publicirt vnd an tag gegeben vnd aber dazumal/ vmb des geringen ansehens willen desselben das fundament vnd dem weg wie alle dise ding zu machen....ein jedes fürgenommen ding/ auss rechtem grund der Geometria/ auff en ebne flecken gerissen......[1]

Martino Bassi as part of a controversy with Pellegrino Pellegrini published Dispareri in Materia d'Architettura et Perspettiva (Bressa) in 1572.[2] Bassi complained that on a relief in marble in the Duomo at Milan,

> .....il nuouo Architetto (i.e. Pellegrini) vi hà lasciato....tutto quello... che fece il suo antecessore; & di nuouo vi ha formato....vn'altro orizonte ......& tutte queste sue cose aggiunte, vbbidiscono al suo secondo Orizonte, & alla sua seconda distanza; rimanendo l'altra opera del primo Architett digradata al suo primo Orizonte, & primiera distanza......(but) giamai, in vna sola opera di Perspettiua, non ho io udito, che si trouasse più d'vn Orizonte, & d'vna distanza.[3]

Against this approach, and Pellegrini's treatment of the columns of the building, Bassi insisted:

> .....che la prattica con ragione non può esser senza la cognitione dell' arte, che è habito, che con scienze produce la sua operatione: essendo la causa principale (come dice non pur Vitruuio nostro maestro; ma Arist.) il fine, il quale muoue all'operare; & in esso è riposta la forma di tutta l'opera. Tal che ogni artefice, che ragionevolmente opera, auanti che egli dia principio all'opera con atto esteriore, delibera nella sua mente, ciò che egli hà da operare. ne far si può tal deliberatione, se prima non si riguarde il fine: ma con questo riguardo si parte dalla scienza, & camino all'atto del'operare.....Ma se l'operare sara senzà ragione: questo sarà, ò à caso, ò ad imitatione.......... (and) l'imitatione può facilmente errare, senza l'guida dell'arte......[4]

Jacques Androuet de Cerceau published his Lecons de Perspective Positive (Paris) in 1576. In the dedication to Catherine de Medici, he explained that his book contained:

> ......quelques principes & lecons familiaires de l'art & secrets de Perspectiue, non moins delectable, què vtile & necessaire à ceux qui prennent plaisir à la Portraicture....[5]

In his preface he further explained:

> CONGNOISSANT le grande affection qu'ont la plus-part des hõmes verteux, de quelque qualité au'ils soient, d'auoir congnoissance de l'art de Perspectiue positiue, pour les grandes commoditez & plaisirs qu' elle apporte.... Somme la Perspective n'est autre chose qu'vn miroir le quel de soy ne fait les choses qui luy sont presentées, meilleures ou pires qu'elles ne sont, mais seulement represente au vray ce que luy est mis au devant ainsi & comme il est.....Par cecy vous pouuez cognoisitre combien il y a grande affinité entre ces sciences d'Architecture & Perspectiue, & combien l'vne est necessaire pour la parfaicte cognoissance de l'autre.....Parce que dessus vous entendez assez que nostre Perspective positiue n'est autre chose que l'art di pouuoir representer sur la papier les choses telles qu'elles apparoissent. Ie l'appelle Positiue, à la difference de la Theoritique, autrement appelee opitcque, qui gist en contemplations, raisons, & demonstrations, dont la nostre a pris son origine, qui consiste en l'operation, & se fait par lignes & demonstrations oculaires: & se pratique ou sur plans, ou sur corps releuez.[6]

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1. f. (iiia), Hans Lencker, a Nurnberg fine goldsmith, died there in 1585. (ALL DEU BIOG) He mentioned Ramus, Ibid., as stimulating him to publish.
2. Pellegrini was the architect on the Cathederal of Milan at the time.
3. Op. cit. p. 15/16.
4. p. 30/1, ibid. Bassi, born 1542 (1548?) studied architecture as a youth. In 1567 he was assistent on S. Vittore al Corpo in Milan. In 1569 his controversy with Pellegrino began. In 1587 Bassi himself became architect to the cathederal at Milan.
5. f. 2a. (From the 1676 reprint.)
6. f. 3a/b. Androuet de Cerceau's work in fact had only 11 folio of text (including preliminary matters) and 60 engraved plates. This engraver and painter was born probably in 1510. Studied in Italy 1530/4, died 1585. He published many works relating to building. For this author on Architecture see below sect. II:(7).

Jacopo Barrozi's treatise Le Due Regole della Prospettiva Pratica (Roma) was published posthumously by Ignazio Dante with commentary in 1583. In his dedication to the Marchese de Vignola Danti wrote

> ...conosceua...V.Eccellenza Illustrissima (la quale è solita pigliar molto diletto di queste nobilissime arti, conuenienti à qual si uoglia honorato Cavalieri) desidirosissima fuor di modo d'apprendere, & impadronirsi della practica di questa piaceuolissima Arte, poi che oltre à tanti cõmodi, che a ella apporta all'arte Militare, reca ancora giouamento notabile all'espugnationе, & difesa delle fortezze, potendosi con gli strumenti di quest'Arte leuare in disegno qual si uoglia sito senza accostauisi, & hauerne non solamente la pianta, ma l'alzato, con ogni sua particolarità, & le misure delle parte proportionate alla distanza....[1]

In the preface Danti further explained:

> SE l'operationi marauigliose tante della Natura, quanto del'arte, tirorno talmente gl'animi degl'huomini in ammiratione, che incominciorno à filosofare, & inuestigare le cagione di quelle; meritamẽte si sono affaticati molti in ricercare la cagione degl'effetti, che accascono intorno alla nostra vista per la varietà de'raggi visuali causata dalla distãze, siti, (etc)....i quali effetti tanto son degni d'esser saputi, quanto trapassano la maggior parte delle cose di ammiratione.....A ragione anchora si sono affaticati gl'artefici di ritrouare regole, & istrumenti, con i quali operando possino con facilità imitare simil effetti (of vision)....(Vignola's rules) ho giudicate degne d'esser da me illustrate cõ i presẽti cõmẽtarij: doue per maggior seruitio de gli studiosi de questa nobil practica ho aggiũto altre regole, & diuersi strumẽti, acciò cõpitamẽte possino hauer cõtezze di quanto se li appartiene. Nè minor cura ho posto in seruire allì piu scientifici, i quali non si soddisfacendo solamente di bene operare, & sapere che la cosa è cosi, ma di piu ricerano le cause, & la ragione de'loro effetti: però mi sono ingegnato da dimostrare Geometricamente tutti le parti principali di quella....Per le cui dimonstrationi ho prima poste alcune definitioni, & suppositioni, come principij necessarij da preconoscersi per acquisitar la scienza delle prefate propositione...[2]

Benedetti in his Diversarum Speculationum (Taurini 1585) gave a short section -- 22 pages out of 426 -- on perspective, in which he examined something of the geometry of the situation under the normal conditions.

In 1596 Lorenzo Sirigatti published La Pratica di Prospettiva (Venetia....librario in Firenze). He explained:

> PARE che di tutte le scienze due sieno i fini principali; vno de quali consiste nel puro, e semplice atto dello speculare, l'altro è intorno al mettere in atto practico le coso speculate: e non è dubio, che il primo di questi due fini, per esser proprio dell'intelleto mostro contemplatiuo parte principal dell'animo nostra, lontano da ogni alteration'materia, e da ogni esercitio meccanico, e del secondo più nobile, e più perfetto; nulla di meno se vorremo hauer riguardo, non alla perfetione, è diletto particulare, ma all'utile, e perfettione vniversale, trouэremo indubitatamente, che il mettare in pratica, ed eseguire le cose speculate, esser piu da desiderarsi e per confermar questa verità con esempli sensati, dico prima, che di niuna, ò pochissima vtilità sarebbe alla vita humana, che il medico fermandosi nella sola contemplatione delle nature, e qualità de simplici, e de composti medicamenti lasciasse gl'infermi priui di quell'aiuto....quando qualche meccanico applica le sue inuentioni à qualche materiale strumento vtile ò in pace, ò in guerra al viuere humano, e degno di maggiore lode, e premio, che se quietandosi nelle speculationi astratte da ogni sensibil materia, disprezzasse applicarle all'vso comune. Concludesi dunque che se bene la speculatione è più nobile della pratica, niente di meno la pratica è più vtile, e lodeuole, per esser quella perfezione, e ornamento d'vn'solo intelletto particulare, e questa vtile è comodo di moltissime particulari, e delle intere Republiche.[3]

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1. Op. cit. p. (iv). Cf Bachot and Busca on perspective.
2. p. (x). But, Danti continued, because his book was concerned with the practice of perspective, "nelli predetti principij nessuno richerchi da me l'ordine & metodo d'Euclide di procedere dalle cose note alla ignote; perche trattendosi d'vn Arte dependente dalla sciẽza dalla Prospettua subalternata alla Geometria, non è possible di procedere cõ la squisitezza de Geometria".
3. Op. cit. f. (iib). Siringati's work was made up or a main section in Bk. I of 43 numbered engravings with a page of text opposite illustrating the methods of perspective drawing. In a second book he gave engravings (44/65) alone showing the results of applying his techniques, many of the regular geometrical solids being shown as no more than exercises. Siringate is known as an architect who worked in Florence. THIEME & BECKER (1907/50).

But perspective during the renaissance was not merely the discipline concerned with representation of objects on a flat sheet. That same designation also covered what today is distinguished as optics. This latter usage of the term 'perspective' was very much part of the older medieval tradition. Probably the most popular treatise in that tradition was John Pecham's Perspectiva Communis.[1] This work was divided into 3 sections, the first on direct vision, concerned with the properties of light, the nature of the eye and perception, and the like; the second was on reflected rays, and the third on refracted rays: the whole with a strongly geometric cast.

In the preface to his work Pecham wrote:

> Inter magnalia mathematicorum certitudo demonstrationis extollit preclarius investigantes. Perspectiva igitur humanis traditionibus recte prefertur, in cuius area linea radiosa demonstrationum nexibus complicatur, in qua tam physice quam mathematice gloria reperitur, utriusque floribus adornata.[2]

While in his account of vision he alluded to physiological processes thus

> Rei visibilis comprehensio fit per pyramidem radiosam, apprehensionis certificatio per axem super visibile transportatam.[3]

even though:

> Pryramis enim radiosa a visibili oculo impressa rem oculo representat...... (so that) Dicunt communiter loquentes quia omne quod videtur videtur sub angulo vel forma triangulari.[3]

On the other hand within optics, as in other areas of knowledge, it was almost universally accepted during the medieval period, that the certain demonstrations of mathematics could never be applied with absolute certainty to the sensible world. As for example, Biagio Pelacani di Parma wrote in his treatise on perspective at the end of the 14th. century:

> ...quod numquam de re naturali per visum et consequenter per intellectum, homo habet tantam evidentiam quanta evidentia haberi potuit et hoc est verum. Et sequitur corolarium ex hoc quoc nulla humana cognitio videtur omnem gradum erroris excludere. Et sequitur consequenter quod suspectum est aliqua(m) posse humanitatem habere demonstrationem de rebus naturalibus, si per demonstrationem intelligas processum excludentem omnem gradum erroris.[4]

With the advent and spread of printing Pecham's treatise was published many times, with at least 5 editions before 1520, and 5 more by the end of the century. Similarly an edition of Witello's treatise appeared under the title 'Perspective' and Euclid's Optics was printed under that same designation.

Introductions to some of the early printed editions of Pecham's treatise were careful to point out that perspective was a 'mixt' discipline, with all that implied. Georg Hartmann in his edition of 1542 (Norimbergae), in his dedication put the problem plainly:

> CVM de dignitate & praestantia artium & disciplinarum, rectissime ex earum subiecto & methodo, iudicium sumatur, ut Aristotles admonet: ea doctrina quae optice seu perspectiua dicitur, meritò principem locũ inter reliquas liberales disciplinas obtinebit. Haec namq per Physicas, & Mathematicas demõstrationes, quibus nihil certius esse potest, absolutissime perficit inchoatas Philosophorũ disputationes, de natura & proprietate lucis & potẽtiae uisuae, qua re nihil admirabilius, nihilq praestantius, in

1. Pecham's treatise probably only gained this title during the 14th. century, earlier circulating under the title of 'Perspectiva' alone, or without title, which same title Witello's treatise bore. PECHAM (1970) p. 12/14. LATHAM (1965) gives the first use of 'perspectiva' in medieval latin as anti 1233. Lindberg PECHAM (1970) p 29. suggests that Pecham's treatise was "by far the most popular" of the medieval works in his area, and counted 62 extant copies form the period.
2. PECHAM (1970) p. 60. 3. Ibid. p 120/22, Bk. I:38. Emphasis added.
4. Quoted in VESCOVINI (1961) p. 192, presented as given.
5. PECHAM (1970) p. 56/7 where Lindberg gives the details. These figures exclude editions which were paraphrases of Pecham.

tota hac uniursitate & rerum natura existit.[1]

On the other hand, in La Prospettiva di Euclide (Fiorenza 1573), by Ignazio Danti for the Italian reader, such niceties tended to be overlooked, and Danti rather praised the value and perfection of the (mathematical) knowledge involved in perspective. Danti's dedication began:

> [3]QVELLE arti fra tutte l'altre debbono essere tenute principalissime, & degne di essere apprese con ogni attentione di animo, le quali dependendo da primij principij, seruono alla inteliegenza, & cognitione dell'arte, tra le quali la Perspettiua tiene vno de'primi luoghi; poiche senz'essa niuna dell'arti liberali puote perfettamente esser intesa[2]......Comè potra adunq; il Filosofo naturale senza la Prospettiua intendere, & conoscere perfettamente il moto, la quiete, il sito, la grandezza, et qualità delle cose naturali intorno alle quali cõsiste tutta la sua speculatione ?[2,4,5]

He further argued against those who contended that perspective was a base mechanic's trade:

> Et lasciãdo da banda il raccõtare il giouamento, & l'utile, che ella (i.e. perspective) arrecca, anzi quãto sia necessaria à infinite arti mechaniche, & particularmẽte alla Architettura, & à tutte le altre arti del disegno, si come à uoi nobilissimi ACCADEMICI è notissimo, dirò solo, che non posso se non marauigliarmi grãdemẽt come possa essere, che appresso le persone scientiate & dotte questa sciẽza della prospettiua sia hauuta in cosi poca stima, anzi, il diro pure, et cõ molto mio dispiacere, pare che sia da ciascuno tenuta à uile, et che nõ bisogni piu andare à imparala nelle scuole de'Filosofi essendo da essi sbãdita, ma quel poco che ci resta, resta tutto in un poco di pratica appresso à gl'artefici meccanici, di che essendoui giudiciosamẽte accorte uoi, hauete nuouamẽte con bell'ordine instituta la nuoua Accademia dell'arti del Disegno....rederete la Città nostra nõ mena adorna di questa sciẽza che ella sia hoggi con molta sua lode, & quanto altra Citta di Italia ornata, & della facultè delle Leggi, & dello splendore delle Armi.[6,7]

1. Op. cit. f.(IIa). Hartmann went on, however to argue against those philosophers who denied the value of mathematics "ad Mathemata amplectenda, cùm harum artiũ immensas quasi vtilitates cernent." (f.(IIIa)) He further insisted in its usefulness "interim tamen verè perspectiuam ad usum conferre volunt videri" (f.(IIIb)) The dedication dated 1542 was to Johan Tscherte, for whom see Durer Biog. Hartmann was interested in earth magnetism, among other things. See HARRADON (1943).
2. Danti went on to argue that astronomy needed perspective because it informed one about the behaviour of visual rays in dense and light mediums, and hence was necessary to the observation of the heavenly bodies. It also allowed one to understand the position and figure of bodies Dante explained, and then went on as given.
3. Op. cit. p (v).
4. Giovan Paolo Galluci in his Della Perspecttiva Commune (Venetia 1593), a translation of Pecham, where Pecham had "Perspeciva igitur humanis traditionibus recte prefectur, in cuis area linea radiosa mathematicae demonstrationum nexibus complicatur, in que tam physicae quam mathematice gloria reperitur, utriusque floribus adornato" (Dedication), Galluci gave, for the phrase after 'complicaur', "nella quale si ritroua la gloria, & la certezza si della physica, si della mathematica" (p. 1. emphasis added.)
5. Dante afterwards mentions as an example the Meterology of Aristotle.
6. p. (vii). The dedication was addressed "Agli Accademici del Disegno di Perugio".
7. Ignazio Danti, mathematican, cosmographer and architect was born in 1536, in a family of mathematicians and arists, and joined the Dominican order in 1555. In 1562 he went to Florence to serve the Grand Duke Cosimo, and taught his sons and Florentine gentlemen. In 1571 he obtained the post of public lecturer in mathematics in the Studio di Firenze. After Cosimo's death he lost his post but in 1576 obtained a similar position at Bologna. In 1580 Gregory XIII named Danti papal cosmographer. Danti also became involved in calender reform. He died in 1586. Danti published a number of works on astronomy and astronomical instruments during his lifetime, and was also apparently a skilled maker of instruments. (ENC ITAL)

While Peter Apian and George Tanstetter edited and published an edition of Vitellonis...quam vulgo Perspetiuam Vocent (Norimbergae 1535), Fredrick Risner when he published his edition of Alhazen and Witello, in 1572, entitled it Opticae Thesaurus (Basilea). However, while the terminology may have been changing Risner still expressed the same idea of a connection between perspective as optics, and perspective as a technique of representation, saying in his general introduction:

> ......opticae artis ui ac facultate omnia efficuntur: ut picturam, architecturam, mechanicam interea tacem nihil admodum nisi opticã esse.[1]

On the other hand when Guidobaldo del Monte published his Perspectivae Libri Sex (Pisauri 1600) what he gave was a work not on optics on the lines of Pecham's Perspectva Communis and others in that same tradition; and equally not a work which ministered to the painter in his need for 'correct' representation: but rather a collection of sophisticated geometrical proofs, which, although concerned with vision conceived on the pattern of the painter's approach, were so rigorous and formal in nature and involved so much detailed proof, as to be much more a contribution to contemplative study, rather than any aid to the painter; in some ways indeed closer to the older 'optical' tradition when Guidobaldo discussed the ways objects were seen in mirrors, yet different in that the treatment was almost entirely geometrical, and without a section on the physiology of the eye or the nature of light, and the like.[2]

Simon Stevin's slightly later work on perspective was not dissimilar although Stevin did attempt to insist on its practical basis. Yet Stevin was emphatic that what was at issue was the need for demonstrable causes, and when he came to deal with the cases of the representing sheet being at an angle to the floor he admitted that such set-ups were not very often required. His study thus also tended to be a purely geometrical piece of contemplative knowledge, even though the roots of the problem concerned were in a practical problem and that way that problem was by then traditionally dealt with.[3]

Thus the painters perspective, as a mode of representation on a flat sheet, in its theoretical aspect, from Alberti on, was an art (or science) essentially characterised by its basis in demonstration by means of the universal principles of Euclidean geometry. A characteristic highly dependent on vision being conceived as ensuing from a single eye point with an analogous 'distance' point forming the centre of organization of the representation. From an early period the analogy between god and the painter was present as a background idea helping to elucidate pattern involved.[4] Equally were present such ideas as the

1. Op. cit. p. (v).
2. Guidobaldo del Monte, was born in 1545 into a noble family and was a pupil of Comandino. He studied mathematics at the University of Padua, served against the Turks, and in 1588 was made inspector of fortifications and cities to the Grand Duke of Tuscany, but soon afterwards retired to cultivate his mathematical studies. (D.S.B.)
3. See above Biog.
4. Within perspective as it was traditionally known during the medieval period, as is well known, ideas about light as a signficant power in the world with certain divine overtones, as in Robert Grosseteste, were not uncommon. These ideas continued to be expressed during the renaissance, as for example in the dedication to Wittelo's text. The renaissance view of light as basically geometrical thus still traded on such views as supportive of their studies, by way of the sense of the deity that came through their activities. As for example in La Pespectiva y Especularia de Euclides (Madrid 1585) trs. Pedro Ambrosio Onderiz f. (va). "DESPVES que el Architecto del mundo huuo fabricado esta casa vniuersal, la qual desde su eternidad tenia traçada ensu diuina idea. Luego crio la luz, y en criando el hombre, le puso en medio toda ella, para que assi como en lo spiritual veya con el entendimiento, mediante la luz de su gracia, lo que esta en el cielo Impireo..."

utility, worthyness and certainty of the mathematical basis of the art; its suitability to persons of a particular estate in society;[1] and the pleasure that might be gained from its application, and its nature as a discipline of contemplation.[2]

On the other hand this approach to representation was no mere arbitrary convention dependent simply on commitment to such ideas. The practical technique dealt with in the renaissance theory of perspective was rooted in and continued to maintain a connection with 'perspective' as it was traditionally known as a purely contemplative study of the nature of vision as found in Pecham's treatise. The notion of an object as having a particular angle at the eye, as a fundamental aspect of vision, and the treatment of vision in terms of the geometry of rays was of great importance in that optical tradition, and in taking up these points the renaissance writers on the theory of perspective did no more than proceed in accord with the science of their time. On the other hand by ignoring such physiological aspects as the scanning of the eye over an object, they emphasised, of course, the purely geometrical aspects of vision to a greater extent than had been the case in the earlier tradition.

Nevertheless, because of this connection with traditional optics, the mode of representation of renaissance perspective, somewhat arbitrarily though its emphasis was, in insisting on the primacy of the single eye point in vision, could be seen to be 'scientific' because it depended on an approach using some of the concepts and techniques as were found in the contemplative study of vision; which same sort of study could then be conceived of as the theory which underlay the practical rules which were used to give the one true method of representation, whether in fact practising painters used this method as rigorously or consistently as they ought to have done, or not.

Thus in renaissance perspective, roots in traditional contemplative knowledge; the value of mathematics, for its certaintly, dignity, and pleasing quality; the suitability of such knowledge to a person of a certain level of life, and the particular approach to representation that was involved, all went hand-in-hand, mutually supporting each other, in an interlocking system.[3]

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1. The social rise of the artist can be seen in CASTIGLIONE (1950) Bk.I, sect 49/52. See also some brief remarks in MARTINDALE (1912). This process is well known. See also Durer Biog.
2. And also in Leonardo, to some extent, the communicability of such mathematical knowledge; see above p.128.
3. This summary is not intended to be even a complete account of the texts presented here, no less than of all the manifold details of renaissance perspective. In the wider context, the way in which texts, particularly those in Latin on perspective/optics, could continue to warn that 'mixt' disciplines did not have the full certainty of mathematics, while other tended to emphasise that quality in those disciplines, and to treat vision as purely a mathematical phenomenon, so sidestepping the difficulty to some extent, must be considered to be extremely suggestive. Here however it is sufficient that what is brought out is just the occurence of such events, as indicative of the mathematical ideology of the period. There is of course a large mass of literature relevant to renaissance perspective which has not been directly dealt with here. The events described here are in fact perhaps more in accord with the views of PANOFSKY (1927) than with others.

II:(4): Surveying[1]

The nature and prevalence of the different surveying techniques that were used in the medieval period is by no means clearly established.[2]

On the other hand the Boke of Surveying (1523) by John Fitzherbert,[3] gave a picture of the activities of a surveyor rooted in the society of the earlier period. Fitzherbert explained the need for surveying, by stating:

> .....do all these great estates and noblemen and women lyve and maynteyne their honour and degre....by reason of their rentes/ issues/ reuenewes/ and profytes that come of their maners/ lordshippes/ landes & tenementes.... (and that therefore) it is necessarye to be knowen/ howe all these maners/ lordships/ landes/ & tenements shulde be extēded/ suruayed/ butted/ boūded/ and valued in euery parte.....[4]

and explicitly stated that:

> ...for a grounde of this treatyse the whiche I do note/ and calle it the boke of Suruayng and of improuementes/ I do take an olde statute named Extenta manerii/ as a principall groūde thereof....[5]

In Chap. XIX Fitzherbert discussed "What a surueyour shulde do", and gave as his duties:

> ......to knowe euery mañes lande as it lyeth to his house one frō another. so that it may be knowen an hūdred yeres after and for euer/ what maner of landes/ and howe many acres euery man had to his house at that tyme/ and where they lyeth.[6]

and continued:

> The name of a surueyour is a frenche name/ and is as moche to say in Englysshe as an ouerseer. Than it wolde be knowen/ howe a surueyour shulde ouerse or suruey a towne or a lordshyppe.....he must outher ryde or go ouer/ & se euery parcell therof. and to knowe howe many acres it cōteyneth/ & howe moche therof was medowe groūnde/ howe moche pasture groūde/ howe moche wode grounde....what an acre of medowe groūde is worthe/ and what an acre of pasture....And what maner of catell it is best for/ and howe many catell it will grasse.......therfore a Surueyour must be dilygēt and laborons.... and so if he shulde view a cytie or a towne/ he must begyn at a certayne place/ as and it were at the drawe bridge of London bridge on the East syde/ and there to make his tytelynge where he begiñeth/ and to shewe who is lorde of the house next vnto the sayd bridge/ and who is tenaunt. And if he be a free holder....Howe moche euery garden is/ how longe euery aley and entre is.....and how many cellars or tauernes there be/ and howe many footes euery one of them be in length and brede.[7]

This tendency to conceive surveying as based on a whole complex of practices of the particular society in which it takes place, continued to be expressed in some English works on this topic during the 16th. century. For, while in the preface of Sir Richard Benese's treatise The manner of measuryng all maner of lande (London 1537),[8] Thomas Paynell expressed a strong belief in the value of geometry in general, and in particular in surveying, thus:

> Geometry.....includeth ỹ measurynge bothe of lande and water, ỹ vse of weyghtes, & knowleg of ỹ vniuersale order of ỹ bodyes aboue, ỹ distaūce and greatnes of starres theyr varites, motiōs & reflectiōs. Carpenters and Masons, wyth suche other artificers do vse Geometry: by the whyche all maner of ingens and craftye ordinaunces of warre and other apperteynyng vnto theyr arte do depende, as hangying roofes, and galeryes, walles, shippes, galles, bryggēs, mylles, cartes and wheles.....what soeuer goeth by weyght, water, wynde or by cordes, as clockes, the whych go by weyghts,

1. 'Surveying' as considered here is characteristically concerned with relatively circumscribed regions and their details, in contrast to mapping as concerned with relationships between relatively distant sites. The difference is by no means clearcut, and tends to relate to a number of factors.
2. See PRICE (1955) for example. Written sources indicate that certain rules, particularly for the determination of the heights of towers, by geometrical methods, were relatively well known in the medieval period. See MAPPAE CLAVICULAE (1974) Sect.211, for example. The 13th. century work of Robertus Anglicus, published in the late 15th. century, on the astrolabe also discussed this problem. Actual surveying techniques were probably much more dependent on visual estimation and the use of rod and line.
3. On the authorship of this work see FITZHERBERT, R.H.C. (1897). The author was much more likely John, a country gentleman, than Anthony, the well known lawyer, his brother.
4. f. (vb/via).
5. f. (viia). The statute of the 4th. year of Edward I's reign accordin to Fitzherbert f. 1a.
6. f. xxxiiiia 7. f. xxxxiiiia/xxxva.
8. Probable date after D.N.B.

> and organes, to whych sounde by the vehemence and force of wynde, doth longe vnto thys noble science. The artificale crafte also of warre, of castynge of belles, and bombardes or gonnes wyth suche other artilerye, whether they be of tymber or of metall, do for the most parte depende of Geometry....It were very tedious to expounde all the termes, partes, propreties, and vtilites of Geometrye, for notwythstandynge that God maye, and can do all thynge wythout nombre, measure, weyght, or ony poynte of Geometry, yet when he gaue the firmament, the planetes and starres theyr motions, the earth fourme and fashion, the sees wyth other ryvers theyr bankes, he dyd it by nombre, weyght and measure. Wherefore I maye well extoll thys moost noble science conteynynge these thre (i.e. Altimetria, Planimetria, Tereometria, mentioned above by Paynell.)wyth the knowlege of many other lyberale and manuell artes, ryghte necessarye for the commune wele of man.[1]

yet in his text Benese did not base his account on purely geometrical superficial area measurement. But explained:

> ....woodlande and fyldeland be not measured with perches of lyke & equale length.......(although) An acre bothe of woodlande, and also of fylde land is alwayes .xl. perches in length, and .iiii. perches in bredth ......(and that) An acre can not lyghtlye be reduced and brought in to a true square, excepte ye shoulde adde to some part aboue the true quantyte of an acre, or els take awaye some parte......[2]

The later work of Valentine Leigh, The moste profitable and commendable science of Surueying of Landes, Tenements, and Hereditaments (London 1577)[3], followed very much after Fitzherbert's approach. Leigh explained:

> ...the sciēce of Surueying of landes....teacheth the gouernmente of the Mannours, landes, tenementes of each persone, and hovv to make a perfecte Surueye of the same to moste profite. And also hovv to engrosse your terors and Rentalls thereof....[4]

and was much concerned, for example, with the legal basis of a manor. However Leigh did grudgingly allow some minor role to Geometry, stating,

> BEcause it is partely appertaining to the Office of a Surueiour, to haue some vnderstanding in measuryng and meating of Lande and wood grounde, and how to reduce the same into true Contentes and numbers of Acres, as often and when as occasion that require: Although they that desire the ful and perfecte knowledge thereof, may reade the same out of the auncient Bookes of Architas and Archimedes, or or worthy Euclides, treatyng of the whole science of Geometrie......[5]

In contrast in mid 15th. century in Italy Leon Batistta Alberti in his Ludi Matematici dealt with surveying as the (pleasurable) operations of mathematics.[6] In this work Alberti discussed, among other things, the measurements of tower height's in traditional fashion. However, additionally, Alberti discussed the firing of a bombard at an unseen target,[7] about which topic he continued

> Voglio alle cose dette di là aggiugnere certo istrumento atto (come per voi penserete) molto a questi bisogni, massime a chi adoperassi il trabocco e simile machine belliche. Ma io lo adopero a cose molto dilettevole come a commensurare il sito d'un paese, o la pittura d'una terra, come feci quando ritrassi Roma.[8]

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1. Sg. +iiia et.seq. Thomas Paynell, the editor of Benese's work, fl. 1528/67, like Benese of Merton Abbey, translated a number of works into English, and in 1541 became chaplain to Henry VIII. (D.N.B.)
2. Sir Richard Benese supplicated for a degree at Oxford in 1519, surrendered his position as Canon of the Augustin priory of Merton in 1538. (D.N.B.). Text Sg.Aiia/b.
3. Dedication dated 27th. Oct. 1562 in which year the work was first published ?
4. Sg. Aiib.
5. Sg. Dib. Leigh then referred one to Benes's work (and to Digge's Techtonicon) where one found instructions as to how to take off the areas of simple figures. But Leigh gave some like instruction himself, saying (Sg. Giiia)"Also the Surueiour should haue some skill in measurying of Lande, that is to saie, what an Acre is, how muche it containeth, ect. and how moste readily, and truely to meate lande by line, or by rodde be it in the plaine or in the valley...(therefore) A small brief enstruction, he shall hereafter finde..." But this was only a short section at the end of the book.
6. ALBERTI (1845) p. 405/439. Published by Bartoli as Delle Piacevolezze delle Matematiche (1568). Alberti wrote (p. 405) in his dedication to Meliaduso d'Este, "forse vi arò satisfatto, quando in queste cose giocondissime qui raccolte vi prenderete diletto, sì in considerarle, sì ancora in praticarle e operarle." GADOL (1969) p. 167 states that the work was sent to Meliaduso in the 1450's; and discusses Alberti's work in this area in some depth.
7. Basically by finding the carry of the shot for any particular elevation by trial, and using surveying to get the range.
8. Op. cit. p. 429/30. According to Gadol, when in the 1540's Alberti constructed his map of Rome he used polar coordinates, a different technique from the one he described in Ludi Matematici.

Alberti then described how, by siting the angular direction of a number of landmarks from three stations, one could plot the relative positions of those landmarks on a sheet, in a technique roughly equivalent to that of plane table surveying.[1] He further described how to find the distance to an object by measuring the angles it gave at the end of a known base line, indicating how the scale of such a plan could be found.[2]

Thus geometrical techniques of surveying, and their 'playful' quality were a focus of interest for Alberti, and he handled them purely in terms of the universal principals of Euclidian geometry without reference to traditional modes or units of measurment, or the particular offices or practices of his society. Equally he was concerned with providing a 'picture' rather than primarily with area measurment and its legal significance.

Pacioli later in his <u>Sūma de Arithmetica Geometria Proportioni & Proportionalita</u>,[3] in his praise of mathematical techniques, stated in his dedication:

> ....diremo đ la cosmographia nō ci demostrā tutti li antichi . Erathostene Strabone. Mario. Ptholomeo e gli altri excellēti cosmometri. q̃to lisia necessario el n°. lamisura e la pportioe. Quado de tutto lo vniuerso mondo debitemēte pportionando lor gradi in vna piccola carta puicie. cita. castelli. E siti marittimi, e mediterranei ha no redatto.[4]

Yet in so far as Pacioli discussed surveying it was only in the taking off of areas of geometrical figures[5] and the traditional problem of finding heights by angular measurement.[6]

Frances Pellos in his <u>Cōpendiō de lo abaco</u> (Thaurino 1492), gave a few pages on "la art de ieumetria" but similarly gave little more than the taking off of areas of simple geometrical figures.

Gregor Reisch in his <u>Magarita Phylosophica</u> (Argentina 1504),[7] in his section <u>Geometriae Practicae</u> (Bk. VI, Trct, II, Cap. iiij) showed a square with a graduated quadrant of which he said:

> ......per hoc igīt instrumētū altitudine turris: pfunditatē putei aut vallis: lōgitudine aut latitudinē cāpi & insupoem lineam rectā potes metiri.[8]

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1. Op. cit. Cap. XVI. Alberti explained that when from two stations a good intersection was not forthcoming, one went to a third. However, Alberti did not suggest plotting directly onto a sheet over the station as in plane table surveying, but that angular measurement be taken, noted down, and plotted later. Nevertheless the two techniques are geometrically equivalent.
2. Alberti's technique was clearly equivalent geometrically to triangulation, and thus Gemma Frisius account in the next century was by no means the unique discovery of this technique as some, for example POGO (1935) have tried to make out. However Alberti did not suggest the iteration of his technique to build up a net work between relatively different places, and in this sense his account was not a complete one of the process of triangulation. In fact, with regard to measuring distances between distant towns, Alberti went on to describe the use of a Holometer after Viturvius.
3. (Venice 1494) 4. f.(iia).
5. Ibid. Pt. II. Dist. I. Cap 8.
6. Ibid. Pt. II Dist. VII "del mōde misurare colviso; cioe col vedere". (p.1.)
7. 1st. published 1503. Reisch, born at Balingen, Wùrtemberg, died in 1523. A student at Freiberg in 1487 he took his bachelor's and master's degrees there. He became Prior of the cloister of Frieburg of the Carthusian order, and confessor to Maximilian I. SMITH, D.E. (1908).
8. Op. cit. Sg. Riia.

He also showed a Jacob's Staff (Baculus Iacob) for measuring heights and lengths.[1]

Juan de Ortega in his Suma De arithmetica: Geometria Pratica vtilissima (Rome 1515)[2], in his dedication, wrote:

......de tutte le arte & scientie da lo intelecto nostro ritrouate.....la vtilita laquale a noi e data per cognitione & luso de quelle fra tutte ritrouaremo le matematice discipline & de epse specialmēte la arithmetica & geometria como summamente necessarie.....senza la intelligentia & vso de queste......senza dubio alcuno ne la vita humana nascera nō poca cofusione..[3]

He further explained at the beginning of his section on practical geometry:

...la Geometria practica e necessaria & molto vtile ad qual si voglia persona.. ...como qual si voglia persona potra mesure: qual si voglia cosa che sia... o torre: o muraglia: o pauiglioni: o fonti: o pozi..... .[4]

But again Ortega's 20 folios (out of a total of 116 for the whole work) on this topic, gave little more than instruction on how to take off the areas of simple geometric figures.

The little handbook of the Tagliente Libro Dabaco che insegna a fare ogni ragione mercadātile: & a ptegare le terre cō larte di la geometria, first published in 1515 ran to many editions.[5] In the dedication the authors wrote of the

......Virtu de la Arithmetica: la quale e chiamata vna de le sette arte liberale. E quella e principio & fundamento de ogni scientia & arte.[6]

But in addition to discussing arithmetic, the authors stated that:

. ...dimostraremo anchora larte de la Geometria: laquale dimostra el modo de lo pertegare le terre: etiam le mure: & a fare altre nobilissime ragione con regole, e modi da impararle in pochi di. Laqual anchora e vna altre dele sette Arte liberale.[7]

However the instructions were again very brief and elementary.[8]

Francesco Feliciano publishe his Libro de Abaco* in 1518, and later Libro de Arithmetica e Geometria speculativa e practicale....intitulate Scala Grimaldelle.[9]

In this last work Feliciano informed the reader:

Hauendo nella eta mia per spatio di anni.XXXII.essercitato nellarte del insegnare a putti & a huomini e contegiare: & etiam essendo stato quasi per tutta L'Italia a misurare in compagnia, e senza compagnia de misuratori, Terre, Feni, Biaue, Vini, Muri, Boshi, Paludi, & Liuelar acque & simil cose.[10]

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1. Sg. Riib. The text is clear, although the illustration given does not tie up with the description. The staff had pre set equidistant stations and a moveable arm equal in length to the distance between these stations. A location was foond at which at one setting the movable arm subtended the object, then a second location was found at which the arm in the next station again subtended the object. The distance between the two locations so found, Reisch explained, was equal to the height of the object. Distances could be measured in the same way he added. In Bk. X, Tract.II Reisch gave some remarks on perspective, generally of a traditional kind.
2. Ortega was a Spanish Dominican who died in 1567. (ENC UNI EUR AM) (SMITH,D.E. (1908) says still living in 1567.) The work quoted was an Italian version of Ortega's work earlier published in 1512 at Barcelona. A French edition was published in 1512 at Lyon* and in 1515 there also. There are some differences between the different editions.
3. Op. cit. f. 2b, where Ortega also stated that mathematics serves "regere & gubernare", "qual si voglia cōgregatione de homini." The 1512 Barcelona edition had a slightly different emphasis in a rather similar introductary section. There Ortega stated, "...entodas las cosas criadas tanto qual quiera de aquellas en mas noble quanto mas comunica su virtud....(so that) el bein entanto es bien: en quanto es comunicable". (f. 1b.)
4. Ibid. f. 97b.
5. Girolamo and Giannantonio Tagliente. Many of the editions do not bear their names. The one used here, B.M.529.b.46., has no place or date. For bibliography see SMITH, D.E. (1908).
6. Op. cit. Sg. Aiia.
7. Ibid.
8. Giving rules for the area of a rectangle, triangle and the like, very shortly.
9. According to SMITH, D.E. (1908), this second work, first published in 1526* was a revised version of the first. To what extent the first work contained the material on surveying, it has not been possible to establish. ROSSI, Giovanni (1871) assumed it was identical. This later work went through many editions during the 16th. century, that used here being the one of 1560/1, substantially the same as the 1526 edition according to Smith. Rossi used the 1545 edition which checks with the one used here.
10. (1560/1). Sg. A1b.

Stating, regarding his subject, that it was:

> .....cosa necessaria a tutte le creature humane ad intedere & essercitare larte negociatoria, non solum mercantesca, ma mesuratoria, senza le quali certamente lhuman seme seria confuso....[1]

Arithmetic and Geometry being:

> .....le due prime de la sette arti liberali, origine & fundamento di tutte le scientie & arte...[1]

Feliciano criticised strongly the state of the contemporary art of surveying, partly because:

> .....quanto sia la difficulta dell'arte misuratoria, non tanto dico della Theorica, quante della prattica, perche la Theorica si e, & sta nella mente de i dotti, & scientifichi Filosofi, ben che credo, che di quelli ce ne siano assai senza prattica, perhce a loro basta le buono theorica per dimostrare le cose alte, & diuine.[2]

The practitioners of his time, Feliciano explained, used three methods: some depended on estimation by eye, others by numeration of the triangle, and only some worked in the correct way, by instrument.[3] Then much of the rest of Feliciano's section on this topic simply showed how the square could be used to allow the altitudes of triangles to be correctly measured so as to allow their true areas to be calculated.

In 1533, as an addition to his second edition of Apian's Cosmographicus liber, Gemma Frisius published Libellus de locorum describendorum ratione,[4] concerned with geometrical methods of surveying. Among other things Gemma discussed the use of the square for measuring distances by similar triangles, and gave an account of triangulation very similar to that earlier given by Alberti.[5,6]

During the same period Jacob Kobel's Geometrei von künstlichem Felmessen appeared,[7] with a good deal on the use of the rod in measuring, as on the use of the Jacob's staff and the quadrant.

Giovanni Sfortunati in his Nuouo Lume[8] (Vinegia 1534) described his work as:

1. Ibid. Sg. Aib. 2. Ibid. Sg. Ria.
3. "....il primo mesurera senza isturmento ma solo a occhio, e lo secondo mesurera con l'istrumento, cioe con lo Squadro, el terzo mesuera con numeri per forza de triangli...." which last process, according to Feliciano, involed taking the two least sides and multiplying ½ one by the other, which process he ridiculed. Sg. Ria/b.
4. For bibliography see POGO (1935)
5. Of this process Gemma wrote ".....hunc modum prouinciam aliquã vel etiam totum regnum com omnibus oppidas describere volueris...." (f. LVIIIb, op. cit.) implying the production of a triangulation network over a large region. But his actual description was of a two station set up, in which he in fact discussed places which could not be seen as examples, without suggesting a sub-triangulation system to bring them in. Thus the whole process of building up a triangulation network for places not mutually visible was largely ignored by Gemma in his account, as it was by Alberti. Pogo (op. cit. p. 75), attempting to make Gemma seem as much of an 'original genius' as possible wrote of this "The value of the clear and methodical exposition is enhanced by such devices as the inclusion of stations....invisible from Brusells " (one of Gemma's basic stations) (!), and stated that Gemma's account was pretty well equivalent to a modern one of triangulation. Gemma's account differed form Alberti's in that he related his stations in the first place to the meridian. Alberti more practically than Gemma postulated the use of three stations to handle bad intersections, while Gemma simply remarked that when a feature lined up with his two stations, another had to be used. Pogo's comment (Op. cit. ibid.) that "Gemma was the first to realize that by determining the bearings of terrestrial landmarks, and by repeating the observations at several stations, a network could be drawn on paper which would give, by the intersections of the corresponding pointings, a map of the country surveyed" was of course quite wrong when Alberti's work is considered. Further it is quite possible that others may have realised the same thing without considering it of any great interest or worth.
6. Gemma Frisius, born 1508, took a medical degree at Louvain where he practised this profession and later taught. In 1529 he published his first edition of Apian's Cosmography, and in 1530 on astronomy and cosmography. (D.S.B.)
7. This work seems to have been first published in 1535* at Frankfurt am Main. See ROTH (1888/9) 3, No. 7. Earlier Kobel had published Von ursprung der Teilũg Mass vñ Messung dess Ertrichs der Ecker, Wyngartẽ, Krantgarden, vn anderer Velder In was form vnd gestalt die sind (Oppenheim 1522*). Ibid. 1. No 37. The 1556 Frankfurt am Meyn edition used here.
8. ".....cõ vno breue trattato di Geometria: per quãto a vno pratico Agrimensore si conuẽga.....Composto per lo acutissime perscrutatore delle Archimediane & Euclidiane dottrine." (T.p.)

.....vna breue operetta d'Arithmetica con vn breuissimo principio di Geometria: di non piccola vtilita: cõsiderando tal faculta e scientia a ciascuna impresa esser necessaria.......(for) ne senza essa alcuna cosa potersi a perfetto fino condurre si concede. Conociosia cosa che perso il numero o la quãtita: il peso la misura rimane il tutto insensato & se n'ha alcuna rationalita.'

He began his text:

DI tutte le sciẽtie che infuse sono nelle menti humane non si deue di quelle alcuno insuperbire. Ne etiam quelle tenere occulte, ma ringratiare il sommo benefattore che à quello le ha concesse & di quelle si deue ad ogn'uno farne quella copia che Dio ha fatto à esso.[2]

In his short section on geometry, Sfortunati explained, his work contained what

....resta al presente darti alquato lume della pratica geometrica si come mensurare terreni, campii, fosse, formaci, muraglie & simili....[3]

and therefore:

....volendo noi a tal scientia principio dare, eglie necessario cinque cose intendere, à questa arte molto appartinenti, delle quali. La prime è punto. La seconde è linea....[3]

But again Sfortunatis' discussion was then mainly on simple superficial area measurment.

Tartagli in his Nouo Scientie discussed the use of the square to measure heights in connection with gunnery, and in later editions the measurment of plane distances. In the Questi et Inventione Bk. V, he gave an account of surveying cities and countries using a circle with a compass, and stated there were two ways of using it in surveying, either with one station or many. The use of one station he explained was better because the compass varied slightly from place to place. In which case the compass seems to have been rather redundant except to orientate the plan.[4]

Cardano in the same period in his Pratica Arithmetice, & Mensurandi singularis (Mediolanum 1539) gave some brief discussion of area calculation and the use of the level.

Oronce Fine in his De Geometria Practica (Argentorati 1544) dealt with the use of the quadrant, staff, and the measurment of the areas of simple geometric figures along with some other assorted topics.[5]

Pietro Cataneo's Le pratiche delle due prime matematichie (Venetia 1546*) had a short section on the same type of practical geometry.[6]

In his Commentariorum in Astrolabium quod Planisphaerium uocant (Lutetae 1550), Juan de Rojas Sariemento in Bk. IIII described the taking of heights by angular measurment in the traditional way[7]; and in Bk. V included Gemma Frisius' Libellius de locorum descriptorum ratione.[8] In his general dedication to Charles V Rojas began:

CVM omnes disciplinae, inuictissime Caesar, caeteris praestantiores habeantur, quae uel subiecto sublimores sunt, uel demonstratione, rerũmue scientia euidentores, aut usui hominũ magis necessariae, omnibus iure optimo (Theologiam semper excipio) Mathematicas artes praeferemus: qua non in inferiorum, mortaliumq̃ue rerum comtẽplatione, neque in Philosoporũ arbitrio, aut opinione, sed manifestissima sui demonstratione in ipso....Hominum uerũ usui eousque caeteris artibus necessariae magis sunt, ut uel sola harum disciplinarum scientia, à reliquis brutis, rationẽq; carentibus animalibus seiũgi, separarique uideamur.[9]

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1. Op. cit. f. 2b. 2. Ibid. f. 3a. 3.. Ibid f. 106b.
4. For details of editions see above II p.5 & 12. In his later Trattati di Numeri e Misure Tartaglia discussed the use of the square in some detail.
5. Including an approximation for 'π', and a section on the volume of solids.
6. RICCARDI (1893). The 1559 Venetia, edition, used here had little more that the taking of areas of simple geometrical figures, and a little on the volume of some solids.
7. And including a section on surveying using polar coordinates, as Alberti had used in his survey of Rome.
8. With commentary.
9. p. (iii).

and continued concerning the use of mathematics:

> Nam ut omittam, quae ad nauigationis pertiiam pertinent, ut omittam fluminum latitudinum, murorumque atque turrium altitudinū, fossarumque profunditatum dimensiones pro pontibus scalis, caeterisque alijs rei bellicae necessarijs machinis fabricandis, quae à nulla arte uel facilius uel certius, quã ab hac mathematica ratione haberi possunt.[1]

Sebastian Münster in his Rudimenta Mathematica (Basileae 1551), gave a good deal of discussion on surveying in Bk. I, mainly on the use of the square and the staff, but also with regard to the use of a special instrument of his for measuring angles.[2]

Gio. Prancesco Peverone in his treatise on arithmetic[3] and geometry stated that he considered that of all the arts, he thought Arithmetic to be the one:

> .....La quale degnamente è da tutti riputata la prima: si per la sua certeza di che tiene il primo grado, come per le molte vtilita e piaceri che ella à chi se ne dilletta apporta.....senze la quale era cosa malageuole amministrar le cose publiche e priuate...[4]

In his dedication to the geometry section, Peverone further stated:

> ......questo Geometria: conoscendo quanto necessaria e quanto gioueuole sia a tutte noi, che certo senza questa noblissima scienza sariamo ogn'hora per le diuisioni de campi à le mani, e ne i litigij trauagliate: e senza essa sarebbe il mondo priuo de la dilettuole Astronomia, del vtile Architettura, de la suaue Musica instrumentale, e de L'allegra Pittura. Ne so como saria senza questa il considerato bombardiere, à terminare i suoi tiri, che hor violentamente, & hor per corso naturale in alto sagliono, scendono al basso.....(How will be able to work) il prudente ingengieri come saprebbe misurari i luoghi inaccessibili, come cauar le pianti de paesi & citta? ne formar bastioni, caualieri, e trinciere, con le quali si defendono le fortezze da fieri nemici![5]

Among later works in the same tradition was that of Cosimo Bartoli (the editor and publisher of Alberti's works including Ludi Mathematici[6]), Del modo di misurare le distantie, le superficae....& tutte le altre cose terrene .....Secondo le uere regole d'Euclide, & de gli altri piu lodati scrittori (Ventia 1564), a compendius work on the square, and the staff, taking a plan by polar coordinates after Rojas, areas and volumes of bodies, and the triangulation method of Gemma Frisius.[7] Silvio Belli's Libro del Misurar con la Vista (Venetia

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1. p. (iii). In the introduction to Gemma Frisius' descriptions Rojas continued in the same vein (p. 201) "TERRAE situs, prouinciarumque dispositiones, maxime Caesar, non erit minus cognitu digna res, nec minus Imperatori necessari...." Here Rojas also suggested Gemma was derivative of Peurbach on the use of the traditional square to measure distances, which Gemma did not appreciate. Geometrically the two methods are equivalent--given base line, the value of the angles the object makes with it give the distance, and hence Rojas was not so very wrong in one way, although the two techniques in practice are very different. POGO (1934/5) discussed the debate, and claimed (p. 480) that Rojas misunderstood the difference between these two rules of surveying, insisting that the account of Gemma was "a monument to the originality of the author".(p.483) However it seems to be Pogo who misunderstood Rojas. For Rojas's remarks of a general nature show that it was demonstrability in science, and its mathematical base, that he thought important, and from this point of view there was little difference between the two techniques. Rojas, son of a marquese, travelled to Flanders with Charles V and Philipp. He was taught at Louvain by Gemma. (ENC UNIV ILL EUR AM, which gives his treatise as of 1540, but this seems to be a misprint. T.p. of the 1550 ed. reads "libri sex nunc primum in luce editi.")
2. Involving jointed rules to make a triangle attached to graduated circles.
3. "Due breue e facili trattati, il primo d'Arithmetica: l'altro di Geometria: ne i quali si contegono alcune cose nuoue piacceuoli è utili, si à gentilhuomini come artegiani" T.p. (Lione 1558), containing a portrait dated 1550. Dedication dated 1556.
4. Op. cit, p. 4. Plato is given in support of the last remark.
5. Ibid. p. 63/4. In the elision other professions are noted as needing geometry, including " legnauiolo", clockmakers, "liuelatore", "orefice", printers. Peverone a relatively obscure figure, was from Cuneo, he gave accounts of the standard topic of the taking of areas and the use of the square, but also described a level and its use, and gave an account of triangulation very similar to that of Gemma Frisius.
6. ALBERTI (1568)
7. Bartoli acknowledged his debt to these and other writers at the beginning of his work. In surveying a province of 300 or 400 miles, Bartoli suggested the curvature of the earth was not significant. (f. 92b op. cit.) Bartoli was a Florentine academian, humanist and mathematician (MAZZUCHELLI (1753/63)).

1565), showing the use of the square and other geometrical techniques:[1] a short section on elementary calculations in Giorgio Lapazzaja's D'Arithmetica e Geometria:[2] Girolamo Cataneo's Dell'Arte del Misure (Bresci 1572),[*] which discussed the taking off of areas and measurment of volume with a short section on leveling:[3] Lorenzo Bonocchio's Breue et universale risolutione d'arithmetica, Con la quale facilmente ogniuno porta ritrouare qual si voglia sorte di misura di terra (Bresci 1574), a collection of numerical tables: Erasmus Reinhold's Grundlicher vnd ware bericht. Vom Feldmessen (Erffurdt 1574):[4] Maffeo Poveiano's Il fattore Libro d'arithmetica et geometrie pratticale (Bergamo 1582), a work on computation: Trattato de Radio Latino.....Inuentato..Signor Latino Orsini,[5] published by Ignazio Danti with commentary, concerning a gadget for measuring angles, mainly in its application to surveying: Jacques Chauvet's La pratique universelle de Geometrie & La pratique universelle de l'arpenterie, both concerned mainly with plane table methods:[6] Francesco Pifferi's Monicometro instromento de misurar con la vista (Siena 1595), involving a technique to facilitate taking and plotting angles: The Rechenbuch (Leipzig 1595) of Andreas Helmreich, containing in Bk. III a section on the taking off of areas (and Bk. VI on sundials): Philippe Danfrie's De l'usage du Graphometre (Paris 1597), concerning a gadget on a tripod for measuring angles, particularly in triangulation: Otavio Fabri L'uso delle squadra mobile (Venetia 1598): L'henry-metre, instrument royal (Paris 1598), by Henry de Suberville on an instrument for measuring angles in surveying and astronomy.[7]

1. Belli insisted "CERTAMENTE è cosa marauigliosa il misurar con la uista...." Op. cit. p. 1. Engineer and mathematician, student of architecture, geometry and arithmetic, Belli practised in Ferrara and Rome, and died in 1575 (MAZZUCHELLI).
2. 1st, published 1566* Naples (RICCARDI (1893)). The edition used here Naples 1569 was not noted by Riccardi. (By Mattio Canceri.)
3. Brescia 1584 edition used here.
4. N.U.C. The 1615 Franckfurt am Mayn edition Vom Feldtmessen,...durch wahern Geometrischen Grund abmessen contained a great deal on computation, with some instructions on the square.
5. Rome 1583* (RICCARDI (1893)). Roma 1586 edition used here.
6. Both published in an uniform editon with Instruction et usage du cosmometre at Paris in 1585. Chauvet was noted in his priveledge as "Lecteur & Professeur ordinaire és sciences mathematiques en l'uniuersité de Paris" Chauvet also published an Arithmetic in 1578 which leant heavly on military examples. (SMITH (1908)) Works in French relative to surveying seem to have been relatively rare. The Geometrie Pratique (Paris 1547), of Charles de Bouelles (possibly first published as Livre singulieri et utile, touchant l'art et pratique de géométrie (Paris 1542*)), did not discuss surveying directly. On the other hand Peter Ramus' Arithmeticae Libra Duo Geometriae septem et viginti (1st. ed. Paris 1555*) in the 1596 Basilae ed. stated in the geometrical section (p. 1) "GEometria est ars bene metiendei. Finis geometriae est bene metri, ideoque suo fine definitur: Bene metiri igitur est cujusque rei mensurabile naturam atque affectionem considerare...Atque hic finis geometriae usu atque opere geometrico multo splendidior apparebit, quám praeceptos, cum animadverte astronomos, geograpuos, geodetas, nautas, mechanicos, architectos, pictores, statuarios..." and included a short section on the staff.
7. For surveying as handled by the fortification treatise writers generally, see Biog. sections. Among other relevant works which it has not been possible to consider here were: Nicolaus Reymers' Geodaesia Ranzoviano Land Rechnen vnd Feldmessen (Leipzig 1583*), (SMITH, D.E. (1908), who stated "The chief interest in the first book (of this work) is in the use made of the compound numbers then needed in surveying".): Mathias Nefe's Arithmetica. Zwey newe rechenbücher....Das ander....wie man rechnet, wie weit von einer stadt zur andern ist, de distanijs locorum (Bresslau 1565*), (N.U.C.): Elie Vinet's L'Arpanterie...livre de geometrie, enseignent à mezurer les champs (Bourdeaus 1577*), (BIB NAT PRS): La Maison champetre (Paris 1607) by Vinet and Mizauld de Mollussa gave as its first book L'Arpenteree which was mainly about simple area measurment, including the use of a square. This work also included a section on dialling. Pietro Maria Bonini's Lucidaro darithmetica (Florence 1517*), the last third of this work, c. 6 folios was on "Speculation geometriche di piu sorte: & prima lequadratura del triangolo" (SMITH, D.E. (1908)): Oliviero Fonduli's Pratiche de Fiorette Merchantili (Bologno 1560*), (Ibid.): Antonio Mariea Visconti Pratica Numerorum & Mensuarum (Brixiae 1581*), (Ibid.): Ognibene da Castellano's Che Euclide & altri Eccelentiss. Mathematici hà trattato oscuramente (Vincenza 1582*), (RICCARDI (1893)): Geronimo Pico Fonticolano's Geometria (Aquila 1597*), (Ibid.) Bartolomeo Cresentio's Proteo Militare (Napoli 1595) "nel quale si fornano tutte le figure de Geometrie, & gl'Istrumenti de Prospettiua, Pittura, Scoltura, e d'Architettura" and "L'arte del Nauigare e quella del guerriggiare" (T.p.) Dialling, gunnery and the surveying of fortifications were also briefly included.

The mathematical approach to surveying, in contrast to the emphasis on the office of the surveyor and the particular practices of the society in which he worked, as found in such writers as Fitzherbert and Leigh, was followed by a number of later English writers.

Robert Recorde in The Pathway to Knowledge (London 1551) emphasised the value of mathematics and the need for its use in surveying, thus:

> ....true felicity doth consist in wisdome and vertu.....then ought all men to trauail for knowledy in matters both of religion and humaine doctrine......And for humaine knowledge thys wil I boldly say, that who soeuer wyll attain true iudyment therin must not only trauail in ẏ knowledy of the tungs, but must also before al other arts, taste of the mathematical sciences, specially Arithmetike and Geometry, without which it is not possible to attayn full knowledy in any art. Which may sufficiẽtly by gathered by Aristotle not õly in his bookes of demonstration (which can not be understand without Geometry) but also in all his other workes[1]....And al be it the chief learĩg be the diuine scriptures, which instruct the mind principally, & nexte therto the lawes politike, which most specially defẽd the right of goodes, yet is it not possible that those two can long be wel vsed, if that syde want that gouerneth health and expelleth sicknes, which thing is done by Physik, & these require the help of the vij. liberall sciences, but of none more then of Arithmetik and Geometry, by which not only great thinges ar wrought touchĩg accõptes in al kinds, & in suruaiyng & measuring of lãdes, but also al arts depend partly of thẽ, & building....[2]

In his preface Recorde further discussed "the commodites of Geometrye, and the necessitye thereof", and there put remarks into the mouth of geometry thus:

> .....I am in nature a liberall science.....can no humayne science saie thus, but I onely, that there is no sparke of vntruth in me....(and) if I should declare how many wayes my helpe is vsed, in measuryng of ground, for medow, corne, and wodde....I thinke the poore Husband man would be more thankefull vnto me, then he is nowe....(for) this may he coniecture certainly, that if he kepe not the rules of Geometrie, he can not measure any ground truely.[3]

Recorde however, while in the Pathway to knowledge he indicated that one might expect 4 bookes, the forth of which "teacheth the right order of measuring all platte formes, and bodies also, by reason Geometricall" in fact gave only the first two, which were purely concerned with Euclidian geometry itself, and not with its application.[4]

Not long afterwards however, Leonard Digges in his Techtonicon,[5] gave instruction on the taking off of areas of simple geometrical figures and the use of the square and cross staff. He explained in his preliminary section:

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1. Recorde went on to adduce Plato, Aristotle's "master", and the inscription over his school entry.
2. Sg.-ʃ-ib/ija. From the dedication to prince Edward.
3. Sg.-ʒ-iiii a/b. He went on to mention the use of geometry by "Carpenters, Caruers, Joiners and Masons, Painters and Limmers". He wrote also that "The shippes on the sea.....were firste founde, and styll made, by Geometries lore. Their Compas, their Carde, their Pullies, their Ankers, were founde by the skill of witty Geometers". (in verse) and mentioned many other trades. Also the use of Geometry in Rhetoric, saying Aristotle supported him here. In logic, in philosophy, physics. He also suggested that "lawes can not well be established, nor iustice duelie executed without geometricall proportion". Bacon's glass for seeing at a distance he insisted did not function "by power of euyll spirites. But I knowe the reason of it to bee good and naturall, and to be wrought by geometrie (sythe perspectiue is a parte of it)......(Sg. ʒiijb)
4. The title page mentioned the use of geometry in this way, and the "arguments of the foure bookes" to the same effect, were listed on the verso of the title page. Recorde, born c. 1510, took a B.A. at Oxford in 1531, and in the same year became fellow of All Souls. Later he moved to Cambridge and took his M.D. there in 1545. In 1547 he was in London probably practising medicine. In 1549 he was made controller of the Bristol mint. In 1551/3 he was surveyour of the mines and monies of Ireland. He died in 1558. (D.S.B. TAYLOR (1954)) In his preface to Bk. II of the Pathway to Knowledge Recorde listed a number of topics "appoynted shortly to be set forth by the author herof", including "The art of Measuryny by the quadrate geometricall"; "The art of measuring by the astronomers staff"; The art of makying of Dials"; The making and use of an instrument... not onely (to) measure distance at ones of all places that you can see together... but also therby to draw the plotte of any countreie"; "The use bothe of the Globe and the Sphere, and therin also of the arte of Nauigation".
5. The first edition seems to be 1556 for it is so noted on the tittle pages of many later editions. However no listing of this edition has been noted. 1570 London edition used here.

> Although (gentle Reader) manye excellent in Geometry, vpon infallyble grounds haue put forth diuerse most certaine and sufficient rules, touching the measuring of all maner Superficiecis: yet in that the art of numbringe hath bene required yea, chiefelye those rules hid, and as it were locked up in strange tonges....[1]

hence his writing of this work, and his resolve to later publish,

> ....a volume contayninge the flouers of the Science Mathematicall, largely applyed to our outward practise, profitablye pleasaunte to all maner of mē of this Realme In the meane time I shall desire the Artificers aboue named (i.e. Landmeaters, Carpenters and Masons) to be contented with this litle Book ..![1]

Leonard, Thomas Digges' son, in Pantometria (London 1571) published some of his father's writings relevant to surveying (perhaps some of those referred to by Thomas, as noted above). In the dedication it was explained that:

> .....the veratie of these experiments and rules shall neuer be impugned being so firmely grounded, garded, and defended with Geometricall demonstration, against whose puissance no subtile Sophistrie or craftie coloured arguments can preuaile.....(when) as fragrant flowers selecte and gathered out of the pleasant gardynes Mathematicall, meete to delite any, noble, free or well disposed minde, and profitable frutes seruing most commodioslye to sundry necessary vses in a publike weale.[2]

The preface further continued:

> ......Geometrie for the certayntie therof haue suche a priuiledge as fewe other Sciences, beeing so fortified with Demonstration that no Precepte or Rule thereof for the veretie can be reproued......And to leue Philosophie, how necessarie it (i.e. geometry) is to attayne exacte knowledge in Astronomie, Musike, Perspectiue, Cosmographie and Nauigation with many other Sciences and faculties,.....the skilfull in Architecture can applye the Stereometria (i.e. in measuring of bodies) to serue his turn in preordinance and forecasting both of the charges(etc).....so Planimetra may serue for disposing all manner grounde plattes of Cities, Townes, Fortes, Castles, Pallaces or other edifices. The Marshall of the field shall also most speedely thereby appoynt place conuenient for his Campe......Also in suruaying, parting and diuiding of Lands and woods, it is most requisite aswel for exact as speedye dispatch therin....The other parte named Longimetra (i.e. distance measuring) the ingenious practizioner wil apply to Topographie, fortification, conducting of mines under the earth, and shooting of great ordinance.....a gentleman especially that professeth the warres, aswell for discoueries made by sea, as fortification, placing of Campes, & conducting of Armies on the lande, how necessare it is to be able exactly to describe the true plattes, ...will confesse these Geometricall mensurations most requisite.... And for science in great Ordinance especially to shoote exactly at Randons (a qualitie not vnmeete for a Gentleman) without rules Geometrical, and perfect skill in these mensurations, he shall never know any thing...[3]

The first book of Pantometrica (Longimetra) dealt with the use of the square, and triangulation. After explaining the taking of bearings from two stations to draw a plan, Digges continued:

> Thus passing or chaunging your stations, you may make sauerall plattes, contayning the true proportion and distances of townes, villages, portes.... and all other notable places through an whole Realme....

and gave detailed instructions about how to put all the separate plans into one sheet in his next chapter.[4]

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1. f. (iia). Leonard Digges, born c. 1520, attended Lincolns Inn in 1537. He published an Almanac and prognostication for sailors in 1555. He probably died shortly after 1558. D.S.B.
2. sg. +iib.
3. Sg. Aib/iiib.
4. Bk I: Cap. 35. In the second book, Planimetra, Digges dealt with the taking of areas: in the third, Stereometry, with solids. The fourth book composed by Thomas on the regular geometrical solids, was added to the earlier writings of his father, about which he explained, "I haue thought good to adioyne this treatise of the 5 Platonicall bodies, meaning not to discourse of their secrete or mysticall appliances to the Elementall regions and frame of Celestiall Spheres, as things remote and farre distant from the Methode, nature and certaintie of Geometrical demonstration". (Cf. renaissance Platonism). Thomas born in 1546 ?, published on astronomy in 1573. Became an M.P. in 1572. He published Stratioticos in 1579, and was later involved with Dover harbour and fortification works there. He died in 1595. D.S.B.

Edward Worsop in his A Discoverie of sundrie errours and faults daily committed by Landemeaters, ignorante of Arithmetike and Geometrie (London 1582) explained:

> There is not any that can measure lands as it ought to be except he first be wel instructed, studied, and exercised in the sciences of Geometrie and Arithmetike.[1]

Worsop considered that the art of surveying in his time was in a very poor state, of which condition, he explained,

> The abusing and contemning of the Mathematicalles is the chiefest cause.... (which had arisen because) In the time of Poperie mosts singular knowledges were shut up. A Ciceronian, was accounted an heretike. They could not abide the opening of learned knowledges. They made darkeness and ignorance, two of their pillers. They fedde the people with scumme and drosse, as well in humane sciences, as in diuine. For as in stead of diuinitie, they brought in superstition and idolatrie: so in stead of the pure Mathematicall knowledges, they used coniurations, soceries, inuocations of spirites, enchauntments, and other vnlawfull practises, under the names of Diuinatorie and Judicall Astrologie.[2]

Such illegitimate use of mathematics Worsop was much against and he stated that he hoped:

> ....that it would please God, to stirre the Queens Maiesties heart, and the heartes of her honourable Counsell, to appoint learned Diuines, and Mathematicians of her Realme, to cull, and seperate, these ill doctrines (i.e. divination and judical astrology) from the good, and lawfull mathematicall sciences...The Mathematicals being greatly applied to sundry vaine, and vngodly practises, and little thought on, or regarded, to bee applyed to such weightie causes in the common weale as most requisitely they ought.[3]

As to the nature of Mathematics Worsop, explained:

> He that hath cunning in mathematicall sciences is called a Mathematician. And those learnings, or sciences, which may plainely be proued by true demonstration, apparant to sense, are called sciences mathematicall. Philosophe, Logike, and certaine other worthy doctrines, are not learned by most certaine demonsration, but perceived by reason, and studius searche. Most men wrongfully conceiue, that certaine vnlawfull practises attributed to Astrologie are parts of the Mathematicall sciences, which chiefely bringeth such great discredit, and contempt of Mathematicians, and of the pure, and single mathematicals. Some professing Astrologie, impudently vsurpe the name of Mathematicans, as popish and superstious Priests, the names of Diuines.. ....They make the mathematicals cloakes to couer their wicked doctrines....

However Worsop's treatment was intended for the "unlearned in Geometry". For a more mathematical approach he recommended Euclid, Techtonicon and Pantometrica, where,

> ....touching the Mathematical part of suruie: you shall there perceiue, what great pleasure, and commoditie, is receiued from learned, and artificial writers.....[4,5]

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1. Sg. D4b. 2. Sg. E3b/4a. 3. Sg. G1a. 4. Sg. F3a.

5. Worsop was a London surveyor aquainted with Sir Henry Billingsly, and much influenced by Dee's preface to Euclid. TAYLOR (1954). He explicitly praised Dee in his work (Sg. G3b.) and mentioned a Doctor of Divinity -- known as learned in Greek who "would ofttimes say, that Logike and Philosophie, could not rightly, and perfectly bee vnderstood except some reasonable vnderstanding of Arithmetike and Geometry, were first had."(Sg. F3b.), possibly referring to Dee who was often know as Doctor Dee. Worsop pointed to the use of geometry by Masons, Carpenters, Joyners, Paynters, clockmakers, Ingenors. However he did not consider surveying to be a mathematical art entirely, but divided it into three parts Mathematical, Legal and Judical (Sg. I3b.) the last two being concerned with the sorts of issues Fitzherbert and Leigh dealt with, and who were mentioned by name by Worsop.

Later English works on the same lines included Cyprian Lucar's Lucarsolace (London 1590);[1] John Blagrave's Baculum Familliare,....of the making and use of a Staffe (London 1590);[2] Richard Agas' A prospect to platting of Lands and Tenements for Surveigh (London 1596);[3] Bk. I of William Bourne's Tresure for travelers (London 1578) where the cross staff, quadrant and triangulation were discussed.[4]

Thus during the 16th. century English published works on surveying suggest a shift from an approach based on the office of the surveyor, and much concerned with particular aspects of the social and physical milieu in which he worked: the legal system under which land was held, the particular uses to which the land was put, and the values that were attached to the land with which he was concerned. The geometrical mensuration of land being only a minor, albeit not one that could be totally ignored, aspect of the art. While later a shift tended to appear towards a technique focusing on the basis of surveying in Euclidean geometry. To some extent the shift being accompanied by justificatory remarks which emphasised the utility, necessity and pleasurableness of the practice of geometry.

In contrast as early as mid 15th. century Alberti in his writings attempted to extend and elucidate purely geometrical aspects of surveying, divorced from any consideration of particular details or practices of the surrounding society. However, while Pacioli emphasised the value of surveying as a mathematical art, in the context of the justification of the value of mathematics, the influence of any such geometrical approach as that of Alberti, seems to have been relatively slight.

Rather in Feliciano's treatise in the earlier 16th. century, was expressed that (mathematical) theory relevant to surveying was sufficiently developed, and what was required was actual application of the straightforward principles of Euclidean geometry, rather than any further geometrical elaboration such as might be produced by a treatise writer.

It thus appears that while emphasis on surveying as a mathematical art increased during the 16th. century,[5] by reference to its basis in Euclidian geometry, yet there was little for the treatise writers to elaborate in the way of theory, because theory was so much simply Euclidean geometry,[6] in their view. What then tended to dominate writing on the subject was elementary explanation

1. Bk. I on geometrical measurment of distances and heights, and discussion of measures; Bk. II on the geometry of maps; Bk. III "....containing plaine certaine; and infallible rules by which an ingenious Reader may learne to make any triangle, square, or long square, to erect a plumb line vpon any part or point of a line, to divide any circle"; Bk. IV on the healthyness of sites.
2. "Newlie Compiled, and at this time published for the speciall helpe of shooting in great Ordinance, and other millitarie seruicies." T.p.
3. Agas stated (p. 2) "The practice hereof for surueying of landes and tenements, is but now, scarsely established: not withstanding I doe affirme and vndertake, that it is certaine, perfect, and true, without any want or defect." The work was mainly a pleas for the use of the theodolite, as against plane table methods.
4. Other English writers in this area are dealt with in the Navigation section below.
5. In contrast to Alberti's work in Architecture and perspective there seems to be little sign that his Ludi mathematici was widely read.
6. Any too emphatic argument about whether Gemma Frisius was or was not the first to elaborate the notion of triangulation, for example, thus appears somewhat otiose. The problem seems not to have been to elaborate any such geometrical technique, for this appears to have been no great problem, at least for anyone interested in geometry, like Alberti. Rather it seems to have been whether there was any great point in publishing any such elaboration, when actual surveying practice was so very distant from the production of the resultant 'pictures'. The position which Tartaglia might have held of a master of the abacus and surveyor, in other words of a computational expert, supports the notion of a surveyor as basically this kind of expert, as expressed by Feliciano and other.

of computational aspects of the geoemtrical art, and the use of particular instruments, particularly the traditional square, but also the staff, with later writers often attempting to push the use of specific instruments of their own invention in order to facilitate the practice of surveying as a geometrical art.

Attempts to justify this geometrical approach, in the published treatises do not seem to have been too emphatic, although from time to time undoubtedly the pleasurablenees and utility of geometry and mathematics was emphasised. On the other hand works on the computational aspects of the art, which often but a part of treatises including important section on arithmetic, tended to emphasise the value of tbe both arithmetic and geometry as necessary particularly to the merchant, in order that everything could be carried out regularly and rationally.

II:(5): Navigation and charting, map making, Geography and Cosmography

While navigation based on the mathematical description of the heavens was extensively cultivated in western Europe during the modern period, in other cultures rather different techniques have been cultivated with no little success.

The navigational methods of the Pacific Islands have been studied with interest by westerners since at least the last century, and while the subject has not been without its controversies, these methods provide striking evidence of indigenous navigation methods with their own particular effectiveness. Recent interest in the field has helped to clarify some of the problems involved. On the one hand Kjell Åkerblom attempted to take a 'hard-headed' look at the actual evidence (mainly from western accounts based on information gained from local informants) in order to assess the nature and effectiveness of the techniques involved, and arrived at the conclusion that "Polynesians and Micronesians accomplished their voyages, not thanks to, but in spite of their navigation methods."[1] In stark contrast, the efforts of David Lewis[2], which included the carrying out of voyages in the Pacific under the guidance of navigators who preserved the traditional lore, have shown the effectiveness in practice of these traditional techniques.[3] Particularly impressive was a voyage made by two navigator half-brothers, which involved a 422 mile ocean crossing by reference to traditional instructions for that voyage; which same instructions the brothers had learnt over 30 years previously from their father, who in turn had learnt them orally many years before, and yet had successfully preserved them, like his sons, without ever having made the voyage.[4]

What particularly emerges from Lewis's work is the wide range of techniques employed by the navigators of the Pacific Islands. For example the use of the direction and nature of wave swells as important aids to navigation,

1. Astronomy and Navigation in Polynesia and Micronesia (Stockholm 1968), closing remarks.
2. We, the Navigators: The Ancient Art of Landfinding in the Pacific (Canberra 1972) & The Voyaging stars: Secrets of the Pacific Island Navigators (London 1978). The former is the more rigorous account, and an extensive bibliography of the subject can be found in it. The latter is useful for anecdotal material, and includes later developments.
3. Another recent work, Edward Dodd Polynesian Seafaring (London 1972) is not very satisfactory. Dodd attempted to make much of a guidance technique involving two stars which gave directions (at rising and setting) 180° different, on line with the course between two islands. According to him, as long as the navigator kept these stars continually bearing 180°, in difference, he knew he was on course, and that when this condition did not hold the navigator knew he was off course and had only to steer to bring them into this condition again in order to get back on course.(p.48/9) But observationally the stars are in practice infinitely distant, and hence once bearing 180° different they would continue to do so what ever course was steered. Ackerblom stated that this technique would be of little use because one would be too far off course before such a variation was detected (Op. cit. p. 32)--a rather odd remark seing as by then one would probably be outside the solar system.
4. LEWIS, D. (1978), p. 176/8. The voyage was from Satawal to Saipan in 1976. It was made not in conjunction with Lewis but apparently stimulated by motives of emulation in the face of the achievements of of other navigators with Lewis. It was all the more impressive in that in inlvoved no back up craft, or emergency western navigation equipment, with which the brothers were unfamiliar anyway. The ostensibly much more impressive voyage of the 2,500 miles between Hawaii and Tahiti, made in conjunction with Lewis in 1976, was in contrast a much more stage mannaged affair, and involved Lewis and others giving geographical information to the navigators, because their traditional information did not cover the whole area of the voyage. (See LEWIS (1978) p.195/200). It did however substantiate the effectivness of the techniques involved given the relevant information. Nevertheless the shorter voyage from Satawal to Saipan remains crucial for it indicates the ability of the oral tradition to preserve the traditional knowledge in sufficiently accurate form even when it was not monitored by continual usage. The brothers apparently set off with little preparation more than that involved in dumping a sack of staple food in their canoe, the price of failure being possible death.

used to be thought to be very much the sole prerogative of the Marshall Islanders,[1] but Lewis discovered that this technique was employed over a very much wider area, and was commonly an adjunct to the traditional star lore found in so many areas.[2] Thus traditional star lore provided the navigator with information as to which star or stars, on rising or setting, indicated the direction from one particular island to another,[3] during the hours of darkness; and then during the day swell direction functioned as an important aid to maintaining a true course.[4] Further, reflected and refracted waves provided important clues for homing in on an island once its vicinity had been reached, in navigation in many parts of the Pacific. This homing in on islands was an important aspect of Pacific navigation, and a wide range of indicators were used to accomplish it. Along with swell pattern, bird behaviour, cloud patterns over islands and shallow areas, and sun reflection in the atmosphere and from clouds, and apparently some kind of luminescence in the water which it was claimed could be detected from 80 to 100 miles out,[5] all were used to aid these navigators in homing in on their destination. This ability to detect the direction of islands from a distance was then all the more useful by the geographical fact that many of the pacific islands form chains of islands and reefs, which formed a screen and acted as a block target towards which the navigator had only to be roughly directed to come within detecting distance of one island, from which when sighted he could direct himself towards his actual destination.[6]

But Lewis found other techniques at work as aids to these basic methods. While directional stars were recognised as giving the course for particular islands, quite distinctly, zenith stars were also known to be associated with particular islands. That is, a particular star was known to pass over head when one was on the latitude of a particular island, and hence functioned as a further independent aid to its location.[7] In addition sea temperature may have helped position location,[8] and observation of wave behaviour on occasion aided assessment of current and hence drift.[9]

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1. See DAVENPORT (1960) for a discussion of their techniques. Wave swells were used in two different ways. On the one hand, set up by prevailing winds over long reaches they had a relatively constant orientation and so provided directional clues when out of sight of land. On the other reflection and interference patterns around and between islands gave indication of the direction of islands.
2. (1972) Cap. 7. (1978) p. 30/31. The main difference being that the stick maps, as teaching aids for instruction in swell patterns, seem to have been confined to the Marshall Islands. LEWIS (1978) p. 119.
3. In a somewhat more sophisticated form the navigation of the Pacific Islands did not depend so much on many discrete pieces of information about particular stars relating to particular courses between particular islands, but on a star compass, in which a whole series of stars were recognised as a series of (unequally spread) points around the horizon in a more general orientating scheme. See LEWIS (1972) Cap. 2.
4. It also, of course could function as a direction indicator at night when the sky was overcast. Ibid Cap. III. 5. LEWIS (1972) p. 208/15.
6. See LEWIS (1972) Pt. 4, where the whole problem and the different indicators are discussed. The basic nature of the pacific islands techniques, involving directional and sophisticated island detection techniques make it clear how dangerous it is to consider these method in terms of accuracy on anything like the model of western astronomical navigation, in contrast to considering them as a total package with its own effectivness. That is, if one attempts to assess these methds in terms of how closely a traditional navigator is likely to know his 'correct' position, after a particular distance run, in order to assess whether he is likely to be able to set the exact course to arrive at any desired island, one gets a false impression because this tends to ignore the effectivnes of his dectional ability. (Ackerblom, at least in part, tended to under estimate the value of these techniques because he thought in this way.) This is in contrast to (pure) western astronomical navigation which depends on knowing ones position at a particular grid reference at any one time, ignoring (at least at the theoretical level) the sort of knowledge that improves homing-in techniques. In a way it has taken the sophisticated device of radar to provide the westerner with the equivalent of these pacific techniques, although in practice for many centuries seamen often used such local indicators as bird behaviour, and sea-bed constitution, as similar aids. 7. (1972) p. 233/46. 8. Ibid. p. 248 & (1978) p. 74.
9. (1972) p. 110/113; (1978) p. 44. (Something seemingly inherently possible in western eyes sometimes -- see ACKERBLOM (1968) for example, p. 46/7 "The set and drift of currents...could only be judged and allowed for with sufficient accuracy when land was in sight.") Lewis suggested this phenomenon was due to upper layers of water moving over stationary or contra flowing lower layers.

In general then, the Pacific Islanders' navigational skills involved a large number of techniques which each in its own way aided the process of getting from A to B.[1] Their traditional knowledge tended to amount to a large number of discrete pieces of information.[2] This information tended to be personal, secret, and learnt only by means of a very long apprenticeship intimately connected with the actual practice of the art.[3] Its application most characteristically involved a high degree of observational skill learnt only through long practice.[4] The tradition was further almost entirely an oral one, and almost entirely devoid of the use of anything like maps.

But the most striking overall characteristic of pacific navigation was its rootedness in its own particular region and its dependence on specific features of that region: as for example, the regular swells developed by the prevailing winds; the islands as small and distant so that they could be considered as points setting up interference patterns with these wave trains; and atmospheric conditions which allowed cloud formations and back light to be significant indicators; among many other factors, such as bird behaviour. Similarly, while star lore formed an important aspect of the techniques involved, it seems to have been generally approached by reference to specific local relationships between specific islands and particular stars, rather than through any general account of the heavens and general relationships between points on the

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1. It is the additive effect of these techniques that makes it so difficult to assess them as a whole from second-hand description. Many in themselves seem relatively crude and fairly 'inaccurate'; thus Ackerblom attempting to assess them one by one in terms of some 'objective' accuracy tended to underrate their overall effectiveness. But it appears that it is this additive effect that makes it possible for these navigators to perform so well: given such a wide range of indicators, if one is not present, the chances are, one or more others will be; equally this kind of redundancy must help to reduce errors. Further, given a skill of this nature it seems almost totally impossible to consider it at second-hand and assess it for its effectivness, because each aspect is likely to be quite low in that very quality of 'demonstrability' that Tartaglia (with others) called for in 16th. century fortification, and only in actual use within the complex locality to which it belongs, can its effectiveness be 'demonstrated'. (See the Tartaglian argument on form II p. 23/6.)
2. As of steering stars for particular islands, see LEWIS (1978) p. 123. The star compass in contrast, to some extent integrated information into a general framework. To some extent an astronomical 'picture' of the heavens seems also to have been used, but the evidence tends to suggest that this 'picture' was very much subordinate to the art of navigation (LEWIS (1972) p. 80), and even to the learning of star information. (LEWIS (1978) p. 123.) The zenith stars and the course stars were simply considered as discrete pieces of information for example, it appears. However the knowledge involved was not always of the form of site, or task specific, discrete pieces of information. The phenomena of wave reflection and refraction around islands formed a theory in the sense of a general account relative to idealised objects, which applied to any island.
3. The Marshall Islanders' stick maps seem to have been only readable by their makers, for example. See DAVENPORT (1960) and LEWIS (1978) p. 118. LEWIS (1978) p. 134, describes how one navigator was taken to sea for formal instruction at 6 years of age, and spent the subsequent 12 years in training. While social pressures seem to have been influential in helping to maintain secrecy in such knowledge, its very relation to so many discrete pieces of knowledge, and the training necessary to aquire and make use of that knowledge must have helped to maintain such a quality.
4. Lewis' accounts are full of descriptions of how the local navigators had to try very hard to get him to recognise many phenomena, and in may cases insisting on the existence of effects that Lewis was never able fully to see, although these effects apparently provided his teachers with effective information. Again given such a quality attempts to assess the effectiveness of the techniques involved by considering specific techniques from verbal descriptions, are only too likely to underestimate the possibilities. In contrast western astronomical navigation techniques as they were cultivated tended not to involve the build up of skilled observation techniques through practice, but rather the search for gadgets or instruments to do this in a mechanical way. In other words to contrast some 'objective' observable datum--which anyone could recognise--with that same datum in some way multiplied or clarified by some instrument. Thus again Ackerblom on this point seems to have been influenced by western epistemological consideration in attempting to consider the Pacific techniques in terms of similar constant 'observables'.

earth's surface and the heavenly bodies.

Thus the great mass of information involved in the tradition, together with is close relation to local features, could not have been transferred to other parts of the globe, without the apprentice going through a process of learning a whole new system of information, even if the same types of skills or something like them might equally be employed in other regions: and while the genesis of the skills and information of the tradition is, and is likely to remain, very obscure, it seems difficult to conceive any process by which such might have evolved or been created, but piece-meal by experience aquired through the day to day practice of navigation and its extension through migration and contact, whether accidental or planned.[1]

Techniques of navigation in the western medieval world were in some ways similar to, and in others very different from, those of the Pacific Islands. The most striking characteristic of late medieval sea going was the use of the portolan chart[2] representing the area through which the vessel sailed, a usage almost entirely foreign to the navigators of the Pacific. The nature and roots of these charts is clear: they depended on the use of the magnetic compass, and were built around information about courses between different points, particularly from feature to feature along the coast, and estimates of the distances involved.[3] That is, from just the sort of information fundamental to the true portulans[4] (or rutters as they were sometimes later called) which contained verbal instructions for sailing from point to point. The charts themselves showed a series of compass roses, generally in a standard layout,[5] the radiating lines that covered the sheet facilitating the taking off of courses. From an early period these charts appeared complete with scale for the assessment of distance. These portolans thus involved a certain codification of the sort of information that was contained in the true portulans, and undoubtedly a good deal of adjustment in order to make the different pieces of information tally in the sheet.

However, while the general background to the creation of the portolan chart, and the type of navigation associated with that device is clear--by compass and estimates of distance, the actual genesis of the early examples is by no means clear, for the earliest examples appear in full blown form with little evidence as to their evolution. While the great mass of the actual information contained in these charts undoubtedly evolved from the experience of the mariner and actual seagoing,[6] the actual construction of the

1. Argument continues as to whether colonisation of the Pacific Islands took place as a result of planned migration, or through accidental voyages. There is no need to linger over these arguments, for all that is involved here, is the nature and effectiveness of such skills.
2. The stick maps of the Marshall Islands, it is very generally agreed, were teaching devices, which were never taken to sea. Portulan charts see discussion of terms II p.x. Striking particularly in that it is the evidence of these charts that allows a certain picture of medieval navigation to emerge.
3. The 'exegeration' of costal features, together with the concentration of information along the coast lines, both in themselves make this clear.
4. Such sailing instruction could contain all sort of other kinds of information of course, such as on tides.
5. This layout was clearly an arbitary convention, in contrast to lines of latitude and longitude, which can not be shifted without altering the representation (unless their designations are altered), while the compass roses of the portolan charts, as long as their direction was maintained constant could be placed anywhere and in any relationship in accord with what was considered handiest without altering the chart one whit.
6. Estimation of speed and course made good, rather than course steered, to any useful degree of accuracy, must have required a good deal of skill and experience. In the last century a method was recorded for assessing speed used in Indian waters, which involved throwing a chip of wood overboard, and pacing along side it: the observer, having learnt the skill of assessing his own speed of walking, could then estimate the speed of the vessel. FERRAND (1928) Congrave. A kind of observational skill which must have required a good deal of experience to practice. However counting techniques of one kind or another were probably most common here.

of such charts, may have been very much a land based activity.[1] The use of a standard pattern of roses also suggests that a technique of chart making, as an activity distinct from sea going, which made use of the mariners particular experience, existed from an early date.[2,3,4]

Be that as it may, the evidence from the later period, particularly that of the renaissance, when such charts were continually produced, indicates clearly that such charts were built up from the experience of navigators as they made their voyages of discovery, even though the construction of actual charts was not simply a matter of sea going experience. Thus navigation by means of the portolan chart, like that of the Pacific Islands, grew out of the actual practice of seafaring primarily, and involved the application of skills which were most characteristically those most easily aquired through practice of the craft involved. Further, pacific navigation methods involved a high dependence on local features for their techniques, and to some extent similarly medieval portolan chart navigation depended fundamentally on information which evolved out of experience of an actual locale in the course of day to day practice of seagoing, the portolan charts being organised around such information and existing only in so far as that experience, with the information that resulted, was available.

Later navigation in the western world in contrast, depended primarily (at least at the theoretical level) on a general mathematical description of the heavens to provide information as to latitude and longitude, and hence was rather different. A portolan chart layout containing merely the compass roses represented no particular region, only when one particular feature had been recorded on it can it have reference to an area of the earth's surface. In contrast a chart based on a grid of longitude and latitude, once those grid lines have been designated by relevant numbers, relates to a particular region of the earth's surface, whether any particular feature of that region is known or not. Thus the use of position finding techniques based on astronomically determined coordinates, involves a technique which is immediately transferable to any region of the globe: and accuracy of position finding on the sheet in no way depends on previous knowledge of that or other areas. On the other hand the use of portolan charts and their accompanying navigational techniques, involves the constraint that position location on the map can not be achieved until some feature of the region to which the map relates is known; and the accuracy of position finding, whether to construct a map or to locate ones position on the map relative any other locality, depends on the accuracy of a string (or strings) of information which connects those localities, in the case of the accuracy of the map;

1. The sort of drawing and manipulative skills in the sheet of the map were hardly the sort that one would have expected the experienced 'sea-dog' to have cultivated. The draughtsmanship of the early charts is to a very high quality and relatively early specialised chart makers are known.
2. If portolan chart making had evolved through individual mariners plotting their own information one would have expected all sorts of rose patterns to occur. However the possibility exists that this did occur and these 'crude' early examples have all perished. Nevertheless the high quality of early examples would still appear to represent very much a land based activity.
3. Traditional geographical values, as for example in the length of the Mediterreanean quite possibly influenced the construction of the early portolans. The literature on portolan charts and the associated navigation techniques is very extensive, but sufficient agreement exists about the general characteristics involved to obviate the need for any detailed discussion.
4. Of course navigation in the middle ages was not confined to portolan chart techniques. On the one hand tables are known which relate course actually sailed to distance from ones desired course. (See TAYLOR (1971) p. 117/21) On the other hand many voyages clearly depended mainly on traditional knowledge about currents and tides, position location by reference to local features such as the depth and nature of the bottom, and on the use of sailing directions containing such information. See for example WATERS (1967) p. 181 et seq. on the Sailing directions for the circumnavigation of England, and elsewhere ibid.

and on the string of information representing ones course, which gives ones position in the map. Once either of these strings are broken one can have no knowledge of where one is in relation to home base. An astronomical fix in contrast always provides (where it can be achieved of course) a basic piece of information no matter how poorly the features of the surrounding area are known.

