Improving the usability of medical infrastructure software: the redesign of a linear accelerator machine log.

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Master of Science
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Computer Science

June 2020

Abstract

Medical Infrastructure Software in the National Health Service (NHS) is pervasive. This type of software is not regulated medical device software, it is behind the scenes software that helps to coordinate the management of equipment that delivers or supports patient treatment.

This software is sometimes developed in-house by Healthcare Professionals such as Clinical Scientists & Technologists, in departments such as Medical Physics & Clinical Engineering. However some of this software is not used as intended and exhibits a lack of use problem. Human-Computer-Interaction (HCI) is an area of Computer Science that aims to address these lack of use issues.

An example of this software is MachineLog, developed by Clinical Scientist & Technologists at the Northern Centre For Cancer Care (Newcastle upon Tyne NHS Foundation Trust). MachineLog has diffused into The James Cook University Hospital (South Tees Hospitals NHS Foundation Trust) and it is intended that MachineLog is used by Radiographers to record faults for medical equipment known as Linear Accelerators (Linacs), machines that are used to deliver radiation to a cancerous tumour in cancer patients. However, in practice, MachineLog is almost never used and this creates a problem with recording and logging faults for the Linacs.

The work in this thesis aimed to understand the factors that influence usability and acceptability of Medical Infrastructure developed by Healthare professionals, and to re-design MachineLog as a Healthcare Professional who is familiar with software development but is not an expert in design or usability. To achieve this, the literature was reviewed to explore the aspects of HCI that can make Medical Infrastructure Software usable in the NHS, leading to methods such as Contextual Design for investigating the lack of use of MachineLog.

A Contextual Inquiry was performed for discovering the existing work of the Radiographers whilst they were using (or not using) MachineLog. The data from this study was used to create personas, existing and new scenarios of use, and was further used to help communicate the requirements of a new prototype called LinacLog. Furthermore, this data allowed us to conclude that the Radiographers will not use MachineLog in its current form because it does not align to their goals of treating patients and is a factor that influences acceptability. It was anticipated that LinacLog be a fully functional prototype, however, limitations due to Hospital IT led to designing a low-fidelity prototype. LinacLog was then evaluated, despite encountering SARS-CoV-19 related difficulties.

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Acknowledgements

I would like to thank my supervisor, Professor Paul Cairns, who has provided invaluable guidance and support on my research journey. It has been a pleasure to work with you over these past 24 months.

I would like to thank Brian Deehan, Consultant Clinical Scientist at The James Cook University as my line manager at the start of my MSc project, for the opportunities he provided for me and supporting both my professional and personal development. Brian provided the time during my working hours in lieu of MSc funding, to direct this project my own way whilst pursuing this research.

I express my gratitude to my colleagues working within Radiotherapy Engineering and Radiographers, providing their time to me for interviews and observations, and providing insight to the work during their busy schedules and for sustaining their engagement during Covid-19.

Like all Healthcare Science disciplines, Clinical Computer Science touches nearly all aspects of patient care. It is a privilege to be a Computer Scientist training as a Clinical Scientist in Medical Physics, Physiological Measurement and Clinical Engineering, directly impacting healthcare and patient care. I would like to acknowledge the Academy for Healthcare Science for their on-going work on the development of Clinical Computer Science as a Healthcare Profession.

To my lovely family, who have supported me during my MSc.

Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Chapter 1

Introduction

The National Health Service (NHS), specifically in England, is often thought of as one national entity. However, a hospital in London could operate completely differently to a hospital providing a similar service in Newcastle-Upon-Tyne. The ways of working, or operating procedures, are often agreed locally within NHS Trusts. From the patient‘s perspective, the end service should be no different between each hospital, for example, a cancer patient in London should expect to be able to receive the same radiotherapy treatment as cancer patient undergoing radiotherapy in Newcastle-Upon-Tyne. However, as NHS Trusts are given flexibility to operate in this way (within legislation and NHS England frameworks), a patient may be treated with a different manufacturer and type of Linear Accelerator (the device used treat a cancer patient‘s tumour). It is important to note that their outcomes should be relatively similar.

This flexibility is true for software development in the NHS. Software is being developed within the NHS by Healthcare Professionals in hospital departments as a tool to support their work. These staff are not employed as professional software developers and do not have formal software development training. As software development resources are pervasive on the internet, self-learning to develop software can be relatively straightforward. This is not to say such practices should be discouraged as staff are developing tools to support their work, as experts in their own work.

Most of this in-house software is not regulated by medical device regulations as it is not used to treat patients. This software does not store patient healthcare records and can be developed with little restriction. However, this in-house developed software has both the potential to diffuse across the NHS and directly impact the work of other staff groups. There are instances of this in-house software that is not being used for its intended purpose and thus exhibit a classical Human-Computer-Interaction problem.

The focus for this thesis is unregulated Medical Infrastructure Software that has been developed by NHS Healthcare Professionals such as Clinical Scientists and

Clinical Technologists, who are not professional software developers, and that is not being used as intended. This type of software is not Medical Device Software and is not regulated by legislation such as the Medical Device Directive (MDD) or the new Medical Device Regulations (MDR), nor is it software that stores patients health and social care records. Medical Infrastructure Software is software that is intended to support the behind the scenes operation of the Medical Infrastructure, the infrastructure that makes NHS treatment possible.

The example used in this thesis is Medical Infrastructure Software known as MachineLog, developed at the Northern Centre for Cancer Care (NCCC) part of the Newcastle Upon Tyne Hospitals NHS Foundation Trust, and has diffused into The Radiotherapy Department at The James Cook University Hospital (South Tees Hospitals NHS Foundation Trust).

MachineLog (discussed in detail in Chapter 3) is a tool (Medical Infrastructure Software) that is intended to be used by Radiographers to report and track Linear Accelerator (Linac) faults and issues in the Radiotherapy Department of The James Cook University Hospital. A Linac is a large and complex medical device (medical infrastructure) that is used to treat cancer patients by using X-Ray radiation beams, and is discussed further in Chapter 2. Managing the faults that arise when operating Linacs is important as Radiotherapy cannot operate without Linear Accelerators. However, MachineLog is not being used as intended by the Radiographers and exhibits a lack of use problem.

At The James Cook University Hospital, MachineLog forms part of a Radiotherapy IT Ecology that is discussed further in Chapter 2. This IT ecology consists of treatment software and maintenance software that together with the Linacs, supports the delivery of Radiotherapy.

Some of this software is regulated as a Medical Device. For example in the context of Radiotherapy, a treatment planning system used to calculate a patient's radiation dose distribution is considered a Medical Device. A further example is the software the drives and controls the Linac. Furthermore, some of this software is in-house developed medical device software.

As this software is used in the delivery of radiation as a medical exposure it is governed by the Ionising Radiation (Medical Exposure) Regulations (IR(ME)R) [2]. In this case, Regulation 15 of IR(ME)R states that the treatment planning software or the Linac control software must be formally commissioned into use with an adequate commissioning and testing process. This means that this type of regulated software is thoroughly assessed and evaluated before being used clinically. However, Medical Infrastructure Software such as MachineLog falls outside of this regulation as it is not used for the planning or delivery of radiation. This is important to mention because regulated medical software can not easily diffuse into another hospital, unlike in-house developed unregulated Medical Infrastructure Software such as MachineLog. There is therefore a mix of regulated and unregulated commercial and in-house developed software in the Radiotherapy IT Ecology.

MachineLog's lack of use can be investigated by using Human Computer Interaction (HCI), an area of Computer Science that draws upon areas such as human factors engineering and psychology. HCI aims to provide solutions to these type of problems (such as MachineLog) by promoting good software and interaction design.

This investigation, using HCI techniques, informed the development and evaluation of a new prototype, beginning to address the lack of use of MachineLog. The prototype was named LinacLog. It was anticipated that the prototype would be a working prototype. However, due to limitations, a low-fidelity design prototype was developed and evaluated.

1.1 Aims of this thesis

As Medical Infrastructure Software is being developed in the NHS by Healthcare Professionals, it highlights that there is a need for such software to exist, as this software is intended to solve a specific set of problems, such as maintaining the Medical Infrastructure (The infrastructure involved in treating patients). However, in practice, this software does not work as intended because the users are not using it properly, despite this software not lacking the functionality required.

MachineLog is an example of Medical Infrastructure Software. The Radiographers are required to use MachineLog to report faults that occur when operating Linear Accelerators, complex devices that are used to deliver radiation to patients. However, in practice, this does not happen, despite MachineLog providing the functions to record Linac faults. The lack of use of MachineLog demonstrates that there is a need for a user oriented approach when developing Medical Infrastructure Software in the NHS.

Therefore, the aim of this thesis is to understand the factors that influence usability and acceptability of Medical Infrastructure Software, whilst focusing on re-designing MachineLog. To achieve this, two goals have been identified, which are:

- To investigate how people are, or more precisely, not using Machine Log in the way it was intended, by using HCI methods.
- To produce a new design prototype for MachineLog: LinacLog Version 1.

1.2 Scope & Limitations

The scope of this thesis is Medical Infrastructure Software that has been created by Healthcare Professionals in the NHS. Specifically, this thesis focuses on MachineLog, software developed by NCCC and in use at The James Cook University Hospital for managing Linear Accelerator faults.

This research does not look at treatment directly, nor the patient experience. There may be mention of patients to provide context to the work of staff, however, patients are not directly observed or involved in this research and Section 1.5 discusses the ethics around this research.

It was anticipated that a fully working prototype be developed. The Medical Physics Department had its own internal IT server infrastructure for hosting the back-end services required, the tools available on the workstations and smart devices for prototyping. However, there was no success in connecting these devices to the hospital WiFI network and contextual constraints were encountered. The Hospital WiFi network was beyond the control of the Medical Physics Department. It is important that the Hospital IT WiFi network is not confused with the easily available NHS staff & patient WiFi, as this WiFi network cannot communicate with servers and IT infrastructure on the Hospital network.

Therefore, a limitation experienced in this thesis was convincing Hospital IT and Information Governance (IG) that the devices were to be used for prototyping and that the devices would not store patient data, despite offering assurances that patient data would not be stored, and access to any databases to demonstrate this. This limitation was further exacerbated by the lengthy delays to responses from both departments. As NHS employees, the only process for requesting access to the hospital WiFi for the purposes of device development, was to raise an IT helpdesk request and engage in e-mail conversation thereafter. Once approval had been finally granted, the research project was near its conclusion and thus constrained by time, consequently leading to the development of a low-fidelity prototype consisting of sketches and user interface designs.

1.3 Contribution & Impact

The overall aim of this thesis was to understand the factors that influence the usability and acceptability of Medical Infrastructure Software.

The work in this thesis aims to contribute to the development of unregulated medical infrastructure software that is undertaken by Healthcare Professionals. Furthermore, the work has the potential to impact real world practice as it involves re-designing MachineLog. MachineLog is an example of medical infrastructure software that is not usable and fits into a bigger challenge in this thesis: attempting to resolve the frustrations experienced by the users of unusable medical infrastructure software. MachineLog will be re-designed to understand how HCI methods inform the design and evaluation of this software and to advocate the use of HCI methods.

However, the discourse of HCI research, further examined in the literature review (Chapter 4), in the context of healthcare, is directed towards patient care and patient safety. Some software (such as MachineLog) within the healthcare context, developed by Healthcare Professionals, sits outside this discourse, behind the scenes and not directed towards patient care or patient safety. Therefore, there may be a gap in this literature, suggesting that this is an under-researched area. Therefore, the work in this thesis contributes to improving usability in unregulated medical infrastructure software, developed by Healthcare Professionals, such as Clinical Engineers and Medical Physicists who are UK statutory registered as Clinical Scientists.

Clinical Scientists, further discussed in Chapter 2, are often overlooked as Healthcare Professionals. Nevertheless, Clinical Scientists are heavily involved in healthcare, both from a clinical (interpreting and advising on results) and non-clinical point of view [3]. Clinical Scientists sit on the boundary of regulated and unregulated activity, developing both regulated [4] and unregulated software [5]. It is the unregulated software for unregulated activities that goes overlooked when considering design.

This thesis aims to contribute to understanding that staff, such as Clinical Scientists, are in good position to observe other Healthcare Professionals, where there is a lack of design expertise. Furthermore, this thesis highlights that HCI techniques such as Contextual Inquiry [6] can formally set out the methods for performing an observation, as a non-design expert.

It appears that despite the lack of awareness of HCI in Healthcare [7], and many evaluation methods requiring a design expert to perform the evaluation, Human Factors frameworks directed towards patient safety and medical devices can also inform the evaluation of Medical Infrastructure Software [8], developed by Healthcare Professionals, as non-design experts. Although, this is not to say design experts should not be involved.

By investigating the methods that are available for informing software design and by using these methods with our example software Machine Log, in Chapter 5, a better understanding how staff perform their work was identified, by modelling and describing staff interactions. This helped to discover where Machine Log currently fits into staff workflow. Performing this study led to developing a view on how, as Healthcare Professionals,e might bring contextual inquiry methods into the development of Medical Infrastructure Software that is developed by Healthcare Professionals. Furthermore, these methods were able to inform the design of a new prototype, called LinacLog, that aims to replace MachineLog.

1.4 Thesis Structure

This thesis is structured as follows:

- Chapter 1 - The Introduction, introduces this research.
- Chapter 2 - The Research Context, provides an overview of The Author's role

in the NHS and it introduces Radiotherapy and the equipment used to deliver Radiotherapy, including the staff who work within radiotherapy.

- Chapter 3 - The Problem: Machine Log, delves deeper into MachineLog.
- Chapter 4 - Literature Review, reviews literature surrounding HCI.
- Chapter 5 - The Study, utilises contextual inquiry to perform and report on observations.
- Chapter 6 - Personas and Scenarios, communicates requirements for the new prototype.
- Chapter 7 - Software Requirements Specification, defines requirements for the new prototype.
- Chapter 8 - Prototype Design, introduces the new prototype and its interfaces.
- Chapter 9 - Prototype Evaluation, evaluates the new prototype.
- Chapter 10 - Conclusion and Future Work, describes what has been achieved and the work that can continue after this research.

Some of the work in this thesis has been written in the first person. This is to reflect the researcher's own experiences, work and position.

1.5 Ethics & Intellectual Property Statement

All investigations and observations in this thesis were given approval by the Department of Computer Science‘s Ethics Committee. The study in Chapter 5 was performed in accordance to The University of York‘s Research Integrity Code of Practice.

All directly observed participants were over the age of 18 years old and employed by the South Tees Hospitals NHS Foundation Trust, including the author. NHS ethics approval was advised as not required due to being an employee of the hospital where the staff were observed. Patient presence was indicated in the study but patients were not directly observed during the investigation, nor was any data about patients gathered as part of this work. Under no circumstances are patients identified within this thesis. Furthermore, by using the Health Research Authority Approval Decision Toolkit (Appendix B), it was apparent that NHS Research Ethics Committee Approval was not required.

This thesis builds upon the work that the author was employed to perform (Redesigning MachineLog) and all staff participating in observations were consented verbally, as the staff observation was performed as part of the author's employed role. The author was provided time to perform this work during the working day in lieu of Masters Degree funding as it was agreed that the author be able to undertake this Masters Degree as career development, self-funded, providing that it benefits the Medical Physics Department at The James Cook University Hospital. Accordingly, this work was authorised by the author's Head of Department, The Head of Medical Physics.

Intellectual Property (IP) was discussed with The James Cook University Hospital's Innovation and Research team, as the research project was conducted as an employee of JCUH, and as an idea that emanated from employment. It was established that South Tees Hospitals NHS Foundation Trust will not own any IP that may be produced in this work as this work would be performed as part of a University Masters Degree. As such, IP produced in this work falls under university regulations.