Further the use of portolan techniques depends on experience of a region in a much more fundamental way than does the technique of astronomical position fixing. Where a region is frequently sailed through the information provided in the chart will be more accurate: and equally when it it well sailed over and such charts exist, when the string of information that constitutes the past course taken has been broken, whether through storm drift, or culmination of error, once one coastal feature or series of features has been discovered ones location again becomes known. In contrast in infrequently sailed areas, once a coast line has been lost sight of and course information has become unreliable, the next new piece of coast line (or island) can not be located on the map. Equally even when rudimentary charts are available once course information has broken down the poverty of the information available makes it much less likely that on finding a piece of coast line one will be able to reliably locate ones position.[1] Thus the greater the frequency of passages within an area, the more satisfactory portolan techniques tend to be.

In contrast the use of astronomical position fixing either of oneself or geographical features simply depends on the effectivness of ones technique, while accuracy is (roughly) constant in every part of the globe, independent of how little or how much that region has been previously sailed over, although of course the <u>use</u> of that accuracy increases strongly as information increases with continued exploration, in uncharted waters.

Thus while the techniques of the pacific islands depended very much on local knowledge and grew out of the practice of seagoing, medieval navigation equally tended to grow out of the activity of shipmasters, and to be quite heavily dependent on the existence of the local knowledge that experience involved, although to some extent that type of information was dependent on a codification process in a land based activity. On the other hand the use of the compass, which functions over nearly all the earth's surface made that technique somewhat more transferable, and the use of the portolan chart made the knowledge involved somewhat less personal and more transferable. On the other hand astronomical position fixing had a basis in an external reference system which was pretty well transferable across the whole earth's surface, and gave the navigator a tool which did not depend on the growth of local knowledge and the experience that accrued about the localities sailed in.

The early growth of astronomical navigation and position finding in western Europe took place most extensively in Portugal during the 15th. century in the period of the voyages of discovery down the west coast of Africa, and later on to India.[2] However the precise dates of the appearance and

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1. Diogo Gomez de Cintre expressed just this difference about using a quadrant on a voyage to Guinee in 1462. "Et ego habebam quadrantem, quando iui ad partes istas, et scripsi in tabula quadrantis altitudinem poli arctici, et ipsum meliorem inveni quam <u>cartam</u>. Certum est quod in carta videtur via marinandi, sed semel errata, numquam redeunt ad primum propositum". GOMES (1959) p. 54. This passage comes from a section of the work referring to events of 1462, which date is usually given as the first known use of this technique. TAYLOR (1971) p. 159 for some reason states that this was in Gomes' voyage of 1456/7. Taylor described Gomes as 'a young gentleman', but according to GOMES (1959) Intro. he was born c. 1402. He spent many years in the service of Henry the Navigator and of course may have been using this technique earlier.

2. See PRESTAGE (1933) for a description of these voyages and the well known role of Prince Henry the Navigator. Some writers have suggested that astronomical methods are rather older, but ALBUQUERQUE (1972) Cap. I, discusses this idea in some detail and points out that the sources to support such a view are not available.

acceptance of the new techniques is by no means clear,[1] although the general nature of the rise of navigation tchniques so based, particularly with regard to astronomical observation in order to establish latitude, is well established. Traditionally many Jewish and Muslim astronomers had found refuge at the Portugese court,[2] and the role of such figures as the source of astronomical understanding in this process is hard to doubt. On the other hand when such influences began to take real effect is much more difficult to assess. Astronomical studies by Henry the Navigator and his use of astronomers to advise his captains on their voyages of discovery are frequently mentioned.[3] Yet there seems to be some doubt as to the reliability of such tales, or at least about the influence of such activities; and even the later 'Junta' of John II,[4] is by no means the well established body it is often taken to be. It is stated that in 1451 a fleet was directed with the assistance of "masters in astrology learned in the routes by the stars and the pole",[5] but more reliably the use of the quadrant to record latitude relative to navigation is known circa 1462.[6] Gradually then it seems, during the later part of the 15th. century methods for the determination of latitude by reference to the altitude of the pole star, and later by reference to the declination of the sun in the southern hemisphere,[7] began to become known and accepted and to some extent practised.

One well established figure in this process was Abrahm Zacuto, whose work, written at Salamanca 1473/78, was translated by his pupil Jose Vizinho from Hebrew into Latin, and published under the title of Almanac Perpetum at Leira in 1496.[8] This work, it is generally agreed, formed the basis of instructions to mariners (in itself not being suited to this) on matters relating to navigational astronomy, which were in all probability circulating in Portugese circles as aids to voyagers during the last decades of the 15th. century. The earliest known printed version of such a work however Regeimento do estrolabio & do Quadrante & Tractado da Spera da mundo is attributed to 1509, although it

1. The rigorous policy of secrecy held to by the Portugese court during the period seems at least in part responsible for this state of affairs and it is likely that many of the precise details of the process will never be known.
2. BENSAUDE (1912) p. 52 et. seq. lists the relevant figures and their works back to the 12th. century. 3. WATERS (1958) p. 46, as one of many.
4. ALBUQUERQUE (1972) p. 251/2 wrote: "A ideia de ter existido uma escola naval rudimentar em Sagres, tese desenvolvida pela historiografia romantica do século passado, está hoje inteiramente posta de lado. É mesmo muito duvidoso--como nesta lições procuramo mostrar-- que no tempo do Infante D. Henrique além do maiorquino Jaime de Maiora tivessem sido chamados cosmógrafos e astrólogos à corte do principe para se ocuparem da nautica astronómica, como pretendem ainda hoje algunas historiadores. No tempo de D. João II, quando os problemas da técnica de navegar se tornaram mais prementes, tambén não foi através de um simulacro de Academia que se procurou dar-lhes solução; o rei encarregava de estudar o assunto qualquer astrólogo que lhe merecesse confiança, consultava Diogo Ortiz, mestre Rodrigo ou José Vizinho, mas nunca pensou em organizar uma "Junta de Matemáticos" que só existiu na imaginação dos mesmos histórіografos". URE Prince Henry the Navigator (1977) agrees earlier writers were somewhat exaggerated the position (p. 98), but accepts the view that Henry encouraged his captains to take the cross staff with them and encouraged them to make observations on land with it. (p. 105)
5. Quoted in PRESTAGE (1933) p. 316. This might mean anything or nothing. The fleet carried the Empress Leonora wife of Frederick III from Lisbon to Pisa. The astronomers might have been mainly concerned with horoscopes.
6. See above p. 154, n. 1.
7. It seems that at first the navigators did not think in terms of degrees and angles but simply marked each place directly on their instrument as Diogo suggested. Then to get to that same latitude again one simply sailed till that same reading was found again. (Ibid.) Vasco da Gama in 1497 on his voyage to India, stood well out into the Atlantic to make his southing, then turned east and struck the coast of Africa just north of the cape. He made observations on shore to determine how far south of him the cape actually was. PRESTAGE (1933) p. 253. Nothing like this would have been possible with portolan navigation. In 1506 the Venetian ambassador Quirini reported to the Senate on how the Portugese reached the Indies, and described to them the taking of the declination of the sun. Ibid p. 323.
8. BENSAUDE (1912) p. 22. Zacuto was born in Salamanca in circa 1450 and died after 1510. He became professor of astronomy at Salamanca. In 1592 he went to Lisbon to take service with John II as a result of anti Jewish feeling in Spain. GR ENC PORT BRAZ.

seems this was not the first edition of the work.[1] Included was a Regiment of the North Star, and a table of declination of the sun, both for the determination of latitude.[2] The work was not merely a practical seaman's handbook but was issued in conjunction with a section on the sphere of Sacrobosco.[3]

During the same period, with the voyages of Columbus and the discovery of America, Spanish interest in the new methods grew. The <u>Casa da Contraction</u> at Seville, first organised in 1503 to administer and handle the American voyages and associated trade, in 1508 had the department of the <u>Piloto Major</u>, to take care of matters of navigation and map making, added to it, and training there was given at first by the portugese navigators. When the new navigation was later taken up by English writers, it was in fact the Spaniards rather than the Portugese authors that were followed.[4]

During the 16th. century a number of navigation treatises in this Iberian tradition were published. Martín Fernández de Encisio in his <u>Suma de geographia</u> (Seuilla 1519) gave some cosmographical discussion, included tables of the declination of the sun, and explained the regiment of the north, as well as giving geograhical information.[5]

Francisio Faleiro in his <u>Tratado del Esphera y del arte del marear</u> (Seuilla 1535)[6] in his prologue explained

> ....los brutos enla . tierra y cosas d̃lla paran; & los peces enel agua: las aues enel ayre: los moros y gentiles en la quinta essencia y en sus significaciones. Mas el christiano que por todo esto passare contemplando & viendo como el esphera y la orden della es la mas excelente y admirable obra entre todas las obras despues de la que dios a su semejança hizo: con mucha mas claridad conocera la gradneza/ poder/ y saber del que tal obra hizo: con mucho mas concimiento....[7]

and stated that the first part of his work

> ....trata q̃ cosa sea esphera y de la forma d̃lla: y q̃ especies cõtiene: y del sitio y calidad de cada vna: y de la ordẽ de sus mouimiẽtos .....En la segũda parte se trata del orizõtes y de zu variaciõ: y d̃les reglas delas alturas del sol y del norte/ cõ las declinaciones del sol y regimiẽto cõplido del arte del marear cõ reglas y exẽplos nueuamẽte escritas & muy necessarias.[8]

Pedro Nũnez explained in the dedication of his <u>Tratado del Sphera</u> (Lixboa 1537):[9]

> ....aciencia nam he outra cousa senão hum conhecimẽto habitua do no entendimento: o qualse acquirio per demostração....A sciencia não trata das cousas que sam somente ymaginarias falsas ou ymposiueys: mas das certas & verdadeiras.[10]

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1. Fasc. BENSAUDE (1914/19) Vol. I p. 8/9. Only one copy is known at Munich, whose title page is defective making the date unreadable, so that its date is only probable.
2. TAYLOR (1971) p. 162/3, took it as a representation of the state of practice c. 1580/1, as it contains a list of latitudes only going to the equator. But reasons of security migh well have precluded the inclusion of material for be southern hemisphere, and such an inference is somewhat dubious. ALBUQUERQUE (1972) p. 121 suggest that the first 4 yearly nautical tables were prepared for 1593/6. The regiment of the notth star allowed the height of the celestial pole to be determined from the pole star by reference to the guards. The regiment of the guards had been long known--from the time of Raymond Lull at least--as a time telling device. TAYLOR (1971) p. 145/48.
3. This is true of both the copies of early editions extant at Munich and Evora. See BENSAUDE (1914/19) Vol. I & II. BENSAUDE (1912) p. 70 points out that in the Munich copy the two frontespieces have the same basic illustration indicating that the two parts should be considered as a single work.
4. SALVAT. WATERS (1958) p. 62, 496. For further details see PULIDO RUBIO (1950).
5. Fernández de Enciso was active as a captain in the Indes in 1509/10. ENC UN ILL EU AM.
6. BENSAUDE (1914/9) Vol. 4.
7. Op. cit. Sg. aiija. Faleiro and his brother Ruy, the astronomer, left Portugal in 1517 with Ferdinand Magellan, who they proposed to accompany in his voyage that was to circumnavigate the world. Francisio, an experienced navigator was to be captain of one of the vessels. But this fell through. The brothers remained in Spain where Ruy . died. BENSAUDE (1912) p. 163.
8. Sg. aiijb.
9. Including <u>Defensam da carta de marear</u> & <u>Sobre certas duvidas ha navegação</u>. Fasc. BENSAUDE (1914/9) Vol. 5.
10. Op. cit. p. 3.

In his opening remarks to his section in defence of charts Nunez explained his intention to

> ....trazer nam somente cousas praticas da arte de nauegar: mas ainda pontos de geometria & da parte theorica.[1]

and further clarified his aim:

> MAs porque meu intento nesta pequena obra: he desculpar a carta das culpas & erros: de que todos generalmente a acusam: & nam as ygnoranςias: enganos: perfias & contumacias dos mareantes: quero trauar daqui: poys que faz ameu proposito: & me veo ternas mãos este lugar de Ptolomeu que tratey. Porque razam: sabendo a rota per que se nauega de hum lugar pera outro: & a distancia do caminho tambem he sabida: manda Ptolomeu tirar a terça parte dos estadios que ha na rota: pera que tirando per esta arte a desiguladade ou irregularidade: fique ho caminho continuado per derecto.[2]

Pedro da Medina in his Arte de Nauegar (Valladolid 1545) began his preface:[3]

> ENtre las virtudes, tãto es algũa mayor q̃nto cõlas otras mas se comunica. Por lo qual, la virtud de justicia es mas perfecta entre las otras virtudes, porq̃ mas comunica y participa con todas. Pues assi entre las artes el arte dela nauegaciõ es mas excelente que las otras, pues non solo comunica con ellas mas incluye ensi las mas principales, ea a sa saber, Arithmetica, Geometria, Astrologia. Estas tienen excelencia entre las mathematicas por las demostracion verissima que de sus conclusiones hazen. Y que esta arte tenga el principado y grandeza entre las otras artes, muestra se por tres razones siguientes. ¶ La primera por razon de su subtileza. ¶ La segunda, por razon de su certinidad. La terca, por razon de su prouecho. ¶ Allo primero. Quien basta a dezir vna subtileza tan grande q̃ vn hõbre con vn compas y vnas rayes sẽnaladas en vna carta sepa rodear el mundo...Alo segundo. Es tanta la certitud desta arte.....Prueua se en que acontesce venir vn piloto navegando, y tomarle vna torienta trezientas leguas enla mar, y de dia hazer gran cerrazon, y de noche tan escuro que estando a la popa de su nao no vee la proa y aun apenas el mastel, y dando muchas bueltas enla mar corriendo đ vnas partes a otras subiendo y descendiendo con el ympetu de los vientos y fuerça đlas mares, y cõ todo esto porla certinidad đl arte, saber el camino q̃. a ãdado y el lugar dõde esta, y llegado ala tierra toma puerto aunq̃ sea đ noche q̃ no vea la tierra.[4]

Later he remarked:

> EScripto esta en el libro đ la sabiduria, q dios hizo todas las cosas en numero peso y medida.[5]

and further that:

> VNa đlas cosas mas subtiles, y de mayor entendimiento q̃ enel arte del nauegar ay, es el altura đl sol, porq̃ esta enseña verdaderamẽte el camino q̃ el que nauega haze o a de hazer....Esta altura, es tante parte para la buena nauigacion, q̃ los que nauegan a partes remotas y muy distãtes no podriã hazer sus nauegaciones ciertas si est faltasse.[6]

In his Regimiẽto de nauegaciõ, Medina further explained:

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1. Sg. Bia, op. cit. p.117.
2. Sg. Biiijb. Pedro Nunez Salaciense was born in Portugal in 1502, possibly of Jewish parents and studied at Salamanca in 1521 and 2. He moved to Lisbon in 1524 or 1525 where he received his Bachelor's degree in Medicine and studied mathematics and astronomy. He was appointed Royal cosmographer in 1529 and made professor of moral philosophy at Lisbon University in the same year, in 1530 taking the chair of Logic. In 1531 and 2 he also held the chair of metaphysics. In 1532 he received his Licentiate in medicine. He took the chair of mathematics at Coimbre in 1544. In 1547 he was named chief royal cosmographer. In 1572 he was called by the crown to advise on weights and measures, and was also made professor of mathematics for pilotage and cartography. He died at Coimbra in 1578. He published on mathematical and astronomical subjects as well as on navigation. (D.S.B.) His remuneration seems to have been extensive. See FONTOURA DA COSTA (1969) p. 23/5.
3. This was a very influential work and appeared early in English and French translations.
4. Sg. aiiia/b. This of course was highly exagerated. Any sailor who behaved as is suggested would be nothing but a damn fool, particularly in the days when longitude was such a problem. In fact just a few pages before in his dedication Medina had written: (Sg.aiib) ".....y assi los mas pilotos solamente tienen el vso dela nauegacion por lo qual cada vna sigue su opinion a parescer, de dõde acontesce muchas vezes hallar se en vna nao nauegando dos o tres pilotos, y el vno dize que segun su cuenta la nao va nauegando por tierra, y otro seqũ la suya, dize q̃ la tierra la esta muy lexos...." But of course this defectivness of practice only showed the need for the true navigation in Medina's view; and in fact he continued "esto causa el carescer de la verdadera sciencia dela neuegaciõ....."
5. Bk. III Cap, XV. Op. cit. f. xxxiiijb.
6. f. xxxvja, Bk. IV Cap. 1.

> ENtre las cosas de gran calidad q̃ el ingenio humano inuẽto para sustento delos hõbres vna muy principal sue fabricar nauios en tãtes diferẽcias: y hallar arte para los gouernar y traer nauegando por la mar.[1]

and that:

> El primor y subtileza q̃ la nauegacion d̃ la mar tiene es tãto y tan subido q̃ conuino regirse en elle por los cuerpos celestiales.[2,3]

Martin Cortés in his Breue compendio de la sphera y de la arte de nauegar (Seuilla 1551), claimed:

> No q̃ero d̃zer q̃ el nauegar no sea ãtiguo......mas digo auer sido yo el p̃mero q̃ reduxo la nauegacion a breue cõpẽdio/ poniẽdo p̃ncipios infalibles y d̃mõstraciones euidẽtes/ escriuiendo pratica y theorica d̃lla/ dãdo regla dadera alos marineros/ nostrãdo camino a los pilotos/ haziẽdo les ĩstrumẽtos p̃a saber tomar el altura d̃l sol/ p̃a conoscer el fluxo y refluxo d̃l mar/ ordenar les cartas y bruxolas p̃a la nauegaciõ/ avisãdo les d̃l curso d̃l sol/ mouimeĩẽto d̃ la luna/ relox p̃a el dia y tan cierto q̃ en todas las tiasseñale las horas sin d̃fecto alguno/otro si relox ĩfalible p̃ la noches/ d̃scubriẽdo la p̃preidad secreta d̃la piedra yman/ clarãdo el nordestear y nordestear/ d̃las agujas.[4,5]

Juan Perez de Moya, in his Obra intitulada fragmentos mathematicos. En que se tratan cosas de Geometria, y Astronomia, y Geographia, y Philosophia natural, y Sphera, y Astrolabio, y Nauegacion, y Reloxes (Salamanca 1568/7) began his first book (on practical geometry as the basis for the rest of his work):

> GEometria, aun q̃ puede significar mas cosas, propriamente es Arte de medir la tierra, inuentada de los Egypcianos.....[6]

What followed was a very varied collection of remarks of a rather elementary nature on many topics, as indicated by his title, the navigation section including tables of the declination of the sun and a discussion of the regiment of the north.

In his Tratado de cosas de Astronomia, y Cosmographia, y Philosophia Natural (Alcalá 1573), Perez de Moya explained, in his dedication:

> LA CAVSA principal porque refiere Platõ se le dieron al hõbre los ojos, fue por el Astronomia, y assi cuẽta Diogenes Laercio de Anaxagoras Clazomeno, que siendole preguntado para que auia nacido enel mũdo, respondio que para ver el Cielo, y el Sol, y la Luna. Por esto sin otras muchas consideraciones se puede entender la excelencia delas cosas de que este libro trata. Y verdaderamente por esta arte vienẽ los hombres (como quien por los effectos busca la causa) en conocimiẽto de Dios, hazedor de toda la machina y fabrica del vniuerso con todo lo que enel se contiene. Porque quien aura de tan poco entendimiento, que alguna vez mirãdo el Cielo, y la hermosura de las Estrellas, y mouimiẽtos tan ordenados, que no se admire? y de la admiraciõ venga en desseo de querer conocer, o saber quiẽ fue el Architector di tal edifico? y quanto mas en ello pensare, ha llara ser estas cosas camino de adquerir alguna noticia de la immẽsa Sabiduria y poder de Dios, y de nuestra immortalidad. Y quien duda, sino que si por estas artes no fuesse viuiriamos tan confusos, que seria vide de Barbaros, o por mas claro hablar de Animales. Porque mediante los mouimientos de los Cielos, y Planetas, tene mas orden enel tiempo, que de sus mouimeĩtos se causa. Pues las cosas de Philosophia natural y Cosmographia, y las demas materias de Mathematicas que en esta obra se enseñan, nunca dexaron en todos los siglos passados de ser en mucho tenidas y alabadas, por ser como son causa de la comunicacion

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1. This is from the 1563 Seville edition, f.ija. An early edition, Seville 1552* is known. Other editions of 1543 and 1562, sometimes quotes, as for example by WATERS (1958), are somewhat doubtful. See PALAU Y DULCET (1954/5).
2. Ibid. f.iiib.
3. Born in 1493, Medina, a cleric, may have graduated from Seville. At some time librarian to the duke de Medina-Sidonia he taught mathematics and in 1538 Charles I commisioned him to draw charts and prepare pilot books. In 1549 he was named "cosmógrafo de honor". He made instruments and published also on more literary topics. That he ever practised navigation is in some doubt. He died in 1576. (D.S.B., which work does not know the Seville 1552 ed. of the Regimento, but N.U.C. lists a copy.)
4. f. iiib.
5. Martin Cortés de Albacar, of a noble Aragon family was in Cadiz before 1530 and died in 1582. (D.S.B.).
6. p. 1.

de todo lo que ay debaxo del Cielo. Considerando pues a quien materias tan altas deuiã offre cerse por su dignidad.....'

Rodrigo Zamorano in his handbook Compendio de la arte de navegar (Sevilla 1581), began:

TODA LA ARTE CONque se nauega por derrotas y alturas, se diuide en dos partes principales, Teorica, y Pratica. La Teorica da el conocimiento de la compostura de la Esfera del Mundo, en general; y en particular enseña el numero, figura y mouimientos de los cielos, principalmente del Primer mobil, noueno, octauo, quarto y primer cielo, le figura, cantidad y sitio de los Elementos, principalmente Tierra y Agua, y los circulos que enesta Esfera se imaginan, sin cuyo conocimiento es impossible nauegarse. La pratica enseña la fabrica, composicion y vso de los instrumentos que en la nauegacion siruen.....con el Regimiẽto del Sol, y de la Estrella, las reglas de la Luna, y de las Mareas, y la declaracion de la Carta: con otras cosas a esto pertenecientes.[2]

Among later works in this same tradition was the Hydrografia (Bilbao 1585)[3] of Andrea de Poza[4] Examen & Censura (Sevilla 1595)[5] by Simon de Tovar:[5] Regimeto Nautica[7] (Lisboa 1595) of Juan Baptista Lavanna.[6,7,8]

Published treatises on navigation[9], other than those by Iberians, were in contrast slow to appear. However Paolo Interiano published his Inventione del corso della longitudine at Lucca in 1551;[10] and John Taisner in his Opusculum Perspetue (Colona 1562) discussed magnetism after Pellegrini, for the purpose of navigation.

Then in 1581 Michael Coignet published Instruction Nouuelle..... touchant l'art de nauiguer (Anvers 1581). In this work he explained:

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1. Op. cit. p. 3. Juan Perez de Moya, born at the beginning of the 16th. century, studied at Alcalá de Henares and Salamanca. Ordained in 1536, he lived a very retired life to a good age, studying particularly in mathematical fields. ENC UNI ILL EUR AM. He published Libro de cventa....de las quatro Reglas generales de Arithmetica (Toledo 1554*) (PALAU Y DULCET (174877)). His Tratado de Geometria Pratica, y Speculatiua (Alcala 1573) was a much enlarged version of the first part of his Fragmentos Mathematicos on practical geometry. It contained a good deal on surveying and discussed such topics as the use of the square, the computation of areas, with something on volumes. The second work quoted was a reworked version of the remaining part of the Fragmentos Mathematicos to a great extent, and was published uniformly with the Geometry.
2. Rodrigo Zamorano was born in 1542 and became astronomer, mathematician and cosmographer to Phillip the second. He was named to the Piloto Major in 1586/9 and again in 1598. He died in 1620. In 1576 he published a Castilian translation of Euclid. The text from op. cit. f. 1a.
3. Which contained a long section of sailing instruction, together with a shorter section on the usual navigation topics.
4. Studied 9 years at Louvain and 10 at Salamanca where he was licensed in law in 1570. He later became professor of the Nautical School of San Sebastion. (ENC ILL UNIV EUR AM)
5. This work contained detailed geometrical instructions about the use of the staff and other typical navigational instructions.
6. Juan Baptista Lavena (Labana) was born possibly circa 1550 and died in 1625. He perfected his studies in Rome and became chronicler of Portugal to Phillipe III, and cosmographer to Phillipe IV.
7. A short handbook on the usual topics but including a table of the declination of a number of fixed stars.
8. In contrast to this tradition in Las Obras (Toledo 1539) of Antonio de Guevare, which contained Vn libro de la nautica del mare, the author expressed a rather different attitude, saying: "....mucho mejou nos estara raser gouuernado/ pre la q tiendo ano d'experiecia: que por el q tiene diez de sciencia." (Sg. AAiib) Guevara however was more concerned with the sailing of the ancients than that of his own time. Also the work of Diogo de Sa (Jacopo a Saa) De Nauigatione (Parisiis 1549) was of a different cast. In fact most of Bks. I to IV up to folio 86 constituted discussion about the nature of the mathematical sciences on very Aristotelian lines with continuous references to Aristotle's various works. Only in Bk. III (f.86/106) did Sa briefly deal with some of the mathematics of navigation. Sa, a portugese, served many years in India. He distinguished himself at the battle of Cheul (1528), and the taking of Beith (1531). ENC UNI ILL EUR AM.
9. This excludes from consideration the Routiers or sailing directions. On which see the work of Pierre Garcia, and the French and English works in this field in WATERS(1967). Giglio Georgio Giraldi's De Re Nautica (Basilaau 1540) was about nautical matters in the ancient world. Michelangelo Biondo's De Ventis et Nauigatione (Venitijs 1546), merely considered knowledge of the winds and its application to navigation. Very few relevant works seem to have been published in Germany also. ANTHIAUME (1920) gives a summary of the state of the art and the different works published in different countries, in the 16th. century.
10. In a uniform edition with Ristretto Delle Spera. Of his method of longitude Interio wrote: "...come per piu facilità de i Nauigãti nel conoscer la Lunare distanza da i Meridiani, elleto il punto della Mezzanotte. Sopra la cui Anticipatione ò ritardenza, vien come si e detto tutte il fondamento de questa nostro inuentione riposto." f. (ivb). This work had only 9 folios.

NOus appellons comunement l'art de nauiguer la science de bien & seuremēt gouuerner & diriger par reigles certaines le nauire, de l'vn port a l'autre. Ceste pratique est repartie en deux, à sçauoir en la nauigation comune & la nauigation grande. La nauigation comune ne se sert d'autres instrumēs, que de l'experiēce, de l'aiguille, & de la sonde. Car l'entiere science de ceste nauigation commune ne consiste en autre, qu'à bien & parfaictemēt cōnoistre tous les caps, ports, & riuieres, comme iceulx se monstrent & s'apparoissent en mer, quelle distance il y a entre eux, quelle route ou cours ils tiennent, aussy à quel rumb de Lune la marée est pleine ou basse, le cours & descente de toutes eaues, auecque la qualité, profondeur & fond d'icelles. Ce que principalement....s'apprend par experience, & instruction des anciens Pilotes bein exercitez. ¶ La nauigation grand se sert outre les pratiques susdites, de plusieurs autres reigles fort ingenieuses & instrumens prins de l'art de l'Astronomie & Cosmographie, lesquels instrumēts & riegles no' presupposons de deduire en ce petit traicté, tant clairement & facilement que sera possible, le tout selon l'exigence de la mattiere. ¶ Or puis....les reigles principales de la grande nauigation procedent de l'Astronomie, il est tres necessaire que tout Pilot sort premier bien instruit ēs fondemens, & premiers principes de cest arte.[1,2]

Camillo Agrippa in his Nuove Inventioni.... Sopra il modo de Nauigar (Rome 1595) explained his intentions, thus:

PER esser la nauigatione tanto importante, & hauendosene sin hora tanta theorica, & tanta prattica; nondimeno, per esser le scientie lunghe, & la prattiche sempre atte amigliorarsi, ho preso ardire di trattare dell' istessa nauigationi, & cose pertinenti alla prattica di quella....[3,4,5]

In contrast in the later 16th. century in England many treatises on navigation and related matters appeared.

William Cuningham in his Cosmographical Glasse[6] (Londini 1559), in his dedication, expressed himself thus:[8]

DAEDALVS THAT EXcellent Geometrician....when as with the eyes of knowledge, he did beholde that horrible Mōster Ignorāce, he therwith praesently conceiued suche intollarable griefe, that he daily sought occasion ether how to banish hir his prysence and comanye: or els by what meanes to escape, oute of her lothsome labyrinthe. At lengthe, perceiuing she coulde not be banished, he prepared winges (through Science aide) and so did flye oute of hir mooste filthy prison....wherein dotne he (that is man in contrast to the beasts) so neare approache vnto God in likenesse: as by Science, and Knowledge? for this thing is proper to God only, to know all thinges.[7]

In 1574 William Bourne published his Regiment for the Sea at London, following much in the Iberian tradition.[9] Robert Norman in The Newe Attractive (London 1581), on the declination of the compass, explained:

...albeit it maie bee saied by the learned in the Mathematicalls, as hath been alreadie written by some, that this (i.e., the lodestone) is no question or matter for a Mechaniciā or Mariner to meddle with, no more then is the finding of the longitude, for that it must bee handeled exquisitely, by Geometricall demonstration, and Arithmeticall Calculation, in whiche Artes they would haue all Mechanicians and Seamen to bee ignorant, or at least insufficiently

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1. p. 5/6.
2. Coignet, born in Antwerp in 1549, died in 1623. He published a work on exchange in 1573, and later an edition of Ortelius. He made instruments and clocks. BIOG NAT BEL.
3. p. 1.
4. Camillo Agrippa was born in Milan. In 1535, when the problem of moving St. Peter's obelisk in Rome was under consideration he produced a project for this, which he published in 1583. He published also on the organisation of Battle arrays and on the sphere. He probably died a little after 1595. BIOG DZ ITAL.
5. Other Italian works which are listed and may be relevant to the field which it has not proved possible to examine include: Filippo Bartolomei's Principiorum artis nauticae sylloge (Rome 1553*): Bernardino Baldino's Regola certissima di mesurare quietamente ogni spacio fatto dalli nauiganti in mare (Milano 1556*): Paolo Cristoforo Nezelli Systema artis nauticae in usum tyronum (Neapoli 1598*): all listed by RICCARDI (1893).
6. "conteinyng the pleasant Principles of Cosmographie, Geographie, Hydrographie, or Navigation" T.p.
7. p. (iii).
8. William Cuningham of Norwich studied at Cambridge and took a degree in medicine at Heidelberg just before publishing this work. He made astronomical observations and engaged in surveying work at Norwich. He designed mathematical instruments and produced Ephemerides, and practised medicine in London. (TAYLOR (1954)).
9. For a description of the work see TAYLOR (1963) where the first edition is reprinted.

furnished to preforme such a matter.....(Nevertheless) albeit thei haue not the vse of the Greeke and Latine tongues to searche the varietie of Aucthours in those artes yet haue they in Englyshe for Geometrie Euclides Elementes with absolute Demonstrations: and for Arithmeticke Recordes works....and diuerse other.[1,2,3]

John Blagrave in his Mathematical Jewel (London 1585) described an instrument for angular measurment which, he suggested, was of immense value in many fields;[4,5] In 1587 Rober Tanner published his Mirror for Mathematiques (London),[6,7] a work which covered the practical mathematical sciences generally: both of which works had relevance to navigation.

Thomas Hood, who published on matters relating to navigation, in a lecture given to the City of London in 1588, and later published,[8] stated:

> .....as I call to minde the great commoditie that wil henceforth arise vnto our Realm in at this day there is a platforme laied for the better increace of the Mathematicall science, a science neruer (very?) worthely to be commended, then do I begin to be somewhat glad...[9]

and expanded:

> Now that these their vertus (i.e. of the captains of London) may increace, and also their learning be enlarged, and they more fit for experiẽce to come it pleased them (diuers graue, wise and politick men, giuing encouragment therunto) for their priuate instruction to erect a lecture for ẏ mathematicall science, a knouledge most conuienient for militarie men.[9]

Thomas Blundeville published his Exercises[11] in 1594,[10] a work to a great extent comprising a compilation of others efforts.[12] Blundeville explained his reasons for writing the work thus:

> I greatly reioyce to see so many of our English Gentlemen, both of the Court & Countrie in these dayes so earnestly giuen to trauell as well by sea as land.......following therein the good example of diuers worthie knights & Gentlmen...And because that to trauell by sea requireth skil in

1. p. (ix/xii). Norman had just previously explained "I mean not to vse barely tedious coniectures or imaginations, but briefly as I maie to passe it ouer, foundyng my argumentes onely vpon experience, reason, and demonstratiõ, whiche are the groundes of Artes."
2. Norman was a seaman turned instrument maker. TAYLOR (1954).
3. William Borough in his Discours on the Variation of the Cumpas...to be annexed to The newe Attractive of R.N. (1581) wrote Sg.ii jb. "....I wishe all Seamen & Travellers, that desire to bee cunnyng in their profession, first to seeke knowledge in Arithmetic & Geometrie, whiche are the groundes of all Science and certaine artes...."
4. "The vse of which Iewel, is so aboundant and ample, that it leadeth any man practising thereon, the direct pathway (from the first steppe to the last) through the whole Artes of Astronomy, Cosmography, Geography, Topography, Nauigation, Longitudes of Reigons, Dyalling, Sphericall triangles, Setting figures; and briefly of whatsoeuer concerneth the Globe or Sphere: with great and incredible speede, plainenesse, facilitie, and pleasure...Compiled and published for the furtherance, as well of Gentlemen and others desirous of speculative knowledge, and priuate practise: as also for the furnishing of such worthy mindes, Nauigators, and traueylers, that pretend long voyages or new discoueries...." T.p.
5. "John Blagrave of Reading, Gentleman" as he advertised himself, was possibly born in 1558. A self taught mathematician, he worked as a surveyor and in dialling, and constructed instruments. In 1590 he published on the staff; in 1596 on the astrolabe; in 1609 on dialling. TAYLOR (1954).
6. "A Golden Gem for Geometricians: A sure safety for Saylers and an auncient Antiquary for Astronomers......also.....howe to make...an Astrolabe" T.p.
7. "A work most profitable for all such as are students in Astronomie, & Geometrie, and generally most necessarie for all learners in the Mathematicall artes" T.p. Robert Tanner, an obscure figure, advertised himself as "Gent. practitioner in Astrologie & Phisick".
8. A copie of the speache made by the Mathematicall Lecturer (London 1588?).
9. Sg. Aij. Thomas Hood was a fellow of Trinity College Cambridge. When his mathematical lectureship to the City of London, established in 1588 ceased after a few years Hood turned to private teaching. In 1590 he published on the cross-staff and the Jacobs staff. In 1592 on the use globes and an addition to Bourne's Regiment for the Sea: and in 1598 The geometrical Instrument called a sector.
10. The 1597 edition quoted here had 8 books as against 6 of the first edition.
11. "....containing eight Treatises...which are verie necessarie to be read and learned of all yoong Gentlemen that haue not bene exercised in such disciplines, and yet are desirous to haue knowledge as well in Cosmographie, Astronomie, and Geographie, as also in the Arte of Nauigation..." T.p.
12. Bk. I, on Arithmetic: II, first principles of Cosmography: III, Globes: IV Petrus Plancius, his universal Mappe: V, M Blagrave his Astrolabe: VI, First and chiefest principles of Navigation: VII, Vniuersal Mapes and Cardes: VIII, Ptolemy his tables.

the Arte of Nauigation, in which it is vnpossible for any man to be perfect vnless he first haue his Arithmeticke and also some knouledge in the principles of Cosmographie...I thought good therefore to write the Treatises before mentioned, to serue as an introduction for such young Gentlemen as haue not beene exercised in such kinds of studies....[1]

The section on Vniuersal Mappes and Cardes, Blundeville had earlier published (London 1589), and there he explained:

I Dailie see many that delight to looke on Mappes....but yet for want of skill in Geography, they knowe not with what maner of lines they are traced .....Wherefore, somewhat to instruct those that haue not studied Geographie (without the knouledge whereof methinkes that the necessarie reading of Histories is halfe lame, and is neither so pleasant nor so profitable as otherwise it would be)....[2,3]

John Davis in his Seamans Secrets (London 1595) began his dedication:[4]

RIght Honourable and my especiall good Lord, as by the instinct of nature all men are desirous of knowledge, and take pleasure in the varieties of vnderstanding, so it is likewise ingrassed by the same benefit of nature, in the hearts of true nobilitie, not onely to excell the vulgar sort, but also to cherrish, support, and countenance all such as shall in due course prosecute their vocation: and as such practises either speculatiue or mecanicall, shall receiue fauourble place in the honourable opinion of nobilitie, by so much the more shall the practiser be esteemed.[5]

With regard to the state of the arts mathematical, and Navigation in England, Davis wrote:

......I thinke there be many hundreds in England that can in a farre greater measure and more excellent methode expresse the noble art of Nauigation, and I am fully persuaded that our Countrie is not inferiour to any for men of rare knowledge, singular application and exquisite execution of the Artes Mathematick, for what Strangers may be compared with M Thomas Digges Esquire, our Countryman the great master of Archmaistre, and for Theoricall speculations and most cunning calculation M. Dee and M. Thomas Heriotts are hardly to be matched: and for the mecanicall practices drawne from the Artes Mathematik, our Countrie doth yeelde men of principall excellencie, as M. Emery Muelleneux....M. Baker for his skill and surpassing grounded knowledge for the building of Ships aduantageable to all purpose....[6]

As to the nature of his treatise, Davis however continued:

To manifest the necessary conclusions of Nauigation in breefe and shorte tearmes is my onely intent, and therefore I....(have not) laide downe the cunning conclusions apt for Schollers to practise vpon the shore, but onely those things that are needfullye required in a sufficient Seaman.[7]

Yet, as to the nature of the art itself, Davis explained:

NAuigation is that excellent Arte which demonstrateth by infallible conclusion, how a sufficient Ship may be conduted the shortest good way from place to place, by Corse and trauers.[8]

However, with regard to charts he explained:

The Sea Chart is a speciall instrument....whereby the hidrographicall description of the Ocean Seas....are supposed to be in such sort giuen, as that the longitudes and latitudes of all places....might thereby be truely knowne. But because there is no proportiable agreement betweene a Globus superficies and a plaine superficies, therefore a Chart doth not expresse that certaintie of the premisses which is thereby pretended to be giuen...[9]

But for better understanding Davis suggested:

.....I do in friendly curtesie aduise all yong practisers of this excellent arte of sayling that they doe not onely by their Charts proue the trueth of these answered questions, but also indeuor themselues to propound diuers other sorts of questions and in seeking their answers, to enter into the reason therof: for by such exercise, the yong beginner shal vnderstand the substantiall groūds of his Chart, and grow perfect therein....[10,11]

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1. f. (iva).
2. To the Reader.
3. Thomas Blundeville studied at Cambridge and later worked as a mathematical tutor to a private family. His writings, according to TAYLOR (1954), were largely designed for the use of young gentlemen at the Inns of court.
4. Dated 1594. 5. Sg. ¶ 1a. 6. Sg. ¶ 3a. 7. Sg. ¶ 3b/4a.
8. Sg. A1a. 9. Sg. G1a. 10. Sg. G4a.
11. John Davis 1552/1605 spent his life at sea and gained a reputation as a navigator. TAYLOR (1954).

While then mathematical navigation began to develop in the Iberian peninsula and was later taken up by the English practitioners, another strand of the mathematical treatment of the world developed from roots in 15th. century Italy.

During the early part of the 15th. century Ptolemy's Geography, with maps accompanying the text, became well known in Italy in the form of Jacob Angelus's Latin translation of the Greek text which had been preserved in the Byzantine world.[1]

In Book I of the Geography Ptolemy set out the general framework of the discipline as he understood it. He there distinguished between Geography and Corography. The later was concerned with local detail:

> ".....even dealing with the smallest conceivable localities, such as harbours, farms, villages, river courses, and such like...It needs an artist, and no one presents it rightly unless he is an artist.[2]

While, on the other hand:

> Geography looks at the position rather than the quality, noting the relation of distances everywhere.....(and) Chorography does not have need of mathematics, which is an important part of geography. In Geography one must contemplate the extent of the entire earth, as well as its shape, and its position under the heavens...It is the great and exquisite accomplishment of mathematics to show all these things to the human intelligence...[2]

In 1466 Donus Nicolaus Germanus, A German who worked in Florence, presented a manuscript copy of the geography to the Duke of Ferrara together with new maps on a new trapezoidal projection, which were to form the basis of the maps of a number of later editions.[3]

In a letter of dedication to Pope Paul II (1464/71) which was printed in some of these later editions,[4] Donus explained:

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1. This translation was dedicated to Alexander V the (Pisan) Pope 1409/10. It was apparently begun by Angelus' teacher Emanuel Chrysoloras a learned Byzantine. (SANZ (1959) p. 57/8.) This translation was widely distributed, at first without maps, but then along with 27 sheets from the byzantine sources. (BAGROW (1964) p. 77). Its popularity is evidenced by the number of extant redactions, on which see LYNAM (1941) p. 6/7, who dates this popularity after 1455. In 1427 one version was produced with maps of the countries of the north. (BAGROW (1964) p.71.) This translation formed the basis of the later published editions of Ptolemy's work and was entitled "Cosmography" which term was similarly used for 'geography' in the text. (NORDENSKIOLD (1961)). The problem of the origin of 'Ptolemy's' Geography and how much of that work can be actually attributed to Ptolemy, particularly with regard to the maps that were found in the byzantine tradition, is a complex question, subject to much debate (See for example BAGROW (1946)). It is not of prime significance here, for, to the renaissance student, what he dealt with was simply 'Ptolemy's Geography' (or Cosmography).
2. This is from Bk. I Cap. I in STEVENSON'S (1932) version based on the printed versions of the renaissance as well as on manuscripts."...chorographia.....discribens ferme singula etiã minima contentorũ a se locorũ: quemadmodũ port9 uillas uicas fluuiorũ scissiões ac huiusmodi alia... .....Vnde chorographia pictura eget nullusque eã recte cõponit. nisi hõ pictor". "Cosmographia uero magis ad quãtitatẽ q̃ qualitatẽ intẽdit. Nam de pportione distãtiarum animaduertit ĩ õibus....Quare illi mathematica opus ẽ. Sed cosmographia ea ẽ potior pars. Contẽplari enĩ in hac oportet tocius (totius) orbis maguitudinẽ & formã. Preterea situs ad totuȝ orbẽ ut fas fit ptem contentã qualis & quanta fit dicere: & sub quib9 celestes spheras parellelis locetur......Et omnibus deinde que ad rationẽ habitat ionuȝ nostrarũ spectant diserere poterit: quas hũanis ingeniis mathematico iure demõstrari altissimũ atq pulcherimũ est". As the 1477 (1462) Bononia edition gave it. During the 16th. century the precise meaning of the Ptolemaic text at places, came in for some argument. The last section here on the significance of mathematics was one point of contention. Ruscelli in his translation and commentary took issue with Pirckheimer's version, and insisted "L'istrumento, con che dimosterano, sono le Matematiche...." although what was at issue was really only a point of emphasis. (Veneto 1598 edition, further annotated by Giuseppi Rosaccio, f. 6b. Ruscelli's version first published, Venetia 1561* (RICCARDI (1893)). While Leonardo Cernoli in his translation after Magini's version (Venetia 1598) f. 5b. attacked Ruscelli's account, again though only on the matter of emphasis.
3. BAGROW (1964) p. 77/9. NORDENSKIOLD (1961) p. 10. KLUNING (1955) p. 19. LYNAM (1941) p. 7. The editions of 1478. 1490, 1507, 1508, all at Roma. This projection was used in a star map of the early 15th. century. KLUNING, ibid.
4. Ulmae 1582 for example.

On me fugit beatissime pater. Cuq̃ summo ingenio exquisetaq doctrina ptolomeus cosmographus pinxisse in his aliquid nouari attemptaremus fore: ut hic noter'labor in moltorū reprehensiones incuireret. Omnes enim q hanc nostram picturā....continetur viderīt geometrice presertim rationis ignari. ab ea quā ptolomeus edidit. paululum abhorrentem. certe nos. Uel imperitie vel temeritatis argument...(but) At si qui erūt qui non oīno geometrie siue cosmographie expertes sint quiq īpm ptolomeū sepius legerīt ac picturā deinde notrā placata mente contemplauerit. hi certe nos aliq̃ laude dignos nō rephensione vt illi putabūt.[1]

The first edition of the Geography[2] with maps, however used a conic projection.[3] In a section of text introducing a table of the maps included, which came after the Ptolemaic text, it was explained that many of the errors that had crept into Ptolemy's work were eliminated and

Opus utrunq summa adhibita diligentia duo Astroligae pertissimi castigauerūt Hieronimus Mamfredus & Petrus bonus.[4]

The Ptolemaic tradition in geography formed a central strand for work in this field from the later 15th. century on. Seven editions of Ptolemy were published before 1500.[5] During the 16th. century a large number of editions of the work were issued, mainly in Latin versions, but with a small number in the vernacular, particularly in Italian and often with extensive commentary.[6]

Moreover, Ptolemy's account of geography, which defined the art as fundamentally depending on mathematics, further defined the mathematical part of the discipline as relating specifically to the location of places by reference to the mathematical account of the heavens.[7] This gave rise to the notion of geography as a subsection of cosmography, and cosmography then, concerned with the mathematical description of the heavens, provided the framework for the subsequent mathematical description of the earth's surface. During the 16th. century then many treatises were published under the rubric of Cosmography, with sections, of a greater or lesser extent, on geography, the mathematical description invloved linking the two areas within the traditional mathematical account of the heavens which often followed closely after Sacrobosco.[8]

Within this tradition of Ptolemaic geography the mathematical nature of the discipline, and its utility and pleasurable qualities, were frequently noted.

Francesco Berlinghieri, in his edition in Tuscan verse, stated that the subject:

....il guardo/ Ne sol la militare arte nutrica/ ma la philosophia et la scriptura/ historica et poetica...[9]

The introducary work Cosmographiae Introductio cum quibus dam Geometriae principiis ad eam rem Necessariis[10] (Sancti Deodati 1507) was much concerned with the geometry of the heavens and the description of the earth's surface within this framework, and further explained its contents as:

1. Op. cit. In this last ection STEVENSON (1932) gives "geography or cosmography", rather than "geometry or cosmography" which is clearly given in for example the Ulm 1482 edition, as such, and seems to be more apt in context.
2. Bononio bearing the date of 1562. A document relating to the production of this work shows it should be 1577. 500 copies of the work were ordered. See LYNAM (1941).
3. Conic in the sense that its parallels were shown as arcs of circles as against the straight lines as in Donus' projection, both using straight converging meridians.
4. Op cit. and also corrected by others. LYNAM (1941) refers to this passage as an "Address to the reader" and denigrated the efforts referred to by stating that the text remained very corrupt. But these remarks by their placing with the table of contents of the maps suggest that they should be read more against these productions rather than against the text.
5. The first edition without maps Vicenciae 1575. The first with maps Bononiae 1477 (see above n.2). Romae 1478; Florentiae 1482 (Italian in verse); Ulmae 1482; Ulmae 1486; Romae 1490. See Sanz (1959).
6. Ibid.
7. And not to any mathematical approach to local topography in itself.
8. See titles and works listed below.
9. Sq. aia the work Firenze 1482 according to SANZ (1959).
10. Not to be confused with Peter Apian's work with the same title of a later date. Published with Americi Vesputtii nauigationes as a final section. This work appeared in a number of editions.

Vniuersalis Cosmographiae descriptio tam in solido & plano/ eis etiam insertis quae Ptolomaeo ignota a nuperis reperta sunt.[1]

and

Cum Cosmographiae noticia sine preuia quanda astronomiae cognitione/ & ipsa etiam astronomia sine Geometriae principijs plene haberi nequeat: . dicemus primo in hac succincta intruductione paucula de Geometricae inchoamentis ad spherae materialis intelligentiam seruientibus.[2]

During the same period the 1507 and 1508 Rome editions of Ptolemy's Geography included his treatise on the Planisspherum. The 1514 Nurnberg edition by Ioanes Werner, in the privilege had the words:

......velle p comuni studiosoru omnium: qui liberalibus scientiis operam nauant: vtilitate super mathematicis artibus in lucem edere....[3]

and in the dedication Werner wrote:

.....philosophiae: ac bonaru artium studiis me libetius addixi: huius praesertim philosophiae: quae mathematica dicitur...Hanc demu mathematicam disciplinam: successiuis horis: quado alia studia magis necessaria...... disciplinae huius: allectus praecipue de lectatusq veritate & certitudine. Ipsa em primu certitudinis gradum: inter coeteras obtinet humanas scientias.[4]

Werner included a section discussing projections of his own creation.[5]

Laurenta Phrisius in his edition of Ptolemy (Agentorate 1522), in his dedication stated:

Mathematicus rationibus et clarissime indiens ita elucidauit....

Henricus Loritus in his De geographia liber unus (Basilea 1527) wrote:

INTER DISCIPLINAS LIBErales, quae citra controuersiam plurimum adferunt utilitatis . uitae mortalium, Ornatissime uir, mea quidem sententia praecipuus locus debetur Geographiae...Nihilo secius interim & in priuatis actionibus plurimum conferens & commoditate & uoluptatis.[6]

Fra Mauro's Sphera volgare novamente tradotta con molte notande additioni di geometria, cosmographia, arte navicatoria, et stereometria, as his title incicated,[7] treated of a wide range of subjects from a mathematical viewpoint, generally at an introductary level, and including, for example, a short section on the taking of the height of a tower by angular measurment.

In his later Annotationi sopra la lettione della spera del sacro bosco Doue si dichiaramo tutti e principii Mathematici & Naturali, che in quella si possan desiderare (Firenze 1550), he there explained his aim:

Pensando sempre.....tirare innanzi & incitare, li studiosi & nobili spiriti della citta alle cose mathematice. A ogn'altra Scienze & Arte, oportune & necessare.[8]

and that:

...il soggetto, & ordine delle 4. Mathematici; & dichiaratione delle sperica sostanziale, & natural Macchina del mondo) che il il soggetto di questa Nobilissima scienza della astrologia, e...naturale, & nobilissimo per esser incorrutibili... diciamo Questa scientia della spera...esser scienze reale, & naturale...Similimente per il modo del dimostrare, & prouare le sue ragioni che à Mathematico, per vna sola formal cagione) & certo; percio, che le scienze mathematiche, tengon'il primo grado ci certezza...Per questo dunque sarà Nobile, reale, certissima: & auenga che il Mathematico abstragga, & separi le forme...dalla materia & dal mouimento.[9]

On the topic of "Qual sia l'vtilità di questa scienza" Mauro wrote:

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1. T.p.
2. Sg. Aiib. After an explanation of something of the heavenly sphere, very briefly, Sect. 6 was "De Parelellis"; 7, "Declimatibus orbis"; 8, "Deventis..."; 9, "...de diuisiõe terre..." Ibid.
3. Sg. aib. 4. Sg. aiis.
5. Werner 1468/1522 studied at Nuremberg with an interest in mathematics. He was ordained at Rome where he was 1493/7. Friendly with Stabius he sometimes gave advice to Durer. Appian followed him. D.S.B.
6. f. Ib. His chapter one was "De geometrae principiis ad Sphaerae astronomiae notitiam necessarijs."
7. Venetia 1537, 8. p. 3. 9. p. 21/2.

L'utilita di questa scienza dell'Astrologia, per le cose gia dette è manifesta per che ogni scienza & arte in qualche parte, ha dibisogno e vopo di quest ....come è la Medicina!....Cosi anchora è necessaria per la geographia, & chronographia; che sono scienze che descriuono il sito della terra; & il corso de tempi; per l'agricultura, Historia, Poesia, Architettura, Sacra scrittura, & per tutte l'altre...[1]

and further:

NELLE scienze humanamẽte acquisitate, non è altra cosa certa che le matematichi scienze, & quelle per conoscer l'opere de Dio, & la admirabili & ineffabili proprieta di quello, son'enigmatiche & oscure.[3,4]

Jacopo Gastaldo in his La Geografia di Claudio Ptolemeo (Venetia 1548), stated:

Imperoche tal scienza di Cosmographia si conuiene non solamente a i Philosofi, Theologi, Astronomi, Medici, Legisti, Oratori, Poeti, & altri huomini dotti in qual si uogli scienza, per farli capaci con la uerita di quelle cose del mondo, che spettano alle scienze loro, Ma e anchora necessaria a Principi, a Rettori di Republiche, a Condottieri di gente d'arme, a Capitani, & Ammiragli d'armate di mare, a priuati Naugãti, a Soldati, a Mercanti, a Gentilhuomini, a getilissime Madonne, a Viandanti, & Pellegrini, et finalment a ciascuno gẽtile spirito, che per generosita d'animo si diletto de uoler sapere, che sia questo nostro mondo.[5]

In Elementale cosmographicum, quo totius & Astronomiae & Geographiae rudimenta,.... (Parisiis 1551), the dedication began:

QVAM iucundae, quàm vtiles, quàm denique necessariae Mathematicarum disciplinarum sint tum traditiones tum perceptiones, non solùm ed eruditionem comparandan solidam, sed ad totam vitam instituendam, nemo est vel parum humanus, qui negare aut dissentire vlla ratione possit.[6]

Geronimo Girava in his Dos libros de cosmographia (Milan 1556) stated:

QVE la Cosmographia sea necessaria para qual quiera action. humana, assi en la administracion de las Republicas: como tambien en las cosas de la Guerra: est prouada ya, confirmado, no solamente por los antiguos: pero tambien por los modernos.:.[7,8]

The edition of Ptolemy, Venetia 1561, based on Pirckheimer's translation, edited by Josepho Moleto, explained:

QVAM utilis & necessaria....sit cognitio Geographica ijs solum iudicandum relinquitur, qui lectitant historias praeter quòd studium Geographicum, utilitatem, delectationemq́ue maximam, omnibus praebeat studiosis.[9]

The Venetia 1574 edition of Ptolemy in Ruscelli's version, corrected by Malombra, stated:

...sapendo quanto esse Matematiche siano necessarie a chi habbia & sia per hauere gouerni egregij; fra le quali Mathematich contenendosi pur anchora la Geographia.:.[10]

Francesis Barozzi in his Cosmographia (Venetijs 1585), began:

COSMOGRAPHIAM....caeteris omnibus Scientijs cùm iucundiorem, tum vtiliorem esse cuilibet perspicuum est, consideranti rem ispi subiectam, in qua versatur, nil aluid esse nisi vniuersam Mundi Machinam, seu Spheram a Deo Opti, Max., summo rerum omnium Opifice, tanto ordine, tantaque arte, ac prouidentia creatam, atque constructam, vt in ea, cuntisq́ suis partibus mirandum in modum ipsius Creatoris summa Diuinitas elucescat,.....Nam abisque perfecta Spherae Mundi cognitione, nec tota Mathematice ipsa, neque Naturalis neque Diuina Philosophia, neque etiam Medecina, nec Agricultura, neque Historia, neque Nautica, nec alia quaepiam Ars, siue Liberalis, siue Mechanica rite percepti exerceriq́ue possunt.[11]

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1. Galen and Hippocrates mentioned. 2. p. 35. 3. p. 147.
4. This work included a discussion of sundials using a stick held in the hand. Its tone was strongly Platonic and Mauro included a section on Vna Spera Theologica, Christiana & Diuina, and another on Excitationi Mathematiche, et incitamenti enigmatici Nella Spera Platonica Theologica & Diuina.
5. Sg. iiija.
6. The work is attributed by B.M. CAT. to Martin Borrhaus. The dedication was by Achilles P. Gusseto.
7. p. 1.
8. Girava gave in his contents list: "Il libro primero es proprio di Cosmographia...El segundo libro es proprio de Geographia...(in which) Quart se trate de la Nauegacion..."
9. p. (iii)
10. f. (xv) from a section by Giordano Ziletti the printer.
11. Sg. a2a/3a.

Giasone di Nores' Sphera (Padova 1589) had published with it a section Intorno all Geographi, in which he wrote:

Mathematici...presuppogno in un certo modo le cognitione delle ueremäte essistenti, per essere in esse appoggiate, & demonstrate.[1,2]

Gioseppi Rosaccio in his Teatro del Cielo (Fiorenza 1594), stated:

.....la Cosmografia, secondo la sua vera etimologia, origine, & significatione del vocabolo, è la discrettione di tutto il mondo, ritratto in disegno, qual'è composto de' quattro elementi, Terra, Acqua, Aria, & Fuoco, & finalmente di tutti i pianeti, & altre Stelle, con tutto quello, che si contiene nel circuto del Cielo; Questa scienza considera prima i circoli, quali c'immaginiamo esser composta la sua prema sfera; dopo la distintinoe; & parimente dalli detti circoli, dichara il sito della terra, & li dà proportione secondo il Cielo; dimostra la distantia de'climi, de'giorni, & notti, secondo il suo vero sito, & altezza de'poli, rappresenta il moto de pianeti, & suo nascimento, con similtudini vere, & infallibili di Matematica.[3]

G. Antonio Magin in his Geographiae Universae (Venetiis 1596) had:

.....nulla gloria praestantior, nulla prouinca illustrior existimari debet, neque vero iniucundum tibi fore munus nostrum sum ratus, cum & res per se ipsa sit Principe magno digna, qui enim natus est Imperijs, Prouincarum quoque situm debet intelligere, quibus dominari aliquando vel possit, vel speret, aut cogitet, & cupiat, (debet autem praeclarus quisque Imperator exercitus, ac rei militaris bene sciens Princeps omnibus cogitare, ac cupere cum fieri possit, vt omnibus possi , vel exemplo Alexandri qui non vni mundo tantum, sed pluribus si extitissent imperare sibi proposuerat) & sit iucunum, iuxta Homeri praeceptum & Vlyssis exemplum....ad quod accedet tuorum studiorum ratio, cum enim mathematicis delecteris (vt omnibus etiam artibus Principe dignies. haec non aliena ab illis mihi visa cognito...[4]

and stated:

GEOGRAPHIAE cognitionis vtilitas & necessitas conspectior, ac euidentior est, quàm ut demonstrationem requirat...[5]

Girolamo Ruscelli's remarks in the Venetia 1598 edition of Ptolemy, edited by Giuseppe Rosaccio, read:

E Tanto l'vtilite, & diletto, che si trahe dalla Geografia...il studio della Geografia, non solo sia conuenuole à ogni animo libere; ma, che glià sia anco necessario....[6]

and:

Le qual cose (i.e. geographical/cosmographical features) tutte sono d' altissima, & belissima speculatione, facendoci elle per vie, ò arti Matematiche comprendere...[7]

Leonardi Cernoti, in his edition of Ptolemy,[8] gave Magini's comments thus:

OGN'Vno sà quanto la Geographia sia vtile, e necessaria: perche non v' hà professione alcuna, che à lei la Geografia non sia di grande ornamento, e non porti grandissimo aiuto; e primamente l'Histoira...(but also) la militar disciplina, l'arte de nauigare, e la mercatantia à senza questa (i.e. geography) smozzata, & imperfetta.[9]

Thus a varied selection of values, both practical, and concerned with the nature of the discipline as a subject of study, were conceived to legitimate geography during the renaissance, and the mathematical aspect of the subject helped to a greater or lesser extent, in different authors, to

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1. f. 1b.
2. Nores also published Breve trattato del Mondo (Venetia 1571) containing a good deal on natural philosophy together with discussion in the mathematical disciplines relative to his topic.
3. p. 3/4. He went on to explain that geography was different and considered only places on the earth's surface, and not celestial matters.
4. p. (v).
5. p. (vii).
6. f. (iiib).
7. f. 1b. 2nd. pagination.
8. A later version of the Magini edition. Venetia 1598.
9. f. 2b/3a. 2nd. pagination. The edition mentions the standard disciplines such as Theology, Philosophy, Medicine and Law.

substantiate those values.[12]

The problem of map projection was another aspect of the mathematical nature of geography during the renaissance, and from the period of the early work of Donus Nicolas Germanus, the production on maps on projections not given by Ptolemy, was a subject of interest to many.[3] However, while discussion on the problem appeared in a number of treatises, for example the works of Werner[4] and Stoffler,[5] and the remarks of Michael Coignet in Jode's Speculum Orbis terrarum,[6] this topic did not form a major aspect of treatise writing. Rather it was in the production of mapping nets themselves, that so much activity actually took place.[7] An activity which proliferated to such an extent that Keuning[8] was forced to pose the question as to "What led the geographers of the sixteenth century to invent a much greater number of projections than was needed in reality?"; for, as he remarked, "The number of projections invented in the sixteenth century bears no proportion to the few which were used for world maps in the two following centuries."

The underlying problem was of course that the traditional body of Euclidian doctrine did not allow the spherical surface of the globe to be 'truly' represented on a plane sheet, as Ptolemy had pointed out. What this meant was that there was no particular method by which the earth's surface could be represented on a plane sheet, which could be seen to give a uniquely satisfying relationship between the object represented and its representation: each 'projection' resulted in its own 'distortions';[9] and no particular method of 'projection' was demonstrable by any process analogous to that of the painters perspective which gave a 'demonstrable' representation of a scene on

1. Among other works in this mathematical tradition of geography were, for example: Johann Stoffler's Cosmographicae (Marpurgi 1537) concerned with map projections; Oronce Fine's De Mundi Sphaera, siue Cosmographia (Parisiis 1542) including a section of projections, and on a portulan chart: Antonio Mizald De Mundi Sphaera (Lutetiae 1552) a cosmographical work with a short section on geography at the end: Giovanni Paolo Gallucci's Theatrum mundi et temporis (Venetiis 1588), a general cosmographical account with the discussion of some topics relevant to navigation: Ioannen Myritium Opusculum geographicum (Ingolstadii 1590) generally in the Ptolemaic tradition. Peter Appian's Cosmographiae intruductio (1529 (1532)) and Cosmographicum liber (Landshute 1524), with many later editions and taken up by Gemma Frisius as later editor.
2. The mathematical tradition in geography however, was by no means the sole possessor of the field during the renaissance. The purely descriptive work of the ancient geographer Pomponius Mela Cosmographia, for example, appeared in many editions from the late 15th. century on. With the new discoveries also many works were published of a purely descriptive nature. Sebastian Münster's Cosmographia, while it had a short introduction on the mathematical aspects of the art, was substantially a massive collection of information, rather than a treatise on these mathematical aspects; and there were many later works such as Cosmograpia Das is Warhafsteeigentliche vne kuntz Beschreibun de gantzen Erdboden (Frankfurt am Mayn 1576) of a purely descriptive nature; and Lorenza Anania's L'Universale Fabrica del Mondo ouer Cosmographie (Venetia 1576), which was organised as sections of description of the different continents.
3. The problem of map projections was not however a new one: Roger Bacon had discussed long before (See KEUNING (1955)), but the intensity of the interest was.
4. See above p. 165.
5. See above n. 1
6. Antwerpe 1578*. See KEUNING (1955), who also mentions Jacobus Servetius De orbis catoptrici (Paris 1590*).
7. KEUNING Ibid. discussed this in some detail and notes for instance the work of Leonardo in this area, and Durer's projection of the globe on the same basis as that of the painters perspective.
8. Ibid. p.2.
9. Livio Sanuto for example noted this in his Geografia (Venegia 1588) f. 2Ua, stating: "è impossibile ritirar dissegno in piano, che tutto vnito corrisponda perfettamenti alla palla....Di quella poi, che si vede conforme di cuore; e nello Emisperio Settentrionali si dimostran con mediocre proportione, nella Australe appare insopportabile. Di quella poi, che fatte è con due circonferenze intere...."

on canvas. Hence particular needs could be put forward for all sorts of different projections, and each mathematician (or map maker) produced his own scheme, by and large.

On the other hand the Mercator projection, by using the criterion of maintaining rhumb lines as right lines in the map, grounded the resultant network on a particular (imagined) need, so that the maps that resulted had a particular 'demonstrable' quality. As a result, Edward Wright for example, towards the end of the century could describe this projection as giving agrement with the globe.[1] The world map that Mercator produced on this basis being of course of little relevance to sailors, and much more merely a picture of the world.[2,3]

Now while in many ways these developments in mapping can be seen as a direct development of Ptolemy's ideas, and merely an extension of his work in mathematical geography, on the other hand, chorography, or the picturing of small areas, Ptolemy contrasted with Geography, through the latter's dependence on mathematics.[4] Yet during the renaissance the topic of surveying tended to become more a purely mathematical one, as detailed above;[5] and in Gemma Frisius's Libellus de locorum for example, provinces began to be considered primarily in terms of their mathematical description.[6] Equally, while Donus Germanus used a trapezoidal projection for local regions, Ptolemy had been content that regional maps should use merely a rectangular grid,[7] and only considered such inclination of the meridians necessary in world maps. Again Ptolemy's projections for mapping the world were designed with reference to the oecumine, or inhabited part of the earth.[8] In contrast such projections as Dürer's tended to treat the earth as a geometrical sphere, and the problem of its representation as simply that of representing a sphere, no matter what part happened to be inhabited or not, or was required to be portrayed. Further

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1. Certaine Errors in Navigation (London 1599). Wright explained that the first part of his book contained "a most plaine and sensible demonstration of the disagreement of the common Sea-chart, and the agreement of the Globe with the chart before discribed (i.e. the Mercator projection)" (Sg. ¶¶¶ 3a.) Wright was much in favour of mathematical navigation and noted "those auncient maisters of shippes, who M. Bourne maketh report of, who not many yeares since, wedded likwise to their accustomed vsage, haue mocked them that haue vsed Charts, or Crosse staues, saying that they cared not for their sheepes skinnes, they could keepe a better account upon a bourd: and them that obserued the Sunne or starres for finding the latitude, they would call sun shooters, and starre shooters, and aske if the had hit it" (Sg. gg4a). Wright further suggested that "The longitude also would well deserue both labour and cost to be skillfully and liberally bestowed, for the finding thereof: whereby it were possible to bring it to that passe (the motions of the Sunne, and Moone, and places of the fixed starres being verified, whereof that noble Tycho Brahe affoordeth great hope)...(that it could be used by seamen)". (Sg. gg2b) Something like the Mercator poujection appeared in a little map on the cover of a pair of sundials made by the Nurnberg cartographer and instrument maker Etzlaub in 1511/13. But no other example of this projection seems to be known until Mercator's world map of 1569. See KEUNING (1955) who states that this type of chart "was not appreaciated or used by the conservative nafigators". SANZ (1959) suggests that Willibald Pirkheimer in his edition of Ptolemy (Nurnberg 1524), in his dedication indicated his intention to construct maps on such a projection.
2. This is well recognised. See for example WATERS (1958) p. 229. TAYLOR (1971). Any world map of handleable size is going to be on too small a scale to be of much use for sailors. Yet D.S.B. continues to repeat the notion that it was designed for sailors.
3. For Mercator and his work see AVERDUNK (1915).
4. See above p.163 Stevenson's translation puts the contrast perhaps a little too strongly, but it was undoubtedly there to some extent.
5. See above sect. II:(4). 6. See above p.140.
7. Grid adjusted to the average latitude of the map. See Bk. 8. CapIII
8. Bk. I Cap XXIV.

while Ptolemy had been keen to point out the difficulty of assessing distances at sea in order to arrive at geographical distances, during the renaissance the tendency was to integrate navigation, as a discipline that helped to describe the earth's surface, with the general mathematical description of the world. The basis of both disciplines in the mathematical description of the heavens aiding the process, while, for example, the printing of Sacrobosco with the early navigational tables symptomised the trend.[1]

Thus there was a general tendency during the renaissance for map making, whether of local regions or of the whole of the earth's surface, navigating and charting, and local surveying all to develope along mathematical lines, while mathematical astronomy similarly provided a framework which integrated these disciplines.[2]

In general then, by the end of the 16th. century the conception of a mathematical world/universe had come to be accepted, not merely as an esoteric theory of the learned, but as a primary description within which many day to day practical affairs were organised, or if not, at least ought to be, while that same mathematical description could simultaneously function as a desirable object of contemplative study.[3]

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1. See above p. 155/6.
2. This process seems not quite to have been fully completed by the end of the 16th. century, however, for, what has not been isolated is any tradition of discussion of the problem of the integration of local geometric surveying, into the geometrical description of the earth as a sphere, that is, taking account of the earth's surface in local topographical work, although this problem was definitely recognised. See above p. 142, n. 7.
3. The normative aspect of navigation by reference to mathematics can be seen in Wright's remarks (see above p.169,n.2) It is common coin among students of the field that the 'conservative' sailors were slow to pick up such (scientific) methods, as for example the mercator projection. TUCCI (1959) in discussing Venetian techniques in the 16th. century showed how very traditional they remained in practice. That this was a not unreasonable attitude to take on the part of seamen can be seen in a number of ways, on which see further bibliographical and other notes to this section below p. 318.

In mid 15th. century Alberti suggested the need for mathematical surveying in order to be able to assess the range of targets which could not be physically approached, so that they might be bombarded. He also discussed the problem of setting a gun to a particular elevation, something necessary after each shot, and how to place the gun to any elevation for which its range had previously been proved.[1]

In the gunnery treatises of the 16th. century these two aspects of the art often came up for mention, and were noted as mathematical parts of the art. For example Tartaglia in his Nova Scientia (Vinegia 1537), in his dedication gave an account of the gunners quadrant for setting the elevation of the piece; and in Bk. III discussed surveying with the square to assess range.[2]

To what extent in practice however, such mathematical activity in gunnery was of significance, is unclear, at the very least. William Bourne in The Arte of shooting in great Ordnaunce (London 1587) complained about the poor quality of English gunners. He explained:

> .....the principal vse of the quadrant, is to know what any peece will cast at the mount of euerie Degree, and so from degree vnto degree, vnto the best of the Rander......(but) I doe know diuers that will haue instruments, and yet be vtterlie voide of the vses of them......And the necessariest thing that this kind of giuing of leuell (i.e. setting the elevation of the peice) in the time of seruice (as being in a Castell, Forte, or Towne, or such like, the Gunners hauing charge of any peece) is to beate al those marks that be apte to doe any seruice at, and to know how manie inches will reach any marke. etc[3] but to become a cunning Gunner, he shall neuer be, although he should shoot 100. shottes euerie day through a yeere, for that he neuer doth know by that meanes the distance of any marke, but in euerie peece he must make a new proofe, if that peece be remoued or chaunged from that place...(and)...I do know few Gunners...that hath anie capacitie, to know the distance vnto anie marke assigned, if that marke be such that they can not come vnto it directly by land, and yet there be verie true and exact wayes to know the distance vnto anie marke assigned, howsoeuer the thing is, if that it may be seen by Geometrie perspectiue: and the lacke therof amongst Gunners is the principallest point that doth deceiue thẽ...[4]

On the other hand, in contrast to any such mathematical emphasis, many of the 16th, published works on gunnery tended to be introductory handbooks, concerned with a wide range of practical topics, as: the size and weight of different guns; the number of horses required to draw them; the charge required; weight of shot of different sizes and in different materials;[5] the various

1. See above p. 137. Alberti specifically mentioned traditional artillery when considering ranging but this was obviously equally applicable to gun powder artillery ranging. This technique might have been particularly valuable at night when 'spotting' the target and adjusting elevation as required, as could be done during the day, could not take place.
2. See II p. 5. for description of this work. Later editions had some further discussion of surveying added to Bk. III. Girolamo Ruscelli, in his Precetti Della Militia Moderna (Venetia 1568), which contained a good deal about gunnery, gave a brief discussion on the square and its use at f. 2a/3b. See also Gabriel Busca who did not think too much mathematics was needed for surveying relative to gunnery sometimes. See II p. 110; l. 33/40. But also II p. 111; l. 1/15. Gentilini II p. 120; l. 13/31. Capobianco's Corona e Palme Militare di Artiglieria (Venetia 1602), (1st. pub. 1598, RICCARDI (1893)), (which had a short elementary section on fortification), also discussed surveying briefly and showed the quadrant. Many other works as well as those noted below had similar sections.
3. Inches of elevation of the piece in question, in its length.
4. p. (vi/vii) op. cit. Continental gunnery Bourne contended was of better quality than that of English gunners, for, he said: "....the principall point that hath caused English men to be counted good Gunners, hath been, for that they are hardie or without fear about their ordnance: but for their knowledge in it, other nations and countries have tasted better thereof, as the Italians, French and Spaniards, for that the English men haue had but little instructions but that they haue learned of the Doutchmen or Flemings in the time of King Henry the eight." p. (v).
5. This of course partly dealt with mathematically, and often graphically presented.

auxiliary equipment of guns, such as laddles and rammers; the duties of a gunner and the various ranks in the profession; as well as sometimes a certain amount of information about the ranges of particular guns, usually merely at point-blank and (maximum) random.[1,2] One particular topic that was also often dealt with in such works was the production and composition of gunpowder, associated with which was the problem of grenades and fireworks, and the publication of works concentrating on these last topics formed a particular tradition during the 16th. century.[3]

But the use of mathematics in gunnery during the 16th. century, occured in its most sophisticated (and even esoteric) form, in the area of ballistics,[4] a topic which was discussed in some few works during the period, undoubtedly the most well known of which was Tartalgia's Nova Scientia of 1537. In Bk. II, Prop. VIII Tartaglia argued that the maximum range of a piece was achieved at an elevation of 45 degrees (all other things being equal), basically from considerations of symmetry, 45 degrees being half way between the vertical and the horizontal.[5,6] Then, given his assumption that any trajectory involved a straight portion, a circular section, and finally a vertical section, the straight and curved sections being tangent[7]; and his 'Supposition' IIII of Bk.II -- that the greatest range on any plane was achieved by the trajectory which struck that plane so that its vertical portion began there[8] -- he arrived at a determinate trajectory for 45 degrees of elevation.[9] Then having established that the level (point-blank) range of a piece is 1/10 th. of the maximum range (at 45 degrees), also, Tartaglia went on to show that the first straight part of the trajectory at 45 degrees, was approximately 4 times the point-blank

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1. Dealt with most often summarily and in no way in terms of any mathematical account, On which approach see below.
2. As well as the works mentioned above there was: Girolamo Cataneo's Essamine de Bombardieri included in his other works II p. 52/3 . Sections in Reinhard. (See above p.54, n.11 f.). Büchsenmeisterey (Nürmberg 1599) by F. Joachim Brechtel. The Inventioni (Parma 1579) of Gio Battiata Isacchi also had a certain amount about gunnery. Iusto Lipsius' Poliorceticon (Antverpiæ 1596) on the other hand dealt with machines of attack in the ancient world.
3. On of the best known early works in this tradition was of course Biringuccio's Pyrotechnia (Venice 1540). But the Feuerwerksbuch (of 1420) was also early published. (See HASSENSTEIN (1941)). Johannem Schmidlap's Künstliche vnd rechtschaffene Feuerwerck (Nürnberg 1608), first published 156[ ] * was in this same tradition. As was Joseph Boillot's Modelles Artifices de Feu (Chaumot en Bassig 1598). For an early manuscript on guns not dissimilar to the later printed treatises see HALL, B.S.(1971).
4. See [56] [58].
5. Digges later took issue with Tartaglia on this insisting that horizontally the piece had a certain point-blank or level range, and suggested that the mean elevation and hence the one at which maximum range ought to occur, ought to be half way between the horizontal and that elevation near to the vertical, which gave the same range as point-blank range. DIGGES (1590), p 365 & 358.
6. Tartaglia's arguments here were not altogether convincing or clear in application. He gave as example the variation in the angle between chords of different sectors of a circle , and the variation of day length in the year, as cases where a function had critical values mid way between their two extremes, those two extremes participating equally in the mean, the maximum value was then found at the mean. "Seguita adonca che tai propositioni ouer argumentationi sempre se uerificano. In quanto al senso in quel termine ouer qualita media che giace fra due qualita contrarie in proprieta ouer in effetti cioe che equalmente participa di caduno di quelle".(Sg. Gib op. cit.)
7. Bk. II, Sup. II, Sup. III (& Def. VI. Bk.I)
8. "Lo effetto piu lontano dal suo principio, che far possa vn corpo equalmente graue di moto violente sopra a qualunque piano, ouer sopra a qualunque retta line, è quello che termina precisamente in esso piano, ouera in essa linea (essendo electo ouer tirato da vna medema possanza mouente.)"
9. Because on a level plane the centre of the circular part of the trajectory, must from this last be on that plane, with the assumption of the straight motion being at 45° to that same plane gives a determinate trajectory thus

range.[1] Now, while in the table of contents in the Nova Scientia Tartaglia listed as Bk. IV a section containing range tables for all angles of elevation, and mentioned such tables as in his possession at a number of places, such tables never appeared and remain unknown.[2] As to the actual trajectories Tartaglia may have proposed there is not much more to go on than some further hints he gave in Bk. I of the Quesiti, where he stated that the distance between the range at 5 and 6 points (using a twelve point square) was so small as to be often masked any accidental differences (in powder and the like)[3]; that there was some kind of proportion by which the ranges increased at every elevation[4]; and that a piece at zero elevation never shot as far by right line, as one somewhat elevated, and the more it was elevated so much the more did it shoot by right line, and equally when being depressed it fired by right line further than when level.[5]

From such geometrical consideration as these it seems Tartaglia constructed his ballistic tables. In itself his account seemes not an unreasonable

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1. In Bk II Prop, IX. Why Tartaglia considered the level range to be 1/10 th. of the maximum is a little obscure. In his introduction he explained (Sg. Aia/b) "Da poi conobbi con ragion Archimedane qualmente la distantia dil sopra detto tiro elleuato alli .45. gradi sopra al orizonte, era circa decupla al tramito retto dun tiro fatto per il piano del orizonte: che da bombardieri è detto tirar de ponto in bianco...." (First edition). Some later editions have "ragione naturale". What the argument might have been here is obscure. But in Bk. I of the Quesiti et Inventione (Venetia 1546) f. 9b/10a, Tartaglia wrote: "....la qual colobrina (per quella sperientia che fu fatta à Verona, naratta nel principio della nostra noua sciẽtia.....) io trouo che tal colobrina nel sito della equalita (che stando eliuellata) tirata de mira, ouer per linea retto circa passa .200." As Tartaglia took the maximum range as 2,000 paces, the implication is that the fraction of 1/10 th. was arrived at from experiment. (One slight problem is that he gives in the introduction of the Nova Sceintia (Sg. *iiiib, 1537 ed.) the maximum range as 1972 "pertiche" "da piedi .6. per pertica, alla ueronesa".) The Archimedean or natural reasoning might then simply refer to the rounding off of the ratio to an exact and precise figure of 1/10th. However it is not impossible that Tartaglia thought that he could justify this ratio by some kind of geometrical reasoning also, perhaps by reference to weights and lever arms, in some way or other. This would have been then in entire accord with his principle that 'the inner eye sees more clearly into universals, than the corporeal eye does into particulars'. (See Biog.)
2. In the dedication to the Nova Scientia, concerning the experiments at Verona Tartaglia suggested that the tests had not been altogether accurate "Perche.... la ragion ne dimestra che il secondo...tirò alquanto piu dil douere alla proportione del primo, ouer che il primo tirò alquanto manco di quello che doueua tirare alla pportione del secõdo come nel quarto libro (doue trattaremo della pportione di tiri) in breue qlla potra conoscere e uedere". (The first shot at 45 degrees having been found to have a range of 1972 perches, and the second at 30 degrees 1872.)
3. Op. cit. f. 6b.
4. Ibid. 7a "...noi habbiamo ritrouato in che specie di proportione, ouer ordine uano augumentando li detti tiri in ogni elleuatione....." and not only at each degree but minute by minute.
5. Ibid. f. 8a. "...ogni sorte di artegliaria necessariamente tirara piu per linea retta stanta alquanto elleuato dauanti di quello fara stante quella a liuello, & quanto piu stara elleuata tanto piu tirara piu retta linea, el medisimo si debbe intendere essendo arbassata, cio che molto piu tirara per linea retta stante quella alquanto arbassata dauanti, di quello fara stante a liuello, & quanto piu stara arbassata tanto piu tirara per linea retta."

one.[1] That is except for one major difficultly, for Tartaglia's crucial Supposition IIII of Bk. II, seems to be incoherent. Given that the maximum range on any plane is achieved by that trajectory which begins its natural motion at that plane, the range of every trajectory must then be of that same range which the maximum has.[2] It is possible that Tartaglia never paid any attention to this difficulty, and ignored this presupposition after he had used it to determine the trajectory at 45 degrees. On the other hand he might have argued that there were approximations involved with these curves,[3] as he clearly did with regard to the first straight part of the trajectory, and that this somehow got rid of any such difficulty: or that as a result of some kind of limiting condition, this presupposition was only fully fulfilled for the plane of the horizontal.

Be that as it may, it is clear from this how very geometrical were Tartaglia's arguments whereby he set up a condition (albeit incoherent) which then allowed him to arrive at a determinate trajectory at the key angle of 45 degrees, so that then applying notions of proportion he could arrive at the other trajectories. His whole approach, based on a relatively few observations, wholly in accord with his general approach to the practical mathematical sciences on the basis of his principle that the inner eye sees more clearly into universals than the corporeal eye does into particulars.[4] As a result the general intellectual relationships which he could determine from a relatively few observations were used in turn to determine what was accidental about those observed phenomena.

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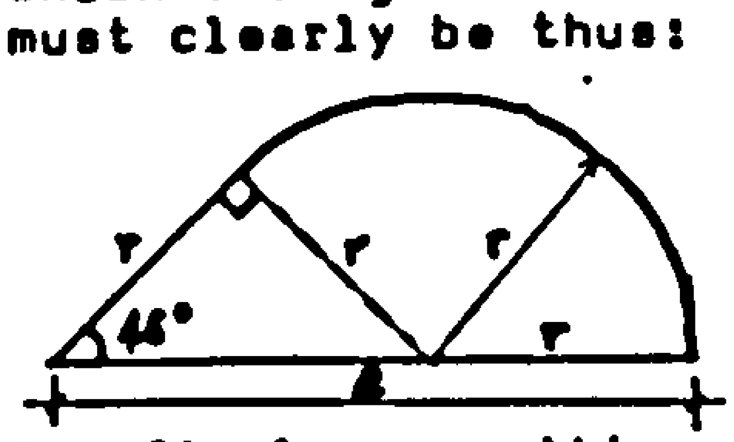
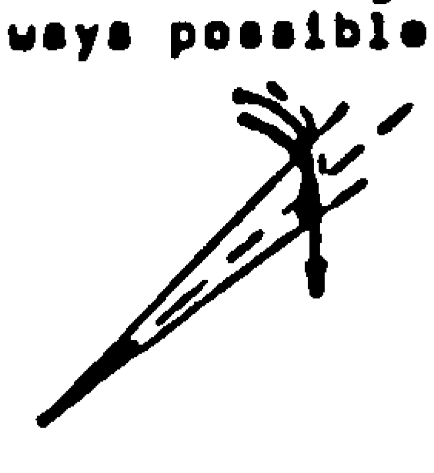
1. DRAKE & DRABKIN (1969) seem to have missed the central drive of Tartaglia's arguments. In their note 28 p. 95 they state, relative to Tartaglia's trajectory for 45 degrees, that its curved part "must have its centre on the surface of the earth making the trajectory predominantly circular -- a new and unexpected development in view of earlier textual discussion." apparently missing the point that this stems directly from Supposition 4, Bk. II (See above p.172), without which Tartaglia's whole argument will not go through. The resultant trajectory must clearly be thus:



In an earlier note (9, p.166) they stated "If the point-blank range is taken as unity, and the 'straight' travel at 45° is four times as great, then the horizontal distance traveled when 'curved movement' begins, for the maximum trajectory, is 2 $\sqrt{2}$ or about 2.8; but if the total horizontal travel is 10, the 'curved movement' must be about 2.5 times as great horizontally as the initial 'straight movement'. The final proposition of Book II shows how Tartaglia attempted to reconcile his theory with the assumptions. But from the diagrams in Book I, it would appear that Tartaglia thought the observed horizontal motion to be about equally divided between the 'straight' and 'curved' portions. The difficulties implied here (empirical knowledge versus attempted mathematical representation) precluded his development of the promised general ballistic formulas." Now what is objected to here is rather obscure. Given the 45 degree trajectory of Tartaglia's as shown and the range being taken as 10, then $R=10=(\sqrt{2}r+r)$, and so $r=10/1+\sqrt{2}=4.14$, that is equal to the 4 and 1/7 that Tartaglia arrived at in Prop. IX Bk. II as the more accurate figure for what he referred to in his text generally as 'about 4'. This being determined geometrically. The proportion that diagrams of this nature have in a text when not so defined can not of course indicate anything.

2. Any attempt to plot trajectories conforming to this condition makes it clear that something is awry. Generally, consider two planes close together. It is always possible to draw a plane between them on which the trajectory must be more nearly equal to the range on the plane below, and in the limit equal to it. But the range on the plane above must be greater than that on the plane below, therefore it must approach and in the limit be equal to that on the plane below. Hence every plane above a plane with a maximum range must have a range at least equal to that maximum range. (The crucial factor here being the verticality of the trajectory of maximum range on any plane.)



3. This Tartaglia noted in Sup. II Bk. II of the Nova Scientia, and was a point he discussed at some length in the first part of the Quesiti, in regard to the straight part of the trajectory, which he admitted was never actually perfectly straight.

4. See above Biog.

But Tartaglia's arguments on ballistics can not be understood as arising merely from a geometrical approach to the topic. Indeed the whole of the first book of the Nova Scientia was devoted to the description of motion in terms of the Aristotelean notions of violent and natural motion, and undoubtedly these concepts helped Tartaglia to chrystalise certain ideas in particular ways, most especially in his suppositions about the division of the trajectory into three regions.[1] Further Tartaglia claimed to have proved that all trajectories of whatever elevation, no matter how great or small the range, had a geometrically similar shape. But this was an assumption that had to be built into his approach in order that he might give a general mathematical account of ballistics. Yet because he attached the particular form of the trajectory to considerations about violent and natural motion, Tartaglia could claim to some extent to have 'proved' his assumption.[2]

Nevertheless, even allowing this kind of function to Aristotelian notions in Tartaglia's thought in this area, his approach remained a highly mathematically determined one. For, one looks almost entirely in vain for any way by which the concepts of natural and forced motion were analysed to give detailed dimensions of the trajectories, or parts of them. Rather, once certain outlines of the problem had been given by these concepts Tartaglia tended to treat the mathematics of motion as a subject functioning in its own autonomous field, and constrained only by the internal standards of mathematics and the ability of that field to give results from a few basic principles deduced from observation.[3]

Towards the very end of the century Tartaglia's geometric ballistics was taken up and modified by Diego de Alaba y Viamont[4] in his El Perfeto Capitan, instruido En la diciplina Militar, y nueua cencia de la Artilleria (Madrid 1590). In Books V & VI of this work (f. 224/257), Alaba y Viamont, after some preliminary discussion including the use of the quadrant, recounted Tartaglia's contention that at 45 degrees the range was at a maximum, and that the point blank range of a piece was 1/10 th. of the maximum range. He however then gave ranges for points between these elevations as simply in direct proportion to the elevation,[5] attributing this scheme to Tartaglia. He claimed that the resultant table "sera muy

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1. Tartaglia described his discoveries in ballistics in this way in the introduction to the Nova Scientia: Having become interested in the problem of ballisitics through contact with gunners he first deduced the maximum range was at 45 . (Probably from the sorts of considerations of symmetry he gave.) Then he considered the problem in terms of natural and violent motion, presumably there finding the idea of the trajectories' three regions, then plugging in his notion of the level range being equal to 1/10 th. of the maximum, along with certain presuppositions about the geometry of the situation, proportions, etc. to get his developed trajectories. Op. cit. *iiia/Aib.
2. Ibid, & Prop. VII Bk. II.
3. This pattern however in Tartaglia's account of the pattern of movement of projectiles, was in strong contrast with an other aspect of his ballistics. In Bk. I of his Quesiti et Inventione he discussed the problem of percussion, or 'effect' as he termed it, of projectiles and other matters in a way very much directly determined by his account of the Aristotelian notions set up in Bk. I of the Nova Scientia.
4. Alaba y Viamont or Alava y Beaumont was born in 1557 ([illegible]) The 'Approvacion' signed Luys de Barrientos stated "este libro a me parecido muy bien, y trabajado con curiosidad lo que en el se trata, y que sera de proueccho, y que se le podra dar licencia al Autor, para que le imprima". In the dedication Alaba refers to his father as "Captain General of artillery to the King" of long standing, and explained that he, Diogo, had studied many years under Geronimo Muñoz, "Catredatico destas ciencias (i. e. mathematica) enla vniuersidad de Salamanca". Here and elsewhere Alaba made clear the fact that his familiarity with gunnery, such as it was, was mainly second hand.
5. I.e. with 12 points to the quadrant. Range at level 200; at 6 points (45°) 2000. At 1 pt. 500; 2 pts. 800; 3 pts. 1100; 4 pts. 1400; 5 pts. 1700. Alaba y Viamont actually used tables with twenty points to a quadrant, and in his more detailed efforts gave ranges down to every 1/10 of a point.

à proposito para los artilleros que fueren poco Ariameticos",[1] and suggested that for guns with a different range one simply worked proportionately. But then Alaba gave a section "Repruevase la Primiera suposicion di Nicolo Tartalla", where he stated of the 10 times ratio "que jamas pude persuadirme à ser esto verdad";[2] and that in his view experience showed that "quanto mas larga, y bien proporcionada la pieça de artilleria, tãto menos sera la proporciõ del tiro disparado por los 45. grad. à la que se dispara de punta en blanco".[3] Alaba y Viamont then went on to criticise Tartaglia's contention that the non straight part of the trajectory of a projectile formed a circular arc, insisting:

> .....en el mouimiento natural no contrasta el peso de la pelota al mouimiento, pero en el violento contrasta, y la fuerca del motor se va remitiendo proporcionalmente....(and) quando començare à tener el peso de la pelota sensible proporcion con el impetu del motor: y como este respeto, ò correspondencia sensibile que ay entre los dos, vaya creciendo, y no vniformemente, por ser el mouimiento violento, de forma que es mas lijero al principio que en su remate; no podra jamas hazer parte de algun circulo: sino irregulares arcos, y tanto mayores, quanto mas se allegara la peloto al principio de suo mouimiento natural, y nunca tocara en linas del niuel.[4]

In Bk. VI Alaba y Viamont went on to argue that the shots at different elevations travelled unequally and in accord with the sines of their angles.[5] This then provided him with a more developed table of ranges, constructed, he explained, by taking the ranges at point blank and 45 degrees as the maximum, as he had explained before, but then giving intermediate elevation ranges in accord with the sines of their angles.

Thus Alaba y Viamont's final approach was not so much an account of the geometry of trajectories, but rather a computational technique arrived at in terms of rather general arguments, the actual shape of the trajectory remaining undefined in any precise way.[6]

On the other hand in Stratioticos (London 1579) Thomas Digges had given a section on "Certeine Questions in the Arte of Artillerie, by Mathematical Science ioined with Experience, to be debated".[7] One part of this section was on Randons and included the following questions for debate:

> 11 Whether the vpper part of the Circuite made by the Bullet be a portion of a Circle as Tartalea supposeth.
> 12 Whether it be not rather a Conical Section and different at euery seueral Randon.
> 13 Whether it be not at the vtmost Rãdon a Sectiõ Parabolical in al kind of Peeces, and to differ in greatnesse according to the greatnesse of the Cone that to euery Seueral Cylinder or Peece of Ordinaunce is conuenient, being Proportionally charged according to the perfection heretofore mentioned.

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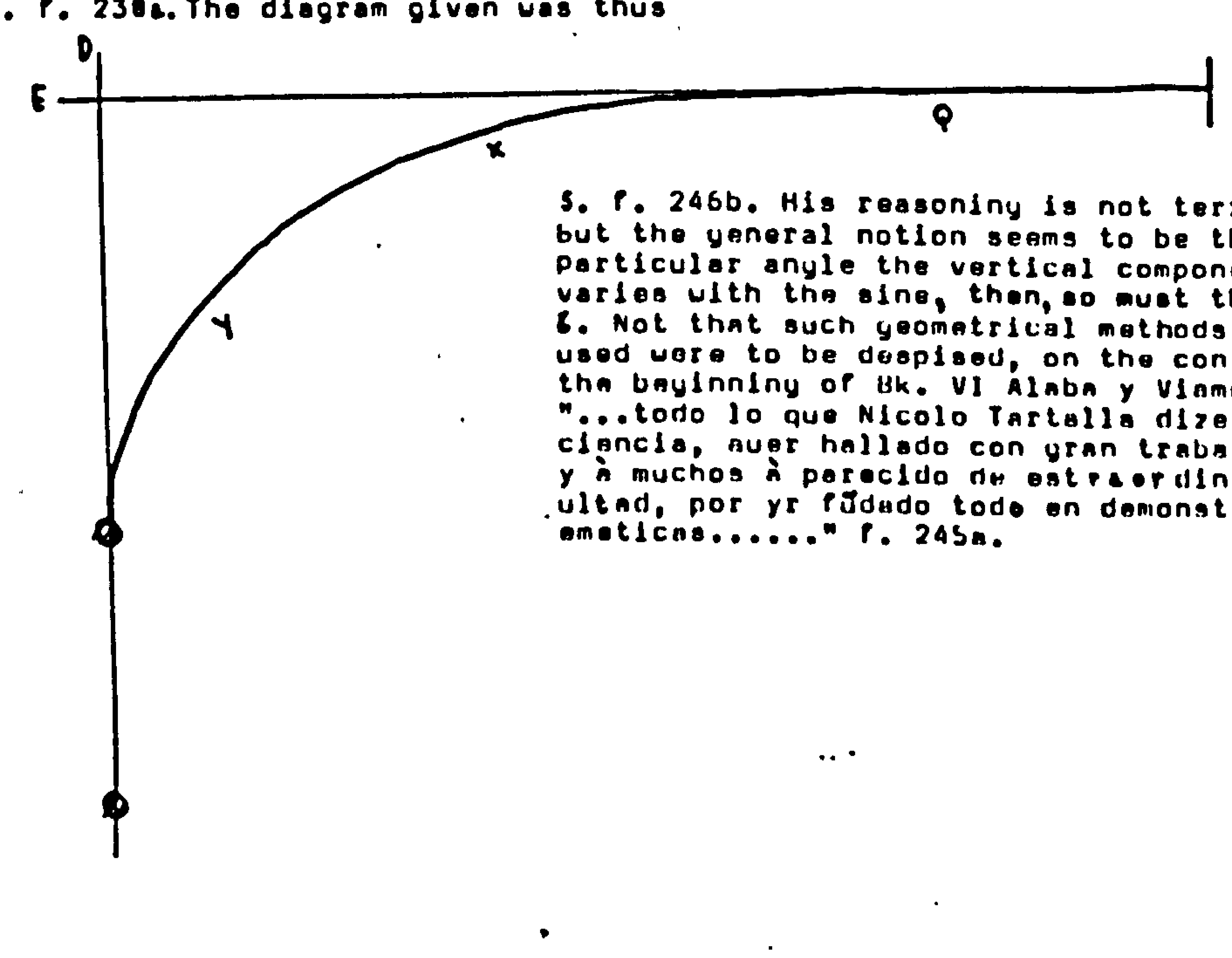
1. f. 230b.   2. 234a.
3. f. 234a, which ratio had to be established empirically.
4. f. 230a. The diagram given was thus



5. f. 246b. His reasoning is not terribly clear, but the general notion seems to be that at any particular angle the vertical component varies, and varies with the sine, then, so must the range.
6. Not that such geometrical methods as Tartaglia used were to be despised, on the contary, for at the beginning of Bk. VI Alaba y Viamont wrote: "...todo lo que Nicolo Tartalla dize en su nueua ciencia, auer hallado con gran trabajo, y cuydado, y à muchos à parecido de estraordinario dificultad, por yr fũdado todo en demonstraciones Mat ematicas......" f. 245a.

> 14 Whether at al inferiour Rādons that Arke by Tartalea Imagined Circular, be not an Eleipsis, & the same altering according to the capacitie of the Cone to the Peece appropriate, & also according to the difference of the Angle of Randon.
>
> ....
>
> 16 Whether al Randons aboue the vttermost, the sayde Curue Arke, be not an Hyperbole.[1]

With regard to such questions, Digges remarked:

> THese may suffise to giue some tast how large a Sea of Inuentions ŷ ingenious Mathematitian hath to wade in, ŷ wil aspire to the perfection of the Art of handling gret Artilerie....But as it is vtterly impossible for Archimedes himself (if he wer liuing) without Exsperience, long Practise, & sundrie trials to demōstrate ŷ manifold varieties of that mixt Helical Arcke or circuite of the Bullet, componed of violente, & natural motions... So it is far more impossible & absurde to imagine, that any ignorant of those Sciences, (i.e. mathematics) should euer be able to approache the Cates of that Arte (of shooting)[2,3]

In the 1590 edition of Stratioticos (at London), Digges gave some further remarks after those same sections that had earlier appeared, entitled: "An Addition to Stratioticos concerning great Ordinance". There he explained:

> Albeit there are diuerse Reasons that moue me not to Imprint my Treatise of great Artillerie, Fireworks etc. Yet finding none sithēce the publishing of those my Questions of great Ordināce that will take on thē to answere any one...[4]

he therefore:

> ....resolued the greater part and briefly opened diuers great Secrets of that Science, by my father first found out, and neuer since his death to thos houre by any els......discouered....[5]

Yet the great majority of what Digges presented was merely an attack on certain errors of other writers. Namely: the view like that of Santbech that a shot travelled straight to a certain point, and then dropped vertically to earth; that ranges are proportional to the length of the piece, all other things being equal; that range is proportional to charge, all other things being equal; that range is directly proportional to elevation and that the maximum is achieved at 45 degrees. Only in this last case did Digges put forward anything substantive. Here, after dismissing the idea that the increase of range is the same for every point up to 45 degrees, with a similar reduction above, Digges indicated his acceptance of the kind of arguments Tartaglia had put forward as to the maximum range being at some kind of symmetrical mid-point, but then proposed that elevation should be mid way between level and the high elevation that gave the same range as level range.[6]

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1. p. 187/8. 2. p. 188.

3. In his preface Digges quoted approvingly the idea that a man transplanted to a paradise would find the experience horrible if he could not communicate the state of his 'felicitie' to any other man. Then continued: "Euen so, albeit the straunge varietie of Inuentions in the more subtile part of these Mathematical Demonstrations did breede in me for a time a singular delectation, yet finding none, or very few, with whome to conferre & communicate those my delites .....After I grew to yeares of riper iudgement, I haue wholy bent my self to reduce those Imaginatiue Contemplations, to sensible Practicall Conclusions..." p. (v/vi).

4. p. 361. This treatise is now unknown. Digges claimed, immediately following, of its contents "wherein also by exact and most rare Instruments shallbe taught the perfect Arte to shoot at all Randōs frō one grade of altitude to 90 with all kinds of peeces, with Rules infallible to find out their seueral Rāges...."

5. Ibid.

6. In the first edition Digges attacked Tartaglia by name for his contention that the maximum range was at 45 degree. In the 'addition' of the later edition, Digges explained, of those that he disagreed with, he omitted those "Authours names (so that they be) not further blemished nor called in question". It seems likely that the view of range in direct simple proportion to elevation, Digges like Alaba y Viamont, attributed to Tartaglia, presumably from where Tartaglia talked about range being proportional to elevation. But this was a very crude reading of Tartaglia.

Thus the sophisticated mathematical treatment Digges indicated he thought necessary to ballistics did not appear even in this later edition, although Digges there claimed to be opening up great secrets.[1]

In contrast, a rather different approach to ballistics appeared in print more than once during the 16th. century. Sebastian Münster in his Rudimenta Mathematica (Basileae 1551) discussed briefly the use of the idea whereby the projectile was conceived to proceed in a right line to the highest point of its trajectory and then to descent vertically to earth from that point where violent motion ran out. Munster gave a description of the relevant triangle having a base, cathetus or perpendicular, and hypothenuse, and explained:

> Cognitis his duabus distantis, basi scilicet & hypothenusa, inclinanda est machina iuxta affixi quadrantis normulum, ut globus piceas hypotenus e tramitem rectè incedat, atque deficiens in cursusuo, descendendo cadat in destinatū locum.[2]

Daniel Santbech in his commentary to his edition of Regiomontanus' De Trianqulis Planis et Sphaericis (Basileae 1561) dealt with ballistics in the same way, but in some greater detail in terms of the number of problems dealt with by the device of the simple right triangle.[3]

However, the discussions of the writers indicated above did not comprise all the developments in 16th. century ballistics, and at one point in print, another kind of tradition in the subject was indicated. A geometrical ballistic diagram appeared in Fronsperger's Kriegsbuch (1571/73) with intriguing characteristics.[4] Taken purely as a computational device -- and not as an accurate representation of trajectories -- Fronsperger's construction gives a function for range on a level plane equivalent to that which is arrived at from the Galilean account of the motion of a falling body in a vacuum.[5] However, when one comes to consider how this construction might relate to the path of the projectile, it becomes rather problematical. Taken rigorously this construction

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1. In his questions of the first edition Digges had hinted at the view of the angle of maximum elevation as noted above, and also that the right line of maximum range was in mean proportion to the right lines of the two extreme ranges. But after that it is not too clear how he intended to proceed. Digges claimed that his father "....ioyning continuall experience for many yeres with Geometrical Demonstrations, sought, and at last founde, and did frame an Instrument, with certaine Scales of Randons to performe all that by Tartalea his Tables promised." But, he bemoaned "such is my harde Destinie, that as Gods pleasure was to take my Father from me in my yong and tender yeares, and euen at that verie tyme when I began to grow capable of these Secretes...."; and that he had not been able to "enter into triall and practise of these Conclusions (of mathematics, for) by continuall Lawe Brables...I haue for manye yeres bene so vexed and turmoyled...(and) I haue scarsely hitherto had any time of repose or quiet to wade effectiuely in any one, saue onelye that of great Artilerie..." (1579 ed. p. 189/91)
2. p. 29. But of course knowing the hypotenuse was the central problem. Münster in his discussion seemed very keen on burning projectiles.
3. Sectio Sexta, on Complectens Absolutum Artificium Eiaculandi Sphaeras Tormentaras of his Problematum Astronomicorum et Geometricorum sectiones septem, published with the work of Regiomontanus, although with separate register and pagination. The title page of which read "Quam Multiplicem usum haec triangulorum doctrina omnibus legitimè philosophantibus adferat non solùm ad expeditè absoluendas, quaecumque in locis terrestribus ac maritimes occurāt, dimensiones, sed etiam ad intelligendos fontes eius disciplinae, quae extructa est à Ptolemeo & Copernico de Revolutionibus orbium caelestium, qui sana rerum intelligentia sunt iustucti, in sequenti opere, quod complectitur ordinatā Astronomicorum & Geometricorum problematum descriptionem, tanquam in clara luce intueri & experientia infallibili duce deprehedere poterunt." The commentary contained a good deal on dialling and surveying as well as on other topics. Daniel Santbech from Nijmegen remains an obscure figure. See. KLEINERT (1976) who discusses his ballistics and insists he conceived it as only an approximate scheme.
4. See [56] [58].
5. See [57]. Tartaglia had pretty well defined the problem as one of a body in a vacuum by way of his notion of a body 'equally heavy' which he gave thus: "Corpo egualmente graue è detto quello che secondo la grauita della materia, & la figure di quella è atto a non patire sensibilmente la opposition di l'aere in alcun suo moto." Def. I Bk. I Nova Scientia (1537). Of course the Fronsperger diagram in no way agrees with the details of trajectories arrived at from Galileo's account.

implies that at level range the projectile trickles out of the barrel and immediately falls vertically. Clearly the draughtsman who produced the diagram felt something of this difficulty, and at low angles of fire (the most important one might think) gave rather variable solutions on the different sides of the diagram. The source of this diagram, its development, and the way it was understood, then, remain obscure, for all the text Fronsperger gave was only a single page with little more than a description of the lines of the drawing -- AB is the line for the shot at one point of elevation, and the like. Yet clearly what was involved here was an attempt to arrive at a general function to describe range by means of the application of geometrical patterns, perhaps developed directly from Tartaglia's work.[1]

Further, a manuscript by one Giusto Aquilone, of probably the late 16th. century, gives a discussion of ballistics centered on a geometrical construction rather like Fronspergers,[2] which was clearly a development to some extent of Tartaglia's ideas.[3]

Aquilone explained the basis of his construction thus:

> FACCINSI i tre cerchi in tal maniera, che tutti e tre insieme si tocchino, e non si seghino, si come si uede nella descritta figura il maggiore de quali chiameremo il Cerchio del mouimento perche il mouimento e la esalatione uentosa, che si causa dentro all'Artiglieria per causa de i tre materiali, & queste esalatione è possente à far muouer quel corpo ugualmente graue, & la forza, o potenza di questa mouimento è maggiore, ò minore secondo la postura del pezzo però non lascia questa potenza tanto maggiore come minore di tendere ciascuna al centro doue restrigne tutta sua potenza, & questi centri di necessita si hano a trouare nella circunferenza del Cerchio del mouimento. Gli altri due Cerchi si chiamano della contingenze, perche nelle circumferenze di questi circuli si cauano tutte le contingenze de'mouimenti retto, et curuo.

Using his construction Aquilone came to the conclusion that Tartaglia had been wrong about the elevation which gave the greatest range. Upon this topic he wrote:

> E una diputa fra il uulgo, & un Tartaglia e quello che l'ha mossa, et dicono che tirando una palla con qual si uoglia pezzo d'Artiglieria per li 45 gradi....ch mette il Tartaglia, che si allontanera piu che il centro del mouimento in un piano che in nessuna altra eleuatione. Questa è falso perche per Geometria si troua, & si dimostra, & trouiamo, che essendo tirata la palla per la eleuation di 40 gradi e mezzo si allontanera piu dal centro del cerchio del mouimēto, che in qual si uoglia altra eleuatione: ma nel medesimo piano.[4]

But such a mathematical approach, and the attiudes expressed by such authors towards the acceptability of gunpowder weaponry, and towards the relative value of the different types of skill that could be associated with their use, was not universally accepted during the 16th. century. Roger Ascham,[5] for

1. It seems unlikely that Fronsperger himself developed this diagram. His interests and approach were not such as to suggest this, and it is not impossible that the diagram was devised by Tartaglia himself and circulated amongst those interested in theoretical gunnery.
2. See Pl. [58]. The m.s. mentioned ranging experiments at Ibiza in 1565 and the author seems to have been very familiar with actual details. He also quoted Girolamo Cataneo's Essamine de'Bombardieri (1564), which work he took issue with, as if it was a recent authority.
3. Even though Aquilone disagreed with Tartaglia (see below), His construction of the trajectory at 45 degrees was equivalent to that of Tartaglia. he further referred to bodies 'equally heavy'. He also gave a proof of the similarity of trajectories of the same elevation with different ranges after Tartaglia.
4. A detailed analysis of the m.s. is in progress which it is not possible to give here.
5. Ascham was born in 1515 as the son of the house steward to Lord Scrope, of Bolton. He gained an education in the family of Sir Anthony Wingfield who sent him to Cambridge in 1530. He qualified B.A. 1533/4. In 1534 he became a fellow of St. John's. In 1537 he received his M.A. Around 1538 he was appointed Greek Reader at St. John's. "In 1539 he apparently sought....a mathematical lectureship although he candidly confessed in later life that, compared with classics, 'Euclid's pricks and lines' had little educational value." In 1546 he became public Orator to the University. His other activities included being tutor to the young (future)Queen Elizabeth. He died in 1568. DNB.

example, in his Toxophilus, The schole of shootinge conteyned in two bookes (Londini 1545) condemned 'artillery' as a weapon far inferior to the longbow.[1] He explained:

> Artillerie now a dayes is taken for.ii.thinges: Gunnes & Bows, which how much they do in war, both dayly experience doeth teache, and also Peter Nañius[2]....(who) when he hath shewed excedyng commodities of both, and some discomodities of gunnes, as infinite cost and charge, combersome carriage: and yf they be greate, the vncertayne leuelyng, the peryll of them that stand by them, the esyer auoyding by them that stande far of; & yf they be lytle, the lesse both the feare and ieoperdy is in them, besyde all contary wether and wynde, whiche hydereth them not a lytle: yet of all shotyng he can not reherse one discommoditie.[3]

Of his opinion of the longbow Ascham explained, it is

> ....a wonderful example for all commune wealthes to followe: that is euermore to regarde and set most by that thing whervnto nature hath made them moost apt, and vse hath made them moost fitte. By this matter I meane the shootyng in the long bowe, for English men...I wolde counsel all the gentlemen and yomen of Englande, not to chaunge it (i.e. the bow) with any other thyng, how good soeuer it seme to be: but that styll, accordyng to the oulde wont if England, youth sholde vse it for the moost honest pastyme in peece, that men myght handle it as a mooste sure weapon in warre....And here I would desire all gentlemen and yomen, to vse thir pastime in suche a mean, that the outragiousnes of great gamyng, shuld not hurte the honestie of shotyng, which of his owne nature is alwayes ioyned with bonestie....[4]

In his table of contents Ascham gave as headings: 'Shootynge fit for princes and greate men'; 'Shootyng, fit for Scholers and students'; and in his text he remarked:

> ....shooting is fitte for great mens children, both bycause it strengthneth the body with holsome labour, and pleaseth the mynde with honest pastime.......[5]

He further explained:

> The strength of war lyeth in the souldier, whose chyefe prayse and vertue, is obedience towarde his captayne, sayth Plato....Obedience is nouryshed by feare and loue.....After this inward virtue(i.e. vnfayned obedience) the nexte good poynt in a souldier, is to haue and handle his weapõ wel, whereof the one must be at the appoyntment of the captyne, the other lyeth in the courage and exercise of the souldier....[6]

and that:

> ....God is well pleased wyth wyse and wittie feates of warre (and)....is pleased to haue goodly tombes for them which do noble feates of warre...[7]

Later Ascham explained:

> ...I was neuer so well sene, in the Posteriorums of Aristotle as to inuent and search out general Demonstrations for the setting forth of any newe Science. Yet by my trothe yf you wyll, I will goe with you into the fealdes at any tyme and tell you as much as I can, or els you maye stande some tyme at the prickes and looke on thẽ which shoote best and so learn.[8]

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1. Although it was presumably the hand gun as the competitor of the longbow which was Ascham's main target.
2. Petrus Nannius a well known humanist. Oratio de Obsidione Louaniensi. Adiunctus est dialogus de milite peregrino (Louuan 1543). Sg. Giib. "Habẽt preterea id cõ modi arc⁹, quod facillime instuũtur, hastili tantũ & neruo opus est, quorũ materia ubiq offertur. Ad bombardas instuẽdas opere metallicorũ, officine fabrorũ, cũ omni suo apparatu necessario desiderãtur. Nitrũ requiritur, serenũ coelũ requiritur & cũ oĩa feceris sępe inter amicos foedifrage disiliũt, & nõ min⁹ suos q hostes ledũt..."
3. f. 26a.
4. Sg. Aiiija/b. From a section headed "To all Gentleman and yomen of Englande".
5. f. 7b.
6. f. 25b/26a. Cf. Gian Tommaso Scala.
7. f. 28b. This section in the table of contents was listed as "God is pleased with strong weapons and Valyaunt feates of war".
8. f. 46b. This sounds as if it might be a direct (although somewhat ironic) attack on Tartaglia's. Nova Scientia, with that work's dependence on general demonstration, and Tartagli's claim as to how little practice he had.

and that:

> ...euery crafte and science standeth in two thynges: in knowing of his crafte, & working of his crafte: For perfyte knowledge bringeth a man to perfyte workyng. This knowe, Paynters, Karvers, Taylours, shomakers, and all other craftesmen to be true. [1]

Thus geometrical ballistics was not a subject to please all writers during the 16th. century for a number of complex reasons.[2,3]

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1. f. 49a. The pagination in this section of this edition is somewhat awry. In his second book Ascham went on to give practical hints for good shooting.
2. On the topic of gunnery and archery see ESPER (1965).
3. Other works listed sometimes as relevant to this subject include: Two treatises on Artillery in the Parmese collection; Su'Cannoni anonymous 16th. century m.s. Vatican 389 art. 67; Artillerie by Solms, Graf, 16th. century m.s. in the Hesse Darmstadt Ducal library; Emmanuel, S.A. Duc Charles Discours sur l'Artillerie Turin archives; V Preuss Ordnung.Nahmen und Zahl Aller Buchsen (Strassburg 1530); Kaspar Burger Unterricht (Strassbury 1591*); Ferrufine, J, Tratado de Artilliera National Library Madrid; Isla, Lazaro de la Breve Tratado del Arte de Artilleria, geometria y artifice de fuego(Madrid 1595) -- according to Cockle this little book has nothing notable about it except its rarity. All given in RILING (1951), who also gives Tomaso Moretti Trattato Dell'Artglieria(Brescia 1572*) but this it seems should read 1672. CHARBONNIER (1928) gave also Martena (Ital) Mines Artifices (Naples 1576); Manus (All) Artillerie et artifices (Dantzig 1578*); Catherinot Traite sur l'artillerie (1585)*; Galle Table de la portee des cannons (1600).

II:(7): Architecture

Alberti's De Re Aedificatoria, composed around mid 15th. century, was undoubtedly an influential work during the renaissance, and put forward a relatively clear picture of the nature of the Architect's activities, and the basis of his art.[1]

According to Alberti, the Architect, if he were not to be ridiculous, had to proceed by way of rule and art. He explained

> Whoever would build so as to have their Building commended, which every reasonable Man would desire, must build according to a Justness of Proportion, and this Justness of Proportion must be according to Art ......consequently this Part of Building, which relates to Beauty and Ornament, being the Chief of all the Rest, must without doubt be directed by some sure Rules of Art and Proportion, which whoever neglects will make himself ridiculous. But there are some who will by no means allow this, and say that Men are guided by a Variety of Opinions in the Judgment of Beauty and of Building; and that the Forms of Structures must vary according to every Man's particular Taste and Fancy, and not be tied down to any Rules of Art. A common Thing with the Ignorant to despise what they do not understand![2]

The rules in question Alberti conceived as being purely a matter of the form of the structure, which aspect he maintained was quite distinct from the actual material of the structure, and which hence could be manipulated in the imagination:

> .....the whole Art of Building consists in the Design, and in the Structure. The whole Force and Rule of the Design, consists in a right and exact adapting and joining together the Lines and Angles which compose the form and the Face of the Building. It is the Property and Business of the Design to appoint to the Edifice and all its Parts their proper Places, determinate Number, just Proportion and beautiful Order: so that the whole Form of the Structure be proportionable. Nor has this Design anything that makes it in its Nature inseparable from Matter; for we see that the same Design is in a Multitude of Buildings, which have all the same Form and are exactly alike as to the Situation of their Parts and the Disposition of their Lines and Angles: and we can in our Thought and Imagination contrive perfect Forms of Buildings entirely separate from Matter, by settling and regulating in a certain Order, the Disposition and Conjunction of the Lines and Angles. Which being granted, we shall call the Design a firm and graceful pre-

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1. BORSI (1977) notes the disagreement between authorities as to whether Alberti's treatise was fully complete when he presented it to Nicolas V in 1452. Published at Florence in 1485; Paris 1512*; Strassbourg 1541*; Venice 1546*; Florence 1550*, in the Latin version. An Italian translation by Pietro Lauro was published in 1546*, with Cosimo Bartoli's translation appearing at Florence in 1550, and reprinted at Venice in 1556. A French version appeared in 1553* at Paris, and an edition in Spanish at Madrid in 1582*. Alberti was of course widely quoted during the 16th. century as an authority.

2. Bk. VI, Cap. II. This is from James Leoni's translation of Bartoli's Italian version, and gives something of the flavour of the Italian version of mid. 16th. century. This passage is ALBERTI (1955) p. 113, which edition is quoted from throughout this section. Alberti's Latin version, from the 1485 edition, which again is used here throughout, gave: "Qui ita aedificat/ ut quae aedificēt probari uelint/ quod uelle debēt qui salem habent hos certa sane moueri ratione. Facere quidem aliquid certa cum ratiome artis est...equidem certe ipsa haec pars quae circa pulchritudinē ornamentaque uersatur/ primaria omnium quom sit huius nimirum ipsius partis aliqua certa et constans erit ratio atque ars quam qui negligat insulsissimus est. Sed sūt quibus ista non probentur/ dicantque solutā et uagam esse quadam opinionem/ qua de pulchritudine atque omni aedificatione iudicemus: pro cuiusque libidine uariam et mutabilem
et uagam esse quedam opinionem/ qua pro cuiusque libidine uariam et mutabilem esse formam aedificorum nullis artium praeceptis adstringendam. Commune hoc ignorātiae uitium est: quae ne scias ne quicquam esse profiteri." (Sg. mviib/ viiia). However Alberti allowed sometimes that the rules involved did not have to be universally applied to the same degree of rigour, stating: "Whereas in publick Works not the least Deviation is allowed from the exactest Laws of Proportion, in private Works such a Deviation is often handsome and commendable." Bk. IX, Cap. I, p.188, op. cit. As to the extent to which the Ancients in Alberti's view, followed such rules, see below p. 183, n. 3.

> ordering of the Lines and Angles conceived in the Mind, and contrived by an ingenious Artist.[1]

Beauty was then the underlying organising principle which determined the design of the form of the structure, and, according to Alberti:

> We should therefore consult Beauty as one of the main and principal Requisites in any Thing which we have a Mind should please others....(and) that very thing we speak of is itself no small help to Conveniency and Duration: For who will deny that it is much more convenient to be lodged in a neat handsome Structure, than in a nasty ill-contrived Hole? or can any Building be made so strong by all the Contrivance of Art, as to be safe from Violence and Force? But Beauty will have such an Effect even upon an enraged Enemy, that it will disarm his Anger, and prevent him from offering it any Injury: Insomuch that I will be bold to say, there can be no greater Security to any work against Violence and Injury, than Beauty and Dignity.[2]

His account of beauty being given thus:

> I shall define Beauty to be a Harmony of all the Parts.... fitted together with such Proportion and Connection, that nothing could be added, diminished or altered, but for the Worse.[3]

Central to the creation of this beauty were the orders of columns:

> In the whole Compass of the Art of Building, you will find nothing that either for Workmanship, Expence or Beauty, deserves to be preferred before the Columns.[4]

The example of the ancients' was then of great significance in determining how to produce the columns, as other aspects of the building, to the correct and hence most beautiful proportions. With regard to this area, Alberti claimed:

> There was not the least Remains of any ancient Structure, that had any Merit in it, but what I went and examined, to see if any Thing was to be learned from it.[5]

But Alberti further contended that a more universal account of

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1. Bk. I, Cap. I, op. cit. p. 1/2. "Tota res aedificatoria lineamentis et structura ɔstitua ẽ: Lineamẽtorũ om̃is uis et ratio consumitur: Vt recta absolutaq habeatur uia coaptande iungendiq lineas et angulos: quibus aedificii facies comprehendatur atq concludatur Atqui est quidem lineamenti munus et officium praescribere aedificiis et partibus aedificiorum aptum locum et certum numerum: dignumq modum & gratum ordĩem: ut iam tota aedificii forma et figura ipsis in lineamentis conquiescat. Neq habet lineamentum in se ut materiam sequantur: Sed est huiusmodi ut eadẽ plurimis in aedificii esse lineamenta sentiamus: ubi una atq eadem in illis spectetur forma. Hoc est ubi eorum partes: et partium singularum situs atq ordines inter se cõueniant totis angulis totisq lineis. Et licebit integras formas praescribere animo et mente/ seclusa omni materia: Quam rem assequemur adnotando et praefiniẽdo angulos & lineas certa directione et connexione. Haec cũ ita sint: erit ergo lineamentũ certe constansq praescriptio concepta animo/ facta lineis et angulis pfectaq animo & ingenio erudito." (Sg. aiiia/b, op. cit.)
2. Bk. VI, Cap. II, op. cit. p. 112/3. "Dignissima igitur atque ĩ primis affectanda pulchritudo est his praesertim qui sua uelint reddere non ingrata...Accedit q haec una de q̃ loquimur com̃oditati atq etiã pẽnitati plurimũ affert adiumẽti. Quis.n. nõ secũagi com̃odius affirmabit/ ubi sese ĩtra ornatos/ q̃ si neglectos intra pietes recepit: aut qd alioqntã obfirmatũ effici ulla hominum arte poterit quod ab hominum iniuria satis munitum sit. At pulchritudo etiam ab infestis hostibus impetrabit ut iras temperent/ atq inuiolata se esse patiantur: ut hoc audeam dicere nulla re tutum aeque ab hominum inuria atq illessum futur opus: q̃ forme dignitate ac uenustate." (Sg. mviia/b, op. cit.) At other places Alberti considered the strength of defensive works in a more practical way than is implied here. See below p. 186/7.
3. Ibid. "...diffiniemis: ut sit pulchritudo quidẽ certa cũ ratione concinnitas universar partium ĩ eo cuius sint: ita ut addi/ aut diminiui/ aut ĩmutari possit nihil/ q improbabilius reddat." (Ibid.)
4. Bk. I, Cap. X. op. cit. p. 14. "Tum et tota in re aedificatoria nihil inuenies quod opera et impensa et gratia praeferas columnis." (Sg. bviia op. cit.) See also Bk. VI, Cap. XIII. "The Principal Ornament in all Architecture certainly lies in the columns." (Op. cit. p. 130)
5. Bk. VI, Cap. I. p. 112, op. cit. "Nihil usq̃ erat antiquorum operum/ ĩ quo aliqua elucesceret: quin ilico ex eo peruestigarem siquid possem perdiscere." (Sg. mvib, op. cit.) Alberti also mentioned here the texts left by the ancient writers as sources of proportions. But the most important author, Vitruvius, Alberti rather decried -- "so maimed with age" (Bk. VI. Cap. I. op. cit.) In Bk. VII. Cap. VI, Alberti noted some rules for columns left by the Ancient architects of which he said "Not that I can say, upon those Measurements which I have taken of ancient Structures, that these rules were always strictly observed among the Romans." Again in Bk. VII, Cap. V, Alberti noted that "By an Examination of old Buildings, I find that this middle Interspace (of the colonades) was not always made according to this rule." In Bk. VII, Cap VI, Alberti noted that the ancient rule for the diminution of the columns was not scale free, but varied with the actual height of the column. (These are the rules mentioned above in this note.)

beauty could be given; that particular mathematical ratios had their own inherent value and that as a result these such should be used to determine the final proportions of the building. He explained:

> I Now come once more to these Points which I before promised to inquire into, namely, wherein it is that Beauty and Ornament universally considered, consist, or rather whence they arise....Then observing that those three Things which we have already mentioned, namely, the Number, Finishing and Collocation, were what chiefly conduced to make the the whole beautiful, they (i.e. the ancients) found out how they were to make use of them from an examination of the Works of Nature... By the finishing I understand a certain Correspondence of those several Lines, by which the Proportions are measured...... THE Rule of these proportions is best gathered from those Things in which we find Nature herself to be most compleat and admirable; and indeed I am every Day more and more convinced of the Truth of Pythagoras's Saying, that Nature is sure to act constantly, and with a constant Analogy on all her Operations: from whence I conclude that the same Numbers, by means of which Agreement of Sounds affects our Ears with Delight, are the very same which please our Eyes and Mind. We shall therefor borrow all our Rules for the finishing our Proportions, from the Muscians, who are the greatest Masters of this sort of Numbers, and those particular Things wherein Nature shews herself most excellent and compleat....(But) There are some other natural Proportions for the use of Structures, which are not borrowed from Numbers, but from Roots and Powers of Squares. The Roots are the Sides of square Numbers: the Powers are the Areas of those squares: the Multiplication of the Areas produce the Cubes....(Further) We are now to say something of the Rules of those Proportions, which are not derived from Harmony, or the natural Proportions of Bodies, but are borrowed elsewhere for determining the three Relations of an Apartment; and in order to this we are to observe, that there are very useful Considerations in Practice to be drawn from the Musicians, Geometers, and even the Arithmitians...By the help of these Mediocraties (i. e. Arithmetical, Geometrical and musical means: $\frac{a+b}{2}$; $\sqrt{ab}$ $(b-a) = (c-b)\frac{a}{c}$) the Architects have discovered many excellent Things, as well with Relations to the whole Structure, as to its Several Parts....But the most common Use they have made of these Mediocrities, has been however for their Elevations......[1]

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1. Bk. IX, Cap. V/VI, p. 194/200 op. cit. "Nūc quod dicturos pollicit sumus ad ea uenio ex quibus universa pulchritudinis ornamentorq genera existāt: vel quae potius expressa ex oī pulchritudinis rõ emanavit: dificilis nimir puestigator... Post haec cū tria illa quae recēssedamus aduertissent praecipue ad pulchritud ne assequēdā facere: numer/ finitione/ collocationē: his tribus quomodo uterētur naturae opibus p̃esitatis comptū fecere pricipuii uti opinor ductis hinc. Finitio quidē apud nos est correspodentia quaedā linear inter se/ quibus quātitates dimentiant .....Finitionis ratio aptissime ducit ex his/ qbus pspectū quidē et cognitū e naturā sese nobis spectandā admirandāq praebere. Et profecto iter atq iter affirmo illud Pytagorae. Certissimū est naturā in oībus sui esse psimilē. Sic se habet res. Hi qdē numeri p quos fiat ut uocū illa cōcinnitas auribus gratissima redatur/ iidem ipsi numeri pficiunt/ ut oculi aiusq uoluptate mirifica compleāt. Ex musicis igit quibus ii tales numeri exploratissimi sūt: atq ex his praeterea qbus natura aliquid de se cōspicuū dignuq praestet tota finitionis ratio pducet.....Diametris etiā finiūdis īntae sūt quaedā correspōdētiae quae numeris necq terminari possūt: sed captātur radicibus et potentiis. Radices sūt latera quadratorum numerorum. Potentiae quidē sūt ipsor quadrator areae. Ex arear accretione cōcipiūtur cubi.......Quae aūt deffinitionis ratio nō īnatata armoniis et corporibus: sed sumpta aliude ad diametros ternatī iungēdos subseruiat nūc dicendū est. Et .n. sunt quidē triū diametror ī opus coaptandor annotationes quaedā ualde commode ductae cū a musicis/ tum a geometris/ tū etiam ab arithmetricis: quas iuuabit recognouisse...Huiusmōi mediocritatibus architecti et totium circa aedificiū et circa ptes opis pq pluriā dignissima adinuenere quae lōgū esset pseq. Atq mediocritatibus qdem istiusmōi ad altitudinis diametrū extollendā usi sunt." (Sg. xviiia/yvb, op. cit.) But Alberti appears not to have considered this use of mathematics to proceed in any kind of deductive way, in order to produce beauty. He suggested that in designing a building, it was best to make models and for everybody to criticise them (Bk. II, Cap. I) saying: "It is really wonderful how by a kind of natural Instinct (monente naturale) all of us knowing or ignorant, immediately hit upon what is right or wrong in the Contrivance or Execution of Things, and what a shrewd Judgment the Eye has in Works of this nature above all the other Senses....(but) everyone can not propose the Remedy, but only such as are well practised and experienced that Way." The implication seems to be that the skilled architect, when the design does not look right, either to himself or others, goes and tries different ratios till its proportions give the required desirable effect. Given the great number of ratios that Alberti suggested might be used, together with such a process, it is difficult to see a great deal greater function for this use of mathematics, than a rationalising and dignifying function, after the fact, apart from very minor (insignificant?) adjustments to dimensions. For a concrete application of ratios see Bk. I, Cap. XII, where Alberti noted a rule for doors, the larger ones being twice as high as broad, while the smaller ones were to be $\sqrt{2}$ times as high as broad. For a more decorative rather than structural use of mathematics by Albertis, see Bk. VII, Cap. X "......I would have the Composition of the Lines of the Pavement full of musical and geometrical Proportions; to the Intent that which-soever way we may turn our Eyes, we may be sure to find Employment for our Minds."

The use of Mathematics Alberti considered as crucial to the profession of Architecture:

> The arts which are useful, and indeed absolutely necessary to the Architect, are Painting and Mathematicks....Painting and Mathematics are what he can no more be without, than a Poet can be without the Knowledge of Feet and Syllables...[1]

This was clearly in accord with Alberti's notion of expertise in the profession being acquired to a significant degree, through literary activity in the examination of the works of authorities:

> ....in the study of his Art I would have him follow the Example of those that apply themselves to Letters: for no Man thinks himself sufficiently learned in any Science, unless he has read and examined all the Authors..[2]

and was central to Alberti's picture of the Architect, for he said:

> ....it is not a Carpenter or a Joiner that I thus rank with the greatest Masters in other Sciences; the manual Operator being no more than an Instrument to the Architect. Him I call an Architect, who, by sure and wonderful Art and Method, is able, both with Thought and Invention, to devise, and, with Execution, to compleat all those Works which....can, with the greatest beauty, be adapted to the Uses of Mankind. And to do this, he must have a thourough Insight into the noblest and most curious Science.[3]

The very dignified nature of the profession defined the actual kinds of problems to which an Architect should apply himself, in Alberti's view. For:

> To run up any thing that is immediately necessary, for any particular Purpose, and about which there is no doubt of what Sort it should be, or or the Ability of the Owner to afford it, is not so much the Business of an Architect, as of a common workman.[4]

and he recommended also:

> I would also have you, if possible, concern yourself for none but Persons of the highest Rank and Quality, and those too such as are truly lovers of these Arts. Because your work loses of its Dignity by being done for mean Persons.[5]

This view of Architecture and the Architect, that Alberti put forward, in such remarks, was clearly most applicable to civil structures with its emphasis on the orders of columns, decoration and dignity, and beauty. Nevertheless Alberti did have something to say about the layout of the

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1. Bk. IX, Cap. X, op. cit. p. 206/7. "Quae aũt conserãt/ imo quae sint architecto penitus necessaria ex artibus haec sũt. Pictura et mathematica.....Verum pictura et mathematica non carere magis poterit q̄ uoce et syllabis poeta." (Sg. ziib op. cit.) Alberti states here, implicitly referring to Vitruvius, that it is ridiculous to emphasise, like a certain author, that the Architect should be deeply learned in the other relevant arts.

2. Ibid. p. 205. "Caeterũ sic gerat ueli sese uti ĩ studiis litterarũ faciũt. Nemo .n. se satis dedisse opam litteris putabit, ni auctores oẽs et nõ bonos legerit atq cognorit...." (Sg. zib, op. cit.) This was very evident in Alberti's treatise itself, which contained a great deal about building practice which leant on the ancient authors and was heavily bespattered with their names. The actual practice of building was indeed by no means ignored in Alberti's treatise even though he concieved this aspect of his art to be much less of significance as compared to the 'dignified' part of the art. At the end of Cap. I Bk. VI, just before he went on to discuss beauty, Alberti stated: "Of these Properties required in all Manner of Buildings, namely, that they be accomodated to their respective Purposes, stout and strong for Duration, and pleasant and delightful to the Sight, we have dispatched the two first, and are now to treat of the third which is by much the most Noble of all, and very necessary besides."

3. Preface. Op. cit. p. ix. "Non einem tignarium adducam fabrũ: quem tu summis caeterarũ disciplanarum uiris compares: Fabri enim manus architecto pro instrumento ẽ Architectum ego hunc constituam/ que certa admirabiliq ratione et uia tum mente animoq diffinire; tum et opere absoluere didicerit quecunq ignissimus hominũ usibus bellissime cõmodentur." (Sg. aia, op. cit.)

4. Bk. IX, Cap. X, op. cit. p. 205, " Praeterea facere quae usu cõmoda uideãtur: et quae posse p instituto et fortune ope fieri no dubites/ non magis architectiẽ/ q̄ aparii fabri." (Sg. zib, op. cit.)

5. Bk. IX, Cap. X, [illegible] "Velim quoq quoad liceat cures/ sit res tibi nõ nisi cũ splendidis/ et harũ rerũ. cupidissimis principibus ciuitatũ. Opa .n. quibusius praestita nõ dignis uilescit." (Sg. ziiia. op. cit.) In his preface Alberti expressed it that Architecture "....is inexpressibly delightful, and of the greatest Convenience to Mankind in all Respects.....and in Dignity not inferior to the most excellent" . (of all the Arts) .

city and its defence.[1] With regard to the last Alberti explained generally:

> It is certain the Form of the City and the Distribution of its Parts must be various according to the Variety of Places; since we see it is impossible upon a Hill to lay out an Area whether round or square, or any other regular form, with that Ease, that you may upon an open Plain. The ancient Architects in encompassing their Towns with Walls, condemn'd all Angles jutting out from the naked Wall, as thinking, they help the Enemy more in their Assault than the Inhabitants in their Defence, and that they were very weak against the shock of military Engines....[2]

Yet

> At the famous City Perusia which has several little Towers placed here and there upon the Hills, like the fingures of a Man's Hand extending out, if the Enemy offers to attack one of the Angles with a good Number of Men, he can find no Place to begin his Assault, and being obliged to march under those Towers, is not able to withstand the Weapons that will be cast, and the sallies made upon him. So that the same Method for walling Towns will not serve in all Places.[3]

As a general rule Alberti then proposed:

> .....we may conclude that of all Cities, the most Capacious is the round One; and the most Secure, that which is encompassed with Walls broken here and there into angles or Bastions jutting out at certain Distances[4]..Because it is certain, the Enemy cannot come up to the Wall between two Angles jutting out without exposing themselves to very great danger; nor can their military Engineers attack the Heads of those angles with any hope of Success. But, however, we should be sure to make use of all the natural Advantages that offer themselves for the security of our Town or Fortification; as we may observe the Ancients did, according to the Opportunity or Necessity of the situation.[5]

On the other hand he remarked:

> ....some think no Wall is so safe against Battery, as those which are built in uneven Lines, like the Teeth of a Saw.[6]

But also advised:

> The greatest Defence to the Walls either of a City or Fortress is to be so provided, that the Enemy cannot approach you on any Side without being exposed to imminent Danger. This is done both by making very broad and deep Ditches ....and also by leaving private Loop-Holes almost at the very Bottom of the Wall, by which, while the Enemy is covering himself with his Shield from the Besieged above, he may be taken in his Flank which lies unguarded. And indeed there is no kind of Defence so servicable as this. You gall the Enemy from these Loop-Holes with the greatest Safety to yourself..[7]

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1. This emphasis on civil building and the orders, with just a few remarks on fortification, was very much the pattern of Vitruvius's text, of course. Alberti's general notion of beauty being a certain kind of 'fitness' found in the just proportions of an object, meant that to some extent this notion could be extended to fortification, although at times it tended to lead him to extremes. (See above p. 183) Yet Alberti seemed to make little attempt to define what such 'fitness' in fortification might be, in either any detailed or general way. With regard to the layout of the streets of a city he stated "if the City is noble and powerful, the streets should be straight and broad, which carries an Air of Greatness and Majesty"; in contrast in small towns Alberti suggested it would be useful for them to be full of twists and turns, at least in part, from defensive considerations. (Bk. IV, Cap. V, op. cit. p. 75)
2. Bk. IV, Cap. III, op. cit. p. 70. "Ipsius urbis ambitum et partium distributionē intelligimus pro locorū uarietate futuram esse oportere uariam: quādo quidē montibus non dari inpromptu est: ut sue rotundā/ seu quadrāgulam/ aut quamodiam probes/ murorum descriptionē possis aeque atq aperto in plano ducere. Veteres architecti oppidis circūdendis/ murorū angulos improbarunt: q hostibus lacessentibus magis q̄ incolis defendētibus opitulent: q item ad machinarū iniurias tolerandis sint nequaq̄ ualidi." (Sg. hvb op. cit.)
3. Ibid. p. 71. .Ad Perusiam urbem celebrem/ q uicos hac illac quasi a manu dispansos digitos p obductos colles porrigat: si uolet hostis anguli frontem petere/ non palebit illic ubi multa incesset manu/ et quasi aliqua supinsidente arce exceptus/ tela eruptionesq non perferet" (Ibid.)
4. Leoni clearly got it quite wrong here, his 'angles or Bastions', should be sinuous curves, or the like, while Bartoli's version was closer to Alberti' sense. See next note.
5. Bk. IV, Cap. III, op. cit. p. 72. "....omniū erit capacissima urbs/ quae fit rotūda: tutissima quae sinuosis anfractibus munorum obualletur:.....Non enim sine discrimine hostem intra sinus/ aut certa cū spe frontibus machinas admotorū statuūt. Cōmoditatibus tamen ipso ex oppido capiendis prospiciemus; quam rem pro locorum oportunitate et necessitate fecisse ueteres aduertimus." (Op. cit. Sg. hviia)
6. Bk. IV, Cap. IV, op. cit. p. 74. "Et sunt qui murum cōtra machinamēta missilium tutissimu putent enim qui lineamēto ita ducator/ ut serrae denticulos imitetur." (Sg. hviiia, op. cit.)
7. Bk. V, Cap. IV, op. cit. p. 87. "Praecipua quidem ad tuendos urbis et arcis muros ī hoc erit ratio: ut cures penitus ne hostis impune propius possit appellere. Id fiet cum fossa qua diximus profundunaque lataq: tum et futariis ut ita loquar sub fissuris per ipsum imum podii disposites. Vnde hostis dum se scuto/ superne protegat/ qua fit parte nō tectus trāsueberetur." (Sg. Kiiia, op. cit.)

Thus Alberti gave a fair selection of advice on the form of the city walls; and while to some extent he emphasised the importance of being able to attack the enemy as he approached the defences, he never made this principle a foundation of a system or method, and tended always to emphasise the need to make use of the natural strength of a place, as the ancients had.[1]

Antonio di Piero Averlino -- Filarete -- in his Trattato di Architettura of a date not long after the mid 15th. century,[2] evidenced an attitude to architecture slightly different from that of Alberti. At the beginning of his treatise he introduced a speaker who said:

> ....pcerto pare facciate grande stima diquesto hedificare & a me non pare tanta cosa quãta molte lafanno che dicono bisognia sapere tante ragioni di geometria & didisegni & molte altre cose....Io non cercho tante misure ne tante cose quando fo fare alcuna cosa di murare & nonuo p tanti punti di geumetria quanti dicono costoro & pure stanno bene.[3]

Whereupon another speaker replies:

> Non dice cosi che auolere fare uno hedificio credo bisognia bene intendere le misure & anche eldisegnio come auolere compartire uno casameto/ o/ chiesa/ o altra ragione dedifitio sanza dubbio stimo che altrimenti nollo possa fare che bene stia senon a ildisegnio & misure & altre parti anchora credo glibisogni dintendere auno chesimette auolere hedificare[4]..

Filarete then spoke out in person. He mentioned Vitruvius and Alberti had written on his subject, the last being,

> ....molto pito maxime neldisegnio il quale e fondamento & uia dogni arte... e ingeometria & daltre scientie e intendentissimo....[5]

Himself, he contrasted with this:

> .....nomisono exercitato troppo inletiere ne in indire.....(but) inquesta exercitij misono dilectato & exercitato come indisegno & insculpire & hedificare & inalcune altre cose....Per questo credo che acquelli chenon sarrano cosi dotti piacera & quelli che piu pita & piu inlettere intendenti sarranno leggerenmo gliautori sopradetti. (i.e. Vitruvius and Alberti).[6]

Though on the other hand Filarete had already explained in his dedication, that in his work

> ....si contenghono proportioni & qualita & misure & donde diriuano i loro primi origine & questi mosterro pragione & p auctorita & p exempio....[7]

and had explained that, in his view, in Architecture,

> ....dalla figura & forma dello huomo tutte diriuano.....[7]

With regard to modern churches and the defects of contemporary architecture, Filarete noted:

> ....loro mancamenti huniuersale.....sono procceduti quasi danna oppinione huniuersale diche fa fare alcuna cosa che appartengha acquesto exercitio dedificare & aogniuno gli pare esse buono architecto & p queste e piu maestri di questa arte che diniuna altra mameno bene senetroua buoni che dellaltre & massime diquesti come sanno mettere una pietra incalcina & inbattarla dimalta pare loro essere optimi maestri darchitettura & serisucitasse Archimede/ o Dedalo che fece illaberinto pare alloro essere piu degni & quello che fanno sepure alcuna cosa fanno/ e piu pur loro pratica che pacienza didisegnio/ o dileuere/ o dimisure che abbino....pche none intendono ne misure ne proportioni delle cose che apartenghono allo hedificare.[8]

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1. Alberti gave a good deal of information also of course on battlements and the like. On the use of defensive fire, there is no doubt that by the time Leoni came to translate Bartoli's version, there was a tendency to over emphasise somewhat this idea. But it certainly was present in Alberti's text to a significant extent.
2. Spencer in FILARETE (1965) states it was composed in Milan 1461/4. (p. XIX)
3. Ibid. f. 1v. 4. Ibid. 5. f. 1v/2r. 6. f. 2r 7. f. 1v.
8. Ibid. f. 2r/v. Filarete's questioner had just asked how buildings were made in that time such as the churches of Milan and Florence, which were to his opinion beautiful. Filerete simply replied: "Sir these are of great expense". The question had been prompted by Filarete's claim "che antichamente sifaceuano piu degni edifitij che hora nonsifanno"; parts of which method, lost and abandoned Filerete claimed to have rediscovered. (f. 2r, ibid.)

Thus Filarete did emphasise to a fair extent the need for 'theory' in Architecture, and was concerned with the correct proportions of structures, although he did not emphasise any sophisticated mathematical approach to the art to the extent that Alberti had.[1] Equally in contrast to Alberti he wrote for the less 'learned' and emphasised his own practical skills, and this was possibly connected with the difference in emphasis.

But there was a contrast between Filarete and Alberti in another way. While at an early stage Filarete described the conception of a building as taking place by cogitations of the Architect in his mind in a long process assisted by the use of drawings,[2] at other points, particularly as he presented his ideas by way of a dialogue between Architect and patron during the course of his project, he tended to present a picture of design as taking place very much in a continuing process of interaction between the Architect and the Patron.[3] This was rather in contrast to the idea of the Architect predetermining the structure in all its details in an intellectual process before building began, which Alberti tended to suggest, and which Filarete himself came closer to in his general account. In part this was probably a response to the form of the treatise that Filarete chose to write, to be read possibly as the sort of renaissance court entertainment which Castiglione illustrated.[4] Thus Filarete's account of design in architecture, in his presentation probably approached closer to actual practice than did his 'idealised' account.

Further, with regard to the "rocca" of Sforzinda, Filarete allowed to the patron, rather than to the architect, the specialized knowledge necessary to design such a structure, because of the patron's own personal experience and knowledge. Filarete had the patron say:

> Io uoglio hordinare laroccha amio modo perche epotrebbe bene essere chequesti altri hedificij tugliordinerai meglio dime.. Ma questo perche misono pure ritrouato apigliaro & perforza & peraltre me Siche louoglio hordinare umpoco amio modo...[5]

To which the architect agreed, so that the patron then requested him;

> TROVAMI VN PAIO DI SESTE o/ due & una righa chetelouoglio disegniare in unun foglio tutto ilfondamento & poi seguiterai secondo ti diro & truoua uno libro & scriuerrai tutte queste chose misure & modi chio tidiro acio chesepure tusasse dimente che tu possa ricorre alla scriptura delibro....[6]

But the most striking difference between Filarete and Alberti was in their very different handling of the layout of the town. While Alberti suggested that towns ought to take advantage of the site and hence would differ from site to site, Filarete, whose treatise centred around the construction of

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1. As Spencer remarks, FILARETE (1965) p. xxii, "None of the complexities of Alberti's musical harmonies, of square-root proportions, or of Fra Luca Pacioli's golden section appears in this treatise (of Filarete)". Filarete did however give a rule for doors involving the "diameter" of a square. (f. 60r)
2. Bk.II, f. 7v/8r. Filarete used the verb "generare' and drew a parallel between human conception and the 'conception' of a building. The patron was then the father who conceives the project with the architect, who is the mother, and who carries it in his mind for 7 to 9 months turning it over and over and considering it with the aid of drawings. Birth Filarete considered to occur when the architect made a model of his design.
3. Describing one stage in the process of building his city Sforzinda, Filarete explained that the patron "hordinata egli latorre fechendo che era stara lasera dinanzi disegnata." (f. 33v) Later (f. 36r) the patron is depicted modifying the Architect's conception of the gate towers by replacing part of their height by four small towers at the corners of the basic square pattern.
4. Spencer states "The spoken word seems to domminate in the treatise", and noted that the"peripheral matter -- the flights of fancy, the allegorical conundrums and the digressions -- tend to obscure the true aim of Filarete's treatise". (FILARETE (1965) p. xix). Filarete in his dedication suggested that his work might be read aloud.
5. f. 37v.
6. Ibid. The beginning of Bk. 6. Spencer gives "Find me a pair of compasses or two, and a ruler, so I can draw the foundations for you on a sheet of paper. Then do as I tell you and find a book. You can write down all the measures and proportions that I give you. If you forget anything you can turn to the book and find it there again.

Sforzinda, based his design on the abstract geometric pattern of two overlapping squares.[1] Round towers were to be set at the points of the resultant star, with intermediate square towers between them, and square gate towers in the re-entrant angles.[2] These towers Filarete conceived to function together to some extent, for, he explained:

> ....nellangholo segnato A & quallangholo uoglio fare una torre tonda grossa dicinquanta braccia & nellangholo non retto segnato K uoglio fare laporta che sara dispatio di cinquanta braccia come qui siuede disegnata la torre dellangholo retto segnato .A. & quellangholo segnato .b. sara guardia della porto dellangholo segnato K & dellangholo segnato .L. & chosi tutte per ordine seranno difese decqueste torri degliangholi retti.[3]

However, although Filarete did thus to some slight extent relate his abstract geometric trace to defensive fire, he did not emphasise this to any significant extent, and gave not much attention to the provision of openings in the towers for defensive fire.[4]

Thus Filarete in being perhaps somewhat less emphatic about an intellectual 'method' in civil architecture generally, than Alberti had been, on the other hand in planning the town and its walls he was more concerned with abstract form than Alberti had been, although the relation of that form to defensive fire was only weakly pointed to in Filarete, as it had been in Alberti.[5]

Luca Paccioli in his Summa da Arithmetica (1594), mentioned the application of mathematics to architecture and praised Alberti highly:

> ....Vitruuio in suo volume. E Leon Batista....in sua pfetta opa de architectura. molto dmostrano esserli. accomodata pportionādo suoi magni: et excelsi hedifitii.[6]

He also mentioned the application of mathematics to warfare and the architecture of defense, and his studies in Euclid during his discussions with the condottierre Camillo Vitelli on such topics.[7]

In his Divina Proportione (Venetiis 1509), in his first main section on that topic he repeated the same ideas,[8] and then in a further section went on to give a discussion on Architecture.[9] Pacioli distinguished 3 branches of Architecture:

> ....luna sia deli tempi sacri. laltra de quelli deputati ala salute e defensione dele piccole e grādi republiche e deli luoghi ancora priuati e particulari la terça di quelli ala ppra oportunita necessarii deli pprii domicilii..."[10]

1. f. 13r. 2. f. 28r.
3. Ibid. The round towers were to have walls 6 braccia thick on the side furthers from the city, tappering to 2 braccia on the side nearest the city. (f. 33r.) The gate was to have a triangular ravelin battlemented in front of it 12 braccia high, against the 30 of the tower. (f. 36v)
4. Concerning the round towers the patron asked: "Ilumi della scala pbombardieri & balestriere & ancora perfinestre quando uenisse acquelli luoghi chenon fusse detrimento?" but got no real detail in answer. (f. 33v) About the square gate towers Filarete simply remarked as requiring "usci & finestri & balestriere & bombardiere & tutte quelle cose opportune chebisognio faceua" (f. 35v).
5. Filarete's treatise, in contrast to Alberti's, was not published until the modern period. Filarete was born in 1400 at Florence. He was active first at Rome as a sculptor and then at Milan as an architect. For details see DZ ENC ARCH URB. He was resident in Rome from 1433 to 1447. He worked in Milan from 1451 to 1465 on the Castle Sforzesco, the Cathederal, and the Ospedale Maggiore. (Spencer in FILARETE (1965) p. xix) See TIGLER (1963) for a discussion of Filarete and the new architecture in contrast to medieval practice. See also SAALMAN (1959). 6. f. (11a).
7. See below next page and also with Gian Giacomo Trivulzio. See above p.127, n.7.
8. Pt. I Cap. II, f.2a. The first part of the work was dated 1597 at Milan (f. 23a).
9. f. 23a/35b Cap. 1/20. Headed by a dedication dated 1509 at Venice.
10. f. 23a.

Pacioli went on to explain that a great deal needed to be said on the problems of defence:

.....conciosia che infinite quodammodo sieno le machine e dispositioni militari. Maxime per'li nuoui modi di artegliarie e bellici instrumenti quali dali antiqui mai foron excogitati. Deliquali li nostri strenui Borghesi a pede e caualla al tutto ptissimi (non che a Italia tutta) ma fin che dela terra el suonovsci.[1]

Pacioli, after a long section mentioning many military men and their deeds then continued:

Or breuiter dilectissimi miei dela parte prelibata darchitectura a defensione publica comme de muri e antimuri merli mantelletti torri reuellini bastioni e altri repari turrioi casematte etc. Con tutti li gia viui e morti discorsi ale volte comme confabulando acadi.misso. o con luno or con laltro molto con la experientia oculta e palpabile affatigato. Arguendo ora a vno modo e ora e laltro vdendo loro e sue ragioni apprendēdo e non manco. Con la Illustre S. miser Giouaniacomo traulçi con lo degno oratore del Dominio Fiorentino alora Pier vetori con ꝑsentia del Pontano nel palaçço del Conte de Sarno in Napoli. E non manco con lo Magnifico e degno condoctiero S Camillo vitelli dela citta de castello legēdoli Io per anni tre el sublime volume del nostro Eucli. E in milano con lo mio a quel tempo peculiar patrone meser Galeaço Sanseuerino. e piu volte con lo excelētissimo D.L.M.SF. Finaliter trouano questa parte dela defensione esser molto profonda ali tempi nostri ꝑ le noue machine de artiglierie: quali al tēpo del nostro.V. non si trouauano: e pero questa al presente lasciaremo e con piu amplo dire la reseruaremo etc.[2]

Pacioli then went on to discuss the third part of architecture,

...ala oportunita e necessita comme de palaççi e altri casamenti dentro e defora con tutti suoi membri....[3]

Here he stated:

....nulla parte de dicta Architectura non e possibile al tutte bene essre adorna.....non seino adorni comme de colonne cornici e frontespicii e altri ornamēti si ala parte difensiua e publica oportuna comme ala parte dele sacre. E perche questa parte tanto piu rende li hedificii ornati quanto ella con piu debita diligētia de ꝑportioni ꝑportinalite ella sia disposta le quali cose e voi e cadauno in tale exercitandose summamente sonno necessarie.[3]

About which topic Pacioli explained:

......ꝑma diremo dela humana ꝑportione respecto al suo corpo e membri pero che dal corpo humano ogni mesura con sue denominationi deriua e in epso tutte sorti de proportioni e ꝑportionalita se ritroua con lo dete de laltissima mediante li intrinseci secreti dela natura.[3]

Pacioli's discussion then continued in terms of this basic model, and was almost entirely in terms of the order of columns, Vitruvius's contentions and the practice of the ancients, and what proportions were to be used in what parts of the building. Reference to the golden section did not in fact form a basic device of Pacioli's discussions here, although he did suggest relative to this topic:

.....vericordo che nō siraño da biasimar leuostre ope se aleuolte cōme meglio vi pesse vi pōesse o ꝑ basa o capitelli ālcuno de quelli nri corpi meli in ꝑpria forma ve ho mostrati auenga...Ançe siraño de dignissima cōmendatiōe del vro opifito ꝑ che nō solo lo rēdaraño adorno ma ancora ali docti e sapiēti daraño da specualre conciosia che sempre sieno fabricati cō quella scā e diuina ꝑportione hñte medium duoq extrema etc.[4,5]

1. f. 23b. 2. f. 24b. 3. Ibid. 4. f. 32b.

5. BIGGIOGERO (1960) states, in "il Tractato delarchitetura il Pacioli mostra che la proporzione "divina" si presenta come principio di bellezza nelle forme architettoniche e nel corpo umano." But Pacioli in this section followed very much a Vitruvian analysis, (as for example noted in D.S.B.) with little emphasis on divine proportion as noted. He did state however "E pero la natura ministra dela diuinita formando lomo dispose el suo capo contutte debite proportioni cōrespondenti a tutte laltre parti del suo corpo." (f. 25a.) Yet his setting out of the human head was based on the equaliteral triangle and not on any golden section. PORTOGHESI (1957), in analysing Pacioli's ideas on the golden section in architecture was forced to make use of Pacioli's general section on this topic almost entirely, rather than the specialized one, which he stated was "in gran parte ispirate a Vitruuio." He remarked on a certain tension in Pacioli between theory and practice. He also stated that in the problem of 'entasis' Pacioli "si ricorda di avere scritto un trattato sulla sezione aurea e definisce tutta la materia con dati numerici elementari tolti direttamente da Vitruvio". In one of his illustrations to the architectural section Pacioli again note the necessity of number measure and weight in design.

Diego di Sagredo in 1526[1] at Toledo published Medidas del Romano, which, in the form of a dialogue, discussed the orders. Sagredo explained:

> ...los primeros fabricadores no tuuiessen reglas para tracar/ repartir y ordenar sus edificios: parceioles deuian y mitar la composicion del hombre: el qual criado y forma de natural proportion...de donde tomaron ciertas reglas y medidas naturales para dar proporcion y autoridad alos repartimientos y ordenças de sus edificios.[2]

After discussing something of the roots of architecture Sagredo went on to expound:

> De alqunos principios de geometria necessarios/ y muy vsados del arte del tracar.

and there stated:

> La sciencia de geometria es vna delas siete ates liberales: muy necessaria a todos los officiales mecanicos; ca sino tienen parte enella; no pueden ser bië resolutos ë sus artes. Es la geometria instrumëto que mucho ayuda a comprehender todos los saberes del mundo: por tanto Plato mando escruier sobre la puerta de su escuela...[3]

and continued:

> ...se lee de vn pintor que vuo en grecia natural de Macedonia que se dezia Eupompo: el qual sue maestro di Apelles: que por auer sido en las artes de geometira y arismetica muy sabio: alcanço muchos secretos y primores enla arte de la pintura/ & hizo marauillosas obras de perspetiua: por donde consiguio mucha fama y fue muy celebrado por toda grecia: y fuerõ sus obras de tanta excelëcia y en täta admiraciõ tenidas: q ordenarõ de alli adelante los griegos que la arte dela pintura se numerarse cõ las liberales: y no con las mecanicas. (Picar.) Desde entonces verdadermete somos todos los pintores pobres: ca por ser liberales gastamos quanto tenemos: y este es el prouecho que se nos sigue del priuilegio q̃ tiene la pintura: el qual creo/ no tomarian los oficiales q̃ llamas mecanicos a vn que les rogassen conel: los quales te ruego me digas qualis son: & assi mesmo q̃ cosa es architeto/ q̃ tantas vezes por ti es nõbrado. (Tamp.) A q̃llos se llaman oficiales mecanicos q̃ trabajan conel ingenio y con las manos: como son los Canteros/ Plateros/ Carpinteros/ Cerragéros/ Cãpaneros y otros oficiales q̃ suo artes requieren mucho saber & ingenio. Pero liberales se llaman los q̃ trabajan solamẽte conel espiritu y conel ingenio: como son los Gramaticos/ Logicos/ Retoricos/ Arismeticos/ Musicos/ Geometricos/ Astrologos: con los quales son numerados los Pintores y Esculptores: cuyas artes son tan estimadas por los antiguos...Has orto si desaber que architeto es vocablo griego: quiere dezir principal fabricador & assi los ordenadores de edificios se dizen ppriamente architetos: Los quales según parece por nuestro Vitruiuo: son obligados a ser execitados enlas sciencias de philosophia y artes liberales. La de otra manera no pueden ser perfectos architetos cuyas ferramientos son las manos delos officiales mecanicos. y nota que el buen architeto se deue proueer ante todas cosas: de la sciencas de geometria: dela qual escriuieron muchos autores: & principalmente Euclides padre de Ypocras: de cuyas obras se tomaron los principios siguientes.[4]

After giving a few geometrical definitions Sagredo's work was concerned almost entirely with presenting details of the orders and their proportions.[5]

Sebastion Serlio began the publication of his multi volume treatise on Architecture with Regole Generali di Architettura Sopra le Cinque manier de gliedifici (Venetia 1537),[6] which formed Bk. IV of the total work.

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1. 1542 edition used here. See PALAU Y DULCET (1948/77) & ZAMORA (1947) for detailed bibliographical information of the many editions of this work.
2. Sg. ava.
3. Sg. aviiia. Sagredo went on to explain that not knowing arithmetic and geometry one can not be truly called a man.
4. Sg. aviia/b.
5. Sagredo adverted to himself as "cappellan dela Reyna" at the head of his dedication.
6. Serlio set out clearly his total scheme in this work. Bk. I on geometry; Bk. II on perspective; III on ancient buildings; IV on the orders; V temples; VI great and more lowly mansions; VII on the 'accidents' of architecture.

In his forward Serlio explained:

> Benigno lettore, hauend'io apparecchiato alcune regole nel Architettura, presuponendo, che non pur glieleuati ingegni l'habbiano ad intendere, ma ogni mediocre anchora ne possa esser capace.... lequai regole sono in sette libri diuise.....poi che'l soggietto il comporta, ho uoluto incominciar da questa quarto libro a mandarle fuori, che è piu à proposito, & piu necessario de glialtri, per la cognitione de le differenti maniere de gliedificij, & de i loro ornamenti.....[1,2]

Serlio's technique of presentation, here as in his other texts, was to give a series of designs each with text as commentary on it, rather than to develop any series of ideas in a continuous text. Equally, Serlio explained with regard to the subject of this book:

> ....Et ben che ne le colonne & ne i suoi ornamenti non siano tutte le proportione, & le misure notate, ma solamente le principali, per regola generale, non dimeno a suoi luoghi non si mancherà che tutte non sia notato piu minutamento. Ma queste è solo, come ho detto, per dimostrar una regola generale.....[3]

In this same volume Serlio made clear his feeling that fortification was outside his brief, and rather its own specialised subject. And while he wrote of the Tuscan order:

> ....al parar mio, conuiene alle fortezze; come sarebbe à porte dicittà, a rocche a castelli, a luoghi di conseruar thesori, o doue si tenyon le munitioni, & le artigliarie, a le prigioni....4

he further explained:

> Ho promesso in queste presente volume di trattar solamete de gliornamenti, et de le differenti maniere de gli edificij: il perche non dira hora, come si debban collocar le porti de le citta, & de le fortezze, con i loro fianchi, et cannoniere, & altre loro circostantia per diffesa, lasciando tal carico allo Architetto di guerra, secondi i siti, e gliaccidenti, che ocorreranno; ma dirò ben collocato la porta de la citta o de la fortezza, il modo, nel quale ella si ha da adornar per mi auiso......[5]

Serlio's Bk. III on the antiquities of Rome appeared in 1540 at Venice*; and Bk. I & II appeared in 1545 at Paris*, Serlio having by this time emigrated to France, with text in both French and Italian.[6]

At the beginning of Bk. I Serlio explained:

> Quanto sia necessaria a qualunque persona la certissima arte della Geometria ne possono rendere testimonio tutte colloro che hanno vn tempo operato senza quella, & dipoi son venuti in qualche cognitione di tal arte: li qual veramente con essa fanno, che tutte le cose da loro pensate & fatte senza Geometria, furono senza arte alcuna, ma a ventura & a caso. Per il che essendo la profundissima arte dell'Architettura abbracciatrice di molt arti nobili, primeramente fa di mistiero, che l'Architetto ne sia, se non dottato, almen tanto di sorte ch'egli n'habbia qualche cognitione, & massimamenti de i principij, & anco piu auanti, & non come molti consumatori di pietre, & di calcine, imo de marmi che al di d'hoggi tengono il nome di Architetti, liqual non sanno pur render conte che cosa sia punto, linea, superficie: o corpi, ne che sia correspondentia, o harmonia. Ma guidati da vn suo proprio parere, & complacentia d'occhio, seguitando le vestigie di glialtri, che con pocca cagione han fatto, varo operando, & di qui viene la disproportione e mala corrispondentia che in molti edificij si vede, dico per la magior parte, & perho (come di sopra dissi) lo primo grado delle buone arti e la Geometria, dellaquale intendo trattare alquanto, & darne tanto di cognitione a l'Architetto: che di quello ch'

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1. p. v.
2. In his dedication Serlio had mentioned other architects of note and stated: "che dirò io di messer Vettor fauste ? il uiuo & sottil ingegno del quale è cosi applicable all'architettura, come alle scientie & alle lingue...& alquanto al l'operar con le mani & da la non prima creduta pruoua ch'ella si sia nel suo nascimento uedute quinguereue, ch'era state settecent'anni morta con grandissimo honore, & reputationi de la petru sua".(p. III.)
3. f. Vb.
4. f. Va/b.
5. f. VIIIb.
6. DINSMOOR (1942) p. 68 & 74. The Venetian 1551 ed. of these Bks. used here.

egli operara, ne sappia render conto, guidato dalla ragione.[1]

With regard to perspective ("senza laquale l'Architetto non seprebbe cosa buona operare")[2] Serlio explained:

...ne mi stēdero in philosophare o disputare che cose sia perspetiua ne d'onde sia deriuita: pciohe il profondissimo Euclide ne tratta sottilmente cō la speculatione, ma vendendo alla pratica & al bisogno de l'Architetto, diro...[3]

With a rather different emphasis Serlio explained of his 3rd. volume, on the antiquities of Rome:

....dipoi lo terzo volume delle antiquita per le diuerse cose che vi sono, dalle quali olta le piaceuolezza di i varij & belli edificij, si puo per mezzo deiscritti formare vno giudicio nella mente per saper fare elettione del bello, & abbandonare lo incorporabile.[4]

In 1551 Serlio published his 'Extraordinary Book', on gates and portals, at Lyon.[5] Serlio's Bk VII, was only published after his death at Frankfurt-am-Main in 1572.[6]

In Bk. VI Serlio gave designs for residences for individuals of different levels of life.[7] Now while he had earlier rather left fortification rather aside, Serlio in this work attempted, to some extent, to integrate the pointed bastion style into some of his designs. In one "Della casa del principe illustre in modo di fortezza" he showed a square residence with towers at the corners whose faces were clearly defined by flanking fire from the adjacent towers in the standard pattern.[8] Then in another "Della casa del principe illustrissimo per fare alla campagna"[9] Serlio showed a 300ft. square residence with a square bastion system surrounding it. Between the outer curtain and the residence was "a garden" 200 ft. deep on all sides. In another design, "Delle casa del principe Tiranno per far fiori alle campagne", the square residence had towers on the pointed bastion trace at its corners, and was also surrounded by a square bastion system with curtain walls at least 14 ft. thick, terrepleined with countermines.[10] In another scheme Serlio showed a pentagonal bastion system surrounding a pentagonal residence, and here explained:

Fouri dela forma quadrata per diffensarsi con fianchi: io truouo la penthegona essere la piu facile, per cio che la triangolari fa li belouardi troppo accuti et ui rimane puoco spacci de drento se ella none grandissia, per il che jo ho uoluto dispore una fortezza sopra la forma de cinqui lati per lo principe tiranno...."[11]

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1. f. 2a. In the dedication to Bk. IV (1537 ed.) Serlio had earlier indicated his belief in the need for theory. There he wrote "A uoi dico o HERCOLE.II, che tenate il nome del sole, la cui nobilissima casa da Este ha sempre hauuto & ancor haue gran copia dogni Excellente ingegno in tutte le nobile arti, & fra quelle, in questa de l'Architettura quanto a la Theorica, come e Messer Celio calcagnino, che non pur di tutte le scientie è pertissimo, ma di questa intende quanto alcun altro si sia." (p. IIII) Of his teacher Serlio wrote: "...precettor mio Baldessar Petruccio da Siena: ilqual non solamente dottisimo in quest'arte & per Theorica & per practica, ma fu anchor cortese, & liberali assi...." (f. va) In these sorts of passages Serlio seemed to assume that a good architect would be wise in the theoretical part and that it was all the more to be marvelled at when he was also wise as to the practical aspects.
2. SERLIO (1551) Bk. I, f. 1b.
3. Ibid. Bk II. f. 1a.
4. Ibid. Bk. I f. 1a.
5. Venetia 1558 edition used here. This work appeared in error sometimes in compilations of Serlio's work as the sixth book, that work not being known to his contemporaries. See DINSMOOR (1942).
6. Ibid. p. 78. Venetia 1584 edition used here.
7. Fasc. SERLIO (1966) with commentary by Rosci, See DINSMOOR (1942) for a discussion of this work. Two m.s. of the work exist with rather different texts, the fasc. being of the copy in the Bavarian Ducal library. It has not been possible to compare this with the Harvard version. This design is no. XVIII.
8. f. 18v & 18a. The points of the towers were rounded off. The same scheme was used in the design on f. 28 & 29. It was used at times in constructed buildings during the 16 th. century. See for example [10].
9. f. 25v & 26. Design XXVI.
10. f. 27v & 28 . Design no, XXVII. The external bastion system was 250 "varchi" square but was not represented properly to scale, Serlio explained, because the sheet was too small.
11. f. 29v & 30 . The curtain the same length and thickness as before. The area within the bastion, Serlio described as "per spazzare la compagna". He provided countermines in the wall. Loopholes for arquebus fire were provided in the lower section of the residence to guard the entrance. The external wall of the residence was blind.

In all these cases where an external bastion system surrounded a residence, Serlio showed lines of fire determining the top of the curtain wall apparently relating that height to the height of the residence, so that the defensive barrier masked the internal building.[1,2,3,4]

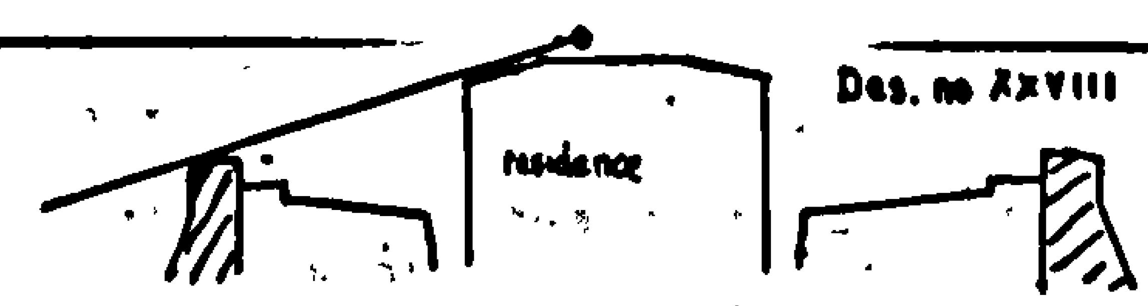
Antonio Labacco's Libro appartenete all'architettura (Rome 1552*)[5] was concerned with presenting engravings of contempory and antiquarian structures of Rome. Giovanni Battista Bertani's Gli Oscuri et difficil Passi dell'opera ionica di Vitruuio (Mantoa 1558*)[6] was concerned to elucidated the order named particularly as Vitruvius had described it.

Jacques Androuet du Cerceau published a number of works relevant to Architecture, mainly containing engravings of ancient and modern buildings, with only the briefest descriptions as text. His works included a volume in 1549 on the antiquities of Rome.[7] As well as his first and second Livre d'Architecture,[8] he published Les plus excellent Bastiments de France in two volumes,[9] and Petit traitte des cinquies ordres de colonas (Paris 1583*).[10,11]

In 1561 Philibert Delorme published his Nouvelles Inuentions pour bein Bastir et a petit fraiz (Paris), a work mainly concerned with some practical topics in building.[12] Then in 1567 Delorme published Le Premier Tome de l'Architecture (Paris*),[13] and in the next year a second edition of this work appeared.[14] There Delorme stated:

> ....qu'il y a auiourd'huy peu de vrais Architectes, & que plusiers que s'en attribuent le nome, doibuent plustost estre appellez maistres maçons, qu'autrement. Car les vns se sont seulement voulus exercer aux oeuures manuelles, sans se soucier de la cognoissance des lettres & disciplines, qui a esté cause qu'ils n'ont tant secu par leurs labeurs, qu'ils ayent acquis grande reputation. Les autres tout au contraire se sont arrestez aux lettres seules, & demonstrations Geometriques, sans les appliquer à l'oeuure, qui a fait que seulement ils ont suiuy l'vmbre de ce beau corps d'Architecture, sans aucunement paruenir à la vraye cognoissance & vsage de l'art.[15]..Bref l'Architecture est vn art & science tresadmirable, contenant & embrassant en soy autant de disciplines & artifices que les bastiments qu'elle monstre à construire contiennent & reçoiuent en eux se matieres, membres & parties...[16]

> .....touchant les sept choses neceesaires pour la construction & conseruation d'vn corps de logis, veu que a grand Architete de l'vniuers, Dieu tout puissant, le nous a figuré & mõstré quãd il a creé les sept estoilles errãtes appellées Planettes, cõme la matiere (si ansi fault parler) ou plus

1. 

2. DINSMOOR (1942) discussed the evidence which shows this book to have been completed around the mid or late 1540's.

3. Sebastion Serlio 1475/1554 spent ehe early part of his working life in Perugia. Went to Rome c. 1514 where Baldassare Peruzzi was his teacher. In the early 1540's emigrated to France in search of patronage for his treatise. See CHABVET (1869) for further details and DINSMOOR (1942).

4. As to Serlio as an architect generally, ARGAN (1932) described him as an "empirico" and stated "lo spazio serliano non si determina come construzione geometrica". p. 189. ROSCI (1966) p. 30 stated however "Inoltra, l'altro aspetto fundamentale degli ordini cinquecenteschi, (i.e. as against the anthropomorphic model) il loro constituirsi come base modulare du tutti i rapporte spaziali, dai massimi ai minimi, della pogettezione, se non è teorizzato dal Serlio, è da lui applicato empiricamente in ogni modello proposto."

5. ASHBY (1914). Rome 1557 edition used here. Labacco worked on the fortifications of Parma and Piacenza under Antonio da San Gallo the younger, and also it appears under Bramante. Ibid.

6. The B.M. edition, one of only two listed in INDEX AUR, was destroyed during the war. POLENI (1739/41) gives a latin version.

7. INDEX AUR at Orleans. Quinque et vigenti Exempla arcum, partem...inuenta partia ex veter sumpta monumentes tum Romae tum alibi (Aurelone*)

8. Paris 1559*, Paris 1561* Ibid. 9, Paris 1576, Paris 1579. 10. Ibid.n.7.

11. Androuet De Cerceau born 1510/12, travelled to Italy 1531/3, and in 1541. He died in 1585. DZ ENC ARCH & URB. On his work in perspective see above p.130.

12. De l'Orme gave many details on the timbering of roofs, for example.

13. BLUNT (1958). 14. At Paris.

15. f. 1b. Delorme went on to discuss the disciplines that Vitruvius declared as necessary to the Architect, and played down Law and Medicine. At f. 10a/b he again played down these disciplines again, and mentioned there that he followed Alberti to a great extent.

16. f. 2a. Delorme listed 7 part to building: the walls; gates; "cheminées"; windows; "l'aire & paue"; floors; coverings.

tost la fome de l'establissemẽt, perfection & conseruation du tant admirable bastimẽt & theatro de ce mõde inferieur. De sorte que si l'vn des susdicts planettes defaillot à la cõcurrẽce de ceste occulte harmonie qui entretient en bonne concorde les elements discords, le susdit bastiment de ce petit monde seroit inhabitabile & inutile......[1]
.......Dieu est le seul, le grand, & l'admirable Architecte, qui a ordonné & creé de sa seule parole toute la machine du monde tant celeste que elementarie & terrestre, auecques vn si grand ordre, vne si grãde mesure, & si admirables proportions, que l'esprit humain sans son ayde & inspiration ne les peult comprendre, & signamment l'architecture & fabrique du corps humaine.....bien en la grande harmonie & plusque admirable proportion & symmetrie qui est entre tous les membres & parties interieures que exterieures d'iceluy. Laquelle contemplent ou doiuent contempler & sçauoir les docte & expertes Architectes, à fin de l'accõmoder aux bastiments qu'ils entreprennent auecques vne diuine excellence...
O granade & insigne bõté de Dieu enuers les hommes!O magnifique & supernaturel Architecte, qui co tant voulu honnorer l'Architecture & fauoriser à l'Architecte, que luy enuoyer des hauts cieux, & prononcer de ta tres-sacrée bouche les vrais mesures & proportions, desquelles il se doit ayder...[2,3]
Il seroit tres bon que l'Architete eust esté nourry de ieunesse en son art, & qu'il eust estudié aux sciences (outre que nous auons dict) qui sont requises à l'Architecture, comme entẽder bein l'Arithmetique, ie dy en sa praticque & theorique: la Geometrie aussi en theorique, mais plus en pratique, pour les traicts qui sont le vray vsage d'icelle: pareillement, l'Astrologie, Philosophie & autre disciplines, comme i'ai dict, & sur tout entendre bein la raison des symmetries, per doñer les mesures & proportions à toutes choses.....Il sera aussi fort bien, qu'il ne soit du tout ignorant de la theorique de Musique, pour sçauoir representer l'Echo, & faire resonner & ouyr la parolle & voix....[4]

In Bk. I Delorme discussed other preliminary matters: the choice of the site, and the qualities of materials, for instance. In Bk. II, III & IV Delorme discussed something of geometry and showed many complex geometrical settings-out of vaults and arches and the like.[5] At the beginning of Bk. V he again praised goemetry, but then most of the remainder of his work was concerned with the architecture of the orders, and their correct proportions.[6,7]

During this same period there appeared another French work: <u>Reigle generalle d'architecture des cinques manieres de colonnes</u> (Paris 1564)[8] by Jean Bullant. With regard to this work Bullant explained:

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1. f. 2b. Delorme went on to mention 'Trismegiste'. He had praised among others, in his dedication, Ficino.
2. f. 4a.
3. Delorme previously wrote of "la premiere creation, soub certaines mesures, pois & nombre, ainsi que plus à plein nous le deduirons quelque iour (Dieu aydent) en nostre Tome & œuure des Diuines proportions" (f. 3b), which "sainctes & diuine mesures & proportiõs dõnes de Dieu aux saincts peres du vieil testament" (f. 4a); although "Certes ie ne me pius assez merueilles, comme tant de diuines mesures & proportiõs n'ont esté cognues, obseruées, & pratiquées par les anciẽs ou par aucunes des moderns". (f. 4b). There was of course a certain tension here with the idea of measuring the ruins of the (pagan) ancient world as a method of discovering true proportions. The work on divine proportions however, never did appear.
4. f. 10b/11a.
5. Much of which was necessary for masons as well as architects, according to Delorme, as he explained at the beginning of Bk. V (f.128a).
6. At the beginning of Bk. VI Delorme insisted that the proportions used by the ancients could not be followed unless one built on the same scale as them.(f.131a/b)
7. Philibert Delorme was probably born 1505/10, son of a successful master mason of Lyon. He went to study the antiquites of Rome in 1533/6. On the accession of Henry II in 1547 he was put in charge of all the king's buildings except the Louvre. He died in 1570. See BLUNT (1958) who described Delorme as in part stemming from the tradition of the medieval masons, yet as much an educated renaissance architect following a classical style. See also BRION-GUERRY (1955). DZ ENC ARCH URB however states b. 1510 "Figlio di un imprenditore....Dopo severi studi attenere il baccallierato in teologia".
8. INDEX AUR. 1568 Paris edition used here. The work was "suiuant les reigles & doctrine de Vitruue" t.p. Bullant was first noted as an architect in 1556. He visited Rome to make drawings at some time (c. 1550). BLUNT (1970) who suggests he was born 1520/25 rather than earlier. For his work in other areas of the practical mathematical sciences see above

...cest oeuure est plus duisant & conuenable pour artisans qui besognent au compas & à l'esquierre, (pour lesquelz ie me suis principalment trauaillé) que pour les grands seigneurs, qui tousiours sont empeshez aux affaires ....Ce neantmoins ie me suis tant fié de vostre bonne & vertueuse affection, Monseigneur enuers tous hommes studieux des artes & sciences liberalles, que i'ay bien osé vous dedier, offrir & presenter, ce mien labeur, quelque simple & mechanique qu'il soit.[1]

The substantive part of Bullant's treatise was then concerned with illustrations on a large scale, with a good deal of information about the proportions of detailed features, of the 5 orders, and discussion centering around the problems involved with them.

During the same period John Shute published The first and chief groundes of Architecture (London 1563*).[2] In his forward to the reader, Shute propounded:

.....there is nothing eyther for the dignitie and worthines of the thynge self, or for the wonderfull estimation and price whiche in all times it hath bene in more excellent, pretious, and comendable then learnyng, knowledge and science, the which alone causeth mortall men to be most like immortall Goddes......And amongest all other studies there is none in my simple iudgement of this sorte that diserueth greater prayse, then that whiche is of the grekes named Archetonica, and of the latins Architectura.[4].. Amd surely such is the amplitude and largnes (I may well say perfection) of this facultie, that without sum acquaintaunce with many other artes ye shall not enter into ÿ depe secretes: for it hath a natural societie and as it were by a sertaine kindred & affinitie is knit vnto all the Mathematicalles which sciences and knowledges are frendes and a maintayner of diuers rationall artes: so that without a meane acquaintance of vnderstanding in thē neythe paynters, massons, Goldsymthes, embroderers, Caruers, Ioyners, Glasseyers, Grauers, in all maner of metalles and diuers other moe can obtayne any worthy praise at all.[3]

Further that:

.....an Architecte must be sharpe of vnderstandinge and both quicke and apte to conceiue the trewe instructions ana meaninges of Men that haue written therof: and must also be a perfect distributor of the great misteries, that he hath perceiued and experymented, that playnlye and breefly he maye discusse and open demonstrations of that which shallbe done or mete to those persones, that shalbe the fownders of any noble workes wherefore he ought first to be a very good Gramarian, then to haue experte knowledg in drawing and protracting the thinge, which he hath conceyued, Nexte he muste haue a good sight in Geometrie, Consequently in Opticke and in such lyke sciences he must haue good perceuerance. Likewise in Arithmetick[4]...