Chapter 2

Research Context

The goal of this chapter is to provide context prior to delving into MachineLog, by introducing various job titles, the author‘s role, Radiotherapy, Medical Physics and the roles professionals undertake in maintaining Radiotherapy Equipment.

This research was conducted within the Radiotherapy Department and Medical Physics Department at The James Cook University Hospital, a hospital belonging to South Tees Hospitals NHS Foundation Trust. There are many behind the scenes healthcare professions (both regulated and unregulated) working within Radiotherapy and Medical Physics such as Clinical Scientists, Therapeutic Radiographers and Clinical Technologists.

A suite of different types of software exists. This includes regulated Medical Device software such as treatment planning systems and unregulated software for performing safety testing. The purpose of this chapter is to explain Radiotherapy, introduce Linear Accelerators, explain the different software used in Radiotherapy and how MachineLog fits in with this suite of software for supporting the delivery of Radiotherapy.

2.1 The Role of Medical Physics & Clinical Engineering in the UK

The NHS is regarded as being made up of Medical Practitioners, Nurses and Allied Healthcare Professionals (AHP). However, there are many behind the scenes staff working within the NHS. Some of these staff are also Healthcare Professionals who work on the boundary of clinical and non-clinical work, sometimes working with patients and sometimes working behind the scenes. Gradually, since the “Hello my name is” initiaitve by the late Dr Kate Grander [9], Healthcare Professionals working on this boundary have been encouraged to better identify themselves and their roles. One such Healthcare Profession is Healthcare Science.

Medical Physics & Clinical Engineering are Healthcare Science departments in the NHS that provide support to various other departments in hospitals. Not all departments are structured in the same way and may be labelled differently, for example: Radiation Protection Department, Clinical Physics Department, Biomedical Engineering Department. However, the purpose of medical physics is universal: to provide scientific and engineering advice and support. The purpose of Medical Engineering initially appears obvious. However, there is some confusion over Medical Engineering and Clinical Engineering and what a 'Clinical Engineer' does. Clinical Engineering departments are usually joined to Medical Physics and are known as Medical Physics & Clinical Engineering (MPACE), whereas Medical Engineering departments are often responsible for Medical Equipment Asset Management. At the time of writing, there is on-going work to standardise MPACE departments and services [10].

It is useful for the context of this research, to highlight Medical Physicists and Clinical Engineers as Healthcare Professionals working within the NHS. There are two types of registration that a NHS Medical Physicist or Clinical Engineer could possess. The first being Clinical Technologist and the second, Clinical Scientist. The former being a voluntary registrant of the Register of Clinical Technologists (RCT) and not a title that is protected in law and the latter, a title protected in law and regulated by the Health Care Professions Council (HCPC). Within Medical Physics & Radiotherapy, Medical Physicists are usually registered Clinical Scientists and Radiotherapy Engineers are usually Clinical Technologists.

The HCPC define a Clinical Scientist as someone who "oversees specialist tests for diagnosing and managing disease. They advise doctors on tests and interpreting data, and carry out research to understand diseases." [3]. The RCT define a Clinical Technologist as " healthcare scientists working in a range of clinical and healthcare locations including NHS hospitals, private health care, academic institutions and the medical device industry" [11]. Despite these differences, Clinical Technologists and Clinical Scientists are Healthcare professionals that are developing software.

Clinical Engineers who are registered with the HCPC as Clinical Scientists have a broader scope of practice. This type of Clinical Engineer can also use medical equipment on patients and are Healthcare Professionals sitting at the intersection of clinician, scientist and engineer, from a science and engineering background. It is important to make this distinction as Clinical Scientists are afforded more responsibility within the patient treatment pathway in comparison to an unregistered Clinical Engineer or Clinical Technologist, who may be responsible for the repair and maintenance of equipment. There is the potential that software developed by Clinical Scientists be used in clinical applications directly impacting patient care.

Specialist IT Engineers working within Medical Physics & Clinical Engineering are also regarded as a type of Clinical Engineer. Usually, these IT Engineers are Clinical Technologists and can register with the Register of Clinical Technologists (RCT).

Clinical Engineers registered as either a Clinical Scientist (state regulated healthcare professionals) or as a Clinical Technologists (voluntary regulated healthcare professionals), build both regulated and unregulated software [5] [12]. It is worth noting that medical devices built in house can be used inside the hospital that they were built in for treatment purposes, provided it meets certain conditions, of which can be found in Article 5.5 of the Medical Device Regulations 2017 [13]. For example, the Intracranial Pressure Monitoring device (ICP) created by Clinical Scientists Charlotte Kemp and Stuart Marsden, and Clinical Technologist Ian Boddy, in the Medical Physics Department at The James Cook University Hospital [4]. This matters because in-house developed regulated software has stricter development requirements and is important because it cannot easily diffuse across the NHS without evaluation from external bodies such as the Medicines and Healthcare Products Regulation Agency (MHRA), as the approving authority [13].

This in-house built ICP monitor is used by Clinical Engineers registered as Clinical Scientists, in theatre and on the wards, connecting the device to the patients. It is important to mention that this device contains in-house developed regulated software and is used as intended. Furthermore, it is important to mention that unlike unregistered software developers or Clinical Engineers, Engineers registered as Clinical Scientists are able to use the technology that they develop, on patients, and are able to interpret the results and data that are generated from these devices and software for clinical decision making.

2.2 The Author's Role in Medical Physics & Clinical Engineering

This section provides context on the author's own role in the NHS and has deliberately been written in the first person to reflect the author‘s experience of working within NHS Medical Physics & Clinical Engineering and Radiotherapy.

Upon starting this research, I was employed as a 'Clinical Technologist (Computing)' in the Medical Physics Department of The James Cook University Hospital. This role is responsible for IT infrastructure supporting the Radiotherapy Department, and is a specialised role because the work involves maintaining servers and equipment that are involved in the delivering of radiation to patients, an area heavily regulated. It sits alongside other IT professionals that are working within the main hospital IT department, but working within a Medical Physics Department. This role could be considered a form of specialist IT Engineer.

However, my interest in Healthcare Science and Computer Science led me to progress in my career and later, I transitioned into a new role in the same department, as a Pre-Registration Clinical Scientist, specialising in Clinical Physiological Measurement & Computing within Medical Physics & Clinical Engineering, working towards Healthcare Professions Council (HCPC) registration. In essence, I am a Computer Scientist becoming a Clinical Scientist, much like a Medical Physicist or Electronics Engineer becomes a Clinical Scientist.

This role involves applying computer science, physics and clinical engineering to physiological measurement techniques, with the clinical training to perform physiological measurements. This means I am very much involved in both device development and clinical work. For example, I am involved in developing the intracranial pressure monitor described earlier and connecting this to patients in theatres and on wards. Furthermore, I have developed software that directly influences clinical services such as the Home Oximetry Service that we provide in the Medical Physics Department at The James Cook University Hospital [12]. This is important to note as it is a published example of Clinical Scientists and Clinical Technologists, as healthcare professionals, developing software to support their involvement in their aspects of patient treatment.

In summary, this role allows for the development and commissioning of medical devices in the NHS and the ability to use these devices on patients. Gradually, I have become less involved with the Radiotherapy IT infrastructure and more involved with using Computer Science, Engineering and Physics with direct patient care, providing a solid foundation to apply and promote HCI into my work. As the change in role was within the same department, the research was able to continue.

The previous role of Clinical Technologist meant that there was responsibility for supporting the development of software in the department. One common complaint was that MachineLog was not being used by the Radiographers and the Radiographers often complained about having to use MachineLog. The Machine Engineers approached me to install MachineLog on more workstations for the Radiographers. This gave rise to the motivation for this research, to investigate why MachineLog is not being used and to develop a usable prototype. The change of role has provided stronger motivation by being in a position that allows the influence and changing of practice. Furthermore, both roles allow for directly working with and alongside Doctors and other Healthcare Professionals.

2.3 Introduction to Radiotherapy

Before delving deeper into MachineLog it is useful to introduce Radiotherapy and Medical Physics. Radiotherapy is a treatment modality that Medical Physics specialists and MachineLog supports.

Radiotherapy is concerned with using radiation as a therapeutic medical exposure for treating a patient‘s medical condition. The most notable use of this radiation therapy is for treating cancer. However, it is important to note that Radiotherapy is not exclusively concerned with treating cancer as it is a rapidly evolving area but for the purposes of this thesis, it enough simply to equate Radiotherapy with cancer treatment.

Briefly, the patient journey is usually:

- Patient receives cancer diagnosis and is a candidate for Radiotherapy.
- Patient undergoes Radiotherapy Planning CT Scan.
- Patient has radiation treatment planned by using the CT Scan.
- Patient undergoes Radiotherapy Treatment.

Radiotherapy involves Consultant Clinical Oncologists, who are doctors specialising in treating patients with Radiotherapy and involves Therapeutic Radiographers, who are Radiographers specialising in treating patients with Radiotherapy. There are also Diagnostic Radiographers who are Radiographers specialising in imaging patients using radiation.

Radiotherapy Physics is a service that is responsible for providing physics and engineering support to Radiotherapy departments. After all, Radiotherapy is concerned with using radiation to treat a patient.

Radiotherapy physics is established as a sub-discipline of Medical Physics & Clinical Engineering; specialisms that provide scientific and engineering support to other services in NHS hospitals. Each NHS hospital configures these services/departments slightly differently but all share a common purpose of supporting Radiotherapy. At The James Cook University Hospital, Radiotherapy Physics is a section of the Medical Physics Department and consists of Radiotherapy Physics, Radiotherapy Engineering and Radiotherapy Computing.

Radiotherapy Physics involves Medical Physicists (Clinical Scientists) and Radiotherapy Engineers (Clinical Technologists), working in partnership to provide scientific and engineering support. Furthermore, there are specialist IT Engineers (Clinical Technologists) that provide the support for the medical infrastructure software that drives modern Radiotherapy, for example, my role at the start of this thesis. It is worth noting that not every department has a Computing section with trained Computer Scientists or IT Engineers that can provide software development skills for the development of in-house software.

Radiotherapy is not to be confused with Radiology, which uses radiation to image a patient. Although Radiotherapy does include aspects of medical imaging, it is important to highlight this difference because Radiology uses low doses of radiation to image a patient whereas Radiotherapy uses high doses of radiation to treat a patient using a Linear Accelerator. A Linear Accelerator has a greater complexity of scientific and mechanical components than a standard X-Ray machine.

Use of radiation as a medical exposure is governed by the Ionising Radiation (Medical Exposure) Regulations 2017 or IR(ME)R abbreviated [2]. Therefore, Radiographers, Medical Physicists (Clinical Scientists) and Radiotherapy Engineers (Clinical Technologists) working with Radiation are highly trained as they are highly regulated (Regulation 17 of IR(ME)R 2017 [2]), more so than their HCPC and RCT registrations, respectively. Aspects of Radiotherapy that are not regulated give rise to unregulated software being built, such as MachineLog that is intended to help manage Linear Accelerator faults.

2.3.1 Linear Accelerators

Linear Accelerators (shown in Figure 2.1) are the tools, or in our case, the Medical Devices that are designed to deliver high doses of radiation to a patient for treatment and therapeutic purposes. They are colloquially known as ‘Linacs’. Very simply, Linacs accelerate electrons in order to produce a high powered X-Ray that can destroy biological cells.

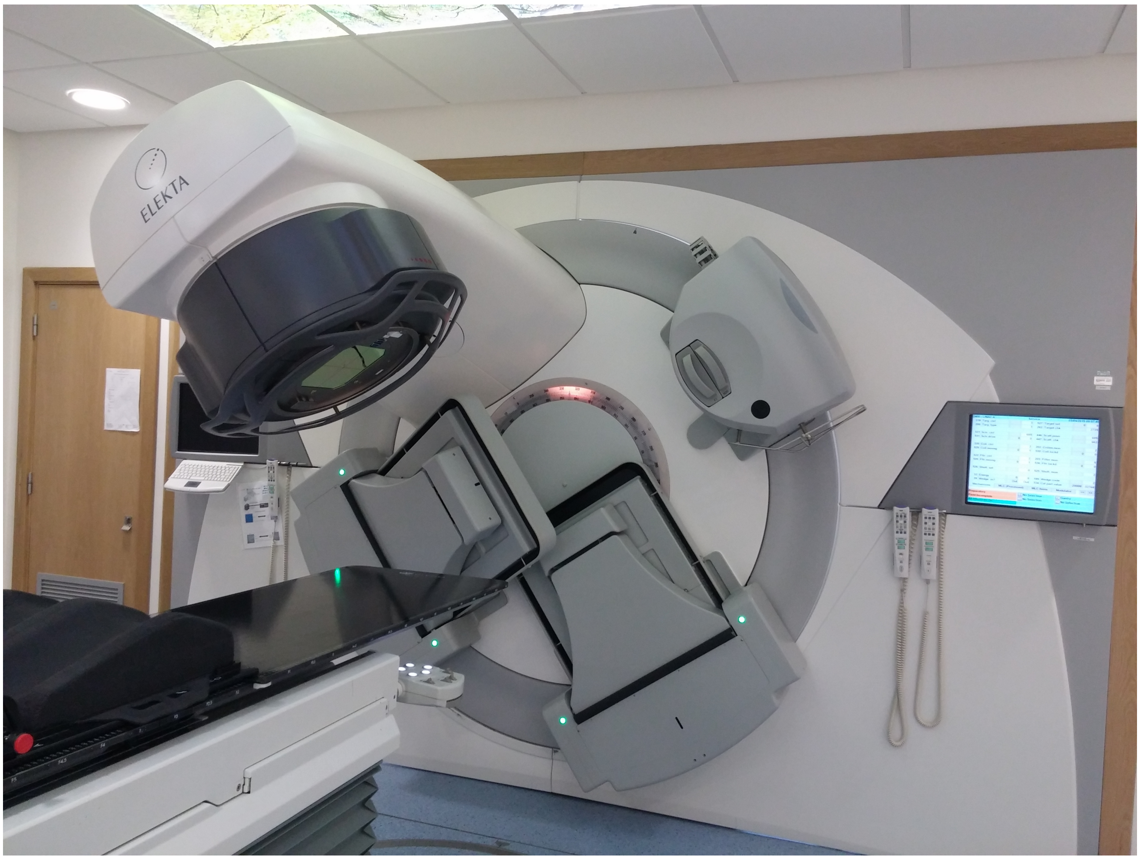


Figure 2.1: A Linear Accelerator at The James Cook University Hospital

This thesis refers to different physical locations of the Linac. The first location or room that the Linac is housed in is known as the Linac Bunker, a heavily shielded room. This location is shown in Figure 2.1.

In this room the patient lays on a carbon fibre bed and the gantry rotates 360° around an isocenter. The patient is moved into this isocenter so that the tumour is also in the isocenter. To move the patient, the Radiographers are in the room with the patient, using the controls shown on the wall in Figure 2.1, to position the patient to this isocenter. This is something that is not done outside the room for safety reasons. This initially demonstrates that Radiographers move around rooms frequently and are interacting with many objects.

The corridor leading to the Linac Bunker is known as the Linac Maze. This is because the corridor, also shielded, is shaped in two or three 90° turns and resembles a maze. The maze is designed to reduce radiation scatter whilst the beam is switched on. At the end of this corridor is a large and heavy shielded door leading out of the Linac Maze and into the Linac Control Area, shown in Figure 2.2. This control area consists of several workstations used to control the Linear Accelerator.