Shute, after his introductary section on the notion of architecture, then went on simply to describe the proportions and details of the different orders. In his closing paragraph he then explained:

Therebe also diuerse other orders of measures and example that the Antiques aluayes vsed in their times, which shulde be tedios (to relate)....Thus ending this treatie of the Introduction and measures of these for sayd pillars, which are the original first grounds and entring into this noble science of Architecture, practised and alowed by right mighty and worthye potentates, and Emperors...the Elegance thereof, of all antiquitie hath bene and yet presently is as a parfaicte example and a myrroure to behold, lerne and take trewe measures....[5]

Giacomo da Barozzi (Il Vignola) published his Regole delli cinque ordini d'architettura (Rome*)[6] in 1562. In his forward Barozzi explained that he had for many years worked:

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1. Sg. Aiia, op. cit. From the dedication to Francois De Montmorency.
2. Fasc. ed. Londin 1912.
3. Sg. Aiib.
4. Sg. Biib. Shute stated that he was following Vitruvius, and went on to mention the need for such disciplines as Music, Physic, Philosophy, Astrology and History.
5. Sg.Fijb. Shute advertised himself as "Paynter and Archytecte" on his title page and was described in his epitaph as "Painter-stainer. In his dedication he explained that being a servant to the Duke of Northumberland, in 1550 that magnate sent him to Italy to improve his knowledge. Of his text he explained: "I haue put no title in any part thereof cōcerning ÿ proportiō & simetry to vse the accustomed terme of the arte of the fornamed columbes, whiche I haue not aswell seene and measured in Italie...as read and studied in England in the Antentique writers". He mentioned Vitruvius and Serlio at many points as authorities Shute died in 1563, and whether he was ever responsible for the construction of any buildings is doubtful. See Introduction SHUTE (1912).
6. CONNALLY (1960) Venetia 1603 edition used here.

.....vedere di trarne vna regola, nella quale io mi acquetassi con la siccurezza, che ogni guidicioso di simil arte douesse in tutte, ouero in gran parte piacere.......E per far questo lasciando da parte molte cose de scrittori doue nascono differenze fra loro non picciole; per potermi appoggiare con fermezza maggiore mi sono proposto innanzi quelli ornamenti antichi delli cinque ordini....(thus) ho trouati quelli, che al giudicio comune appaiano più belli, e con più gratia si appresentano à gli occhi nostri; questi ancora hauere certa corrispondenza, & proportione de'numeri insieme meno intricata, anzi ciascuno minimo membro misurare li maggiori in tante lor parti apunto. La onde considerando più adentro quanto ogni nostro senso si compiaccia in queste proportione, e le cose spiaceuoli esser fuori di quella, con ben prouano li Musici nella loro scienza sensatament, ho presa questa fatica più anni sono di ridurre sotta vna breue regola facile, & spedita da potersene valere il cinque ordini di Architettura.....[1]

to which end Barozzi stated he had made,

.....scelta di tutti gli ordini cauandoli puramente da gli antichi tutti insieme, nè vi mescolando cosa di mio si non la distributione delle proportioni fondata in numeri semplici senza hauere a fare con braccia, ne piedi, ne palmi di qual si voglio luogo; ma solo ad vna misura arbitraria detta modulo diuisa in quelle parti, ch'ad ordine per ordine al suo luogo si portrà vedere...[2]

Barozzi's presentation, after a few such opening remarks, was then based almost entirely of illustrations of the orders with their proportions, and with only very brief notes as commentary.[3]

In 1554 Palladio published his work La antichita di Roma (Roma).[4] Then in 1570 his I Quattro libri Dell'Architettura (Venetia). There he explained that in his first book:

si tratterà della preparatione delle materia, e preperata, come, & in che forma si debba mettere in opere dalle fondamenta sino al coperto: oue sarrana quei precetti, che vniuersali sono, & si deono osseruare in tutti gli edificij cosi publici, come priuati.[5]

Palladio further explained in Bk. I, Cp. I

Tre cose in ciascun fabrica (come dice Vitruuio) deono considerarsi... l'vtile, ò commodità, la perpetuità, & la bellezza....La commedità si haurà, quando à ciascun membro sarà dato luogo atto, sito accommodato, non minore che la dignità si richiegga, ne maggiore che lvso si ricerchi: & sarà posto in luogo proprio, cioè quando le Loggie, le Sale, le Stanze, le Cantine, e i Granari saranno posti a'luoghi loro conueneuoli. Alla perpetuità si haurà risguardo, quando tutti i muri saranno diritti à piombo, più grossi nella parte di sotto, che in quella di sopra, & haueranno buone, & sofficienti le fondamenta[6].....La bellezza risulterà dalla bella forma, e dalla corrispondenza del tutto alle parti, delle parti fra loro, e di quelle al tutto....[7]

After some short chapters on materials and construction, Palladio continued:

Hora c'habbiamo parlato de'muri semplici; è cõnueneuole che passiamo à gli ornamẽti, de'quali niuno maggiore riceue la fabrica di quello, che le danno le colonne, quando sono situate ne'luoghi conuenenoli, e con bella proportione à tutto l'edificio.[8]

About which subject he then explained:

Io porrò partitamente di ciascuno di questi le misure, non tanto secondo che n'insegna Vitruuio, quanto secondo c'ho auuertito ne gli edificij Antichi: ma prima dirò quelle cose, che in vniuersale à tutti si conuengo.[9,10]

Then, after a long section[11] concerned with many minutae of the orders, given in minutes (sixtieths), Palladio turned to the problem of the basic dimensions of the rooms within the building, on which topic he explained:

1. Sg. Aia.　　2. Sg. Aib.
3. Jacopo Barozzi 1502/73 studied painting at Bologna, worked in painting and architecture at Rome 1541 and in France 1543/5. DZ ENC URB ARCH.
4. WITTKOWER (1949) p. 56, mentioned its tourist guide qualities.
5. p. 6. Palladio further emphasised this need for method in Bk. I, Cap. XX p. 51, stating about the facade :"nõ si deue però far ciò contra i precetti dell'arte, & contra quello, che la ragione ci dimostra onde si uede che ancho gli Antichi variarono: nè però si partirono mai da alcune regole vniuersali, & necessarie dell'Arte, come si uedra ne'miei libri dell'Antichi. Palladio's book was apparently issued first of all in 2 parts, and then as the four books in the same year. This later version used here. (GRAESSE (1859/69))
6. Palladio explained this involved the pattern whereby columns were placed above each other, and openings likewise, on different stories.
7. p. 6.　　8. Bk. I Cap. XI p. 14.
9. Bk. I, Cap. XII, p. 15.
10. In Bk. I, Cap. XII, Palladio stated the diminution of the column diameter at its top depended on height; and that the module of the column divided into 60 minutes was used to define the parts of all the orders, except the Doric, where 30 seconds, equal to ½ the column, gave the module.
11. p. 16/54.

> Le Sale seruono à feste, à cõuiti, ad apparati per recitar comedie, nozze, e simili solazzi: e però deono questi luoghi esser molto maggiori degli altri, & hauer quella forma, che capacissima siat acciò che molta gente commodamente ui possa stare, & vedere quello, che ui si faccia. Io son solito non eccedere nella lughezza delle Sale due quadri: i quali si facciano della larghezza: ma quanto più si approssimeranno al quadrato, tanto più saranno lodeuoli, & commode.[1]

And more generally that:

> Le più belle e proportionate maniere di stanze, e che riescono meglio sono sette: percioche ò si faranno ritonde, e questo di rado: ò quadrate: ò la lunghezza loro sarà per la linea diagonale del quadrato della larghezza; ò d'vn quadro & vn terzo; ò d'vn quadro e mezo; ò d'vn quadro, e due terze; ò di due quadri.[2]

In Cap. XXIII (Bk. I) Palladio went on to discuss the height of the rooms. In square rooms, flat ceilings were to be as high as the room was broad; if vaulted to be 1⅓ the room width. When rectangular he explained the height of the vaults could be drawn out of the length and breath of the room in 3 ways. 'h' (height) $= \frac{1}{2}\, l \times b$ (l = length, b = breath); or $h^2 = l \times b$; or equivalent to $h = 2\frac{l \times b}{l + b}$ In each case Palladio gave a geometrical construction, and showed how an example worked out in numbers.[3] Concerning these three ratios he explained:

> Stanno queste altezze tra loro in questo modo, che la prima è maggiore della seconda, è queste e maggiore delle terza: però ci seruiremo di ciascuno di queste altezze, secondo che tornerà bene per fare che più stanze di diuerse grandezze habbiano i uolti egualmẽnt alti, e nondimeno detti volti siano proportionati à quelle: dalche ne risulterà e bellezza all' occhio, e cõmodità per il suolo, ò pauimento che andarà loro sopra; perche uerrà a di esser tutte vguale.[4]

But despite the apparent great value of this mathematical scheme, Palladio went on immediately afterwards to admit:

> Sono ancora altre altezze di uolti; li quali non cascano sotto regola: & di queste si hauerà da seruire l'Architetto, secondo il suo giudicio, & secondo la necessità.[5]

With regard to doors and windows Palladio explained:

> NON si può dare certa, e determinata regola circa le altezze, e larghezze delle porte principali delle fabriche, e circa le porte, e finestre delle stanze. Percioche à far le porte principali si deue l'Architetto accomodare alla grandezza della fabrica, alla qualità del padrone, & alle cose, che per quelle deono esser condotte, e portate.[6]

He did however go on to give some general recommendations about the proportions to be used for doors and windows.[7] Then Palladio went on to describe some simple geometric setting out rules for the ornaments of the doors and windows -- of the architrave, frieze and cornice. A few short chapters discussing mainly stairs then closed Palladio's first book. This then was the extent of Palladio's account of universal rules to be used in Architecture.[8]

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1. Bk. I, Cap. XXI p. 52. 2. Ibid.
3. Palladio admitted that in the case of the second method it was not always possible to work out the answer with numbers. The rooms above to be 1/6th. less in height than those below.
4. Bk. I. Cap. XXIII. p. 54. 5. Ibid.
6. Cap. XXV p. 55.
7. To divide the "spatio dal piano" or "suolo alla superficie della trauatura" into 3½ parts (after Vitruvius Bk. iiij, Cap. vj); to make the windows twice this in height, and in width one of these parts less 1/12th. the height. ("in due farne la luce in altezza, e di vna in larghezza, manco la duodecima parte dell'altezza"). Room doors not to be wider than 3ft. or heigher than 6½ft., or less than 2ft. in width and 5ft. in height. Windows had to vary according to the size of the room in accord with considerations of light and heat. They should not be "più larghe" than ¼ the "largezza" of the room, nor narrower than 1/5th., and in height 2 1/6th. times the width. ("alte due quadri, e di più la sesta parte della larghezza loro") (The difference in the two formulations of window proportions, the first 2: 5/6, and the second 2 1/6: 1, that Palladio gave here suggests that he may have been a little confused or careless about simple arithmetical ratios.) But windows had to be all equal "nel loro ordine o solaro". Palladio therefore suggested that one took the room of proportion 1:1 2/3; divided its breath by 4½ and made all the windows to that width and in height 2 1/6th. The windows on an upper story were to be reduced by 1/6th. over those below. (Bk. I, Cap. XXV, p 55)
8. Bk. II was on personal residences; III on roads bridges and public buildings; IV on temples.

Thus Palladio's account of the 'universal rules' of Architecture, to a great extent mainly comprised very detailed description of the orders and their features. The more mathematical rules he gave, for determining the proportions of rooms and other features of the building, he clearly indicated were useful aids to which the Architect was by no means rigorously tied down, but which he was to use when he could, or would.[1,2]

A further Italian work of the period was Della Architettura Secondo i Precetti di Vitruuio (Venetia 1590) by Giovanni Antonio Rusconi, a relatively elementary work following quite closely after Vitruvius, which discussed a wide range of practical building problems, though with some detail on the proportions of the orders.[3]

In the Germanic tradition Hans Blum published Quinque Columnarum Exacta descriptio atque deliniatio (Tiguri 1550)[4] which concentrated pretty well entirely on illustrations to give the proportions of the orders, although with some commentary. Jan Vredeman de Vries published a similar work: Architectura (Antwerp 1565*),[5] and in the same genre was Wendel Dietterlin's Architectura von Aussteilung. Symmetria und Proportion der fünf Seulen (Nurnberg 1593/4).[6]

While in Spain Sagredo's work went through many editions, in the later period Juan de Arphe y Villafane published De varia commensuracion para la esculptura y Architectura (Sevila 1585). At the beginning of this work Arphe Villafane explained:

> Las esperiencias, reglas y preceptos/ las gran perfectiones y primores/ Por quien son en sus artes mas perfectos/ los doctos Architectos y Escultores/ Con otros mil auisos y secretos/ tambien Plateros y Pintores/ A quien principio da la Geometria/ es lo que a descuir la pluma mio.[7]

and:

> Es de las Mathematicas, primera/ la Geometria, y puerta de otras Artes/ Demostracion muy cierta, y verdadera/ para la proporcion toda y en partes/ Por esto hara primero su carrera/ mostrando por figura, algunas partes/ Como son Lineas, Circulos y Puntos/ que diuiden los cuerpos q estan juntos.[7]

Arphe y Villafane's work owed a good deal to Dürer's Unterweysung der messung. Bk. I on Geometry generally, treated also of dialling and the development of the regular solids. Bk. II treated extensively of the proportions of

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1. This account differs from that of Wittkower in his well known Principles of Architecture in the age of humanism. A detailed account of Palladio's designs of Bk. II is therefore given in an appendix to this section. p. 206/11.
2. Andrea di Pietro della Gondola was born in 1508 and was apprenticed to a stone carver in Padua at 13, but broke his contract and went to settle in Vicenza and there worked as an assistant to a carver who worked on buildings. In 1538 he met Count Giangiorgio Trissino during the construction of the Count's villa. Trissino took Palladio up and directed him towards a liberal education. Palladio accompanied Trissino to Rome in 1541. Palladio contributed drawings to Barbaro's edition of Vitruvius, and died in 1580. ACKERMAN (1977) & DZ ENC ARCH URB.
3. Rusconi, painter and architect, c.1520/87, worked on water control for Venice. He was involved with Palladio in work at Brescia in 1562. DZ ENC ARCH URB.
4. The title continues "cum symmetrica earum distributione, vtilis est hic liber pictoribus, sculptoribus, fabris aerarijs atq lignarijs, lapicides, statuarijs, et uniuersis qui circinio, gnomone, libella, aut disque certa mensura opera sua examinant". Hans Wounteil's English translation of the commentaries included the explanation that the work was "Drawne and counterfeited after the right Semetry and cunning measure of Free-Masons". (t.p.) Wounteil explained in an introducary section "Though some men be of the opinion, bookes of building are onely necessary for Artificers...(but) I offer this booke as well to noble Gentlemen as Richmen." (London 1608). CONNALLY (1960) has Blum as master-builder and wood-carver.
5. CONNALLY (1960). Anvers 1577 ed. used here. Vredeman de Vries(1527/1604?) a Strassburg painter and architect, also published a work on perspective Scenographiae (Antwerpen 1560*) similarly depending on illustrations to show the principles involved. Lugduni Batavorum 1604/5 ed. used here.
6. CONNALLY (1960). Nuremberg 1655 edition used here. Dietterlin wrote in a short introductary section "Demnach Ich aber befunden/ das solches nich so viel dem vnfleiss/ oder auch der vnwissenheit zuzuschreiben/ als diesem das die bericht vnnd vnderricht von rechter Proportz vnnd Symmetria (ob wol die ein zeit wie die ander/ im ihrem fundamento vnverruckt beleiben/".
7. Bk. I, Cap. I f. 1b. Verse form.

the proportions of the human body after Durer. Bk. III was on the proportions of animals, and only the last relatively short Bk. IV considered Architecture directly. There Arphe y Villafane gave some brief instructions on the proportions of the orders and then went on to show their application to church ornaments.[1,2]

However, the rather small number of original architectural texts published during the renaissance, was suplemented, particularly in Italy, by a relatively copious number of editions of Vitruvius.[3] The first was published in 1486.[4] A later version dated 1497 at Venice was issued with Cleonides on music and harmony, and with Frontinus on aqueducts.[5]

In 1511 the first fully illustrated[6] version of Vitruvius edited by Fra Giocondo[7] was published. The illustrations included plans of villas, details of various aspects of the orders, a diagram to aid understand Vitruvius's remarks on dialling, and a chart of the musical scale and its consonances.

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1. Sevila 1585 edition used for the 1st. and 2nd. books. Madrid 1773 edition for the 3rd. and 4th. Editions of this work appeared right up to the 19th. century.
2. Juan Arfe y Villafane, born in 1537 studied under his father who was an engraver and worker in gold. He attended a course in anatomy at Salamanca. He was best known for his elaborate monstrances, and was named by his contemporaries the spanish Cellini. He published also Quilatador dela plata, oro, y Piedras (Valladolid 1572). DIC ENC EUR AM.
3. See POLENI (1739/41)
4. At Rome. CONNALLY (1960), with Frontinus on acqueducts.
5. Including also writing of Politiano. Some copies appear to have been issued without the Cleonides and Politiano sections. (CONNALLY (1960) No. 2.) A 1495/6 edition without the Cleonides was also published.
6. Early editions tended to have just a few very sketchy diagrams appended.
7. Fra Giocondo, born 1433/5, in his early years was much occupied with ancient buildings and transcribing ancient epigraphs, and in collating the ancient texts, probably a good deal of the time at Rome as well as in other parts of Italy, as Vasari indicates. He is first documented at the court of Naples in 1489 occupied with antiquities. In 1492 a payment is noted for parchment given to "Fra Jocondo de Verona per fare alcuni disigni di fortezza del reame et altri lochi". In the same year he was given a payment relative to the production of two books of 126 designs of "Mastro Francesco di Siena.....uno darchitetura et altro dartigliaria et cose appartenenti a guerra." In 1492 he was noted as "architecto illustrissimi D. Ducis Calabria", and in 1493 received a benefice. When in 1496 Charles VIII returned to France from Naples he carried with him many learned Italians including Fra Giocondo. During his period of French residence Giacondo was apparently connected with the building of a least one noted bridge over the Seine at Notre Dame. In 1504 Francesco Morosini wrote to the council of ten of Venice, about Fra Giocondo's possible employment, and stated "Saria per le Excellentie Vostre per consigliar et preesser ala munition de le artigiarie de quelle ma che e molto pratico......" and that he had "havuto commertio cum domino Filiberto et servitolo per secretario al qual, per deletarse de queste cosse matematice et architetture et istrumenti bellici, leze Vitruio". In 1506 Fra Giocondo went to take service at Venice, about which a contemporary wrote "In el Conseglio di X fu conducto cum salario de ducati 200 a l'anno uno frate Jucundo veronese, apostetta, quale avea famma da esser grande inzegnier et praticho etiam de forteze et de tirare aque atorno le citade et fortifichar una citade over uno castello." During his service at Venice Fra Giocondo was active advising on water control, on the reconstruction of the area around the Rialto bridge and on that bridge itself, and on the fortification of Treviso, Padua and Cremona. A document relating to 1507 on his work on the lagoon described him as "inzegner et mathematico". In 1514 Fra Giocondo was appointe to advise, with others, on St Peters Rome. A letter noting his death the following year described him as "docto et in grecho et latino." As well as publishing Vitruvius Fra Giocondo edited Ceasar's commentaries, published 1513; a work on agriculture from the ancient writers, published 1514; and was active in translating other such works which were later published. In his dedication in the Vitruvius volume, Fra Giocondo mention his work "de architectura & de mathematicarum disciplinarum vsuu, which was apparently published, and seems to have been known till the 18th. century at least, but which now appears not to exist in any copy. See BRENZONI (1960) who prints the sources.

Then in 1521 at Como the massive and elaborate edition of Vitruvius by Caesarino, appeared.[1] In the dedication to Francis I, Augustine Gallo Nouocomese explained:

> LA Diuina prouidenria Christianissimo & Inuictissimo Re si como del tutto gubernatrice per la conseruatione del humana generatione ha ordinato li Principi: li quali dopo epso Dio certamente obteneno in terra primo loco ....(such persons to defend) dal impeto hostile le hano munite de muri e fortalitie...Per questo adunche meritarono essere dimandati diuini. E perho il nostro VITRVVIO sapientemente in deci uolumini del opera sua ha recolcto tute queste cosse. E considerādo che nessuna altra materia era piu degna de uno sumo principe....rationabilmente la uolse dedicare ad Augusto Caesar Monarcha del uniuerso. Per tal exemplo io sono inducto espa opera. . .in materna lingua Italiano Cōmentate e Historiata per alchuni homini Docti ho procurato fare in stampa: a la uostra Sacra & inuicta Maiestati humilmente offerire: si come dono pertinente ad uno tanta Principe: senza dubio ordinato dal sūmo factore per la salute de li subditi: sperando che quella ne hauera piacere e delectatione...[2]

Commenting on the opening words of Vitruvius in his dedication to Caesar -- "Quando la tua divina mente et Deita imperatore Caesare, andava obtinendo lo Imperio di tutte il mondo"[3]-- as he gave it, Caesarino wrote:

> O sūma laude & gloriosa exaltatione de li homini quando cō li loro effecti dimostrano poterși assimilare al diuina mente....[4]

In his commentary on Vitruvius's account of the nature of Architecture, Cesarini wrote:

> Considerādo Vitruuio la maxima grauita de questa scientia......Vitruuio adunche per qsto si e conato cō magna eruditione succurrere quilli che uolendo Architectare: & per che la cognosciuto che tutte le arte si usano con certi cōmuni termini. sicut in primo posterior habemus Vna queq sciētia habet sua ppias Iterrogatiōes & resposiōes & disputatiōes: E primu principiū uno quoq genere ē propositio necessaria & demonstrabilis & scientia cuius est precipue quia hec scientia est uti geometria que non supponit falsa.... La Scientia de Architecto si e ornata de molte discipline & uarie eruditione. Cū sia la rationale scientia de numero bonourm & honarabilium....Ma cū sia che le humana generatione uine con ratione & arte: quale arte e generata per molti impedimenti p suplemento de la naturae dificientia...Et perho essendo la experiēte cognitione de la cose singulare & larte de le universale[5].....Cum sia adunche cheli docti Architecti quali hano acquistato laude & ȳmil honoramēte p il studio de la exquisite doctrine si como et p le manual pratice....Ma quilli sono nominati pseudo architecti che....a gran pena sapēdo fare una pocha praticheta calculatoria p la materia de la fabriche aut superficie senza geometrica schematione symmetriata....Et perho uoi non solū mechanici: ma ogni professori de le bone scentie, & precipue uoi Signori del arte militari non siate immemori ne tardi a intendere qsta scientia: acio non restati inerudite da la ingeniosita qual certamente supera le forze[6] (se pur uoleti conseguire molti effecti & mirande operatione) & etiā si aptamente altrui populi a uoi uolete subiicere. Et cosi se sareti diligenti problematori consequireti la uera ratiocinatione : cioe parlamenti disputatui con ratione uel con bona calculatione numerabile & compartitione....Adunca ha Vitruuio ha dicto maximamente in la architectura gli in sono qste due cose: idest quello che a significato. hoc est dimostrata con espressa manifestatione come e a designare una

1. Throughout much of the work the commentary dominates over the text in mass and was printed surrounding small blocks of a translation of Vitruvius. The work included an elaborate geometrical analysis of the facade of Milan cathederal, which was apparently shown in incorrect proportions. (See ACKERMAN (1949)) Caesarino did not personally see the work through the press and final corrections and editing was done by Benedicti Iouio & Bono Mauro.
2. La Prefatione. Augustine Gallo financed the work.
3. The first Latin edition gave "CVm diuina mens tua: & numen Impator Caesar imperio potiretur orbis terrarū...."
4. f. Ia. The whole conflation of the divine Roman emperor with the christian view of fallen man, in some way paralleling God, at least to some extent on the mental level, amounted to quite a shift of course.
5. Compare Tartaglia's position later Biog.
6. Compare Zanchi's remarks later II p.36; l.13/14.

Iconographia & ortogrophia di qualche cosa sienda. aut significare explicatamenti per archetipale dimostratione quale ha piu forza del signifare che le cose designate in plano....Consimilmenti la doctrina uen significata de luno homo al laltro secondo le operationi qual il discipulo ha del preceptore....[1]

After commenting separately on the many different disciplines mentioned by Vitruvius as necessary to an architect, Caesarini continued:

Anchora el bisogna che la Architecto sapia la Musica: p che qlla proportione talhora che non se fare trouare in le symmetrie geometrice uel arithmetici promptamente si come sono quelle del cōmune uso questa al beneficio dal architectura le insegnara. & non solamente sapera cōmodulare le pportione de liaedificii: ma le loro intonantie: & nominatione de ogni complexo & proportionabile numero & da le quātite magiore distrahere la minore....[2]

Caesarini further justified the need for music in architecture in a later section thus:

Cosi li medici Rythmus se po intendare la indicatione de la cōmodulatione de le pulsatile uene.....Similmente cum li Astrologi. & musici e una cōmune disputatione de la Sympathia de le stelle......Symphonia ben che di sopra e dicta esser una dolca melodia de la canore. uel sonor voce......Ma in questa parte symphonia significa nisi iusta concordantia adoe che in li quadrati superficiali uel corporei: cosi etiam in li Triognali. in epse aspiciente angularie proportionalmente trouerai le consonantie & concordantie si como di le uoce che formano il diapente & chi il Diatessaron. de le quale figure. ben che qualche cose Georgio Purbachio in la Theorica de lo aspecto de li radii Planetarii habitia sentito....Io comprehendo questa essere non solum seruiente ale supredicte: ma etiam al optica & quasi a ogni senso cōmune del anima...possiamo anchora dire che e cōmune disputatione di proportione ad alcune secte de philosophi como sono Pythagorici & Platonici circa al anima del mūdo: & nostra rationale & como dice principalmente Aristotle.....& anchora Cicerone....il quale licit chel parla de la proportione quale si retrouano il Coeli e una medema ratione del anima cel Coelo. come dice Auerois & de lanima nostra rationale: seu e una medema ratione & del anima dīmundo Como dice Themistio in primo de anima: Idest le preportione quale si ritrouano in Macrocosmo: se ritrouano anchora ne Microcosmo quale si e lhomo. Cioe ne le potentie de la sua anima rationale. Appare adunche che le proportione sono Cōmune a li Philosophi ma diuersamente considerate. perche il medico le considera nel polso: lo Astrologo ne la Sympathia de le Stelle: idest ne li diametri: Trigoni quarate & Sextili. Ma il musico nelle cōsonentie como sono li Diapente: Diatesserō: Diapson &c. Ma il Philosopho ne il Coeli & le potentie del anima rationale.[3]

But while musica and its consonances was an important aspect of the mathematical nature of Architecture in the account of Caesarini's commentary, mathematics in itself had to be understood at a high level according to Caesarini, who stated:

Io considero...che la Arithmetica si po estratere dal Encyclio: Et la piu parte de li gran richi & altri perseguenti questa hano extracta. Et la infarano senza fundamento de le altre: mi par cosa miranda che in lei sola sia quasi piu forza ala comune necessita che in tute le altre liberali...Vltra di quello uedi le subtilita del algibra seu restauratione de li numberi: como se hano li censi: & censi di censi: & li binomii & trinomii & quatranomii & li recisi: & le multiplicatione & le loro radice: & molte altre infinita quale ut diximus ab Euclyde & lo predicto nuouo cōmentatori frate Luca tene dara assai sufficiente instructione.[4]

In his commentary on Bk. V, Cap. IV, "De la harmonia" Caesarino gave a good deal of detailed discussion on music. There he explained:

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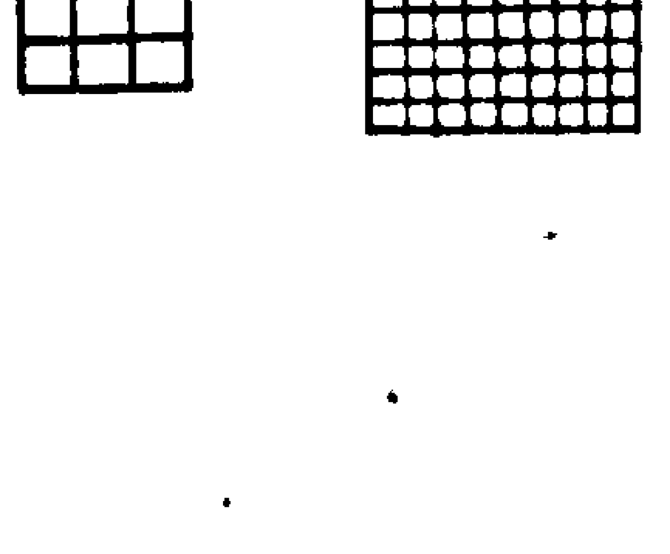
1. f. IIb/IIIa. The mixture of latin and Italian in this section, and the quotation from Aristotle is typical of the style of the commentary. This section applied to the opening section of Vitruvius's Bk. I, Cap. I of a few short lines. While Caesarini did not neglect practice, his whole detaile account with its emphasis on theory amounted to a certain shift from the original text.
2. f. IIIb/IIIIa.
3. f. Xa/b.
4. f. IXa. 'Censo', "Terminie usato dagli algebristi del secolo XV per indicare il quadrato dell'indeterminata e a volte ance la prima potenze" GR DZ IT. CAPORALI (1536) f 13a, on this section gave an explanatory diagram:



Et a ben che la piu parte de li texti[1] in queste lectione siano depravatie tamen quanto piu ho potutolo ho correcte & consultate fidelmente: acio che de tante obscure dictione possi illuminando explicarti. Si como ho hauto non solum il consilio: ma le praesente figure che infrascripte io ti pono: dal solerte Franchino Gaffuro: quale me ha denotato nisi.15. corde: cosi etiã da alcuni periti organisti maxime da Iohanne Maria noue Commense rarissimo musico & organista. cõ il assenso de li quali le praesente expositione quiui ti scribo...... [2]

In the introduction to the edition of Vitruvius published at Venice in 1524, Franceso Lutio Durantie explained that compared to Architecture,

.....certamenti di nulla altra cosa piu bella, piu necessaria, & utile haria potuto trattare....quella Architettura, che ha suegliato, & mosso tanti ingegni humani......li quali Architettori sono d'ogni laude, & premio degni....Onde essendo Larchitettura cosa si degña & eccellentie, si delettabile & utile, dourebbi ciascuno con ogni studio & arte dar opra in quellã, il che accio che cõmodamente nõ solo dali dotti, ma anchora dalli huomini uulgare fare si possa, cõ summa diliyentia é stato stampato Vitruuio uulgare.[3]

The edition by Caporali (Perugia 1536), of the first five books of Vitruvius only, was not a great deal more than a reworked version of the Caesarini edition. It had the same format of closely printed commentary surrounding smaller blocks of text, used many of the same illustrations, and ofter followed Caeserini's commentary very closely differing only in the wording given with translation of the Latin quotations. In the translation of Vitruvius, necessary Caporali claimed because Caesarini and his collegues had misunderstood the text, at many places again nothing seems to have been given but a rewording of

1. Of Vitruvius.
2. f. LXXVII. For the diagram see Pl. 59 Caesarini's diagram and its numbers followed closely after that found in Gafurius's printed works, as for example Practica Musica. However it omitted 5 notes, 2187, 2048, 1944, 1728, 1536, 1036.8, explaining why all the numbers given were all divisible by 2. See GAFURO (1969). Gafurius was apparently an important musician of his time. As one modern commentator put it "No single incunabulum on music achieved as great an influence upon musical thought of sixteenth-century Western Europe as did the Practica Musica of Franchinus Gafurius." (Young in GAFURO (1969) p. xv.) This work was published in 1496 at Milan. Gafurius was born in Lodi in 1451. He studied music at many Italian centres, investigated the Greek musical texts with much care. In 1480 he published Theoricum opus musicae disciplinae (Naples 1480). He was then invited to Milan as director of the music in the Ambrosian Cathederal by Ludovic Sforza Il Moro. He held a chair of music at Pavia 1494/9. (Said to be the only certain example of a chair of music at any Italian University.) He died in 1522. According to Young (Ibid. p. xxii/xxiii.)"Gafurius, practical musician that he was, was forced to concede that in composition the logic of theory often had to give way to the ameneties of sound. He appreciated the suavitas of a composite fifth consisting of a major and minor third tuned to the ratios of 5:4 and 6:5 respectively, and endorsed these "sweet"-sounding modifications of their Pythagorean conterparts 81:64 and 32;27 as eminently suitable in practice. But at the same time he felt the need to justify these changes on rational grounds, and he resented innovations not supported by scientific explanation. By the addition and the subtraction of the minute interval of a comma in a 81:80 ratio Gafurius was able to justify the conversion of Pythagoras' thirds into the more artless formulae of just intonation." If renaissance musical theorists were able to adjust their (pseudo ?) precise mathematical ratios like this in order to make their theory accord with practice, it is difficult to see how the poor renaissance architect could get any sure guidance about the required ratios in his structures from such a source. Equally he could hardly be criticised for indulging in the same kind of 'figure fudging' in order to prove that any proportions whatever in his structure were in consonance and hence beautiful.
3. The illustrations were taken from Fra Giocondo's edition. CONNALLY (1960) notes this edition as a plagarism of Caesarino.

the earlier version.[1]

Gulielmus Philander's well received annotations on Vitruvius were published in 1543.[2] The work was in Latin and involved serial commentary on particular phrases and words in Vitruvius, a work by the scholar for the scholar more than anything.

In the 1547 French translation by Jean Martin (Paris) the illustrator, Iān Gouion, in a section at the end explained:

> Vitruue dict, messeigneurs, & plusiers Autheurs antiques & modernes le conferment, qu'entre les autres sciences requises a decorer l'Architecture, ou art de biē bastir Geometrie & Perspectiue sont les deux principales: & n'est aucun digne d'estre estimé Architecte, s'il n'est preallablemant bien instruict en ces deux.[3]

This was the same period at which Walter Herman Ryff published his translation of Vitruvius, together with his companion volume as a commentary on Vitruvius which contained so much from so many Italian authors such as Tartaglia, Caesarino and Serlio, mainly of a mathematical nature.[4]

Daniel Barbaro's edition appeared in 1556, in the same tradition of extensive commentary on an Italian translation of the basic text, with emphasis on mathematical aspects,[5] as found in Ceasarini. Barbaro gave a good deal of discussion relating to dialling; sun tables; star tables; and a fair amount of commentary on surveying, in addition to discussion of music.

But Barbaro also included a plan of a bastion system, and the details of the layout of a single bastion. On this topic he wrote:

> PArera forse a molti, che il trattere delle fortificationi sia cosa da esser tenuto secreta, come, che a Principi, & a Republiche solamente debbia esser manifesta....A questi io non rispondo, perche da se stessi uanno a basso come quelli, che essendo huomini, mancar uogliono dell'ufficio della humanita....[6]

Thus it was more in the field of Vitruvian commentary that there was a tendency to emphasise and develop the mathematical aspects of architecture. In contrast the original published treatises on architecture of the renaissance, while they emphasised in places the need for a general method in the subject, and the power of mathematics, always tended to emphasise the orders of columns as the core of their discipline, the achievment of true proportion

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1. The work was rather smaller in size than Caesarini's massive tome, but finer print was used. Where for example Ceasarini had the passage given above p. 203 Caporali had "Si come habbiamo hauto non solamente il consiglio, ma le presente figure che sotto disegnato ti ponemo, dal diligente Franchino Gafur, il quale ne ha denotate solamente.15. corde cosi anchora da alcuni dotte organisti, col consenso de quali la presente exposition" f. 112 which is only a repetition of Caesarini leaving out a name who presumably Caporali could not have known. Caporali 1476/1560 trained as a painter in Perugia and seems to have concentrated on architecture in the last decade of his life. DZ ENC AR URB. VERGHA (1964) attempted to find a connection between Caporali and Gafuri, but seeing as he depended on Caporali's text which was so derivative from Ceasarini, his efforts were rather inapt. On an uncharitable view all Caporali did was to steal Ceasarini's text. The Como 1521 ed. privilege was for only 10 years so by the time of Caporali's edition it would have been defunct. But for Caporali to have requested a priviledge as an author, presumably he had to make some effort to make the text look like his own, and hence at many places simply changed the wording around a bit. This is certainly true of the early sections of the work and that on harmony, mainly considered here. POLENI (1139/41) equally appeared to find little new in him. Caporali's edition had a dedication dated 1532 with his privilege from the pope Clement VII dated 1533.
2. At Strassburg. Argentorati 1550 used here.
3. VITRUVIUS (1547) Sg. Diiia of the annotations.
4. See II p. 175/182.
5. See II p. 146/51 where Francesco di Marchi's text follows closely after a section of Barbaro's work.
6. VITRUVIUS (1556) p. 39. The pagination is odd just where this section occurs as if it might have been added as an afterthought, although such oddness is common enough in works of the period.

in those features providing the basis of correct design:[1] those proportions to be discovered to a great extent, by reference to the ancient ruins. But in order to clarify the general rules involved there was always the text of Vitruvius as an aid. A further more general basis for those same proportions could then be elucidated by following the Vitruvian anthropomorphic model.

However the use of the orders of columns did involve a mathematical approach to some extent if only in virtue of the use of the particular numbers and ratios involved. Such auxiliary disciplines as geometrical drawing and perspective, and surveying, then helped to support the notion of a mathematical base to architecture.

On the other had while on many occasions from the time of Alberti on the idea of the proportions of the building being controlled by certain inherently desirable mathematical ratios, particularly those drawn from music, was expressed, and backed up by reference to Pythagorean/Platonic doctrines for example, this approach was never developed in any detail at the theoretical level in the published treatises, despite their call for method, universal rules, and a certain emphasis on mathematics; and the importance of understanding the musical consonances tended to appear much more clearly in Vitruvian commentary than in contemporary detailed accounts of the nature of architecture. Thus only as commentary was more distant from the details of design practice and the practising architect, was it more emphasised. Given the rather tautological nature of this theory of beauty, in that so many ratios were available that beauty in one way or another could be discovered in almost any proportions, it must be concluded that what was at work here was more a certain rhetoric of mathematics rather than a significant determining instrument of practice.[2,3]

1. The humanist Alvise Cornaro who composed an unpublished treatise of a few pages on architecture expressed a dissenting view. He stated "io lauderò sempre più la fabrica honestante bella, ma perfettamente commoda, che la bellissima et incommoda"; that "io tratto di stantie da Cittadini et non da Principi"; and that "una fabrica può ben esser bella et commoda, et non esser nè Dorica nè di alcuno de tali ordini". See FIOCCO (1965) who prints two drafts the first '57/66.

2. WITTKOWER (1949) expressed a rather different view. But Wittkower admitted that "practical prescriptions of ratios supplied by the artists themselves... are not very common" (p. 110). Of the few examples he then put forward one was of Serlio's construction for the properties of a door. Yet earlier in the same work, on centralized churches, Wittkower had written "Serlio's work is pedestrian and pragmatic, consisting of a collection of models rather than expressions of principle, and we cannot expect to find here any of Alberti's philosophical concepts." Indeed Serlio's construction for a door was an isolated instance in a great mass of material and can hardly be taken as evidence for some underlying general approach. Palladio who was Wittkower's most significant example is considered in an appendix to this section. Francesco Giorgi's memorandum on S. Francesco delle Vigna did indicate these kinds of ideas about musical harmony at work but this clearly was just a memorandum and not a detailed design, and written by one who cannot be considered significantly a practising or theorising architect. Caesarino was a practising architect but his strong expression on musical harmony was in commentary on Vitruvius and not on the details of contemporary practice. Barbaro was not significantly a practising architect either. Wittkower gave an illustration from VILLALPANDO & PRADO (1596/1605) but this was a work of biblical commentary in no way primarily addressed to problems of contemporary architecture. Delorme's promised work on proportions never appeared. Paccioli wrote on divine proportion, but in his section on architecture followed Vitruvius; and was hardly significantly a practising architect. This is not to suggest that the search for true proportions in accord with abstract or musically favoured ratios was never practised in the renaissance. Only to point how how much more the evidence is consistent with such discussion being to a good extent merely rhetoric. Indeed for such rhetoric to have functioned at at all it must be reasonably assumed that it did to some extant relate to practice.

3. Other works connected with this area include F.M. Grapaldi's De partibus aedium libri due which appeared in a number of editions from the late 15th. century on. It was however mainly a discussion of many passages and terms in the ancient authors. Joseph Salviati's Regola di far Perfettamente col compasso la Voluta Et del Capitello Ionico (Venetia 1552) consisted of only 4 leaves. Carlo Borromeo's Instructionum fabricae ecclesiasticae (Mediolani 1577*) was mainly concerned with the layout of the church in accord with sacradotal practice. (CONNALLY (1960))
The many works on the antiquities of Rome have largely been ignored here as of no great significance. Silvio Belli's Della proportione et proportionalita (Venetia 1573) was on proportion in the abstract mainly, and gave little indication about application.

II:(7): Appendix: Palladio's design techniques as found in his villas and palaces of Bk. II of the Quatri Libri (1570)

In many of the short sections of description that Palladio gave about the Villas and Palaces of Bk. II of his Quatri Libri he indicated briefly how the rules about the dimensions of rooms were applied in the particular designs presented. In the great majority of these cases the rules referred to the "stanze grande" or "maggiori".[1] From the drawings and Palladio's remarks it is clear that the rooms he referred to in such cases were a symmetrically placed pair, usually flanking the doorway, portico, or entrance hall,[2] although sometimes placed in the middle of the building or at its rear.

In two cases Palladio made it substantially clear how he attempted to hold the ratios between the heights and plan dimensions of the rooms, to favoured proportions, while keeping the vaults near the same height in order to provide a flat floor above, along the lines he had indicated in his text in Bk. I.[3] However the constraints on room sizes seem to have been so many and varied that apparently he was not able to achieve his ideal ratios very often and sometimes had to hold the room height to a particular dimension in rooms of different sizes.[4] Often indeed Palladio must have had to proceed by "judgement and necessity" in this fixing or room heights as he noted in Bk. I, in view of the vary varied room sizes he used and the relatively close ratios he gave for heights, or else he would have often arrived at impractical room heights.

Examination of the plan dimensions of these key[5] rooms, in those designs where a pair of such rooms is pretty clearly distinguishable, gives the following results. Of 43 designs, there are 32 which potentially fall into this category.[6] Of these 14 have to be excluded from analysis for various

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1. For details of the designs see the analysis sheets added to the end of this section. In No. 1, the "stanze maggiori" have their heights to the 2nd. rule. In No. 2 "le stanze maggiori" have their heights to the 1st. rule; "le mediocri" had the same height; "i camerini" "amezati". In No. 3 the rooms "che sono a canto le dette entrate" have their heights to the 3rd. rule. In No. 7 "le stanze grandi" are to the 1st. rule. In No. 18 the "maggiori" rooms, have their height to the 2nd. rule. In No. 19 to the 1st. rule. In No. 21 "Le stanze maggiori sono lunghe un quadro e tre quarti" with height according to the 2nd. rule; "I camerini, e l'andito sono di uguale larghezza: i uolti loro sono alti due quadri". This gives the height of the great rooms as just over 21ft. ($=\sqrt{16 \times 28}$), and that of the small ones as $22\frac{1}{2}$ft. (= 2 x $11\frac{1}{4}$), possibly the $11\frac{1}{4}$ should read $10\frac{1}{2}$, or else the given figures are close enough to give an even floor above. In No. 22 "le stanze maggiore sono lunghe un quadro, e tre quatri" height according to the 1st. rule. This poses a problem for the plan shows 16 x $26\frac{1}{2}$, rather than 16 x 28 to give the noted ratio. Assuming these last dimensions the height comes out at 22: "le mediocri sono un quadre il terzo più alte che larghe" which gives $21\frac{1}{3}$ (16 x 4/3); "i camerini vi sono mezati". In No. 23 the "maggiore" rooms are 21 height which is in accord with the 1st. rule (26 x 16 rooms). In No. 25 the "stanze maggiori sono lunghe vn quadro, e cinque ottaui, e alte quante larghe" (the plan reads 16 x $26\frac{1}{2}$ rather than 16 x 26 as it then should). In No. 27 the large rooms 1:1 2/3; "la altezza della Sale è la metà più della larghezza, e uiene ad essere al pari dell'altezza della loggia". In No. 37, 2 rooms 1:1 2/3, height as 1st. rule (= 24); 2 other rooms 1:$1\frac{1}{2}$, and 2 small rooms similar; "sala" 1:1 2/3; 2nd. floor 20' heigh; 3rd. 18'. In No. 38 the rooms "che sono da i fianchi" height according to the 1st. rule; in the smaller rooms halved. In No. 39 greater rooms 26 in height, lesser 18. For the larger rooms this ties up roughly with the 3rd. rule. The smaller rooms vary a good deal in size, but one size is 18. No. 40, rooms beside the entrance 1:1 2/3, as high as large. Small rooms halved, No. 42 "stanze maggiori" to 3rd. rule.
2. As in designs 1. 2, 3, 18, 19, 21, 22, 27, 31, 38, 39, 40. In many cases these are the only rooms that will tie up at all with the dimensions on the elevations, in others Palladio explicity mentions their proportions in plan, or averts to their position. In No. 23 the key rooms were in the middle of the building, in No. 25 at the rear. No. 7, the rotunda is a unique case.
3. No. 22 & No. 21. No 21 is a bit ambiguous because the dimensions do not tie up too well. No. 23 is plain if the correction as in n.1 above is accepted.
4. In No. 2 for example the medium rooms have their height the same as that of the larger ones, the height of the small rooms halved which gives height equal to width. See also the variations in n. 1 above.
5. The information listed above comprises the great majority of what Palladio gave on proportions in his separate descriptions to the designs of Bk. II.
6. Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 31, 35, 37, 38, 39, 40, 41, 42, 43.

reasons,[1] leaving 28. Of these 18 give clear proportions with the following distribution: 1:1½, four; 1:1 5/8, two; 1:1 2/3 six; 1:1¾ two; 1:1 4/5 one; 1:2, three.[2] In the case of No. 18 (14 x 21½) it looks as if there might be simply an error in printing and that it should read 14 x 21 giving further case of 1:1½.[3] In the case of No. 17, 16 x 26½ it is tempting to think that the figures should be corrected, because in two other cases where just these dimensions appeared, Palladio's text shows a correction to be needed.[4] But in one case the result is 16 x 26, and in the other 16 x 28. But whatever is done here this leaves among others, two cases of 16 x 27,[5] two of 17 x 27[6] and one of 17 x 28,[7] as well as more akward ones. Now one might consider the 17 to be a misprint in those cases where it does occur, because it factors out with no other number, being prime. This might be allowable with No. 28 (17 x 27), but in the case of No. 1 (17 x 28), this figure is repeated to give a square room 17 x 17;[8] and in the case of No. 8 (17 x 27), the figure is repeated in two similar rooms at the rear of the building (and in this last case smaller rooms of 13 x 13 appear so we might as well start changing them too): thus to make such 'corrections' amounts to radically altering the designs presented. Now Wittkower suggested that 16 x 27 had to be read as 16:24:27 to give an analysis in terms of desirable musical ratios.[9] But obvious no such process can work with 17 x 27 or with 17 x 28, because 17 is prime. In fact all these proportions are simply good approximations to the ratios Palladio used in the unproblematic cases: 17 x 28 = c. 1:1 2/3 (= 17:28⅓); 17 x 27 = c. 1:1 5/8 (= 17:27 5/8); 16 x 27 = c. 1:1 2/3 (= 16: 26 2/3).[10]

Now there is good reason to think that Palladio's figures have to be taken to some extent, not too literally (leaving aside the way his verbal descriptions give ratios different to the figures in the drawings, sometimes), for in some cases the dimensions given, do allow for wall thickness, and sometimes they do not.[11]

Again prime numbers, while they by no means predominate, occur too frequently in Palladio's designs to be considered printing faults or other like errors, and only by taking them as approximations can the favoured ratios be

1. Some cases are more dubiously of this type than the majority. In No. 4 & 5, the rooms do not have the full dominance in the design as in many, but they have been allowed. No. 6, the key rooms are at the rear but they have been allowed. No. 7, the rotunda, is a unique case and has been excluded. No. 9, 16, 19, 22, 25, have been corrected in accord with information from the text. No. 29 has not been accepted, being a dubious example, and the figure only a guess. No. 38 an akward site has been rejected. No. 14, has been rejected for lack of dimension of the key room.
2. See analysis sheet.
3. Palladio's general remarks on preferred ratios (see above p.198) make this reasonable, as does the way his verbal discriptions give ratios different to those in the drawings. (See above p.206, n.1)
4. No. 22, 25.
5. No. 24, 35.
6. No. 8, 28.
7. No. 1.
8. Although very unusually, in the drawing that room does not look square.
9. WITTKOWER (1949) p. 114.
10. Only 17 x 27 is more than half a unit out, and if taken as = c. 1:1 3/5 gives 17: 27 1/5.
11. No. 3, 9+10+9+2 walls = 30, 1 for a wall.
No. 16, 18+24+1 wall = 42, 0 for a wall.
No. 17, 8+16+8+2 walls = 34, 1 for a wall.
No. 28, 12+15+1 wall = 27, 0 for a wall.
The cases where wall thickness was allowed for seem to be in the great majority, but the cases of Nos. 16 & 28 where it is not taken into consideration seem quite clear; and attempts to alter these cases to so do would tend to invlove akward numbers and ratios. An interesting case is No. 22, where the figures on the drawing give what looks as if 16 + 32 + 16 + 2 walls = 26½ + 10 + 26½ + 2 walls, which seems reasonable to give 64 + 2 walls = 63 + 2 walls. Yet Palladio's text gives the key rooms as 1:1¾, which gives 28 + 10 + 28 + 2 walls for the first, i.e. 64 + 2 walls = 66 + 2 walls, while the walls on the drawing appear much the same thickness.

discerned. The case of the Rotunda illustrates the problem.[1] The design in plan is strictly doubly symmetrical.[2] The rotunda itself was 30 in diameter; the large rooms 15 x 26; and the small 11 x 15 (the portico 12 x 30). In his accompanying text Palladio suggested the 15 as ½ of 30. But 26 and 11 will not factor out with 15, and 11 is prime and only relates to 22 which gives the akward 11:13 with 26. 15 only relates to 26 by means of rather akward intermediate ratios.[3] But 11:15:26 is a good approximation to 3:4:7 (= 11¼:15:26¼).[4] Or if the building is taken as simply a geometric grid 15+30+15 square, allowing 6 for the passages as Palladio gives, the large rooms come out 27 long, and the small ones 12 wide (instead of 26 and 11 respectively); and 12:15:27 = 4:5:9 then one has only to juggle about with the wall thickness of 1 to arrive at the given figures of 11:15:26.[5]

Accepting approximation then, and estimated figures the distribution of the proportions of the key rooms in designs where they occur is as follows: 1:1¼ one; 1:1½ <u>seven</u>; 1:1 5/8 four; 1:1 2/3 <u>ten</u>; 1: 1¾ three; 1:1 4/5 one. The most favoured ratios 1:1½ and 1:1 2/3 being two of those Palladio mentioned as being most favourable.[6]

Examination of the whole range of proportions in the whole series of Palladio's designs of Bk. II further shows that approximation must be resorted to in a good many case to bring out regular ratios,[7] in rooms or spaces appart from the key rooms. If all such ratios are considered, their distribution in terms of the number of designs in which any particular ratio occurs, in the range 1:1.2 to 1:2, is as follows: 1:1 1/5 five; 1:1¼ <u>eleven</u>; 1:1 2/5 five; 1:1⅓ <u>eleven</u>; 1:1½ <u>twentyone</u>; 1:1 3/5 six;[9] 1:1 2/3 <u>thirteen</u>; 1;1¾ six; 1:1 4/5 two. The predominance of the ratios Palladio listed in his gneral is thus clear.[10]

However, although this kind of regularity in accord with Palladio's avowed preferences appears fairly clearly in the designs of Bk. II, particularly when the figures are seen as approximations, those designs still contained many aspects which did not fall into any such neat pattern. It was apparently in the rooms of personal habitation by the patron, as against more minor rooms with storage functions and the like, and the more public open spaces, that Palladio attempted most strongly to maintain his favoured ratios. In other places in the design it seems dimensions were not considered so significant,

1. No. 7.
2. WITTKOWER (1947) p. 66 in one context stated that this villa "is the most perfect realization of the fundamental geometrical skeleton" yet he gave no harmonic analysis of it.
3. 15 only relates to 18, 20, 21, 24, and 25, which give 9:13, 10:13, 21:26, 12:13 or 25:26. "La Sala e nel mezo...I camerini sono amezati.."
4. On approximation it should be noted that WITTKOWER (1949) p. 95 wrote "It is probably true to say that neither Palladio nor any other Renaissance architect ever in practice used irrational proportions, and this is an argument <u>per negationem</u> in favour of the case we are going to state. We must repeat that Palladio's conception of architecture, as indeed that of all Renaissance architects, is based on commensurability of ratios". (Incommensurables of course have to be approximated.) Now Wittkower's view appears to be plainly wrong, if not actually perverse. For example in No. 26, while there is no pair of key rooms, the main room at the back of the building is dominant: and its proportions are 15 x 21¼ which is an extremely good aproximation to $\sqrt{2}$ (= c. 15:21.21). A lesser room in No. 1 is similar (17 x 24, $\sqrt{2}$ = c. 17: 24.04.) Explicitly on No. 12 Palladio wrote "LE SEGVENTE fabrica è del Conuento delle Carità...ui ho fatto l'Atrio..il quale è lungo per la linea diagonale della quadrato delle larghezza." (Wittkower himself (1949) p. 72/3, quoted this right up to where Palladio began the clause about the diagonal, and choped it off there.) However it is probably true to say that Palladio did not make much use of this ratio, yet on his 2nd. rule of vaults he explicity stated that numerical ratios could not always be found:"Ma è da auertire, che non sarà sempre possible ritrouar quest' altezza, cõ i numeri (p. 53. Bk. I); and then used that rule sometimes.
5. See sheet III.   6. See sheet III.
7. For example in No. 4 the dominant courtyards are given as 50 x 34 which begs to be 51 x 34. But 50 relates to 30 nicely the dimension of a (probably) dominant room, so possibly it should have 30:33⅓:50 to give 3:5 and 2:3. No. 6 has a garden on which it is explicitly written "longeza circa piede 120 e di largeza 60. See also design sheets.
8. Equivalent to $\sqrt{2}$ of course.
9. 1:1 3/5 and 1:1 5/8 included together.
10. Except for $\sqrt{2}$, while 1:1¼ and 1:1¾ seem to be the next prefferred.

or had to remain in akward ratios for various reasons.[1]

Now Wittkower attempted to make much of the musical harmonies he purported to discover in some of Palladio's designs considered as a whole here.[2] But given the technique of design isolated above indicating the ratios Palladio generally used, together with the typical regular grid he so frequently adopted in which room sizes tended to interlock, the breath of one room forming the length of another, a square room locking together two different sized rooms onto a single dimension, for example, not to mention such devices as halving heights and relating them to plan dimensions, the picking up of a dimension of some simple fraction of another dimension, to form another room -- really the effect, at least in part, of merely a modular approach -- harmonies were bound to appear with some degree of frequency, particularly as Palladio tended to favour 'factorable' numbers. To a great extent this was simply because Palladio preferred such ratios as 1:1⅓, 1:1½ and 1:1 2/3 which were considered to be basic harmonies at the time. But against this it should be noted that given the harmonies put forward by Wittkower, taking the most common types of rooms which were between the square and double the square, and limiting the ratios to those involving fractions involving the small integers from one to five, of the 9 possible ratios, only two are disharmonious,[3] 5:7 & 4:7. Now 5:7 is very close to √2 which Palladio noted as desirable. Thus but one reprehensible ratio, 4:7, remains. Yet that very ratio Palladio used clearly in two designs in the critical ratio of the key rooms of these designs.[4] It is thus

1. On occasion however the 'sala' might form the centre of the design and provide a key ratio. In Bk. II, Cap. II Palladio stated "Ma le stanze grandi con le mediocri, e queste con le picciole deono esser in maniera cõpartite, che (como ho detto altrue) una parte della fabrica corrisponda all'altra.", indicating that it was the "stanze" which were to be most attended to in accord with the above interpretation. Wittkower however read this as simply that the plan ratios should be in harmonic proportions, yet it was through the heights of the vaults that, Palladio clearly stated in his text, different rooms could be related in proportion; and the term 'compartite' simply suggests the modular approach. In this same chapter Palladio indicated that the more minor rooms could be given less attention saying "Ma si come Iddio Benedetto ha ordinati questi membri nostri che i piu belli siamo in luoghi piu eposti ad esser ueduti, & i meno honesti in luoghi nascosti, cosi anchor noi nel fabricare; collocheremo le parti principali, e riguardevoli in luoghi scoperti, e le men belle in luoghi piu ascosi a gli occhi nostri che sia possible....."

2. A few irritating defects in Wittkower's account which do not substantially affect his interpretation, but which are noticeable, ought to be mentioned here. Wittkower used the counterfiet 18th. century edition. (GREASSE (1859/69) dates it 1770/80 at Venice.) In the case of No. 24 the key dimension 12 is given in the counterfeit edition was not clearly given as such in the original first edition, although the assumption that it is 12 is quite reasonable. In No. 19 the crucial dimension 16 is not given at all although the assumption that this is what it should be is again very reasonable. Both these figures being used by, and crucial to, Wittkower in his analysis. Again on No. 2 Wittkower wrote ((1949) p. 118) "The long wings behind the main building contain three groups of three rooms each -- two of these groups are repeated at each side of the third central one -- the widths are inscribed as 16, 12, 16; 20, 10, 20; 9, 18, 9..." As can be seen from Wittkower's own illustration (from the counterfiet edition) the last 9 was not in fact inscribed, although it can be read off from symmetry as such. As part of Wittkower's account was that Palladio meant one to read off clearly such inscribed musical ratios this was a slightly unfortunate slip. However it again does not substantially undermine Wittkower's interpretation. In the case of No. 22 however WITTKOWER (1949) p. 115, n.2, gave as a series of significant dimensions for it, 16, 24, 27, 32, while in both the first edition and the counterfeit the figures are as in sheet and only 27½, and not 27, appears, while he ignored the key dimension 26½ which from the text must be 28. In the case of No. 33 Wittkower showed only part of the design for his harmonic analysis (as his illustration noted). As what he gave was the main block of the building leaving out the surrounding details which, although they did not fit into his nice harmonic scheme may be considered less important, Wittkower was perhaps justified in this to some extent, but the illustrates the way he selected particular designs and even parts of designs to fit his thesis.

3. See sheet.

4. In No. 22 in figures which are repeated elsewhere on the plan. In No. 23, 26½ having to be corrected to 28 to give that proportion as the text requires. In both cases these dominant rooms have only to be altered by one foot in one dimension to give what Wittkower thought a marvellous harmony, 16:27.

difficult to conceive that Palladio was over much preoccupied with harmony. On the other hand that ratio did not occur with any great frequency in Palladio's designs, rather he tended to adhere to the ratios he mentioned in his general remarks on this topic, which were of course harmonious. Thus in the selection of his favoured ratios Palladio seems to have been somewhat influenced by the parallel between musical harmony, and visual beauty as outlined by Alberti, but once this basic selection process had occured, he merely favoured those particular ratios -- rather than sticking rigerously to them -- and was not too unhappy to use other ratios, disharmonic or not, when he felt it necessary for whatever sort of reason.[1]

As in the case of vault heights, in the selection of room proportions in favourable ratios, this was not a rigorously constrained process but rather was done when it could be, and in many cases where it was done was represented only approximately. It was thus rather a loose constraint on design. Just how loose such a constraint could be, given the nature of the background ideas about harmony, and its use in architecture, on the basis as outlined by Wittkower, can be seen from a consideration of the great number of harmonic ratios that were as a result allowable. Taking the basic harmonic ratios, together with those generated by multiplying any two within the series, one arrives at a sufficiently large number of proportions, within the range of the typical room size -- square to double square -- such that if a designer gave a room any proportion whatsoever, that proportion could only be at a maximum, less than 6% away from a harmonic proportion; and only very infrequently would the error be more than 2½/3 %.[2] Thus even without allowing for approximation,[3]

1. Wittkower sometimes seems to be suggesting this kind of interpretation. He stated (p. 115 op. cit.) "we are far from suggesting that Palladio while planning these buildings, was consciously translating musical into visual proportions". But elsewhere he suggested (p. 117 ibid.) that "nobody will doubt that Palladio's numbers were meant to be suggestive of certain ratios"; and more generally (p. 102/3 ibid.) that "In analysing the proportions of a Renaissance building one has to take the principle of generation into account. It can even be said that, without it, it is impossible to fully understand the intentions of a Renaissance architect"; and (p. 94/5 ibid.) "Behind Palladio's matter-of-fact rules there is usually more thought and accumulated wisdom than might be apparent to the modern reader. It is obvious that his notes on proportion cannot be arbitrary, but must refer tacitly to some generally accepted mathematical truth". Wittkower thus seems to have rather wanted it both ways; to understand the architects intention, one analysis the proportions in terms of musical harmony, even though the architect was not consciously using them. 2. See sheet III.
3. There are further grounds for accepting the need for approximation over those noted above. Palladio stated that wall thickness should diminish in the upper stories (see above p.197). This then must have altered proportions of rooms from floor to floor, so that if a room on one level was harmonious on one level it would tend to be only approximately so on the next. Further Wittkower himself (op. cit. p. 113 for example) noted that the constructed buildings which Palladio illustrated in his treatise were by no means as regular as their representations. BERTOTTI SCAMOZZI (1776/83) in his measured drawings of some of Palladio's designs gave No. 3 for example (Tav. VI) with the 30 x 20 key room as 29' 2" x 19' 9"; and the 20 in the 20 x 20 room as 20' 7"; In No. 2 (Tav. X) the 30 x 18 room as 28' 3" x 17' 4", c. 2% error in the first two cases and c. 2½% in the last. ACKERMAN (1977) p. 167/8 stated of (No. 24) "The Villa Emo, as shown in two recent surveys is built with a precision of measurement rare in the Renaissance. The rooms at the four corners of the piano nobile and the porch were found to be the same width within a few centimeters, and the great sala precisely square." The main rooms he shows as 26' 1" x 15' 8" = 1:1.67, as against 1.685 (=Wittkower's favourite 16:24:27), 1% error. Square rooms 1½% error. Of course Wittkower rightly noted Palladio's work gave 'rationalisations' of designs of actual buildings. But then went on to insist that the inscribed numbers were meant to teach the reader about the harmonic aspects of such drawings. But the inscribed numbers of the full range of Palladios designs of Bk. II vary in so many ways when considered as a whole and not in the few selected cases taken by Wittkower, that this seems impossible to accept in any general way. Further on this type of view, because in two cases Palladio used the disharmonic ratio of 4:7, one would be entitled to conclude that Palladio wished to teach that one did not have to stick to harmonic ratios. Of course Wittkower then accepted that Palladio allowed himself to break his own rules (op. cit. p. 23 n. 2). But this again undermines the didactic function.

whatever proportion a room was given on such a theory it was within very narrow limits necessarily bound to be beautiful. In other words, on Wittkower's account, the theory was almost totally tautological.[1] This however is not to suggest that such a theory would have no effect. What it means is that the late 16th. century architect working in accord with any such theory could sketch out plans (of a Palladian type as considered here) and arrive at whatever layout he fancied for whatever reason, ignoring that theory. Then, very minor adjustments of dimensions would bring the design into complete harmony, if it was so desired, in accord with the theory. Such a theory would then not be any basic determining 'principle' of architecture, rather it would be a 'finishing' device to use Alberti's term: an adjustment, justification and rationalisation of a result actually otherwise determined.

In practice however Palladio seems to have favoured a much smaller number of ratios, and in this way the constraint of such a 'finishing' device would have been somewhat greater.[2] At the same time his quite frequent use of 'irregular' ratios shows that he used this constraint in only a relatively weak form, so tending to make the theory more tautological again.[3]

Thus Palladio's design techniques as found in Bk. II of his treatise are found to have been a series of relatively loose constraints based on favoured ratios with a certain relationship to musical harmonies, but which were applied with no great emphasis on the universal need for such kinds of ratios. However, given the nature of these ratios, the tendency towards to tautology, the need to approximate, and the regular grids he used, despite the rather loose nature of the constraints involved, Palladio's techniques had the effect that one could nearly always hope to discover some kind of harmony in his design if one so wished. An approach which therefore meant that the rhetoric, of mathematically correct harmonies in architecture, as a legitimising and rationalising tool, was generally supported, while the architect was free to proceed with 'design' largely free from any such constraint. Thus Wittkower's tendency to read into the process wonderous musical harmonies was a tendency to confuse the rhetoric with the reality which grossly exaggerated that aspect of Palladio's design technique and gave a totally false impression.[4]

1. This is not to suggest that renaissance architects could have considered the problem in this way. One may imagine that if the large number of possible harmonic ratios available to them had been pointed out they would have suggested that this really indicated the power of their approach.
2. Thus Wittkower's desperate search for obscure harmonic relationships between different numbers, in so far as it is allowable, makes Palladio's technique more tautological and less an attempt by the designer to feed in musical harmonies in any determining way..
3. Because if the theory does not have to apply everywhere one can simply point to where it does apply in order to justify the design as beautiful.
4. This interpretation then allows one to return to the Quatri Libri and to read it as a text as it stands. For, the most problematic aspect of Wittkower's interpretation is why in his quite long text Palladio never even began to explain how such harmonic musical ratios were applied if their use was as important as Wittkower suggested. Particularly in view of the way Palladio claimed to be teaching the true general rules of architecture, and went into so much detail about the orders. But given that musical harmony functioned merely to provide the favoured ratios, which were only applied only when they could be; and when it was accepted that the architect, on not infrequent ocassions had to proceed by way of "necessity and judgement", there was not a great deal more that Palladio needed to say. Indeed there was not a great deal more he could say when such a 'finishing' process was so loose and variable instead of being a rigorously determining method. Thus the view of architecture presented in Palladio's treatise is found to be what a plain reading of the text gives. That design in architecture depended centrally on the orders, a few simple rules on the proportions of rooms allowing the achievment of beauty in other aspects of the structure at times. This last being in accord with the rhetoric of the application of the musical harmonies to visual beauty in architecture.
ACKERMAN (1977) is rather more balance than Wittkower, and stated P. 167, "Palladio seems to have been especially attracted to musical proportions early in his career...In works after this period Palladio did not so much abandon harmonies as relax his application of them."

TABLE I

No	DESIGN	DIMENSIONS GIVEN	ROOMS	RATIOS
1	Pal. Antonini Vdene p. 4/5 Cap. III	17, ?, 28, 8, 12¼, 12½, 24, 17, 11.	17 x 28, 24 x 17, 17 x 17, 8 x 12½, 12¼ x 12½.	17x28 = c. 1:1⅔ (= … 17x24 = c. 1:√2 (= … 8 x 12½ = c. 1:1½ (= …
2	Pal. Chiericato Vincenza p. 6/7	13, 15½, 54, 30, 16, 18, 18, 11¼, 18, 19, 12.	18 x 30, 16 x 54, 18 x 18, 18 x 12.	18 x 30 = 1:1⅔, 16 x … 12 x 18 = 1:1½
3	Pal. Iseppo Porto p. 8/9	30, 30, 20, 20, 20, 9, 7, 10, 10, 30.	20 x 30, 30 x 30, 20 x 20, 9 x 20, 7 x 9.	20 x 30 = 1:1½, 9 x 20 = c… 7 x 9 = c. 1:1¼ (= 7:8¾ …
4	Pal. della Torre Verona p. 10/11	17, 10, 19, 11, 15, 30, 50, 22½, 18, 19, 18, 34.	19 x 30, ctyd. 34 x 50, 17 x 19, 19 x 19, 19 x 11, 19 x 15, 22½ x 18	19 x 30 = c. 1:1½ (= 20 x 30) 17 x 19 = c. 1:1⅛ (= 17:19 … 15 x 19 = c. 1:1¼ (= 15:1…
5	Pal. Thieni Vincenza p. 12/15	20, 34½, 20, 56, 20, 20, 30, 55, 102, 12, 74, 74.	20 x 30, 20 x 34½, 20 x 20, 56 x 20.	20 x 30 = 1:1½, 20 x 34 … (= 20 x 33⅓), 20 x 55 …
6	Pal. Valmarana p. 16/17	8½, 17½, 10, 20½, 20, 44, 15, 18, 19, 38, 35, 10, 10, 14, 18, 36.	38 x 19, 18 x 15, 20½ x 17½, 18 x 36 (stables)	19 x 38 = 1:2, 18 x 36 = … 15 x 18 = 1:1⅕, 17½ x 2… (= 17½ : 19¼ …)
7	Villa Rotunda p. 18/19	15, 15, 11, 11, 15, 15, 26, 26, 30, 12, 12, 6, 6.	15 x 26, 11 x 15.	15 x 26 = c. 1:1¾ (= 15:2… c. 1:1⅓ (= 11¼ x 15), 11:1…
8	Pal. Capra p. 20/21	17, 27, 13, 13, 32, 32, 13, 13, 17, 27.	17 x 27, 13 x 13, 32 x 32. Cty	17 x 27 = c. 1:1⅗ (= 17 … = c. 1:1⅝ (= 1…
9	Pal. Barbarano p. 22/23	19, 24, 16, 16, 12, 7, 8½, 11, 33, 23, 9, 25, 41½	(19 x 24), 16 x 24, 16 x 16, 12 x 16, 7 x 12, 23 x 12 stables, 11 x 25, 33 x 25, 25 x 41½.	16 x 24 = 1:1½, 12 x 16 = 1:… (= 1:1¼), 12 x 23 = c. 1:2 (… = 1:1⅓, 11 x 25 = c. 1:2¼ … 33 = c. 1:1⅓ (= 25:33⅓), 25 x …
10	Atrio Toscano p. 25/26	20, 18, 20, 25, 40, 60, 18, 9, 11, 20, 66, 85, 30, 38, 11, 20, 28.	20 x 28, 20 x 25, 30 x 38, 40 x 60 Cty.	20 x 28 = 1:1⅖, 20 x 25 = … c. 1:1¼ (= 30:37½), 40 …
11	ditto in maggiore forma	19, 18, 18, 18, 67½, 45	18 x 18, 45 x 67½	45 x 67½ = 1:1½
12	Atrio di quattro colonne p. 27/8	16, 16, 16, 16, 16, 16, 17½, 35, 52½, 6½.	16 x 17½, 35 x 52½.	35 x 52½ = 1:1½ 16 x 17½ = c. 1:1⅒ (= …
13	Atrio corinthio p. 28/32.	9½, 30, 9½, 14½, 14½, 26, 40, 54, 78?, 63.	63 x 78, 40 x 54	63 x 78 = c. 1:1¼ (= 63 x 7… = c. 1:1⅓ (= 40 x 53⅓)
14	Atrio Testuggiant e casa private p. 33/4	18, 27, 6, 36, 72, 12, 18, 18, 36, 21, 20, 20, 36, 99, 20, 36, 20, 20, 48.	18 x 27, 72 x 36, 36 x 18, 21 x 18, 20 x 18, 36 x 36.	18 x 27 = 1:1½, 36 x 72 … = 1:2, 18 x 21 = 1:1⅙, …
15	ditto in mag. forme p. 35	22½, 21, 20, 21, 50, 83'-4"	50' x 83'-4", 20 x 21.	50 x 83'-4" = c. 1:1⅔ (= …
16	Cap. XIII Villa Pisani p. 47	22, 22, 19, 16, 18, 18, 24, 16, 32, 42, 8.	18 x ?, 16 x 24, 16 x 16	16 x 24 = 1:1½ (18 x (30) …
17	Villa Badoero p. 48	20, 14, 14, 20, 16, 12, 32, 34, 26½, 16, 8, 12.	16 x 26½, 16 x 16, 16 x 32, 8 x 16.	16 x 26½ = c. 1:1⅔ (= 16 … = 1:2, 8 x 16 = 1:2.
18	Villa Zeno p 49	20, 14, 14, 20, 14, 14, 14, 29, 12, 14, 21½, 14.	21½ x 14, 14 x 14, 12 x 14.	14 x 21½ = c. 1:1½ (= 14 x … = 1:1⅙.
19	Villa Foscari p 50	12, 24, 12, 16, 16, 32, 46½, 7.	24½ x ?, 16 x 16, 16 x 12	12 x 16 = 1:1⅓. (16) x 24 = …
20	Villa Barbari p. 51	16, 12, 16, 46, 20, 10, 20, 9, 18, 12, 6, 14, 20, 12, 20, 12, 32, 20, 32, 60, 12, 4.	20 x 12, 6 x 12, 9 x 20, 12 x 32, 16 x 32, 46 x 20, 18 x 20, 20 x 20.	12 x 20 = 1:1⅔, 6 x 12, 16 x 32 = … 9 x 20 = c. 1:2¼, 20 x 46 = c…
21	Villa Pisani p. 52	16, 26, 10, 16, 28, 28, 16, 8½, 8½, 11¼	16 x 28, 28 x 28, 16 x 16, 8½ x 16)	16 x 28 = 1:1¾, 8½ x 16 …
22	Villa Cornaro p. 53	24, 26½, 10, 16, 16, 16, 32, 27¼, 10, 11.	(16 x 26½), 16 x 28, 16 x 24, 10 x 16, 27¼ x 32	16 x 28 = 1:1¾, 16 x 24 = 1:… 27¼ x 32 = c. 1:1⅙ (= 26⅔ …
23	Villa Mocenico p. 54	10, 16, 16, 26, 32, 32, 16, 16, 20, 16.	16 x 26, 16 x 16, 10 x 16, 32 x 32.	16 x 26 = 1:1⅝, 10 x 16 … = c. 1:1⅔ (= 16 x …

cty = courtyard.
ed = edition
drg = drawing

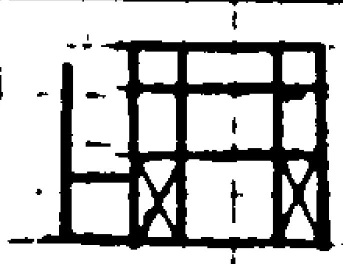
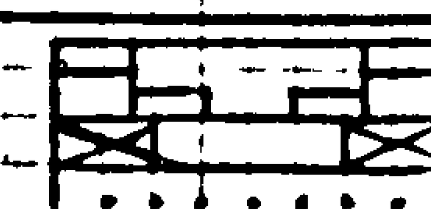
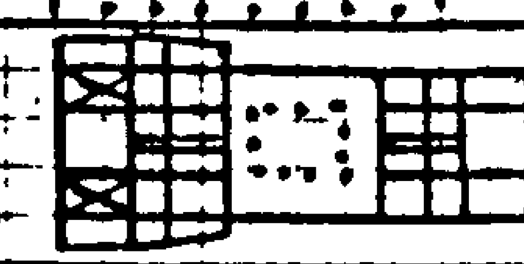
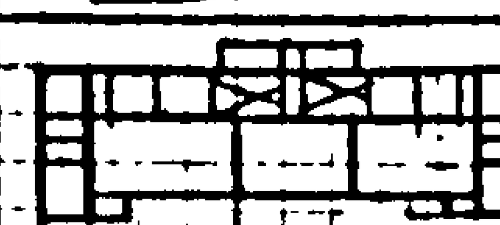
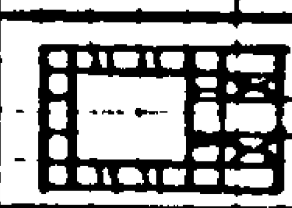
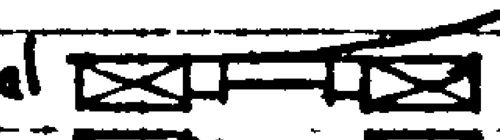
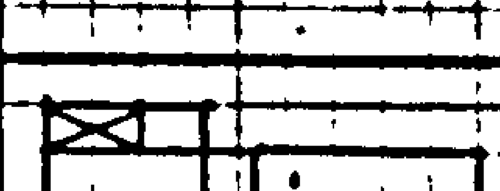
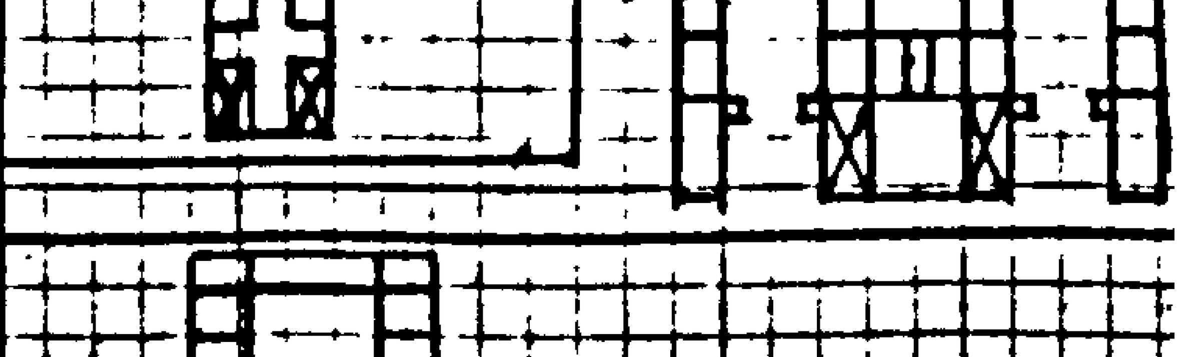
...TIOS	TEXT	NOTES
= c. 1: 1⅔ (= 17: 28⅓) 4 = c. 1: √2 (= 17: 24.04) ½ = c. 1: 1½ (= 8:12)	'stanze maggiori' vaults 1st mode. 'Le stanze di sopra sono in solaro, e tanto maggiori di quelle di sotto, quanto importanto le contratture, ò diminutioni de' muri & hanno i solari alti quanto sono larghe.'	 Counterfeit ed. gives 32x28 room
= 1:1⅔, 16 x 54 = 1:3⅜ = 1:1½	'Le stanze maggiori' vaults to 1st rule. 'camerini' vaults 'amezati'	
2 = 1:1½; 9x20 = c.1:2¼ (=9:20¼) = c.1:1¼ (=7:8¾)	"Le stanze prime ... a canto le dette entrate" Last rule of vaults.	
= c.1:1⅔ (=20x30), 34x50 = c.1:1½ (=34:51) = c.1:1⅛ (=17:19⅛), 11x19 = c.1:1¾ (=11:19¼) = c.1:1¼ (=15:18¾), 18x22½ = 1:1¼		 Counterfeit gives an extra 32
2 = 1:1½; 20 x 34 = c.1:1⅔ (33⅓), 20 x 55 = 1:2¾		
= 1:2, 18 x 36 = 1:2, = 1:1⅕, 17½ x 20½ = c.1:1⅛ :19½)	On the drg. 'longeza del giardino e c?? piede no 120 e di largeza 60'	Complex design. Central cty 20½x17½ room flanking entrance 19 x 38 rooms toward rear. Possibly key rooms.
= c.1:1¾ (=15:26¼), 11x15 = (=11¼x15), 11:15:26 = c.3:4:7.	"le stanze grandi" to 1st rule. "Camerini" amezati. (Height? length?)	See table
7 = c.1:1⅗ (=17:27⅕) = c.1:1⅝ (=17:27⅝)		unsymmetrical 
= 1:1½; 12x16 = 1:1⅓, 7x12 = c.1:1⅔), 12x23 = c.1:2 (=12x24), 9x12 , 11x25 = c.1:2⅓ (=11:25⅔), 25x 1⅓ (=25:33⅓), 25x41 = c.1:1⅔ (=25:41⅔)	"La entrata... Dalla destra, e dalla parte vi sono due stanze lunghe un quadro e mezo" &c. 19x24 should read 16x24	 The rooms 33x25 & 11x25 are only divided by columns might be considered one = 25x44 = c.1:1¾ (= 25x43¾)
= 1:1⅔; 20x25 = 1:1¼, 30x38 (=30:37½), 40x60 = 1:1½.		Complex design around central cty
7½ = 1:1½		
2½ = 1:1½		
½ = c.1:1 1/10 (=16:17.6)		
= c.1:1¼ (=63x78¾), 40x54 1⅓ (=40x53⅓)	"vi ho fatto l'Atrio ... è lungo per la linea diagonale della quadrato della larghezza"	
= 1:1½; 36x72 = 1:2, 18x36 18x21 = 1:1⅙; 18x20 = 1:1⅑	"L'atrio è lungo per la diagonale del quadrato della larghezza."	
'-4" = c.1:1⅔ (=50x83'-8")		
= 1:1½ (18x(30) = 1:1⅔)	"Le stanze sono in solaro alte quanto larghe le maggiore 1:1⅔ gives key rooms 18x30, others 1:1½	 With large cty
½ = c.1:1⅔ (=16x26⅔), 16x32 8x16 = 1:2.		
½ = c.1:1½ (=14x21) 12x14	'stanze maggiori' to 2nd rule	
1:1⅓. (16)x24 = 1:1½)	'stanze maggiori' 1st modo. key rooms probably 16x24 = h = 20 roughly ties up with faced.	 Key rooms look like 24x16
1:1⅓; 6x12, 16x32 = 1:2, 12x32 = 1:2⅔, = 1:2¼, 20x46 = c.1:2⅓, 18x20 = 1:1⅑		 With cty,
= 1:1¾, 8½ x 16 = c.1:2 (=8:16)	'stanze maggiori' 1:1¾, 2nd mode of vaults. Le med. quattro I camerini e l'andito volti due quadre	
1:1⅗, 16x24 = 1:1½, 10x16 = 1:1⅗ 2 = c.1:1⅓ (=26⅔x32)	'le stanze maggiori' 1:1¾, gives 16x28 'le mediocre sono quadre il terzo più alte che large'	
= 1:1⅗, 10x16 = 1:1⅗ = c.1:1⅔ (=16x26⅔)	'le stanze maggiori' 2nd vaults, 'mediocre' similar, smaller 97'	 With wings

TABLE II

No	DESIGN	DIMENSIONS GIVEN	ROOMS	RATIOS
24	Villa Emo p. 55	48, 12, 24, 16, 27, 16, 15, 20 (12 ?)	20×48, 20×12, 20×24, 16×27, 16×16, (12?×16)	16×27 = c.1:1⅔ (=16 =1:1⅕, 12×20 = 1:1⅔, 20
25	(Cap. XV) Villa Sarraceno p. 56	15, 15, 30, 16, 12, 28, 26½, 15	(16×26½), 12×16, 15×30, 15×15, 16×26	[16×26½ = c.1:1⅝ (=16: 1:2, 12×16 = 1:1⅓, 16
26	Villa Ragona p. 57	15, 50, 12, 21¼, 15, 17, 18, 12 15.	15×21¼, 12×15, 17×18.	15×21¼ = c.1:√2 (=15 =1:1¼, 1
27	Villa Pogliana p. 58	30, 18, 18, 36, 8, 18, 17, 30, 10, 17, 15, 10, 15, 20.	18×30, 17×30, 10×36, 17×18 8×17, 20×17	18×30 = 1:1⅔, 17×30 = 29¾), 10×36 = 1:3⅗, 18×17
28	Villa Valmanara p. 59	12, 15, 12, 27, 45, 17, 15, 12, 25, 32½.	17×27, 15×15, 12×12, 15×12, 25×32½	17×27 = c.1:1⅝ (=17:2 1:1¼, 25×32½ = c.1:1¼
29	Villa Trisini p. 60	15, 14, 12, 18, 36, 30, 15, 20.	14×18, 14×36, 12×18.	14×18 = c.1:1¼ (=14×17 1:2 ⁴⁄₇, 12×18 = 1:1½
30	Villa Thiene p. 62	18, 12, 18, 36, 36, 16, 16×16	36×36, 18×36, 18×18	
31	Villa Angarano p. 63	20, 15, 10, 18, 18, 36, 22, 13, 15, 20, 10, 15.	18×22, 10×13, 18×36	18×22 = c.1:1¼ (=18:22 1⅓ (=10:13⅓)
32	Villa Thiene p. 64	68, 102⅓, 28, 130, 56, 44, 11, 20 20, 20, 18, 30, 41½, 11.	28×56, 30×41½, 68×102⅓	28×56 = 1:2, 30×41½ = 68×102⅓ = c.1:1½ (= 6
33	Villa Godi p. 65	20, 32, 12, 24, 24, 16, 36, 24, 16, 56, 13½, 10, 60, 100, 16, 21	24×36, 16×24	24×36 = 1:1½, 16×24
34	Villa Sagredo p. 66/7	24, 10, 10, 10, 24, 18, 24, 36, 12, 20, 12, 12.	18×24, 24×24, 10×24, 20×20 20×36.	18×24 = 1:1⅓, 10×24 = 1: 1:1⅕, 20×36 = 1:1⅘
35	Villa Sagredo p. 68	16, 9, 20, 24, 12, 16, 27, 4, 4, 15, 40, 10.	16×27, 20×40, 9×24, 12×16, 16×16.	16×27, = c.1:1⅔ (=16:2 1:2, 12×16 = 1:1⅓, 9×24 =
36	Cap. XVI. Dela casa de gli antichi p. 69/70	25, 25, 8, 60, 40, 19, 19, 19, 11¼, 73, 19, 19, 44½, 44½, 40, 6, 16, 19, 19.	40×40, 40×60, 44½×44½, 73×111¼.	40×60 = 1:1½, 73×11 = (73:109½)
37	Cap. XVII (Diverse sites) p. 71	7, 18, 30, 30, 30, 14, 27, 18, 18, 12, 30, 30, 30½, 16.	18×30, 18×27, 12×18.	18×30 = 1:1⅔, 18×27 12×18 = 1:1½
38	p. 72	34½, 20, 37½, 45, 20, 11, 8, 24, 40, 24, 30, 20, 8, 10, 20, 16, 40, 40.	20×34½, 37½×45, 8×20, 20×30, 16×20.	20×34½ = c.1:1¾ (=20: 16×20 = 1:1¼, 37½×45 = 1:1
39	Pal. Trissini p. 73/4	10, 23, 20, 15, 14, 15, 20, 40, 8, 18, 46, 62, 8, 12½, 7.	20×40, 15×20, 20×23, 18×20 46×62. Cty	20×40 = 1:2, 15×20 = 1: 20×23 = c.1:1⅕ (=20:22⅔
40	Pal. Angarano p. 75	18, 30, 50, 12, 50, 30, 18.	18×30, 30×50, 12×18.	18×30 = 1:1⅔, 30×50 12×18 = 1:1½
41	Pal. della Torre p. 76	20, 36, 40, 20, 15, 40, 20, 15.	26×36, 15×20.	20×36 = 1:1⅘, 15×20
42	Pal. Gbrzadore p. 77	18½, 16, 8, 28½, 20, 12.	18½×20, 16×18½, 12×18½, 8×16, 20×28½.	16×18½ = c.1:1⅛ (=16:18⅔), 12 18½×20 = c.1:1⅒, 20×28½ =
43	Villa Mocenico p. 78	24, 16, 16, 40, 20, 75, 59, 76, 30, 20, 20, 15.	20×40, 15×20, 30×76, 59×75 Cty.	20×40 = 1:2, 15×20 = 1:1⅓ (=30:75), 59×75 = c.1:1¼ (

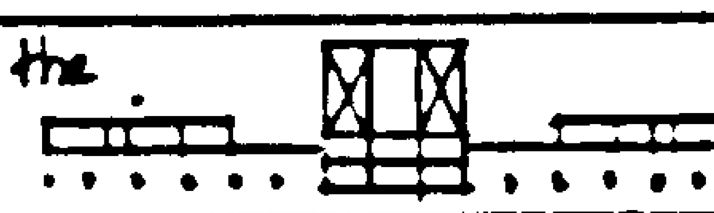
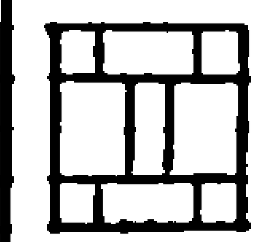
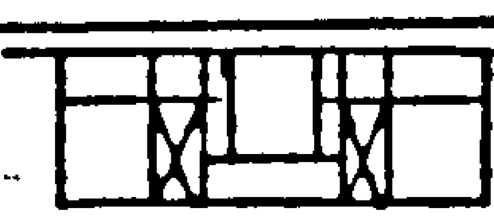
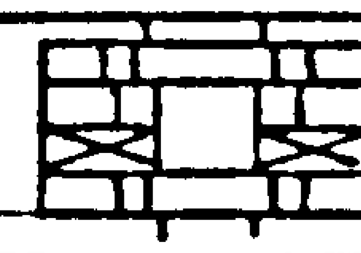
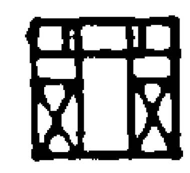
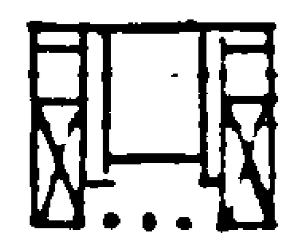
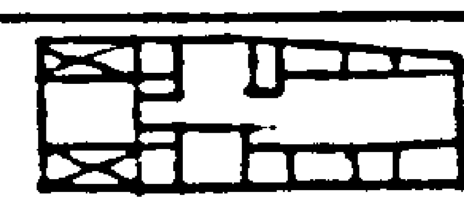
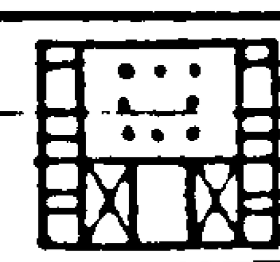
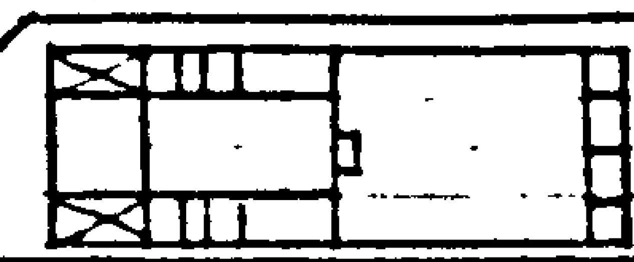
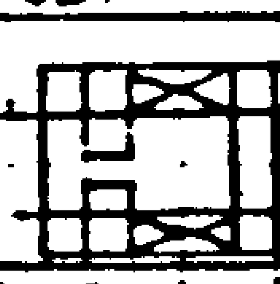
Ratio	Designs	No
1½	3, 5, 9, 19	4
1⅝	23, 25,	2
1⅔	8, 16, 20, 27, 37, 40	6
1¾	21, 22,	2
1⅘	41	1
2	6, 39, 43	3

KEY ROOMS.

Ratio	Designs	No	+ No	= Total No
1¼	31	1		1
1½	4, 18, 38	3	4	7
1⅝	28	1	2	4
1⅗	8	1		
1⅔	1, 17, 24, 35,	4	6	10
1¾	7	1	2	3
1⅘			1	1
2			3	3

+ approximation

Ratio	Designs
1⅕	6, 22, 24, 34, 38
1¼	3, 4, 10, 13, 24,
1⅖ = √2	1, 10, 26, 32, 42
1⅓	7, 9, 13, 19, 25,
1½	1, 2, 3, 5, 9,
1⅗	8, 22, 23,
1⅝	23, 26, 28
1⅔	1, 2, 5, 9, 15,
1¾	4, 7, 21, 22, 27,
1⅘	34, 41,

TIOS	TEXT	NOTES
27 = c.1:1⅔ (=16:26⅔), 20x24 s, 12x20 = 1:1⅔, 20x48 = 1:2⅖		Counterfeit ed. has 12 where the 1st ed. has '2' to give 12x16 room 
26½ = c.1:1⅔ (=16:26⅔)] 15x30 = 12x16 = 1:1⅓, 16x26 = 1:1⅝	'le stanze maggiori' 1:1⅝ gives key rooms 16x26	
21¼ = c.1:√2 (=15:21.21), 12x15 ¼, 1		 With ctyd
30 = 1:1⅔, 17x30 = c.1:1¾ (=17:) 10x36 = 1:3⅗, 18x17:?, 8x17 = 1:2⅛	'le stanze grandi' = 1:1⅔	With wings 
27 = c.1:1⅝ (=17:27⅝), 12x15 = , 25x32½ = c.1:1¼ (=25:31¼)		
8 = c.1:1¼ (=14x17½) 14x36 = 3/7, 12x18 = 1:1½		Guess 18x30 key rooms. Round central Wings. Too few dimensions given.
		Square block with wings.
22 = c.1:1¼ (=18:22½), 10x13 = c.1: =10:13⅓)		 With wings
56 = 1:2, 30x41½ = c.1:√2 (=30:42.4) .102⅓ = c. 1:1½ (=68:102)		Organized around ctyds.
36 = 1:1½, 16x24 = 1:1½		Central block with wings
24 = 1:1⅓, 10x24 = 1:2⅖, 20x24 = 5, 20x36 = 1:1⅘		Central ctyd.
27, = c.1:1⅔ (=16:26⅔), 20x40 = 2x16 = 1:1⅓, 4x24 = 1:2⅔		 Central Ctyd.
60 = 1:1½, 73x111¼ = c. 1:1½ 3:109½)		
x30 = 1:1⅔, 18x27 = 1:1½, x18 = 1:1½	Rooms beside entrance 1:1⅔, 1st mode of vaults. Other rooms 1:1½. Sala 1:1⅔ which does not seem to tie up.	
34½ = c.1:1¾ (=20:35), 20x30 = 1:1½ 20 = 1:1⅓, 37½x45 = 1:1⅕, 8x20 = 1:2½	Rooms next entrance 1st mode of vaults	
40 = 1:2, 15x20 = 1:1⅓, 18x20 = 1:1¼ 23 = c.1:1⅓ (=20:22⅔), 46x62 = c.1:1⅓	26' high great rooms, medium and minor 18'	
30 = 1:1⅔, 30x50 = 1:1⅔, 18 = 1:1½	Rooms beside entrance 1:1⅔ as high as large	
36 = 1:1⅘, 15x20 = 1:1⅓		Key rooms flanking entrance. Large central area
½ = c.1:1⅛ (=16:18⅔), 12x18½ = c.1:1½ (=12:18) 20 = c.1:1 1/10, 20x28½ = c.1:√2 (=20:28)	Vaults of the "stanze maggiori" 3rd mode	
0 = 1:2, 15x20 = 1:1⅓, 30x76 = c.1:2½ 75), 69x75 = c.1:1¼ (=60x75)		Central ctyd. Key rooms flanking entrance

	Designs	No
5	6, 22, 24, 34, 38	5
¼	3, 4, 10, 13, 24, 26, 28, 29, 31, 38, 43	11
√2	1, 10, 26, 32, 42	5
3	7, 9, 18, 19, 25, 31, 34, 35, 39, 41, 43	11
2	1, 2, 3, 5, 9, 10, 11, 12, 14, 16, 18, 19, 22, 29, 32, 33, 36, 37, 38, 40, 42	21
⅕	8, 22, 23,	3
⅝	23, 26, 28	3
⅔	1, 2, 5, 9, 15, 16, 17, 20, 24, 27, 35, 37, 40	13
¾	4, 7, 21, 22, 27, 38	6
⅘	34, 41,	2

All designs allowing approximation.

TABLE III

Source	Z	Z	F	F	P	P	F	P
Harmony	1	2	3	4	5	6	7	8
Ratio	9:10	8:9	5:6	4:5	3:4	2:3	5:8	3:5

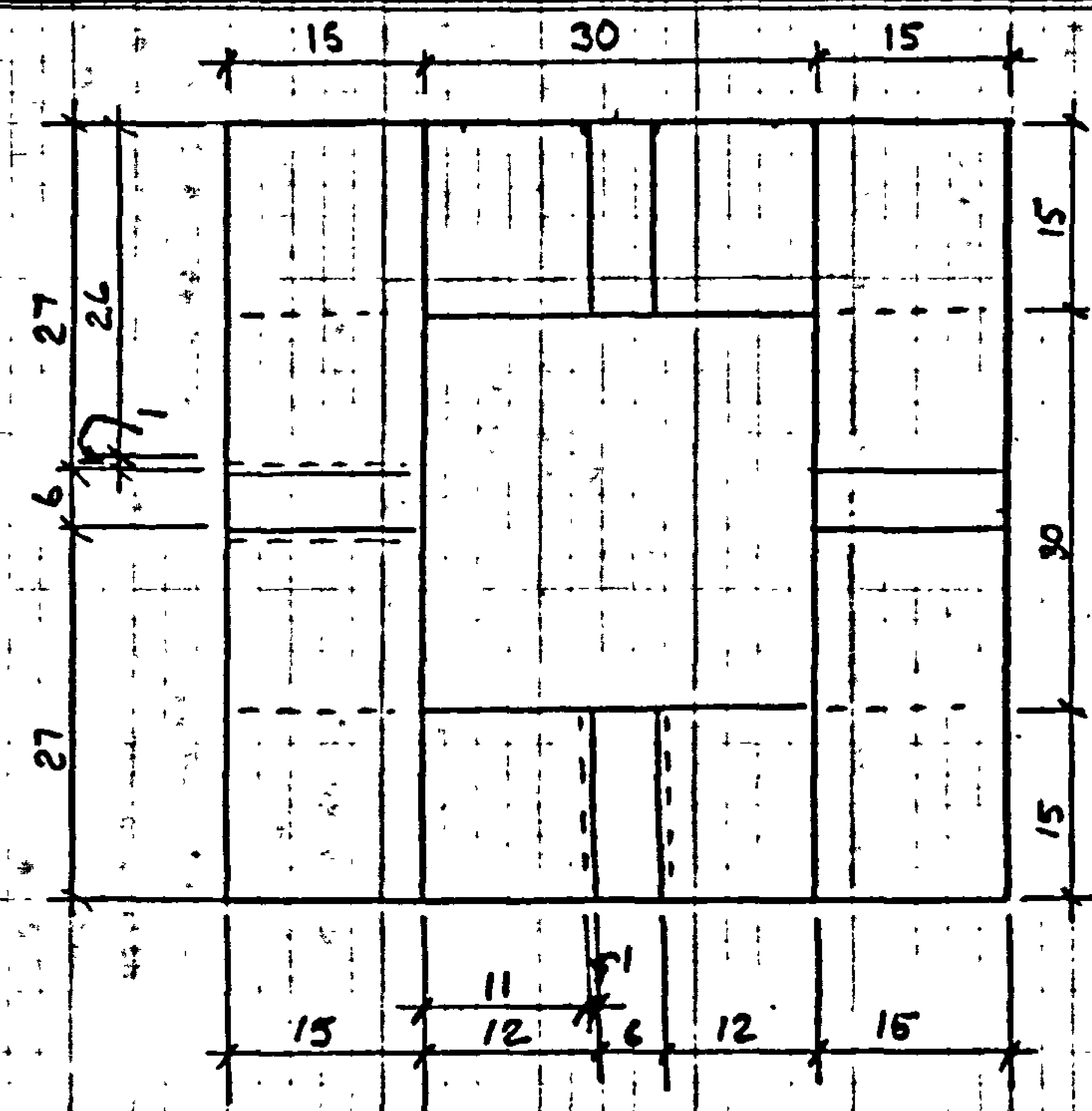
WITTKOWER (1949) p. 91/2 Platonic harmonies 1:2:3:4 = P
p. 116/117 Ludovico Fogliand of Modena = F
gave also 5:6; 4:5; 5:8; 3:5; ...
p. 116/117 Zarlino 8:9; 9:10. = Z

Harmony		1	2	3	1x1	4	2x2	5	1x4	2x4	3x3	1x5	6	4x4	7	8	2x6	1x7	2x7	1x8	2x8	3x7	
Ratio	1.00	1.111	1.125	1.20	1.234	1.25	1.265	1.33	1.39	1.41	1.44	1.48	1.50	1.56	1.60	1.67	1.69	1.78	1.80	1.85	1.87	1.92	2.0
Difference		.1111	.014	.075	.034	.016	.015	.065	.06	.02	.03	.04	.02	.04	.04	.07	.02	.09	.02	.05	.02	.05	.08
½ Difference		.055	.007	.038	.017	.008	.008	.033	.03	.01	.02	.02	.01	.02	.02	.04	.01	.05	.01	.03	.01	.03	.04
Max. error as % of smaller ratio		5½	¾	3½	1½	¾	¾	2½	2¼	¾	1½	1½	¾	1½	1¼	2½	½	2½	½	1¾	½	1½	2

Small integer ratios up to 5 as denominator between 1:1 & 1:2

1:1⅕	1:1¼	1:1⅓	1:1⅖	1:1½	1:1⅗	1:1⅔	1:1¾	1:1⅘
5:6	4:5	3:4	5:7	2:3	5:8	3:5	4:7	5:9
F	F	P	c.√2	P	F	F	☒	= 5:6 x 6:9 F x P

No 17
The Rotunda



PART III: ANALYSIS AND INTERPRETATION

(1) Theoretical technology and craft practice

(i) Summary: The development of the practical mathematical sciences during the renaissance[1]

Many of the ideas which were expressed in the fortification treatises of the later 16th. century were equally at work in other similar practical mathematical sciences from the mid 15th. century on.[2] That is, such notions as the need for method, the value of mathematics, both in utility and in its pleasurable qualities; the certainy mathematics gave, and its publicly demonstrable quality; and suitablity of the resultant knowledge for persons of a particular (elevated) station in life; together with the justificatory analogy between god as creator and governor of the world by way of mathematics, and the prince or other governor of his own estate in the earthly region.

In the field of naval architecture however, such ideas had little success in the creating of a general mathematical theory of ship design, with an accompanying record of extensive publication in the vernacular, as occured in fortification, even though such attitudes were in evidence during the 16th. century, at least from the time of Vettor Fausto on, and with the desirability of a general method expressed by a number of later writers.[3]

In the field of dialling with its roots in Vitruvius's[4] treatment of the topic, and the tradition of discussion of the astrolabe of the medieval period, there was a greater tendency than in other areas for the topic to be considered a 'learned' subject and for publication in the area to be in Latin. The notion of the subject enabling men to grasp the lord's handywork, and the mathematical regularity of the heavenly phenomena was a point of emphasis in this area.[5] But the value of the sundial as a tool of social regulation was expressed relatively early by such writers as Köbel with his hand and stick dial.[6]

In perspective Alberti in mid 15th. century expressed the basic attitude that the foundation of true representation was to be found in mathematics, and the notion that in such case one acted in some way analogously to god. While later during that same century Piero della Francesca expressed the same attitude by claiming that painting was nothing if not the demonstrating[7] of areas and bodies in accord with the assumption of the single eye point.[8] Later the 'scientific' nature of the technique was supported by treatises dealing with the 'theoretical' aspect of the discipline in the tradition of medieval geometrical optics.

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1. For the more detailed survey of fortification see above, Sect. I:(ii).
2. More tentatively at first, at least in terms of expression in the type of material considered here, but gaining in force as time went on and generally appearing most strongly in in the later 16th. century as in the fortification treatises.
3. Such as Taisnier and particularly by the later English writers such as Bourne, Digges and Waymouth with the last in manuscript only.
4. Bk. IX.
5. As in Bonet de Lates.
6. As in Witekind and Clavius for example.
7. There was a certain ambiguity here between demonstrating as "showing" and demonstrating by way of a Euclidian proof.
8. Espressed by Leonardo also.

During the 16th. century, in surveying (of smaller areas) a number of English writers published works expressing an attitude to that craft which emphasised a wide range of detailed knowledge as necessary to its practice.[1] But the emphasis on the mathematical basis of the art and the elaboration of such techniques and accompanying gadgets was emphasised by many works from the time of Alberti on. The necessity for which was expressed for example by Juan da Ortega when he stated that with such human life would be in no little confusion.[2]

The rise of mathematical navigation based on astronomical position fixing which grew out of activities of exploration in the later 15th. century in the Iberian peninsula; the interest in Ptolemaic geography and mathematical charting; and the mathematical description of the earth in geography as a sub-section of cosmography of a similar nature, all tended to fuse into a particular mathematical view of nature, during the whole period in question. While in navigation the notion of the utility of the mathematical approach tended to be to the fore, in geography the pleasurable qualities of the discipline were more frequently considered important, as well as the utility of the discipline at the level of political and military action. The associated field of mathematical cosmography of course tended to be more a learned discipline with more frequent publication in Latin and a greater Platonic emphasis on occasion, particularly in association with the idea of reaching an understanding of the 'great machine of the world' which was the result of god's handywork.[3]

In ballistics, while during the 16th. century Tartaglia's geometrical analysis remained a standard work with some minor development, relatively few published works considered the problems of this area, the topic of practical gunnery providing a not unsuccessful competing area of publication, although there is evidence that such an approach to ballistics through mathematics was being cultivated to some extent.[4]

In general architecture, while a mathematical aspect of the true method in design was emphasised from Alberti on, the primary focus was the

1. Fitzherbert and Leigh for example.
2. See above p. 139 ; also Feliciano above p. 140 ; and Peveronne, p. 142 who suggested that law suits would ever arise without such a mathematical base. The publishing of many sections on practical geometry in Italy in works which also gave elementary instruction in arithmetic for those in trade needing it clearly helped to emphasise this kind of mercantilistic view.
3. This is true also to some extent with dialling.
4. It is not easy to be clear why geometrical ballistics did not create a greater interest with the publication of many works, as happend in other areas of the mathematical sciences during the period. Probably an number of reinforcing factors were at work. Practical gunnery because of its complications in terms of variability of instruments and materials was probably in itself very intractable in terms of being subsumed under any general mathematical theory, and hence remained very much a craft practise of relatively low status. (Errard at the end of the 16th century found it necessary to define two shots as having the same range when the piece shot powder and situation were the same.) Equally the understanding of motion was a very esoteric and learned discipline of the period and this probably made the more practical interpreters a little wary of getting involved with the complexeties of such a problem. Again the sort of mathematical sophistication needed, evidenced by Digges, for example, probably put more practical workers off attempts in this area. Gunners as for example Busca seem to have more easily drifted into the relatively simple mathematics of fortification rather than to have to tried to elaborate the mathematics of motion. The need for a good predictive theory was equally proably fairly low. The piece could be proved easily enough for different elevations, and hence it was the mathematics of surveying that was needed to determine the distance to inaccesible places, and this was emphasised by gunners. Further the Euclidean epistemological model at work in so many areas during the period does not seem to have been sufficiently powerful to handle motion in this area in any simple and direct way. The desire for a few simple 'self-evident' truths about projectile behaviour which would allow the geometry of the trajectory to be directly produced, seems to have almost entirely precluded the treating of motion in terms of the two variables of time and position

elucidation of the orders and the proportions to be found in them, rather than any demonstrable approach from general principles as developed in the specialized branch of military architecture.

In all these disciplines the utility of the mathematical approach was emphasised again and again; nearly always matched by an emphasis on the nobility or dignity of the particular science in question, although sometimes alternatively when not merely additionally, by an emphasis on the nobility and dignity of the practioner in that science, with a tendency to ignore any distinction between contemplative and practical knowledge in such 'sciences', aiding the process. This whole implication that the social status of the practitioner or reader of whatever art was under discussion, was of prime importance, ran through the whole of this type of literature in the practical mathematical sciences during the period, either explicitly or implicitly, but most often explicity. The most extreme expression of this attitude was evidenced perhaps by one of the earliest treatises considered here, Alberti's on architecture, where the dignity of the architect was taken to determine the particular range of problems which were conceived to be the proper range of the subject.[1]

III: (1): (ii): Theoretical technology in contrast to craft practice

The cluster of ideas that appeared so frequently in treatises in the practical mathematical sciences during the renaissance, in one combination or another, as seen in the fortification treatise of the later 16th. century and in other like areas as noted briefly above in summary, suggests a particular attitude to practical problems and the cultivation of a particular kind of approach in this field. Fundamentally, an attitude which emphasised theory as central to the cultivation of any art in proper fashon, in contrast to the effectiveness of any mere (mechanical) practice.

Further, the example of pacific ocean navigation, the views of some of the English treatise writers on surveying, such as Fitzherbert and Leigh, the case of naval architecture and shipbuilding as those practices obstinately remained in the face of attempts to provide a theoretical approach, the example of some of the German writers on fortification such as Reinhard, all suggest a strongly contrasting attitude to technology. An attitude which tends to focus primarily on the practice of the art as the source of understanding of the practical problems involved.[2]

Thus two contrasting types of technology can be conceived. The one fundamentally theoretical, while the other remains primarily dependent on craft practise. Each of these types of technology can then be characterised by a cluster of contrasting qualities.[3]

Theoretical technology involving the cultivation of a general, and as far as possible, universal method in the art, that is the use of theory; the discovery or development of theory arising from the activities of individuals who need to be only moderately familiar with the practice of of the art, on the basis of timeless principles from which results can be deduced in an activity separate from practice; this activity being essentially intellectual and the probity[4] of that intellectual activity guaranteeing to

1. See above p. 185.
2. The Roman surveyors also tend to provide a certain contrast to 16th. century attitudes. See for example DILKE (1971). The views of Ascham on the bow, as against guns, also fall more into this opposing type.
3. See Coignet also above p. 160 who in distinguishing between the "grande" navigation and the common, outlined the very distinction used here.
4. Cf. 'science e virtu'. Of course 'virtu' in the period tended to be not a great deal more than a kind of effectiveness, but there was a residual sense in the notion of effectiveness through being in some sense 'right'.

some high degree the applicabilty of these results in practice; this activity typically generating a text book tradition by which individuals could be instructed in the art to a high degree of expertise before they ever came into intimate contact with practice, or even if they never did at all. These qualities in turn giving rise to a kind of technological activity equivalent to that of the cultivation of a learned discipline, and on a par with study in the humanities, and in the cultivation of speculative knowledge, for example. An activity as a result distant from any mere mechanical practice and hence suitable to gentlemen, whether as a leisure activity for the pleasure of the kind of understanding it brought, or to enable one such to advise on problems in a practical area in an informed manner, if not to actually practise the art: which very qualities made it suitable to a gentleman's station in life. But, such an activity being relatively distant from practice, and the probity of the intellectual processes involved being the guarantee of the worth of the results achieved, that guarantee was best enhanced by the quality of public demonstrability in the theoretical results achieved.[1] By this same means definitive argument at the theoretical level was made possible among experts of a certain station of life, and without there becoming embroiled in the details and uncertainty of the physical practice of the art. The general method involved at the theoretical level then allowing discussion to take place in a rational way in an activity distant from practice, the possibilty of control of practice at a certain administrative or political distance from the actual location at which the practical activity to which the theory relates takes place, was enhanced. The publicly demonstrable results considered to ensue from such discussion were then all the more easily transmisable over a distance because of that same quality.

Theoretical technology based on mathematics as in the practical mathematical sciences of the renaissance, then forms a paradigm of a certain type of technological activity. The demonstrability, certainty and universal nature of the principles conceived to exist so preeminently in mathematics, together with the possibilty of the cultivation of this discipline simply for its own pleasure, giving just those range of qualities which appear most valuable in the theoretical technology of the renaissance.

In contrast craft technology depends on familiarity with particular problems, situations, and practices of the art, with little dependance on general theory. Knowledge in the art being dependent on the possession of a great many discrete pieces of information,[2] and additionally or alternatively the ability to generate piecemeal relatively simple results by means of simple mechanical devices.[3] The skills involved often relate to the ability to apply a large number of mutually supporting techniques, where and when necessary, which techniques themselves often relate intimately to particular aspects of the local environment and society[4] in which the art is practised,[5] rather than depending on demonstration from universal principles; and often successful past activities are taken as examples to be copied or modified. The quality of the knowledge incorporated in the traditions of the craft is guaranteed by the success of actual practice on specific projects, which

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1. Cf. Dürer.
2. See for example the Venetian shipbuilding rules and the star courses of pacific islands navigation.
3. As for example the revolving square of the medieval masons (see SHELBY (1977)) and the devices of the Venetian ship builders to produce sweet lines.
4. As for example in pacific island navigation, and the German tradition in fortification.
5. See Fitzherbert and Leigh on surveying for example.

knowledge as a result tends to be built up piecemeal and to grow out of the practice of the art alone. Acquisition of such knowledge characteristically takes place through a long personal apprenticeship in the craft by the individual.[1] As a result this knowledge may often be tacit without its possessor being able to state why a certain process works, but simply being able to demonstrate in practice that some technique does work relatively effectively. The piecemeal nature of the knowledge involved, the nature of the long process of apprenticeship by which it is normally acquired, and the tacit quality so often found in it mean that such knowledge tends to remain personal and private rather than public, dissemination to be a slowish process, and transmission over a distance difficult except by way of migration of an individual possessing the relevant knowledge. Control of such knowledge and the practices to which it is applied then must depend largely on the employment of an individual whose expertise has been proven in the past rather than on some demonstration by him in the present before he undertakes his task. The practice of the craft is then the prerogative of an artificier or mechanic who uses practices which are mechanical in the sense that they work to some extent practically but are not demonstrable in the way that for example Euclidian geometry is demonstrable. Such a practice therefore remains a base art rather than a liberal art in the vocabulary of the medieval period and the renaissance.

The cultivation of the practical mathematical sciences of the renaissance then can be seen as involving a preference for a particular cluster of interlocking values, social, political and epistemological, as against an alternative set of practices and the values inherent in them.[2]

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1. See II p. 173; 1. 24/34.

2. Lest it should seem that in such an activity as fortification, so much a part of warfare, where, one might be disposed to think, what was at issue was so much a matter of 'pure force', no such motivations as are implicit in the cultivation of theoretical technology could have possibly had influence it should be noted that at least one contemporary spoke out against what was so often conceived to be the common sense of the business of renaissance fortification, on the grounds that Italian designers were over influenced by such attitudes. LA NOUE (Basle 1587) wrote. p. 336. "ON doit donner cest loüange aux Italians qu'ils ont esté les premeirs qui ont trouué plusieurs belles manieres de fortifier, lesquelles il ont reduites en art, qui a depuis esté estimé honnorable. Mais il n'a pas este moins profitable à ceux qui s'en sont meslez. Et parauanture que ce dernier poinct ici a esté en partie occasion qu'ils ont persuadé les Princes que tãt (tant de choses) conuenoyent pour rendre vn ouurage en sa perfection, & digne d'eux. En quoy il n'ont pas esté mal-habiles; car par le moyen de la grande & longue despense l'eau est venue à leur moulin. Ie n'ignore point qu'il ne soit bien scant aux grãd Princes de faire les choses grandes, parce qu'ils ont beaucoup de moyẽs, & que les petites ne les contentent pas." One of De la Noue's major criticisms was the expense of building in stone when earth would suffice, and he continued (p. 337) "...la citadelle d'Anuers, en laquelle on peut dire qu'on n'a rien oublié de richesse, de diligence, d'inuention, & d'abondance de matiere: de sort qu'en toute la Chrestiẽté ne s'est point veu vn plus beau chef d'oeuure en la fortification. Mais si de l'autre costé on vient à considerer qu'elle a cousté à batir quatorze cens mille florins, & que si elle eust esté assaillie, parauanture n'eust elle pas resisté dauantage qu'Oudenarde ou Mastrich, que n'estoyent fortifiees que de terre, on sera curieux d'examiner ces affaires plus exactement. Et specialement les petis potentats & les petites villes doyuẽt y regarder de pres: car s'ils vouloyent mesurer leur defense à l'aulne des grands Princes, ils seroyent apauuris voire ruinez, auant qu' estre demi fortifiez ....Ce que ie ne dis pas pour faire trouuer estrange que ces grands Princes ayent tant employé en de petis chasteaux: car ils son bien de plus inutiles despenses. Mais c'est pour faire voir que s'ils vouloyent selon cest order (of the citadelles of Metz and Turin)....fortifier vne telle ville que Malines ou Orleans....il faudroit qu'ils employassent cinq millons de florins: & pour en accomoder plusiers leur conuendroit vendre le quart de leur estat, ou faire paix auecques leurs voisons pour cent ans, à fin d'y trauailler à loisir." . As well as building in earth for cheapness, at one tenth the cost La Noue suggested (p. 337,(2nd)) "...que l'expereince a fait

2. (cont.) approuuer à beaucoup de gens, c'est de detacher les bastions des courtines, mesmes les porter outre le fossè. Et ancores qu'ils ne soyent pas defendus d'artillerie d'aucunes Casemates basses, ils ne laissent de l'estre tres-bein de l'harquebusierie des courtines, qui est vn offension cõtinuelle impossible d'oster.....(also if these ravelins are taken the fortress does not fall)". La Noue continued "...l'vsage des retrenchemens qui est vn remede merueilleusement vtile: (1)..quand ils sont de bonne forme & grands, ou ils conseruent, ou ils donnent vn mois de temps, ou plus (que est vn souuerain acquest aux assiegez que l'aller peu à peu gaignant)..(p. 339) QVAND on veut attacquer vne telle place, il faut par necessité que se soit par vn rauelin, qui est vn aduertissement tres-asseuré qu'on battra apres la courtine par ce costé. Alors besonge-lon aux retrenchemens sans s'occuper ailleurs: & auecques du temps on fait vne nouuelle ville, quand il y a beaucoup de peuple & vn ingenieur entendu. Il me semble qu'vn rauelin, ou il y a soldats, doit tener vne mois par le moins, fust-ce contre le Prince de Parme, qui est le plus dextre assailleur de villes que ie sçache:...Or quand vne place de frontier arrestera autant de temps que i'ay dit vne puissante armee, elle aura tres-being fait son deuoir (car il y a peu de villes imprenables) & le Prince, qui l'aura perdu, aura ce reconfort de ce qu'ayant peu cousté à acommoder, son ennemi aura consumé beaucoup de temps, d'hommes & de deniers en l'expugnation. " With regard to the contention that reveted structures were preferable because earth ramparts tended to be washed away, La Noue insisted."....le rabillage couste peu.....(and) on fortifiera vne ville moyenne toute de terre, pour ce que coustera le reuestement d'vn bastion fait de brique ou de pierre auec ses contremines. I'approuue ceste maniere ici pour vn autre regard. C'est que les Potentats & Republiques ont meilleur moyen de pouruoir aux fortifications interieures, que doyuent acompagner les exterieures, lesquelles consistent en tout especes de prouisions necessaires qui manquent en plusieurs villes, si ce n'est en tout au moins en partie. Et s'en est perdu par ces defaute presque autãt que per faute de bastions.". Thus La Noue rejected the abstract approach to fortification in the ideal world of theory, and criticised contemporary fortification engineers for going for elaborate schemes without considering properly what reasonable cost might be employed, at least in part from motives of feathering their own nests. His approach in contrast was much more an attempt to get to grips with the problem of allocation of resources. He saw the siege of a place as very much a matter of attrition, and tried to respond to the resultant needs, so that the attacker needing to expend his resources on a frontier town would tend to be worn down. Equally cheaper structures allowed the defender to better allocate his resources so as to supply the fortress able to resist. Similar views as to the value of earth structures were expresed by Robert BARRET (1598) p. 132 ".....a number of..places fortified with earth and turf onely... in the Low countries...haue endured such gallant batteries & fierce assaults, sufficient to wearie a great Prince his power and purse, and sundry other goodly Cities in East Germanie, which I haue seene fortified in no other sort...."

III: (1): (iii): The social model and the invention model as accounts of renaissance mathematical technologies.

The strong social component in the cluster of values which comprise theoretical technology as outlined, suggest that the drive towards the cultivation of the particular kind of technology that was involved in the cultivation of the mathematical technologies of the renaissance must to a great extent be found in the motivation of individuals to cultivate a type of knowledge which was conceived to be best suited to a relatively elevated style of life; that the nobility and dignity which was conceived to be inherent in the practical mathematical sciences was influential in inducing them to cultivate theoretic technology; and that it was their preconceptions on this level about the need for method and the like, which pushed them towards the cultivation of the practical mathematical sciences.

Undoubtedly such forces were at work, and can be detected particularly in the biographies of the fortification treatise writers of the later 16th. century. Mora explicitly in his published works was much concerned with the nobility of arms as against literature and to some extent made use of the theoretical nature of such disciplines as fortification to support the status of arms.[1] On the other hand Giacomo Lanteri, the author of the most theoretical treatise in the field, seems to have been able to gain preferment through the publication of that work, and even offended against the strict canons of Euclidian geometry in order to produce the most general method. Tartaglia, rather differently, in his contributions in many of the practical mathematical sciences, in the way that he was involved to such a great extent in the publication of his own works, seems to have attempted to make a career for himself as a writer of texts in these areas. Girolamo Cataneo as a court expert teaching in fortification and writing on other mathematical topics appears much as a court mathematician gaining a career by virtue of the theoretical component conceived to be significant in areas of practical knowledge. It seems probable that Zanchi was assisted in gaining employment in fortificat- practice through his publishing of his treatise. Theti seems to have prepared his manuscript treatise on fortification in the hope of gaining preferment at the court of the emperor. Alghisi's elaborate treatise can hardly be taken as anything more than an attempt to impress the public with his skill at a particular kind of theoretical level. Maggi's edition of his own and Castriotto's writings appears as part of the process by which a literary figure shifted his career towards military matters. Pasino's work was very much concerned with the dignity of the military architect and his profession, and must be taken to a great extent as a justification of his own personal position. Jacopo Aconcio may have written on fortification at least in part in order to demonstrate 'method'. A letter written by Lorini indicates his distress at the idea that his treatise would not be published and that his labour would then in some sense be lost. The rate at which Belluzzi became a renowned expert in fortification indicates the extent to which long practice in the profession was not considered the necessary ground of expertise. Simon Stevin's treatises on fortification to a great extent seem to have been an effort by the author to demonstrate his mathematical skill in but one of the mathematical sciences on which he worked.[2]

1. See Biog. This tendency however was not very pronounced in Mora, although undoubtedly it was present, and he made no great play about the value and status of mathematics -- he seems to have been too much the practical soldier himself to have given any too great emphasis on this.
2. See individual Biogs.

In general, it is difficult to conceive that the theoretical approach to technology, as found so often in the practical mathematical sciences of the renaissance, was not something that facilitated such events and made such careers possible in many cases; and that therefore the cultivation of the theoretical approach by such writers in fortification, as elsewhere, was not unaffected by their own personal interests.

Further, considering these writers as a group it is clear that, very generally, they all emphasised the value of the theoretical approach with only an occasional lone voice of an individual such as Gian Tommaso Scala being raised against such theorising. Yet the relative emphasis given to theory as against practice varied a good deal from figure to figure within the group. Varied in a rather striking way such that the particular emphasis given by any figure tended to correlate fairly highly with the career pattern of that particular individual. Dürer for example, while he pushed towards a theoretical approach to fortification, presumably much under the influence of his Italian visits, in effect outlined an approach which bore signs of a piecemeal craft approach in accord with his early craft training. Equally Specklin while he accepted the pointed bastion system of his time in his approach can be detected at points to show evidence of his early craft background. On the other hand such figures as Lanteri and Tartaglia, writing from a position very distant from practice, manifested a highly theoretical approach. Again the views of Castriotto and Maggi in their treatise published by Maggi were by no means precisely the same on this dimension, and it was the more practised Castriotto who denied the need to universally use the pointed bastion system, while the more learned Maggi more distant from practice, insisted on the need to universally apply the theory of his time. Further, such figures as Busca and Gentilini with a background in gunnery and the craft practice therein involved, while to some extent they used the theoretical approach to fortification to support a particular view of their own skills (and hence station), tended not to take a strong view on the use of theory with a denial of the contribution of practice. Alghisi in contrast, employed more in architecture than fortification, took a highly theoretic stance. Theti in a career in which he gained much employment in fortification took a rather middle view, and Lorini was much the same.[1]

Thus not only does the cultivation of a theoretical approach by the fortification treatise writers of the later 16th. century appear in their interests in terms of career patterns, but there was also a fairly high degree of correlation between the extent to which they emphasised theory (as against practice) and their individual career patterns.[2]

There were at least two ways in which the writing and publishing of theoretical treatise in the practical mathematical sciences can be conceived to have benefited their authors. That activity itself might have led to financial gain by way of direct remuneration for the sale of their writings. Tartaglia it appears may well have been hoping for gain in this way. However, the signs are that the business of publication was not something from which an author could realistically hope to gain any substantial benefit, especially to the extent of providing an independent source of income sufficient to

1. See individual Biogs.
2. There tends to be a certain amount of circularity in the discussion here in that career structures of individuals and the views they expressed were discussed in the biographical sections very much as a whole. But there was a good deal of consistency between these dimensions in many figures, so the process seems legitimate.

to support him at a reasonable standard of life.[1] The achievement of reputation through the composition and publication of a theoretical treatise, which in turn might lead to patronage, preferment or pupils, was therefore probably the most important mechanism by which treatise writers could hope to gain benefit through their work at the theoretical level.[2] Undoubtedly the production of multiple copies by means of the printing press during the 16th. century must have immensely facilitated the spread of an author's reputation to his benefit in this way.

Thus the cultivation of public knowledge in accord with the principles of theoretical technology, and the cultivation of a general method which made possible the writing of a comprehensive treatise without, as Zanchi put it "becoming too tedious", together with the dissemination of the treatise in relatively many copies by means of the printing press, taken together formed a package of ideas and events which undoubtedly were in the interests of the treatise writers to promulgate in order to gain personal benefit in a particular way. In addition, that this theoretical activity was conceived to generate a product suitable to 'gentle spirits' must have facilitated the creation of an audience to buy, or at least to read, those same products, hence making the whole process possible.

In short, there was a wide range of conditions, social, and social cum economic, that was conducive to the late 15th century and 16th. century treatise writers embracing just those ideas enshrined in the notion of theoretical technology and the cultivation of the practical mathematial sciences.

It seems reasonable then to assume that to a great extent the acceptance among treatise writers of the idea of the great worth and value of theoretical technology and particularly the practical mathematical sciences during the renaissance was a result of this kind of social force.

But there are good grounds for considering that such a social model at the very least does not provide any complete account of the process by which the practical mathematical sciences and theoretical technology came to be so widely cultivated during the renaissance.

In the first place the generation of a body of theory in any particular discipline within the practical mathematical sciences of the renaissance was clearly not simply a product of the desire of particular individuals for a certain kind of knowledge relevant to a particular kind of practical problem. This is no where more clear than in the case of naval architecture, in which discipline there were attempts to cultivate a general mathematical theory of design, but which by and large had relatively little success or effect. The very intractability of the problem in the face of the type of relatively simple mathematical solutions which were typical of what

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1. Tartaglia is again the main source here. The number of copies of his works he held at his death suggest that a single issue might run to figures only in the low hundreds. The 500 copies of the Ptolemy edition ordered in the late 15th. century supports this kind of figure. It is difficult to think that such short runs would have brought any substantial income. The apparent poverty of Tartaglia at his death despite his having published quite a large number of works in more than one edition, and his relative fame, supports this. Nevertheless although such an income may not have been achievable in this way in practice during the period, it is not impossible that -- like the modern novelist perhaps -- the 16th. century treatise writer may have been influenced by such hopes in believing that he would some day write 'the big one'. The huge benefits that the treatsie writers so frequently mentioned as going to ensue from their efforts, suggests that this may have been the case.
2. Cf. Locatelli II p. 89; l. 10/18.

was desired in such a discipline during the period, was, it must be considered, a major factor mitigating against the creation of any full mathematical theory of design in this area on the lines of other disciplines of the time[1]. Equally it seems probable that development of an extensive literature on mathematical ballistics was discouraged by the intractability of the problem involved.[2] Again while astro-mathematical navigation was, by and large, a successful discipline during the 16th. century which built up a body of theoretical knowledge, the problem of longitude remained intractable for a long period.

Thus the application of the ideas of theoretical technology to particular fields as occured during the renaissance can not be conceived as being a response simply to the desires of individuals for such a type of knowledge. Any such process must also be seen to bave been determined by the susceptability of the particular subject in question to that type of approach. Where a field was very intractable as in shipbuilding and extensive body of theoretical knowledge in the discipline did not appear. Where it was somewhat less intractable, as in mathematical ballistics, presumably, a certain amount of work was done but no extensive theoretical literature appeared. Only where the subject matter of a particular discipline was relatively easily handled by way of the preferred approach, as in fortification, or where a particular intractability of the subject in question was conceived to be out-weighed by other advantages, as in astro-mathematical navigation, and where the difficult area was conceived to be potentially subject to solution, did a successful body of theory emerge.

Thus the very nature of the problems of any particular field must be conceived to have been a determinant of whether that particular discipline developed along the lines of theoretical technology, however great may have been the social pressures towards the creation of such knowledge. Of course, taken at its most extreme such a view becomes that of technological determinism, that is the view that results in technology are determined primarily by the particular (most often 'physical') problems of any field, or by a particular central problem of the field in question.

Associated with such a view one may often expect to find the need model of technology -- that is, the idea that necessity is the mother of invention, as the saying goes, which was commonly quoted in our period. For, if technological solutions are determined primarily by the problems to which they provide an answer, still, solutions will not be required to all the possible problems that might occur, and so need determines which problems are to be solved in accord with the nature of the problem in question.

And clearly, in certain ways the cultivation of certain of the practical mathematical sciences of the renaissance must be conceived as a response, at least in part, to particular needs. There are good grounds for conceiving that astro-mathematical navigation was a response to the needs of overseas voyages of discovery if only, in view of the time and location of its early development. Equally one can detect a fairly clear need for mathematical surveying in range finding of inaccessable places to assist gunnery.[3]

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1. See for example Stevin's work on overturning moments. The scale effect and the need for different types of ships for different purposes, meant that it would bave been pretty well impossible to arrive at any simple set of lines, or a general method for producing them, as seems to have been desired.
2. See above p. 213, n. 4. One has only to look at the complexity of modern mathematical ballistics to see how difficult any practically useful solutions are to achieve, purely from the nature of the mathematics involved. Again the way that at different velocities air resistance is in accord with different functions, which functions have thier own individual ranges, makes mathematical ballisticsa a complex problem.
3. Within the interaction of the practical mathematical sciences of the renaissance one can also see this at work, particularly in the 'need' for perspective in architecture for example.

Mercantilistic needs were also suggested during the period as giving rise to the need for surveying, as were social needs noted as requiring dialling, and military needs, geography.

Taken together then, technological determinism and the need model can then be conceived to comprise the invention model of technological change. The need providing the stimulus and the nature of the problem determining the outcome in whatever is invented to cater to that need. This invention model then provides a contrast to the social model of technological activity, and yet is one which the detail developments of the practical mathematical sciences of the period provide good reason to support.

As is so often the case when opposing view points are both supported by the evidence to some extent or other, the nature of the process of technological change during the renaissance as evidenced by the cultivation of the practical mathematical sciences of the period, must in fact be conceived as some combination of the social and the invention models (and within the invention model as some combination of technological determinism and need).

III: (2): The earlier development of theory in renaissance fortification
(i): The roots of the ideas of the later treatise writers

Having outlined a particular set of ideas at work in the fortification treatise of the later 16th. century and having traced that same cluster of ideas at work in many other areas from mid 15th. century on; now, having outlined the sorts of processes which seem to have been active to some extent or another in the cultivation of the practical mathematical sciences of the period in general, earlier events in the growth of renaissance fortification must be examined against this background.

In mid 15th. century Alberti was concerned with the need for a learned method in general architecture, although in treating fortification as part of that subject he was content to consider that aspect of his art as very much a problem of adaption to circumstances and only gave a very minor role to the needs of defensive fire.[1] Again Filarete a little later organised his ideal city around a simple geometric form but again gave only minor emphasis to the need to provide for defending guns. Luca Pacioli at the end of the century insisted on the need for a mathematical approach to warfare and fortification.

The working through and progress of such attitudes in fortification can however be discerned to a much greater extent in the writings of Francesco di Giorgio.[2]

The nature of the ideas about the requirments of the architect prevalent at the court of Urbino where Francesco worked under and with Federico de Montefeltre, and where so much of his thought on fortification appears to have developed, can be discerned in the patent given by Federico to Luciano Laurana in 1468, in which Federico explained:

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1. Alberti did however briefly allude to a very significant idea when he suggested walls should be battered to reduce the impact of projectiles. Bk. V, Cap. IV "The outward Wall, or Incloaure of the Fortress should be built very strong...with a good Slope on the Outside...(for various reasons and) that Things cast at the Wall by the military Engines may not strike it full, but be thrown off aslant." ((1955) p. 87). "Arcis podium ponetur solidum...linea extrinsecus obliqua...tormentis immissa non usq aritent: sed ex obliquo dissilant". ((1485) Sg. Kiiia).
2. According to WELLER (1943) p. 1, Francesco never signed himself Martini, and this part of his name rarely occured in the records.

"Quelli uomini noi guidicamo dover esser ornati e commendati, li quali si trouarano esser ornati d'ingegno e di virtù e maxime di quelle virtù che sempre sono state in prezzo apresso li antique e moderni, com'è la virtù dell'artitettura fundata in l'arte dell'arismetrica e geometrica, che sono delle setti arti liberali, e delle principale, perché sono in primo gradu certitudinis, e è arte di gran scienze e di grande ingegno, e da noi molto estimata e apprezzata. E avendo noi cercato per tutto, e in Toscana massime, dove è la fontane dalli architettori, e non avendo trovato uomo che sia veramente intendente e bē perito in tal misteiro; ultimamente, avendo per fama prima inteso et poi per esperienze veduto et conosciuto quanto l' egregio uomo Maestro Luziano, ostensore di questa, sia dotta e instrutto in quest'arte.....Noi havendo elletto e deputato il detto maestero Luziano per Ingegnero et Capo (of the works on the Ducal palace.)...."[1,2]

Francesco di Giorgio however in an early draft of his treatise of c. 1480,[3] when he discussed the nature of architecture gave very much the Vitruvian description of the architect ornamented by very many disciplines,[4] rather than any strong mathematical view, although that same collation included a discussion on surveying.[5] Yet the draft as a whole by beginning with the topic

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1. Quoted in BRUSCHI (1978) p. 19/21. Lucian Laurana, born 1420? originally from Dalmatia is first documented at Naples in 1451. In 1465 he was at the court of Mantova while Alberti was active there, perhaps concerned with a project for a castle on the Po, which Filarete described, and gave advice at Pesaro. In 1568 he was invited to Urbino. In 1472 he was recorded as "maestro de artillerie" at Naples. During 1476 to 1479 he was at Pesaro working on the Rocca there -- a heavy stone structure, square with round towers at the corners. According to DIC ENCY URB "Determinante l'influsso de Piero della Francesca nel modo di pensare i volumi architetonici semplificati al massimo, nel valori geometrici elementari e nello studio di portiti luminosi." See PAPINI (1946) p. 7/10 & COLASANTI (1922).
2. The drawings of Francesco in the B.M. Dept. of Prints and Drawings (Machinarum liber 197.b.21 formerly Dept. of mss. Harlean 3281) dedicated to Federico which largely comprised machine drawings in the tradition of Taccola (a copye of Taccola's De Ingenis, attributed to Francesco (of c. 1460/70) is noted by PRAGER (1972) p. 191) may have been presented as part of Francesco's search for patronage. See POUNCEY & POPHAM (1950) for the tone of the dedication. This work contains also a number of schematic fortification plans, quite a number of a circular form with round towers on the circle. The circular form as the basis of a fortification plan being rejected later by Francesco indicate these designs to be an early stage in his fortification thought. The dedication being addressed to the Duke of Urbino, it is after 1474 when he received that title and before 1582 the date of his death.
3. Transcriptions of different drafts are given in MARTINI (1967) ed. Maltese, who in his introduction discussed thouroughly the question of the relationships between the main extant manuscripts of Francesco. The 'early' draft as it is distinguished here being that comprised basically by the Codice Torinese Saluzziano 148, as Maltese gives it and dated 1478/81 by that author. (p. xxx.) The 'later' draft comprising Magliabechiano II. I.141 and Codice Senese S.IV.4, together as Maltese gives them, the later having been begun a little before 1489 and the former having been finished a little after 1492. (P. xxx & lxii). More recent commentators have questioned these dates for various reasons, see for example (BETTS (1977), FIORE (1978) discussed the whole matter again and came to the conclusion that Maltese's datings remain the most satisfactory. They are thus accepted here, although not any too precisely, but as representing the general pattern and periods of the development of Francesco's writings.
4. In the section headed by Maltese "Templi" op. cit. p 36/7. There Francesco stated: "In prima è da sapere due cose grandemente necessarie: fabrica e ratiocinazio...E siccome dice Vitruvio all'architetto ingegno e dottrina a lui bisogna, perché lo ingegno senza dottrina o la dottrina senza ingegno l'artefice perfetto far non può. E pertanto bisogna che in più facoltà isperto sia." Francesco then went on to mention 'design', geometry, arithmetic, philosophy, music, physic, civil law and astrology.
5. The early draft tended to be a collection of separate discussion although it was not altogether so. Maltese gave the following headings in this order. Fortezze; Ponti di Fortezze e altre tipi di difese; Città; Opere de idraulica; Templi; Colonne; Architettura antica e moderne e pratiche costruttive; Geometria e modi di misurare distanze altezze e prefundità; Levi di ruote e Mulini; Sorgenti e modi di elevare e condurre l'acqua; Modi per elevare e condurre acqua, conche navigabli, argani giru e verricelli; Arti militare e macchine bellice antiche e moderno; Conventi; Congegni e consigli pratici diverse; Capane, campanili, guardini; Dal 'Libro dei fuochi' di Marco Greco. The surveying section (p. 117/140) had a good deal about the measuring of heights of towers in the traditional medieval fashion. It included a very few brief remarks with diagrams on perspective.

of fortification to some extent emphasised the importance of that subject, but only as one of many topics relevant to architecture in the Vitruvian tradition. The basic organising device Francesco di Giorgio used in this early draft in fortification was an anthropomorphic account of the city. In the first passage of his first discussion he stated

> Siccome dice Vitruvio tutta l'arte e la ragione tratta essere dal corpo umano ben composto e proporzionato....Adunque la rocca de'essere principale membro del corpo della città, siccome el capo è principal membro di tutte el corpo.[1]

The use of the anthropomorphic model in general architcture then gave Francesco di Giorgio a general 'method' to some extent, which he saw as underlying both civil and military architecture.[2]

With regard to the details of fortification, Francesco di Giorgio wrote in the earlier version:

> Parmi che le fortezze colle loro circuizioni in tal modo adattate sieno che dalle macchine delle bombarde o scalamenti o altri stromenti bellici difendere si possino[3].....(and) che le mura della fortezza, città e castella amprie e grosse da fare sieno che alle macchine delle bombarde resistare possino....[4]

and a little further on he explained:

> Io per me, quanto considerare ho potuto in nelle difese delle bombarde, assai difficil mi pare da esse potersi diffendare. Ma de'più salutiferi modi che veder ci possa, sia da fare grosse ed amprie mura con alte e dependenti scarpe, tonde, acute, facciate, e smisurati torroni....E certissimo se le mura non sono di smisurata grossezza e congrua froma difficilmente ostare possano. Le quali mura in questo modo da fare penso, che quando la formazione della rocca overo torre ordenata sia, di fare un muro de pietre tufigne per coperta da la banda di fuore, overo mattoni di grossezza di due piei in tre. E simile dal canto di drento. E tutto el vano che è infra l'uno e l'altro muro di minutissima iara e calcina ben confetta riempita, imperoché detto muro e composizione, fatta la presa, marvigliosamente resiste.[5]

In contrast in his later draft of c. 1590[6] Francesco in a preliminary section began with a strong expression of the mathematical ideology thus:

> Scrive Eupompo di Macedonia, egregio matematico, nissuna arte perfettamente nelli omini essere senza aritmetica e geometria. Similmente non solo da lui ma da molti altri eccellenti non meno necessaria era stimata l'arte del disegno e qualunque operativa scienza che le prenominate. Questo

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1. MARTINI (1967) p. 3.
2. From the earlier draft, op. cit. p 68. "I diligenti e curiosi architettori hanno di ciascuna cosa la misura cavato da edificare come che dal corpo umano el dito, palmo, braccio e pie." Francesco continued by discussing desirable numbers and ratios. On this topic see MILLON (1958) who stated "Francesco, like Procrustes, stretches or amputates..the human figure to conform to his abstractly conceived bed of modules." Which same author further posed the question about others of Francesco's time wondering whether "other achitects also pay lip service to an intellectual doctrine while in practice relying on visual judgments to make final decisions."
3. p. 3, op. cit.
4. p. 4. He continued "e tutte le mura basse non per sé ma el luogho e fossi, le torri colle difese per fianco e da basso in luogho che dalle macchine offese non sieno, con rivellini..."
5. p. 13/14. the total wall to be 18, or 20 to 24 feet thick and more. Vitruvius had discussed such doubled walls. Bk.I, Cap.5.
6. This later draft is a more united treatise. In his preamble Francesco explained the work was divided into 7 parts -- "In lo primo si determinarà di alcune proprieta generali a ciascuno delli altri 6, seguendo la sentenzia di Aristotle nella sua Fisica dove insegna che dalle cose universali in le singulari nelle scienzie bisogna procedere." (P. 299) The 2nd. was on "Parti delle case e Palazzi. Modi per Trovare l'Acqua." 3rd. "Castelli e citta." 4th. "I templi." 5th. Forme di Rocche e Fortezze." 6th. "Parti e forme di porti. 7th Macchine per mouvere pesi e trarre acqu. Pietrini e mulini." as Maltese gives them.

> medesmo giudicando Apelle e Melanzio esperti matematici, solerti pittori ....constiturono che li padri di famiglia a li figlioli loro e posteri fessero imparare l'arte antigrafica. E conosciuto dopo breve tempo la utilità sua e la nobilità di molte scienze delle quali presuppone la notizia, fu in modo celebrate che, si come ne scrive Plinio, nel primo grado de le liberali era reputata, ne permettevano che a servi fusse insegnata. E benché ai di nostri sia reputa vile et inferiore a molte arti mecaniche, niento de meno chi considerasse quanto sia utile e e necessaria in ogni opera umana, sì nella invenzione, sì in possere esplicare li concetti,[1] sì nell'operare, sì all'arte militare -- dall' altra parte geometria, aritmetica, prospettiva a questa essere affine -- facilmente guidicaria essa essere uno mezo necessario in ogni cognizione et opera dell cose fattibili, con dritte ragione.[2,3,4]

In this later version, while Francesco continued to make use of the anthropomorphic analogy in his description of the form of the city,[5] this device tended to be of less significance[6] in the face of an increased emphasis on the importance of the human intellect in constructing defensive protection. For example at the beginning of his third section (Castelli e citta) Francesco wrote:

> La natura universale....a tutte le cose viventi con cognizione ha dato tutto quello che ad esse è necessario...essendo l'omo più perfetto corpo corruttibile et animale più nobile di tutti li altri, per l'ingegno del quale et instrumenti suoi infinite operazioni possano seguire, quello volse creare innudo, senza vestimenti & senza armi difensive, delle quali cose tutti li altri animali perfetti sono dotati, solo per questa allegata ragione, perché esso omo ha in sé l'intelleto e la ragione e la mano, la quale è chiamata organo delli organi et instrumento di tutti le altri instrumenti, per li quali principi ogni spezie de vestimenti a di armi et altri sue comodità può fare et ordinatamente componere.[7]

At the beginning of his fifth section (Forme di Rocche e Fortezze) Francesco expressed similar sentiments thus:

> La umana natura, a similtudine et immagine del fattore suo produtta, come delle altri corpores (creature) è più nobile e perfetta sapienzia sopra quelle constituta, in terra ha ottenuto el principato e domino temporale. E dove, come testifica Aristotle nella Metafisica sua, vive con arte e ragione, per questo differente da tutti li altri animali....Questa natura dell'omo ragionevole et intellettuale, non solo conosce sé essere sopra alle altre di ragione privati, ma eziandio l'uno omo all'altro concilia, et alla società e conversazione inclina, per orazioni esplicando li soi mentali concetti.[8]

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1. Cf. above in the later 16th century.
2. The underlined words are additions to the later draft of the later version of Francesco's writings. This convention is used throughout below, omissions in the later draft are similarly indicated with brackets, but not all of these as given by Maltese are included, only the more significant ones.
3. p. 293/4
4. c.1538 Francesco da Hollando put the same sentiment almost exactly in one his fourth dialogue. See below p.242, n.3. But more correctly mentioned Pamphilius and not Eupompo his master. Maltese remarked that Francesco di Giorgio distorted Pliny here in the general practise of the renaissance in attempting to raise the status of 'design'.
5. p. 361. "l'omo, chiamato piccolo mondo" with a marginal note "A che cosa la cita son assimilgliata.
6. The Magliabechiano m.s. shows 'ideal' plans for cities like the earlier Codice Torinese Saluzziano but does not contain the diagram of a man's body overlying a city as does the earlier version.
7. p. 360. This section appears only in the Magliabechiano m.s. and not in Codice Senese, which, within the later version of Francesco's writings, is probably in turn a late addition. To some extent Francesco di Giorgio seems to be echoing Alberti on the relation between architect and artisan.
8. p. 414. Francesco di Giorgio continued "E certamente non senza efficaci ragioni conducati (con decente in the earlier version) effetti et ottimi fine a questa obbedienzia molti in alcuni altre induce."

Francesco then continued that, as Aristotle explained, every man wishes to dominate and not to be dominated so that

> ....fu necessario escogitare alcune difensioni, per le quali la minore potenzia alla maggiore potesse resistere. E questa difesa non può esser se non (per) fortezza di loci naturali overo artificiale con diverse forme di muri....[1]

Against the background of these kinds of ideas Francesco, when he came to expound the needs in fortification, no longer wrote of walls being made sufficiently massive and great to be able to resist bombards, or of walls that "resist marvellously" as in his earlier draft, but instead insisted:

> .....li moderni, ultimamenti hanno trovato uno instrumento di tanta violenzia, che contro a quello non vale gagliardia, non armi, non scudi, non fortezze di muri, perochè con quello ogni grossa torre in piccolo tempo è necessari si consumi.[2]

and

> Per resistenzia della quale (i.e. artillery), insino al presente tempo, al mio iudizio (per esperienzia confirmato) non si è trovato edificio (o sua forma alcuna) che in breve tempo (non sia stato o) non potesse essere da quella superato.[3]

He further explained,

> Onde considerati li edifici per fortezze fabbricati in Italia massimamente si può dire con verità che el non sia rocca alcuna o fortezza che per via di bombarde, gittando le mura a terra, overo almeno le offese (e diffese), non si possi espugnare e debellare...[4]

and that,

> Sono stati alcuni che per defendere le mura dalla potenzia della bombarda e per più offendere li inimici, hanno fatte le mura grosse e con più torroni con difese et offese per fianco. Le quali più per grossezza che per ingegnoso[5] remedio fanno alquanto maggiore resistenzia che le altre antiche, niente dimeno per spazio di tempo infine sono superate.[4]

Further, that compared to ancient instruments of attack

> ...la bombarda (molto piu facilmente, e con più brevita), el medesmo fine conseguire...[6]

Francesco explained his intentions in this section, thus:

> Dovendo adunque dare notizia in questo trattato delle forme che si recercano alle fortezze, prima è da vedere alcune parti generali, e dipoi discendere alle particulari, per la ragione preallegato.[7]

and that guns overcoming, or weakening, all structures:

> ...non proibendo però la fortezza del sito naturali....dove la natura più presto che l'arte si puo laudare. Onde fa bisogno, per salute e conservazione delli (stati e) pontentati, più modi e diverse figure demonstrare (diverse dall altre ingeniose), mediate le quali si die modo e freno a tante violenzia...[4,8]

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1. p. 417.
2. p. 417/18.
3. p. 424. The omission of "per esperienze confirmato" in the later version could be significant.
4. p. 428. These three passages are in a different order in the original.
5. Cf. Tartaglia. The significance Francesco attached to "ingegno" and its high value suggests quite strongly that he intended just the kind of ideas that were later so often and strongly expressed with the structures made resistant "per grossezza" being denigrated. But it should be noted that the idea is not made in a fully explicit way.
6. p. 422/3 7. p. 429.
8. This again seems to prefigure the sentiments expressed by Tartagli dividing structures into those strong by nature and by ingenuity which last (in terms of form) were of most interest. But undoubtedly this has to be read into the actual expression to a great extent.

which end

> Colui adonque che a questa offensione trovasse la difensione, piu presto doveria esser chiamato divino che umano ingegno.[1]

and with regard to the desired solutions

> ....li instrumenti e mezze cagioni non sono né utili né necessarie, se non per conseguire l'ultimo fine overo effetto (dell'agenti): adunque, quanto di minore (momento e) difficultà e maggiore simplicatà sarà quello che ci conduce desiderato fine, tanto più potente si debba esistimare, perochè per quello più facile e breve si può tutto, che per li altri più (e più) difficili si poteva...(lequali, insegnate, facilmente da ciascuno di mediocre intelletto sono intese.....)[2]

Thus Francesco di Giorgio in the later version of his writings expressed a good many of those ideas which in the published treatise of the later 16th. century were characteristically averted to in justification of and as basis for the theory of fortification as it was then understood: the value of mathematics in practical sciences, the nobility and utility of such sciences which were to be conceived rather liberal arts than base mechanical practices, and the value of mathematics in enabling ones concepts to be expressed and to give a true method; the significance of the activities of the intellect, which particularly human attribute made man more like god than animals, and which allowed knowledge to be publicly expounded, the distinction between places strong by nature or by skill; the idea that the mere multiplication of defences or masses did not indicate much skill; the need for general rules and a simple method; and the need to concentrate on the form of the fortress, albeit this tended to be more implicit in Francesco's exposition and was not argued for in a direct way from these considerations as it tended to be later, by Tartaglia, for example. All these ideas being expressed in a strong form in his later draft,[3] and not appearing or being less emphatic in his earlier version, while at the same time in the later version Francesco insisted on the inability of structures to resist bombards, while earlier he had been more concerned with constructions to resist that weaponry.

There thus seems to have been a quite radical shift in Francesco di Giorgio's thinking between his earlier and later drafts, and one might perhaps reasonably expect that this would have been reflected in the types of detailed solutions he would have chosen to put forward in the different versions. Yet the illustrations of both drafts were in pretty well exactly the same style, involving round and square towers on relatively simple geometrical plans, heavy scarps and emphatic machiccolations, relatively high structures with a tendency of his designs to stack up design schemes, pyramidal fashion, one on top of another,[4] to give strength. Further, even if this similarity might be considered to be the result of misconceptions on the parts of copyists[5]

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1. p. 424. 2. p. 428.
3. The earlier version had (p. 6) "Quantunque gli antichi non avessero..." bombarde, a la cui rabbiosa furia assai difficilmente né senza grande industria di potenzia a essa riparar puossi e certo chi a tale macchine riparar potesse, divino ingegno più che umano dire avere potersi." But apart from the anthropomorphic model and the Vitruvian account of the architect's skills, such discussions were almost entirely missing from the earlier version, in whose looser structure such general discussions were much less cultivated.
4. The upper level of one set of towers and curtains forming a base upon which was set, another set, like or unlike, the upper some what smaller in plan. built. The later draft having a great many more specific examples, might be considered to have perhaps a some what smaller proportion of cases where such 'stacking up' occured, but the difference can not be considered very great.
5. This in itself does not seem too likely. PAPINI (1946) shows some structures from one m.s., which are very similar to those of both versions reproduced by Maltese. This later author further suggests that the later draft of the later version of the treatise had its illustrations prepared under Francesco di Giorgio's personal supervision. Those reproduced by PARRONCHI (1966) are very similar except that they lack castellations and machiccolations at the top of the walls in many cases.

the actual detailed design rules that Francesco di Giorgio gave in the different versions were pretty well exactly the same in both cases. In both the earlier and later versions he dismissed the circular form in the basic plan of the fortress. In the later version explaining

> ...le figura rotunda della mura biasimo grandemente, perché volendole fortificare di torri saria di bisogno, acciò che l'una potesse guardare l'altra, farle propinquissime: donde ne seque spesa grandissima. Un'altra incommodità ne seque, che quelli che fanno la guardia e custodiscono le mura, faccendosi fuore dal merlo non possono vedere se non quasi perpendiculare.[1,2]

In the earlier version after dismissing the circle Francesco then went on

> Laude avendo in me medesimo esaminato qual forma fusse più facile, forte e di maggiore utilità, parmi la figura de rombo e romboido esser assai perfetta. Ecci l'equilatero e l'equicuro e 'l diversilatero di forma molto convenienti. Similmente quadr'latero, ortogonio, pentagoni, esagonio: e tutte queste forme sono da adattare in ogni grande estremo luogo pe' movimenti degli angoli loro voltando le stremità a la parte della offensione, acciò che fuggitive e non ostacol sieno.[3]

The later draft repeated these same ideas on shapes almost word for word up to the mention of the hexagon, figuring there as the 15th. of the 20 general rules Francesco gave for the form of the fortress; while in the 16th. condition he gave

> che le torroni sieno tondi, e le mura angulate[4]

and in the 17th.

> ...che le estrimetà delli anguli si vollino dove può essere la fortezza più offesa da le bombarde acciò sieno le mura fuggitive delle persosse delle bombarde....[4]

while he had earlier explained

> E stata aprovata dalli antiqui la rotundità delle torri....La quale alle torri io confirmo essere utile e necessaria, perché piu resiste (per la rotundità) e meno riceve le percosse della bombarde.[5]

Thus Francesco's ideas about the detail needs of design were very similar in both his drafts, in the later version clearly defining the trace of the fortress by reference to a basic simple geometrical plan of an angular nature at whose apexes were set round towers which best resisted at the points most attacked, while the sections of curtain walls receding from them equally receded from the attackers fire. Thus in his 'theory' of fortification Francesco di Giorgio did not make any central use of the notion of flanking fire, but was more concerned with the kinds of ideas, that were

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1. In contrast to the schemes of the B.M. m.s.
2. p. 430/1. In the earlier version Francesco di Giorgio gave somewhat differently "....gli antichi architetti lodassero molto la forma circulare perché in se perfetta è, nientedimeno non pare in un gran diamitro da esercitata perché, necessitata dello forza dalla difensione d'essa, bisognarebbe fare spessissime torri a volere che l'una all'altra aiuta desse, e perché essendo tanto propinque più per nuociare che per giovare stareino, ché le difese che ne'fianche si fanno, per la poca distanzia l'una all'altra si percotaria." (p. 7.) While the ideas expressed in both these versions are not altogether plain, in both cases Francesco seemes to have been groping towards the ideas about flanking fire that became so central in later fortification theory. But while he did to some extent give significance to the needs of flanking fire (see above p. 220 for example) it remains that in his writings this was not the dominant deterinant of design as was later the case. (See below on his later designs in contrast.) The interaction of towers in defence had of course been expressed in Vitruvius, (Bk. I, Cap. V) "Intervalla autem turrium ita sunt facienda, ut ne longius sit alia ab alia sagittae missionis". (1931/4).
3. p. 7. 4. p. 431. 5. p. 430.

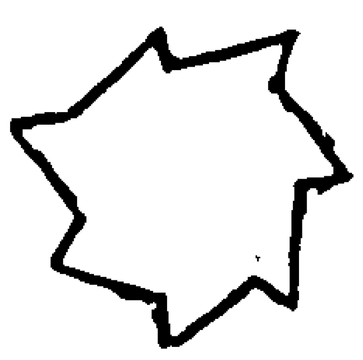
later argued for in the device of the 'forbici',[1] although in many of his detail descriptions of designs flanking fire was mentioned as an important consideration, and this held true in both his early and later versions of his treatise.

Thus the shift in emphasis from the earlier to the later draft of Francesco's text, though it involved an increased emphasis on general theoretical considerations, and a radical shift in its teachings on how in general bombards in attack ought to be responded to, involved no radical shift in detail design techniques or in designing, which remained very much as before and reflected the earlier attempts to find best resisting structures, to a great extent.

Further like so many later fortification theorists Francesco di Giorgio gave an historical account, in the later version of his treatise, as to why architects had not previously produced designs sufficient to deal with the contemporary power of artillery (bombards), which made central reference to the introduction of a new powerful artillery. He stated

> ...non voglio imputare ad ignorazia delli passati (propinqui a noi el non avere trovato remedio a questa violenzia, in) fra li quali non dubito essere stati ingengi perspicacissmi, ma reputo di questo essere state due cagione potissime. La prima che, considerando alcuni la inestimablie furia et incredible potenzia che per la foco la bombarda demostra, gittando per aere tanto pondo et a tanta distanzia con tanta velocità, come diffidati di loro medesmi, non esistimavano essere possible, secondo la prima apprensione, a qu(e)sto impeto possere resistere, onde non esercitorono el discorso loro per trovare al morbo le suo remedio. La secondo che invero per lo passato li instrumenti preditte (quanto a tutte le sue spezie) non furono (mai) di tanta efficacia longhezza e grossezza, e si ingineosamente operati quanto al presente (dì, peroché da non molti anni indietro la bombarde erano piu per larghe in bocca che appresso alla coda e di minore grandezza, donde non erano di tal forza quale oggidì sono): (peroché che) ~~ora~~ ogni grossissime bombarda (oltra all virtù sua) sì spesso et indifferentementi in ogni loco e trattabilmente si mette in opera, che

1. Leonardo in Madrid Codex II gave sections from Francesco di Giorgio (Dated 1504, see RETTI (1974) Ap. B). Retti translated these passages "The fifteenth, the towers must be round, because round towers resist more and support better every impact, and the walls must be angular and never round, because the lateral defenses of the tower could hardly be effective on a curved surface (perchè l'offese delle torri che son per fianco pocco d'essa mura scopre, per la lor curvità). One tower would not be able to defend the other and we would incur great expense with little utility. The sixteenth shall be, that the angles of the wall face, as much as possible, the sites where the artillery can be situated in order to achieve flanking fire." Thus Leonardo seems to have synthesised a number of Francesco di Giorgio's remarks here. But Retti's English version of the 16th. point does not even seem to make sense, while Leonardo's actual words at this point had nothing about flanking fire and simply repeated Francesco di Giorgio's idea "che lli angoli delli muri sieno volti il più che si può a cquel loco, dove l'artiglieria pò esser piantata acio chè lli colpi sieno fugitivi" (F. 94a/95r). On the other hand the notion of flanking fire precluding the use of circular plans seems slightly stronger in Leonardo's version. Francesco gave one particular design based on flanking fire (Maltese Tav. 260) which he indicated "Volendo ordinare una circunferenzia di mura senza spesa di torri, tutta intorno difesa per fianco" (p. 451). The same trace was given in the earlier draft also (MALTESE (1967) tav. 5. Francesco's designs show perhaps a slight shift from the earlier to the later versions in respect to this characteristic, in that pure plan traces are more common to some slight extent in the later version and while towers on a plan very close to that of the pentagonal bastion appeared in the earlier version (Milanese Tav. 4, for example), much more clearly in the later version a triangular fortress shown in pure plan form appeared with quite definite pointed bastions at its corners, although the faces do not line up in accord with the needs of flanking fire and the principle of no dead ground, and gunports were indicated more numerously than in accord with that theory. (MALTESE (1967) Tav. 301)

Thus 

ogni edificata resistenzia presto è superata.[1,2]

From this passage it would then seem reasonable to consider that the shift in emphasis between Francesco's earlier version and his later version of his treatise, the first more concerned, at least at the general level, with attempts to resist artillery, the second admitting the impossibilty of this, ought to be seen as just such a response as is so often suggested to the introduction of a new powerful artillery.

However Francesco's later version gave bombards as commonly 15 to 20 feet long with a "peitre" of 300 lbs. with a barrel 5 to 7 diameters excluding the chamber,[3] while in the earlier version he had said when discussing "ponti delle bombardi" that

> Poniamo che la bombarda libre trecento di pietra tragghi...[4]

and while discussing bombards stated

> ...sia una pietra de lire trecento, el cannone non mano di tre à da fare e le tromba peitre sei.[5,6]

Thus he seems to have considered bombards to be much the same in both versions.

Moreover in his earlier version at some points Francesco implied that one had to assume that bombards were to be considered overwhelmingly damaging, at least at times; for, in discussing "ripare" he stated:

> Poniamo che la longhezza del muro che può essare dalle bombarde ruinato sia piè dugento.

Thus the size (and type) of bombards and the sort of effectivness that had to be attributed to them, did not differ so very much, if at all, between Francesco's earlier and later version of his text although from some passages one might assume that this had to be the case.

Thus neither the types of designs Francesco di Giorgio drew, nor the simple geometric type of plan with round towers at its corners, he put forward as most to be desired; nor the power of the

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1. p.242
2. There was a certain kind of tension between the two different points Francesco made here. On the one hand earlier artillery was considered so powerful no one attempted to work out how to try and resist it, but on the other hand it is only recently become powerful. Perhaps Francesco considered these as alternative explanations, but it seems more likely that he rather wanted it both ways: that is, to emphasise his ingenuity in being the first to be able to think up ways to resist it, or even to dare to, and at the same time to insist that he was only responding to new conditions which made it necessary that his approach be followed. The idea that early bombards were wider at the mouth than at the bottom of the bore is slightly odd perhaps. Any such defect in early guns is not widely reported by students of the history of artillery, nor do such weapons appear very frequently in collections of early guns. Further the early type of bombard formed by annealing lengthwise strips of iron would have been much more complicated to make in this form. In the B.M. m.s. by Francesco, guns tapering in this way on the outside do appear. Now WELLER (1943) p. 209, suggested that Francesco's drawings of guns "are curiously dependent on historic artistic precedent" and the B.M m.s. itself seems to owe a good deal to the earlier machine book tradition such as represented by Taccola's work. It thus seems possible that Francesco was misled by what may have been merely a drawing convention, or what may have been meant to show external tapering alone and not that of the bore, in early drawings. Taccola's drawings seem all however to show parallel bores. If Francesco himself had been referring to mainly an external tapering it is difficult to see how this would have been very detrimental to performance, apart from affecting mobility.
3. p. 418/19. A diary of the war of Ferrara of 1582 notes twice a new type of bombard firing 300lb. shots. See CALEFFINI (1938/40) 17 June, 15 July 1582.
4. p. 213. 5. p. 220.
6. p. 418/9. This tends to substantially undermine any idea that Francesco was reacting to a new powerful artillery of which a major aspect was the introduction of metal shot instead of stone, which is so often generally alluded to as a prime factor in the shift in fortification style in accord with the ideas manifested in Francesco's later version. In smaller guns Francesco specifically mentioned metal shot, so 'pietra' can not be read as shot or ball which might be of metal. Thd diameter of the guns again excludes metal shot. Total length would be 8 to 10 diameters (he gave 2½ for the chamber) which would give a diameter getting on for 2ft. which could not be metal.

offensive gunnery which he considered he needed to take account of, varied, between his earlier and later versions of his treatise, in anything like a major way,[1] yet his account of the basis of military architecture varied between the various versions in a radical way. In the earlier version the military architect was expected to search for structures with the best possible resistance to attacking artillery, while in the second he was expected to understand that such resistance could not be practically achieved. The change was thus more of a 'gestalt switch' about how the problems of his field should be approached, rather than any major change in 'the facts'; a change of thinking at the normative level rather than about the actual problems that had to be coped with; and a 'gestalt switch' in the sense that many of the same elements were present in both versions, but which were considered to function together to give very different results in the different versions. The focus at the general level on the geometrical form of the structure was a common element in both, as was the conception of the need to respond to attacking artillery as a very powerful weapon. In the earlier version the architect had to respond as best he could, while in the later he had to accept that that could not be done.

A 'gestalt switch' that is is difficult to conceive was not facilitated by preoccupations with general considerations about 'art and method' and, science, as found in Architecture, and more particularly in perspective,[2] during the period, especially in conjunction with the idea that pil [illegible] up masses to resist artillery did not evidence much skill or ingenuity on the part of the designer, which ideas all figure so much more strongly in Francesco's later version than in the earlier.

Thus at least in part the shift in Francesco's views as evidenced by the different versions of his treatise appears to have been a response on the lines as indicated in the description of the social model of technological change during the renaissance, and not a simple response to a new powerful artillery, the shift being more at the justificatory level and concerned with the basis of theory rather than with details of design.

But these developments were not the total of the evolution of Francesco di Giorgio's thinking on fortification. Magliabechiano II.I.141 contains a selection of designs without text which can with some confidence

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1. For example in his later version Francesco di Giorgio noted as one of his 7 principle topics for discussion in fortification was "capatannati, difesa nuovamente inventi e trouati per resistere alle bombarde"(p.433)-the last phrase in the later draft of the later version only -- which taken with the later version on its own, seems to suggest that this device was thought up in response to the new powerfull artillery. But in the earlier version (p. 13) Francesco had "Possansi in ne'fosse fare alcune occulte difese in nelle loro bassezze overo infra gli angoli, acciò che due facce difendare possino. E questi fatti sieno in più varie forme, a guisa di chiocciole overo d'acuto mantellette. Anco campanati, a tesudo, capannati e a guisa d'acuto piramida, sotto vacui, colle basse defese, e in esse della rocca l'entrate formati di grossime e perfette mura." The later version also describes capanati in very much the same terms at the bottom of the fosse. (p. 439).
2. Perspective figures strongly of course in Francesco's preamble to the later version of his treatise in the justification of the mathematical approach in practical matters.

be attributed to Francesco. They were in all probability a product of the last years of his life during the 1490s, and show a clear development from the illustrations which accompanied his earlier written versions. The tendency of Francesco to stack up designs pyramid like is very much less in evidence in these later designs, as is his earlier tendency to present designs as three dimensional objects in perspective. Instead here structures appear more frequently simply represented by their plan, and in other cases as single level structures. In addition the characteristic machiccolations of many of Francesco's earlier designs have disappeared in many cases. The pentagonal bastion form occurs more frequently and as a predominant feature in these later designs, on occasion being very clearly shown with characteristic rounded orellions and retracted flanks. However in no case is a line indicationg flanking fire from the neck of the bastions shown, and in a number of cases the pentagonal form was shown with gunports occurring in places other than the neck of the bastion. In one case a high round tower was shown in the fosse as a protection to the entrance of the fortress, which lay in the middle of a solid curtain between two pointed bastions. The nature of these designs was therefore somewhat intermediated between the designs of Francesco' written texts and the 'pure' pointed bastion style of the later period, and were thus clearly a development from his thought of even his latest texts.

Thus in the development between the two versions of Francesco's written text on fortification little change in the details of design took place, and it was rather at the level of theory and the justification of theory that the most significant changes occured. But this stage in turn was followed by the development of detailed designs which were much closer to the forms at the basis of the fortification treatises of the later 16th. century which were to be justified by their writers in just that same theoretical way that Francesco had outlined in his later thinking at the theoretical level.

III: (2): (ii): Changing forms of structures and their relationship to theory

A number of those tendencies that were at work in Francesco di Giorgio's earlier drafts can be discerned at work from somewhat earlier in the 15th. century.

A document dated 1440 relating to repairs and modifications to structures at Foligno mentions walls to be scarped at a number of locations,[2] and the device of scarping heavily emphasised, along with heavy machiccolations was to form a striking aspect of may Italian structure of the later 15th.

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1. These are reproduced by FIORE (1978) being f.193/244 of that codex. (HALE (1970) reproduced two of these, one indicated as f. 140r, but this is clearly a misprint for 240r.) Maltese suggested that these drawings were not from Francesco's hand, but did not consider the matter in detail. FIORE (1978) argued for their attribution to Francesco. It is difficult to accept anything but the very high probability of this attribution, for the designs although clearly involving a development from his earlier writings still contained many elements characteristic of the earlier designs. The later version of the later draft of Francesco's treatise further included at the close of the section on fortification the following words "...benché sarebbe da discrivere cose assai e da dimostrare molte e varie forme et infinite, le quali, per non essar prolisso e longo, quelle resecando tacerò, perbenché alcuna semplice figura senza scrittura dimostrario, a di(la)tazzione et utilità delle iusti principi e potentate e gloria di colui che alli omini il domino conceda." which may very well have referred to these actual later designs or their like.
2. ANGELLUCCI (1866) p. 477/8.

century.[1] More significantly, in the later part of the century these features were combined with simple geometrical plans, often square, with relatively massive round towers at the corners, to the pattern that Francesco di Giorgio indicated, such structures forming strongholds alone or in combination with other structures.[2] At Sarzanello a fort on this pattern was built during the 1590s; an equilateral triangle with massive round towers at its corners formed the basic plan of the structure while a massive ravelin added on one side turned the basic plan into that of a rhomboid along the ideas as expressed by Francesco di Giorgio.[3] A design of a not dissimilar pattern is to be found in one collection of Guilio da Sangallo's work.[4] Equally are to be found amongst his drawings sketches, presumably ideal plans of fortresses, one showing a star shaped plan formed by two overlapping equilateral triangles with round towers at the points, another having a triangular plan with round towers at two corners, and what appears to be a pentagonal bastion with its point chopped off at the third corner,[5,6] again following a pattern not dissimilar to the general method Francesco di Giorgio outlined.

Thus the search for form in fortification and the use of simple geometric shapes with round towers at their apexes was not confined to Francesco di Giorgio during the later 16th. century, although the detailed relationships between the different protagonists and the detailed dating and origination of such ideas remains obscure; and this search can be seen at least in part as consistent with the search for rule and method as found for example in Alberti in general architecture, in the context where ancient models were by no means so readily available, in accord with the social model as outlined above.

However, as was suggested above in a general way with regard to the practical mathematical sciences during the renaissance, it must be considered that the processes involved in the social model can not be conceived to be at work without the possibility of such other processes as are involved in the need/invention model. That is, that there were also factors of practice at work which determined whether the drive for theory, mathematics and method could or could not be successfully cultivated, and which determined in part the nature of the resultant discipline. This seems equally true of fortification in the earlier renaissance.

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1. See for example HALE (1965), who gives illustrations of many of them. On occasion the machiccolations appear to be blind, but it is difficult to be sure how much this might be due to late restoration.
2. Volterra (from 1472). Forlimpopoli (1471/80). Imola (1472/3) Pesaro (1475/1505). Senigallia (c 1480). Forli (1481/3). HALE (1965). At Lolevaldelsa (1479) only two towers with a curtain wall in this style appeared. At Ostia Antica one of the drums was replaced by a pentagonal tower (1482/6). At Livita Castellana, begun in 1494 only one of the apexes has a round corner tower, while the rest are pointed. At Civitavecchia, begun 1508, rectangular in shape with a massive keep, the corner towers were again round in this pattern.
3. In 1488 it was decided to consider the works at Sarzanello, the work was begun in 1493 on the basic triangle with round corner towers, and the ravelin was only added later. It is not altogether clear whether the ravelin was part of the original design. See NERI (1885). A design of Guilio da Sangallo's has a very similar form.
4. SAN GALLO, G (1910). Commentary p. 3.
5. SAN GALLO, G (1910). Reproduced in SEVERINI (1970) also.
6. Ibid. The ✡ shape is reminiscent of Filarete's Sforzinda and some of the ideas on its defense (see above p. 189), but clearly was conceived on a much smaller scale.

Clearly to some extent or other observation of or reports about the effective use of artillery against static defenses was a factor in the responses of 15th century military architects as is traditionally held.[1] This was quite explicit in Francesco di Giorgio's thought in its earlier phases c. 1480. where the problem was strongly emphasised. Filarete's device of thickening up the walls of his towers at the perimeter of his star shaped enceint must equally be accepted as evidence of this kind of thinking. In the rather earlier account of 1540 of the work required at Foligno the mention of a tower "bombardato", and that this occured just after the siege of the town by Cardinal Vitelleschi in 1539 give support to the idea that the new works were such a response, at least in part, to attacking artillery.[2]

On the other hand during the early 15th. century gunpowder weaponry came to be a part of the arsenal of the fortress, sometimes in only relatively small numbers, but sometimes in greater quantity. This can be seen in both the provisioning of fortresses[3] and in the adaption of structures to take account of its use as defending artillery.[4] However, defensive fire could function in a number of different ways which in turn gave rise to differing

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1. Notices of occasions where artillery damaged structures in the early 15th. century can be found in a number of authors. See for example NAPOLEON III (1851) p. 65. The later 16th. century treatises of course held the view that the mode of design was necessary because of the introduction of a new effective artillery which was irresistable in attack. Modern workers in the field have followed this view almost entirely and seen the whole development of renaissance fortification as essentially a mechancial response to such a new weaponry. This occurs in the earlier Italian writers in the field such as Marini and Promis, with later Rocchi and Maggiorotti following the same view. More recent English speaking writers in the field such as De La Croix and Hale have taken a similar stance. See also below p. 243 n. 1.
2. ANGELUCCI (1886) p. 478.
3. Christian de PISAN (1937) p. 141, Bk. II, Cap. XV "Item for the garnyson & stuffe longinge to the deffense bihouen many gonnes & foyson powdre for ŷ same & grete plente of gonne stones...." p. 143/4 Cap. XVI, for every 200 men of armes and their archers in defence in a siege "prouysyon vpon the faytte of the defense of the said place/ First atte aldre lést /XIJ/ gonnes castyng stones wherof two of them muste be gretter than eny of thother for to breke engynes manntelles and other habyllementes yf it be nede." See also GASPARI (1886) who gives detailed inventories at many places in the period 1436/1459 with nearly every one listing gunpowder weaponry. At the Rocca di Pergola 1436 "Doi Bombardelli picholi...Vna Bombarda mezana di mittalo .....Vna altra Bombarda de ferro pichola.....Vna Bombarda de ferro". Spoletto 1444 included "libbre 1019 de salnitro....8. Barili de polvere da-bombarda de peso di libbre 1586" as well as "2 Barilotti et 1. Barile da vino de polvere da bombarda" in one room. "17 Bombarde tra grandj e piccole" "In cima alla Torre maestra Bombardelle ferrate". At Narni 1444 "8. Barili e mezzo de polvere....1. Barile de Salnitro et un cartello e due sachette de salnitro...1. Tina da Carbone da far polvere da Bombarda....4 Bombarde cioe 1 grande e 3 mezzane,..3. Bombardelle 2 scoppietti de ferro". Jesi 1455 "A la entrate de la canaua...Tre Bombarde de ferro"..."Sei scoppietti di ferro....In cima Turris Certe prete da bombardi". Serra S. Quirico 1453 "Due bombarde grandi de ferro vna grande et vna picola". Rocca Contrada 1455 "Vna botte meza de carbone de salcio, due barili de polvere da bombarda, xiij scioppiecti et quatro de bronzo....Quattro bombarde de ferro due grandi et due piccole". Rocca Contrade 1448 (?) "Tre bocticelle di polvere da bombarda....In cima del muro del circuito della dicta Roccha Vna bombardella....Nella revellino della dicta Rocha Vna bombarda grossa"..."Vna Bombardella....Vna bombarda grande....Vna bombarda de metallo...Vna botte con carboni che salci...dodici scoppietti de ferro....due barile de polvere da bombarda". Corinaldo 1445 "Duo bombardelle ....Vna bombarda grossa....Vna barilono grosso de polvere da Bombarda....Vno bauleto dj polvere da schiopettj...Vno baule al quanto seme di polvere da Bombarda....Vno altro baulo....Vno altro mezo barilletto...In summo de la Torre Do bombardine in forma di scopittj Vno schiopetto di brozo pur voto Vn bombardella de ferro col suo ceppo....Pietre da bombarde circha 50 et non piu. "...Vna bombarde grossa..... Doi bombarde." (1459) "Vna bombardella...Vna bombardella. ...xxj schiopetti...I baule grosso de polvere de bombarda...I barlecto de polvere di schioppetti...I. barilo un poco seme de pulvere de bombarda....II altri barili....In la cima de la torra Vna bombardella....Vna bombardino de ferro....I altro bombardello de ferro ....II scioppietti di bronzo rotti". Fabriano 1449 "Vno bombardella grossa.....IIIJ bombarde....Vna bombarda... Due bombarde....Dodeci schioppecti da ottono....In cima de la torra....Pulvere

de bombarda llibr. Centoquarantuna. Pulvere da schioppetti libr. vintecinque Solfaro libr. quarantasey. Salnitro". "Due bombarde mezane....Due bombarde piccola luna piccholissima". 1445 "Tres bombarde ....una bombardelle parva ferrei...decem scoppiecti octonis.Duodecim pallucte ferree pro bombardis.. polvere dela bombarda libr. CCXX...polvere..libr. LXXV." Assisi 1455 "una bombarda de ferro....duodecj scoppeti de ferro boni....vna scoppeti de ferro rotto... sacheto de polvere da bombarda de libra quaranta". Rocca Gualdo 1455 "vno cavallecto da bombardella". Rocca Fabriano 1455 "quarto bombardi piccoli... sette bombarde grandi...vnideci scoppeti de ferro....deci scoppeti dottoni... vno barille mezo di polvere da scoppeti......doy altri barillj... de polvere da bombarda....vna bombarda grande de ferro...doy bombardella e una bombarde grande da metallo...vna altra bombarda grossa....quatro Scoppetj de bronso....deci scoppetj de ferro....tre barilli e doj betticelli pieni de polvere da bombarda et scoppetj.....doy bariletti de plovere da bombarda." Rocca Contrade 1455 "salnitro libre cento...solfo libre settanta". Corinaldo 1455 "vna bombarda grande...doy bombarda piccole....vna bombarda e vna bombardina piccola....vno barille grande pieno di polvere da bombarde...vno altro barille mezo pieno....tre barille con polvere da bombarda e scoppeti e pocha....doy scoppeti de bronso rotti....sedeci scoppeti de ferro". Serra S. Quirico 1455 "doy bombarde granda e vna altra piccola....deci libre de polvere de bombarde...(assignate)...deci scoppeti novi....solfo libre settanta...salnietro libre cento". Iesi 1455 "doi bombarde grande....vna altre bombarde picola... vndeci libri de polvere da bombarde...doy barili uno pieni di polvere da bombarda". This ignores much of the auxiliary equipment of these weapons in the inventories, which of course included many mentions of traditional weapons as particularly cross-bows. However it is not altogether clear to what extent these weapons may have only been in the castle or fortress as in a repositary for use in the field or elsewhere, but sufficient indications are given of gunpowder weapons at the "cima" of structures to indicate that at least in these cases they were intended for use in defense of the structure. See also ANGELUCCI (1886) on the munitions of "la Rocha daquafrancha (1445) "Vno scopito di mettallo...Vna bombarda grossa....Vno barille de poluere...Vno scopito di ferro". 1452 "inuentarium munitonis comunis Fulginei...scoppitte con haste 63.....scoppitti 12 con haste....scoppitti 3...scoppitte noue......Scoppetti 3" these last assigned to a particular persone. "Bombarde grandi et piccole con ceppi et senza 9...Poluere di bombarda in uno barile trista et guasata". 1457 Roche Verchiani "Bombardelle doi de ferro". "Inventari delle munizione consegnate a Gaspare Varcananti Camerlego del Comune (1458 ?) "Schioppecti de ferro numero 168...de bronso 2....4 canonj de fero da bombarde....1 bombardella rocte de ferro....16 bombarde con vna di bronzo"."Expensa facta per Nicholatum de Mugiascha circa repara que fieri facit pro bombarde XXVIIJ in ciuitate." ANGELUCCI (1869), 1311 "Queste sieno le cosse le quale sieno in la Bastia da Formane per municione iiij schiopi grandi fornidi de poluere et balota...iiij schiopi pizzi da man fornidi". 1399 "doe bombarde e polvere et li soy fornimen per la difese de la terre."

4. Christain da PISAN (1937) p. 137 Bk. II, Cap. 14. "And a proper place must be ordeyned and made atte euery face of the walles for to sette gonnes and other engyns for to shute without/ yf nede be to make deffence...." See also ANGELUCCI (1886) with regard to Fogliono in 1426 in the context "dellauorio dellantiporta del ponte dellabbadia dela dicta citta de Foligno" when the work was to be done "bene et lialmente, con bumbardieri et balestiere". The suggestions of 1540 suggested "bombardiere" were to be made in a number of parts of the work. ANGELUCCI (1869). In 1399 "Pro Castronuouo..che in lo recete soura Po se faze le teraze con le bombardere e con due Beltresche". "Pro Castro Guillmo..bisogna fare v. bombardere in lo receto per defessa de la intra del castello" (p. 246).