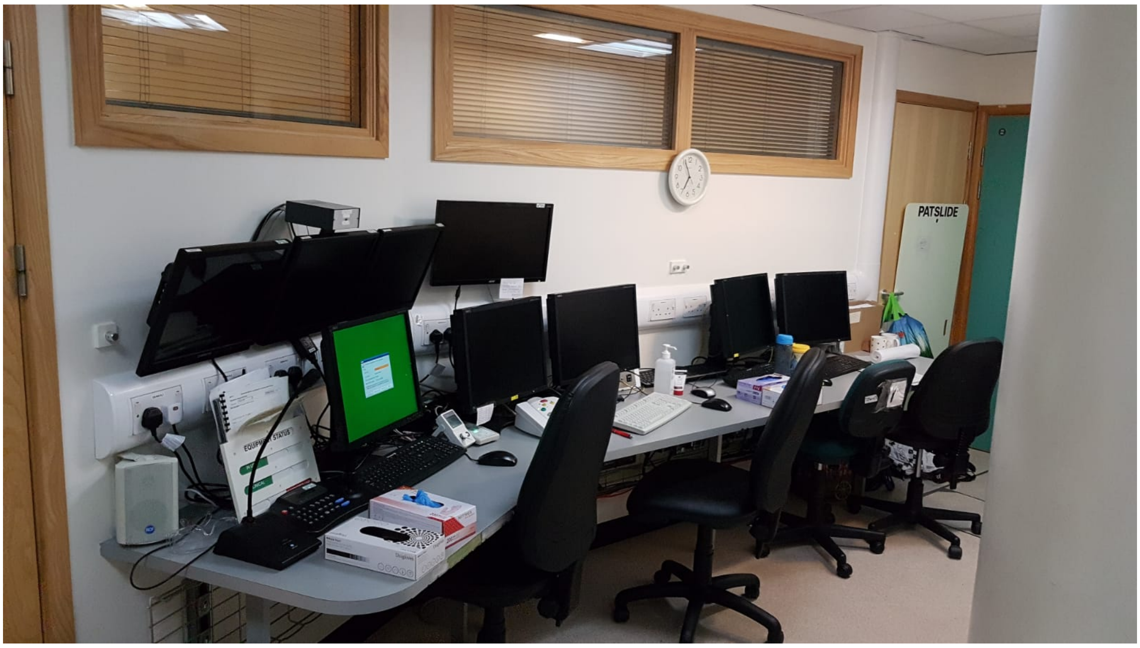


Figure 2.2: The Control Area of Linear Accelerator 4 at The James Cook University Hospital

The collection of these rooms is colloquially known as 'The Linac'. When the Linac is described in this thesis, it is intended to represent all of the locations, objects and components that are involved with the Linear Accelerator, including the actual Linear Accelerator.

Once the patient has been setup on the bed, the Radiographer moves to their main area of work - the Control Area, displayed in Figure 2.2. This area is normally staffed by at least two radiographers who sit in this area when delivering the treatment to a patient. Firstly, for safety reasons (The Radiographer must not be irradiated and a second Radiographer must second check patient identification etc.), and secondly for practical reasons; the workstations that control the Linac are located together here. The Radiographer can observe the patient using CCTV cameras installed in the Linac bunker.

In this case, the Radiographers are Therapeutic Radiographers. Importantly, Therapeutic Radiographers are trained and work differently to their Diagnostic Radiographer colleagues.

Briefly, the procedure that the Radiographer follows for patient treatment when in the Control Area shown in Figure 2.2 is:

- Load patient file.
- Confirm that the patient is the correct patient.
- Send patient treatment information to the Linear Accelerator.
- Start treatment by using the Function Keypad shown in (Figure 2.3).

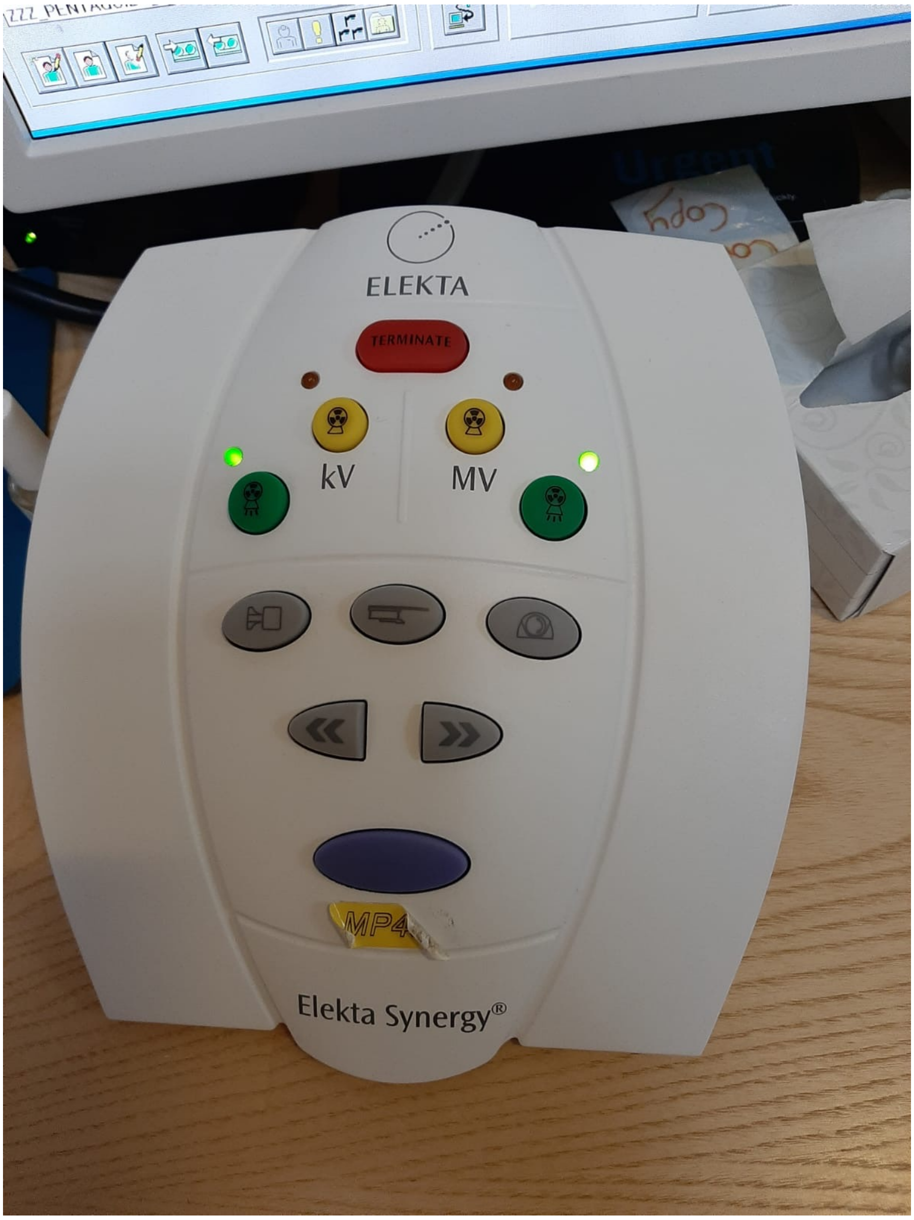


Figure 2.3: Linac Function Keypad

Figure 2.4 below shows the opposite side of the control area. This area is often used for administrative work. It is useful to highlight this as MachineLog is installed on the workstation displayed on the left in Figure 2.4, away from the main control area.

Figure 2.4: LA4 Control Area (Rear)

At the time of writing, The Radiotherapy Department at The James Cook University Hospital contains 6 Linear Accelerators spread across two buildings called The Endeavour Unit and The Main Hospital.

Within The Endeavour Unit, there is:

- LAA - Linear Accelerator A or colloquially, Linac A.
- LAB - Linear Accelerator B or colloquially, Linac B.
- LAC - Linear Accelerator C or colloquially, Linac C.

Within the Main Hospital Radiotherapy Department, there is:

- LA4 - Linear Accelerator 4, or colloquialy, Linac 4.
- LA5 - Linear Accelerator 5 or colloquially, Linac 5 (Later Decommissioned).
- LAD - Linear Accelerator D or colloquially, Linac D.

Faults that might arise when operating Linear Accelerators are not only limited to the actual Linear Accelerators. For context, the types of failures that might occur could be:

- Actual Linear Accelerator Problems, for example: Linac Gantry problems, waveguide problems and vacuum problems.

- Linac ancillary problems that can occur while operating any of the Linacs, such as: Linac warning sign problems, CCTV failures, door opening issues, etc.

Modern Radiotherapy is driven by a complex IT infrastructure that provides many different IT systems used in the planning and delivering of patient Radiotherapy.

2.4 Introduction to The IT Ecology of Radiotherapy

Radiotherapy, supported by Radiotherapy Physics/Medical Physics, is driven by a complex IT ecosystem. This IT infrastructure includes regulated medical device software and unregulated medical infrastructure software developed by commercial organisations. Regulated software that is involved in delivering radiation is commissioned into use by a formal commissioning process undertaken by registered Clinical Scientists/Medical Physicists who are 'Medical Physics Experts' [2]. For example, a treatment planning system used to plan a patient's distribution of radiation dose is formally commissioned and tested. There is no requirement for unregulated software to be formally commissioned in this way.

At The James Cook University Hospital, the Linear Accelerators have been manufactured by Elekta, a company who also develops software for the use of their Linacs. It is usual that Radiotherapy Physics provide support for the Radiotherapy IT infrastructure with specialist IT Engineers (Clinical Technologists), such as my previous role.

Most of these systems interconnect with each other. For example, software can acquire a medical image and send it into a patient management system, this is visualised in Figure 2.5.

This section aims to present the range of Radiotherapy systems that a Radiographer is required to use whilst performing their daily working activities, before delving deeper into MachineLog.

Pushing Medical Images using a DICOM Server

Medical Images are stored in a specific standardised inter-operable format, known as a DICOM Image. DICOM stands for Digital Imaging and Communications in Medicine. The DICOM file contains a variety of information as well as the actual Medical Image.

2.4.1 MedCom Prosoma

A Radiotherapy patient is imaged using a CT scanner within the Radiotherapy Department. The diagnostic radiographer performs the CT scan/MRI scan and the Medical Image, stored in DICOM format, is imported into Prosoma.

Prosoma is a virtual simulation software and is used at the first stage of Radiotherapy Treatment Planning. After the image is imported into Prosoma, the Consultant Clinical Oncologist, who is a medical doctor, outlines the tumour.

2.4.2 Elekta Monaco®

After the doctor has outlined the CT scan in Prosoma, a Clinical Dosimetrist, who is usually a Radiographer trained in planning patient treatments, uses Monaco to position and calculate the physical positioning of the radiation beams produced from the Linear Accelerator (Linac). This produces a Treatment Plan that the Linear Accelerator uses.

Elekta Monaco is one example of a Treatment Planning System (TPS) in Radiotherapy and is essential for developing treatments plans.

2.4.3 Elekta Mosaiq®

Mosaiq is the Oncology Information Management System (OIS) here at The James Cook University Hospital. It is a suite of software that stores patient demographics that are received from the Hospital's Patient Administration System (PAS). The doctor will input the patient's diagnosis in Mosaiq and all future medical information for the patient will be stored within Mosaiq.

Monaco, the TPS, pushes the treatment plan into Mosaiq. This treatment plan is then used by the Mosaiq Sequencer to deliver the radiation to a patient.

The treatment plan is then sent from Mosaiq, by the Mosaiq Sequencer (operated by the Radiographer) to the Treatment Control System (TCS). The Mosaiq Sequencer is a Windows PC which is able to run the Mosaiq OIS software in the Linac Control Area. The sequencer operates behind a firewall and interfaces directly to the Treatment Control System (TCS), a computer that interfaces with and controls the Linear Accelerator.

2.4.4 Linac Software

The Linacs at JCUH contain X-Ray-Volume Imaging (XVI) capability - a kV Cone Beam CT Scan (CBCT) that is used to image a patient so that the Radiographer can match the image with another image taken previously. This image matching is particularly useful for prostate tumours. The prostate moves around and it is important that the Radiographers ensure that the prostate is in the correct position (isocentre). A piece of software known as XVI is used to capture the XVI images and the Radiographer manually matches the images.

Furthermore, there is another piece of imaging software known as iView that is used for the Linac's on-board Mega-Volt (MV) CT Scanner. The Radiographer may want to undertake a basic CT Scan of a patient before delivering treatment. This is another manual image matching process.

2.4.5 Linac Quality Assurance Software

There are many other commercial systems that are not directly used for treating patients but are used to perform safety checks of Linacs. One such example is AtlasQA, software that is used to record radiation beam outputs for safety testing. Most of this software is not regulated.

The general perception is that this software is being used as intended by the Radiographers. According to the Radiotherapy Physicists, the beam settings/configuration data recorded in these systems is frequently used for safety testing and validation. Furthermore, safety testing of Linacs is a regulated activity, requiring this data to be recorded and stored [2], despite the actual quality assurance software not being a regulated medical device. The role of the Radiographer in safety testing is discussed later in Section 2.5.

2.4.6 Other Software

Alongside software that is critical to the operation of Linear Accelerators and Radiotherapy treatment is software that has been developed in-house. MachineLog, an in-house developed tool to manage Linac faults, fits in with 'Other Software'.

Software introduced earlier such as Mosaiq and Monaco, is regulated commercial medical device software that is critical to the operation of Linear Accelerators and patient treatment. This software is well supported by Medical Physicists, Radiotherapy Engineers and Radiotherapy IT specialists. Arguably, MachineLog is critical to this operation by supporting the availability of a Linear Accelerator. However, MachineLog is in-house developed and could be considered an optional extra. Earlier it was mentioned that MachineLog is installed on a workstation located away from the main control area. For example, installed on a workstation displayed in Figure

2.4.

Not only is MachineLog expected to be used for recording Linac faults, it is expected that MachineLog is also used to record faults that arise when using Linac Software. This use is specific to Linac software faults that impact upon the Linac's ability to treat patients. For example, an error displayed on software controlling the Linear Accelerator.

One further example of Medical Infrastructure Software that fits into this 'Other Software' category is QA3VMAT, a web interface which links into the results from Atlas QA and produces a pass or fail based on a baseline. This software is intended to be used by the Radiographer but is often not used as intended. This suggests there is a wider spread of software Medical Infrastructure Software that is being developed which impacts the work of other staff, and is not being used as intended.

However, there are instances of Medical Infrastructure Software being developed in the NHS that is used as intended. One such example is the JCUH QA Database. It is a Microsoft Access Database and is used by the Radiotherapy Physicists rather than the Radiographers. It is used to record the results of weekly QA. This is an example of a tool developed by NHS physicists for physicists, i.e. developed by the users using the tool and who understand the work of the users expected to use the system. This suggests a pattern of lack of use of Medical Infrastructure Software that has been developed for other staff groups.

2.4.7 Radiotherapy Systems Flow

The names and types of software were briefly introduced. However, it is useful to visualise the connections between these systems (Figure 2.5). The diagram is constructed to represent the journey the patient undertakes during their Radiotherapy treatment, from CT scan to treatment delivery and adds context to the Linac Software and the Other Software that sits alongside.

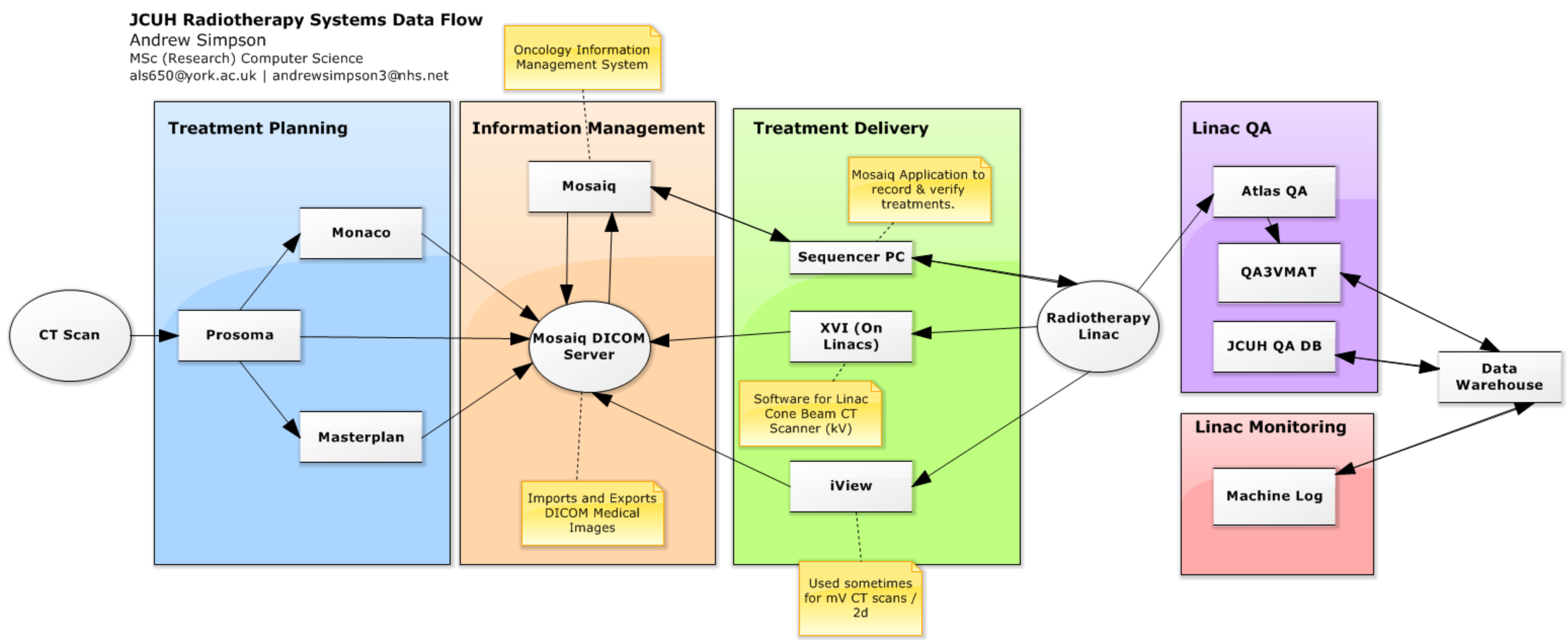


Figure 2.5: A visual representation of the interaction of Radiotherapy IT systems

2.5 Introduction to Radiotherapy Maintenance

As Linacs are complex machines, they require regular maintenance and maintenance schedules to ensure that patient treatment remains safe. It is important to provide context on the roles that staff perform in maintaining Radiotherapy Equipment such as Linear Accelerators.

Radiographers were briefly introduced as professionals treating patients by using Linacs that deliver radiation. Radiographers are also involved with aspects of Quality Assurance (QA), by performing daily testing of the Linacs before use on a patient. This is an important aspect of treatment delivery because the Radiographers are helping to ensure the safety of patients and Linacs by performing basic safety checks to agreed protocols and procedures. For the Radiographers to perform their daily QA checks successfully, it is beneficial that the Radiographer has information regarding outstanding faults or restrictions on use (Restrictive Use Certificates) which may impact their ability to treat their patients. Restrictive Use certificates are issued by Medical Physicists restricting the use of certain beam settings on the Linear Accelerator. This is not managed by MachineLog and is instead indicated by a plastic sign displayed in the Linac Control Area.

More advanced safety testing of Linacs is performed by Radiotherapy (Medical) Physicists. Medical Physicists are tasked with a wide-range of duties such as providing expert scientific advice whilst understanding the biological implications of their work. One could think of the Medical Physicists in the IT context as providing 3rd line support for the physics aspects of radiation delivery but do not repair the Linear Accelerators. The work of the Medical Physicist is to oversee the safety of the Linear Accelerators by performing tasks such as full day Quality Assurances, testing every beam setting on the Linac and using devices (Phantoms) to measure that the dose received matches the dose intended. Medical Physicists take precise measurements of the radiation delivered by Linacs to ensure that the Linac does not either underdose (so that the treatment is ineffective at treating the tumour) or overdose the patient. Any overdoses that are clinically significant are incidents that are reportable as Radiation Incidents [14].

It is usual that a Medical Physicist, specifically a Consultant Clinical Scientist, would be accountable for the strategic direction and overall management of the Machine Engineers (although not every cancer centre operates this way). Consultant Clinical Scientists are often certified as Medical Physics Experts (MPE) to meet Regulation 14 of IR(ME)R 2017 [2]. This means that they are entitled to be completely involved in any aspect of radiation delivery used for patient treatment. Medical Physics Experts are required to ensure expert scientific decision is made correctly by competent and experienced physicists or scientists. This includes commissioning software for use in the delivering of radiation and commissioning Linacs for clinical use after they are first procured and installed in a hospital.

In conjunction with Medical Physicists are Machine Engineers (Clinical Technologists), who are responsible for the maintenance and repair of Linacs. Explicitly, the Engineers perform the repairs on the Linacs. Some of this work may be ad-hoc due to a failure and some of this work may be planned. The Engineers are led by a senior engineer who is responsible for the day-to-day workload of the Engineers.

The Senior Engineer is usually accountable to a senior Medical Physicist (Consultant Clinical Scientist) responsible for the Linacs, i.e. 'The Head of Machines and Dosimetry'.

There are also the IT Specialists (Clinical Technologists) who are responsible for maintaining the complex IT infrastructure that supports Radiotherapy. All professionals work together to resolve issues surrounding Radiotherapy equipment. MachineLog is a tool that is intended to facilitate this working partnership.

Linear Accelerators are the core devices that allow Radiotherapy to function. The necessity of maintaining the Linear Accelerator and its ancillary components suggest that a tool such as MachineLog should exist. MachineLog should enable a smooth operation of a Radiotherapy Department by ensuring that Linac faults are properly recorded and tracked. However in practice at The James Cook University Hospital, MachineLog is not used as intended because according to the Machine Engineers, there is a frequent need to remind the Radiographers to enter fault information retrospectively when the Machine Engineers become aware of a fault.

2.6 Summary

This Chapter has introduced some of the job titles in the NHS and discussed the Author's role in the NHS. Radiotherapy was introduced and the department that support Radiotherapy (Medical Physics), including the staff that are involved with delivering a Radiotherapy service.

Some of the work performed by the Radiographers was briefly discussed, such as their involvement in treating patients and safety testing. Work performed by Engineers was briefly discussed, as staff who repair and maintain the Linacs. From this it is understood that Radiographers and Radiotherapy Engineers are interested in the availability of the Linacs. Radiographers for treating their patients and Engineers for troubleshooting.

MachineLog was briefly introduced as a tool and the medical infrastructure software that is intended to inform the Radiographers and Engineers of any faults and availability of the Linacs. However, MachineLog is not being used for this purpose. MachineLog is intended to be used by the Radiographers to report faults to the Engineers. In practice, this does not happen.

Chapter 3

The Problem: MachineLog

Previous chapters focused on introducing this research and introducing the context of this research. MachineLog was briefly introduced as being a tool to manage Linac faults. This chapter aims to delve deeper into MachineLog.

Cancer centres require tools that facilitate the maintenance and operation of Linear Accelerators (Linacs). At The James Cook University Hospital (JCUH) in Middesbrough this is provided by MachineLog. MachineLog is Medical Infrastructure Software developed by the Northern Centre for Cancer Care (NCCC)'s Radiotherapy Physics Department.

MachineLog, deployed by Medical Physics staff, is intended to be used by Radiographers working within the Radiotherapy Department to report faults encountered when using the Linear Accelerators and its ancillary components such as workstations, warning signs, etc. (previously discussed in Chapter 2). According to the Machine Engineers, the faults should be reported immediately after occurring. The Radiographer should then contact the Machine Engineer by telephone to report the fault. Furthermore, it is expected that the Radiotherapy Engineers use this tool for managing the faults reported by Radiographers.

Additionally, MachineLog is also supposed to be used for recording the start and end times of different 'sessions' during the day, providing 'up-time' and 'downtime' metrics. For example, a Quality Assurance (Safety Checking) session, a patient treatment session (up-time) and whenever the Linear Accelerator is undergoing periods of downtime for repairs. This information provides a picture of the 'state' of Linear Accelerators and their availability for patient treatment.

However, according to the Machine Engineers, there is little evidence suggesting MachineLog is being used as intended.. Unlike regulated radiotherapy software which requires formal commissioning, testing and training, MachineLog diffused into The James Cook University Hospital without evidence of evaluation. Nevertheless, Radiographers are expected to use MachineLog but are not using it.

The purpose of this chapter is to describe and present MachineLog by gathering screenshots and annotating their features. The chapter starts to suggest initial reasons that could explain why MachineLog is not being used properly by discussing aspects of MachineLog that are difficult to use. In practice, MachineLog is a piece of software installed on a workstation located away from the Linac Control Area's main area of work. Although MachineLog does include the functions to record Linac faults, MachineLog is not used as intended.

3.1 MachineLog User Interfaces

Figure 3.1 displays the first and default interface the end user encounters. The purpose for this interface is to provide an overview of options and Linac status. Machine Log appears to be structured into a timeline. The Y axis shows different categories and the X axis shows time. There are a few menu icons at the top for recording availability and activities. It is not immediately obvious on how one would change the Linac. However, the Home Icon has a drop-down associated with it, which allows the user to select the Linac they wish to record for.

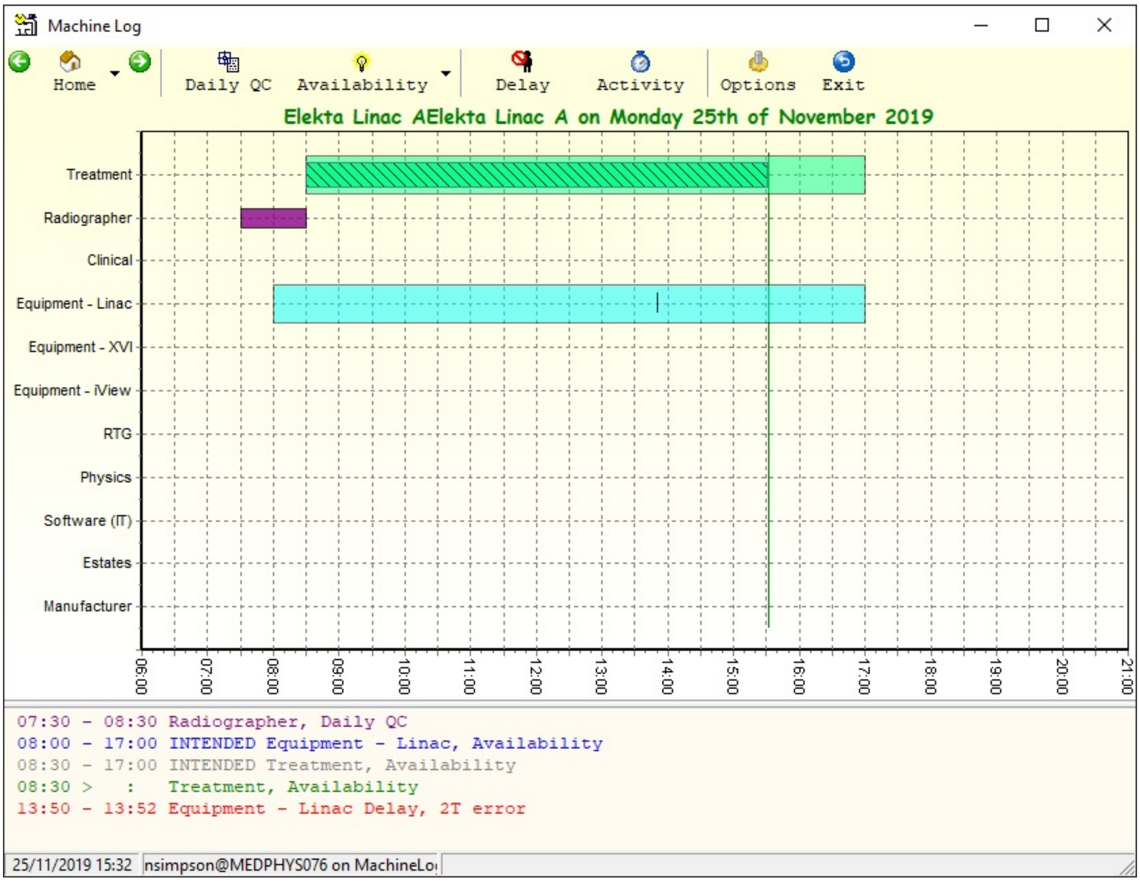


Figure 3.1: Default Machine Log Screen

Moreover, it is not quickly clear where one would capture a Linac fault on this interface. In this case, a fault is regarded as a 'Delay' and appears to be within the Delay button on the menu bar. It becomes apparent that equipment faults are displayed as a Delay in the Log Window as red text, located at the bottom of the interface shown in Figure 3.1

Figure 3.2 displays the interface that allows a user to add an Activity. There are various drop down boxes allowing the user to select details such as Location, staff group, type of activity and details. This is the interface that the Radiographer would be required to use for inputting activities such as morning quality assurance.

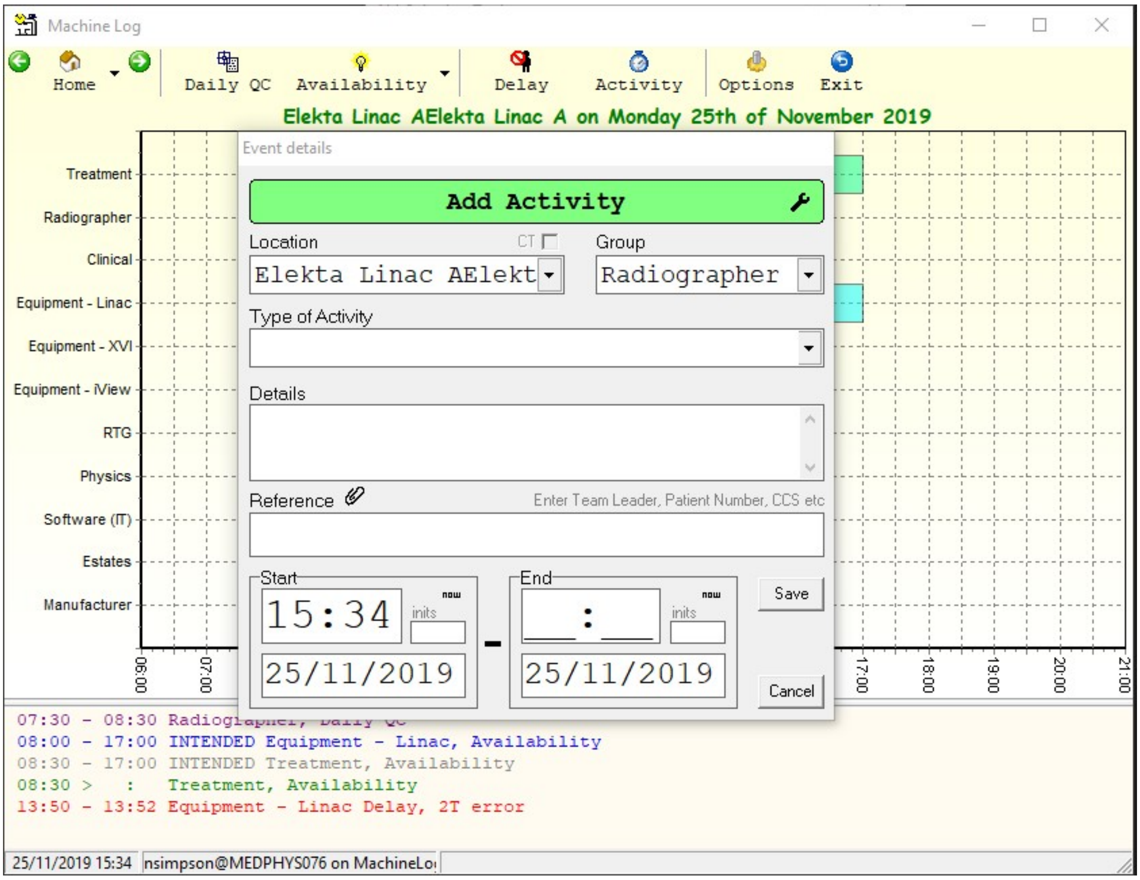


Figure 3.2: Adding an Activity

Figure 3.3 demonstrates that the user is able to add Availability. The interface is entitled 'Edit Activity' but seems to suggest Availability is an activity. The drop down for type of Activity includes:

- Other...
- Availability
- Availability (Diagnostics)
- Availability (Trials)

It is not clear what these types of activity mean.