This need is of course noted, although in only a minor way in both Alberti and Filerete. Francesco in his earlier version of his writings mentioned "balestra saettimi, cerbottane, spingarde, e altre artigliarie a le difese appartenenti". ((1967) p. 10.) He also discussed the problem of storing powder . In his later version (p. 422) he argued against the ancients having had artillery by pointing out "che nelle mura antique mai è stato visto alcuno vestigio di bombardiera", indicating his assumption that if they had possessed these weapons they would have modified their structures to handle them. Such openings appeared in many 15th. century structures, but tended to be rather small and constrained. See HALE (1965) for example. For the use of artillery in defence in the earlier period see NAPOLEON (1851) p. 75 et. seq. WAUWERMANS (1878) p. 144. COLVIN (1963) on Calais p. 448 "...under Henry IV and V there are references to the making of 'gunholes' and rests for guns, and by the accession of Henry VI the artillery at the Captain's disposal included 60 iron guns to shoot stones, 49 brass guns, and 19 iron and 4 brass guns designed to shoot lead pellets. When the Duke of Burgundy invested the town in the summer of 1436 the defensive preparations included the making of earthen 'bulwark' outside the Boulogne and other gates and piercing them for gunfire. In 1438/9 an opening was made in the east curtain for the insertion of a great timber 'loop' through which the 'great bombards' were to shoot." At Guines p. 452 "A great 'loupe' for guns was made in the walls of the castle in 1438/9".

requirements which can be detected at work during the 15th. century. Firstly, defensive fire could be used in a general way to attack the enemy frontally as he attempted to approach the fortress. In such case a relatively solid platform was needed to support the defensive guns,[1] and if it was pushed forward from the main body of the fortress so it would tend to be able to hold the enemy that much farther back. In the case of a number of structures built after mid century this function can be detected.[2] Secondly it is clear that defensive fire had another, and in all probability increasingly significant, role, during the whole period, when it functioned as flanking fire. Now flanking fire itself can be conceived itself as essentially fire which strikes the enemy on his flank rather than against his front. In this basic form flanking fire was a particularly important way of using projectile fire, because, one, in so far as the enemy advances in line, which one may expect to occur quite frequently, a flanking shot passes along his line and hence may be expected to do that much more damage as a result. But equally, striking him on his side, the enemy tends to be less able to reply, his major drive being towards his front, and in attacking to his front will tend to be less protected there.[3]

Flanking fire in this sense had clearly become a significant aspect of siege warfare by the end of the 15th. century. An anonymous report of the siege of Pisa in 1499 explained

> ...li inimici volere accamparsi....appresso il convento di Santa Croce, perche da quilla parte dicevano la città essere più debile e poco atta ad offenderli per non avere quella parte alcuna fortezza da offendere per fianco...[4]

and

> ...si fece un rivellino al torrione delle Porta........e questo per dui rispetti. Il primo perchè il torrione ditto era voto e debile per quello fortificare. Il secondo per potere battere il nemico per fianco: che accampandosi quivi non poteva essere offeso come ditto avemo....[4]

Thus the value of flanking fire in a general way had become accepted, at least in some quarters, by the end of the century.

However flanking fire as a defensive weapon in siege warfare could function in a more specific way. When the enemy attempted to assault the main defensive barrier either through a breach or by scaling, flanking fire was a means by which the defenders could hope to severely gall him. At the end of the century Guiccardini described how in the events leading up to the siege of Pisa mentioned above, at

> .....thenterprise of <u>Librafatte</u>....<u>Pavvle</u> (Vitelli), assaying in vain thre days together to mount vp with ladders, beganne to dout much of the successe, the rather for that the armie receiued great harmes by a peece

1. At the siege of Constantinople for example, according to RUNCIMAN (1965) p. 94. "There were also several cannons in the city; but they proved to be of little value. There was a shortage of saltpetre for them; and it was found that when they were fired from the walls and towers which was necessary if their missiles were to reach the enemy lines, the reverberations damaged the fortifications. (Chalcocondylas Bk. 8.) "that the guns placed in contrybattery, in shaking the walls, did more damage to the defenders than to the Turks." PEARS (1903) p. 250/2. See also LEONARD of Chios (1866) p. 928 "Nam si quae magnae erant, ne muros concuteretur noster, quiescabant." The account of Machiavelli's of the early 16th. century of his visit to Florence to consider the fortifications there included modifications to towers to take care of this need to some extent. See also at the siege of Pisa of 1499 below, and p. 238, n.2.
2. See for example HALE (1965) on Matteo Nuti's polygonal work in the town wall of Fano 1464/9, which, although it had no flanks to speak of, seemed to have this function. The guns in ravellins often in the earlier period mentioned, particularly when that structure protected a gate (see on the "nanteport" at Fogliono above for example p.231a) in all probability had such a function, at least in part. WAUWERMANS (1878) notes such a structure built during a siege in the 14th. century.
3. Of course he can protect himself on his flanks, but this greatly increases the weight of his labours, and will be all the more arduous in that attacking to his front he can not afford to dissipate his efforts by using his weaponry to strike back at the flanking guns.
4. La GUERRA del Millecinquecento (1845) p. 364.

> of artillerie which came from the towne by a lowe lowpe hoale: But his industrie & vertue was aided by the benefitte of Fortune....for that with a great shotte out of the camppe the peece which bette them was broken, and one of the best Cannonyers within the place killed...[1]

and the next day the place yielded.

Such low level flanking fire of course had the advantage that guns so emplaced would tend to be best protected from offensive fire. Francesco di Giorgio's "capanati" were conceived to function in this way.[2] Equally Francesco in his writings indicated his acceptance of flanking fire as a significant part of defence[3] although he never made use of the need to cater for this fire as a principle of design in any thoroughgoing way. Earlier Alberti had alluded to something like this kind of defence. Further many structures of the transitional type of the later 15th. century showed gunports wich at least in some cases could have functioned to give flanking fire.[4]

Some German 15th. century sources equally indicate the same pattern. An anonymous treatise considered by Jähns, and dated by him as c. 1450, according to this commentator took the view that

> Die Gräben sin je nach Umständen trocken oder nass. Ersterenfalls sind sie durch "gut vermauerte ligende hutweren mit Schiesslöchern" zu sicheren...[5]

Similarly another treatise described by Jahns and attributed by him to the last quarter of the 15th. century (c. 1480), had a short section of text:

> So man ein stat oder schloss vmb machen will, die da vest soll werden, der nem dy muster im anfengt vmb dye tor der pasteyn. Darnach mit lange schuten. Darnach mit einen perg. Darnach wieder mit ein schutt. Dernach wieder mit einer pastey umb ein stat oder ein schloss. Dem anfanck soll man anheben mit wafen zwifach auf einander vnd sol hinder den wafen erden schuten, und soll auf die erden vnd waffen wellen legen, die wellen sollen hinten vnd forn gepunden sein, vnd hinter der schut soll ein grosser zaun sein mit zwifachen punttwergk, forn in zaun hinter in die schut, und die schieslöcher sollen gancz aichen sen nach der leng durch schut foren eng, hinten weyt, Des bewer ich hanns schermer.[6]

making clear the desirability of catering for the defensive guns in the structure.

Phillip Duke of Cleves in his treatise completed by 1498[7] equally advised,

> ....fare par dedans vostre ville, vn rampar de bois & de terre, aussi hault que vous pourrez, mais qu'il fust hors de la baterie, ou qu'il fust si puissant, qui cela ne luy peut nuyre à quinze ou sieze pieds arriere de vostre mur, aussi loing au'il vous semble qu'ils pourroiẽt battre votredicte muraille; & aux deux bouts dudicts rampar, le feroye ioindre à la muraille, que lon ne pourrait batre: & feroye vn fossé entre ledicte rampar, & la muraille le plus profond que ie pourroye: & à chacun bout dudicte

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1. GUICCARDINI. (1579) p. 199/200. Bk. IV. (1561) p. 279.
2. See above p. 231, n. 1.
3. He gave expression to this need in his later version in the 9th. of his 20 general points thus "che le torri sieno applicate alle mura per sé overamente con ale o muri angulati, della grossezza et altezza delle mura, con le offese per fianco". He also gave a specific design based on this need saying (p. 451) "Volendo ordinare una circumferenzia di mura senza spesa di torri, tutta intorno difesa per fianco" which trace appeared as an illustration in his earlier version (MATESE Tav. 5.) This need seems equally to have been part of his argument against round enceints. See above p. 228.
4. At Ostia and S. Leo for example. However, as HALE (1965) p. 479 remarks with regard to a number of these structures with round corner towers "Gun ports are few and small, providing inadequate flanking fire." The internal chambers tended also to be very restricted.
5. JAHNS (1889) p. 426. This work contained as well a section on 'Feuerwerks' and one on tactics. Jahns notes also that the work suggested "Burgen in den Ebene sollen nicht hohe aber dicke Mauern erhalten, und namentlich muss der alles überhöhende Hauptturm von grund off bis under das dach gelich dick vnd als vest syn, das er starken büchsen widerstehen muge." p. 426.
6. Ibid. p. 431/2. The text was accompanied by four sheets of drawings with endorsements. One sheet had two 'bastions' and the curtain between with under the curtain written. "Das ist ein schut von einer pasteyn zu der anden, oben ain schrancken auf der schud, auch ein Igl vnd dye schud. Item zwichen der peden pasteyn gehort ein perg, darauf man das leger vmb en stat wer(ff) mit dem puchsen auf dem perg." ibid.
7. JAHNS (1889) p. 340. Philippe of Cleves b. 1460 d. 1527.

> fossè, ou en lieu de ioindre à la muraille, ie feroye vn demyrond qui battroit au long dudict rampar & le fosse.. & tout cela ie feroye fort perçer, pour tirer parmy ceulx qui viendroient en ce fossé peur gaigner mon rampar, & metroye quelque petreaulx de fer au fonds, qui tirassent pierres, auec plusiers petits pierres dedans, pour tirer dedans le fonds de ce fosse: & de là en amont, tout plain de hacquebuttes & de coulourines...[1]

and

> Et peult on aussi faire des bastardeaux couuerts de fiens & de terre, qui trauersent les fossez, tant de vostre ville à voz douues, que de vostre douue aux champs qui est vne tresbonne fortification, car ils batent le long de voz fossez.[1,2]

It seems reasonable to infer, therefore, that during the 15th. century with the increasing use of guns as defending weapons in siege warfare there tended to be an increasing need for solid platforms to support guns to attempt to keep the enemy as distant as possible from the defensive barrier, and to provide emplacements which would allow flanking fire to be employed to the best advantage.[3]

However, the rationale of design as expounded by Francesco di Giorgio, based on simple geometric plans with round towers at the apexes, which type of design was used in a number of cases during the later 15th. century, paid little heed to the needs of flanking fire. While such structures relatively solid, and squat in proportion, as gun platforms from which to direct frontal fire at the enemy, may have been relatively satisfactory, Francesco di Giorgio's account of this basic design concentrating on the need to resist the attacker's fire, ingored almost entirely the need for flanking fire at the basic level of design. Even in his later version of his text where Francesco completely altered his account at the general level to the postulate that the search for any such resisting structure could not succeed, he dismissed those who attempted to design by multiplying flanking fire.[4]

On the other hand the idea that the needs of flanking fire might act as a significant determinant of the form of the fortress was expressed during the earlier period, albeit very tentatively, even while barrel towered fortresses continued to be built. At Foligno for example in the discussions of 1440 it was decided to

> ...far le bombardere ale mur della cità daluno canto e da laltro che rade li dicti spigoli.[5]

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1. PHILLIPE of Cleves (1558) when his work was first published, p. 92 & 120.
2. Even if these writing are not as early as Jahns considered, they certainly must be taken to represent something of the practise of defence in the decades around 1500. See also at Rhodes where according to BROCKMAN (1969) p. 52. "At first compromises were made. Many of the medieval towers were cut down and strengthened with parapets of low 'command'. Subterranean chambers were excavated in the bottom of the ditch to provide direct fire along the bottom" -- on the developments after the siege of 1480.
3. On this last point it would be obstinate not to consider such defence functioning to some extent effectively earlier, if it could so do in 1500. Flanking fire is after all only a limiting condition of frontal fire which holds the enemy back. For, as he gradually approaches the defensive barrier one should surely keep firing at him as long as one can, that is right up until he is in the fosse. If this is possible from any 'pushed forward' structures, flanking fire will then be in use. Thus if guns need to be catered for in the case of the first type of fire, that is frontal fire -- and it is difficult to see what so many guns were doing in defensive structures if it was not to provide such fire -- then there would seem to have been a need to have catered for flanking fire in the structure, whether in fact that need was properly catered to or not. (Need of course here must be conceived to be in the context of where it was considered desirable to modify structures in accord with the particular conditions of warfare of the time, it is not an absolute given.) If the notion of a need is not allowed on the grounds that if something is not responded to it is not a need, with the implication that only those needs which are responded to, are needs, then one must give a purely social account in which only people's conceived needs are of significance, as such they can not err and they could design here however they happened to conceive to be the best, whether their structures were completely ineffective or not. In such a case it is difficult to see how any military architect would gain a practice.
4. See above p. 226.
5. ANGELUCCI (1866) p. 418. "radere" = to shave, skim.

And, as noted above, Filarete -- albeit to a minor extent -- related his trace of Sforzinda to flanking fire.

Thus the method of design as expressed by Francesco di Giorgio in his earlier writings, focused on but one way in which gunpowder weaponry of the period could function -- in attack -- and made the proper response to that need, almost entirely, the determinant of the basic form of the fortress. His method was then focused on a universal principle -- the need to resist attacking artillery -- and the search for form in accord with that need, and clearly involved a choice between approaches reasonable and possible in his time.

At least in part then it seems that the forms of some structures designed by many military architects during the 1470s and 1480s were likely to have been determined by the contemporary preoccupation with method and such general notions as that the round form resists best.[1]

In contrast to this sort of design method using round corner towers on simple geometric plans, the enceinte built at Brolio from 1484 on shows angle towers at its corners with tiers of gun ports (although only suitable for small arms fire) in the flanks.[2] More emphatically the enciente at Poggio Imperale shows a relationship between gunports and the basic trace indicating an increased concern with the needs of flanking fire and the determination of the trace by reference to those needs.[3] Documents indicate that this fortification complex was the work of Giuliano da San Gallo from 1488 on in conjunction with his brother as superintendent at a later date.[4]

The use of the notion of flanking fire as a primary determinant of the plan trace of the fortress, especially and almost entirely, through the employment of the pointed bastion, appeared consistently in works of Giuliano and Antonio da San Gallo from this period on. The fortress of Civita Castellena by Antonio, begun in 1494 had 4 angle towers and one round one on its basic (not quite regular) pentagon.[5] Between 1495 and 1499 the enceinte of Firenzuolo alos by Antonio employed pointed bastions and piattaforms.[6] In

1. That the application of defensive artillery to the defense of a fortress was clearly of concern to those who had to defend it, even though such architects as Francesco di Giorgio did not give it central attention, is indicated by a document of 1499 from Como, which states "elligerunt infrascriptos quatour ciues qui debeant intendere et sollicitare quod bombarde platentur ed ordinentur in locis alias situatis, et quod bombarde accipiantur vbi sunt". ANGELUCCI (1869) p. 157. According to HALE (1965) p. 479 "the progress towards the angle bastion made between the 1440s and 1460s was restricted in area and carried out for the most part, in obscure hill towns. It was halted for a while by the adoption of round forms in a series of splendid and conspicuous palace-fortresses." This tends to support the idea that the round forms were the product of the court military architect with his concern for method and such ideas as that the round form resisted best. In contrast the work decided on at Foligno in 1440 seems to have been much more a product of local consultation of a group of townsmen and masons. For example "Berrardus moria priores populi ciuitates fulginei" and "magister Saluutinus de Scanderario comunitates fulginei, magister lapidum" were the sorts of individual involved in the discussions. That such individuals were more sensitive to the needs of defensive fire than were the court architects, because they would have been that much more likely to have had to defend these structures seems not unlikely. However the direct evidence of the ideas behing the early angle bastion forms is minimal and such a view must remain largely inferential.

2. HALE (1965) p. 482. SEVERINI (1970).

3. For description see HALE (1965) p. 482/3. This relationship is particularly noticeable in the 'town' enceinte. One section has a re-entrant trace with gunports covering the faces from the internal angle for example. Flanking fire however does not in this structure determine the trace in a rigorous way and it seems to relate a good deal to the shape of the site. The relationship in the accompanying citadelle however between these two aspects seems to be more clear. For a plan see SEVERINI (1970) p.21.

4. See REPETTI (1847/51). HALE (1965). SEVERINI ( ).

5. SEVERINI (1970) p. 30.

6. Ibid. p. 34/5.

1497 Giuliano returned to Florence and was put in charge of the works at Firenzuolo and Poggio Imperale. In 1500 Giuliano worked on the design of Borgo Sansepolcro, and in 1502 on Arezzo, while towards the end of this decade brothers were involved on the work on the new citadelle at Pisa.[2] After the death of Giuliano, Antonio worked on the fortress of Livorno begun between 1517 and 1518.[3] And all of these works made significant use of the pointed bastion.[4] The use of the pointed bastion was carried on by others, among them Antonio da Sangallo the younger in his designs for the urban enceinte of Civitavecchia of 1515,[5] and in his later well known design of the Fortezza da Basso at Florence of 1533.[6]

However the acceptance of the notion that the basic principles of design were related to the needs of defensive guns giving flanking fire, in its expression in the use of the pointed bastion, was by no means immediate. The work on the town enceinte at Ferrara of Biagio Rossetti continued to use round bastions.[7] Likewise the town walls at Padua and Treviso in both of which cases Fra Giacondo was involved, in the face of the invasion of 1509, were probably based on round bastions, and the work of 1513 consolidating the earlier efforts continued to employ that form.[8] The Rocca at Civitavecchia built under Bramante and begun in 1508[9] continued to use the round forms although a drawing from the hand of Antonio da Sangallo the younger showed a number of different traces for this fortress with the pointed bastion employed quite clearly in one layout, and with another in which the lines of defensive fire defining the trace were quite clearly shown.[10] Two very large round bastions were also employed at Loretto in the work carried out 1518/20.[11] Similarly at Verona round bastions were built up to 1525, and Michele dai Leoni, apparently responsible for some of these earlier works seems only to have begun to employ the pointed bastion form in the Maddalene Bastion of c. 1527.[12] Sanmichele, who took over the work at Verona and consistently employed the pointed bastion form there from c. 1530[13] did not however endorse this form in any absolute way even as late as 1544, for in that year regarding the defences of Padua he wrote

> ...qual se alcuno mi dicese che essendo tondo il (il torriono Boro) reste indefeso, gli rispondo, che l'è tanto poco questo diffeto che non è da tenire conto ne havigli consideration.[14]

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1. Ibid. p. 36. 2. Ibid. p. 37/48. 3. Ibid. p. 60/61.
4. The contributions of these brothers are difficult to untangle. Severini suggested that a major role ought to be given to Antonio which he described as "un ruolo determinate". In a number of these cases, as at Nettuno for example the point of the bastion was rounded off, or other wise varied to help to avoid the weakness of the slender points presumably. A sketch in Taccino Senese of Giuiliano shows a rectangular enceinte with bastions together with the other 'star' like plans with round towers. See FALB (1902) reproduced in SEVERINI (1970).
5. GIOVANNONI (1960) p.74. 6. See HALE (1970).
7. HALE (1965) puts the time at 1500/06. According to ZEVI (1960) the work involved Alessandro Biodo as well as Rosetti who took on the project of the new walls in 1495 (p. 24). Shortly after the death of Ercole I in 1505, Rossetti left his post as Ducal architect and entered the service of Ippolito d'Este. (ibid.); and "nel 1499 la nuova cinta fortificata era compiuta e si potevano demolire le vecchie mura". (p. 155) A drawing of 1498 shows the course of the fosse complete, but the new wall not yet built. The designs one would assume must have been essentially complete then or not long after. Ibid.
8. HALE (1965) p. 489/90
9. BRUSCHI (1969) p. 938/9.
10. The attribution is GUGLIELMOTTI's (1886/93) Vol. 10. He read the incription of the drawing "Chome lo papa vuole partire la rocha di ciuita, chosi". Tav. LI & p. 217. According to CALISSE (1898) p. 398 "Per addatta alle condizioni del luogo e per soddisfare ai de desideri di cortigiani, Bramante fece sulla medesime pianta, più designi, a quadrato e a triangolo, con torrioni e con baluardi." But as BRUSCHI (1969) notes, from whom the 'desegni' come is unclear.
11. HALE (1965). 12. LANGENSKIOLD (1938) p. 156. 13. Ibid. p. 273.
14. Quoted by SEMENLATO, in SANMICHELE (1960), his presumed date.

Sanmichele thus expressed something of Castriotto's attitude at this date and did not hold to any doctrinaire insistence on the employment of the pointed bastion form in every case without exception.

In the case of Michelangelo, Francisco da Hollanda in his dialogues portrayed him as emphatic as to the need for a true method in painting, thus:

> It is practically only the work done in Italy that we can call true painting ...(although) In Flanders they paint with a view to external exactness or such things as may cheer you...all this, though it pleases some persons, is done without reason or art, without symmetry or proportion....(and) good painting is nothing but a copy of the perfections of God and a recollection of His painting; it is a music and a melody which only intellect can understand, and that with great difficulty.[1]

and as praising the skills of the painter in warfare thus

> What can be more servicable in the business and enterprise of war tha the art of painting, or what more useful in the stress of sieges and assaults ? Know you not that when Pope Clement and the Spaniards were besieging Florence it was only by the work and skill of the painter Michael Angelo that the besieged were long defended, if not the city actually delivered ?-And-the besieging captains and soldiers were for long overwhelmed and harrased and slain by the defences and supports that I set up on the towers, lining them in a night with sacks of wool, and excavating others and filling them with fine powder, with which I heated the Spaniards' blood and hoisted them in fragments into the air. So that I consider great painting not only useful by indispensable in warfare, for the machines and instruments of war, for catapults, battering-rams, mantelets, 'tortoises', and iron-clad towers and bridges, and (since this iron age no longer uses these weapons but rejects them) for the fashioning of mortars,[2] guns, strong cannon and muskets; and especially for the shape and proportion of all forts and rocks, bastions, moats, mines, countermines, trenches, parapets, casemates; for ramparts and escarpments, ravelins, gabions, embrasures, battlements; for the fashioning of bridges and scaling laders, for besieging camps and dressing the files of soldiers and ordering squadrons.....drawing is of the greatest use in war in making plans of distant places....[3]

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1. HOLANDA (1928) p. 16. The order of the ideas altered. HOLANDA (1955) p. 19/20. "Sòmente as obras que se fazem em Itália podemos chamar quase verdadeira pintura....Pintam em Flandres pròpriamente para enganar a vista exerior, ou cousas que vos alegreom...a boa pintura não é outra cousa senaõ um traslado des perfeições de Deus e uma lembraça do seu pintar, finalmente una música e una melodia que sòmente o intelecto pode sentir." Holanda travelled to Italy in 1537/8, and stayed some 9 years. His 4th. dialogue is set in his first year there.
2. Bell's translation is not altogether happy here (see n. 3 below). "trebucos" obviously refers to trebuchets which interestingly are contrasted with other ancient machines as not being yet out of date.This part should then read "bombardes, trebuchets, heavy cannon and archibuses". The technical fortification terms are not too accurate although the general effect is reasonably accurate. "ramparts and escarpments" should obviously read more like "retrenchments and cavaliers" Mendes gives "repairos = carretas de Artillaria", but the notion of 'repair works' seems much more likely.
3. HOLONDA (1928) p 50/52."E que cousa há mais proveitosa nos negócios e empresas da guerra qua a pintura, nem que mais sirva las opressões dos cercos e rebates, que a pintura ? Naõ sabeis vós que quando o papa Clemente e os Espanhois sobre Florença tiveram o assédio, que só pela obra e virtude do pintor M.Angelo foram os cercados (por não dizer livre a cidatte) bom pedaço defendidos: e os capitães e os soldados de fora bom pedaço espantados todos e opressados e mortos com as defesas e propunháculos que eu fiz sobre as torres, forrando as em uma noite, por fora, de sacas le lã, e outres, vas andoas da terra e enchendo as de fina pólvora, com que um puoco quiemei e sangue aos Castelhanos que pelo ar mandei espedaçados en peças ? Assim que a grã pintura, não sòmenete a tenho eu por proveitosa, mas é na guerra grandemente necessaria: para as máquinas e instrumentos bélicos, e para as catapultas, arietes, vineas, testudines e torres ferradas e pontes, e (pois o malvadoe férreo tempo se já destas armas de todo não serve, e as enjeita as bombardas; para a feição das bombardas, trabucos, canhões reforçados e arcabuzes: e mormente para forma e proporções de todas as fortalezas e rocas, bastiões, beluartes, fossados, minas, contraminas, trincheiras, bombardeiras, casamatas; para os repairos e cavaleiros, revelinos, gabiões, merlos, ameias; para o inventar das pontes e escadas: para o sitar dos campos: para a ordem das fileiras, medida dos esquadões....Além desso, serve o debuxador na guerra grandissimamente para mostrar em desenho o sítio dos lugares apartados..." HOLANDA (1955) p. 57/9.

However Michaelangelo's fortifications designs associated with the siege of Florence in 1529[1] did not employ the 'true method' as it was coming to be accepted in fortification, based on the principle of no dead ground and the use of the pointed bastion. His designs, while they were clearly concerned with the needs of defesive fire from concentrated strongpoints, were not based on the needs of flanking fire and a determination of the trace by reference to that need. His drawing of this period rather show the defending guns firing outward in all directions through complex 'zoomorphic' shapes.[2,3] However by the 1540s Michaelangelo seems to have accepted by and large the common sense of his period and design using the method of the pointed bastion.[4]

Even into the 1540s occasional round bastions appear to have been built, but perhaps these were not very important cases.[5] But the period of the 1540s with the carrying abroad of the pointed bastion method of design[6] with its basis in the needs of defensive artillery and flanking fire, and the beginning of the period of specialised and theoretic treatise writing in fortification was clearly the period in which that rational of design became accepted fully as the proper mode of approach in the specialised discipline of fortification.

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1. De TOLNAY (1940) quotes a document concerning Michaelangelo's appointment to the charge of the fortifications of Florence for 1 year in 1529 which stated "Considerata la virutù e disciplina di Michelangelo di Lionardi Buonarrote vostra cittadino, e sapendò quanto egli sia eccellente nella architettura, oltra alle altre sue singularissime virtù et art liberali." (n.21)
2. See HALE (1965) & de TOLNAY (1940). (For the best reproductions see ZEVI (1964).) His exagerated view of the value of Michaelangleo's schemes has been sufficiently rebutted by the first author not to need discussion here.
3. While Michaelangelo, in Hollanda's picture of him, is shown as expressing many of the attitudes which were used in support of 'method', at the same time be is also shown as by no means ignoring 'individual achievement' and the laborius cultivation of this as the basis of achievement in Italy. Hollanda puts the words in his own mouth thus: "a natureza dos Italianos é estudiosissima en extremo....E se alqum determina di fazer profissão, e seguir alguma arte ou ciencia liberal, não se contenta com o que lhe basta para ser por aquela rico e do numero dos oficiais, mas por ser unico e estremado vigia, e trablha continuamente..." (1955) p.12. And it was rather in painting Hollanda showed Michaelangelo as practising a liberal art, not mathematically based disciplines which were so often praised in the same way. In his fourth dialogue at which the absence of Michaelangelo was strongly emphasised the further view was expressed with greater emphasis on mathematics: "Panfilo, pintor di Macedónia, foi o primeiro pintor que foi erudito em toda a doutrina, principalmente na aritmética e geometria, sem a qual dizie que nehum podia ser meastre....E por autoridade deste pintor se fez constiutição...que os moços fidalgos apredessem a debuxar; e qua a arte da pintura fosse recebida no primeiro grau das artes liberais...pelo que nesta arte so não acha obra de nehum servo." (Cf. Francesco di Giorgio) p. 111/12 HOLANDA (1955). Of course how much this discussion was intended by Holanda, and further to what extent it can be imputed, to Michaelangelo, from this evidence, is not altogether clear. But it would seem possible that painters like Michaelangelo wished to raise the state of the craft by alluding to its 'true' nature and 'sufficient' qualities to lift the profession as a whole, yet at the same time they may not have wished to emphasise a public and simple method too much, but rather their own individual skills (and even genius) to lift themselves above the rank and file, when easy rules for perspective were so widely known. Given this Michaelangleo may have conceived his own personally derived skills and his personal 'genius' could suffice to elevate a painter from the run of the mill perspectivist. (In another work Holanda gave strong support to the value of the science of design in peace and war, and noted he had measured many of the principle fortresses of the world (1846) Cap. II/V.)
4. HALE (1965) p. 492. ZEVI (1964) p. 898/9. 5. HALE (1965) ibid.
6. The most striking case is in the English records. See SHELBY (1967) for example. There sems to be a very great dearth of fortification treatises in the early 16th. century records and for example Promis in his many biographies of many workers in the field did not list any until such figures as Belluzzi and Leonardi began composing their works in the 1540s. It is possible that as Paccioli indicated the subject was considered a rather difficult one and that debate continued over some decades until the method of the pointed bastion became sufficiently accepted and writers could express the theory of the commonly accepted knowledge. One known work by Escriba dated 1538 shows him defending what is essentially the forbici type of design, defended from the internal angle. See ESCRIBA (1878).

III: (2): (iii): Developments in gunnery and their relation to theory

Traditionally the development of renaissance fortification has been seen as primarily a response to the power of a new effective artillery of attack which made entirely inevitable the changes that did take place. Frequently, especially when this process is alluded to in summary form, the complex of events that actually occured is alluded to as if the mere contention by contemporaries that the new artillery could not be resisted, together with the changing forms of structures, is sufficient to explain the whole process of change. This view is then to a great extent an expression of technological determinism in accord with the invention model, that is of a new technology (or condition) setting up particular problems which had necessarily to be responded to, and which were responed to in a manner uniquely determined by the nature of the new technology (or condition); the process requiring merely the production of the requisite invention response, and its historical description merely the detailed description, which expounds how and at what point, and when, each part of that response occured.[1]

There are however severe limitations to such a view of renaissance fortification. Firstly, as has been indicated in some detail, during the second half of the 16th century, the design methods widely accepted and used in fortification, through their basis in theory, were conceived to be be but

1. For some modern expressions of this sort of view, see for example HALE (1965) p. 471/4. "Radical changes in fortification only take place when there is a radical change in offensive weapons." (As a generalization this seems to be simply not true. It is difficult to conceive that it was not the use of rapid firing small arms in defence, that revolutionised the whole notion of defence in the late 19th. and early 20th. century.) "The gun provided for the first time a hard-hitting long-range horizontal blow and by the fifteenth century a reasonably accurate one. To counter this...." DE LA CROIX (1972) "The cannon provided the attacker with a breaching weapon that rendered machicoulus galleries useless....its emergence as an irresistable siege weapon was, of course, gradual...Only towards the end of the 15th. century did it become the devastating weapon that rendered traditional fortification methods obsolete." For an earlier account see ROCCHI (1894) p. (v). "La fortificazione moderna ebbe origine in seguito alla intoduzione delle armi da fuoco, quando l'azione delle artiglierie raggiunse tale efficacia da toglieri qualsiasi valore difensivo alle mura turrite e merlate delle fortificazione medioevale". (p. 47) "Soltanto dopo l'invenzione delle polvere e la conseguente sostituzione dell' artiglieria da fuoco dell'artiglieria da corda, si manifesto la necessita di radicali rivolgimenti nell'arte fortificatoria." This type of view runs throughout the literature and there is little point in setting out the differing forms it takes in different authors, for this position functions more as an obviously acceptable principle with which to interpret the sources (and in turn to be supported by them), rather than an idea to be elucidated by the record. It is of course in direct descent from the position expressed during the renaissance and found in the 16th. century printed treatises. Undoubtedly in such writers as Promis and Rocchi the very quality for which it was valued by the renaissance treatise writers -- that is as a general, clearcut, and indubitable principle, which helped to legitimize the art at a theoretical level -- was congenial to their predilections, particularly in allowing them to study the evolution of the subject as one of progress towards a 'scientific' approach to fortification, scientific in just that same sense as was expressed by the renaissance authors, in being based on true, universal, and indubitable principles. As such, of course, it became, in the same way as occurred during the renaissance, a truth basically without a history, because it was simply a universal truth, which only had to be enunciated to be fully grasped. Hence the general pattern of study in the whole area ever since has been almost entirely the examination of structures, and how and when that principle came to be grasped and expressed in the forms of structures. In this context the evolution of theory has little significance, and for example, the use of round towered structures in the later 15th. century, even while earlier evolution towards the later bastion forms had begun, is seen as some kind of aberration or hiatus in the progress towards the later 'scientific' fortification (See HALE (1965) p. 479 "The progress toward the angle bastion made between the 1440s and 1460s...was halted for a while by the adaption of round forms...") and not, primarily, as evidence about how thought about the art (i.e. theory) was developing.

one case of a particular kind of (desirable) approach at the epistemological level, to practical problems, which attitude itself was grounded in a whole complex of ideas and assumptions frequently expressed in many parallel disciplines. Fortification theory was therefore in that period highly integrated with its cultural background. Any account of the evolutionary pattern in the discipline, which ignores this aspect, as a result, ignores an important characteristic of how the discipline of fortification was understood, at least at one level, during the later period, and a fortiori how such an understanding evolved.

Furthermore, even if the parallels between the understanding of fortification in the treatises relevant to the subject of the later 16th. century, and that of other disciplines of the period, is put aside, it must be insisted that to the writers of such works— and they were not infrequently practising fortification engineers — the theoretical understanding of their discipline was an important aspect of their discipline, if only to judge from the extent to which they all commonly expressed such views. Any account which ignores the way this aspect of the discipline evolved therefore ignores an important aspect of contemporary thinking about fortification.

To dismiss such developments as 'scholastic' or as some irrelevant academic-obfustication of 'the real' problems of fortification of the period,[1] even if such theoretical discussions have to be considered pure rhetoric,[2] is to close off from consideration a significant aspect of how contemporary individuals understood their discipline, in favour of the overweening assumption that we today know what 'the real problem' was, whatever contemporaries may have thought.

Thus, even if it were the case that the development of renaissance fortification was primarily a result of the introduction of a new powerful artillery of attack, as is the traditional view, the pushing aside of these other aspects, and the use of that traditional view as the basic organising device for considering the sources of the period, cannot be conceived as legitimate if we wish to understand the ideas and forces which were at work in the field during our period.

However, as noted, it cannot be ignored that the kind of views expressed by so many figures in the later 16th. century on the value of fortification theory, may very well have been almost entirely rhetoric. It certainly can be postulated that the fortification style of the renaissance developed in a particular way for various reasons -- in response to artillery for example -- and individuals, finding that it had developed in a particular way, then, for their own particular purposes -- rhetorical or whatever -- used fortification as an example of a certain kind of discipline to justify their own personal assumptions and beliefs, albeit the subject had its particular nature for quite different reasons.

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1. See for example ROCCHI (1894) p. 2. "La fortificazione è essenzialmente, per necessita storica, arte practica. Nata e sviluppata in relazione alle esigenze di guerra, deve, in base a queste, delineare le proprie forme e stabilere i propri ordinamenti. Le sue attinenza con le arti e con le scienze sussidiarie, come il disegno e la geometria, hanno, in taluni periodi, fatto deviare dal suo scopo la fortificazione falsandone il charattere...Dipendentemente dal carattere pratico della fortificazione, la sua storia deve riguardare exclusivamente le manifestazioni reali sul terreno, determinati da bisogna di guerre e non gli studi e le proposte accademiche. Soltanto col riferirsi alle manifestiazioni reali dell'arte difensiva sarà possible di ricostruirre lo svolgimento."
2. Rhetoric is after all a device of persuasion, and at least at a first analysis must be considered to be part of the process by which the knowledge to which it refers came to be disseminated.

There is no doubt that this sort of process did in fact occur to some extent in renaissance fortification. Such figures as Lanteri and Stevin for example at least to some extent must be considered to have been acting in this way.

Further, although the expression of the mathematical ideology associated with linked ideas at the epistemological level occured most extensively in the treatises of the second half of the 16th. century, and such writing, if it was not totally absent, was at least very much more rare during the earlier period when the forms of structures favoured, was undergoing the most radical changes, hence suggesting just such a pattern of development in practice, yet such does not seem to be a fully satisfactory account.

In the first place, the expression of that cluster of values on the epistemological level, while it is most clearly in evidence in the second half of the 16th. century, was not a new product of earlier technological development. Those particular ideas had roots in the 15th. century, notably in architecture, out of which the military branch became a particular speciality, although to a significant extent less strongly there (most noticeably in terms of the idea of the demonstrabilty of the discipline from general abstract principles, which in general architecture tended to be replaced by the ancient models), but relatively clearly in perspective which was a tool for representation of the very objects military engineers tended to be concerned with. Equally in the crucial decades around 1500 a figure such as Pacioli,[1] studied Euclid with a condotiere and was interested in the application of mathematics to warfare; and was a member of a cluster of figures who interacted at that time and were concerned with fortification, such as Fra Giocondo, who met (probably) Francesco di Giorgio at Naples, and was concerned with later figures such as Leonardo and Bramante, while the San Gallo's interacted with this group.[2]

Thus any rhetorical role for the attitudes towards theory in fortification during the second half of the 16th. century can not be conceived to have developed only after established practice had changed. These attitudes were expressed contemporary with the period of crucial change in the art circa 1500, and were present at least in a general way in the previous decades. Thus such attitudes, as rhetoric, if rhetoric they be, must be conceived to have developed with the practice of the art. This of course does not preclude the possibility that practice developed from other causes simultaneously and in parallel with the rhetoric of the business, but essentially independent of such influences.

But in the case of Francesco di Giorgio -- the one military architect of the period in whom the development of his ideas can be traced in detail -- patterns of thought can be detected which manifest very much signs of a preoccupation with method on the same lines as later was expressed so frequently. In an earlier phase of his thought Francesco took as a principle of design the attempt to provide resisting masses against artillery through the use of round towers at the corners of simple geometrical shapes whose sides tended to flee the attacking artillery. Then at the next stage of development

1. Pacioli is stated to have been in contact with Francesco di Giorgio at the court of Urbino when the latter was working on the earlier stage of his writings (BRUSCHI (1978) p. 39,)
2. While later the same attitudes can be found strongly in Cesarino for example who constructed a fortification tenaille at the castle of Milan. The employment of Oronce Fine on the Milan fortifications while his basic skills seem to have been mathematical are examples of the continuing tradition.

of his thought, although presenting the same detailed notions of design, Francesco expressed the general problem of military architecture in a diametrically opposite way -- artillery can not be resisted. The development of the forms of structures followed exactly this kind of radical shift, round towered geometric forms as understood on Francesco's way had a plan determined in its geometry by the need to resist attacking fire, while the pointed bastion system as it appeared circa 1500 had its basis in design in the needs of flanking fire and the principle of no dead ground. At the theoretical level: that is, with regard to the primary setting out of the basic geometry of the structure, these involved diametrically opposite approaches to design, based on diametrically opposite view as to how to respond to the gunpowder-weaponry of the period. In each case one of a pair of needs was made the basis of theory -- that is of the intellectual activity by which the plan of the fortress was determined and legitimised. But in both cases this type of response was just the sort of response that enabled theories to be elaborated in best accordance with the preoccupation with method and general rules as can be detected throughout the period (although more strongly later): that is through a simple principle or way of approaching the problem which immediately reduces the problem to a matter of geometry which then can be handled -- as least so it was conceived -- in a purely deductive way. Either one set out to try to resist artillery and argued that this or that geometrical form best resisted artillery; or one set out to cater to the needs of defensive artillery and argued, for example, that because of the need to avoid dead ground, one had to use the pointed bastion.[1]

Given the desire to produce geometrical solutions which could be argued to be deductively correct, it is not difficult to see why renaissance military architects focused at different times on each need alone (at the primary level of design that is). Any attempt to have handled both needs simultaneously would have involved, one must assume, a process of immeasurably greater complexity, which complexity, together with the need to balance these different principles, could not have resulted in the type of clear cut deductive determination of the geometry of the problem, which the simplicfication of considering only one of the two needs allowed. The renaissance military architect then at the theoretical level tended to go for one extreme or another, and made little attempt to find a middle ground. The exception to this was perhaps only expressed in those urban enceints as at Treviso, Padua and Ferrara, which used round forms for bastions, which form was considered to resist best, while those bastions functioned probably just as much as stable platforms for defending artillery. But this was a rather temporary phase in the development and these round platforms rapidly died out as the pointed bastion and the principle of no dead ground became the accepted doctrine of the day. A process which it is difficult to see as having occurred, when in the middle decades of the 16th. century an engineer so experienced in the field as San Michele could have suggested that even on occasion that the dead ground left by a round tower did not matter and equally one such as Castriotto with a long career in the business could express the same notion more strongly by stating that such undefended minutiae made no difference, if it had not been for attitudes which

1. One exception to this was the 'forbici' which carried over the idea of the plan resisting because of its shape into the stage where the needs of defensive flanking fire were the order of the day. But this device was somewhat anomalous at the theoretical level, because if no material could resist artillery, why try ? and it was equally not very popular in general.

favoured so strongly the simple mathematical basis of the art that could be elucidated so strongly through the use of the pointed bastion system.

Thus it is difficult to conceive that the preoccupations with theory method and mathematics so prevalent during the period did not at the very least tend to push the renaissance military architect, when he attempted to work out his general approach to design, into one extreme or another -- into concentrating on defensive fire, or on resisting masses -- for it was by cultivating one of these extremes that he could arrive at what he considered was a rational approach to the art.

Hence, while there may undoubtedly have been a degree of rhetoric in statements about mathematics and method throughout the period, it seems equally true that these same attitudes tended to push designers towards one simple design rationale or another. But, this kind of pressure from preoccupations at the theoretical level can not obviously be considered a cause in itself, for clearly it was a 'multiplier' or 'tendencey' rather than any casual agent in itself. It thus becomes necessary to consider other aspects of the problems of fortification of the period which could have acted to tend to produce that change from concentration on the structure as a resisting mass, to contentration on the needs of flanking fire, in design, on which such a multiplier could act.[1]

Firstly the development of gunnery and its significance in this realm, must be considered.

It is difficult to question the idea that during the earlier phase of renaissance fortification, before roughly 1500, the use of heavily scarped walls and relatively squat solid structures -- in comparison to many castles of the middle ages -- were a response by designers to the threat they conceived to exist, to such structures, in the use of projectile weaponry, particularly of the gunpowder type.[2]

It is equally clear that the Italian peninsula during the last decade of the 15th century became aware of and subject to a new force in the realm of attacking artillery, and that this occurred with the descent of Charles VIII into Italy in 1494.

Perhaps the clearest evidence on the employment of this new artillery in the Italian peninsula during this decade comes from the anonymous account of the siege of Pisa. Our informant explained that the besiegers in their attack on the town had artillery of which

> La grossa era da quaranta booche; e il resto, secondo la verità, ascendeva in tutto ad pezzi centocinquanta.[3]

With regard to the larger guns employed, he explained at one point the enemy planted

> ....quindici bocche de artiglierie grosse, intra la quale erano tre bombarde che gittavano di pietra libbre centocinquante in dugento...[3]

and that the first day the enemy battered

> ...le torre e il muro, dando seicentocinquantatre, e che dice settecentocinquantacinque botte di palle, come ferree, colate e bronzine, di peso di libre settantacinque, sessanta, quarantacinque e trentacinque, connumerando in questi li colpi trasseno le bombarde grosse che tiravano pietra del peso ditto...[3]

1. Again it is that radical shift in Francesco di Giorgio's thought from one extreme to the other, on the possible responses to artillery, even though his drawings show no similar radical alteration and he gave no different detailed description of artillery between the two stages, that makes it so plain that what can be detected in structural responses is not simply an accidental quality, but is characteristic of the type of thought of the individuals concerned.
2. In support of this is the building proposals at Foligno of 1540; the remarks of Alberti around mid century and the later writings and designs of Francesco di Giorgio for example.
3. La GUERRA del Millecinquecento (1848) p. 365/7 for all these passages.

In contrast the artillery that Francesco di Giorgio described comprised bombards commonly firing 300lb. stone shot and smaller, and smaller guns and mortars, equally firing stone shot, while only the lightly shotted pieces -- the passavolonte, basalisco, cerbottanta, spingarda, arco buso, and scoppetto, used metal shot of which the greatest was only of 20lb.[1]

The employment of a medium shotted artillery using metal balls with a rapid rate of fire as indicated by the informant at the siege of Pisa,[2] was just the development that took place in French artillery during the period.

The five artillery trains employed by Charles VIII in his 1489 campaigns included "58 cannon, 33 grandes couleuvrines, 13 couleuvrines moyennes, 45 faucons", one half the "grosses couleuvrines & canons" using stone and one half metal shot.[3]

The Venetian Ambassador at the court of Charles VIII explained his weaponry thus

> Le artiglierie del re sono bombarde che tirano belotte di fero, che se fossero di peitra peseriano circa libbre cento: le quali sono assestate su carrette con un artificio mirabile, in modo che senza zocchi e altri preparamenti da portare, tirano i loro colpi benissimo...quando vogliono debellar qualche luogo, che ruinano le mura con queste medesime bombarde molto più facilmente e in manco spazio di tempo che non si faccia con le nostri grandi.[4]

Informants again wrote to Piero de Medici from Lyon in June 1494 on the eve of Charles' campaign:

> Costoro (i.e. the French) portano con loro e per mare e per terre uno numero grandissime di artiglierie tutto in sulli carri: le artiglierie non sono troppo grandi, che sono di trecento in cento libre; ma hauano le pallotole de ferro, che sono maggior peso: e comprendiamo, per darli maggiore forza, le fanno molte grosse nel cannone o nel culaccio dove si mette la polvere; e a poco a poco vanno diminuendo, in modo che nella bocca sono quasi sottili, e hanno nel mezzo certe alie de poterle appogiare e fermare in sul carro: e ogni artiglieria ha i suo carro, e li bombardieri, e le sua pallotole, e una numero grande di cartocci di polvere acconci e misurati per detta bombarda.... Dicono queste loro artiglierie passerono uno muro di otto braccia, che lo forano; e, benchè il buco sia piccolo, per la gran moltitudine de'colpi, bisogna che tutti li macini, perchè cominciano a trarre in quella benedetta ora, che mai restano o dì o de notte....in modo che, non avendo mai requie, quelli di dentro non possono avere spazio a fare ripari, e non fanno debio niuno in uno dì pigliare Livorno, in due Pisa....[5]

This picture of a rapid firing, mobile artillery, of medium weight, and depending mainly on numbers and these qualities to provide a more effective besieging weaponry, indicated as present at the siege of Pavia, and in these ambassadors reports, is supported by Giucardini's account. He stated

> ....the french men fordging peeces of farre greater facilitie,(than that of the earlier weapons), and of no worse mettale than brasse, which they called cannons, vsing bulletts of yron, in place of those of stones of the first inuencion, vsed to drawe then vppon wheels, not with oxen (as was the custom in <u>Italy</u>) but with horses, and with such agilitie of men & instruments appointed to that seruice, that they almost kept march with the armie. And being brought afore townes of walls, they were braked and planted with an incredible diligence, and with a very small intermission betweene the shotts, they battered with such violent furie that, what before was

1. MARTINI (1967) p. 418/19. This is from Francesco's later draft.
2. See also a letter of 7 July 1499 from Florence "Essendo in procinto della expeditione contra a'Pisani et dubitando no ci manchino per questo effecti palle di ferro da trarre con le artiglierie". ANGELUCCI (1869) p. 283.
3. CONTAMINE (1964) p. 266/7.
4. ALBERI (1860) p. 23. From the <u>Relazione di Francia</u> by Zaccaria Contarini 1492.
5. DESJARDIN & CANESTRINI (1859) p 401/2.

wont to be done in Italy in many daies, they dispatched it in a few houers..[1]

The effectiveness of this artillery clearly was not so much the invention of a new technological artifact in itself, i.e. a new type of gun that delivered a much greater blow against any opposed barrier, than any earlier single gun had done before. It was rather the more effective employment of artillery along with its development in ways in which, by becoming more mobile and rapid firing, with each shot having some reasonably high degree of effectiveness it was abe to do rather greater effect than the older weaponry. It thus depended for its effect on numbers, and, in the last analysis on the number of shots fired, to damage structures.

But if Charles' VIII's artillery thus depended on numbets in the sense that its effectiveness arose from the cumulative effect of a large number of shots, the development of artillery cannot be conceived as a particular invention effect alone. If the earlier types of weapons in use had been increasing in number so as to give a similar effect, even though perhaps not to the same degree, they must be conceived to have had a similar effect.

To some extent this in fact does seem to have been occurring in Italy. Francesco di Giorgio for example wrote

> ...ora ogni grossissima Bombarda (,oltra alla virtù sua,) sì spesso et indifferentemente in ogni loco e trattabilmente si mette nelle in opera.[2]

Again, a verse form 1482/4 supports this pattern thus,

> ...sei grosse Bombarde si pintoe/ Alla gran Roccha, dicta Figharolo,/ Più de tre millia colpi de'Bombarde/ Descaricò alle Mura ghagliarde....Che della Roccha gran parte guastata...el valoroso, e gran Duca de Urbino/ Molte passavolanti avea piantato/...E similimenti fuocho lavorato;/ Serpentine, e grosissime bombarde,/ Senze poi numerar molte spingarde...El Ducha Alfonsa armigero valente/ Fece molte Bombarde apparaechiare/ Alle Terra d'intorno prestamente/ E molti grandi e horribili mortare, e briccole, e trabucche similmente...[3]

While the guns mentioned by this author are often of the smaller type the

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1. GUICCARDINI (1579) p. 45. Guiccardini of course utilized the ideas of the new powerful artillery of Charles VIII as part of his explanation of the disasters of his period ushered in by Charles' descent into Italy: "Those artillery were the cause, that all Italy stoode in great feare of the kings armie...." he stated just after this passage, and in his Maxims (1845) 64, that "Before the Year 1494 at which time the ambition and blindness of Duke Ludovico opened the road to the ruin of Italy, the manner of War was, as every man doth know, very different from what we presently see. The storming of Cities was but scratches, the Battle of other sort, and scarce a drop of blood shed." Thus he may have tended to exagerated somewhat the new power of artillery. But his account tallies with others of the period and undoubtedly this is how artillery was perceived during the period. This phase of gunnery development amounted to the introduction of guns in the form that they were to keep for many centuries. Later lists of guns from the later 16th. century on show cannon with metal shot up to 60/80 lb. plus as the standard weaponry of their times. See for example tables in HOGG (1970). Stone shot however lingered on CILLARD (1586) discussed weapons using it as did FRONSPERGER (1571/3) and the Spanish navy had many such weapons in their descent against England of 1588. (See LEWIS,M(1961))
2. MARTINI (1967) p. 424.
3. See over p 250, n 1.

author clearly felt that what was significant was the number of this weaponry.[1]

Further if the shift from the attempt to meet the power of attacking artillery by means of the best resisting form, to attempts to design primarily for defensive fire, as a response to attacking artillery, is to be accepted, it seems to be inescapably necessary to allow that some such greater use of artillery must have been taking place before the French invasion. For, in the first place, that change is evidenced in structures before that event. At Brolio for example, perhaps more tentatively, but more clearly in the citadelle and enciente at Poggio Imperiale. However as this last structure was building all through the 1490s and the date of design of what is actually extant is by no means definitely established, this might be conceived to be a structure very much influenced by the French invasion. The temptation is then to also see Francesco di Giorgio's later views on the irresistability of artillery as a product of this event. This however is much more difficult. Francesco di Giorgio insisted on the irresistability of artillery yet the artillery he described bore no marks of this new medium weight metal shotted weaponry of the French; and equally his text seems to hold no echo of the events surrounding the French invasion. It is difficult to see him being strongly influenced by this new French artillery and not mentioning the surrounding events of its impact on Italy which contemporaries felt so strongly. He thus evidenced a shift in attitude too early for it to have been caused by the French Invasion, and the clear picture emerges of a gradually increasing effectivness of artillery all through the period.[2]

Thus the increasing power of artillery in attack seems to have been as much a gradeal process as any sudden invention, albeit the increasing use of the weaponry in Italy was probably very slow and dilatory (as Guiccardini

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1. ANGELLUCI (1869) p. 270/4. One has to allow a certain amount of poetic licence here of course. The verses referred to the war of Ferrara and Venice in 1482. A diarist of Ferrara (Ugo CALEFFINI (1938/40)) penned the following remarks, Jan. 1482"....la Signoria de Vinesia principiono a mandare.... art(i)arie in quantitade....il duco....mandoli grandissima moltitudine de bombarde..." 3rd. Feb. "Tutto il giorno si attese a mandare nel Polesine di Rovigo...arma, spingarde, bombarde et altri art(i)arie". (Another diarist of Ferrara stated the Duke sent all the artillery of Reggio, Modena and Rovigo.) May 23 "Per avere piombi da fabricare palle da cannoni, il duca aveva fatto togliere i piombi che erano al palazzo vescovile di Ferraro. Egli aveva mandato a Fieasolo 30 carioli con spingarde lunghe e grosse e con bombarde. Nel nostro campo erano 3.000 schioppettieri e piu di 4000 balestrieri." May 27 "speditione...per spianare il bastione che i nemici avevano costruito...cento barilli de polvere de bombarda e ventiocto boche de spingarde, et bombarde assai et altre artearie in quantitade." 17 June "Se atese a furia a fare duj boni bastioni et forti... cum 18 boche de bombarde, spingarde et passavolanti, fortissimo et grande... Oltre la bombarda nuova in construzione, che getterá palle di 300 libre..." See also ESSENWEIN (1872/7) 1444 Wien "Der Stadt Zeug", "2 Kuphrein viertheil puchsen vnd 8 klain kuphrein Pűchsen...und 7 Kuphrein püchsen sind new gefasst. 5 Kuphreine Hagkenpűchsen und 98 kuphreine Handpűchsen" and others. 1471 "Der berühonteste Buchsenmeister jener zeit war Martin Merz zu Amberg der von sich erzählt, er habe in den gennanten beiden Jahrer 372 Tonnen Pulvers verschossen". 1479 Inventory of Wurtzburg "9 Stein buchsen, darunter 2 kammerbuschen, 8 Tarasbuchsen, 16 Böcklein, 3 neue Schlangenbuchsen...105 Hakenbüchsen, 226 Handbuchsen". 1483 "Zeug der Stadt Breslau","die grosse Buchse, zwei zunehst der grossen. Fünf Virtel Büchsen, 1 Glot. Eilf lange Hauffnitzen. Zwanzig Hauffnitzen, 1 St. Eine Beuchichte und Eine Kammerbuchsen. Drei grosse lange Tarris Buchsen. 1 Gl. Funfhundert vierzehn Hocken Büchsen mit den eisernen". 1488 "Zeug register der Stadt Passau", "die Wulpin, das Wöffel, eine grosse Taras... 2 Taras auf Scheiben, 5 Bockbuchsen, 12 eiserne Büchslein, einen kupfernen und 2 gegossene eiserne Mörser...." The sources on this point of numbers are however spotty and very often equivocal, particularly with regard to weight of shot. It is really the increasing mentions of bombards and other types of guns in the sources as the time progresses and the way they are mentioned as the ordinary paraphernalia of war, that suggests their increasing employment. The pattern seems however to a good extent to be an increase in the number of small calibre weapons, more than any others.

2. We have already three stages, the early one to cause the early modifications. The next as evidenced by Francesco, and then the period of the new French weaponry.

indicated warfare was before the French invasion) and the French lessons meant a radical increase in the rapidity of the sort of progress in question.

But whatever the relative rates of progress in the employment in of artillery as an attacking weapon in siege warfare were, it appears fairly clear that the significant advances introduced by the French were related quantitative developments as well as qualitative one in weaponry. Thus if the use of artillery was becoming an increasingly important aspect of siege warfare as a weapon of attack, it seems difficult to understand why it was not also becoming an increasingly important weapon of defence.

The siege of Pisa, again, makes clear the significance of the employment of defensive artillery in siege warfare, particularly in that it occured under conditions when higher fire power rates of attacking artillery were in evidence. The account of the siege from the defenders point of view, that is of our anonymous author, reads very much as an artillery duel.

On the close approach of the Florentine army, because they encamped where they could not be "flanked", a ravelin was built "per potere battere il nimico per fianco." Then in the early stages of the siege our informant tells us

> Noi che vedevamo il nimico sollicitare la oppugnazione e il battere le mura con poca paura e senza potere essere offeso de noi; sì perchè la torre di Stampace non li posseva più offendere, per esser continuamente battuta: sì etiam che le nostre artigliarie erano state levate con le difese per ordine e consiglio di un nostro bombardiero: feccemo aprire da scarpellini certe nostre bombardiere basse che pareano (postovi e quelle le artigliarie) offendere potessino il nemico che vagava sicuramente la campagna: e incontinente aperto quello, vi furono piantata due nostre grosse artigliarie, videlicit uno cortale et uno passavolante,[1] e facendo il bombardieri buono frutto per quello giorno, ne uccisono e guastorno buon numero, chi dice sesant e chi più.......... lo secondo giorno, veduto il nimico il danno li faceano quelle artigliarie, deliberò ovviare; e la notte seguente, alla volta delle ditte nostre bombardiere vi voltò quattro bocche di fuoco grosse; e sollicitando il trarre, per tutto il terse gorni piu non possemo usare le nostre bombardiere e l'artigliarie, perchè ce le offendeva, e non manco chi le serviva; e quel dì li bombardieri inimici ci ruppeno uno cortale: non possendo noi più tirare con quelle e battere in nimici...e cosi feceron, che per quel giorno e l'altro seguente rovinoron di molta muraglia....[2]

Then

> Veduto li inimici esser caduto il muro fuori de sua espectazione, mutorono proposito, e voltorno le lor forsa e artgliarie a batter il rivellino di Stampace...qual con ogni sollicitudine battendo le artigliarie, comincerono a passar e offendere li nostri, che senza indugio lavoravano e riempievano di terra quel loco. E però, veduto il danno e pericolo imminente, dliberamo obviare; e subito fatto piantare nel rivellino della Cittadella Vecchia appresso lo Arno, uno passavolante mezzano, qual operava maestro Gerardo bombardiere lucchese e pisano, optimo maestro di epsa arte: il qual tantemente tirrò quel giorno che senza dubio ucise bombardieri inimici; ruppe artigliarie e fece gran danno al campo. Talchè il nimico fu costretto ritirare le sue artiglierie più indentro, che da quel rivellino non si potessin vedere nè offendere... Parvici ancor offender quelle che battevano il rivellino verso il borgo decto....facemo con celerità piantar in quella Cittadella uno cortale, uno passavolante grosso, e uno basalichio[3] sotto la rocca detta Ghibellina...

1. 'Passavolante' according to Francesco di Giorgio was c. 18ft. long firing a composite iron and lead ball of c.16lb. He described a 'cortana' as 8ft. in the barrel and 4ft in the chamber firing a stone of 60 to 100lb. (1967) p. 419.
2. p. 368 op. cit. Guiccardini later described these events thus "The shot.... so thundred vppon the soldiours in the camp, together with the great artillerie from the towne, specially from a plot forme that was vppon the Toure of Sainct Marke, that the whole Camp was constrained either to remoue their tents to ha e better couuerture, or els to pitche their Cabinettes within the ditches.(1579) p. 231.
3. According to Francesco di Giorgio a 'basalisco' was 22 to 25 ft. long. It shot (pietra) of whatever metal c. 20 lb. GRASSI (1833) stated "Nome dato ad un cannone di gran calibro del secolo XV" firing shot of 48/100 lb. c. 20' long. and quoted Bembo who stated it was 22' long with a shot of 100lb. of iron with a range 'se impedita no era' of 3 miles. Francesco di Giorgio's description seems the more reasonable. One might plant such weapons as he describes with some speed, but hardly very much larger guns, particularly without making mention of the labour involved.

e per fianco battendo trovamo in pochi colpi li artigliarie inimiche...
(and) facevano le nostre non piccol danno all'inimico....Per il che le artigliarie inimiche furono constrette per quel giorno più non tirrare.... ma la notte seguente...li fortificarono con ripari e gabioni piene di terra, sicche non possevano più essere offesi....[1]

However the fortress of Stampace and its ravelin being ruined, the enemy attacked and "si comincio una crudel battaglia" in which the enemy had many casualties "perche le nostre artigliarie della Cittadelle gli offendeva mirabilmente". The enemy however being superior according to our informant, the Pisans attempted to attack them with "fochi lavorati"; but by misfortune a stone came and broke "un fiasco" and everything was set alight so that both sides retired. Upon which the enemy having another way of getting up took the fort and immediately began repairing and protecting themselves. However

...quello loco...per esser fuori della città, non ne prendemmo molta molestia; perchè prima si perdessi, con gran celerità facemo tante riparo quanto tiene dal principio di quello, appresso a stampace, sino....[2]

The enemy then with many "marraioli e mastri d'ascia" attempting to consolidate himself on Stampace

.....subito facemo piantar un cortaldo....e piantato tirrave continuamete, tal che impedi il disegno del nimicio...Per quel di non si intese che esso facesse nuovo impresa; escetto volti due bocche di fuoco grosse ad la Porte ad Mare per impedir lo nostro cortaldo, e tagliar quel muro....[3]

The defenders then having made some repairs, conceived

....ci parre necessario per contra a Stampace nel fosso....far una casamatta per offendere lo inimico, se per lo muro rotto ci temptassi di battagli; e così perfetta a tre balchi di buon trave, vi collocamo dentro all' ordine suo nuove bocche di artigliarie.[4]

But

Il nimico, vista questa opera di casematto, deliberò con suo potere levella, perchè conosceva di quanto danno li posseva essere....con gran fatice ne fece un'altra che batteva le nostra: e piantato vi due bocche di bombarde grosse, la offenderon si che in due giorni la roinorono....e così sumo necessitati levare de nostre artigliarie e abadonare le casamatta; benchè dereto ad quella poco lontano in pochi giorni ne facemo un'altra, che non posseva essere offesa dalla inimica; et è oggi ancora in piedi.[4]

The enemy then attempted to work up to the walls, to ruin the repairs of the defenders and give battle. But, according to our informant, many of the enemy sickening, they could not achieve their ends, and also

....che per fianco in sul nostro riparo vi avessimo di molti falconetti, e altre bone artigliarie ferree, quale averiano fatto macello delli inimici se avessimo presunto darci battaglia....[5]

Not, as our informant remarked, through

...alcuna detta viritu nostre, che in ogni pericolo e conflitto l'ha esso ben provata.[5]

However the enemy expecting to be newly reinforced the defenders still did not lose hope

...per esser noi ben fortificati e di ripari di artigliarie e omini...[6]

The enemy however

...continuamente batte con artigiliarie or la Porta ad Mare, or il suo ponte, talhor li ripari, e qualche volta la città, con trabucchi e altri mortari.[7]

But the defenders continued to make repairs in the face of the enemies attack, and,

1. Op. cit. p. 269/70. 2. p. 370/1. 3. p. 372/3.
4. p. 373. 5. p.374. 6. p. 375. 7. p. 376.

> Non contenti ancora ad questo, deliberamo alle quattro boche di loro artigliarie opprovi le nostre.....E piantatovi tre bocche di nostre artigliarie grosse, battevano le inimiche facendo non poco danno, come li loro ad li nostri; e per offendare il nimico quanto possevamo, e più se dir lice, vi conducemo il nostro passavolante grossissimo chiamato dalli inimici il Bufalo; il quale cominciò ad percuotere le artiglia de inimiche, e quelli che servivano. Veduto questo, lo inimico comandò tutte le artigliarie si voltassino al Bufalo...[1]

to the effect that the Buffalo was damaged. But soon however it was got back into working order so that

> Per il che, si estima il nimico leverà le sue artigliairie di Stampace, che non ve le può tener, benchè con molte balle di lana le guardi; perchè il Bufalo roina ogni cosa....[1]

Thus the successful defence of Pisa in 1499[2] involved the application of defensive artillery as potentially able to cause considerable damage and embarrassment to any attacker even though that attacker could call on the use of substantial and rapid firing artillery, and yet employed, apparently, just that weaponry that had been available in the decades before.

It seems reasonable therefore to conclude that military architects who earlier had attempted to design on the principle of resistance to attacking artillery, had done so only at the cost of ignoring, or at least not giving sufficient attention to, the significance of the use of defensive artillery in response; that further with the increasing employment of artillery in siege warfare, both in defense and in attack, they were unable to continue to ignore this need to the extent that they had done before; that, in the face of increasing tension between the practice of siege warfare and their favoured design principles, their preoccupation with 'method', resulted in their swinging to the opposite extreme and insisting that the needs of defensive guns had to become the basic determinant of design theory; that the very radical nature of the jump from one extreme to the other, which resulted, created a need for an explanation, so that the conception of the new irresistable artillery of attack both explained that change in design methods, and legitimised the later design techniques which concentrated on the needs of defensive fire at the theoretical level, as seen in the treatises of the later 16th. century. The very lack of any middle ground between these two diametrically opposed approaches in both the earlier and later phases, emphasises the way in which designers, at the theoretical level, made little attempt to cater for both resistance to attacking artillery and the needs of defensive guns.[3] It seems equally clear that it was

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1. Op. cit. p. 377.
2. For further discussion on the siege of Pisa and the contention that the Pisan resistance was only successful because of the treachery of the Florentine commander, Paolo Vitelli, see below p. 261.
3. This of course appears by concentrating consideration on the round barrel forms that were often used in the later 15th. century and ignores the gradual developments towards the pointed bastion as found in many small hill towns, as noted by HALE (1965). But those are the very developments that appear to have been choked off by this preoccupation with these round resisting forms. It also ignores such structures as those built at Treviso, Padua and Ferrara, as noted above p. 240, but these were very much in the transitional phase, and the approach used in them was not followed up. It equally ignores the later frequent mention of the 'forbici' to give resistance, but again as noted this was not a very popular device. The strength of this tendency to go to extremes at the theoretical level can be seen in the later period when the trace of the fortress was determined by reference to the functioning of defensive guns -- in accord with the principle of no dead ground. In practice of course the curtain had some resisting power, while if theory had been pushed through to its logical conclusion, given the irresistability of artillery, it would have been considered pointless to build it at all. Theory was equally incoherent in this phase in the use of the principle of no dead ground, for if artillery was irresistable the point of the bastion was bound to be demolished, leaving roughly round masses anyway. But again it must be insisted that theory provided the justification of the pointed bastion form, which was the basis of the great majority of schemes in practice.

a similar preoccupation with method which meant that progress in terms of types of structures built did not occur by way of a gradual evolution in which ad hoc solutions, differing from site to site, and varying over time in the way these different needs were catered for, were tried, until the optimum solutions in terms of balancing these needs, appeared.[1]

Thus on the one hand it was the actual behaviour of designers during the period that tended to create the central causal role for attacking artillery;[2] but on the other, the increasing opportunity the new weaponry gave to the defender to punish the attack, even as it gave the attacker a more effective weaponry against fixed defences, was the situation which determined the sorts of responses designers could make. Equally, by ignoring the needs of defending artillery, the very weapon that could, at least on occasion, at the very least do something to militate against and negate the power of attacking artillery, the power of that attacking artillery was bound to be perceived to be that much the greater.[3]

Therefore, just as in the later 16th century fortification theory can be seen as the result of a blend between preoccupations on an epistemological level and the exigencies of warfare and the practice of the art, so equally the developments of the earlier period appear as a blend between the search for method and the exigencies of gunpowder warfare.

This whole pattern can then be seen to be the result of the very simple fact that the possibilities of the use of defending artillery in defence were slow to be taken up and given sufficient emphasis by designers: indeed it is not too great an over-simplification to suggest that the whole developmental pattern of renaissance fortification in its practical and theoretical aspects, with, in the later period its justification in the need to respond to an irresistable artillery of attack, flowed from this pattern.[4]

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1. An approach which, at the very least, can be conceived to be detectable in a writer such as Reinhard. Again the earlier developments in certain small hill towns are closer to this pattern.
2. In Francesco di Giorgio for example one finds in the earlier period his emphasis on the need to design by reference to resisting masses, and in his later writings the contention that artillery is irresistable. His contention then that this was a new situation, and that he did not wish "imputare ad ignoranzia delli passati fra li quali non dubito essere stati ingegni perspicacissime" blame for past failures, makes clear that he was in part coming to terms with his own earlier views to the contary, and equally was trying to justify earlier efforts so that the rupture would not be too great.
3. It is this sort of interaction that makes it so difficult to accept any mechanical causal pattern in the whole area. It might be suggested that the armament of fortresses in the earlier period seems to have been to slight to have provided a satisfactory defensive arsenal. But here again there must tend to be an interactive problem. It is no good supplying fortresses with many guns if they can not be emplaced in defence. But it is no good designing structures primarily in accord with the need to emplace defensive guns if those weapons are not likely to be available.
4. There were of course other factors at work, on which see below.

III: (3): The wider background to renaissance fortification

(i): Favourably and unfavourably progressing conjunction systems

In the evolution of renaissance theory of fortification, two interacting elements can be discerned: that is, the needs of defensive structures to take account of contemporary gun-powder weaponry, and a certain preoccupation with 'method', and social considerations about the status of the knowledge involved and that of its producers and users, involving in the later period an emphasis on the needs of defensive fire and the principle of no dead ground.

But in itself such a description is hardly to be considered a satisfactory account of the evolution of renaissance theory of fortification, for these elements were themselves in a process of change. In all probability the effective employment of artillery gradually increased throughout the period, and it certainly did in the later 15th. century in France; equally that cluster of ideas which were related to a theoretical and mathematical approach in practical matters was ever more strongly emphasised as the 16th. century progressed.

Thus over a period of time the process cannot be conceived as one of the continuing interaction of the same factors, when the very factors at issue were themselves in a process of change.

This is particularly clear when the practical mathematical sciences as a whole, with fortification as but one member of that group, is considered.

Firstly, the cultivation of a particular kind of theoretical and mathematical approach in these disciplines did not occur to a constant degree of intensity throughout the 15th. and 16th. centuries. While some disciplines such as perspective began to be cultivated in this way relatively early, during the 15th. century, others, such as ballistics on this pattern only began to emerge during the 16th. century. Equally the intensity and frequency of expression of the desirability of a theoretical approach within the different disciplines, increased as time went on, and it was only in the second half of that century that such views can be taken to form a commonly accepted approach in practical matters. Thus, to take the wider acceptance of this general position in that later period as a factor tending to facilitate and induce that same approach in the particular case of fortification, when the appproach involved appeared rather earlier in that discipline, seems to be incoherent. Yet the treatise writers of the second half of the 16th. century, by virtue of their quoting other disciplines as being successful under the theoretical and mathematical approach they favoured in fortification, clearly used the wide-spread acceptance of such views to support their approach -- which very approach had clearly appeared earlier, and whose very existence helped to spread those sorts of views. In other words we seem to have either the future pattern determining earlier events, or, alternatively, the wide-spread acceptance of theoretical technology in the later 16th. century cannot be considered to have been an influence on the course of renaissance fortification.

While the former is clearly unacceptable, the latter seems to raise grave difficulties. If it is assumed that the widespread acceptance of theoretical technology in the later 16th. century had nothing to do with the developments of renaissance fortification, it then would seem to have to be accepted that it was simply some happy chance that the approach of the earlier period in the subject was such that during the later period similarities could be found between that discipline and so many others.

Of course, to this it might be objected that it was by no means a happy chance that this occured, that it did occur because of the underlying geometrical (or mathematical) nature of reality, and as a result the protagonists of the theoretical and mathematical approach being simply cultivators of the 'true scientific method' -- or at least an early form of it -- they were bound to be successful with that approach once it was properly cultivated, and that that pattern was bound to arise when success was added to success as the 'scientific method' spread, so that later successes could be used to further support the desirability of that approach. (Very much as contemporay writers would have had it of course.)

But, while such a view seems reasonably acceptable, perhaps even the only obvious one in areas such as surveying and dialling -- which were real mathematical problems, were they not ? -- in the case of fortification itself this is by no means so clear. While surveying and perspective for example may relatively easily be conceived to 'represent' some 'underlying mathematical reality' this is by no means the case in fortification, for there, the geometry was impressed on created structures. Further and more genally, even if one postulates some underlying mathematical reality, the fact that in certain disciplines, the general approach of fortification and the other areas of the practical mathematical sciences noted in the later 16th. century, was by no means altogether successful, particularly in naval architecture and perhaps to some extent in ballistics, indicates that the general approach cultivated and used, was by no means a guarantor of success, that at the very least, it was some 'lucky chance' that particular disciplines in which such an approach could give success, did happen to be cultivated.

The dilemma thus remains, that either the future is to be considered as determining the past, or the support other disciplines were claimed to give fortification, by the treatise writers of the later 16th. century must be considered irrelevant to the development of renaissance fortification. However the last point suggested, that is that it was (to some extent) a happy chance that a certain number of disciplines were cultivated in which the approach as by the fortification treatise writers was successful, provides the clue to the solution of this problem.

Clearly the cultivation of, and writing about fortification theory in the 16th. century did not take place in a vacuum or in a static world. Such activity took place in a world where other changes by no means irrelevant to fortification, in different ways and at different levels, were taking place. In so far as those wider changes took place in ways which were consistent with, and tended to support the way in which fortification as a discipline proceeded, even though the way it did proceed was at least in part determined by particular details of the problems of that discipline, so much the more must the particular approach of fortification have been further supported. Conversely had such changes not taken place, or had changes occurred inconsistent with and contary to the approach in fortification (for example a great renaissance in Aristotelian knowledge in an area relevant to fortification) so much the more difficult would it have been, one must conceive, to support that approach that was found in fortification.

Thus it appears necessary to postulate two types of continuing change as possible in the case of the cultivation of a discipline such as fortification. One, in a system with favourably progressing conjunctions, in which variables external to one particular discipline, change in a way favourable to that discipline's pattern, or changing pattern, determined at least in part, by particular problems of that discipline. In short in which inter-disciplinary changes mutually support each other. In contrast, in unfavourable progressing conjunction systems the reverse may occur.

Thus the relationship of fortification during the renaissance to the other areas of the practical mathematical sciences was clearly that of a favourably progressing conjunction system, which must be conceived to have continually supported and tended to reinforce the approach of the theory of fortification of the period; equally the whole system of the practical mathematical sciences of the renaissance must be considered to have had a similar pattern; while again, such a sub-group as navigation, geography, cosmography and surveying, with rather diverse roots and their own particular problems, developed in such a coherent way with so many conjunctions as to provide by the end of the 16th. century a single mathematical description of the universe.

On the other hand the early phase of renaissance fortification theory basing design mainly in the need to resist artillery, must be seen to have been, in relation to the increasing effectiveness and use of artillery in siege warfare as time went on, a case of a progression of increasingly unfavourable conjunctions with that development -- that is the more artillery was employed in attack the greater was bound to have been the difficult (and hence costly) to construct to resist it, while similarly the more artillery was used in defence the more that approach was out of tune with the contemporary need to take account of that fact centrally in design. The degenerating program was thus replaced by one more favourable to this need, which mutation in turn allowed the general program of a search for method in fortification to become a progressing program.[1]

III: (3): (ii): The progressive system of later renaissance fortification theory

(a): The height factor

Sixteenth century fortification with its basis in the needs of defensive fire and the cultivation of the pointed bastions trace interacted with various needs in a favourable way. Gradually, though only very slowly, during the later 15th. century defensive structures were built with a lower profile.[2] Undoubtedly this was a response to two different factors, to some extent or another. Given the threat of attacking artillery a lowering of structures, particularly into the landscape, while maintaining a reasonably scaling height by using a relatively deep ditch, will have tended to have masked the main

1. It is not impossible of course to conceive that the idea of resisting forms might have been developed in a theoretical way by reference to their geometry. But such could hardly have had the 'elegance' of later fortification theory with its complete divorce from material.
2. See HALE (1965).

structure from the attackers fire.[1] Equally the use of relatively low squat structures must have facilitated the provision of solid platforms necessary to support defensive artillery,[2] and that same profile will have enabled the defending guns to have swept the surrounding coutryside all the more easily.[3] During the 16th. century structures tended to retain a relatively low profile, and, particularly when they were of any substantial size, to become masses developed very much in plan rather than in height. Thus the plan trace, the foundation of the fortress, as it was often termed, determined by the principle of no dead ground, in accord with the plan geometry of the problem all the more easily became the focus of the theoretical approach.

However the tendency to reduce the height and to sink the fortress into the landscape was rarely if ever pushed to the extreme. For, while it seems eminently reasonable in principle to design in this way, particularly if the fundamental problem of design is seen to be an attempt to respond to 'irresistable' (attacking) artillery. On the other hand the need to emplace defensive guns was not so well served by any too great a lowering.[4] Too low and they would tend to be commanded by the attackers weaponry, from earthen ramparts which might always be build relatively easily to allow this, even if it was ensured that the fortresses was so placed that no natural rise allowed this.[5] The compromise generally favoured in the face of these conflicting needs was then to design relatively low structures with cavaliers on which to mount the defensive artillery. The result was that the plan trace handled in a theoretical way could remain a major focus of design, while the 'theoretically' desirable condition -- in the face of irresistable artillery -- of masking the strucutre completely in the landscape[6] was partly fulfilled, while at the same time it

1. This is a well recognised pattern. It can be found in Francesco di Giorgio for example, on which see over.
2. See for example above p. 236, n. 1. At the siege of Pisa, according to Guiccardini, Paul Vitelli abandoned the fortress of Stampace because it had been shaken by the guns firing from it, as well as at it. ((1579) p. 233.)
3. Diego Ufano for example writing in the first years of the 17th. century outlined the problems of depressed fire then. (UFANO (1612) p. 151) He explained "because of the imbasing of the mouths of the Peeces on high beyond their proper uses shall cause the Carriages, Extrees or Wheeles to break and be out of order and cannot long be servicable, which I have observed in divers places." (ELDRED's (1646) translation p. 156.) Earlier this type of mounted artillery may not have been in use but the tendency for a depressed piece to lift on recoil must have tended to create grave problems. The 'sything' effect of a shot fired from a relatively low level nearly parallel to the ground one imagines had significant advantages.
4. Ufano had a section for example, in which an experienced Captain argued at some great length to convince a new General that given equal power in battery outside and on a town wall, those in the country were in less danger from those on the wall than vice versa. The general insisted that those on the wall firing down onto the attacking guns would do the most effect. But Ufano insisted those in the field could have better protection built around them.
5. See for example Reinhard II p.113 on planning fortifications so that heights could not fire into the rear of the opposite front of the fortress. Ufano indicated how common such earthworks had come by the beginning of the 17th. century. See also [3].
6. The advantage of such lowering was probably not as great as it might at first sight appear when the aim of the attacker to reach the edge of the fosse with his batteries, is considered. Diego Ufano, for example, writing at the beginning of the 17th. century explained with regard to the best distance of an attacking battery, that "it is the opinion of many good soldiers, to advance as nere as possible, even to the very Rampiers and Ditches." This, he added, did involve some danger, but that danger "is not so great, chiefly if we consider the place to be equall with the earth and of no great height, and that there be earth sufficient for workes and Covertures." (ELDRED (1646) p. 163/4.) Thus if the structure is lowered too much its 'command' is reduced making it easier for the enemy to bring his battery close to the edge of the counterscarpe, where, in turn, lowering is of less advantage. Hence the compromise. Of course this implies enough workers to build the 'covertures'. But over a century earlier at the siege of Pisa our anonymous informant stated that the attacking Florentines had "marraioli e guastatori tremil" in the force including 600 men-at-arms, 500 heavy cavalry, 8000 "provigionati pagati" and 4000 "comandati", with 150 bombardiers. He noted them particularly as building protective works around the attacking artillery. La GUERRA del Millecinquecento (1845) p. 365.

gave way to the exigencies of practice and the needs of defensive weaponry. Francesco di Giorgio for example enunciated this pattern of lowered structures, by implication quite clearly, because of the power of artillery fire, in his later version there saying for example that ravelins ought to be

> ....fondati in logo sì basso che da le bombarde non possino essere offesi, e niente dimeno el muro suo debba essere della altezza delle mura o circa, secondo la comodità, con uno fosso intorno conveniente a quello...[1]

even though his detailed designs tended not to follow this as a principle to any great extent, as later was done more consistently in the 16th. century.

But, undoubtedly the resultant relative low structures, related to the context of both attacking and defensive artillery, tended to facilitate the designing of a fortress being conceived as based fundamentally in the needs of defensive fire which determined its plan trace, and hence the idea that fortification was an indubitable mathematical science.

(b): The size factor

It was noted above that fortification design as described by the treatise writers of the later 16th. century on the basis of the pointed bastion system involved the conclusion on the theoretical level that the larger the fortress the better it was because this tended to obviate the difficulty of the pointedness of the bastions.

Now in contrast, in the earlier period Francesco di Giorgio wrote:

> Unde a me pare di dire delle moderne e nuove formazioni, delle città, rocche e castella, con che ordine modi da edificare sieno. In prima è da considerare....che la fortezze sieno accolte e strette, e di piccol diamitro la sua circuizione, perché quanto è manco, più facilmente difendere e guardar puossi.[2]

Francesco di Giorgio also continued to emphasise the need for the tower of of the residence of the keeper of the castle to be the strongest:

> ...la torre principale del castellano sia più forte e più eminente delle altre, e che possi tutto el resto della fortezza offendere e non essere offesa, acciò che el castellano sia signore delli altri.[3]

It is equally the case that these structures built in the later 15th. century up to the rocca of Civitavecchia of Bramante of 1508 with regular geometric figures with round towers at the corners were relatively small compact structures.

In such a context, where the small structure was focused on as one likely to be strong,[4] where certain needs such as that of the castellan for something like the older keep were to the fore, where patrons required small compact complexes, the search for structures to resist artillery must have been all the more reasonable and possible. Small important strong points after all should presumably have offered the opportunity to build, in massive solid stone work (say), albeit at a very high cost per defender, or per unit protected, while still in total cost not being completely beyond the patron's resources.

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1. FRANCESCO DI GIORGIO (1967) p. 436.
2. FRANCESCO DI GIORGIO (1967) p. 6. This is from the earlier version of his writings. In the later version as the 7th. of his general rules relating to the form of the fortress he gave "che la fortezza sia di minore circunferenzia che possibile e non pretermittendo la (ragionevole quantita) e debita proporzione". Ibid p. 429/30. 3. Ibid. p.429
4. GUICCARDINI (1579) p. 53 wrote on the French campaign of 1494 "they had with a part of tharmie assailed the borow of Bubane, but in vaine, because by his litle circuite a small strength sufficed to defend it..."(although also for other reasons).

On the other hand the needs of a length of urban enciente in terms of sheer size of structure determined by what it was designed to protect -- i.e. the urban area and the defenders within it, the sheer total cost involved must have meant that 'ingenuity' was what was required and that the search for a resisting barrier under such circumstances would seem to be an uninviting prospect, simply from the point of view of the total costs involved.[1,2]

The shift in focus towards an emphasis on the urban enciente is reflected in such views as those of Machiavelli, who had little faith in any citadelle within the main defensive barrier stating

> Si io hauessi per tante ad edificare rocche, io farei loro le mura gagliarde, & i fossi nol modo habbiamo ragionato, ne ui fareidentro altro che case per habitare....Et che ciascuno intendesse che perdute le mura & il fosso fusse perduta le rocca.[3]

Machiavelli at the same time as he took issue with the views such as that expressed by Francesco di Giorgio that small fortresses were the strongest. His dialgue continued

> Batista. Voi hauete detto che le cose piccole hoggi non si possono difendere, et egli mi pareua hauere inteso al contrario, che quanto minore era una cosa meglio si difendua. Fabritio. Voi non haueui inteso bene, perche egli non si piu chiamare hoggi forte quello luogo, dove chi lo defende non habbia spatio da ritarsi con nuoui fossi con nuoui ripari. Perche egli è tanto il furrore delle artiglierie...[4,5]

It is not that Machiavelli's view on fortification was particularly influential, for many citadelles were built, but his assumption that the fortress was lost when the basic urban enceint was lost, reflected the shift towards conceiving the urban ancient as the primary unit of defence. As was noted above this shift towards conceiving the urban enciente as a major problem of design, rather than the small concentrated stronghold or citadelle, was consistent with attitudes during the renaissance towards the city as the characteristic container of 'virtue', as the bare titles of many fortification treatises indicated.

However this shift was by no means an absolute one. In many cases relatively confined forts were built such as the famous Fortezza de Basso at

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1. Cf. Alghisi II p. 84; l. 11/15.
2. The sort of structure in fact that contemporaries were prepared to accept in the whole period in this sort of situation was an earth bank with or without, generally with, a masonry skin and counterforts. Dürer's approach to fortification can be seen as directly in contrast, and involving a search for resistent structures, his honey comb forms as attempts to get resistance without going for solid brick or masonry, and these he used clearly as strong points and as relatively strong compact structures to reinforce an old wall or support and bank and ditch situation, as well as in slightly different design acting as individual blockhouses, tending to emphasise small size resistant forms, which in turn provided for defensive flanking fire.
3. Libro della arte delle guerre (Firenzie 1521) f. 102a. His grounds for his view was of course that such a place of safety would tend to encourage defenders to abandon the outer defences too early.
4. Ibid. f. 102b. This seems to be somewhat in tension with his point about citadelles, at the very least. If citadelles had a bad psychological effect on the defenders it is hard to see why retrenchments would not equally.
5. In this same section Machiavelli explained generally about fortification "...le terre & le rocche possono essere forti ò per natura ò per industria.... Perche quelle posse sopra à monti, che non sieno molto difficili à salirgli sono hoggi rispetto alle artiglierie & le caue, debolissime. Et pero il piu delle volte nello edificare, si cerca hoggi uno piano per farlo forte con la industria. La prima industri h fare le mura ritorate & piene di uolture & di ricetti. La qual cosa fa ch'el nimico non si puo accostare a quelle, poterlo facilmente essere ferito non solamente à fronte, ma per fianco." (Ibid. f. 100a)

(cont. over)

(cont.)

He thus expressed a good deal of the attitudes evidenced by the later treatise writers without any doctrinaire insistence on the pointed bastion and the principle of no dead ground, and concluded "tanto che io fo una citta cosi ordinata al tutto inespugnabile" (f. 101a). On the other hand at other places Machiavelli denigrated the utility of the fortress altogether, as for example saying "As to the building of fortresses to defend oneself against enemies from without, I say that they are not necessary to peoples and kingdoms that have good armies, and to those that do not have good armies, they are useless, for good armies without fortresses are enough for defense; fortresees without good armies cannot defend you". (Discourses II 24 (1965) p 397) "....a wise prince who is more afraid of his own people than of foreigners builds fortresses he who is more afraid of foreigners than of his own people rejects them....Even though you have a fortress, if the people hate you, it does not protect you, because the people when they take up arms never lack foreigners to aid them... Considering all these things then, I praise one prince who builds fortresses and another who does not build them; I blame any prince who, trusting in them, considers the hatred of his people unimportant." (The Prince Cap. 20 (1965) p. 80/81.) On the other hand while in the above quoted passage Machiavelli suggested his ideas will give an invincable fortress, at other places, as when he wrote about size (quoted above p. 260) he insisted it was quite impossible to resist artillery so powerful had it become. In his Discourse II Cap. XVII he stated "mi è uenuto in consideratione la oppinione uniuersale di molti, che uuole, che se I quelli tẽpi fussine state le artiglierie non sarebbe stato lecito a Romani, ma si facile pigliare le prouincie, farsi tributarij i popoli, come si fecciono." Considering artillery in siege warfare Machiavelli then makes the point about size as quoted above the fact he described because in a samll fortress everything will be destroyed by the artillery and there will be nowhere to retire to, and "Se tu difendi una terra grande...sono non di mĩco senza coparatione piu utili le artiglierie à chi è di fuori, che a chi e dentro: Prima perche a uolere, che una artiglieria nuoca à quelli che sono di fuora, tue sei necessitato leuarti con essa dal piano della terra, perche stando in sul piano, ogni poco di argine....rimane securo & tu no gli puoi nuocere." But if you try raising up guns you cannot protect them with banks as can the enemy outside, and one can not get as heavy pieces high up as the enemy can use outside. (1531) f. 76b/77b. (In this same section Machiavelli argued also against the view that "la guerra si ridurra col tẽpo I sù le artiglierie". (ibid.)) Machiavelli thus took almost a stronger view of the power of artillery sometimes when he wrote this, as if it was almost certainly impossible to defend against it. Then in his description of Germany Machiavelli wrote (1965) p.43. "The cities of Germany...(only) obey the Emperor when they feel like it; they do not fear him or any other potentate near them because they are so fortified that everybody reckons their capture as sure to be tedious and difficult. They all have adequate ditches and walls; they have plenty of artillery.... (and plenty of provisions) ... Thus depending on the context and points he wished to make Minchavelli tended to take whatever view of the power of artillery that suited him so his remarks in any particular place can not be taken too literally as indicating the power of artillery. As Machiavelli was secretary to the council of ten at Florence during the siege of Pisa and handled much of the correspondence to the commissioners in the field during the siege and the successful defence of the town in 1499 this may seem all the more strange. But of course, he, like other Florentines insisted that this only occured because of the treachery of Paolo Vitelli the sige comander who, toute suite, lost his head. In fact it is clear that so strong was the belief of his contemporaries in the power of attacking artillery, that the Florentines took the attitude that so well had Vitelli been supplied, it could have only been treachery that prevented the fall of the town to them. For example BARINCOU (1955) I. p.34. gave a French translation of a letter from Biagio Buonaccorsi to Machiavelli of the 27th. July 1499 which had the passage "Nostre expédition de Pise va de bien au mieux, et nos Magnifiques Seignerus ne cessent jour et nuit d'accumuler le ravitaillement,

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l'argent et toute autre chose nécessaire...et l'on considère comme certain que Pise est presque au pouvoir de notre Magnifique Segneurie.." Machiavelli himself is equally given as stating (p. 53 ibid.) in a minute of 30 Sept. 1499 on the siege, to "un chancelier de Lucques" "Je vour remerceirai d'abord des congratulations que vous échangez avec votre Pisan au sujet de la gloire dont se couvre Pise et de l'infamie que en rejaillet sur nous....Je vous demanderai ensuite: comment ces deux choses peuvent-elle à la fois tenir debout, que notre cité ait dépensé un trésor incalculable et que vos Pisans aient per tenir bon comme vous le prétendez, sans le fortaiture di Pagolo Vitelli ?" While money and supplies are only generally referred to there it is clear that they were comprised to a good extent in artillery (on which see below p. 265). On the 27th of October "La Segnieurie" wrote to the commissioners in the field "Sa Majesté Très-Chrétienne....a décidé d'envoyer ici à titre d'information, un grand maître de l'artillerie accompagne d'un autre personnage....(to examine among other things to) évaluez...ce qui nous reste d'artillerie et sa valeur.... nous voulons que vous leur montriez toute notre artillerie, et qu'à ces propos, vous trouviez habilement le moyen d'accuser le funeste comportement et travail de Pagolo Vitelli en leur demontrant qu'avant d'envoyer nos canons contre Pisa ....que ne fut meme pas la le moindre de nos dommages, mais qu'il nous fit depenser bien pres de 200,000 livres de poudre et cela pour rien...