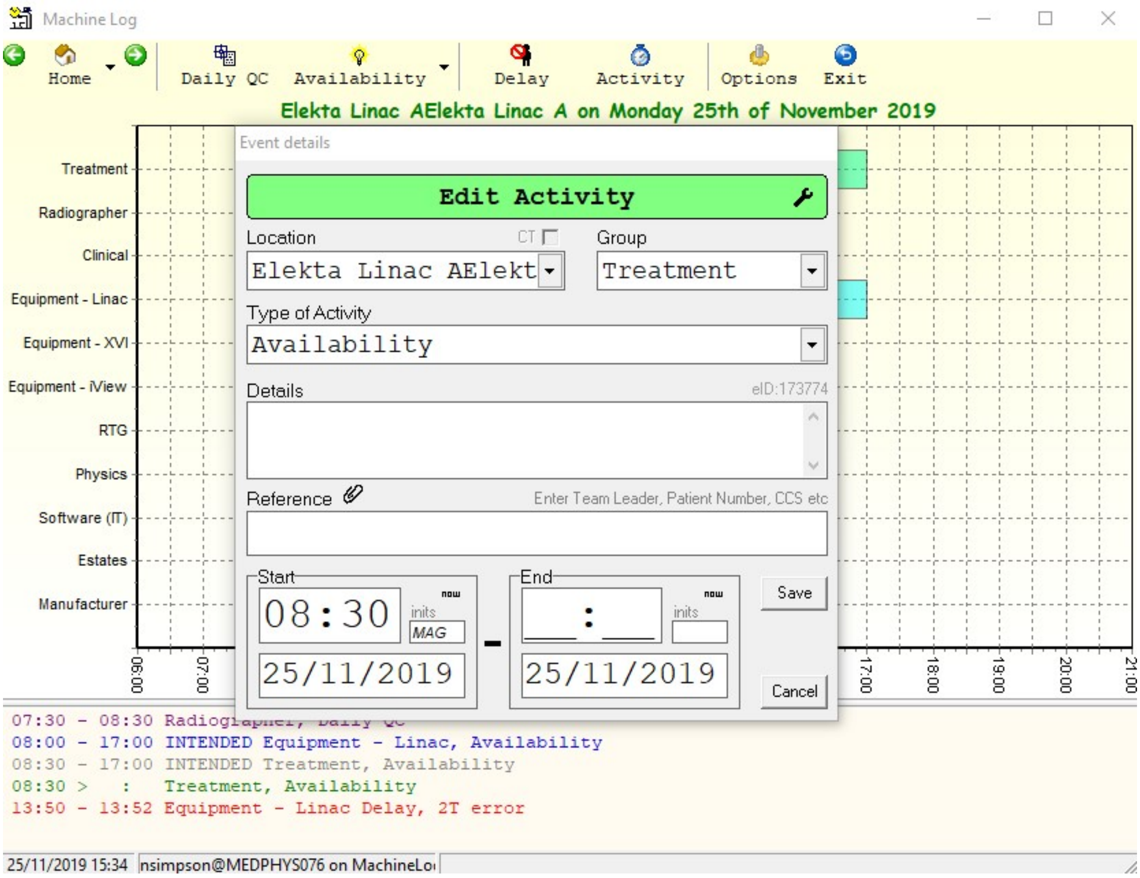


Figure 3.3: Adding Availability

The interface shown in Figure 3.4 allows the user to add Daily QC (Quality Check) records. This interface shows that the terminology used differs. At The James Cook Hospital this QC is known as QA (Quality Assurance).

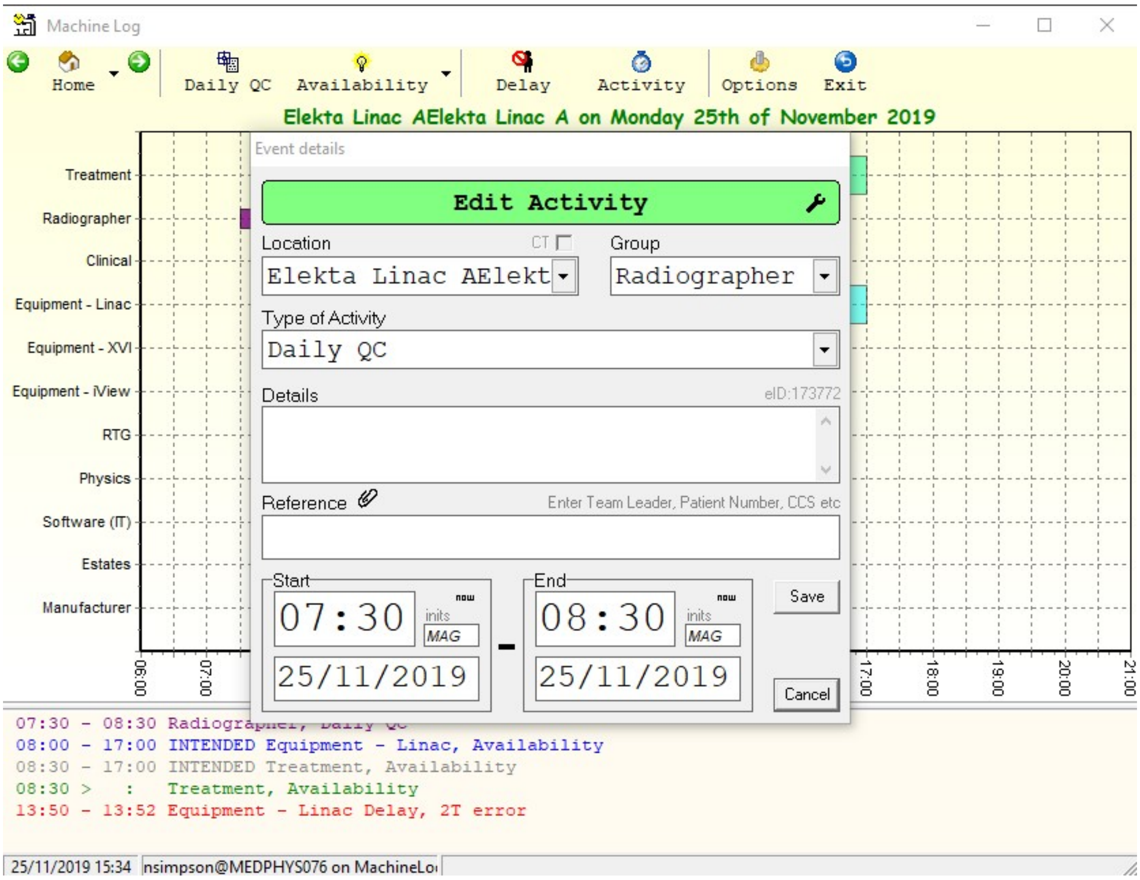


Figure 3.4: Adding Daily Quality Checks (QC)

Interestingly, this interface seems to provide more options than just Daily QC that are not found within the other interfaces. Figure 3.5 displays other Activities such as staff meeting and staff unavailable and it is not immediately clear how this is linked to a Daily QC interface.

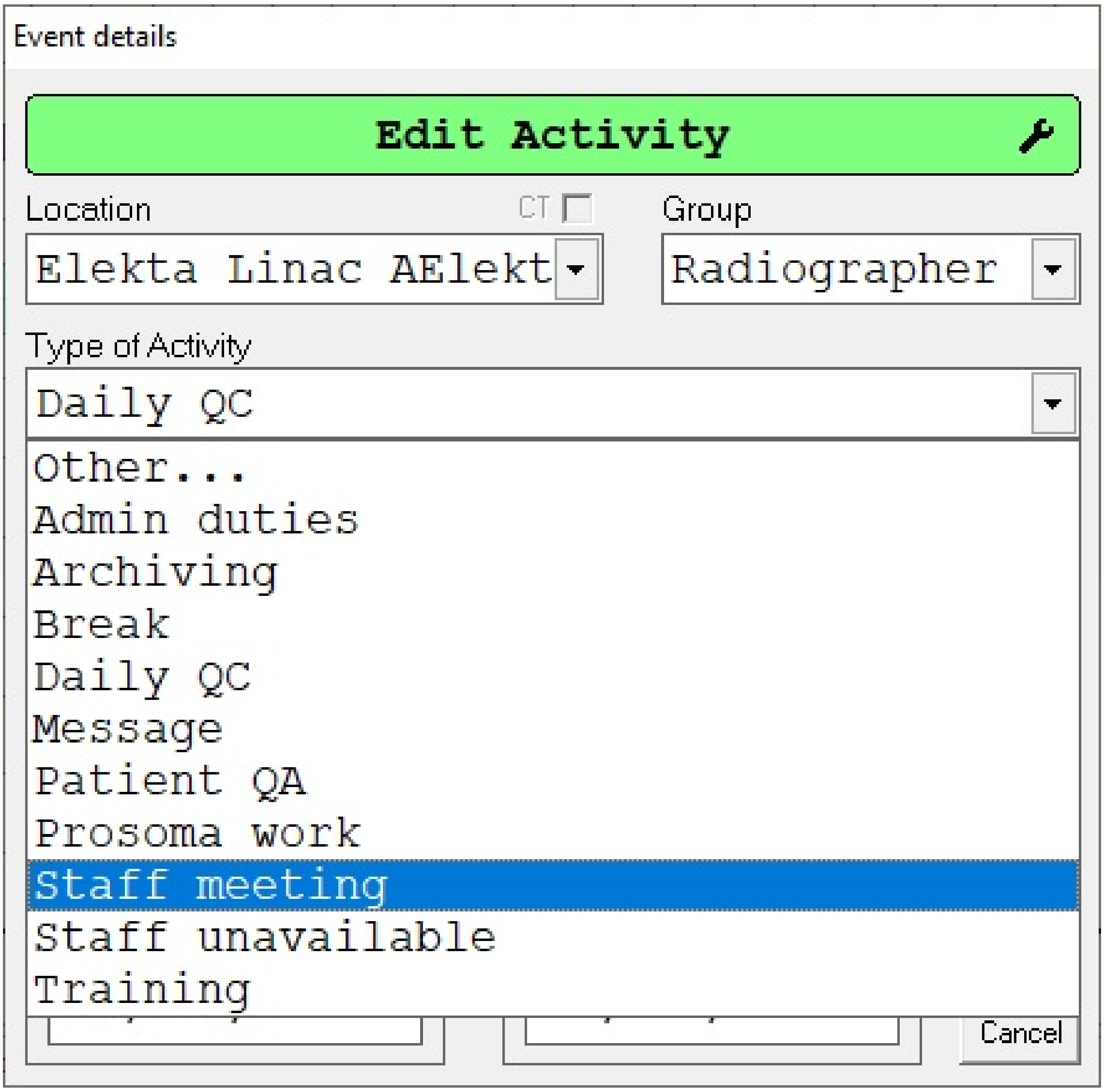


Figure 3.5: Expanded activities drop down menu within the Daily QC interface)

3.2 MachineLog Discussion

According to the Machine Engineers, MachineLog is intended to be used for recording Linac faults and Linac availability or 'uptime'. For example, recording when and how a Linac has broken during patient treatment (fault), recording the duration a Linac has undergone scheduled maintenance (downtime) or the duration a Linac has been used for treating patients (uptime). When a fault occurs, the Radiographer must immediately report the fault by using MachineLog. The Radiographer must then telephone the Machine Engineer, to alert the Machine Engineer of the fault.

However, MachineLog is not used in this way. According to the Machine Engineers, MachineLog is only used retrospectively and only when prompted by the Machine Engineers, well after a fault has occurred. As time passes, the fault information entered often becomes inaccurate.

Therefore, the Radiographers are not using the system as intended although there is a need for Machine Log to be used as a tool for monitoring metrics such as clinical up-time, and providing fault logging functionality.

The figures above summarise Machine Log's interfaces. However, Machine Log is a piece of software which is not being used properly. Reviewing the interfaces identified there appears to be a lack of affordances, a term coined by James Gibson [15] in his theory of affordances. Affordances are properties of objects that we would automatically determine a purpose for. One example could be drawn from objects such as a screwdriver. Let us imagine that one was tasked with creating a small round hole in a piece of paper. We could expect that one would use a screwdriver if it was already visible on a desk as it is obvious to the majority of people that if the screwdriver is pushed through a piece of paper with force, it would create a hole and thus complete the task. However, the screwdriver's intended purpose is not to create holes. On the other hand, we subconsciously recognise that it can be used for such a purpose.

The theory of affordance can be aligned to software. MachineLog lacks affordances (it lacks any clear call to action). It is not obvious what purpose each menu button serves. For example, in Figure 3.5 it is not clear or obvious that this drop down menu is accessible via the 'Daily QC' button and thus lacks the affordance of being able to record that there is no staff availability in Machine Log. It is also not obvious how the user selects a different Linear Accelerator. On a daily basis the Radiographers are required to use a wide range of systems which are specific in function, including Machine Log.

Furthermore, it turns out that MachineLog is installed on computers away from the Control Area displayed in Figure 2.2. For example, MachineLog used in LA4 is installed on a workstation behind the Control Area. This workstation is displayed in Figure 2.4. This is important as it suggests that MachineLog is out of view from the Radiographer.

The task of managing Linac faults is widespread (i.e. all Radiotherapy Departments have a Linac to operate and thus manage). Therfore, MachineLog at other cancer centres was investigated.

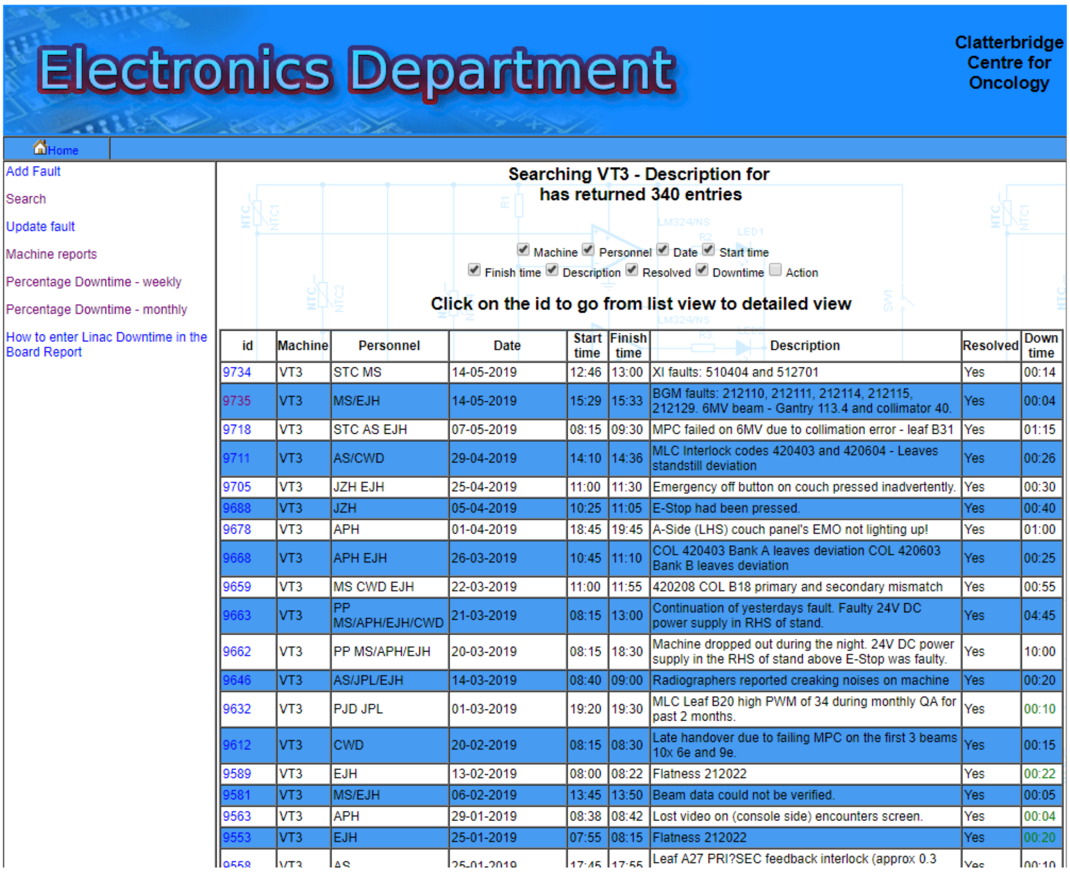
3.3 MachineLog at Other Cancer Centres

After uncovering the interfaces of MachineLog at The James Cook University Hospital, investigation into the use of MachineLog at other cancer centres was performed. This involved sending an email to the Medical Physics Distribution List "Discussion amongst academic Medical Physics in the UK (MEDICAL-PHYSICS-ENGINEERING@JISCMAIL.AC.UK)", an email list for medical physics professionals across the UK, requesting screenshots of their own versions of Machine Log.

Three valuable responses were received. The responses included screenshots and basic descriptions, confirming that other Cancer Centres are developing their own Medical Infrastructure in-house and have developed their own versions of MachineLog to manage their Linac fault recording and tracking.

3.3.1 The Clatterbridge Cancer Centre

Figure 3.6 shows a screenshot of the Machine Log used by the Radiotherapy Engineers in Clatterbridge. The tool was developed by the Engineers at the Clatterbridge. This tool is a web interface. Each time a fault is recorded the engineers record it in the software and estimate the downtime of the Linac. This downtime is then used as a key performance indicator and given to the Trust management board.



Electronics Department

Clatterbridge Centre for Oncology

Home

Add Fault

Search

Update fault

Machine reports

Percentage Downtime - weekly

Percentage Downtime - monthly

How to enter Linac Downtime in the Board Report

Searching VT3 - Description for has returned 340 entries

Machine Personnel Date Start time Finish time Description Resolved Downtime Action

Click on the id to go from list view to detailed view

id	Machine	Personnel	Date	Start time	Finish time	Description	Resolved	Down time
9734	VT3	STC MS	14-05-2019	12:46	13:00	XI faults: 510404 and 512701	Yes	00:14
9735	VT3	MS/EJH	14-05-2019	15:29	15:33	BGM faults: 212110, 212111, 212114, 212115, 212129. 6MV beam - Gantry 113.4 and collimator 40.	Yes	00:04
9718	VT3	STC AS EJH	07-05-2019	08:15	09:30	MPC failed on 6MV due to collimation error - leaf B31	Yes	01:15
9711	VT3	AS/CWD	29-04-2019	14:10	14:36	MLC Interlock codes 420403 and 420604 - Leaves standstill deviation	Yes	00:26
9705	VT3	JZH EJH	25-04-2019	11:00	11:30	Emergency off button on couch pressed inadvertently.	Yes	00:30
9688	VT3	JZH	05-04-2019	10:25	11:05	E-Stop had been pressed.	Yes	00:40
9678	VT3	APH	01-04-2019	18:45	19:45	A-Side (LHS) couch panel's EMO not lighting up!	Yes	01:00
9668	VT3	APH EJH	26-03-2019	10:45	11:10	COL 420403 Bank A leaves deviation COL 420603 Bank B leaves deviation	Yes	00:25
9659	VT3	MS CWD EJH	22-03-2019	11:00	11:55	420208 COL B18 primary and secondary mismatch	Yes	00:55
9663	VT3	PP MS/APH/EJH/CWD	21-03-2019	08:15	13:00	Continuation of yesterdays fault. Faulty 24V DC power supply in RHS of stand.	Yes	04:45
9662	VT3	PP MS/APH/EJH	20-03-2019	08:15	18:30	Machine dropped out during the night. 24V DC power supply in the RHS of stand above E-Stop was faulty.	Yes	10:00
9646	VT3	AS/JPL/EJH	14-03-2019	08:40	09:00	Radiographers reported creaking noises on machine	Yes	00:20
9632	VT3	PJD JPL	01-03-2019	19:20	19:30	MLC Leaf B20 high PWM of 34 during monthly QA for past 2 months.	Yes	00:10
9612	VT3	CWD	20-02-2019	08:15	08:30	Late handover due to failing MPC on the first 3 beams 10x 6e and 9e.	Yes	00:15
9589	VT3	EJH	13-02-2019	08:00	08:22	Flatness 212022	Yes	00:22
9581	VT3	MS/EJH	06-02-2019	13:45	13:50	Beam data could not be verified.	Yes	00:05
9563	VT3	APH	29-01-2019	08:38	08:42	Lost video on (console side) encounters screen.	Yes	00:04
9553	VT3	EJH	25-01-2019	07:55	08:15	Flatness 212022	Yes	00:20
9558	VT3	AS	25-01-2019	17:45	17:55	Leaf A27 PRI?SEC feedback interlock (approx 0.3	Yes	00:10

Figure 3.6: Screenshot of Clatterbridge's Machine Log

3.3.2 East & North Hertfordshire NHS Foundation Trust

Figure 3.7 shows a screenshot of the Machine Log used by the Radiotherapy Engineers in North & East Hertfordshire. It appears different to The James Cook Hospital and Clatterbridge Cancer Centre's MachineLog. It provides some of the same information. It demonstrates that the same challange exists in this Hospital as there has been an attempt to manage Linac faults.

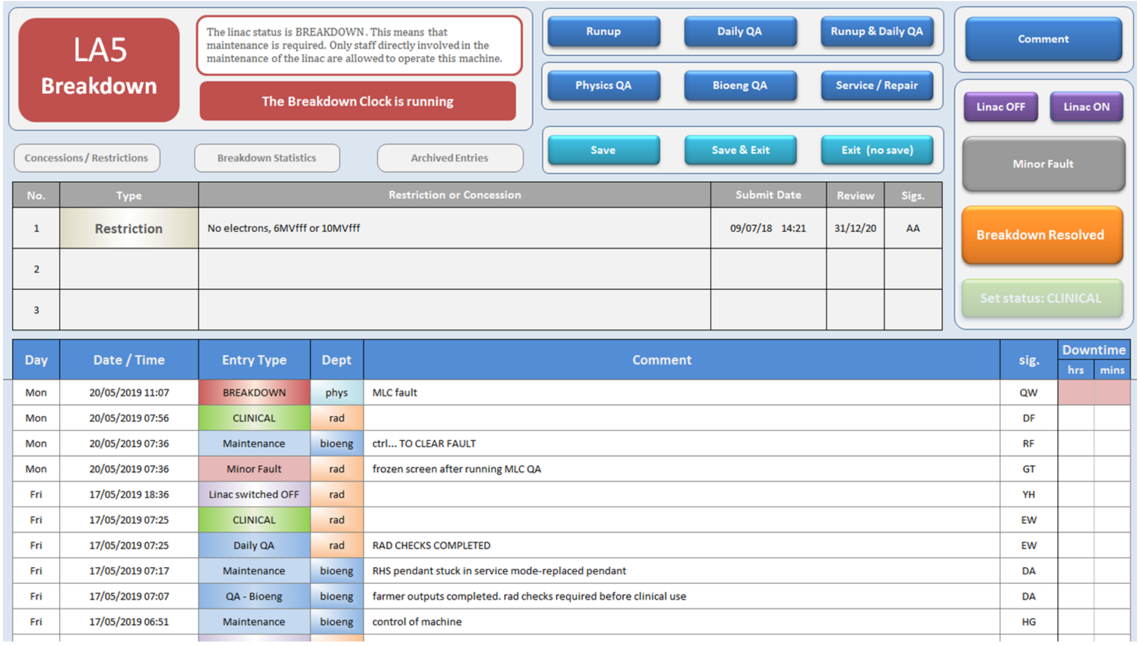


Figure 3.7: Screenshot of East & North Hertfordshire's Machine Log

3.3.3 Portsmouth Hospitals NHS Foundation Trust

Figure 3.8 shows a screenshot of the Machine Log used by the Radiotherapy Engineers at Queen Alexandra Hospital in Portsmouth. Again, this is different to the other cancer centres. It appears to be a Microsoft Access Database which displays a list of Open Calls (Open Faults).

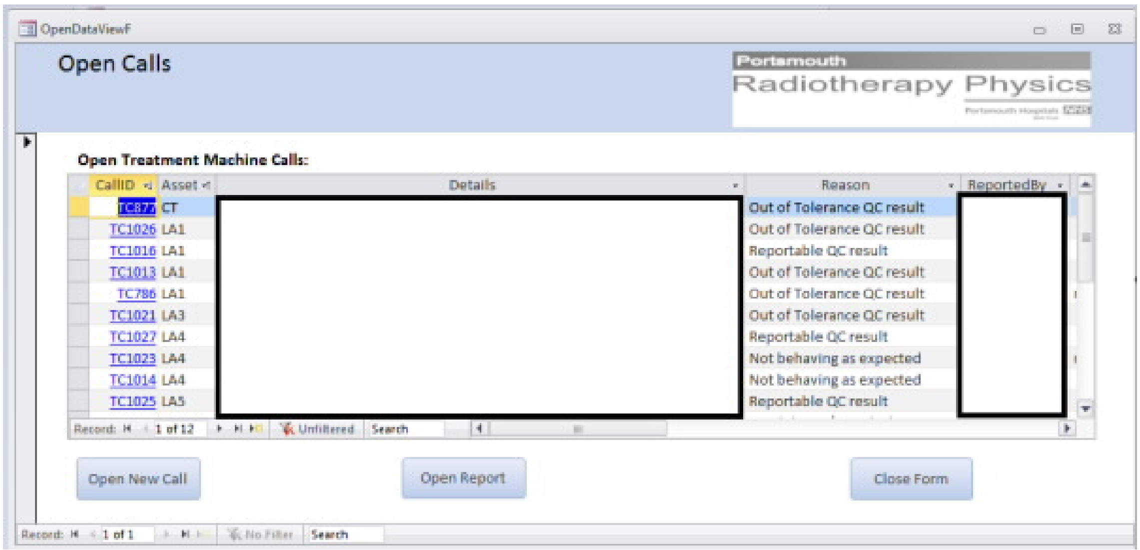


Figure 3.8: Screenshot of Queen Alexandra Hospital, Portsmouth's Machine Log

3.3.4 Discussion

Only three cancer centres responded to the request to provide information and screenshots on their systems that record Linac faults. This suggests that although most cancer centres operate Linacs to treat cancer patients, some trusts may not recognise this as a problem, or may not be concerned.

However, by gaining this picture of the state of Machine Log across the three trusts that responded, it is clear that the challenge of recording Linac faults is something which is shared. Each trust has crafted their own Medical Infrastructure Software in order to address this challenge. It is clear that these versions of MachineLog across the NHS share similar functionality, to record faults.

This chapter has exposed the current system and has explored software sharing similar functionality yet crafted independently. This suggests that other NHS hospitals are attempting to address the challenges of recording linear accelerator usage with the aims of improving their medical infrastructure availability. However, some feedback suggests that there is a struggle in getting users to use the systems, or that the systems are not working very well.

In contrast, there is suggestion that in-house developed MachineLog is used as intended in Clatterbridge. The intended use of MachineLog at Clatterbridge is directed towards the Machine Engineers using MachineLog to record faults and not the Radiographers. It appears that the Radiographers do not need to use this system. Although it is not clear how the Radiographers report faults. However, this initially suggest that the Machine Engineers should be using MachineLog and not the radiographers. Nevertheless, MachineLog at The James Cook University Hospital (JCUH) is not being used as intended and an aim of this thesis is to investigate why MachineLog is not being used at JCUH as intended.

3.4 Conclusion

Radiotherapy is a complex domain and there is a need to manage the faults that are encountered when operating Linear Accelerators. Interestingly, software intended to manage Linac faults exists demonstrated by delving into MachineLog at The James Cook University Hospital (JCUH) and exploring its in-house developed variants at other hospitals. This suggests that this is a shared challenge and that there is a need to manage Linac faults and a need for MachineLog to exist.

MachineLog, built by the Northern Centre for Cancer Care, has diffused into the Radiotherapy Department at the James Cook University Hospital. MachineLog attempts to address the problem of managing Linac Faults. However, in practice MachineLog is not being used as intended by the Radiographers at The James Cook University Hospital.

Delving deeper into MachineLog shows that it does not lack the functions to record faults in its software. Although, these functions are difficult to find due to a lack of affordances. Nevertheless, MachineLog is not being used. Figure 2.5 visualises critical software interacting with one another for the delivery of radiotherapy treatments and it appears that MachineLog sits outside of all other software.

The aim of this thesis is to investigate why Radiographers are not using MachineLog. To understand the techniques available for investigating this lack of use, the literature was reviewed.

Chapter 4

Literature Review

The goal of this chapter is to review the literature in order to address two aims of this thesis. Firstly, to understand how HCI methods might enable and facilitate the investigation into the work performed by the users of MachineLog and thus understand MachineLog's lack of use, and secondly, to guide the development of a prototype for addressing the lack of use, as a non-design expert.

The first stage of the review considered what Medical Infrastructure Software such as MachineLog might actually be, and why it is important to investigate the lack of use of this type of software. Literature surrounding Healthcare Professionals developing software, was then reviewed.

General HCI methods that are used in the design of software, were next considered. Accordingly, this aimed to uncover the broader existing work that has been performed by using HCI. The next stage of the review focused on how these methods have been applied to software in healthcare, allowing us to discover techniques for investigating why healthcare professionals are not using software as intended.

Efforts were then focused on exploring literature that applies HCI techniques to Medical Infrastructure Software developed by Healthcare Professionals for use by other Healthcare Professionals. However, reviewing the literature suggested that Clinical Scientists and Clinical Technologists are not explicitly identified or considered as Healthcare Professionals developing and manufacturing software that is expected to be used by other Healthcare Professionals to support the medical infrastructure. Furthermore, the discourse of the literature appears to be directed towards patient treatment and patient safety, whereas Medical Infrastructure Software such as MachineLog is not used for patient treatment and does not need to consider patient safety. This may suggest a gap in the literature and an under-addressed area of research.

Nevertheless, literature shows that previous research into HCI methods can be used to inform the design of Medical Infrastructure Software. This included techniques to investigate and observe how Radiographers interact with MachineLog and methods for developing the first iteration of our prototype named LinacLog.

The final stage of the review considered literature concerned with developing and evaluating prototypes as non-design experts, such as using a design review and user testing, to inform future development of LinacLog.

4.1 Medical Infrastructure Software

MachineLog and Medical Infrastructure Software may be considered of form a hygienic IT, an idea coined by Alan Cooper [16]. Cooper explains that hygienic IT comprises of corporate and practical goals that needs to be met in order for something to function properly and when it functions, it becomes taken for granted. When it stops working, people become interested.

According to Cooper [16], Hygienic IT requires:

- Personal goals, which are simple and personal goals, for example: To care for my patients.
- Corporate goals that focus on design for the big, for example, The Radiotherapy Department must be able to treat cancer patients, which is driven by the NHS goal for treating patient illness.
- Practical goals, such as maintaining a Linear Accelerator for treating cancer patients.