...ce qui aura le double avantage de démonstrer la perfidie de Pagolo et de prouver aux autres que si sa Majesté désire venir promptement a bout de Pise, il faut non seulement qu'elle envoie son artillerie toute fournie de poudre, boulets et toutes autres choses nécessaires, mais qu'en outre elle fournisse ceux de nos cannons qu'elle désirera utiliser." To the Florentines clearly, having spent so much money and provisions and provided Vitelli with the requisite arms, that he did not take the city could only meany treachery or dissamblement of some kind. Yet Guiccardini had to admit that no confirmation was got from Vitelli under torture, and likewise after his death, while some of his immediate suite were of the opinion that had hoped to gain a position for himself in Pisa, and so was treating with them, the majority on examination maintained he was innocent and was simply discontented with the Florentines on some minor matters, one of which was the lack of delivery of supplies. In one report (1500) Machiavelli wrote with regard to Pisa he recommended that the town be invested for 40/50 days to try and sap morale and gain defections then "fare in un subito quanti fanti si può: fare due batterie e quanto altro è necessario per accostarsi alle mura: dare libera licenza che se ne esca chunque vole....e così trovandosi i Pisani voti di difensori dentro, battute dai tre lati, a tre o quattro assalti saria impossible che reggessero si non per miracolo, secondo che i più savi in questa materia hano discono" (1949/50) Vol II p. 444. Yet when Pisa was eventually brought under domination it was mainly by a siege of starvation and Machiavelli himself wrote of this "E quattro mesi introno ivi posati/ Con gran disagi e con assai fatica" ((1949/50)II,p. 457.) (In the face of such attitudes perhaps Paolo Vitelli ought to be considered an early martyr to technological determinism). But again when faced with the needs of defence Machiavelli's more extreme attitudes were less in evidence. In his report on the fortifications of Florence after his inspection and consultation with Pedro Navaro in 1526 the recommendations made were much after Machiavelli's opinions as given in The art of war in their more optimistic expression. High protruberances were to be done away with and Machiavelli wrote ((1949/50)II,p.542) "Quivi gli parebbe da fare o una casamatta o un baluardo tondo che batesse per fianco"; and that further around the enciente "si trova una torre la quale gli pare da ingrossarla e abbassarla, e fare in modo che di sopra vi si possano maneggiare due pezzi de artiglieria grosse: e così fare a tutte le altri torri che si trovano: e dice (i.e. Navaro) che per esser fitte l'uno sotto l'altra che le fanno una fortezza grande, non tanto per il ferire per fianco ma per fronte: perché dice ragionevolmente le città hanno ad avere piu artiglieria che non si può trainare dietro un esercito, e ogni volte che voi ne potete piantare piu contro il nemico che il nemico non ne può piantare contra a voi, gli è impossible che vi offende: perché le più artiglierie vicono le meno: in modo che potendo porre grosse artiglierie sopra tutte le vostre torri, ed essendo le torri spesse, di necessità ne sequente che il nimico vi può con difficultà offendere." (Although perhaps Machiavelli personally was less happy with this view.)

Florence to keep the inhabitants in check.[1]

To some extent on the other hand cases where a new bastioned enceinte was built, before a citadelle in the new style was constructed, or without one altogether, may be taken to indicate the working out of this pattern.[2] Nevertheless this pattern can hardly be taken as a mere shift of the focus of design from the older medieval keep or relatively confined stronghold, to the urban enciente. Too many urban enceintes were built with citadelles during the period, and equally urban encients were often built during the medieval period without a castle complex. Rather, the pattern was, that given the search for 'method' in fortification, when such a method had to cope with both urban enceints and citadelles, the approach that might have been more reasonable for the more confined structure in searching for resistant forms, would have been less congenial in view of cost considerations, where the general method had to cover both such small structures and extended urban enceints.

To some extent the developments in structures during the later 15th. century supports this pattern, with a tendency for developments in certain small town enceints to be more towards the pointed bastion form, than the design of the small rocca's which can be understood on the pattern of Francesco di Giorgio's method of design. Equally the urban enciente of Broglio of the 1480s and the urban enceinte together with the citadelle at Poggio Imperale being noted as significant steps in this pattern also.

But, in view of the lack of detailed sources to indicate the way in which the designers of such fortifications approached such works, too much weight can not be put on such considerations. However the French invasion and the urban building projects such as at Padua, Ferrara and Treviso, circa 1500, must be taken to indicate that the problem of the urban encient in the face of contemporary conditions of warfare was a significant focus of interest for certain designers.

Thus during the early 16th. century an increasing concern with the problem of the urban enciente, the valuation of the urban nucleus and, defensive needs, formed a mutually supporting package, which, by reference to the needs of defensive fire in siege warfare and the principle of no dead ground, was responded to in fortification theory by means of the characteristic use of the pointed bastion, which practice then allowed the discipline to become a true mathematical science in accord with the wider social and cultural preoccupations of the time.

The reduction in height of structures necessary both in the face of attacking artillery and to cope with the needs of defending guns, together with large schemes being the focus of design, particularly at the theoretical level, then in turn tended to mutually interact to enable the conception of design as focusing in its most significant aspects on the plan of the fortress, to function all the more easily.[3] In turn any tension that might have arisen because on the theory of the pointed bastion solutions of

1. HALE (1968).
2. As for example at Berwick-upon-Tweed where the old castle complex was excluded, and the final scheme as built was purely an urban enceinte. At Antuerp a bastion enceinte around the town was built some years before the well known citadelle was constructed by the Spanish to hold the town in thraul. See also II p. 72; 1. 418.
3. In practice equally, where undoubtedly the big schemes such as at Palma (nova), for example, were the exception, and where the problem of the urban enceinte was often dealt with piece-meal with a bastion or a ravelin added here or there at one stage, with another built some years later, theory could equally be applied to the design of each unit added by reference to the principle of no dead ground. Similarly as the enceinte developed over time, theory on the standard lines allowed the various additions to be integrated on a rational basis.

the greatest size were favoured, and small fortresses posed a certain difficulty, was mitigated in the context of a focus on larger scale schemes.

(c): The changing nature of warfare

But, as conceptions of design in fortification were changing during the renaissance so was the nature of warfare in transition during the same period, both in a general way and in siege warfare in particular.

The French invasion of the 1490s for example saw the introduciton of gunpowder mining.[1] Traditional mining to bring down walls had of course been long known. This increase in the power of mining must certainly have made the high medieval types of structures increasingly vulnerable, earthquake effects for example might damage of demolish structures quite distant from the site of the explosion. On the other hand relatively low solid banks, will have been perhaps somewhat less vulnerable to such effects. However this form of attack was another weapon in the arsenal that could cause a breach in the defensive barrier, if carried out effectively, so that the need for defensive fire rather than any passive barrier was equally increased by the use of this new technique, as well as by the introduction of an effective attacking artillery. Here then is another factor tending to favour the grounding of defence in the use of defending artillery.[2]

The use of gunpowder mining was however but one facet of the increasingly technological nature of warfare during the renaissance. As artillery became increasingly to play a part in warfare, and particularly in the siege, the production of guns, and in addition and most importantly, the supplies necessary to maintain their use at a siege, became an increasing load on the war-making body. This factor became increasingly more significant, and its nature more clear with the 'new effective artillery' introduced by the French. This new artillery, as noted, was not so much a new invention, but the product of the procurement of particular kinds of guns and their effective employment. It depended on a large number of shots fired over a relatively short period to accomplish its effects, rather than on a more powerful type of gun: and hence depended as much on quantity as in quality in the weaponry, so that it equally depended on the organisation which supplied the mass of matériel needed in terms of powder and shot. The fact that this weaponry depended on an attrition of many blows rather than on overwhelming blows which acted at a stroke, is made clear by contemporary descriptions of its effects.

The Venetian ambassador wrote to the senate in 1492 explaining its effects thus

> Dicemo queste loro artiglierie passeranno uno muro di otto braccia, che lo fonaro; e benchè il buco sia piccolo, per la gran multitudine de colpi, bisogna che tutti li macini...[3]

and our anonymous informant on the siege of Pisa in 1499 also explained

> ...continuamento e senza alcuna posa batterono con le artiglierie le torre e muro vicino; tallmente che alle ventitre ore abbono rotto il muro de uno todo di braccia uno per ogni verso; e non solo feceno il buco, ma taglierone quasi la fotrezza dalla parte loro verso San Dominio.[4]

1. This topic is discussed in a number of authors and the general consensus now seems to be that its use against the French in Naples in 1494 was the first successful use of this technique. See PRAGER & SCALIGERI (1972). ROCCHI (1908). BRINTON (1934/5).
2. The treatise writers of the later 16th century quite frequently made reference to the need of contemporary fortification to respond to contemporary forms of attack and gunpowder mining. However they rarely made such points as mentioned here. Responses to mining was mainly discussed by them in terms of providing countermines
3. Quoted above p. 248.
4. La GUERRA del Millecinquecento(1848) p. 366.

Further at the same siege it is clear that the supply of the necessary provisions and shot to achieve the required attrition effects posed something of a problem.

For example on the 16th. of July, Machiavelli on a trip to obtain provisions and troops, wrote from Castrocaro that the shot there had all been used the previous year in the siege of Vico and the powder left by the French there, of only a small quantity, had been destroyed in a fire which ruined a part of the castle in which it had been stored.[1] On the 18th. however he wrote that he had received a promise of 10,000 pounds of salpetre, but that it was impossible to obtain anything more from the same source.[2] During the siege the council of ten wrote

> Andando la cosa in lungo potrebbero mancare le munizioni, e revera e'sarebbe impossible a mezza Italia sopperire a coteste artiglierie, quando le avessino a trarre molti dì; -- e ogni uomo poteva intendere facilmente che se tanta artiglieria aveva a durare troppi dì a trare, che non che noi ma qualunque gagliarda potenza aria possuto riparare alla polvere & palle che le fussino di bisogno...[3]

and further that,

> ....mancando il ferro e il piombo si fecero palle di rame e di bronzo con grandissime dispenio, e macando le polvere, si mandarono maestri di salnitri pel territori fiorentine a cercare terra da salnitre.[4]

The quantities of powder involved in supplying such artillery were by no means insubstantial. Contamine, for example, quoted figures for each of the 5 artillery trains that Charles VIII employed in his 1489 compaigns as 60,000 lb. in one case and 70,000 lb. in another.[5]

The Florentine council of ten on this topic complained that they had expended 200,000 lb. of powder at the siege of Pisa[6] -- and this was part of the grounds why Vitelli must have been misbehaving. According to Guiccardini one of the complaints Paolo Vitelli's followers said he had with his employers was that he had not been properly supplied.[7]

This question of supply was not merely a question of the amount of material involved however. It was compounded by the fact that it had to be available all at one particular time, to be effective. Nearly all the accounts of the new artillery introduced by Charles VIII suggest that it was its rapid firing qualities that were crucial to its effectivness. The rate of attrition was crucial because its effectivness depended on its ability to damage the defenses at rate greater than that of the defenders to repair such damage. The letter to Pietro di Medici from France in 1492 emphasised this.[8] Again our anonymous chronicler of the siege of Pisa

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1. (1955) p. 18/19.
2. Ibid p. 24/5. This is from 20,000 lb. Leonardo Strozzi had bought on his own account at Pesaro.
3. Quoted in CANESTRINI (1857) p. XXI. On the general costs of the siege they wrote (1500 18th. July) that the Republic "ha sostenuto la guerra in casa pericolosissima gai sei anni, nella quale ha speso vicino a tre milioni d'oro, e da un mese e mezzo in qua ci troviamo avere spesso 115 mila ducati, e di tante spese non vedendo ancora il frutto." i.e. the fall of Pisa. On the other hand they wrote at another point "Dalla ribellione di Pisa in qua abbiamo speso circa 105 mila ducati." Quoted ibid. XXXI/XXXII.
4. According to Canestrini ibid. See also above p. 248 n. 2, on iron shot.
6. See above p. 262 letter of 27th. Oct. 1499. 5. (1964).
7. (1579) p. 234. "the difficulties they vsed in thexpedition of prouisions which hee demended." The council of X wrote to the commissioners in the field on the 20th. of August saying they had supplied all that was asked with the greatest possible speed; but added somewhat equivocally "nous ne voyons pas en quoi nous avons pas." (1955)
8. See the letter quoted above p. 248.

outlined this pattern whereby after the early bombardment the defenders laboured mightily, particularly the women of the town, to repair the damage. To such good effect we are led to believe that Paolo Vitelli on inspecting their efforts stated

> ....è necessario con le artegliarie battere questa muraglia, altrimeti poco onore ne riporteriamo; e con massima sollicitudine, perchè li inimici più reparano che noi non disfacciamo.....[1]

Guiccardini made the same point when he stated that the older guns

> ....gaue little frute or successe to the seruice, but left to the defenders leasure and oportunity at wil, to reenforce their rampiers and fortifications....[2]

The importance of this factor explains why so often in the make up of a siege train was found a relatively large number of smaller pieces.[3] Because, if the artillery had to function merely as a battering agent such weapons would have added little effect one supposes. But it now appears that these smaller guns had the important task of deterring the defenders from making repairs when the main guns were not firing. Philip of Cleves explained

> ...les faulcons ne doibuent iamais cesser de tirer, en aux defences, iusques à ce qu'ils ayent arriere rechargez leurs gros bastons, & iamais & iamais ne doibēt cesser de tirer si longuemēt que le iour dure...& souuent de nuict tirer...& tousiours des faulcons pour guarder que lon ne face rempars.[4]

Thus rate of fire, that exceptional quality of the French guns so often mentioned, was of crucial importance. The quality of mobility of those same guns related to the same problem. For, the quicker the attackers guns could be placed in battery, and begin to fire, the less time would the defenders have to strengthen the point to be attacked.[5] It was on just these dimensions of mobility and rate of fire that artillery had improved and continued to improve. Philip of Cleves stated that a cannon could fire 40 shots a day.[6] Hexham in his remarks much after Ufano had the following section:

> Gen. You make your account then that every peece in the space of 10 houers is to shoot 80 shot, that is 8 shot an houer for every peece. Capt. You may make 10 shot an houer if you please, if your peeces be renforced, but as for your ordinary peeces, they have not the mettalline substance enough to beare it: considering also that after you haue made 40 shot out of a peece, it will be so heated, that it must have cooling time.[7]

and

> ...howsoever of late years experience hath taught at diverse sieges, that your halfe Cannon (24lber.) which are more portable having good store of them, will doe the business as well as your whole cannon (48lber.)[8]

Again the attacking artillery of siege warfare is seen to develop not so much in terms of an invention but in terms of a gradually increased effeciency on a particular dimension relatively specific to conditions

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1. p. 368. The fact that on the taking of Paolo Vitelli at the behest of the Florentines his brother Vittellozo escaped to the Pisans, makes this sort of remark more to be considered because it did put the writer in a position to have found out a good deal that went on in the besiegers camp. Though of course this does not make it any less likely that he would do anything but make the defenders actions appear heroic and as effective as possible.
2. Bk. I (1579) p. 45. (1561) p. 64. At the siege of Constantinople reports indicate that while the Turks guns were effective in breaching, the defenders were able to make good the depredations, on occasion, so as to greatly negate the damage -- one of the reasons why the Turks made so much use of (traditional) mining there, one presumes. See BARBARO,N.(1969) p. 25/6 & 49/50.
3. See Fronsperger for example.
4. (1558) p. 51/2. The anonymous chronicler of the siege of Pisa made much of the bravery of the women in such work when being so fired on.
5. See above p. 217, De La Noue (p. 339).
6. (1558) p. 51 "& n'y a canon en ces longs iours, que ne tire quarante coups". CONTAMINE (1964) n. 99 notes a source of 1476 which states 24. The large guns at Constantinople might fire only 7 times a day.
7. (1637) p. 22. Hexham, adding to Ufano, described a siege of c. 1600 where these figures were achieved and explained he had a man making a notch in a stick at every shot to count them. p. 23.
8. Ibid. p. 22.

in that delicate balance between the attacker and the defender.

Thus the problem of supply which the besiegers faced was not one of mere quantity, but of the assembling of the requisite stores in sufficient mass, all available at the one time to achieve the requisite 'blitzkrieg' effect. The requisite organisation therefore had to be present to achieve such an effect.[1,2]

The delicate balance of the artillery duel between defenders and attacking guns in 16th century warfare was then further complicated by the balance between the rate of destruction by the attacking guns and the rate of repair by the defenders. Given this picture the needs of defensive guns must be taken to have been crucial in planning to defend a fixed position. They not only could interfere with the attacking canon as battery weapons in a direct way, but, if they could slow down and inhibit the attacker's fire by only a relatively small amount, they might hope to bring this other activity of defence -- repair -- into play. Further if the defenders could withstand the first onslaught in this way the balance might tend to turn somewhat toward his side. The attacker, with some difficulty (as at Pisa in 1499) having obtained and assembled his supplies for the first onslaught, once that was unsuccessful, not only would he tend to have increasing difficulty in obtaining more supplies, but needed them again assembled in sufficient quantity to produce the requisite multiple rapid hammer blows for success.[3]

Thus the focus of the 16th, century fortification theorists on the needs of defensive fire was a favourable focus in terms of the developing needs of siege warfare, in a general way. On the other hand in terms of their insistence on the principle of no dead ground, it was largely doctrinaire, more in accord with the needs of medieval warfare and men-at-arms mounting scaling laders, of chipping away at the walls with picks, than with the

1. In other words the problems of 16th. century siege warfare was somewhat similar to that of 20th. century warfare in some of its technological aspects. The siege gun can be equated, roughly, with the modern tank. Used piecemeal, while each in itself is a relatively powerful weapon, against prepared positions, neither is by any means an overwhelming weapon -- the frittering away of tanks in their early use during the 1914/18 war shows this. But assembled in mass the multiple hammer blows rapidly applied become overwhelming unless the defenders can rapidly reenforce and reply in kind. One of the major problems is of organisation and supply to bring about that result in terms of assembling sufficient weaponry and its supplies. (This is of course an analysis in accord with Montgomery's doctrines and illustrated best perhaps by Alamein, a doctrine not perhaps without its critics, yet undoubtedly of some significance.
2. The defence of Siena in mid 16th. century which has been studied in some detail (PEPPER (1972)) shows something of this problem. At one phase of the siege the besiegers having transport problems with their cannon, still managed to demolish a section of old wall. Only to discover a 'ritirate' built behind it. Machiavelli's remarks on size must therfore be considered much to the point in such a context.
3. CONTAMINE (1964) p. 147/8 states that the artillery trains used by the French king in 1489 campaign had supplies only sufficient for 8/10 days bombardment and mentions this kind of 'blitzkrieg' effect as necessary with this type of artillery. If the 200,000 lb. of powder used in the siege of Pisa is taken as a base with the rate of fire as given by our anonymous informant at Pisa in 1499 as 750 rounds per day, and the powder to shot ratio is taken at 2/3:1 and the average shot at 30lb. this gives a this gives a total of 20 x 750 lb. per day = 15,000 lb, and the total quoted gives a supply for only about 13 days. This suggest that something like this occurred at Pisa. However the details available do not give sufficient figures to make this calculation very reliable. The average weight per shot is problematic. Again late 16th. century tables make the shot to powder ratio reasonable as given, but Francesco di Giorgio's figures were very different. While those for the large stone firing guns he gives as 16/100 may be ignored when metal shot was in use, he did give 10/100 for some of the smaller metal shotted weapons however odd it sounds. Only in the case of the archibus at 50/100, and scoppieto at 8/10 did he give figures near the later ratios. But the above analysis shows that the 100 tons of powder so proudly quoted by the Florentines was by no means excessive. According to Guiccardini it was hoped before the siege to take Pisa in 15 days. For the rather larger figure given for the late 15th. century see above p. 250 n. 1.

developing needs of contemporary siege warfare as these accounts show it, particularly in the face of the expectation, demonstrated by so many illustrations, that the point of the bastion would often be demolished before the assault.[1] [1],[36].

On the other hand although a certain balance between forces in a siege might occur on occasion, there were other factors that could favour the attacker in 16th. century sieges.[2] Machiavelli quoted Pedro Navarro as stating one might reasonably expect a city to be able to have more artillery than an army could carry with it.[3] But was this reasonable ? The defender, not knowing where the blow may fall must tend to have to spread his weaponry over a number of sites, while the attacker has more opportunity to assemble a substantial part of his weaponry to bring it to bear on the point of his choosing;[4] and this holds for both the site of the siege, and the part of the defensive barrier assaulted.[5] The greater the mobility of the siege train the more the attacker can take account of this factor. Hence the importance of that dimension all during the period.

Again, as was frequently stated in the treatises of the 16th. century, the purpose of a fortress was to allow a few to defend against many. In such circumstances the ability of the attacker to command a proportionately greater number of pioneers and sappers to build protective banks for his guns, and to dig the approach trenches, that became so common, must be considered to have given him the advantage, particularly when during the siege the defender suffered attrition of guns -- often too few to start with[6]-- and effectives.

But to these considerations must be added a factor perhaps more important still. The psychological one. The influence of that very view that artillery was irresistable and the undoubted fear and shock that weapon

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1. Further the tendency to ignore the possiblity of resistance may have been by no means so sensible. Guiccardini explained about the siege of Pisa in 1499 "albeit there were no ditches nor trenches before the walles of the citie, yet were they very thick & of auncient building with stones so wel couched by the faculties of lyme and sande proper to that countrey, that their resistaunce was more mightie against thartillery than is in the common sort of walls, and by that benefit, affore they were beaten flat with the earth, the defendantes had good time and leisure to reenforce and reedifie their Rampiers." (1573) p. 230. (1561) p. 319.
2. There were many sieges during the period of short duration.
3. See above p. 262 ((1949/50) p. 542).
4. An interesting case where this did not occur but which illustrates the pattern is the armada campaign by Spain against England. Knowing the attack was coming by sea, and considering the attackers most vulnerable there, the English fleet was gunned in part by weapons stripped from shore defences. See LEWIS (1961). See also above p. 250, n. 1, 3. Feb. The quicker the attacker can being his forces to bear on a particular fortress the less time will the defender have to rush reinforcing weaponry to that site.
5. See above p. 217, La Noue p. 339.
6. By tying up guns in the neck of the bastion in accord with 16th. century theory of the art, fortification engineers of the period very well may have magnified the problem, through their emphasis on flanking fire at the expense of the need to hold the defenders distant with defensive fire. La Noue p. 339, for example (see above p. 217) considered provisions lacked in many fortresses and were lost for this reason.

produced in those who observed it, must have often been influential, particularly against poor fortresses.[1] Given such attitudes, that delicate balance between attack and defence that defenders might on occasion take advantage of, on many occasions must be considered to have given the balance to the besiegers.

But the art of warfare itself, rather than just those aspects directly related to siege warfare, was gradually changing throughout the renaissance. During the later middle ages organised troops of infantry, lightly armoured, began to play an increasing role in warfare, the Swiss mercenary companies rising to predominance during the 14th. and 15th centuries.[2] During the Italian wars of the early 16th. century the Spanish infantry companies equally came to be recognised as very effective fighting units. During this same period the use of hand guns in such companies of infantry began to become a standard practice.[3] Throughout the later 16th. century it

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1. See for example Francesco di Giorgio above p. 229. The effect of artillery on contemporaries is well recognised. That designers insisted on the power of artillery as experts in the subject of defence must be considered likely to have coloured viewpoints to a great extent, making difficult conditions altogther hopless. At the taking of Casina by the Florentines in 1499, just before they went on to besiege Pisa, Guiccardini described the outcome thus: "Casina notwithstanding it was sufficiently manned and vittelled, with a wonderfull strength of trenches and Rampires, was taken, after the sommonance of the artillerie, within lesse then six and twentie hours: for that, the defendants, beginning now to feare the great ruyne which the artillerie had made of their walls being of no strength, ioyning with the forrane souldiours that were within, rendered the place, and compounded only for their lyves and goods..." (1579) p. 230. Such views as those of the fortification treatise writers on the power of artillery must be considered to have acted to a great extent as self fulfilling prophecies, and every successful besieging of a place can only have increased peoples convictions of the truth of their beliefs. When a successful defence took place as at Pisa contemporaries continually referred to the obstinate desire of the inhabitants not to return to their position as subject to Florence as the reason for the successful defence, and as if this was unfair and ought not to have been allowed to withstand the Florentine guns which everyone knew ought to have beaten them down. See also HALE (1966).

2. See for example OMAN (1924) and his account. The difference was not simply one of those who in battle fought on foot, or who fought on horseback. Certainly during the earlier period in the 12th. and 13th. centuries heavy cavalry tended to predominate as the striking force in battle, and continued to do so on many occasions. But later the heavily armoured knight, while his horses provided him with transport, could and did often fight the battle on foot, and this seems to have become more common during the 14th. and 15th. centuries. Christian da Pisan writing in the first decade of the 15th. century (probably) stated "Where vegece putteth many maneres of wayes for to renge an oost in bataylle/ as it shal be sayd herafter the whyche in some maneres may be dyfferentes to the regarde of the ordynaunces of the tyme present. The cause preauenture is by cause that the folke comynly in tho dayes foughten more on horseback than a fote." Bk. I Cap. xxiij (1937) p. 80. She went on to describe an array of men-at-arms in the centre in mass ("by dyuerse rowes one after a nother full smothly renged") with on the wings "aswel gonners/ as balesters/ and archers" an array similar to that used by the English as Agincourt. The Swiss companies were very different in that they marched on foot as well as fought on foot, were less heavily armoured, and depended for their succes on flexibility and movement, but above all on their acting in concert, at first armed with the halberd and then with the pike, which later weapon was particularly effective against cavalary when they went into the movment of the 'hedgehog' whereby simultaneously all these long weapons were faced outwards to form an impenetrable hedge.

3. Machiavelli in The art of war (1965) p.601 stated "we should not reckon more on cavalry than the ancients did....many times in our days they have been put to shame by the infantry." Infantry he noted had pikes 17ft. long and breastplates of steel. A few were armed with halberds and had harquebusiers among them. This being the German, particularly Swiss style. These troops according to Machiavelli were effective against cavalry, but were vulnerable to heavily armoured dismounted men-at-arms and the Spanish infantry who, with their shields and swords could get among the pikes and then had the lightly armoured Swiss at a disadvantage. He thus recomended the use of a company of 3,000 infantry with shields in Roman fashion, 2,000 with pikes and a third with hand guns. (Ibid. p. 597 to & 601). For the introduction of the hand gun during this period see TAYLOR, F.L. (1921). But Machiavelli when he discussed light cavalry said he preferred them all to be "crossbowmen, with a few harquebusiers among them; the later though in other affairs of war are of little use, are very useful for one thing: they terrorise peasants." (Ibid. p. 625) In each brigade he recommended 300 cavalry, 150 men-at-arms and 150 light cavalry. (Ibid.)

was a common idea among the military that such companies of infantry provided the major battle force, although cavalry and men-at-arms were not neglected.

For example De la Noue wrote

> ...le grand Roy François..imitāt la discipline antique, il a sçeau former entre ses propres suiets vn puissāt corps de gēs de pied, pour rendre sa militie plus accomplie... ... Mais depuis que les bōnes regles ont esté posees, & que l'exercitation a suyui, ils sont façonnez, & sont deuenus plus obeïssans, & valeureux. Peu de temps auparauant les harquebuses estoyent venuës en vsage. Ce qui les a rendus fort redoubtables, & si necessaires, qu'on ne s'en peut passer. Puis donque que l'experience de plusieurs guerres nous a ensiegné qu' il est impossible de les bien mener, sans auoir bon nombre d'Infanterie, ne seroit-ce pas erreur de n'en vouloir faire vn fondem nt ? vn qu' on a trouué expedient d'en bastir vn si vigoureux de Cauallerie.[1]

Thus emphasising the need for proper organisation and obedience in such troops.

This development interacted with developments in fortification in a number of ways. Firstly the relatively low solid banks employed were suited to the employment of such troops in defence using handguns.[2] At a more general level the employment of such companies and their organisation provided a problem which commentators were able to discuss in an abstract mathematical way in terms of the setting out of the proper arrays, their evolution from one array to another, and the positioning of the variously armed troops in the company. This was done for example by Machiavelli and Vale in the early part of the 16th. century. It gave rise to such theoretical treatises as that of Girolamo Cataneo which contained many pages of tables numbering off the various ways of ranking troops in companies, all in accord with the same desire for a theoretical approach as in fortification itself. Thus by the end of the century Barret could entitle his work Theorike and Practike of Modern Warres (1598) and discuss in it, in a long section, the evolution of troops. What occurred then during the 16th. century was not merely an increasing use of a particular type of soldier, but an increasing emphasis on a conception of warfare as dependent to a significant extent on organisation and control of troops in the field. In siege warfare the use of large numbers of pioneers both in helping to construct protection of the attacking batteries and digging the required approach trenches,[3] and of marshalling whoever was available to construct retrenchments to resist the attacker, tended to mean that the demands of war became more to involve the organisation and employment of such auxiliary forces and not simply the recruitment of doughty fighters.

Thus the needs of warfare tended to become more technical and organisational during the 16th. century in the use and organisation of infantry in the field and in the use of such techniques as mining and trenching in sieges and in the provision of supplies to support the more extensive use of artillery in siege warfare.

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1. (1587) p. 260/1. See also for example SAVORGNAN (1599) "La fanteria allogia, & camina per ogni qualità di paese, & è atta ad espugnar, & assediar città, & in somma far tutte quelle cose, che conferiscono à conseguir la uittoria; onde nasce, che chi ha miglior fanteria, si uede sempre preualere nelle attioni della guerra." p. 28.
2. See above p. 216/7 La Noue (p. 337). PHILLIPE of Cleves (1558) p. 92/3. "pour tirer parmy ceulx qui viendroient en ce fosse pour gaigner mon rampar...la en amont, tout plein de hacquebuttes & de coulouurines." Tartaglia II p. 19; 1. 10/14. See also the many mentions of "schioppetti" in the sources noted above p. 234/5.
3. PHILLIPE of Cleves (1558) p. 49 "I'ay veu aussi autres aproches par trāches, lesquels faut qu'ils soient menez par discretion, le saigement: car il fault regarder aux tours, aux bouleuers, & aux bateries dela la ville..." See also Valle Bk. II, II p. 1.

III: (3): (ii): (d): Changing views of political reality

By the end of the 16th. century it had become clear to at least some commentators that the prosecution of war had become a business suited to only relatively extended kingdoms and republics with the requisite economic base both social and financial; that the power of such states was very much in direct proportion to their richness on these dimensions: and that equally the defensive needs of these units were best served by relatively substantial fortresses on their frontiers.

Giovanni Bottero expressed this whole position perhaps most clearly. Botero divided 'dominij' into three sizes. He explained on this

> ...che picciolo Dominio è quello che non si può mantenere da se, ma ha bisogna della protettione, e dell'appoggio altrui, come è la Republica di Ragusia, e di Lucca: mediocre e quello che hà forze, & autorità sofficiente per mantenersi, senza bisogno dell'altrui soccoroso, come è il Dominio de' Signori Venetiani, e'l Regno di Bohemia, & il Ducati di Milano, e la Contea di Fiandra. Grandi poi chiamo quegli Stati, che hanno notabile auantaggio sopra i vicini, come e l'Imperio del Turco, e del Re Cattolico.[1]

In regard to strength he explained, mainly,

> ...che si possono chiamar forze d'un Prencipe....sono gente, e molta, e ualorosa; e denari, e vettouaglia, e monitioni, e caualli, & arme de offesa, e da difesa......[2]

and

> VENIAMO hora alle vere forze, che consistono nella gente; perche à questa ogni altra forza si riduce: e chi abbonda d'huomini, di tutte quelle cose abbonda ....(and) ad una Città, che aspira ad imprese grandi, nissuna cosa è di maggior bisogno, che la numerosa moltitudine di Cittadini, de quali essa possa confidentemente preualersi nelle fattioni militari..[3]

Further to which

> La gente, e la forze s'augumentano in due modi, col propagare il suo, e col tirare à se l'altrui: si propaga il suo con l'agricoltura, con le arti, col fauorire l'educatione della prole, con le Colonie.. L'AGRICOLTVRA è il fondamento della propagatione...[4]

On the other hand

> NON è cosa che importi più per accrescere vno Città,[5] e per renderla e numerosa, d'habitanti, e douitosa d'ogni bene, che l'industria degli huomini, é la moltitudine dell'arti; delle quali altre sono necessarie: altre commoda alla vita ciuile; altre si desiderano per pompa, e per ornamtento. ..onde ne segue concorso, e di denaro, e di gente, che, ò lauora, ò traffica il lauorato, ò somministra materia a'lauorati: compra, vende, trasporta da vn luogo all'altro gli artificiosi parti dell'ingegno, e delle mano dell'huomo...quelle delle due cose importi più per ringradire, e per popoloso vn luogo, la fecondità del terreno, ò l'industria dell' huomo? L'industria senza dubbio; prima perche le cose proddotte dall' artificiosa mano dell'huomo sono molto più, e di molto maggior prezzo, che le cose generate dalla natura...[6]

With regard to the troops for the defence of the Kingdom, Botero explained:

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1. (1589) p. 2/3. On the other hand while Botero indicated that the power resided in the larger units, the middle size lasted the longest time, according to him, because the larger states tended to cause the smaller ones near them to combine against them, because "con la gradezza crescono la richezza" which richness created envy and greed in their neighbours.(p.7.)
2. Ibid. p. 177 (Bk. 7) 3. Ibid. p. 191/2. 4. Ibid. p. 197/8 (Bk. 8).
5. 'Stato'(1601) ed. 6. (1589) p. 201/2.

PArlando assolutamente, molto, di maggior importanza è la fanteria; perche il suo valore si stende à molti più effetti,..perche veramente, chi ne i luoghi aperti è superiore di cavalli, sarà ordinariamenti vincitore.....(but) le forze militari consistono in gran parte nelle artigliarie, e ne gli archibugi, che sono molto meglio, e più adoperati da i fanti che da cavalli; e offendono molta più questi, che quelli. Concludiamo dunque, che la caualleria è superiore alla fanteria nella campagna: ma che la fanteria, che pure è di grandissima importanza anco in campagna, l'auanza ne ogni altra fattione militare...[1]

Of defense Botero wrote

.....sicurezza consiste in tener il nemico, e'l pericolo lontana da casa nostra...Hor egli si tiene lontano in più maniere; delle quali la prima si è la fortificatione dell'entrate, e de'passi, che si fa con le fortezze apportunamente fabricate.[2]

and whether against internal or external enemies

....ci assicurano le fortezze, doue tu tieni risposte le machine, e le monitioni da guerra; e mantieni, come à sculo, & in tirocino qualche numero di soldati; e con poco giro di muraglia difendi molto pease, e con poca spesa prouedi à molte occorrēze.[3]

In regard to which fortresses they ought to be placed

....in siti necessarij, ò almeno vtile; e neccessarij sono quelli, che se non fossero fortificati, il tuo paese restarebbe aperto...Vtili, sie difenderanno Città popolosa, e ricca, ò seruiranno di ricorso, e di refugio a'popoli...E di più necessario che la piazza sia grande, accioche ci si possino adopare le varie sorti di offese e diffese, e per questi via straccar l'inimico, e dar tempo à i soccorsi....Glabrio Serbellone, huomo di gran valore, in queste genere, suoleua dire, poca cosa, poca forza.[4]

On the design of such fortresses Botero explained

La... difesa di vna piazza ha tre termini principali; l'vno si è il difficoltar a nemici l'acostersi; l'altro l'impedir loro il piantar dell' artigliaria, e'l battere; l'vltimo l'impedir l'assalto, e l'entrata nella fortezza.[5]

and further added

...i difensori di Famagosta si portarono honoramente in tutti tre i punti ....e con un contra batteria imboccarono molti pezzi....Alla Goletta il maggior errore, che si facesse (come anche à Nicosia) fù il perder subito il primo termine delle difesa, con lasciar, quasi senza cōtresto, approcciar i nemici fin sù l'orlo della fossa.[6]

Further to the defense of his realm the prince ought to have munitions, and Botero explained

MOnitioni chiamo tutto ciò, che può seruir alla guerra: arme da offesa, e da difesa, poluere, palle, corde, ponti, scale, barche, catene, botti, ruote, e simili altri cose, delle quali bisogno hauer copia in pronto' perche l'aspettar à farne prouisione quando è tempo di adoperarle, non ci riuscire: & i bisogni della guerra sono tanti, che con tutta la dilligneza, che si vserà in farne massa, e monitione, sempre ne manchera qualche cose A questo effetto alcuni Prencipi tengono Arsenali...[7]

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1. (1601) p. 349/53 (Bk. 10). The 1589 edition does not have the clause about artillery and small arms as more suitable to the infantry. Both versions however have much the same tone emphasising the importance of infantry in siege warfare-"mancamento di fanteria non potuto afferrare, ne occupare Citta d'importanza, non ridure sotto il suo domino luogo di consequenza." (1589) p. 294.
2. (1589) p. 159 (Bk. 6). 3. Ibid. p. 160.
4. (1601) p. 189/91. The 1589 edition does not directly state the idea of great size being necessary, or mention Glabrio Serbellone, but the tone and implications of the earlier version were much the same. After mentioning the need for large fosses and the like Botero wrote "Ma non bastano tutte queste cose, se la fortezza non è ben prouista di vettouaglie, de machine, di munitioni, di soldati, e principalmente di capo ualeroso.... un buon numero di soldati di ualore buō fortificare ogni luogo, per deboli che si sia. Onde vediamo, che le fortezze, stimate inespugnabili, sono state facilissimamente prese: Perche i Prēcipi, fondendosi della fortezza del sito, non l'hanno prouisto di conuiente presido....." (1589) p. 162/3.
5. This is from Botero's <u>Aggiunte,...Alla sua ragion di Stato</u> (Venetia 1601) f. 81b, in which work he gave a good deal of the ideas common in the fortification treatises of the period.
6. Ibid. f. 82a. 7. Ibid. f. 64a.

As to the role of the Prince in warfare Botero explained

> Non è però necessario, che il Prencipi si troui sempre ne' fatti d'arme: basera alle uolte auuincinarisi all'essercito, & al luogo, doue si combatte: fare finalmente in manieria, che la salute dello Stato si riconosca, ò del tutto, ò in gran parte dal suo giudicio, consiglio, vigilanza, magnanimità, e valore...Ma se la guerra si sarà lungi da casa, non deue il Prencipe lasciar il cuor degli Stati suoi, onde si ha da diffondere l'autorità, e 'l uigore alle parti circonstanti....(and anyway) il Prencipe non si deue mouere, si non per guerre, e per imprese importanti.[1]

Further in order to function as an efficient war leader the prince out to understand the sciences of war, but not as a practitioner, rather in order to employ and organise and control practitioners.[2]

Thus Botero expressed a whole cluster of interacting ideas about the nature of warfare and its basis in matériel, and the functioning of the fortress within the political and social unit which could apply such force: the idea that only a relatively extended and rich teritory could hope to prosecute war successfully on even a limited scale; the idea that population and industry were the basis of richness and power and in direct proportion to them; largeness in population being matched by a need for the largest bodies of infantry, richness of industry being matched by a need for all the multifarious paraphernalia of warfare of both attack and defence in as great as quantity as possible; the fortress having a basic role as the guardian of the frontier of the kingdom[3] and functioning at least in part as a recipient of both troops and matériel; the prince, or leader of such a state being not so much one expert in 'feats of arms' but more an organiser and controller of his forces and the mechanisms by which the relevant materiel necessary in warfare was produced and assembled; the knowledge of warfare he needed being just the sort of knowledge that enabled him to organise and control warfare and the experts' necessary to its technological prosecution.

Thus by the end of the 16th. century the approach of the fortification designer, albeit developed in an earlier period, with his emphasis on theory and his focus on an urban area of a relatively large size, was

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1. (1589) p. 113, & 111 for the later section. The advantage of the prince attending battle was that it would make his subjects the more keen to fight and obey when they knew he was watching, rather than to fight himself.
2. See citation above p. 78 n. 8.
3. The idea that fortresses were primarily needed on the frontier of a kingdom had become a common enough one by the time of Botero was writing. See for example Pasino who indicated that this was the major problem of fortification II p. 100ff. Jean Bodin had expressed a similar view together with the idea of this fortress as a garrison town and the desirability of organised foot in warfare. He stated "But as for royall Monarchies, if their bounds and limits be large, it is not expedient for the Prince to build Cittadels, nor places of strength, but vpon the frontiers..." ((1606) p. 604). And explained "in my opinion a Commonweale well ordained, of what nature soeuer, should be fortified vpon the approaches and frontiers, in the which forts there should be good garrisons trained up daily to arms (although he continued rather antiquatedly) hauing certaine lands appointed for souldiers the which they should enjoy only for their liues, as in old times the fees and feudatories were" (ibid. p. 613); and "king Francis the first, cast the seuen legions of foot, which he had erected within this realme, in the year 1534, euery legion containing six thousand foot. And although that his sonne Henry did renew them twentie years after, yet was he forced to alter his opinion, seeing the Commonweal troubled, and mutinies grown in many places by means of those legions. And yet in the opinion of straungers, and of those that haue iudicially examined the goodly ordinaunces that were made to that end, there was neuer anything better instituted for the art of warre...(Ibid. p. 611)
4. In his Relationi vniuersale (1612) Botero described various kindgdoms and their forces in accord with his general view. About England for example, Pt.II p.11, he stated its strength in part depended on "legni leggeirissimi, e benissimo forniti di ottima artilieria (della quale abbondonato tutto 'l regno grandemete) ...(and) il regno puo mettere in campagna cento mila fanti, e venti mila caualli."

all the more validated by changes in warfare which had to some extent taken place, and were taking place, and which had given rise to perceptions about the nature of warfare and its relation to the state, which involved many favourable conjunction between his ideas and preoccupations and the changing preconceptions of the relation betwen warfare and society.

The nature of the change in preconceptions about warfare and its prosecution, that took place over the longer period, is to be found in a comparison of such views as those of Botero with the attitudes of the medieval period on similar topics.

In the medieval period it was by no means an assumption, in many writers, that power in warfare had any simple relationship to numbers, either of combatants or in mass of matériel. For example Raymond Lull wrote

> ...many batayllee ben many tymes vaynquysshed more by maystrye/ by wytte and Industrye/ than by multytude of people of hors ne of good armours/ [1]

Edigio Colonna argued in De Regeimine Principum

> ...Vegezio...dice...che il re possa sottomettere a sè tutte le genti e nazioni, la principal cosa si è, d'avere con seco e appo sè grande forza di gente...Ma questo non e vero....[2]

Christian da Pisan expressed the same idea at times, and quoted Vegetius with approval thus:

> ...saith vegece/ that it suffyseth for a comyn bataylle to lede a legion of gode men of armes. And al other auctours that hereof haue writon accorden what vegece/ saying that as in an ouergrete quantite is confusion ... ..And it is founde that many ostes haue be dysconfyted by theyre ownc multitude more thenne by the force of theyre enemyes...[3]

and

> ....that bettre is/ a small quantite of folk vsed and wel taught in fayt of armes by contynuel exercise of al that therof may fall in the doubtouse happe of bataill/ than is a greate multytude of rude folk nought knowing....[4]

However such passages are not so much a denial of the value of numbers in itself. They reflect rather the medieval insistence on the well trained and properly functioning man-at-arms as the backbone of the fighting force, and their concern with the problem of the pooduction and use of such combatants trained and exercised to the highest level.

There were two aspects of the power of the medieval man-at-arms that were of greatest concern to contemporaries. On the one hand his abilities depended on training from a young age in the physical manipulations of arms in the role as apprentice to an experienced warrior.

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1. This is Caxton's late 15th. century translation (1926) p. 96.
2. This is from an Italian translation of 1288 (1858) Bk. I Pt. I Cap. X. p.18/19.
3. This again is a Caxton translation (1937) p. 39/40.
4. Ibid p. 27. However Christian da Pisan on this point seems to sometimes reflect more the coming systems of warfare than the past, as she did when she emphaised the use of guns in siege warfare and battle and the provisions necessary thereto; and just before the first passage quoted above she stated: "And bycause that now commynly it is so taken that the vyctorye of the bataille by reason ought to falle to that partye that more folk are/ Agenst this oppynyon saithe vegece. ..." She expressed herself even more strongly in the context of the topic of whether the prince ought to go to war in person, stating: "first to fore all thyng he must beholde & take hede what puissance or power he hath or may haue as moche people/ as of fynaunce & money...for aboue alle thynges they ben necessarie/ & in especial moneye/ for who that hath money ynowh/ & wylle employe it/ he shal alleway fynde ayde & helpe of men ynowh... wytnesse of the warres of ytalie: & in especyal of florence: of venyse: & other places: þ whiche comynly fyght more with theyr money than they of the contree."(ibid. p. 15.)

For instance Lull explained

> The scyence and the scole of the ordre of Chyualrye/ is that the knyght make his sone to lerne in his yongthe to ryde...And therfor euery man that wylle come to knyghthode hym behoueth to learne/ in his youthe to kerue at the table/ to serue to arme/ and to adoube a knyȝt/ for in lyke wyse as a man wyl lerne to sewe for to be a taillour/ or a Carpenter/ hym behoueth that he haue a mayster than can sew or hewe/ Al in lyke wyse it behoueth that a noble man that loueth the ordre or chyualrye/ and wyl be a knight/ haue fyrst a mayster that is a knyght/ for thus as a discouenable thyng it shold be that a man that wold lerne to sewe shold lern to sewe of a carpenter...[1]

And Christian da Pisan explained

> ....of gode men of armes/ vegece recounteth of the proprytees þt behouen vnto them/ and saith that with hardynes without whyche he may not be ought/ must be taught & be maystre in helping of himself in his harneys & to be his ease to thende he may lightly assaylle his enemye/ and to be able to at lepe lightly ouer a dyche and to clymme yf nede be ...to bowe asyde to voyde þe strokes by deyuerres of body....Saluste to this purpose sayth/ The knyght or man of armes is to be chosen that from the tyme of his youthe hath lerned the trauayllis of armes and the maners of bataille....And al sciences & craftes are knowen & lerned by contynuans of vsage...[2]

The anonymous author of the Boke of Noblesse of 1475 recommended

> ....sonnes of princes, of lordis, and for the most part of alle tho that ben comen and descendid of noble bloode, as of auncien knightis, esquires, and other auncient gentille men, that while they ben of grene age ben drawen forthe, norisshed and excersised in disciplines doctrine, and usage of scole of armes, as using justis, to can renne with spear, handle with ax, sworde, dagger, and alle othir defensible wepyn...[3]

But the skills of body and mind learnt by apprenticeship while forming the basis of the power of the man-at-arms, to the medieval mind, were equally considered by contemporaries to be limited in a particular way, particularly when considered in terms of how such power could, or ought to function.

The basic idea at work was that the basic god given order of nature was governed by divine law. As Egiddio Colonna expressed the principle with regard to kingdoms

> .....cosa fatte per forza, e contra natura, non puo durare sempre...[4]

Or as Honore Bonet in his Larbe des battaills wrote more explicitly about combat

> VOus deuez scauoir qũ vng des principaulx fondemẽs de bataille cest force. ....Or pour venir a mon propos ie vos dy q̃ la force de lame est le premier & principal fondemẽt....It sĩ est vertu de lame auoir cõseil et scauoir bien ordõner ceulx qui sceust bien faire bataille...Et ainsi force de lame est principal fondamẽt de bataille. Mais force de corps ne se doit laisser mais quelle soit auec celle de lame....dieu lequel est celluy qui surmonte tout pouoir et toute puissance fait mieulx auoir puissance & victoire a celluy qui est mieulx son amy.[5]

Thus during the medieval period when commentators came to address themselves consciously and articulately to the problems of the the nature of force, they tended to focus not on power as something which increased through addition, and the needs of such addition, but on the qualities and training of the single man-at-arms, and the right and just application of divine law

1. (1926) p. 21/2.
2. p. 37, 33 & 27 in that order, emphasis added. Cf. later attitudes.
3. ed. Nichols (1860) p. 76.
4. (1858) p. 1 Prologue. The Italian version gave "perciò che natura pruova" in support of the idea, while the Latin version had "Nam ut testatur philosophus".
5. B.M. C.54.b.10. Cap. XXIX.

which made that very force possible.

This concern with rights and obligations in the practice of warfare was reflected in at least two basic ways: on the one hand in the notion of "chivalry" or "noblesse" expressed in such treatises as those of Bonet and Lull for example, and on the other in discussion of the rights and obligations of combatants within the social framework of their world.[1]

Of course there is no need to take the 'rhetoric for the reality' and conceive that medieval warfare, as a result of the idea of chivalry was a humane, even gentle, activity, in which everybody 'played fair'. It could be, and often, if not nearly always, was, a bloody and barbarous activity. The Albigensian crusade for example almost extinguished an entire culture. Equally, Keen for example has argued trenchently and at some length that the laws of war in the late middle ages functioned as part of the system whereby war was practised mainly as a trade for its economic benefit in terms of ransom and booty; that these laws were applied mutually between and among the chivalry of the different nations, who identified more with the chivalry of other nations than with the commons of their own, in order to support the system; and that far from any notions of chivalry protecting the weak and the sick, the common folk were often hung, slaughtered or disposed of in whatever way at will, 'in orders to extract a few pennies of ransom from them'.[2]

On the other hand undoubtedly this same concern with rights in warfare simultaneously both coloured the thinking of contemporaries about warfare, and reflected something of the practice of warfare of the period.

On the one hand such ideas tended to function as a legitimation of the social order and the role and function of the man-at-arms in society.

According to Lull, "Thoffyce of a knyght", is

> ....to mayntene and deffende/ his lord worldy or terryen...[3]

but also

> ...to deffende them that labouren the londes and the earthe....[4]

so as

> ....to mayntene the londe/ for by cause that the drede of the comyn peple haue of the knyghtes/ they laboure & cultyue the erthe/ for fere/ leste/ they shold be destroyed/[5]

as well that

> ...the knyghtes by nobless of courage and by force of armes maytene the ordre of Chyualrye/ And haue the same order (tenclyne the peple to deuocion and good lyf)/ to thend that they enclyne the smal peple by drede/ by the whiche the one doubte to doo wronge to the other/[6]

In fact

> ...in the tyme/ in which chyualry beganne was thoffyce of chyualrye to pacyfye/ and accorde the peple by force of armes/[7]

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1. These two aspects were of course closely related. Such a work as Tractatus De Bello, De Represaliis et De Duello by Giovanni da Legnano for example written by a doctor in cannon law at the University of Bologna in 1360 "at a time when a strong army lay before the city, which furnished the cause of my treatise, that it might provide a matter of exercise for the students at that time"...as it finished (1917) tended to be more concerned with legal question than matters of chivalry. (This author seems to have been much less willing to admit of the idea that force was dependant on some inherent 'rightness'. Judical combat (compurgation) he argued was not licit under divine law in calling for a miracle by god to make the weaker victorious when he has justice on his side. Cap. clxxv p. 341 (1917).) Chivalry, in terms of the ideas such as expressed by Lull "Thoffyce of a knyght is to mayntene and deffende wymmen/ wydowes and orphanes/ and men dyseased and not puyssaunt ne stronge..."(1926)p.38. But civil law during the period was not conceived as something different from sacred law, but more a reflection of it, and such treatises as those of Honore Bonet and Christian da Pisan gave a good deal of attention to just those questions as discussed by John of Legnano on 'feudal' obligations.

2. KEEN (1965) Cap. XIII 3. (1926) p. 29. 4. Ibid. p. 41.
5. Ibid. p. 32. 6. Ibid. p. 20/1. 7. Ibid. p. 45/6.

In order to support that system, according to Lull

> ...hit behouethe also that the comyn peple laboure the londes for to bryngе fruytes and goodes/ whereof the knyght and his beestes haue theyr lyuyng/ And that the knyght reste hym and be at seiourne after his noblesse/ & desporte hym vpon his hors for to hunte or in other manere after that it shal pleese him....[1]

and

> Thoffice of a knight is to haue a castel and horse for to kepe the wayes/ and for to deffende them that labouren the londes and the earthe/ and they ought to haue towns and Cytees for to holde right to the peple/ And for to assemble in a place men of many dyuerse craftes....necessarye to the ordenaunce of this world....[2]

But

> So moche noble is cheualrye/ that euery knyght oughte to be gouernour of a grete countre or lond/ But there ben soo many knyghtes/ that the lond maye not suffyse to sygnefeye that one ouȝt to be lord of al thynges...[3]

Thereby giving rise to the social-political hierarchy so that

> Themperour...behoueth that he haue vnder hym knyges that ben knyghtes... And the kynges oughte to have under them dukes/ Erles/ vycoũtes and other lordes/ And under the barons ought to be knyghtes/ whiche ought to gouerne hem after the ordynaunce of the barons.....[4]

In this system the obligation of the knight to defend his lord -- as noted above -- occurring because

> ...for a kyng ne no hyhe baron hath no power to mayntene ryȝtuysnes in his men without ayde & helpe/[5]

Now there is no doubt that this is a highly idealised picture of the society of the medieval period -- ignoring even the disparity between actual behavour in warfare and the chivalric ideals of defending women and orphans and the like. There were many variations throughout medieval Europe in the style of societies and their social and economic functioning. A much more urban Italy, for example, can be contrasted with the more agrarian countries of northern Europe such as Britain. Equally the great changes over many centuries that occured in the years so easily lumped together under the term 'medieval', make it difficult to believe that any such simple account could reflect anything but the most sketchy of pictures of the relationships between people during the whole period.

Yet there is no doubt that the ideas expressed by such a figure as Lull, had their roots long in the past, and equally that those same ideas were expressed by many later writers such as Honore Bonet, Christian da Pisan and the very late anonymous writer of the address to Edward IV of 1475. They certainly represent then something of the way at least certain people understood the nature of warfare and its relationship to society in the later medieval period.

That, that understanding reflected at least something of the actual working of the social-political system of the period is made clear by the fact, if by nothing else, that the castle, the centre of power of Lull's account is matched by so many castles over so many areas of Europe dating from this period. Castles, which form monuments to a social-political order which in so many cases were not replaced by more modern structures when the new style of fortification of the renaissance came to be the order of the day in a very different world.

1. Ibid. p. 19/20.
2. Inid. p. 41. This is a more extended quotation of the passage from which the clause quoted above p. 276 comes.
3. Ibid. p. 27.
4. Ibid. p. 28.
5. Ibid. p. 29.

The significance of the medieval castle within the system as described by Lull arose from the particular conception of power and the practice of warfare of the period.

The hierarchical society of the period was not a mere hierarchy of status. It involved a hierarchy of power. And a hierarchy of power of a particular kind.

Not a hierarchy of power which essentially involved that the lower an individual was in the social pyramid, the less was his power;[1] not a hierarchy of power whereby power was conceived to radiate from a centre and to exist at any particular level only in so far as this was permitted by the centre, as tended to be the model of later writers such as Giovanni Botero: but a hierarchy in which power was conceived as existing in discrete packets, so that at many levels power was possessed and exercised in its own legitimate way, with the power of those higher up depending on their right to support from individuals below them, while those below were equally supported by those under them, when rightfully required. Sanctions both divine and earthly with all their complex connections, being conceived as enforcing the rights and obligations which made the system work.

This view of society clearly supported the use of the castle as a structure both expressing and guarding the power of the local magnate at whatever level. It equally, in part, gave rise to the needs to which the castle was conceived to minister. The castle formed a base, residence and defensive unit which enabled the local seigneur to support himself with his horse, harness[2] and retinue by the explotiation of the local agricultural production of his territory and of such urban folk as were necessary to the production of the other necessities of life, in the estate which enabled him to perform his function of maintaining order both through force of arms or the fear of it, as Lull indicated, or through the exercise of his own local legal juristictions;[3] the very legitimacy of his existing in such a fashion allowing the cultivation of that power which he was conceived as obligated to bring to his overlord.

But while the knight exercised his own independent power in his own estate, he was conceived to exist only in a system in which there equally existed others of the same estate who equally exercised their own legitimate independant power. His power therefore, in theory at least, depended on his own limited domains. In so far as the system continued to function in a stable way in accord with this ideal picture, the individual magnate had to make the best use of his own resources, and thus it was by cultivating his own particular skills through long practice and exercise of valour, that he became the most effective power unit within the system. Similarly power within the whole hierarchy could only be conceived to be legitimately increased at a higher level by assembling the skills cultivated at the lower levels, if the system was to be stable. Hence the medieval conception of power as depending not so much on numbers but rather that it was to be found in good quality men-at-arms. As Lull put it

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1. That is, not merely that the Emperor was more powerful than the king, the king more powerful than the Baron, the Baron more powerful than the local shire knight, even in conception.
2. Lull (1926) p. 54 "a knyght without harnoys may not be/ ne ought to be named a knyght."
3. Ibid p. 30 "By the knyȝtes ouȝt to be mayntened & kept justyce".
4. Ibid. p. 47.

> ...Chyualry hath no regard to the multytude of nombre but louethe only them that ben ful of noblesse of courage....[1]

This well trained knight was thus to the advantage of the lords above him. Supported basically by the agricultural produce of his domain with his relatively expensive accoutrements and the leisure to practise in arms, he equally, by himself or with his followers, was a powerful fighting unit who could hold down (keep order among as it was put) the local peasantry who by virtue of the social order by and large had not the opportunity to train or combine in order to challenge that power.

This framework then tended to create the needs to which the local medieval castle had to respond. The castle provided a local haven or residence for the lord, either against any local uprising or incursions by his neighbours ('evil knights'). In response to his relatively limited local resources it tended to be relatively small, for then a small number could defend its limited perimeter. Height, which increased the difficulty of escalade, equally increased residence or storage space in proportion to the perimeter, which thus could be kept relatively small and be defended by a relatively small number of combatants. A series of defensive barriers of increasing strength up to the strongest of all in the keep enabled defence to be made at the outermost barrier when sufficient combatants were available, or the external forces weak, while lacking combatants or losing them under siege the defenders could fall back to the more confined inner areas. While the keep itself with strength and height of wall could be held by the lord and a relatively few faithful followers or companions, against intrusion, treachery or deceit.

Of course as noted above conditions varied widely both geographically and over time throughout medieval Europe, at different times and different places tending to conflict with the ideal model. The agricultural base for example was very much less applicable to Italy with its much more urban environment all during the middle ages, and to areas of Flanders around the great textile towns such as Ghent and Bruges, during the later period. There were equally wide variations in terms of whether the sovereign was lay or clerical, and to what extent the social hierarchy actually approximated a pyramid, with for example a number of powerful barons at the top with a weak king, and relatively great gap between the baron's power and that of many local knights; or as in the Latin empire where the emperor was rather distant from many small power units well below him. Equally, independent fighting bands and merceneries with no attachment to land, hiring out as professional soldiers for pay or booty were known from a relatively early period.

Yet whether the obligation to do military service for the lord was in return for the granting of the usufruct of ones land, or whether it tended to be more a contract in return for wages, as increasingly tended to happen as time went on; whether the knight fought on horse back or on foot in battle; whether the intermediate power units were knights with their accompanying retinues, or towns dominating a local area, that particular view of the nature of warfare and power in society could still function. Reinforced by the medieval acceptance of the universal church with the interaction between a particular view of society and a particular view of divine revelation, that view of society was relatively stable and provided the basis within which medeival military architecture developed from roughly the late 11th. century to the end of the 14th. century, at least.

Thus medieval military architecture functioned within a system

1. Ibid. p. 47.

very different from that within which the fortification theory of the later 16th. century operated. A system in which the assumptions and preconceptions about the nature of power, of warfare, and the nature of the social and political order, reflected aspects of the functioning of that society which were very different from those of the later period, and which differences in part at least, were responsible for the different fortification practices of the different periods. The castle provided the base by which the medieval lord exploited the agricultural resources of his territory and by which he was in turn supported as a fighting unit. He and his like provided the main force in battle in an army whose strength depended on the assembling of the power inherent in his highly practised bodily skills. His castle was both defensive unit and residence to such warfare and the whole social and economic order.

In contrast the bastioned enceinte of the later 16th. century fortress was conceived to be first of all a guard to a whole kingdom, comprising a relatively extended territory, whose power was conceived to exist in quantity of population, and trade and production, which supported both the men and matériel which could be assembled and guarded in such garrison towns to supply the sinews of war, and which provided the basis for the employment and organisation of coordinated bodies of infantry as the main power in battle, as most fully expressed by Giovanni Botero.

This shift in perception can best perhaps be pinned down to roughly the two centuries between 1400 and 1600, between the writing of Christain da Pisan, who, with her background in Italy and France, expressed quite clearly the old chivalric values and notions about warfare and society,[1] while at the same time she wrote sometimes more as a harbinger of the comming order with an emphasis on the use of guns in warfare and the significance of money and matériel to the Prince in making war, and the clear expression of the modern view as put forward by Giovanni Botero. A shift by no means of an arbitary nature, but matched by changes in warfare, politics and society, which although they can not be conceived to have been, during the same period, anything like as extensive as the equivalent changes on the level of the way things were perceived, were matched to a significant extent at the level of practice, by changes in the same direction.

One way in which this gradual change over a long period can be detected in military architecture in detail is in the gradual emergence of the renaissance palace from the residential and defensive structure of the medieval lord in his castle, the palace appearing as a much more residential or chancellery building and as the residence of the Prince losing its defensive functions. Thus while Francesco di Giorgio and other military architects of the the later 15th. century were concentrating -- at least at times -- on the provision of relatively small powerful defensive structures on the principle that the smaller circuit is most easily defended, in accord with medieval needs, such building as the Castelnuovo at Naples and the Ducal Palace at Urbino were under construction with a tendency for windows to become larger for example, representing the gradual shift away from defensive functions in such structures.

The emergence of the characteristic elaborate renaissance palazzo in the 16th century as a residence for a grandee was a further stage along the same path, with only an occasional writer such as Serlio attempting to integrate the fortification forms of the period with the princes residence into a single unit. Equally for example the emergence of the English country house

1. Christian's account of setting out of a battle array, depending on the notion of static 'battles', advanceguard, rearguard and main mass, comprised of men-at-arms with the 'comyn' people on the wings of the advanceguard in clumps stiffened by men-at-arms, shows most clearly her basis in the medieval warfare of her period.

from the medieval castle can be detected during the same period. In contrast where styles of warfare more like those of the earlier period continued, local strongholds continued to be built albeit generally on a small scale, much more like the medieval castle in style than approaching the bastions systems of the 16th. century. In the Scottish English border country for example where, for various reasons, maurading and raiding continued to take place until the end of the 17th. century peel towers continued to be built.

However at the same time as the head of the social hierarchy of the medieval period, as a leader in war dependent on bodily skills, essentially the same as those of the men-at-arms he led, gradually became the sovereign who in conception was considered to function more as an organiser and controller of his kingdom, resident, in his unwarlike palace, so, out of the new warfare gradually emerged roles for individuals of status well above that of the common man. Cavalry itself remained a significant weapon of warfare and because of the expense remained more suited to those of greater means.[1] On the other hand the new more technological warfare itself created important openings for those willing to undertake its control and organisation, and for those willing to become expositers in the understanding of the new technology such a as in artillery and fortification. But equally the control, organisation and leadership of disciplined infantry provided roles for those whose station in life could not be conceived to be suitable to acting on the same level as that of the common herd. Very crudely speaking, the medieval chivalry of a country -- i.e. the knights and others of such a level -- became the officer class.

Undoubtedly the cultivation of the practical mathematical sciences, which disciplines had qualities which were emphasised as being particularly suitable to gentlemen, must have tended to favour those of noble blood not finding such teaching roles, or the organisation of technology too much beneath their dignity, or too much smacking of the mechanical arts. Equally the leadership and organisation of the infantry and the new technical armies could also be seen as the task of an educated man on much the same lines, with its own textbooks on arraying, for example.

Robert Barret expressed a rather extreme view on this around the end of the 16th. century stating of "The Seargent"

> It is requisite that he be somewhat learned, both to write and reade, and to cypher, whereby to keepe a roll or list of all the souldiers of his cōpany, with their seuerall weapons...And although it toucheth the Carporale to knowe the prouisions which the Souldiers haue of powder, shot, and match, and other munitions and armes, yet the Superintendence thereof resteth in him (i.e the seargent); for besides that it importeth the Princes commodity, the bad distribution thereof doth hazard manie time the sefetie of the whole Armie, coming to faile and want in time of necessetie.[2]

He was perhaps even more extreme when he suggested that all captains of companies should work there way up form the ranks through each grade before achieving that position, and complained of the Spanish practice:

> ....it hath bene seen many times, that both some Generals, Vize royes & Counsellers also haue missed in the consideration therof (that is, in the selection of captains of infantry), bestowing those charges vpon their followers, & Court-familiars and fauorites, wherby hath risen damage to the Prince.[3]

1. See Machiavelli for example at the end of Bk. I of <u>The art of war</u>.
2. (1598) p. 18/19.
3. Ibid. p. 23. Barret had stated that in Spain "Captaines of Infanterie are appointed by the Counsell of state & warre...but with vs the lords of privy Councell do commonly appoint them". (ibid.)

On the other hand De La Noue had earlier stated:

> Auiord'hui ce qui rend en partie l'Infanterie Espagnole en tel prix qu' elle est, c'est que la Noblesse s'y range fort volontiers, (in the infantry) & plus qu'en la Cavalerie, & y vient faire son apprentissage de guerre, à fin de paruenir au degreé de Capitaine, qui est autant estimé parmi eux, qu'entre nous vn Colonnel d'vn Regimen.[1]

With regard to the controller of the artillery who also had the role of overseeing fortifications, Barett explained:

> ...the Generall of the Artillerie, or Maister of the Ordinace, is appointed by the Prince. His function is of great qualitie and trust, for the reputation had of the same, and for the effects which the same preformeth: and therefore is aluay encommended and bestowed vpon personages of great grauitie and authority, and of great prudence, valor and experience.[2]

Thus the development of 16th. century fortification, and the theory of the art, with its dependence on the general employment of the pointed bastion, resulted in a number of favourable interactions on a number of dimensions. With the developing technological nature of warfare, the dominion with large resources of both men and matériel tended to be favoured; with the changing nature of warfare equally the power structures of the medieval period with an important role for the local castle as residence, were less relevant, and the need for the local castle declined, so that while the residential function was taken over by the palace, resources tended to be absorbed by a smaller number of sites and could be concentrated on the fortresses on the border, which could as a result become relatively large urban garrison towns; equally with the decay of local sovereignty and medieval warfare, individuals of rank in the old order tended to lose their predominent roles, but in time could find new positions in leadership and organisation to help to maintain the newer types of kingdoms: the technologies such as developed through the cultivation of the new practical mathematical sciences, conceived to be suitable to gentlemen, and with their public quality, could become then effective, in creating tools of control that favoured the centralization of the more monolithic dominion, and in providing superior roles in society.

Such developments which took place only very gradually over a period of centuries and even at the ideological level only begin to patent circa 1600 -- and which awaited such developments as the fortification works of Louis XIV and Vauban in the later 17th. century for their fuller expression[3]-- can hardly be conceived to have been dominent influences in the relatively rapid changes in fortification practice that took place in a few decades around 1500. Yet at the same time the solutions in fortification, outlined quite clearly in the first decades of the 16th. century, were just such as to fit so well with many of the new aspects of the whole system of warfare, science and society, that began to emerge after that period. To some extent of course the descent of Charles VIII into Italy may well have signalled the coming pattern to those who worked on fortification in the decades afterwards. But to consider such designers as having been

1.(1587 Basle) p. 274. On the other hand La Noue had just complained that French Nobles would not enter the infantry and even often would not take charge.
2. (1598) p. 121. Nobles had been appointed to the charge of artillery as early as mid 15th. century in France (see CONTAMINE (1972)).
3. With such 'hiccups' as the French religious wars of the later 16th. century and the English civil war in which medieval castles were refurbished and surrounded with bastions to withstand sieges, which represent periods of temporary return to styles of warfare more like the older forms and being by no means between states.

able to have seen so many complex developments so far ahead seems excessive. It seems rather then that the developments in fortification theory that occured in the early 16th. century and which were codified during the second half of that same century must be conceived as being part of a series of increasingly favourable conjunctions with the developments of warfare, science and society that took place during the same period; and that that particular pattern continually favoured the dissemination of fortification theory as it emerged, even as tha particular doctrines of fortification helped to bring the various different systems into being.

Thus, not only were there complex interactions between preconceptions about the desirability of mathematics and theory in fortification, and the developing pattern of siege warfare, such as to make grossly over simple any account of the developments of renaissance fortification on the lines of technological determinism and the new powerful artillery; but equally the developments in fortification interacted in so many complex ways with wider factors of warfare science and society, and to some extent helped to bring into being the very needs it turned out best able to satisfy, that any simple functional model of any kind does not seem able to account for the developments in the area.

III: (4): Final analysis
(i): Culture systems

Having isolated a cluster of ideas in the fortification treatises of the later 16th. century concerned with the nature of that art as a 'mathematical science' and having traced those same ideas at work in a number of other branches of the practical mathematical sciences during the same period with roots back into the 15th. century, the earlier history of fortification during the renaissance was then examined to see what influence such ideas as the need for theory, may have had during this earlier period. The discerned responses, in two phases, the early one focusing on the need to provide a structure to resist artillery, the later in terms of basing the design in the needs of defensive fire in accord with the principle of no dead ground, were discovered to be different responses (almost distortions) at the theoretical level linked to the increasingly effective use of artillery in siege warfare both in attack and defence: the connection being of a general nature and by no means a simple mechanical result at the causal level. The relatively lightly shotted but mobile and rapid firing artillery of Charles VII undoubtedly helped to focus new approaches but again by no means produced the shift between the two phases in any simple way. This shift indeed was found to be as much a response to the increasing importance of flanking fire and defensive fire in general as a weapon of siege warfare. The features that may have tended to favour the acceptance of the later renaissance theory of fortification were then examined. It was found that the whole development of renaissance fortification was but one part of a whole complex of changes taking place during roughly the whole period 1400/1600; changes in the nature of warfare, in the increasing technological load of the use of the new gunpowder weaponry, particularly in the case of siege warfare, and also in the increasing effectivness and dependence on the use of infantry companies in warfare; changes in the nature of the political and social order, and how that order and the associated nature of the warmaking function were viewed, together with those changes comprised by the cultivation of the practical mathematical sciences; which changes together formed a mutually interacting package whereby by the end of the 16th. century the view arose that the state as the basic warmaking body needed to be territorially relatively extensive and rich, and that its power was in proportion to the quantity of population and of economic functioning which matched the need for forces in warfare based on organised infantry and the new technological weaponry. Whence arose the conception that the main need in fortification was for fortresses on the frontier of that type of state which were required to be relatively large urban areas to contain garrisons and the matériel of warfare -- a need which 16th. century fortification theory conceived to be just that type of need which design in fortification as it was favoured for technical reasons, was best suited to satisfy. So that there evolved a view of the prince as more an organiser of that state than one able to accomplish feats of arms, who was supported in his organisation and control of that state by those very practical mathematical sciences, such as fortification, which it was considered necessary to cultivate on epistemological grounds. In turn the organisation allowed by the cultivation of these sciences created roles suitable to the nobility who equally could find positions of some dignity as leaders and organisers of the new disciplined infantry, rather than as independent units of power as in the older medieval style.

Thus the success of 16th. century fortification must be considered to be to some extent but a part of the success of the whole package of ideas and their associated forms of functioning in warfare, politics and society which can hardly be considered to have developed in so far as to express the whole body of practices as envisaged by that ideological package, but which in significant ways had developed towards a pattern along the lines expressed.

Thus the story of renaissance fortification must be considered, at the very least, to have occured at a number of levels. It involved both the short term and almost instantaneous 'gestalt switch' in Francesco di Giorgio's thought to the idea that artillery was irresistable, and the very long term changes in culture, warfare and society over centuries. Having examined some aspects of these changes in detail, such as the cultivation of the practical mathematical sciences, and having considere other such as these long term changes generally -- if only sketchily enough to indicate the general nature of the changes -- it now remains only to consider how such a pattern of evolution involving such very disparate levels of change, can be characterised, and to discuss the nature of the interaction between technology and society as represented by fortification, and the other practical mathematical sciences of the renaissance of which it was but a part, during this period, and the significance of renaissance fortification within that whole process by which the medieval world gradually evolved into the world of modern Europe.

In order to account for the many disparate elements and their complex interaction in the story of renaissance fortification it thus seems necessary to postulate some general pattern, mechanism, or merely model, by which the nature of the interaction between a technology and surrounding society as it occurred during the renaissance may be clarified.

One feature that clearly must be built into any such model is that phenomenon that has been discerned repeatedly in many different contexts and referred to either in terms of conjunctions between developments of different areas, or in terms of a system of mutually interacting and supporting elements. The developments of the different practical methematical sciences themselves, each in part at least with its own individual roots, by the second half of the 16th. century formed one such set of conjunctions which formed a system within which each discipline tended to act as an element in a mutually supporting system in that each discipline could refer to all the others as evidence of the value and necessity of such mathematical sciences, and the common approach which was involved at the epistemological level. But also the system of society, science and the prosecution of war had a similar pattern, which was strongly in contrast to the (roughly) equivalent system of the medieval period. While in contrast the early phase in renaissance fortification formed an unstable system, in which the developing needs of siege warfare and society and the notion of concentration on form to resist artillery, increasingly came into conflict.

Generalizing from this sort of pattern, at the most extreme we may conceive the existence of a culture system. That is, at a primary level, of an aggregation of many different kinds of elements: normative views, actual practices, ideological commitments, physical processes and geographical features; available resources of artifacts and knowledge, institutions, beliefs motivation, and so on. In short all the different aspects of a culture which might be picked out for description and study whether by an anthropologist, theologian, historian, technocrat, politician, or whoever. Two different conditions may then be envisaged as potentially existing at any one time. One a relatively cohesive condition in which there is a tendency for the different elements of the system to form groups within which they tend to have mutually supporting interactions. The second, a condition of general tension in which not only do such mutally supporting interactions not occur, but in which the different elements tend to form groups within which the different parts give rise to contary demands, whether at the level of behaviour, belief, practice, or abilities.[1]

Given the distinction between these two kinds of conditions, change over time then appears as tending either towards the more cohesive condition, or towards greater degrees of tension whether in the whole culture or between its different sub-systems.

This general model has clearly built into it the answer to the problem of the very disparate kinds of change, as discerned in renaissance fortification, some rapid and piece-meal, some of a single level, with others which occurred over a long period and were of a general nature. This occurs because the basic notions at work are iteratable in a hierarchical way. The whole culture system itself can be conceived to be tending towards cohesion and hence stability, or towards a condition of tension and hence instability. Equally however any particular collection of culture elements can be examined for tendencies towards cohesion and stability within the group, while that same group may in turn be tending towards tension or cohesivness in regard to other elements of the whole system. Then in turn any single element of such a group may itself be broken down into its elements which can be examined for exactly the same qualities. In this way fortification for example can be seen

1. An intermediate condition in which neither tensions nor supporting conjunct- occur can of course be conceived. But once any change occurs it is highly improbable that any such 'unstable equilibrium' would last.

simultaneously a (quasi) autonomous discipline with its own technical problems within which particular course of action interact in an unfavourable or favourable way, while at the same time it can be seen as having either favourable or unfavourable interactions with other disciplines and the other practical mathematical sciences. While in turn the practical mathematical sciences as a whole can be seen as interacting favourably or unfavourably with wider aspects of the culture system.

As a result we are immediately side tracked from any attempt to give an answer to the question as to what was the cause of renaissance fortification taking the course it did. Rather, using this model as an explanatory device, we are immediately brought face to face with a whole hierarchy of interactions which through their favourable nature account for the reasons by which renaissance theory of fortification took the course it did and was a success. Further and perhaps more importantly, we are side tracked from getting bogged down in the question of whether the course taken by the 16th. century fortification engineers was rational or not. We can trace preconceptions in that area about how such a problem ought to be faced, in their interaction with the problems of the use of artillery in siege warfare for example, and simultaneously trace the whole process by which a certain view of what was a rational approach, was growing up, and assess the interaction in terms of the more favourable or unfavourable interactions, so that we give a description of the processes involved which is not a mere account of the processes which to a modern mind are rational, but which allows the build up of such a view of rationality, as is the modern one, to come under historical scrutiny and be 'explained'.

Moreover this model has other advantages. It liberates us from any too easy acceptance of a kind of 'rigid-rod' causalism (as for example crude technological determinism which by now it should be clear cannot possibly account for all the complex factors at work in renaissance fortification). That is, of a kind of causal view in which cause is conceived on the basic pattern such as involved in the opening of a car door, whereby a handle is pulled, pushed, twisted or whatever, and by means of rods, or connections, or gears, or pulleys (which we may or may not be able to see) a latch operates, and the door opens. So that there are two radically contrasted conditions -- don't touch the handle and the door remains closed, turn the handle and the door opens. In contrast to this type of simple on/off causal picture, the model envisaged here suggests cause as more a response to a whole series of pressures. Change in any one particular direction in one element of the culture system may be seen as setting up tensions with other elements, or, alternatively, cohesions by way of mutually supporting interactions. The cause of an event is thus the net result of additive pressures towards change in any particular direction, in these complex interactions. This picture of cause is important in that when the basic notion of a culture system is iterated on the elements of the system and then on the elements of the elements of the system, and so on, we eventually arrive at the beliefs, actions, wishes, assumptions, situations, and so on, of particular individuals. The same notion of cause is thus applicable at wide levels of general within the whole system and at the same time at the base level of individual action. The individual in his actions is thus seen as subject to the same sort of pressures as occur more generally, in that any particular action of his, will tend to set up tensions within certain aspects of the culture in which he lives, or will tend to involve certain cohesions and favourable interactions with all the many aspects of the world around him.

However when the notion of a culture system as outlined is iterated until the actions of the individual are arrived at, a new factor is found to be necessary. This is as it should be. Individuals are after all the actors on the stage of history. Humans are the power house of the whole system so to speak. And when the individual is conceived as subject to the sorts of pressures, as indicated above, a number of new factors appear. The notion of a culture elements is of any aspect of a culture that can be described. Clearly the individual, conceived as subject to a number of pressures, in that certain actions may set up particular tensions while other may induce favourable interactions, cannot possibly either take into account all these multitude of factors, or predict in any precise way what tensions or favourable reactions may occur. (To assume that he could so do would be tantamount to assuming the individual omniscient.) He must be conceived therefore to exercise choice and judgment in the way he acts in the face of the particular pressures around him. There is therefore not so much, room, in this account, for human choice, it is necessary that human choice be postulated to make the account coherent. This quality is of course equally in accord with 'common sense' in that, it is notorious that at least some individuals, at least some of the time, act in certain ways because they conceive themselves to be subject to certain pressures and wish to do the opposite out of sheer 'bloody-mindedness'. Thus it seems to be necessary in this account to allow the individual choice or 'free-will'. Thus the 'personal-equation' or 'personality' of the individual has got to be conceived as an aspect of events. However this freedom to ignore certain pressures, or, to put it another way to accept certain kinds of tensions that may arise, can not be conceived to be in any sense absolute. The individual who ignores such tensions to any too great extent is liable to rejection as an individual in one sense or another by the world around him. In science be becomes a crank, or in other circumstances he is subject to judical incarceration, or snuffed out, or put in the category of the mad, or, as an unarmed peasant trying to stand up to a well equiped man-at-arms, is gutted. On the other hand occasionally individuals may quite directly challenge those pressures they find around them and insist on breaking with what are considered by others to be the significant pressures of his time; and if by so doing they carry others with them they may create sufficiently favourable conjunctions, for their activities to become a focus for change. But if one fails to so do, then he is all too likely to be subject to one or other of the penalties of his world.[1]

Thus under this model while the individual must be considered to have the ability to exercise choice, that choice is by no means absolute but is quite strongly limited by these different kinds of effect, that is by the fact that favourable conjunctions or tensions may arise as a result of his actions. Thus the individual is seen as both exercising free-will and yet

1. Certain aspects of this construction may be seen to be similar to some of Max Weber's views on history. For example according to RUNCIMAN (1972) p. 28, Weber in his "concept of a social relationship", "he takes to consist in the meaningful behaviour of a plurality of persons all of whom take account of each other's behaviour in their own". And FREUND (1968) p. 71 Weber's view was that to "attempt to explain a historical event by subsuming it under a general law is to distort history, which is made up of a succession of singular events. The only appropriate method is that of individualization, which relates a particular event to particular causes or to a particular complex of causes, which Weber called a 'constellation' ". This is not the place however to go into the complex problem of Weber's views on history, or the difference between the approach suggested by Weber and the position taken here.

is subject to a certain kind of determinism as an individual.[1]

Thus under the the social model of technological change during the renaissance fortification theorists can be seen as favouring a particular epistemological viewpoint, yet at the same time their individual responses in respect of the degree to which they favoured theory or practice, for example, while to some extent they can be seen as stemming from the personal histories of the individuals involved, yet are more fully accounted for by addition of the factors of choice and personality.

Thus the choices of many individuals are seen as interacting to produce regularity of belief and behaviours which, as they emerge and continue are ever subject to pressures and tensions from the whole cultural background. In this way the rather doctinaire attitude of the later 16th. century fortification theorists is seen as a response to the building pressure for theory in the period, while their activities in turn helped to feed that demand, in accord with the social model. On the other hand that response is also seen as sufficiently responsive to the needs of siege warfare in the complex interaction of defence and attack of artillery, rates of repair and barrage, and the problems of matériel, not to have created unacceptable tensions, particularly when that technical approach helped to focus on the urban enceinte with all the favourable interactions that arose within the system of warfare, science and society, of which it was a part. While at the same time the shift in focus c..1500 from the need to find the form to resist artillery, to the form determined by defensive flanking fire, was but one stage at one particular level in a process which was successful for just these reasons, while at the same time it is inconceivable that the individuals involved were able to prevision all these results.

The notion of a culture system further gives a famework by means of which renaissance fortification, particularly in its theoretical aspects, may be set within the whole development of western European culture.

Traditionally historians have used the notion of 'a period': the medieval period, the renaissance, the modern period, and so on. Undoubtedly such terms apply to spans of time during which very broad characteristics remain of significance and characterise these periods; and undoubtedly historians use these terms in a general way with a good deal of confidence, and agreement between authors, if, at the same time, with a very much lesser agreement on the precise nature of the characteristics in question and their stability. It is indeed when one attempts to give accounts in detail of a particular feature of any such period, and particularly the changes that took place in that feature during the period; and when attempts are made to trace continuities from period to period which undoubtedly exist, that such notions seem very much less useful, at the least.[&]

On the other hand the notion of culture systems as outlined suggests that what should be considered characteristic about a period, is not merely certain kinds of beliefs behaviours and processes, but the way those characteristics as elements in the culture system interlock and tend to support each other, or at the very least, to coexist alongside each other, even though over a period those elements themselves may change quite drastic-

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1. In one way this model may seem to be parasitic on itself and hence incoherent with nothing to keep the process going because every ones choices are seen to be in some sense a response to every one elses choices. But the historical process is one that continues over time and every individual finds himself as he grows in a culture with these choices being made all the time around him.
&. For example, just to take a case from warfare itself. The very notion of 'medieval warfare' seems to be very much less clear when the changes from knight service as an obligation in return for a usufruct in land towards a greater emphasis on service in warfare as a contract for pay, are considered, with all the continuities that gives with the later period.

ally. The result ensures that certain kinds of elements of the kind most characteristic of a later period may quite extensively exist at an earlier period alongside the more dominant elements that form significant clusters, so that development of these less significant characteristics of even only a limited extent, when new convergences occur, can produce new significant clusters, and a new culture system and period. In this way detailed piecemeal changes which, when viewed by the historian closely, may seem to occur so slowly and to lack almost entirely radical or revolutionary episodes, so that it is not easy to see how such substantial shifts of the culture as a whole can occur, even allowing for detailed changes in many like areas, can be seen to be able to 'add up' to the substantial kind of change from period to period, which historians so easily distinguish in a general way, because of the new clustering and cohesions that can occur with only relatively detailed and minor changes in the elements that make up the clusters, in the shorter term.[1]

In this way one can see how the seeds of a later pattern can have room to grow causing only relatively minor piecemeal change and tensions in the earlier period, and hence to have their own history in order to become dominant aspects of a later period.[2,3]

From this point of view the medieval period may be conceived to as one of a relatively stable clustering of cohesions, as is represented by the cluster of warfare, views on the social order, and military architecture noted above. In contrast the view of Giovanni Botero then represent an equivalent clustering of characteristics of the modern period as it was developing and continued to develop, as a period of relatively stable clustering of cohesions, the position that Botero put forward being something that many would perhaps accept as not irrelevant to 20th. century states, excepting that is, in his notion of the significance of the fortress and its particular role, which lasted perhaps merely until the 19th. century.

The renaissance in contrast, from this point of view, is a rather different kind of 'period', a period which saw many gradual changes, and some of a quite radical nature perhaps, whose cumulative effect involves just that shift from medieval to modern culture, by way of the mutation of the relevant cohesive clusters.

Thus consideration of the problem of the sorts of long term and short term changes as found in renaissance fortification has resulted in a

1. Thus when one considers the practical mathematical sciences of the renaissance each one can be seen to be developing in its own way, many with only a slightly different degree of emphasis . on mathematics, in a process which goes right back to classical Greece. The change in each of the areas considered is not that great, rather a somewhat greater interest in the areas is all that occurs. But taken together, mutually supporting each other as these areas came to do, one has a new epistemological view which each one on its own could never create even in part.

2. Of course fortification is one of those examples where there was more radical change. Equally it should be noted that to the specialist concerned with any detailed aspect of a period certain kinds of change may appear very radical, while to the non specialist they appear very minor -- say a new way of wording a charter. What apparently occurs here is that the specialist can see how that change will form a cluster with another sort of change to produce a very different kind of relationship connected with such charters. Hence to him it is radical.

3. This general view is in opposition to the old adage 'plus ca change plus c'est la meme chose', and is rather that 'everything remains much the same, yet everything becomes different'. The opposition is not one of contradiction, rather the first sentiment is just that condition which occurs under stable clustering of cohesions which it has been attempted to grasp here, while the later refers to periods when clusters are in flux.

certain kind of viewpoint on the whole period (or periods), in which those changes took place. This is not an arbitary development. The kind of perspective sketched in, while on the one hand it provides a framwork within which fortification during the renaissance may be placed in its wider background, on the other, that perspective growing out of the consideration in detail of one particular field provides a contrast with a number of other views of a general nature on the general changes of the period, in the context of which fortification and the practical mathematical sciences have a special significance. On the one hand we have the general account of the development of society of Marx, and in more detail the account of Boris Hessen of the relationship between (roughly) technology and 'science' in the early modern period. On the other hand, arising in a very different way and concerned with rather different problems we have the account of T.K.Rabb, who attempted to apply the notion of crisis to the early modern period, with a resolution in the later 17th. century, of which he distinguished an important aspect to be the new 'science'.[1]

Consideration of these rather different approaches to the whole period to which renaissance fortification belongs will then help to assess its position within its whole cultural background.[2]

III: (4): (ii): The developemnt of the mathematical ideology in the early 17th. century :Galileo and Descartes

Before attempting however to assess these different perspectives and their significance for the details of renaissance fortification, and the cultivation of the practical mathematical sciences of the period, something must be said about two general problems: the relationship between technology in the renaissance as outlined and 17th. century 'science', and the nature, problems, and extent of epistemological change that took place during the renaissance and the early modern period.

Modern usage of course is all too confusing when the problem of 16th. century 'technology' and 17th. century 'science' is considered. The relationship which has to be considered is between the practical mathematical sciences of the renaissance and the natural philosophy of the 17th. century and this formulation immediately draws attention to a very deep running difference between the two kinds of activity at issue.

Practitioners in the practical mathematical sciences of the 16th. century tended to ignore or to 'fuzz-over' the significant differences between practical knowledge and speculative knowledge, while the sciences they studied were to a great extent addressed to, more specific or more general, types of practical problems. They did not deny the distinction of course, but simply tended to proceed as if natural philosophy was but one discipline similar to those sciences that they cultivated, and that the more practical and the more contemplative 'sciences' were on a par.