The users of MachineLog are the Radiotherapy Engineers concerned with maintaining the Linear Accelerator and the Radiographer concerned with using the Linear Accelerator to treat patients. These goals are powerless to motivate on their own, although they are necessary for the user [16] [17]. Machinelog links the corporate goal with the practical goal: Treat cancer patients by keeping Linear Accelerators operational, by using MachineLog to manage breakdowns and faults.

Without a working Linear Accelerator (practical goal), Radiotherapy cannot treat cancer patients (corporate goal). Without a Radiotherapy department to treat cancer patients (corporate goal), maintaining a Linear Accelerator is pointless (practical goal). Therefore, there would be no need for MachineLog. There is also no user (Radiographer) concerned with treating their patients, nor a Radiotherapy Engineer concerned with maintaining Linacs; the corporate and practical goals are powerless on their own.

For context, when using a light switch, it is expected that the switch will illuminate the room by using something that produces light. The infrastructure behind this is not important to the person switching the light on. However, when this light stops working when it is needed, it then becomes interesting, thus becoming concerned with infrastructure. The lightbulb is powerless without the infrastructure that supports it.

Medical Infrastructure Software such as MachineLog is expected to work, much like an IT helpdesk in a busy organisation. When this stops working, the users become interested in why it is no longer working because there is impact upon goals.

Although the same is true for a wide range of software, the important difference with Medical Infrastructure Software such as MachineLog is that it sits on the boundary between regulated and unregulated systems and processes. Consider a court room, where the recorder is using a word processor to capture legal conversations and information. The word processor does not make legal decisions but the court process cannot happen without the recorder recording the legal decisions by using a word processor. MachineLog and Medical Infrastructure Software could be considered similar to this.

MachineLog needs to work for Radiotherapy treatment to happen because it records the faults that occur with Linacs and helps the engineers fix these Linacs by providing information regarding the fault. Fixing the fault is a regulated activity, recording the fault is not. Therefore, MachineLog sits on this regulated and unregulated boundary, created by the Engineers that sit on this boundary of regulated and unregulated work. Although, MachineLog is not regulated software.

Therefore, Medical Infrastructure Software needs to work because it helps Healthcare Professionals perform regulated activities by providing unregulated information, despite not being regulated software. However, in practice, some of this software exhibits lack of use problems.

4.2 Overview of HCI in Medical Infrastructure Software

There are some Healthcare Professionals (HCPs) who are actively developing software in the NHS. Some of this software is regulated medical device software, commissioned or developed by Clinical Scientists [4] and Clinical Technologists, and some of this software is unregulated software [5] [12], including Medical Infrastructure Software. These professionals are experts within their domains, are comfortable programming and are developing software solutions to address problems in their domains, such as MachineLog.

Whether this software might not exist elsewhere, exists but is not affordable or exists but is not suitable, Healthcare Professionals turn to developing software such as MachineLog and are, with authority, deploying this software for use during their routine work.

4.2.1 HCI & Design Awareness

Despite Healthcare Professionals developing software, from experience, awareness of HCI and design amongst Healthcare Professionals who are developing software for other Healthcare professionals, is lacking. The acknowledgement of this general lack of awareness of HCI by NHS staff is supported by Acharya et al [7], who suggest that "The people working in the area seem unaware of HCI.".

There is suggestion that this lack of awareness may be a barrier for design experts accessing Healthcare Professionals [8] [18]. Furthermore, design experts also find it difficult to access Healthcare Professionals due to NHS staff working at high pressure in a complex environment [19], Radiotherapy being an example of a complex environment operated by staff working under high pressure.

These difficulties may contribute to lack of use problems that are exhibited in software such as MachineLog. Nevertheless, HCI and Human Factors are important aspects of software design and development [20].

Interestingly, Healthcare Professionals such as Clinical Scientists, who are developing software, have easy access to other Healthcare Professionals as part of their routine work. Therefore, this group has the advantage of not experiencing the same difficulties that design experts experience in accessing Healthcare Professionals. Nevertheless, HCI and design awareness is lacking.

4.2.2 HCI & Human Factors Frameworks

There are many Human Factors frameworks available for designing software and devices in Healthcare. Cassono-Piche, et al. [8] argue that applying human factors to improve safety in healthcare plays a positive role in improving technology safety. The techniques that are used for improving safety in Healthcare may also be used to improve the usability of Medical Infrastructure Software and as this thesis explores, there are instances of this software in the NHS that experience lack of use, such as MachineLog.

One Human Factors Framework example is The Systems Engineering Initiative for Patient Safety (SEIPS) 2.0 [21] framework, a framework for studying and improving the work of healthcare professionals and patients. SEIPS 2.0 recognises that the human factors domain and the complex healthcare domains are evolving. SEIPS 2.0 considers the complexity of managing patient care using different staff, involving the patient, managing drugs, etc. The goal of this framework is to improve patient-centered care.

Furthermore, work by Habli [22] and Thimblebly [23] demonstrates that there is active research into the safety of health information technology [24] [25]. Medical Software that is used in the treatment of patients is governed by legislation such as the Medical Device Regulations 2017 [13] and therefore, safety and risk management are important considerations [26]. Medical Devices and regulated software needs to be safe and are governed by laws such as the Medical Device Regulations [13].

However, the discourse of frameworks such as SEIPS 2.0 is directed towards patient treatment and safety, whereas, MachineLog, sits behind this and behind the scenes. MachineLog does not contain data relating to patients nor does it coordinate the care of patients. Although MachineLog has the potential to store some information on faults that may be of a safety concern, the work that happens to resolve faults happens away from MachineLog, as does the work on managing the safety of Linacs.

Radiotherapy safety is managed by using a mixture of professional judgement (Medical Physics Experts) and by using a mixture of regulated and unregulated commercially developed software (earlier mentioned in Chapter 2) for performing safety testing. If a critical fault does occur that is of a safety concern, the Radiographers will not use the Linac to treat a patient, unlike a regulated infusion pump that may be set incorrectly and administer the wrong dose.

It is apparent that these frameworks help inform safe development of regulated software and devices that are involved in treating patients. However, MachineLog is not regulated software involved in treating patients. MachineLog does not need to be regulated software as it is a tool for maintaining the infrastructure that enables Healthcare professionals to perform their roles (MachineLog helps to manage the Linac infrastructure so Radiographers can treat patients). Therefore, applying these frameworks is considered optional and may be overlooked when Healthcare Professionals set out to develop Medical Infrastructure Software. Furthermore, these frameworks do not explicitly capture Healthcare Professionals such as Clinical Scientists that are developing the behind the scenes unregulated software such as MachineLog. Therefore, it is apparent that the development of unregulated Medical Infrastructure Software by Healthcare Professionals such as Clinical Technologists (Radiotherapy Engineers) and Clinical Scientists (Medical Physicists), may be an under-researched area.

Nevertheless, Healthcare Professionals developing software have an advantage in the ease of access of other staff during their high-pressure routine work. Thimbleby comments that "The design of medical devices directly affects the way healthcare practitioners carry out their daily tasks." [27]. Although the discourse of this work is directed towards regulated software and medical devices, it can be extended to unregulated Medical Infrastructure, such as MachineLog, that impacts the high-pressure work of Radiotherapy Engineers and Radiographers. This is important because these staff can investigate the potential impacts of the software that they are developing.

The flexibility of unregulated software and the lack of awareness of design gives rise to challenges such as software, such as MachineLog, being developed by Healthcare Professionals, without proper design or evaluation, despite this software impacting the activity of Radiographers. Despite this lack of awareness, Healthcare Professionals are in an excellent position to apply human factors methods for improving the usability and effectiveness of Health IT, particularly if there is difficulty in accessing design experts [8].

However, some HCI techniques are only able to be performed by design and usability experts [28]. Despite this, where these experts are unavailable, as Healthcare Professionals and non-design experts, it is important to be able to address lack of use problems that arise from in-house developed Medical Infrastructure Software such as MachineLog.

HCI techniques for non-design experts need to be available for Healthcare Professionals developing software, therefore, the literature surrounding HCI techniques for non-design experts was reviewed. Although, this is not to say that design experts should not be involved wherever possible.

4.3 Human-Computer-Interaction Design Techniques

As non-design experts, HCI techniques such as Interaction Design, Scenario-Based Design and Contextual Design that are available for informing software development and software design, were considered. Therefore, this section aims to discuss the literature that was reviewed surrounding some of the fundamental aspects of HCI in software design that may provide insight into the techniques for investigating interaction, investigating lack of use and methods for developing and evaluating a prototype.

4.3.1 Interaction Design

Interaction Design (IxD) is the design of interactive products and services in which a designer's focus goes beyond the item in development to include the way users will interact with it.[29]. This practice focuses on the interaction between a user and a product in a holistic way. The essence of interaction design is discovering user behaviours and goals.

Another definition of interaction design can be found in the book 'Interaction Design' by Preece, Sharp and Rodgers. Preece et al [1] describes IxD as "designing interactive products to support the way people communicate and interact in their everyday and working lives". It considers that interaction design "casts its net wider" than general HCI and draws from wider fields and disciplines as shown in Figure 4.1.

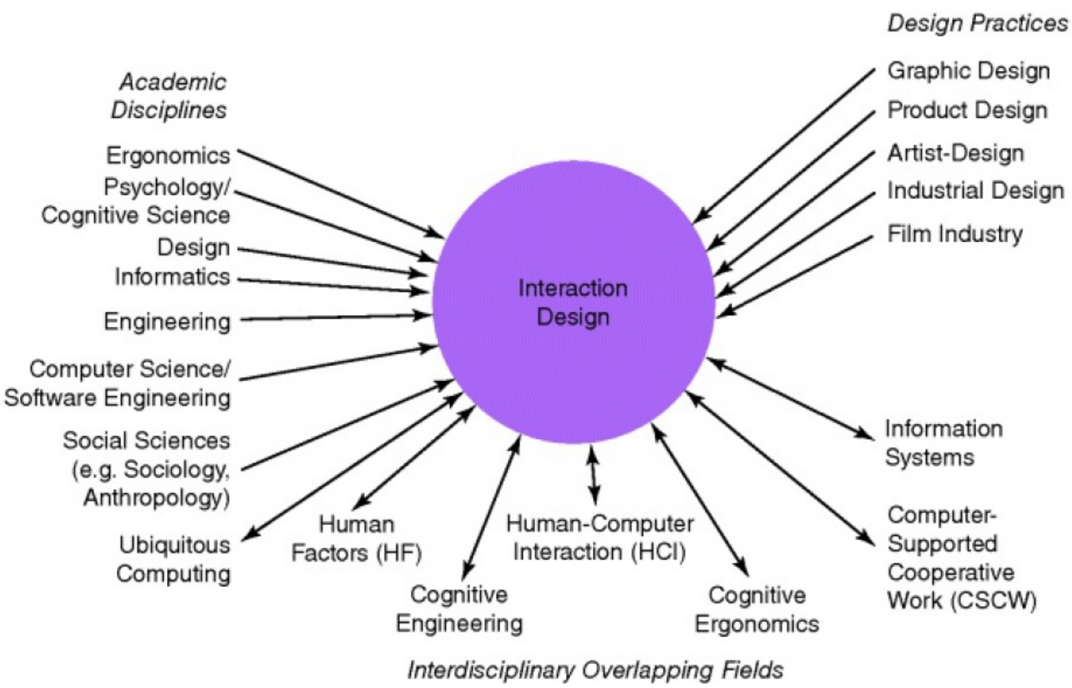


Figure 4.1: The relationship between Interaction Design and other fields, taken from *"Interaction Design: Beyond HCI"* [1]

Interaction Design is a good starting point for designing software as it includes four useful principles:

- Establishing Requirements
- Designing Alternatives
- Prototyping
- Evaluating

These four principles are useful for the development of our new MachineLog prototype, named LinacLog. By establishing requirements, the functionality of LinacLog can be envisaged. By designing alternatives, different designs are able to be developed, to meet the established requirements and inform the development of a prototype.

The prototype can then be evaluated, providing a measure of whether the established requirements have been met. In our case, an evaluation will determine whether the LinacLog prototype has successfully solved the immediate problem of lack of use by the Radiographers.

Preece et al [1] teaches us that it is important that usability is not overlooked. As such, it is important to understand the activities of the users who are going to use the system. Therefore, it is important that the work of the Radiographers who are going to use LinacLog, is understood. By understanding these activities, the requirements for LinacLog can then be set.

Therefore, methods to capture the work of the Radiographers when interacting with MachineLog, are required. One potential method is Scenario-Based Design.

4.3.2 Scenario-Based Design

Scenario-based design is well established. Carroll [30] comments that scenarios are "meaningful and discussable by users" and that "by scenario we mean building object-oriented models of the user's task domain". The motivation for scenario-based design when modeling a user's task domain is one of developing future systems and envisioning that work with technology; The user's task would be modelled in order to create a new system to facilitate that new work. Scenario based design is useful for developing systems that do not exist yet.

Given that MachineLog already exists and that the tasks that the Radiographer and Machine Engineer performs already exists, Scenario-based design was not the ideal method for the full re-design of MachineLog. Although, it is important to note that scenarios, more generally, are a useful tool to capture and reflect practice [31], without necessarily using them to solely drive the full design process. Therefore, scenarios were used as a tool to capture existing interaction and envisage how the new MachineLog might be used by creating a hypothetical narrative for existing and new use.

To completely re-design the existing MachineLog, methods that allow for the re-design of MachineLog by taking a user-oriented approach, whilst learning to understand the existing work performed by the users, were explored. One such method is Contextual Design.

4.3.3 Contextual Design

Proposed by Beyer & Holtzblatt [6], Contextual Design is a method for 'defining customer-centered systems' where systems and workflows already exist. MachineLog is a piece of software that already exists. The staff that are using MachineLog already exist and the workflow for alerting Machine Engineers of faults already exists.

The method allows the researcher to "gather detailed data about how people work and use systems" and to develop a picture of customers' work [6]. After this picture has been created, the research can then generate systems designs from the knowledge obtained and also diagram a set of existing systems, visualising the interactions that take place. This method fits into the goal of this thesis, specifically, investigating how people are or are not using machine log in the way it was intended.

Contextual design provides an array of techniques that can be used for discovering the existing work performed by the intended users, who are thus using an existing system or piece of software. Therefore, contextual design was considered as a method for investigating the lack of use of MachineLog that will allow us to develop LinacLog.

4.4 Investigating Lack of Use

4.4.1 DiCoT: Distributed Cognition for Teamwork

One method that builds upon Contextual Design is Blandford & Furniss's Distributed Cognition for Teamwork (DiCoT): A methodolgy for applying distributed cognition [32]. Distributed Cognition is "An approach to reasoning about the interaction of multiple people and artefact" [32]. Distributed cognition could be thought as something as simple as post it notes being dotted around a workplace providing snippets of information where people need it. Electronically, we can think of it as information being provided from multiple systems relevant to a specific on-going task.

This method is very useful for multiple users of a distributed system that includes many different devices and artefacts. The methodology was given context by applying it practically to the London Ambulance Service (LAS) control room.

Within the control room situation, the operators receive streams of information from various different sources. When the operator is 'buried' in their screen, this signals to other operators that they are busy. This signal can help incident commanders recognise which staff are too busy to receive information and those who are open to receive information. DiCoT is well suited for systems used in a complex and protracted body of work.

However, compared to some more complex and protracted ongoing body of work like that of a control room, the use of MachineLog is primarily as a tool for a single point of data capture. MachineLog is used to capture data at the point in time of an incident occurring. The work then happens around this captured data, away from MachineLog. Considering this, it seems sensible for a less complex system such as MachineLog, to use a different method of capturing the work.