In contrast much of the work which figures so predominantly in the 'history of science' of the 17th. century was very definitely and ex-

1. In neither case are the remarks in this area made here to be considered more than the result of a certain sort of perspective that has arisen from consideration of the nature of the practical mathematical sciences of the renaissance in general, and fortification in particular. The remarks made here are in no way definitive and are only of the most general nature. It is contended however that the material considered here tends to point to the sorts of considerations given, which deserve to be examined in more detail, if only to be refuted.
2. This is not to suggest that these are by any means the only other alternative views on the period in general. These obviously are legion and multifarious. It is simply that certain aspects of these two rather different views have quite strongly similarities in rather different ways to the particular points that have emerged from the detailed consideration of renaissance fortification, and pose useful contrasts.

plicitly natural philosophy, with a tendency for the 'sciences', addressed to more practical problems, to be relegated, as they had been in classical Greece, to a more lowly role.[1] Natural philosophy in this context needs to be distinguished by two specific characteristics. That study was very much addressed to problems very different from those to which practitioners in the practical mathematical sciences of the renaissance gave attention, and most obviously to problems much more like those that had been discussed by the great classical thinkers, above all by Aristotle who for so many centuries had been a focus of interest in the medieval universities. This characteristic was almost necessarily linked to another aspect of 17th. century natural philosophy, which again was in contrast with the activities and approach of the 16th. century practitioners in the practical mathematical sciences. Natural philosophy as a speculative discipline, proceeded without the focus provided by particular practical problems, and hence wily-nilly tended to be more general than the practical mathematical sciences of the renaissance; it was more concerned with 'the nature of local motion' than with merely the trajectories of projectiles; more concerned with 'the motion of the planets' than with the problem of longitude; the behaviour of floating bodies, than the problem of a ship's burden. Thus, while the 16th. century practitioners of the practical mathematical sciences desired a general method, and found that method in the employment of mathematics, in the context of particular practical problems, or ranges of problems, natural philosophy in the 17th. century tended to be more general in the sense of being addressed to overall problems of the natural world, that is simply to understanding the natural world without the focus given by a practical problem.

But this very shift in emphasis, brings out the very similarity between 17th. century natural philosophy and the practical mathematical sciences of the 16th. century. Undoubtedly many of the achievements of 17th. century natural philosophy were mathematical, and in many cases a search went on for a general mathematical account of the phenomena at issue.[2] But the mathematical accounts favoured were of a particular kind. Just as in many of the practical mathematical sciences of the 16th. century as noted above the tool of mathematical analysis was not applied to subtle and complex forces, connections or influences, as for example was attempted in judical astrology. Rather the search was for the most simple unequivocal entities, processes or principles, which, because of their indubitable qualities could provide a basis for true knowledge when they were handled with the demonstrable certainty of mathematics. The model of knowledge was thus to a significant extent, as it had been in the practical mathematical sciences of the 16th. century, Euclidian. Indubitable, simple, clear entities or principles, parallel to the axioms and petitions of Euclid providing a basis for mathematical analysis. This type of approach with a greater or lesser degree of emphasis in different individual, of course, did not function in a vacuum. The basic metaphor of 'the machine of the world' created by God, along with the associated ideas of the practitioner on earth using mathematics (in his own small way) to parallel the deity in creating and controlling the world, disseminated in the practical mathematical sciences of the 16th. century, provided a framework for later natural philosophy within which this mathematical approach flourished. Given this metaphor and the desirability of simple indubitable foundations on

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1. This is a tendency emphasised perhaps more strongly in the traditional 'history of science' of the period than may have actually been the case. Merton, for example, in a perhaps now unfashionable work, considered what was at least a background of practical application to 17th. century 'science'. Yet undoubtedly the growth points in the 16th. century were in the practical mathematical sciences, while natural philosophy, as in the work of Newton of for example, was the focus of the 'exciting results' of the later period.
2. This is not to suggest that 17th. century natural philosophy can be conceived as simply mathematical, it was not, on which see below.

which mathematics could work, 17th. century natural philosophy tended to postulate the simplest and hence clearest type of machine, tending always to drain the basic physical parts of the machine of all qualities except those that were mathematical or might be handled mathematically, and ending up with such concepts as 'pure matter', 'motion', ' sequential time', 'weight' and 'mass' and the like.[1]

Something of the different ways in which this shift took place and its nature can be clearly determined in two figures of the early 17th. century: Descartes and Galileo.

One thing is quite clear about Galileo, he was immersed in the continuing tradition of the practical mathematical sciences of the renaissance.[2] That he was consulted on ship design by the Venetian authorities has been noted above, and he himself wrote of the activity of the Venetian arsenal as providing a large field of study for the studious mind.[3] Indeed practical matters handled in a mathematical way were very much of the background of his Two new sciences, one of which sciences was exclusively concerned with a practical problem, in the performance of beams, while this volume is perhaps best remembered for Galileo's account of local motion.[4] Galileo further wrote treatises on fortific-

1. This to some extent, but only to some extent, is an over simplification. 17th. century natural philosophy had of course its own developments and this applies most readily to the earlier part of the century, in Descartes, for example, on whom see below. In contrast, it was seldom if at all that writers in the practical mathematical sciences of the 16th. century enunciated, or attempted to explore anything like the hypethetico deductive method of Newton in the sense that mathematical accounts were tools in a process of questioning nature, which process by its success was seen as the primary legitimizing process of the 'method' involved. But it should be noted while this note was almost entirely missing from the decidedly static theories of the practical mathematical sciences of the 16th. century, such discussion went on in the context of a practical problem or range of problems which provided a 'test' of theory. Only in the most extreme of discussions was practice held to be of the least significance. In natural philosophy of course as a result of the lack of such a practical focus, this sort of constraint was by no means so immediately present, and observation and experiment came to fulfil the same type of role. The difference between say Descartes and Newton however was a difference in emphasis, particularly in discussions of the basic epistemology they considered most desirable, which has come to be known as the difference between continental rationalism and English empiricism. In one case the deductive qualities of mathematical knowledge being emphasised in the other the process by which this tool was used to question nature. This difference of course can be detected as early as Francis Bacon, who rather than finding a general message in the mathematical approach in practical matters, saw the success of practice as the most important message for the cultivation of knowledge in general.

2. Though of course this was not the only relevant background to his work.

3. The opening section of the Two new sciences "largo campo di filosofare a gl'intelletti specolatiui parmi che porga la frequente pratica del famoso Arsenale di Voi Sig. Veneziani, & in particolare in quella parte, che Mecanica si donanda." (1630).

4. Traditionally in the history of science Galileo's discussion in this work on local motion is given great attention, often in such an exclusive way that the reader is left with the impression of Galileo as the 'pure scientist', fascinated almost exclusively all the time with problems of natural philosophy. There is no doubt that such a picture reflects one aspect of Galileo's predilections and interests, and at the beginning of the third day he alluded to the ancient nature of the problem of local motion and the many philosophers who had written on it. Equally we know earlier in De Motu he had considered the same problem from a much more Aristotelian point of view. But in that same passage at the beginning of the third day Galileo explained that no one had previously pointed out that the path of a projectile was a parabola (as he had discovered) and that "this and other facts, not few in number or less worth Knowing (emphasis added) (nec minus scitu digna), he had succeded in proving: clearly indicating that the solution of the practical problem and the usefulness of the resultant knowledge was of great significance in his view. The background to the dissemination of Galileo's ideas is most clearly seen in the section by the printer of the first Leyden edition (not usually printed with translations) which stated: "TRattendosi la Vita Ciuile mediante il mutuo & vicendeuole socorso de gl'huomini, gl'vni verso gl'altri, & à cio seruendo principalmente, l'uso delle Arti, & delle scientie, per questo, gli'Inventori di esse, sono sempre stati tenuto in grande stima, & molto riuerti dalla Sauia Antichità...questi nostri vltimi Secoli; ne i quali le Arti, & le scienzie, ritrouate da gl'Antichi, per opera di perspicacissimi ingegni, sono per molte proue, & esperientie, state ridotte à gran perfettione...& in particolare, questo apparisce nelle Scientie Matematiche...l'Astronomia....(in quanto ne Cieli, & ne i Corpi Celesti....risplende la Potenza, Sapientia, & Bonta del Supremo

(cont. over)

ation (although unpublished until the modern period) probably in connection with his teaching and lecturing activities in this area.[1] He equally wrote and published on the military compass (1606)[2] very much in the tradition of practical computation and surveying, of the treatises considered above, and got involved in controversy with regard to the plagarism of it.[3] His friend Benedetti Castelli, who was involved in the early controversies on the Copernican doctrines of Galileo, published on hydraulics as one of the earliest attempts to give a mathematical approach to this topic.[4]

Galileo's personal commitment to the mathematical ideology and the way it functioned can be seen in The Two New Sciences. The first day of the discussion of this work began with a problem which, although a traditional one was by no means a central to Aristotelian natural philosophy. Indeed a seemingly obscure and minor problem concerned with what can modernly be distinguished as the scale factor, that is, that a machine of one size may function satisfactorily while a scaled up version may be insufficiently strong (typically). Given this problem, the whole idea that a machine is essentially characterised by the geometry of its parts, becomes extremely dubious, because the two machines to different scales have by definition been assumed geometrically similar (that is of the same nature as it might be put), and one works and the other does not.[5] But Galileo would not in any way allow this to deflect him from a purely mathematical approach in the area. His questioner, Sagredo, put the problem and the assumptions plainly, stating:

> Mà essendo che tutte le ragioni della mecanica hanno i fondamenti loro nella Geometria, nella quale non veggo, che la grandezza, e la piccolezza faccia i cerchi, i triangoli, i Cilindri, i Coni, e qualunque altre figure solide soggette ad altre pàssioni queste, & ad altre quelle, quando la machina grande sia fabricata in tutti i suoi membri conforme alle proporzioni della minore, che sia valida, perche essa ancora non sia esente da gl'inimtri, che sopra aggiunger gli sino sinistri, e destruttori.[6]

Salviati then argued that not only is the common assumption that large scale versions of smaller machines will not work, wrong, but that the opposite is true, giving the example of clocks which function the better the larger they

(cont.)
fattore)...nella presente Opera, nelle quale si vede, lui essere stato Ritrouatore di due intere Scienze nuoue, & dai loro primi principii, & fondamenti, concludentemente, cioe Geometricamente dimostrate; in Vna....l'Altre Scienzia, pure, da i suoi principii dimostrata, e intorno alla resistenza, che fanno i Corpi soldi....Notitia di grande vtilita, & massime nelle Scienzie & Arti Mecaniche...." All of course just what is found in the treatises in the practical mathematical sciences of the previous century. But the printer equally referred to the science of local motion in just the same terms as Galileo did, equally emphasising Galileo's roots in traditional natural philosophy, a pattern all the more obvious in that when Galileo began to discuss this topic at the beginning of the 3rd. day the text suddenly changed from being in Italian into Latin.

1. This interpretation is Favaro's. Galileo's fortification treatises followed very much the pattern of the earlier printed works that have been detailed here, and both were very similar. He began with some brief geometrical constructions and then went on to indicate the principle of no dead ground and the use of the pointed bastion (among other forms) in various situations. He gave a good deal of discussion of methods of attack in siege warfare and of construction. Neither of the treatises included any methodological discussion as found in the works discussed above. One interesting distinction Galileo gave was on the difference between 'Tiro che striscia" adn "Tiro che ficca", the first firing parallel to the face of the bastion, the later at a certain angle to it. The first he stated it was argued was better for knocking down a series of ladders but it could not hit anyone in a cavity in the face of the bastion, while the opposite with the case with the second. (1891) Vol. II p. 30/31.
2. In Difese da Galileo Galilei (1607) f. 2b he stated he had made 100 of them in Padua in 10 years.
3. Galileo puts his position in the controvery in the Difese.
4. All Castelli did in this work really was to argue that the volume of water that the volume of water passing through a cross-section of any particular area had to relate to that area in some way. CASTELLI (1638)
5. Vitruvius pointed out this problem with regard to war machines. The problem is of course that areas increase with the square of the scale, but volumes an and hence weights go up with the cube.
6. (1638) p. 2.

are. Some 'intelligenti' Salviati (Galileo) allows, on better ground hold that common view; but he will not follow them:

> ...i quali della riuscita di tali machine grandi non conforme à quello, che si raccoglie dalle pure, & astratte dimostrazioni Geometriche, ne rimettono la causa nell'imperfezzione dela materia.[1]

Thus any shifting from 'pure & astrate dimostrazioni Geometriche', and getting involved in the problems of materials Galileo will not allow. Assume the material is the same, he explained -- for then we can treat the problem mathematically:

> E perche io suppongono la materia essere inalterabile, cioè sempre l'istessa, è manifesto, che di lei, come di affezzione eterna, e necessaria, si possano produr dimostrazioni non meno dell'altre schiette, e pure Matematiche.[2]

Then, having insisted that the problem was susceptible to mathematical treatment, and having fixed ones assumptions so that this became the case, Galileo explained, one could then demonstrate <u>mathematically</u> in what proportion a smaller machine is stronger than a larger one of the same pattern.[3]

Nothing can be clearer about the working of the mathematical ideology than what Galileo does implicitly here. Mechanics is about geometry and proportions -- he will not give that up. A problem arises -- the scale factor which seems to invalidate that assumption. This can not be allowed to happen, nor is it allowable to bring in questions about the nature of the materials involved to get over that problem. No, that problem itself must be susceptible to mathematical analysis in order to resolve the difficulty.

However this discussion is not only of the greatest significance in that it indicates the way the mathematical ideology was applied, it also relates to other processes and problems. While here Galileo was still concerned with practical problems -- of machines -- his arguments applied to machines in general. While traditionally mechanics had been concerned with the description and accounts of different devices -- the pulley, the lever and the wedge, Galileo here shifted the problem onto the level of machines in general. His approach was therefore rather more general than was characteristic of the practical mathematical sciences of the renaissance with their closer relation to specific practical problems or ranges of problems. Further in a period when the whole problem of the 'machine of the world' was to come under scrutiny his arguments which took what appeared to be a difficulty with any contemplative mathematical account of that machine (as any machine) and almost made a virtue of the difficulty of the scale factor, by treating that factor itself mathematically, (although in this work Galileo made little of any such point explicitly), obviating as it did a major difficulty with the notion of such a machine having a complete mathematical account which encompassed its essential aspects.[4]

This tendency for Galileo to treat problems in a much more general way than was the case typically in the practical mathematical sciences of the 16th. century, while at the same time responding, at least to some extent, to those same problems, is no where more clear than in his discussion of local motions and projectile behaviour. As has been indicated above 16th. century writ-

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1. Ibid. p.23. 2. Ibid. p.3

3. Ibid. "Sagr.....reuochi pur l'opino ..che le machine, e la fabriche composte delle medesime materie con puntuale osseruanza delle medesime proporzioni trà le loro parti debban'esser egualmente, ò per dir meglio proporzionalmente desposte al resistere....perche si può Geometricamente dimostrare sempre le magiori esser in proporzione men resistenti, che le minore...." By this sort of move Galileo circumvented the traditional problem of mixt mathematical disciplines as being only as certain as they were mathematical. He simply insisted that when the problem was not fully mathematical, one treated the way in which it was not so, mathematically.

4. He continued after the passage cited above n.3 "non solo di tutte le machine, e fabbriche artifiziali, mà dell naturali ancora"; hinting that he was consciously concerned with the general description of nature.

ers on geometrical ballistics always approached the problem quite directly, and although the Aristotelian notions of forced or violent motion, and natural motion, often formed a basis by which they began their mathematical analysis, that analysis they attempted to apply chiefly to such basic observables as point blank range and (maximum) random range. In the Two New Sciences Galileo in contrast not only dispensed with the notions of violent motion and natural motion as basic concepts of his analysis, be began his basically mathematical analysis with motion in general, in its different forms. He began with a discussion of uniform motion by way of purely mathematical terms,[1] that is by reference merely to intervals of time and of distance, and the equality and inequality relationships. These concepts being applied to completely neutral decharacterised entities -- particles. He then went on to discuss naturally accelerated motion, and there stated

> ...in the investigation of naturally accelerated motion we were led,... in following the habit and custom of nature herself, in all her various other processes, to employ only those means which are most common simple and easy....therefore, I observe a stone initially at rest falling from an elevated position and continually acquiring new increments of speed, why should I not believe that such increases take place in a manner which is exceedingly simple and rather obvious to everybody? If now we examine the matter carefully we find no addition or increment more simple than that which repeats itself always in the same manner.[2]

Galileo then went on to state that the addition or increment which repeated was that of speed in equal increments of time. The simplicity with which Galileo conceived nature to act with here being of course a simplicity which gave a simple and coherent mathematical account.[3,4] Thus the view disseminated in the renaissance in so many areas of the practical mathematical sciences of nature as fundamentally mathematical became in Galileo's hands the criterion which defined what it was for nature to act simply, while the earlier type of analysis, with its foundation in simple observable principles or objects, became an analysis of dequalitised mathematical objects.[5] At the same time, his account of local motion while it related to the 'practical' problem of projectile motion, was so much more general than earlier efforts in the area, that it became part of natural philosophy, and in being deemed correct within this background, was understood to solve that practical problem almost by a happy accident.

Thus in Galileo's work at a number of points a direct development from the practical mathematical sciences of the earlier period can be detecteo,

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1. More precisely with characteristics that could be expressed purely in mathematical terms, along with mathematical relationships.
2. GALILEI (1952) p. 200. "...ad investigationem motus naturaliter accelerati nos quasi menu duxit animadversio consuetudenis, atque instituti ipsiusmet naturae in ceteris suis operibus omnibus; in quibus exer(c)endis uti consueuit mediis primis, simpliciissimus, facillimis....igitur lapidem ex sublimi a quiete descendentem nova deinceps velocitatis acquirere incrementa animadverto, cur talia additamenta simplicissima, atque omnibus magis obvia ratione fieri non credam? Quod si a tante inspiciamus, nullum additamentum, nullum incredentum magis simplex inveniemus, qual illud quod sempre eodem modo soperaddit." (1538) p. 157.
3. Galileo remarked a little later that he had earlier assumed that the relationship was between distance and speed, and gave an argument to show that this was mathematically incoherent.
4. Galileo's earlier discussion of motion in De Motu was very different, very Aristotelian in character, yet in Cap. 23 he there discussed projectiles and the problem of whether a projectile followed a straight line for a longer distance the higher the elevation, before taking a curved path, or not, indicating his familiarity with and interest in the traditional problems of 16th. century ballistics. He wrote in 1609 of his recent work relevant to his treatise on mechanics particularly with regard to the strength of beams, and in 1610 described a work on local motion. See GALILEI (1960) p. 136.
5. At the end of the Two New Sciences Galileo's entities which underwent mathematical analysis included a weightless string.

a development particularly in terms of greater generalization and towards the cultivation of a mathematical natural philosophy.

Galileo the practical and practising mathematician clearly followed a rather different lifestyle from that of Descartes the gentleman thinker. Descartes, as he himself explained to the reader, was of such a condition of life not to need to cultivate the sciences as a profession for honour or gain, thus

> ....je ne me sentais point, grâce à Dieu, de condition qui m'obligeât à fare un métier de la science pour le soulagement de ma fortune....[1]

This did not mean however that the practical sciences were so far beneath his notice as not to be able to teach him anything. Descartes remarked

> ....it occurred to me that I should find much more truth in the reasonings of each individual with reference to the affairs in which he is personally interested, and the issues of which must presently punish him if he has judged amiss, than in those conducted by a man of letters in his study, regarding speculative matters that are of no practical moment, and followed by no consequence to himself...[2]

To which end, Descartes tells us, after escaping from the mentors in charge of his early education

> I spent the remainder of my youth in travelling, in visiting courts and armies, in holding intercourse with men of different dispositions and ranks, in collecting varied experience, in proving myself in the different situations into which fortune there led me, and, above all, in making such reflections on the matters in my experience as to secure my improvement.[3]

And in explaining his intellectual developments and his working out of his own system he wrote that one of the first thing he considered was that

> ....those ancient cities which, from being at first only villages have become, in course of time, large towns, are usually but ill laid out compared with the regularly constructed towns which a professional architect has freely planned on an open plain...[4]

With regard to his early education Descartes wrote

> I was especially delighted with the mathematics, on account of the certitude and evidence of their reasonings; but I had not as yet a precise knowledge of their true use; and thinking that they but contributed to the advancement of the mechanical arts, I was astonished that foundation, so strong and solid, should have had no loftier superstructure reared on them.[5]

and also that

> ....in the mathematics there are many refined discoveries eminently suited to gratify the inquisitive, as well as to further all the arts and lessen the labour of man...[6]

In the <u>Discours</u> Descartes further explained that as the third of his basic precepts of his Method, he committed himself

> .....to conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend by little and little, and as it were, step by step, to the knowledge of the more complex.....[7]

That this rule was clearly related to the Euclidean method as the basic pattern in knowledge Descartes explained explicitly just a little later, stating

> The long chains and easy reasonings by means of which geometers, are accustomed to reach the conclusions of their most difficult demonstrations, had led me to imagine, that all things, to the knowledge of which man is competent, are mutually connected in the same way...[8]

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1. (1966) p. 131. 2. 1st. disc. (1953) p. 9. 3. Ibid. p. 8/9.
4. 2nd. disc. (1953) p. 10. 5. 1st. disc. (1953) p. 7. 6. Ibid. p. 6.
7. 2nd. disc. (1953) p. 15/16. 8. Ibid.

But, he continued:

> I had no intention of attempting to master all the particular sciences commonly denominated mathematics: but observing that, however different their objects, they all agree in considering only the various relations or proportions subsisting among those objects, I thought it best for my purpose to consider these proportions in the most general form possible, without referring them to any objects in particular, except such as would most facilitate the knowledge of them, and without by any means restricting them to those, that afterwards I might be the better able to apply them to every other class of object to which they legitimately are applicable.[1,2]

Thus a number of ideas on method at one level of Descartes' thought reflected the same clustering as had been cultivated in the practical mathematical sciences of the 16th. century: the value of mathematics because of its certainty and demonstrability; its ability to give pleasure in satisfying curiosity and its value in practical matters; the example of Euclidean geometry as the paradigm of the best knowledge; the need for a generality of method.— although not having to make a trade of knowledge and hence not relating his work to specific practical problems, Descartes attempted to extend that generality over all objects to which mathematics could possibly apply. All in the context of an expression of the general value of practical matters as giving a test of knowledge.

On the other hand in Descartes' thought mathematical knowledge was not merely something of value in itself, he attempted to generalise further and to reconstruct knowledge using mathematical knowledge as a paradigm of the best knowledge. In this process he laid down among his general rules the course of knowledge from the simplest object to the more complex in simple steps as in Euclidian geometry. This to Descartes was clearly a principle that had to be applied to all knowledge and not just in mathematical knowledge. But then in the Discourse he went on to insist that the simplest objects were mathematical objects, saying

> ...I thought that, in order the better to consider them (i.e. the simplest objects) individually, I should view them as subsisting between straight lines, than which I could find no objects more simple, or capible of being more distinctly represented to my imagination and senses...[3]

In fact there tended always to be an interplay in Descartes thought between mathematics as a valuable kind of knowledge in itself, and mathematics as a paradigm by which a general method for the understanding of nature could be constructed. For a number of years, Descartes stated,

> I continued to exercise myself in the method I had prescribed....[4]

but also

> ....reserved some hours from time to time which I expressly devoted to the employment of the method in the solution of mathematical difficulties, or even in the solution likewise of some questions belonging to other sciences, but which, by my having detached them from such principles of these sciences as were of inadequate certainty, were rendered almost mathematical....[5]

The results of this last type of activity which amounted to the cultivation of a mathematical philosophy of nature resulting of course in the separate treatises of the discourse. In other strands of Descartes' thought when he considered

1. Ibid.
2. The extent to which Descartes attempted to go in attempting to reduce everything to geometry is seen in his system of the universe of Le Monde. There he took light as a fundamental principle, a theme easily susceptable to geometric treatment, and attempted to eliminate weight as a basic concept of his description. As he explained in the Discourse "I examined at considerable length what the nature of light must be....I came next to speak of the earth in particular, and to shew how, even though I had expressly supposed that God had given no weight to the matter of which it is composed, this should not prevent all its parts from tending towards its centre (1953) p. 35. Thus attempting a mathematical explanation, rather than a mathematically account, of the natural motion of Aristotle.
3. Ibid. p. 17. 4. 3rd. disc.(1953) p. 24. 5. Ibid.

method in general however the mathematical metaphor remained active, but then the simple objects which in mathematical analysis were simply mathematical objects, became those objects to which certain and distinct ideas could be applied. At this level Descartes considered he could just as rigorously as geometrically in other fields, in metaphysics, prove the existence of god and the soul.

Thus that same mathematical knowledge that had been cultivated so assiduously in the practical mathematical sciences of the 16th. century was taken up and cultivated and used as a much more general level by Descartes, instead of being cultivated in direct connection with practical problems.

But the connection of knowledge with practical affairs, as in the 16th. century was by no means broken by Descartes and although he cultivated speculative knowledge rather than practical knowledge he could still write

> ....as soon as I had acquired some general notions respecting physics..... by then I perceived it to be possible to arrive at knowledge highly useful in life; and in room of the speculative philosophy usually taught in the schools, to discover a practical, by means of which, knowing the force and action of fire, water, air, the stars, the heavens, and all the other bodies that surround us as distinctly as we know the various crafts of our artisans, we might also apply them in the same way to all the uses to which they are adapted, and thus render ourselves the lords and possessors of nature.[1]

III:(4):(iii):(1): Epistemological shifts in religious and political thought during the renaissance and the tensions associated with the new knowledge

But such a shift towards a central dependence on mathematics in epistemology was by no means the only trend over the longer period.

The 16th. century was after all the period of that movement known as the reformation. A phenomenon in which one of the main issues was the source of certain type of knowledge -- that is, religious knowledge or knowledge of god.

Luther and those of his persuasion, despairing of the possibility of reform of what they conceived to be abuses, within the framework of the universal church, and seeking to recreate what they considered the true christain church laboured under a particular difficulty. Traditionally a major aspect of religious understanding had been the traditional interpretations and teaching evolved within the framwork of the universal church. Clearly in attacking that tradition and suggesting a radical change, it was a requirement of the reformers that they should be able to point to a source of religious understanding which was independent of that tradition of interpretation they wished to attack, if they were reasonably to make good their claim.

For Luther the source of the religious understanding in a major way was the revelation of God as given by the holy scriptures. With regard to which problem Luther often seemed to consider that he was merely attacking the monopoly of interpretation claimed, he insisted, by the church, and the refusal of that body to moderate its malpractices which had arisen through misinterpretation. In his Address to the Christian Nobility of the German Nation of 1520, Luther wrote of three walls with which, he claimed, the 'Romanists' had protected themselves. The second of which he gave as

> ...that they alone pretend to be considered masters of the Scriptures; although they learn nothing of them all their life. They assume authority, and juggle before us with impudent words, saying the Pope cannot err in matters of faith...That is why the canon low contains so many heretical and

1. 6th. disc. (1953) p. 49. Emphasis added. "maitres et possesseurs de la nature" (1966) p. 168.

> unchristian, nay unnatural, laws....Therefore it is a wickedly devised fable....that it is for the Pope alone to interpret the Scriptures or to confirm the interpretations of them....we should boldly judge what they do (i.e. the popes) and what they leave undone by our own believing understanding of the Scriptures, and force them to follow the better understanding, and not their own.[1]

At other points Luther was more explicit about his view that interpretation could not be constrained by anything like the traditions of the church, and for example stated

> ...I cannot bear with laws for the interpretation of the word of God, since the word of God, which teaches liberty in all other things, ought not to be bound.[2]

The problem of course then was, who was to judge, or how was to be judged what was the proper interpretation. Luther could hardly allow (at least in any strong form) that this was a matter of argument and consensus among the experts, because then he would have been forced willy-nilly to return to debate with the theologians of the church, which process he had come to consider could not lead to the reforms he considered necessary. He tended therefore willy-nilly to be forced back onto the position that religious understanding was gained by the individual through personal study of the scriptures: that is, to be forced from a position of attempting to create a better interpretation of the scriptures, towards the more general principle that the relevant knowledge arose not through a process of argument and debate amongst those giving the greatest attention to the problem until a degree of consensus arose, but in the personal perusal of the scriptures by any interested individual.

Luther's critics were of course very clear that he was setting up his own personal interpretation against those of many other learned men; that he was equally stirring up dissent in way that was not new; and spreading his own pernicious doctrines in attempting to put the bible in the hands of ordinary people accompanied by his own interpretation.

Henry VIII wrote, or at least allowed to be published over his name, that

> ....the Gospell longe hath ben/ and euer shalbe/ my chefe study....in studye therof/ (I) vse a way contrary to that that ye do: Whiche in the interpretation therof/ (you) vse to folowe your owne fantasticall inuẽtion/ agaynst all the worlde besyde,...But as for me/ I well knowe and knowledge/ that I am vnable of my selfe to the vnderstãdyng therof and therfore callyng for godds helpe/ most humbly submitte my selfe to the determynation of Christes churche/ and interpretations of the olde holy fathers....Where ye on the contrary syde/ settĩg all these olde saynts at nought....admitte no mẽnes wyt but youre own....(and) instigate and sette out rude rebellyous people/ vnder pretext of Euangelicall lybertie/ to ron out and fyght for your faction.[3]

Luther's emphasis on the individual as against tradition in interpretation was paralleled in his emphasis on salvation by faith rather than by good works. There, it was the particular internal condition of the individual that he conceived to be crucial, not his actions within the tradition of his society or the traditional rituals and performances previously associated with religous behaviour.

Calvin's account of religious knowledge had a rather different

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1. (1896) p. 169/71.
2. From Concerning Christian Liberty (1520) (1896) p. 253.
3. (1526) Sg. Bvib/viib. In the preface allusion was made to the old errors and heresies of Wycliff as well as others, which Luther was imputed to have "kyndled agayn" (Sg. Aviiia), in that Luther had entered into agreement with "one or two lewde persons" for translation of the New Testament with "many corruptiõs of that holy text/ as certayne prefaces/ and other pestylent gloses in the margentes/ for the aduancement and setting forth of his abhomynable heriseys...." (Sg. Avb). The preface went on to promise the common people that if they did not "truste to moche to youre owne commentes and interpretatyons" but referred themselves to their "pastorall fathers" it would encourage "well lerned mẽ to set forthe and translate in to our mother tonge/ many good thynges and vertuous/ whiche for feare of wrong takynge/ they dare not yet do." (Sg. Aviiia).

emphasis. Calvin considered each individual had the seeds of religion in him:

> Ue holde it oute of contreuersie, that there is in the mynde of man, euen by naturall instinction a certain feling of the godhead.[1]

But in addition to this the individual found a certain kind of knowledge of god, in no way a matter of tradition, but immediately presented to him as an individual, in the evidence of god's workmanship in the natural world around him:

> ...God hath not onely planted in the minds of men that sede of religion which we haue spoken of, but also hath so disclosed him selfe in the whole workmanship of ẏ world, and daily so manifestly presenteth himselfe, that men cannot open their eies but they must needs beholde him. His substance in dede is incomprehensible...but he hath in al his workes grauen certain marks of his glory, and those so plaine and notably discernable, that the excuse of ignorance is taken away from men, be they neuer so grosse and dull witted. ...As for his wonderful wisedom, there are innumerable proues bothe in heauen and in earth that witnesse it: I meane not only that secreter sort of thinges, for the rarer marking whereof Astrologie, Physike, and all naturall Philosophie serueth, but euen those thinges that thruste them selues in sight of euery one, euen of the rudest vnlearned man, so that men can not open their eies but thei muste nedes bee witness of them. But truely they that haue digested, yea or but tasted the liberall artes, being holpen by the ayde therof, do proced much further to looke into the secretes of Gods wisdome.[2]

Calvin then went on to explain that the bible was like a pair of spectacles, which, when used by those defective in sight, makes clear everything thing, while before they only knew they had a book before them which was all confused.[3]

Thus reformation thinkers gave accounts of (religious) knowledge and understanding which emphasised the individual as an isolated knowing agent against any contribution of tradition and the society around him.

Further, over the long term a new conception of the significance of the individual as an actor in political life began to emerge as the values of medieval society changed towards those of the modern period. During the medieval period the knight, while the basis of his strength was understood to emerge from his own personal efforts in training and practice, yet the power he enshrined was conceived to exist only within the context of the general power structure of his society. His personal strength then became a unit which added strength to the personal strength of the lord to whom he owed allegiance, as in turn his ability to command force was added to through the assembled strength of his subjects. Force was thus conceived to exist then in individuals only within their society and its structure. Discussions of polity, such as that of Edigio Colonna, then tended to focus to a great extent on the norms by which power ought to be exercised within that social framework, and the legitimacy and basis of power, that as a result arose. The nature and distribution of power was thus conceived to be given by the basic social structure even though individuals might attempt to increase their own personal power at the expense of others, and discussion centered on the regulation of the given power system.[4]

During the renaissance writers on political matters began to express rather different attitudes and to discuss rather different kinds of questions. Machiavelli of course in <u>The Prince</u> was one who challenged most strongly the sorts or attitudes that earlier had been more common. His

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1. (1561) f. 3b. 2. Ibid. f. 6a/b.
3. Ibid. f. 12a. See also f. 12b. "...no man can haue any tast be it neuer so little of true and sounde doctrine, vnlesse he haue ben scholer to the Scrypture."
4. p. 4A(1858) "nel primo libro noi insegneremo come si re e i principi e ciascuno del populo si debbono governare, secondo legge e secondo ragione. Nel secondo libro insegneremo come ciascuno debbe goveranre, secondo ragione.. ...la loro famiglia. Nel terzo libro insegneremo come, in tempo di pace e'ne tempo di guerra, debbono essere governate le citta à i reami." Aristotle equally in the <u>Politics</u> assumed the existence of the social group as a natural given from which to start discussion.

analysis there in no way consisted in the elaboration of norms as to the way the prince ought to behave, except in terms of the efficacy of power considered as an attribute existing in its own right independent of the social system. This separation of power as a primary attribute, independent of the social system or the norms of behaviour of the society or group which exercised it, in Machiavelli,[1] was later reflected in the ideas of the individual as possessing powers and rights, which were separable and distinguishable as characteristics of an individual, whether he existed in a society or not. The view of Giovanni Botero for example at the end of the 16th. century, was, at least at one level, of individuals as merely units of productive or military power.

On the other hand somewhat earlier Jean Bodin in his treatise, in expounding the nature of the body politic and the relations between citizens outside their families, explained that before there was any commonwealth or cities men experienced

> ...that full and entire libertie by nature giuen to euery man, to liue as himselfe pleased....[2]

But, according to Bodin, their selfish desires led them into conflict, and the vanquished were forced to give up all that natural liberty, to be subject to a prince or other soverign. The prince or soveriegn power then had to be extremely extensive in order to hold together men in society, in the face of those desires and powers that individuals possessed simply by being individuals.

Thus, while in the medieval period society tended to be conceived the natural state of affairs ordained by and large by god despite anomalies and the dissension that existed; on the other hand in such a thinker such as Bodin society tended to be thought of as a rather artificial creation difficult to hold together, in the face of the, in some sense, more natural condition of men as isolated individuals all too liable to exercise their own natural force.

Hobbes of course was to take up such strands of Bodin's thought in the 17th. century, and, insisting on the value of Euclidean geometry, he attempted to build them into a deductive system in which the very nature of society could be deduced from the qualities of such individuals considered as social atoms. This pattern of considering men outside society, as having certain qualities from which the nature of society could be arrived at was equally central to Locke's political thinking.

Thus, while in certain strands of reformation thought the individual was considered to come to knowledge not by participating in a particular tradition, but personally in the most basic way as an isolated individual, equally there was in political thought certain tendencies during the same period to down-grade society and the polity into a secondary construction organised out of the more primary building blocks of individuals, which in isolation were conceived as having certain particular qualities and powers.

But this emphasis on the individual as against the tradition within which he lived, both in the acquisition of knowledge in the religious sphere, and in the analysis of the individual and society, was just the type of emphasis that arose through the cultivation of the practical mathematical sciences of the 16th. century. That kind of knowledge depended on deduction from universal principles which were conceived to be true for all times and places and hence could in no sense be conceived to be dependent on tradition. The deductive process being conceived further as being open to any individual given he possessed merely the most rudimentary ability to use his reasoning

1. The very shockingness of Machiavelli's ideas can then be seen as not necessarily the apparently very 'cynical' nature they had at many points, but the way he discussed his different topics outside of and separate from any framework of rights and obligations as had been traditionally the case.
2. (1606) p.47.

power, meant that the isolated individual could acquire and extend the needed knowledge equally without reference to any tradition. The beginning of that knowledge in the most simple principles or observations clear to all, togbther with the public demonstrability of mathematics which gave certainty to the whole process, then ensued that that knowledge which was the product of that kind of process did not remain a purely personal construct, but on the con-tary was available to all. Thus the public quality of knowledge was but the reflection of the notion that the road to knowledge was through processes cultivated in the isolated individual whoever sought it.

With the generalization of the method of the practical mathematical sciences of the 16th. century into the mathematical natural philosophy of the 17th. century, along with the use of the notion of mathematical (Euclidian) knowledge as the basic paradigm for knowledge, there occured in Descartes, for example, the attempt to put all knowledge whatsoever on that same foundation.

At the beginning of the first part of the Discourse Descartes explained his conviction

> ...that the power of judging aright and of distinguishing truth from error, which is properly what is called good sense or reason, is by nature equal in all men.[1]

This basic assumption meant that whatever was discovered by the individual by certain deduction in his intellect, would then be open to all. Deductive knowledge about the natural world could then be cultivated without any reference to any tradition. But lacking any tradition to legitimize such knowledge, while the cultivation of mathematics itself was so clear as not to be questionable, to any such as Descartes, yet then he realised he held certain metaphysical assumptions, so that he felt compelled to attempt to bring the same kind of certainty he found in mathematics to his belief in God, self and the very existence of the natural world. Nothing could be taken on trust Descartes considered on this level of thought and it was incumbent on the isolated individual, as an isolated intellect, to demonstrate its own very existence along with the existence of the physical world in order to be able to apply his clear and distinct ideas in different areas, and as a result arrive at dependable knowledge. Thus Descartes attempted to push this drive for individual, publicly communicable knowledge, to its ultimate, so that knowledge would be completely untainted by tradition and accounted for in its every aspect according to that demand. In other words in an absolute sense would be universally true.

On the other hand just as in the sphere of religious knowledge where the claim to individual knowledge led to immense open strife, in the sphere of mathematical knowledge, there were equally certain tensions, and confrontations, on occasion.

The tensions here can be seen more as potential areas of conflict rather than outright confrontation.

The largest area of potential conflict was the general problem with regard to the new mathematical knowledge, such as was found in the practical mathematical sciences of the renaissance, as to where rights and control with regard to the new knowledge were to lie; about how it was to be judged and what was its significance; about the very nature and

1. (1953) p. 3.

basis of such knowledge. The potentiality of conflict can be detected in the system of licensing of books for publication. Nearly every author during the 16th. century applied for a privilege for works he wished to publish. The privilege granted by the civil power, usually for only a relatively short term of 10 or 15 years was intended to protect the author's rights in the work, by setting penalties for plagiarisation. The general notion behind the granting of the privilege, as expressed in many of them, was that the author in composing his treatise -- for the public good -- had gone to great labour, and often to the expense of producing the printed copies, and that he ought to have that investment protected by the grant of a monopoly in the territory at issue.

However, it was probably not so much the actual income from the sale of his works that the author wished protected, since, as noted above it seems unlikely that this would bave been very large, but rather was that the whole problem of his reputation was at issue. By publishing the results of his labours an author might hope to become widely known and respected, with all the possibilty of patronage, pupils and commissions that that might bring. Anyone publishing as his own, results of another author, would tend to throw doubt on their real originator's claim and hence to reduce his reputation as being able to originate such ideas, which was his stock in trade. This in fact seems to have been something of the pattern in the controversy between Galileo and Baldassare Capra. In his Difesa of 1607 Galileo published a judgment against Capra which ran that he, Capra

> ...hauesse in gran parte transportato il libro del predetto Galilei nel suo.....[1]

with the result

> ...onde con tal operatione si causeria non picciolo scandolo & intacco alla riputatione del medesimo Galilei...[1]

and Galileo himself in his text wrote

> Del quale strumento non solo il sopranomato Baldassare Capra si fà autore, mà ne predica me (e tali sono le sue parole) per vsurpatore sfacciato, & pero meritiuole di arrossirmi con mio sommo opprobio, & indegno di comparire nel conspetto di huomini letterati & ingenui.[2]

Thus the straight forward privilege from the civil power helped to protect the author's reputation and inventive out-put. But during the later 16th. century, increasingly such treatises as have been analysed here, appeared with a licence, that is an endorsement from a religious, or religious cum civil, power combined, to the effect that the book is given a licence to be sold as containing nothing 'appertaining to the soul', for example.[3] In some cases indeed works were published with 2 or 3 different licences from apparently different theological jurisdictions.[4] Thus there was a clear potentiality of conflict between the interests of the author in wanting to publish the results of his labours, and the views of the religious licensing authorities, as to what might or might not be published. Even a further potential of conflict between the different theological jurisdictions. But the potentiality for conflict of interests between the writer in the practical mathematical sciences and the theologian, was matched by a similar potential clash between the writer and the civil power. The writers in the practical mathematical sciences, producing knowledge which their authors claimed, was needed to govern states and fight wars, were clearly involved in acts of some political significance. If this

1. Op. cit. f. 22b. The judgment was given by the Studio of Pisa.
2. f. 2b.
3. See Pasino's work for example II p. 90.
4. See for example Busca II p. 114.

knowledge was so important in this way it might have been more to the advantage to the prince to keep it secret, one imagines. But this would have conflicted with the writer's desire to publish in order to enhance his reputation. In accord with this pattern pressures seem to have been brought on Lorini not to publish his work on fortification, for example.[1] But this potential clash appeared in another way. Spanish works in the mathematical sciences of the later 16th. centure carried a general 'Tassa' wich was ordered to be printed in the works indicating that the work had been approved to be taxed at such and such a sum. This then was another way in which the civil power was tending to control publication. But further, in the many different types of licence that appeared, particularly in Spanish works, there was a tendency for one or other of the grants from the civil power to state that as the work was to be considered useful to the community, or was good quality knowledge, or was worthy of publication, or the like, so the licence had been given.[2] (Similarly in Galileo's Difesa the privilege stated that it was "worthy" (degno) to be published.) Clearly, while signs of actual conflict are few, once the right to licence a work came, even tacitly, to allow the right to licence because of the book's quality, the situation begins to imply the right of the licensing power to determine the contents of works published, and hence to create an area of potential conflict between the individual producer or knowledge and the civil licensing power.

But this kind of possible tension between diferent interests involved in the publication of works in the practical mathematical sciences during the later 16th. century, was accompanied by a more explicit clash between different views as to how the mathematical knowledge of nature should proceed. On the one hand there are the remarks of the English surveyor Edward Worksop, who condemed the use of the 'mathematicalls' in such areas as divination and judicial astrology, and expressed his hope that the civil power would undertake to prevent such unlawful practices.[3] The use of mathematics by such 'magicians' (as they were sometimes called) was thus resented and attacked by those pratitioners in the practical mathematical sciences who considered their method open and clear to all because it started with clear public principles before going on to certain demonstrations, while the magicians in contrast although they equally used mathematics were concerned with secret and arcane knowledges and tended to be concerned with the understanding of obscure and difficult concepts by way of mathematics. This type of conflict occured in the early 17th. century in the controversy between Fludd and Kepler. Kepler explained their differences thus

> Motus ego cogito visibles, sensuque ipso determinables: to actus internos considerate...ego contentus effectis, seu Planetarum motibus: tu si in ipsis causis invenisti Harmonias...[4]

Thus Kepler contended that he gave a mathematical account of the simple observables of motion, while Fludd, searching into causes using the mathematical harmonies with all the complexity of understanding of how these harmonies actually related to matter, and to the solar system, used much more complex notions such as those of macrocosm and microcosm, as the basic tools of his research in order to elucidate the causes at work.

It is against this whole background that the most well known

1. See II p. 121 n. 1.
2. See for example Diego Gonzales de Medina y Barba's work II p. 215 n.5.
3. See above p. 146.
4. KEPLER (1621/2) from the last section "Apologia...." p. 43. Ad. Analysis XXVI.

conflict with regard to the use of the new knowledge particularly when it came to deal with the wider problems of natural philosophy, between Galileo and the church, must be seen. A background in which through publication in the practical mathematical sciences a particular view of knowledge had been disseminated, which must be conceived by then to have almost completely demonstrated its effectiveness;[1] a background in which the interests of different groups with regard to the new knowledge were at stake; and in which the nature and function of mathematical knowledge had by no means been universally agreed upon. The conflict can thus be seen as concerned with the possible interactions between different fields of ideas and behaviours.

In his Letter to Christiana Galileo made clear his position

> ....that the Discussion of Natural Problems, we ought not to begin at the authority of places of Scripture, but at Sensible Experiments and Necessary Demonstrations[2]..I conceive . that, concerning Natural Effects, which either Sensible experience sets before our eyes, or Necessary Demonstrations do prove unto us, ought not, upon any account, to be called into question, much less condemned upon the testimony of Texts of Scripture...[3]

A position as absolute and extreme as could be. A position not concerned with any balance of interests and values, but rather one which denied absolutely any mutually favourable interactions between the new knowledge and the sort of traditional knowledge comprised by the christian religion. The new knowledge was to reign in its own autonomous sphere, and implicitly other realms of knowledge were conceived as having to accommodate themselves to whatever 'facts' were so discovered, in a wholly one-way process. In its pure form this doctrine at the same time clearly left no role for the influence or interests of the civil power. The knowledge that was to result from the process of what was given to the senses and necessarily demonstrated, a process which clearly related to the activities of any single individual without any reference to any of the traditions within which he lived, meant that there could be no influence or control on that knowledge excepting the judgments of individuals who created it. In Galileo's position then the individual was inviolate and left no room for the slighest interest or influence of the society in which that knowledge was created. The creators of that knowledge as the arbiters of its acceptability were to be supreme. Whether the results clashed with the values of the surrounding culture or responded to and helped to elucidate those values in a mutually supporting interactions was of no interest whatsoever. Method reigned supreme.

Yet in a way Galileo's position was in no way suprising. The background from which he came and the ideas of that background that he helped to develop from its roots in the practical mathematical sciences of the 16th. century were just such that when those ideas were pushed to their most extreme this had to be the result. The view that knowledge was most valuable when wholly comprising certain demonstration from unquestionable principles, was just the sort of knowledge discoverable by the individual without any reference to any traditional values. Mathematical and Euclidean knowledge as the paradigm left no room for other values and if other values were allowed influence it would tend to cease to have these valuable qualities. Equally in continuing to push the conflict with the Church, Galileo, whether he is considered to have been a martyr to freedom of thought, or whether a rather foolish individual

1. In the practical fields in which it had been in use over perhaps two generations.
2. Cf. above Norman p. 161 n. 1.
3. From the Letter to Queen Christiana in SALUSBURY (1661/5) Vol. I p. 433/4.

who insisted on pushing unaccaptable ideas when he knew these were liable to create conflict, was no more than acting in accord with the values of that same background of ideas and his particular personal position.

As a purveyor of mathematical knowledge his reputation in this area, about which he was clearly sensitive, was at least intimately connected with his publishing results in his field to support that reputation. To have allowed himself to have been influenced too much by other values when taking decisions on publication would bave been for him to have betrayed the values conceived to inhere in the mathematical knowledge that was so much a part of his background. Equally any such action would have negated and made meaningless in an important way a career spent in the cultivation of that knowledge.

Thus while Descartes sought to put the new knowledge on a sound basis through the 'cogito' as an individual with the base of his arguments in the certainty of self, Galileo attempted to push through the rights of the individual in such knowledge to their greatest extent, with more personal trouble.

The epistemological position that emerged was such that the continual mutual interaction between theological understanding and knowledge of the natural world of the medieval period, was replaced by a much more one way relationship. The change paralleling the sort of change that can be detected in the practical mathematical sciences of the renaissance to an emphasis on theoretical knowledge rather than craft knowledge. The tradition of the university and church of the medieval period had amounted to a grounding of knowledge very much more in the continuing tradition of the culture than in any isolated intellection of the individual as seen in Descartes for example. During the medieval period the individual was absorbed into the tradition of knowledge of the university in a general step by step process in an apprenticship, and tended to cultivate a particular style of life in the cultivation of that knowledge; the whole process accompanied by the learning of a specialised language for the cultivation of his profession. Increase in understanding was conceived to occur by study and commentary on the earlier writers in the same tradition. Activity in theology, and understanding of the natural world, being to a great extent merely different reflections of the same general understanding of man and the world, hence, each had to take account of the values of others.

The ideology of the new knowledge was clearly very different. Knowledge, conceived to be essentially based in the individual and immediately and demonstrably true in a universal sense to the individual, was yet publicly available to all because of its simple elementary beginnings and demonstrable qualities. Publication was often in the vernacular particularly by such individuals as Descartes and Galileo. The knew knowledge was conceived to be open to all, the only requirement being the rudiments of reason which Descartes attributed to all men: with its own autonomous (and impersonal) values it stood over and against religious understanding, in conception at least.

This is not to suggest that there were no connections between religious understanding and knowledge of the natural world either during the renaissance or after.

The ideas of the reformation thinkers it has been suggested had their own role in the complex changes of the renaissance. Not that such sentiments as those of Calvin on the discerning of god through his workmanship in the world should be taken as acting in any too direct manner, or setting up some characteristically 'protestant' type of knowledge. The practitioners of the practical mathematical sciences of the period discussed were hardly acting in a direct way to such a sentiment. In fortification for example one of the most 'reformationist' figures, Acconcio, published works nearer to the traditional medieval ideas than others. Rather, reformation ideas tended to carry with them the notion of knowledge as created in and by the individual, and their acceptance by substantial numbers of people tended to shift the centre of gravity of the potential range of positions available to anyone in the culture to which all still tended to feel they belonged. The dissent at the level of religious knowledge itself was equally likely to have made any kind of knowledge with a claim to certainty all the more desirable.

On the other hand there were other possible connections between religious change and the cultivation of the practical mathematical sciences of the later 16th. century. The tradition of church and university as repository of the knowledge of the medieval period tended to allow that tradition a monopoly on the organisation of social life by way of the traditional church callender.

The new public knowledge of astronomy, time keepers, and calendors was in a way a breach of that monopoly and hence may have tended to aid religious fission.

On the other hand in the modern period the view that the new knowledge could uncover the handiwork of God, was a binding force between natural knowledge and religous knowledge for many centuries, tending to mitigate against the divisive nature of the Galilean position.

Something has now been said about some of the complex process, ideas and events of which fortification and the practical mathematical sciences of the 16th. century were a part, to be able to assess in a general way these activities in the wider background both culturally, and in the great changes that took place as the medieval world was transformed into the modern. But one last point connected with the cultivation of these disciplines, perhaps more implicit than explicit, ought to be indicated.

The basic parallel drawn in the practical mathematical sciences of the renaissance between God as creator and governor of the world by way of mathematics, and the practitioner on earth paralleling his activities, while on the one hand it bound the various mathematical areas together and tended to support the claims of the different branches to employ a common and basic epistemology, on the other hand it had wider implications.

While individual writers in these disciplines rarely seem to have made the point directly, once their position was accepted, the power of the mathematical knowledge involved, was by implication almost infinite. If God's pattern could be copied in one area of mathematical knowledge, there seems to be no reason why it might not be copied in any other. The basic metaphor then tended to open up the possibility of almost unlimited progress in understanding and controlling nature. Equally the political metaphor which suggests and equivalence between man's lordship in the world and God's dominion over the whole universe, together with the parallel between man's mathematical knowledge and God's, tends to suggest the possibility and legitimacy of man's domination over nature. Thus the cultivation and dissemination of the knowledge of the practical mathematical sciences of the renaissance with the basic metaphor that was conceived to show the nature of that knowledge and to legitimate it, must be considered part of the process by which attitudes to man's knowledge and control of nature were spread, until Descartes could express the belief that cultivation of the new knowledge would lead to men becoming "the masters and possessors of nature."

III:(4):(iv): Other views of change during the period; Marx and Hessen
T.K.Rabb

In order to clarify the nature of the position of fortification theory in the later 16th. century within the complex of changes of the wider period of which it was a part, two rather different views relevant to the same kind of general problem will be considered.

Firstly the marxist view, expressed generally by Marx and elucidated in some detail by Boris Hessen with regard to the same types of areas as have been a major focus here.

The major difficulty with the marxist view however is that there are as probably as many different accounts of this position, or of what Marx's own position was, as there are commentators. In order to obviate this kind of problem two rather different expressions of the marxist position will be considered. On the one hand we can consider the 'strong view' as outlined by Marx thus

> In the social production which men carry on they enter into definite relations that are indispensible and independent of their will; these relations of production correspond to a definite stage of development of their natural powers of production. The totality of these relations production constitutes the economic structure of society -- the real foundation, on which legal and political superstructres arise and to which definite forms of social consciouness correspond. The mode of production of material life determines the general character of the social, political and spiritual processes of life. It is not the consciousness of men that determines their being, but, on the contary, the social being determines their consciousness. At a certain stage of their development, the material forces of production in society come in conflict with the existing relations of production, or--what is but a legal expression for the same thing -- with the property relations within which they had been at work before. From forms of development of the forces of production these relations turn into their fetters. Then occurs the period of social revolution. With the change of the economic foundations the entire immense superstructure is more or less rapidly transformed. In considering such transformations the distinction should always be made between the material transformation of the economic conditions of production which can be determined with the precision of natural science and the legal, political, religious, aesthetic or philosophical- in short ideological, forms in which men become conscious of this conflict and fight it out.[1]

The impression given here by Marx is of a process in which changes in economic functioning of a society have a very strong causal role and determine in an unequivocal way that superstructure of ideology he distinguished from the mode of production, with changes at the economic level being simply responsible for changes at the level of superstructure; and equally that the description of the economic functioning of the society can be described in an unequivocal way as an independant variable which determines all activites at other levels.

In contrast in Marx's writings can be found signs that this rigid deterministic view was not the whole story and that the whole process he described was much more an interactive one than tends to be implied by the above formulation.

1. MARX (1956) p. 51/2. This is from The material conception of history (1859). The same idea occurs almost word for word in other places in Marx's works.

For example he also wrote

> This conception of history, therefore, rests on the exposition of the real process of production, starting out from the simple material production of life, and on the comprehension of the form of intercourse connected with and created by this mode of production i.e. of civil society in its various stages as the basis of all history, and also in its action as the State. From this starting point, it explains all the different theoretical productions and forms of consciousness, religion, philospphy, ethics, etc., and traces their origins and growth, by which means the matter can of course be displayed as a whole (and consequently, also the reciprocal action of these various sides on one another)...It shows that circumstances make men just as much as men make circumstances.[1]

and

> In the devolopment of the productive forces a stage is reached where productive forces and means of intercourse are called into being which, under the existing relations can only work mischief....Associated with this is the emergence of a class.[2]

He equally left notes on a topic requiring description thus

> War attains complete development before peace; how certain economic phenomena, such as wage labour, machinery, etc, are developed at a earlier date through war and in armies than within bourgeoise society.[3]

In such passages thus Marx gave the impression of a much less rigid determination of the course of history by the economic functioning of society and one more of gradual development and interaction. We may then distinguish a more interactive Marxian view from the strong view. (In a way then these two views may be read as paralleling to a great extend the difference between what was distinguished as 'rigid rod' causation, and pressure causation.)

Boris Hessen in The social and economic roots of Newton's Principia[4] at different points, in different ways, tended to express both these view points. In his introductory section he explicity expressed the strong view point following the above quote passage from Marx almost word for word.[5] In more detail he equally suggested

> Practice has not to be explained by reference to ideas, but on the contrary the formation of ideas has to be explained by reference to material practice.[6]

and stated

> ....we come to the conclusion that the scheme of physics was mainly determined by the economic and technical tasks which the rising bourgeoisie raised to the forefront. During the period of merchant capital the development of productive forces set science a series of practical tasks and made an imperative demand for their accomplishment.[7]

On the other hand Hessen was quite insistent that this sould not be considered as determined in any rigid way. For, he argued

> According to the material conception of history, the final determining factor is the progress of history is the creation and recreation of actual life. But this does not mean that the economic factor is the sole determining factor, Marx and Engels severly critizised Barth for narrowing down historical materialism to such a primitive conception. The economic position is the foundation. But the development of theories and the individual work of a scientist are affected by various superstructures, such as political forms of class war and their results, the reflection of these wars on the minds of the participants -- political, juridical, philosophic theories, religious beliefs and their subsequent development into dogmatic systems.[8]

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1. Emphasis added. MARX (1956) p. 54/5, from The German Ideology (1845/6).
2. Emphasis added. Ibid p. 6. From the same work.
3. MARX (1904) p. 306. From The Introduction to the Critique of Political Economy.
4. (1931). Repr. 1971.
5. Op. cit. p. 2. 6. Ibid. p. 4. 7. Ibid. p. 17.
8. Ibid. p. 27.

Equally his formulation of the relationship between the bourgeoisie and the new superstructure was not one of a class coming into existence and then creating an ideology as based on their relation to the new mode of production, but one of the simultaneous emergence of both class and ideology. For, as he put it

> Science flourished step by step with the development and flourishing of bourgeoisie.[1]

Hessen further made clear that he considered this a very long term process when he wrote

> The great struggle of the European bourgeoisie against feudalism reached its greatest intensity in three important and decisive battles: (i) The reformation in Germany....(and its associated political struggles) (ii) The revolution of 1649-1688 in England (iii) The great French revolution.[2]

Thus although Hessen expressed the strong view in his introduction in his more detailed remarks he tended to express a more long term developmental point of view, accompanied, at least weakly by, implicitly a much more interactive view.

Now what ever view is to be taken on the strong Marxist position, Hessen, particularly when he expressed a more interactive view, clearly put forward an account of the relationship between 'the new knowledge' (science) and 'the rising bourgeoisie' that has certain broad similarities with the account given here of the dissemination of the practical mathematical sciences of the 16th. century. His account referred of course to just those types of activities which were the subjects of those sciences of the 16th. century considered here, as setting tasks for the rising bourgeoisie. Equally, while in this account the notion of 'the rising bourgeoisie' has not been made use of, it has been indicated how at various levels and in various ways the activities in these sciences were related to various 'social' factors.

There are however difficulties if we attempt to associate Hessen's connection between the new knowledge and the rising bourgeoisie with the dissemination of the ideas of the practical mathematicl sciences of the 16th. century and the social background as indicated here. Firstly if 'the rise of the bourgeoisie' involved as an important aspect events towards the end of the 18th. century in the French revolution, this notion is not very helpful, to say the least, in elucidating events of the later 16th. century. Further if the appeal of the treatises considered here, to particular groups is considered, that appeal was by no means clearly, at least on the surface, to the rising bourgeois. Certainly we may argue with Hessen that in certain areas mercantilistic interests were catered for, particularly by such works as in surveying and navigation, for example. But the needs most directly appealed to and catered for in these treatises were those of the prince and his desire for increased power, and more generally to that class that roughly can be distinguished as that of 'gentlemen'. Here at least, on the surface, it was the individuals in power that seem to have their needs catered for, rather than any rising class. This of course is hardly suprising, indedd, almost necessary, one might conclude. The acceptance of a certain kind of knowledge by a particular group is hardly inherently probable if it does not appeal to their interests, and if further it is against their interests it is hard to see it being accepted on any account. Equally the creators or the new knowledge had their own class interests in the new knowledge as noted above under the social model. As the prince was major source of patronage for such writers and part of the purpose of writing such works was concerned with the need for patronage, their catering for his

1. Ibid. p. 20. 2. Ibid. p. 27.

needs is only to be expected. Again, the dissemination of the treatise being necesary to the gaining of reputation and pupils, not suprisingly its contents catered to a more leisured class.

Of course one may agree with the Marxist view that such individuals, as individuals in positions either of power, or with an ability to carry on a particular leisured style of life, had particular relationships with and ability to exploit, the economic opportunities of the time. But a good deal of what was discussed in the relevant treatise referred to warfare, and the class of gentlemen had as a substantial section individuals with interests more military than mercantilistic, at least most directly.

On the other hand if one considers the ways in which perceptions changed towards a conception of a particular kind of centralised economic state in contrast to the more 'feudal' view of the middle ages, one finds that this new kind of knowledge as helping to disseminate a picture of a new kind of society with the new knowledge being very much a part of that society. That that society had roles in the military field and in economic terms for the bourgeoisie has been suggested above.[1] Thus, while at a number of levels the new knowledge related to slow gradual change with economic implications, which were all to the advantage of any emerging bourgeoisie it equally seems clear that the dissemination of that knowledge by helping to suggest the direction and form of a new type of society, was brought about by appealing to existing power interests, as well as giving rise to opportunities for the rising bourgeoise.

Thus if we consider the association of the rise of the bourgeoisie with the emergence of the new knowledge it seems to be necessary to consider the process just as much one of the ideology helping to bring that class into existence, as that class creating (or employing individuals to create) an ideology in accord with its interests. In other words a strongly interactive process rather than any simple one of economic functioning working through a particular class.[2]

Of course when Hessen wrote of the association of the emergence of the new knowledge with the rise of the bourgeoisie he may perhaps be read as having meant just this. But this type of formulation he seemed, almost perversely, to avoid, and at the more general level one tends to always get referred back to the strong Marxist position. Indeed the whole notion of the ideology helping to form the class structure, while in many ways it can be seen as implicit in Hessen's remarks, seems to be explicitly almost totally ignored by him -- though this is hardly suprising in the context of the strong Marxist view where the causal arrow goes from economic functioning to class to ideology.

Thus in one way the material considered here tends to support the type of interpretation put forward by Hessen, although it suggests a number of relatively complex stages in a phenomenon that Hessen tended to treat as a monolithic process. On the other hand it tends to suggest that Hessen and and the general Marxist position tends to handle the complex interactive processes involved very one-sidedly, always referring to the basis of events in economic functioning rather than the complex interaction by which they grew together in a 'dialectic' process, certain tendencies being taken up and developed at the level of superstructure and helping to bring into existence those same tendencies in a more developed form by favouring the spread of certain economic trends, and the influence of the class structure applicable to them.

1. That is in leadership roles and in controlling the new technologies.
2. If one considers dialling for example, the whole conception of an abstract universal time, seems to be much more a view which can be considered to have favoured the factory system of production many centuries later, than a general need of the time. Equally the whole notion of the new knowledge as an abstract device for the control of economic and social functioning at a distance, seems much more applicable to later Capitalism, than to the period of its inception.

The significance of late 16th. century fortification theory thus is seen to be that of one of a number of effects within the complex web of economic, social, military and epistemological developments which was part of, yet helped to bring about the complex processes by which the medieval world through a gradual revolution became the modern.

The views of T.K.Rabb on the general pattern of our period may be briefly alluded to here by way of a contrast with the Marxist approach.[1] Rabb, considering the problem of 'the general crisis of the 17th. century' suggested that the period from at least 1500 on could be considered much on the lines of the medical model of a crisis, particularly as a process which, reaching some kind of climax then resulted in a resolution of the crisis, which event he suggests should be set in the later 17th. century. Rabb considered an important aspect of this process was a crisis of doubt, and that the new knowledge (science) which came to be accepted in the later 17th. century was an important aspect of the resolution of doubt and the whole crisis.[2]

But, while we may certainly agree that the period from 1500 on was one of many kinds of tensions and much uncertainty in certain ways, any attempt to consider the whole period as one of continually increasing tension and doubt and conflict until the rise . peaks with a resultant resolution afterwards, not only leaves out many factors, but complatly distorts certain others. The distortion involved may be seen in Rabb's account of Descartes, referring to whom he stated;

> ...the hesitancy and unease distilled by Descartes provided the impetus for almost every major writer from mid-sixteenth to the early seventeenth century.[3]

Even ignoring the fact that Descartes used doubt as a philosophical tool to resolve problems of knowledge and in order to reach certainty as he saw it, it is difficult to accept this view as but one side of the coin. Descartes view that knowledge had reached the stage where simply by its cultivation man might be expected to become 'masters and possessors of nature' must be set against any background of doubt and uncertainty. Equally the cultivation of the practical mathematical sciences such as fortification during the 16th. century was considered to provide an anchor of certainty in an uncertain world, so that although the doubt and unease of the period may be part of the reason why such knowledge could provide such a foundation, that the early stage of the evolution of aspects of thought that were to become part of Rabb's resolution were being cultivated from the earliest stages of the rising crisis, must be considered just as important as the so called crisis itself. To treat the period as one of increasing crisis is to ignore just these ways in which the elements of the resolution (if it makes sense to talk of a resolution at all) were worked out. Then again if we are to accept the notion of a resolution of tension and crisis, or whatever, in the later 17th. century, it seems necessary to treat different aspects of the culture system (as that idea was indicated above) as both, having their own quasi-autonomous courses, while at the same time acting as events within the wider framework potentially forming either positive interactions, or potential points of tension.

Within the crisis formulation then 16th. century fortification theory must be considered one of the ways in which at a more detailed level certain individual or groups of individuals attempted to bring structure and

1. The struggle for stability in early modern Europe (New York 1975).
2. "Even before the resolution of the final conflict between Newtonianism and Cartesianism, scientists had coalesced around a new found approach to knowledge ....The old, shaky reliance on tradition as the root of knowledge had been replaced with an emphasis on abstract reasoning and sense experience." Op. cit. p. 121.
2. Ibid p. 39.

sense to their activities; and in so far as they achieved that, therefore provided one foundation point on which relative greater stability could be begun to be built.

Thus with regard to both the marxist view and the view of such a historian as Rabb, we may return to the point that the cultivation of 16th. century fortification theory and the practical mathematical sciences of the renaissance, have to be seen as aspects of cultural change both independent and quasi-autonomous from one point of view, which yet, by their very nature knitted into the other changes of the period in particular ways, forming relationships as much central to the pattern of the period as the detailed changes themselves.

III: (5): Conclusions

(i): Scientific knowledge: Empirically based or a social artifact ? Epistemological change during the renaissance

Fortification was but one area among many which developed during the renaissance in directions of epistemological significance. This discipline, like others, while on the one hand it evolved in accord with general perceptions at the epistemological level, equally had to respond to the more detailed technical need to which it was conceived to be addressed. In itself this change in fortification could hardly have been of very wide significance in a more stable background, where its mathematical techniques, if they had occurred at all, might well have remained just the particular techniques of one especial field, to be considered perhaps interesting, if somewhat anomalous. Given however that mathematical techniques were being cultivated in other disciplines, together with the basic mataphor of the technologist paralleling god's activities, the success of renaissance fortification in its own field became part of the success of the mathematical method.

Undoubtedly the nature of the change that took place in renaissance fortification and other fields during the same period was at least in part a response to the way individuals and groups perceived their own and others' roles in society, and how those roles were related and ought to be related. Patrons, practitioners, and consumers -- the audience for the multiple copies of the treatises, all had their own interests catered for in one way or another in fortification and in other fields; and while the different ways in which the different groups found their interests catered for, varied to some extent, in each case the social and economic nature of their interests is not far to seek.

The understanding that resulted, in these seperate fields, and by way of the general method that evolved, was thus constrained in two ways. On the one hand preconceptions at the social level set tasks which it was concieved desirable for knowledge to accomplish, while on the other the practice and needs of the different fields individually had to some extent or another to be catered for.

Thus the spread of the mathematical idiology was no mere arbitary change or fad in response to any mere change of taste. It was not the result of a pattern where at one period certain individuals happened to find Aristotle very interesting and then at a later period happened to find Plato more interesting. It was a complex process in which knowledge constrained at the level of practice, was legitimised by its perceived effectiveness in practice, even while that same practice helped to disseminate it. But neither was this empirical restraint sufficient in itself to independently determine the content of knowledge. There was involved equally a commitment to finding a certain type of knowledge, whether it was the true method in fortification or the solution to the problem of longitude in navigation not merely the view that a certain type of knowledge was desirable, but a commitment to search until the requsite kind of knowledge was evolved or created. Thus the success of the practical mathematical sciences during the later 16th. century and the accompanying spread of the mathematical ideology involved attitudes to knowledge and commitments to certain kinds of behaviour in order to extend knowledge, with strong connections with views on the nature of society and the whole role and functioning of knowledge in society. A success which, in spreading certain kinds of views among significant groups of society provided a base on which such 17th. century figures as Galileo and Descartes could build in a more general way, and without which it is difficult to conceive their having undertaken the sorts of work they did attempt.[1] The activities of these figures thus had their roots in the society of their period.

Thus the search by Descartes for the ultimate foundation of knowledge, demonstrated in, and by, the individual, as knowledge in its most fundamental nature -- yet demonstrable and public in accord with the paradigm of Euclidian geometry — had strong social roots. That is, the very search for knowledge universally true, and conceived to be so because it was believed to be in no way influenced by social forms, traditions, or preconceptions, but was true in an abstract general way -- i.e. the search for 'objective' knowledge -- was itself in part a response to the very kinds of roots from which it sought to break free.

The conclusion thus seems to press itself upon us that that search was in some sense a chimera; that at the ultimate level of epistemological commitment 'objective' knowledge itself tends to be 'tainted' with social preconceptions. But, is this such a bad thing ? May it not be a liberation. If the individual in his search for knowledge is constrained not merely by the intractable physical world, but is also subject to the intractability of social relationships, he cannot be concieved to act in his search for knowledge, in the isolated world of his own 'cogito'. His 'reality' will then be both the physical world and the world of other minds with their own wants, desires, needs, and preconceptions, like his own. Therefore his task will be the matching and creating of the links between these different realms[2] and he will not be enmeshed in the labyrinthine search for whatever 'pineal gland' will bring together what Descartes so irrevocably tore asunder.

III: (5): (ii): The nature of large scale technological change

While preconceptions about the nature of knowledge and the value of a mathematical approach were influential in shaping the ways in which renaissance designers approached the problem of fortification, the products of that art remained always objects which had to function in a world of shot and space, of trenching and mining, of casualties and heroism; and while in the years around 1500, aproaches to design shifted radically, from the definition of the form of the structure by reference to the resisting ability of particular forms, to the determination of the plan trace by reference to the needs of flanking fire, in the long run the resultant structures had to function in the context of the changing nature of warfare and society of which they were a part. The fortress itself designed in accord with the needs of flanking

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1. Particularly in creating an audience ready to accept the mathematical approach in its more general application in natural philosophy, one assumes. In which case it is equally likely that the cultivation of Platonic ideas and neo-Platonism, helped to ready the ground equally. But the difference between the approach of the <u>practical</u> mathematical sciences of the renaissance and such views must not be disregarded.
2. This would involve of course a genetic view of knowledge, as historically constrained (though not determined), with the 'empirical' element providing the contrasting constraint. A view perhaps not without its difficulties. But the picture that has emerged here of renaissance fortification, with the later phase having to be explained as necessary because of the new powerful artillery, at least in part because in the earlier phase the needs of defensive guns tended to be ignored, is just such a pattern.

during the 16th. century became part of a new system of warfare, and thus the change to the later design techniques must be conceived as part of the process which helped to bring the later system into use.

Thus narrowly conceived functions of a purely technical nature cannot be considered the sole determinants of a piece of technology such as a fortress. As a tool used by society such an artifact must of course be created in accord with how the problem to which it is most immediately addressed, is perceived. But the results of such creative acts, by bringing new opportunities, and at the same time creating their own particular loads on the society which employs they may all too soon alter the very surrounding circumstances of their use, and the needs to which they were originally designed to cater for. Technological artifacts of a certain kind, then, seem equally able to do things to men, as well as for them. They cannot as a result be conceived to be artifacts or techniques which relate satisfactorily or unsatisfactorily in any immediate way to a fixed set of practical needs and values. The evolving world of which they form a part and the new needs and values they help to bring into existence, and the loads they impose on the surrounding society, determine their continuing status. It is the viability of the resultant system which include their use, which determines ther success. In so far therefore as created artifacts and techniques such as the fortress lead to courses of change which are consistent with and help to support types of change otherwise thought desirable they will tend to be counted a success. In so far however as they impose loads on a society and call for types of behaviour found increasingly irksome and undesirable, however effective their narrow technological functioning is, they can only be account a bane on the society which it is their purported aim to serve. Certain kinds of techniques, artifacts, and technologies therefore cannot be concieved as inert objects that function merely as tools. Their use is interrelated with the values of the society in which they function as well as its needs. To fail to attempt to assess technolgies and their products on this level then is to become their servants rather than their masters.[1]

III (5): (iii): The development of renaissance fortification

In the context of the increasing use of gunpowder weaponry both in attack and defence in siege warfare during the later 15th. century Italian fortification designers began to seek for a method in fortification which would put the art on a new and sound basis as had happened and was happeneing in the revolution in general architecture begun not so many decades before. At first designers such as Francesco di Giorgio considered it possible to determine the plan of the fortress by reference to the need for simple geometric forms which would best resist attacking artillery, and then to proceed to construct with the most resistant of materials, while the need to deploy defensive artillery in the resultant structure was only given secondary or minimal attention. A simple geometrical polygon (most often simply a square) with round resistant towers at is corners was often employed in accord with this conception in a number of relatively confined and massive structures during the later 15th. century and into the first decade of the 16th. century as in the case of Bramante's rocca at Civitavecchia.

However a number of factors tended to militate against this type of approach continuing to be considered satisfactory. The increasingly effective employment of artillery in siege warfare brought home most effectively to Italians by the invasion of the army of Charles VIII in 1494 with its highly

1. It is perhaps sanguine to remember the ideas of Ibn Khaldun here, expounded so many centuries ago in a rather different context, when he suggested that one wave of bedou became weakened by the luxuries of civilization in the cities, until they were conquered by a new wave, to give his cyclic view of history.

mobile and rapid firing artillery whose rapid attrition of local areas of structures, tended to make responses by way of repair, or the construction of retrenchments more difficult, produced a need to respond more directly to that threat by way of catering for the employment of effective defending artillery. The resultant lowering of structures and elimination of such traditional devices such as machicolations and high towers while on the one hand it tended to reduce the exposure of the structure to the attacking guns, at the same time it tended to make easier provision of platforms for the employment of defending artillery. But equally the problem of the urban enceinte remained, and while equally the similar lowering of structures there tended to take place and the device of the heavily scarped wall was employed to create stability, yet in terms of a principle of design the idea of producing structures best able to resist by way of form in the context of the longer urban enciente carried with it implications of costs which were in tension with the notion of the fortification designer as demonstrating his (almost god-like) ingenuity in design. Thus even as Francesco di Giorgio was ennunciating the idea of form determined through its resistant qualities, designers, particularly the Sangallos began to produce forms in accord with a very different principle. While in the earlier approach form was determined primarily by reference to the need to resist attacking artillery, the new approach involved a complete reversal by which resistance was ignored and the needs of flanking fire through the application of the principle of no dead ground became the primary determinant of the plan form of the structure.

The evolution of renaissance fortification from this point on was pretty well entirely a matter of the dissemination, acceptance and deepening entrenchment of this principle of design as the unquestionable doctrine of fortification design in theory and practice. While at Treviso and Padua under Fra Giocondo and at Ferrara under Baccio Pontelli, in the years around 1500 the new lower structures were employed but with projecting round forms, the new forms in the years that followed became the norm, although, not by any means universally so at first and with an occasional voice refusing to accept the new principles in any too doctrinaire fashion until at least as late as Castriotto. But by the late 1540s the new method was by and large almost universally accepted in Italy and abroad. With the publication of Tartaglia's Quesiti, and its discussion of the basis and principles of the contemporary methods, a new phase was ushered in and fortification on the basis of the new principles became a discipline with a theoretical basis enshrined in a text book tradition by means of which its principles and ideology were relatively widely disseminated by way of the printed word.

This pattern of development was facilitated by a number of factors. For, while the early attempts to resist artillery by reference to the most resistant form tended to run into increasing difficulties in the context of the continuing developments of the period, the later principles tended to work more in accord with them.

As attacking artillery came to be increasingly used as a weapon of attack in siege warfare that same weaponry could be increasingly employed in defence to harry the enemy at a distance, slow down his emplacment of batteris, help to keep him more distant and to slow down his rate of fire. Equally defenders tended increasingly to use flanking fire as the attackers approached the basic defensive barrier or attempted to storm the breach. How long designers could have continued to ignore this possibilty is a matter of conjecture but in the context of increasing employment of artillery in siege warfare it was only a matter of time. Equally, the gradual change by which the feudal lord became renaissance prince and tended towards the form of the soverign of the modern state, becoming more a governor of society rather than a war leader, meant his needs were less for a defended castle in which strength was associated with smallness, and hence his residence evolved into a palace. Thus the focus of the later methods of fortification on urban enceints of a purely defensive nature was in accord with evolving needs. Similarly the changing nature of warfare with an increasing technological load imposed by the new weaponry, and the increasing use of organised infantry as the major force an an army, tended to favour the idea of power based on numbers of both population and soldiery, and increased economic functioning, and hence the notion of individual nation state defended at its frontiers by fortresses of relatively large size tended to become the norm, which in turn favoured large scale encients, which were seen then to be in accord with fortification theory on the later principles to be the most perfect.

But equally the theory of fortification based on the principle of no dead ground and the needs of flanking fire, along with the relatively low and large structures involved, so very suitable to a mathematical treatment at the theoretical level was in accord with the increasing cultivation of the practical mathematical sciences of the period and enabled contemporaries to see that method as so inevitable as to be absolutely necessary in the face what they conceived to be irresistable artillery, which belief only served to further increase their confidence in their favoured method.

Yet in its time that understanding which renaissance fortification helped to form and disseminate was merely part of the wider changes of the period in the search for individual, demonstrable, public knowledge. Its developments therefore further knitted into many developments over the longer period and hence were all the more inevitable from a certain point of view.

Thus the developments of renaissance fortification have to be viewed at a number of levels if their course is to be grasped and understood. The relationship of those developments to the increased employment of artillery in warfare, itself a complex interaction, is but one level. To see all the many levels as merly some mechanical response to a new powerful artillery is to miss a great deal, if not the major part, of what was significant about that discipline in its period. To take contemporary accounts of the history of the art as anything like the whole story is to be captured by the assumptions they made in order to live in and deal with, and to make sense of, the complex world of their time, not to understand the nature of that response, albeit their assumptions proved relatively tenable. The power of a gun is universal by definition, renaissance fortification was manifestly a characteristic product of the Italian renaissance.

Further bibliographical and other notes

Volume I

p. 84, n. 7. "I Belloardi s'hanno sortito questo nome della bellezza et grandezza loro, perche sono edifitij molto bellicosi" Vatican Codex Urb. Lat 821, f. 64b.

Pt. II (1). GILLE (1958).despite the title throws no light on the matters discussed here. On the 16th. century Gille mentions little more than Archimedes and Tartaglia and then jumps to the 17th. century. On this section see also FINCHAM (1851), ALBION (1973). Other works sometimes noted as possibly relevant to this field which it has not been possible to examine include BARTOLOMEI (1553*); FALCO (1554*); NEZELLI (1598*).

p. 113, n. 3. Bourne wrote in the dedication to his treatise on glasses for optical purposes to William Cecil "youre Honoure had some speeche with mee, as touching measuring the moulde of a shipp. Whiche gave mee occasyon, to wryte a little Boke of Statik." See HALLIWELL (1839) p. 33.

Pt. II (2). p. 114. On Munster see BURMEISTER.

Pt. II (4). HALLIWELL(1839) gives some treatises relevant to medieval surveying.

Pt. II (5). See also BARLOWE (1597) "...in the mind onely, pure and true Arte, refined from the drosse of sensible or experimentall knowledge, is to be found. Which when I perceaued must needs so be, and that the great skill of our Seamen was not performed either by rashness of chaunce, or strangeness of miracle, but according to certaine universall precepts or documents, derived from the fountain Mathematical, being the substance of that Arte." Sg. a4b.

p. 170, n. 3. See for example RAVENHILL (1976) p. 82/3. "if Bourne's determinations were relied upon while finding and running down the latitude, the ships' pilots would, at best find themselves in the Bristol channel instead of the English channel; at worst shipwrecked on the granite teeth of the Penwrith peninsula. It is interesting to find all the values in the list given were in degrees and minutes, but clearly instruments of this period, except in a very few cases, were not capable of being read to this fineness of accuracy."

III:(2):(ii). p. 242. One of the very *few treatises of the first half of the* 16th. century indicating something of the new ideas was that of *ESCRIBA (1878)*. Escriba seems to have favoured a trace like that of the 'forbici' flanked from the internal angle. His treatise however was not really a theoretical work like the later works of this genre, but was mainly concerned with specific sites and structures.

III:(2):(iii). On siege warfare see also MARINENGO (1572) "alli 25 detto (April) fecero (the Turks) bastioni per metter l'artiglieria, & le trincere per gli archibugieri, uia presso l'altra, accostandosi a poco a poco con un modo impossibile a uietarlo, lauorando loro il piu di notte di cotinouo da quamanta millia guastadori. Veduto il disegno del nemico, & doue pensava di battere, s'attese dentro con grandissima diligenza a riparare...Si condusse tutta l'arteglieria buona da quella banda doue si aspettaria la Batterie ma preuendendo noi che la poluere uenia meno si fece unal limitatione ne si tiraua piu che 30 tiri per pezzo al giorno con 30 pezzi...fecero nella sorti piu sotto la fortezza, & tolte l'Artegliaria da quelli lontani & aggionto uene sin al'numero 80. battevano con tanto fuore che si numerono nel di 8. di luglio con la notte cinque milla cannonate". The Turkish army was given here as"100 milla persone, di ogni qualita; li pagati 80. millia, oltra quali 14 millia Gianizzeri tolt da tutti le presidii della Saria, Caramaneia, Nallo Nallolia, & parte della porta il Venturieri da spada 60. millia. In 75 girono che e durata la batteua 150 millia palle di ferro, che si sono ueduto & contate." "nel principio non attesero molto a rouinar la muraglia ma trrauano nella Citta, & alli nostri pezzi che li faceuamo molto danno".

III:(3):(ii). GUILMARTIN (1974) looking at Naval warfare during the same period came to the conclusion that the older view that cannon on ships radically altered the whole nature of navel warfare was not satisfactory, and that it was a replacment of a whole system of naval warfare by a whole new system that accounted for the changes. This is very similar to the view taken here with regard to fortification and land warfare.

III:(3):(ii):(c). With respect to the economic load of the new warfare see PARKER (1972). Medieval mounted cavalry could presumably generally forage fairly freely and undertake their own provisioning. Organised foot one imagines posed a much greater problem, and one of the Spanish problems was getting troops to the Netherlands. See also BEAN (1973).

III:(3):(ii):(d). See also STRAYER (1972) "It is undeniable that in the 16th. century European states gained power, took on new responsibilities and received increased respect from their subjects. These success were due far less to administrative reform than to changes in attitudes and behaviours of both the governing group and those who were governed....a new bureaucracy began to emerge from the Council -- a bureaucracy that was more ameanable to the wishes of the rulers and better prepared to cope with the problems of the early modern world." Political considerations could also be conceived to be directly related to the new warfare. For example see BACON (1885) p. 72 "For it hath been held by general opinion of men of best judgement in the wars, howsoever some few have varied, and that it may receive some distinction of case, that the principle strength of an army consisteth in the infantry or foot. And to make good infantry it requireth men bred, not in a servile or indigent fashion, but in some free and plentiful manner."

III:(4):(ii). Attempts to institutionalize the study of the practical mathematical sciences on the lines on which the later academies of science were formed seem to have occurred in both France and Spain in the last years of the 16th. century. See for example VARELA Y LIMA (1846) p. 115. "Ochenta anos antes que habiesen sido creadas la Sociedad Real de Londres y la Academia Real de Ciencias de Paris, existia ya bajo este mismo titulo en Madrid un establecimiento cientifico....(in which there were) Rojas...que explicaba el Tratado de fortificacion. D Gines de Rocamora....que ensenaba las matematicas y publico con este motivo su Tratado de la esfera; el Dr. Julian Firrufino, artillero, que comentaba los Cuatro libros de Euclides; el Licenciado Juan Cedillo, professor de matematicas de Toledo, que leia la materia de sensos; Juan Angel, que ensenaba sobre el tratado de Archimedes, de hisquae vehunteir aquis; y finalmente, el Alferez Pedro Rodriguez Munoz. que leia la materia de escuadrones y forma de ordenarlos, con los principios de aritmetica y raiz cuadro para el uso de los Sargentes mayores de los ejercitos." On France see Errard II p. 216 and ARTZ (1966) p. 42/3 who quotes de La Noue on the desirability of such an academy relating directly to warfare. That these efforts were so short lived may be a sign that what in previous decades may have been thought of most significance in the mathematical sciences, may have been shifting towards the sorts of acitivities Galileo and Descartes and their like, undertook. For a view similar to that of this section see WHITE (1967)B, p. 425 "Yet is is doubtful whether the "Cartesian" mentality, which assumed that mathematics is the key to reality, would have become dominant if Europe had not been assiduously bankrupting itself by building new military defenses in which assurance of safety was achieved less by tangible masses of masonry that by abstract geometrical patterns of lines of fire." ZILZEL on the other hand in this area attempted to make much of the contact of the learned world with craft practice. Yet the treatise writers while often insistent on how practical their efforts were, were often in fact rather impractical and tended to imply sometimes that inventions of theirs, which could not work, functioned satisfactorily in practice. A favourite device for discussion or illustration all through the renaissance was a diver's mask. All that was involved was a mask basically of some form or other with an open tube to the air above. BOURNE (1578) Devise 23, for example discussed this and carefully explained how there had to be floats at the top of the tube. But this type of device must be considered purely a fantasy because under this condition the air in the lungs must be at normal air pressure. As water weighs 64lb./cu. ft. the external pressure on the rib cage must be 64lb. on every square foot for every foot of depth. It would be impossible to breath against this pressure at any significant depth. The importance of this can be seen from the central importance of the bends in modern diving in which air is delivered to the lungs at at least the external water pressure, and hence gases dissolve in the blood causing the problem. Writers such as Bourne equally ignored the problem of the tube collapsing under the external water pressure, showing how imaginary such accounts were. Yet some modern commentators seem to think such devices could have worked. For example KELLER (1964) p. 113 states "A similar device (to that described by Lorini) must have been worn by another military engineer, Francesco Marchi when in 1535 he descended 45 feet into lake Nemi to inspect a Roman wreck". How the laws of physics were different from modern accounts, in the 16th. century, so as to allow this, is difficult to conceive. The device of Tartagli, involving an inverted glass bowl around the head was perhaps somewhat nearer the mark. In principle it can be conceived to act like a diving bell. But in practice it would have been for too small to have been successful. Diving techniques during the period must undoubtedly have been like that Bourne described at another place ((1578) Devise 22) where he told of Italians using a large vessel as a diving bell into which the divers made resort as a refuge to take in air. In this case of course the air is automatically at the water pressure of its depth. Such practical techniques were generally ignored however, when the treatise writers came to discuss their favourite fancies. The impracticality of many of their discussions can be similarly seen in Stevin's 'Almighty', a winch, which he claimed could exert enormous forces, which simply involved gear trains. Of course geometrically Stevin was correct. But with such high multiplying trains friction losses soon start to wipe out theoretical gains, and further, the components involved could never have withstood the strain which theoretically such a gadget could be conceived to induce. Thus Zilzil's emphasis on practicality does not seem very apt. STRONG (1936) took a diametrically opposite view to the one expressed in this section, stating (p.10/11) "The conclusion finally driven home was the conviction that the achievments of Galileo and his predecessors were in spite of rather than because of prior and contemporary metaphysical theories of mathematics". Where Strong went wrong was in analysing the background in terms of modern ideas and distinctions, instead of examining the sources thoroughly to clarify contemporary attitudes. This becomes clear when he states (p. 2) "What seperated pure and practical geometers from the early modern mathematicians was the demonstrative generality of the pure geometer as contrasted with the measuring instruments and operations of the practical geometer", while the texts considered here make it clear that it was a concern with just such a quality of demonstrable generality in practical matters that made the attitudes of such as Galileo so similar to those of earlier practitioners in the practical mathematical sciences.

III:(4):(iii). On medieval traditions of knowledge see for example BALDWIN (1970) p. 52. on Bede's opinion that "Through his ordination, therefore every priest received not only power to administer penance but also knowledge to perform his duties intelligently." On progress see also WOLPER (1970). On privileges see also for example to Gerard de Jode's Speculum orbis terrarum (Antwerpen 1578) "Hoc Geographicum totius Germaniae Imperium, ...nihil continet fidei catholicae contrarium, aut bonorum morum offensiuum, quinimo multum vtilitatis studiosis est allatruum: quare imprimi posse iudico" Sylvester Pardo S. Theolog. Licenciatus, & Cathedr. Ecclesiae Antwerpien. Canonicus.

III:(4):(iv). EISENSTEIN (1979) attempts to make much of the production of multiple copies by way of the printing press particularly, as a significant agent of change during the renaissance. The one-sidedness of such an account hardly needs refuting. Here it has not seemed necessary to emphasise what was undoubtedly a significant factor, but which is well recognised in a general way. Obviously the introduction of the printing of multiple copies interacted in many ways with the factors discussed here in more detail, but this can be taken as read.

VOLUME II

p. 4. CORNAZANO (1493) "fra larte si fan digna d'honore/ Acui lingegno human se industriato/ Militia e fructo ela Scientia un fiore" (f.iia)

P. 90. The Bodleian copy of this work (AA 138 Art) has 4 further plates extra to those in the B.M. copy. Two internally showing horizontal views of fortresses; and two further at the end showing traces of fortresses in circles.