4.4.2 Contextual Inquiry

Contextual Inquiry, developed by Beyer & Holtzblatt [6], is a technique that can be used to collect research data by performing observations and interviews. It focuses on using four principles to achieve this acquisition:

- Context - Go to the customer's workplace and see the work as it unfolds.
- Partnership - To make the customers collaborators in understanding their own work
- Interpretation - Assigning meaning to the observations which are conducted
- Focus - The point of view the interviewer or observe takes while studying the work.

These principles assist the person performing a contextual inquiry. The interviewer is only learning some of the work to support the work with technology, within limited time-frame through the application of an observational technique.. The interviewer is not learning the work in order to perform the work.

The observational technique that is used to perform the interviews is known as the 'Master/Apprentice Model' [6] and encapsulates the four principles for performing a contextual inquiry. Although Holtzblatt mentions that this model is no longer common, it is still is sufficient for use in understanding the work of specific staff groups and can be performed by someone new to design. This is useful for Healthcare Professionals who are developing software as non-design experts.

The Master/Apprentice model is an instruction of shadowing the 'customer' (master) enabling the 'designer' (apprentice) to understand and perhaps even participate in the work that the customer is undergoing. Again, this model can be performed by anyone willing to understand the structure and principles of contextual inquiry. This is useful for Healthcare Professionals, allowing them to understand the work of their potential users.

The Master/Apprentice model leads into a contextual interview, one of the most common structures of a contextual inquiry. In the context of understanding MachineLog, during the interview the radiographer will conduct his or her work and discuss it with the observer. The observer will observe the work and ask questions. This observational and questioning approach helps the observer to learn the work as an apprentice would. It is worth noting that the aim of this is not to become competent enough to perform the work such as performing a Quality Assurance session as a qualified Radiographer would, it is simply a tool allowing the designer to gain some of the foundation knowledge for work such as: the Quality Assurance of Linacs, learning the basic terminology, understanding where to find protocols and understanding how the Radiographer knows how to complete Quality Assurance activities.

The contextual interview consists of four parts. Firstly, it starts as a conventional interview, focusing on getting used to each other as people. This interview allows the interviewer to introduce the focus of the interview to the customer, and in our case, the Radiographer and Machine Technologists. It is worth noting that as Radiotherapy operates under a quality management system which is frequently audited, the conventional interview helps establish trust and a clear understanding that the role of the observation and interview is not one of an audit on clinical practice. Interestingly, Radiographers and Healthcare Professionals may be more receptive to this type of observation because they are aware that they can be audited by other Healthcare Professionals.

The second part of the contextual interview is that of the transition. The interview transitions into rule setting, the interview states the rules such as expecting interruptions whilst performing work due to questions being asked. However, this also works in reverse, where the customer (Radiographer) can tell the interviewer to hold off on the questions if it is a bad time for them, but all rules must be explicit.

After the first two parts of the interview have been complete, the contextual interview proper begins as the third part. The customer starts to work and the observer observes and interprets the work [6]. This brings the Master/Apprentice model into application, the interviewer becomes the apprentice and aims to learn the work as discussed previously. This is where the interviewer follows the Radiographer around, taking notes by hand and being free to interrupt to ask questions. This takes the four principles of contextual inquiry and applies them directly to the observation. Finally, after the contextual inquiry proper, the final part is to wrap-up the interview. This is a chance to look back over on notes and summarise what you have been able to learn from the work of the customer (Radiographer). It is also a good opportunity to ask questions on aspects that were not understood by the observer, or ask questions which may have been put on hold. Again, the whole interview is performed as that of an apprentice, always ensuring to display good attitude and applying the four principles of contextual inquiry.

According to the Interaction Design Foundation (IDF) [33], there are many advantages to Contextual Inquiry, such as:

- The ability to reveal information and understanding that users might not be aware of.
- The veracity of information – observing users in their natural environment tends to lead to very accurate information.
- The detail of the information – this kind of study produces highly detailed information as opposed to many other qualitative methods which produce more high-level information.
- The flexibility of the method – contextual research can be carried out wherever a user operates.

Although not demanding for a design expert, the time and resource intensive nature of a contextual inquiry technique such as an interview, for observers, is a drawback [33]. NHS staff are stretched to meet clinical targets and are very much responsible for their patients lives. Earlier, it was mentioned that design experts experience difficulty in accessing NHS clinicians for observations. However, the advantage of Healthcare Professionals developing software for other Healthcare Professionals is that they have ease of access to these busy professionals. One example of this ease of access is for auditing practice.

During an audit, staff are aware that they should allow the audit to take place despite the intensive nature of the observation together with their high workload.

4.5 Modelling the work

The contextual design method provides tools that allow for the collection and gathering of design data in the field. It is important to know how to collect this data, however, and it is equally as important to know how to present this data. Understanding the work will allow us to investigate how the radiographers are not using MachineLog as intended, and to do this we can produce models based on the 'Language of Work' [6].

There are five ways the 'Language of Work' can be modelled, allowing for a visual representation of the work observed:

- The Flow Model
- The Physical Model
- The Sequence Model
- The Artifact Model
- The Cultural Model

Flow Models are visual representations of the individuals doing the work, the responsibilities of individuals, and breakdowns that occur, such as something preventing a user from achieving success from their task. For example, not being able to find a piece of equipment to complete their activity.

As Flow models help to identify the individuals doing the work and their interactions, flow models appear to be a potentially useful tool for visually representing the work of the Radiographer during an observation. I am interested in observing what breakdowns occur when using MachineLog and how Radiographers and Radiotherapy Engineers interact with one another. For example, is there anything that stops a Radiographer from using MachineLog during a fault?

Physical Models aim to visualise the physical layout of the environment where these activities are being performed. Linacs are busy working environments consisting of many different areas and workstations. Therefore, Physical Models are potentially useful for capturing the layout of a Linac. These models can demonstrate and visualise the movement of Radiographers between workstations.

For capturing work over time, Sequence Models can be used. Sequence Models focus on visualising the intention and triggering of a sequence.

The Artifact model is intended to capture and visualise the objects that are created or used by people and for capturing cultural context, cultural models can be used. Cultural models aims to visually represent the mind-set that people are operating within and where the user's culture prevents the success of a system.

In the context of research, these contextual design models are potentially useful for informing the scenarios that will inform the requirements for the new prototype.

4.6 Designing Prototypes

Prototype design has been well researched and there is a huge library of resources available for the design of prototypes, especially within Software Engineering. This section discusses how personas and sketching are useful tools that can contribute to the design of prototypes.

4.6.1 Personas

To assist with the design of LinacLog, HCI literature surrounding communicating requirements was investigated. One such tool to communicate requirements are Personas [34]. Personas are archetypical representations of the users who will be or who are using the system [35] and can be created from the results of contextual inquiries [36].

There is a rich body of literature surrounding personas, suggesting that it is a well-researched approach. However, there is some debate around the usefulness and validation of personas [37][38]. Design experts experience difficulty in accessing healthcare professionals when designing software and as such find it challenging to develop personas that accurately represent the users[37]. Bowen, et al. [36] mentions that personas were originally intended to "enable designers to focus on people who are not themselves (so designing for actual users rather than their own needs)".

However, in the context of this research, we are Healthcare Professionals with access to other Healthcare Professionals. This may make it easier to develop personas. Bowen, et al. [36] also mentions that in some cases, personas can be useful in participatory design, a method of allowing users to be deeply involved in the design of the software [36]. As Healthcare Professionals developing software, we are able to deeply involve the users into the design. The users in this case, are the Radiotherapy Engineers and Radiographers who both understand their requirements and are able to articulate them.

It is acknowledged that there are problems with participatory design [36]. The users must be comfortable engaging with the design. However, the advantage in our case is that the users are willing to engage in the design process, articulate their requirements and make themselves available and accessible for feedback as part of the author's routine role. Therefore, personas were decided upon as a useful tool to assist in representing and communicating the requirements for the prototype.

4.6.2 Sketching Ideas

Due to limitations of Hospital IT, for example, in this thesis, difficulties with connecting smart devices to the hospital network were experienced, and due Healthcare Professional's lack of experience in software development despite developing software, NHS staff may become constrained by their thinking when developing software ideas.

This limitation and constrained thinking may result in staff being unable to develop smartphone or smart tablet apps, for staff who are mobile and moving around frequently away from desktop workstations. Therefore staff are shoehorned into using clunky desktop applications such as MachineLog, Microsoft Access Databases, spreadsheets, etc.

However, Bill Buxton suggests sketching as a way to to break down this constrained thinking, in his book "Sketching User Experiences" [39], informing the steps to design the look and feel of the prototype by using sketches. Sketches are very useful for creating fast low-fidelity interface designs on paper whilst in the field. This forms part of a concept known as Ideation. Ideation, according to the Interaction Design Foundation [40], is the "process where one generates ideas and solutions through sessions such as Sketching, Prototyping, Brainstorming, Brainwriting, Worst Possible Idea, and a wealth of other ideation techniques".

By starting with sketches, ideas are able to evolve, envisaging how particular interfaces may look and where affordances such as buttons and menus may be positioned. This low-fidelity sketch can become a storyboard of interfaces that can be evaluated.

4.7 Evaluating Prototypes

After exploring the tools and techniques available for designing a prototype, the literature surrounding the evaluation of prototypes in healthcare was then reviewed.

Evaluation of software is important [41] and Usability Evaluation has been well-researched. Evaluating the prototype can begin to ascertain whether the prototype design meets specified requirements. This feedback can inform the next iteration of development, thus revising the software based on the feedback, improving the prototype at each stage until the prototype meets the specified requirements, or in our case, addresses the issue of lack of use.

Literature recommends that the evaluation takes place in early stages of prototyping [42]. Through evaluation, it may become apparent that some requirements were not suitable and thus reconsider the requirements and re-evaluate. Without evaluation, this feedback loop becomes difficult.

One method of Usability Evaluation is the Cognitive Walkthrough (CW) [28]. However, CW must be performed by a design expert as it often requires knowledge of cognitive psychology [43], and is time-intensive. Interestingly, there has been works that build upon traditional CWs such as Cognitive Jogthroughs [44], that aim to reduce the time-intensive nature of CWs.

Further building upon traditional CWs, there are methods that include the user in the CW [45]. Granollers and Lores [45] breaks this method down into three phases:

- Perform a traditional Cognitive Walkthrough
- Ask the user to perform the Cognitive Walkthrough
- Review feedback from the users

Although this method initially appeared useful as non-design experts, as it includes methods such as reviewing feedback, a task that may be performed by non-design experts, the aspects that build upon traditional Cognitive Walkthroughs still need to be performed by design experts. It is important to recognise that CWs require understanding of cognitive psychology, regardless of attempts to simplify the performing of CWs.

There is a need to evaluate the new prototype, LinacLog, as non-design experts. Therefore, general evaluation techniques such as Usability Testing were considered.

4.7.1 Usability Testing

Usability testing covers a multitude of testing techniques and can range from informal to formal testing. There are many approaches to Usability Testing [39] [41] [42].

According to Cassano-Piche, et al. [8], Usability Testing is "a human factors method that allows you to evaluate how a technology or process will function in its context of use". Furthermore, usability testing is important while designing prototypes [42].

Cassano-Piche, et al. [8] mentions that to prepare, one must understand the environment of use, the users and the work. In the context of healthcare, some of this understanding can be easily achieved by Healthcare Professionals, particularly as they are developing software directed towards the environment and the work that they are already familiar and immersed within. However, the challenge is that Healthcare Professionals may not fully understand, or presume to understand, the other users that they are designing or developing for. For the context of this thesis, Radiotherapy Engineers may not fully understand the clinical work of the Radiographers, although Radiotherapy Engineers may understand the Linac environment and the work that happens between the staff when faults arise. However, a contextual inquiry study may assist with this.

Similar to other methods, the discourse of usability testing in the context of healthcare surrounds patient treatment and patient safety [46]. There is an emphasis on evaluating medical devices [47]. MachineLog is not something that will cause medical errors nor is it a regulated medical device. However, MachineLog does suffer from a lack of use problem.

Nevertheless, general approaches of usability testing that have been applied to other areas of regulated healthcare software can be extended to Healthcare Professionals developing and evaluating unregulated Medical Infrastructure Software. One such method is the Usability Testing method by Cassano-Piche's 'Human Factors For Health Technology Safety: Evaluating and Improving the Use of Health Technology In The Real World' [8]. Usability testing in Cassano-Piche's work, as an evaluation, is guided by the context of Healthcare and is useful as a guide to evaluation for the context of this thesis.

A contextual inquiry study can identify a list of tasks and scenarios that can be performed during an evaluation, allowing for the interaction of the prototype to be as realistic as possible.

Therefore when testing, the methods by Cassano-Piche, et al. [8] will be utilised.

4.8 Conclusion

Human-Computer-Interaction (HCI) is a well established discipline informing the design of software. Accordingly, there is a wide range of literature available that informs software development practice. As HCI methods are well established, literature informs that methods of investigating interaction, developing prototypes and evaluating prototypes can be applied to Medical Infrastructure Software from other domains of software development.

Reviewing the literature suggested that there is an emphasis and discourse that is focused on the design and evaluation of regulated medical software and medical devices, from the context of patient safety. The design and evaluation of unregulated Medical Infrastructure Software such as MachineLog, developed by Healthcare Professionals that is then enforced upon other healthcare professionals, may be an under-explored area of research.

Nevertheless, software such as MachineLog, that needs to exist, and is exhibiting lack of use, must be re-designed so that it is usable. This is because without MachineLog, it becomes difficult to manage Linac faults. This lack of use frustrates the Machine Engineers.

However, many HCI methods must be performed by design experts, who have knowledge in areas cognitive psychology [43]. Some Healthcare Professionals developing software may lack this knowledge. Furthermore, there is a general lack of awareness of HCI in healthcare [7] and design experts often experience challenges in accessing NHS staff [8] [18]. Despite this, Healthcare professionals continue to develop software in the NHS [5] [12] and one such example is MachineLog.

Based on the analysis of different methodologies, there appears to be techniques that can be used by Healthcare Professionals who are designing software but are not experts in design. One such technique is contextual inquiry, used for investigating and understanding how and why software is not being used as intended. Furthermore, there are tools such as Personas that can be utilised. However, the use of personas has been widely debated.

Despite the debate surrounding the usefulness of personas, personas can be used to communicate the requirements of prototypes. Furthermore, by utilising techniques from Bill Buxton's 'Sketching Ideas', the look and feel of LinacLog can be envisaged, achieved by sketching ideas and interfaces on paper and by using interface design software. Therefore, the review has identified methods for developing prototypes.

This review identifies that evaluating software is challenging in healthcare, as many evaluation methods must also be performed by design experts. However, as the work of this thesis is embedded in the NHS, it easy to access other NHS staff and therefore to employ methods such as Usability Testing [8].

Chapter 5

The Study

Previous Chapters focused on introducing this thesis, introducing the context of this thesis and reviewing literature that allows us to investigate the lack of use of MachineLog. Previously in Chapter 2, Radiotherapy, including some of the high level work of the Radiographer and Radiotherapy Engineer, and some of the IT Ecology, was introduced. However, this high level introduction does not give a sense of the work that takes place when Radiographers and Radiotherapy (Machine) Engineers are reporting and responding to faults.

Therefore, to investigate the lack of use of MachineLog, a contextual inquiry study was performed. As such, the goal of this Chapter is to discuss the investigation that took place and the possible causes of MachineLog's lack of use, by discussing and modelling observations and interviews. These observations informed the creation of Personas and Scenarios, that are later discussed in Chapter 6, to inform the development of a prototype.

5.1 Methodology

5.1.1 Contextual Inquiry

The method that was selected for performing this study was the Contextual Inquiry approach, outlined in the literature review (Chapter 4). Specifically, the master/apprentice approach was used [6] by shadowing and watching, asking questions and learning the work performed by the radiographers. This provided insight into the sometimes abstract complexities in their work activities that one is not often exposed to.

The tasks for performing an interview were identified by using the the four principles of Contextual Inquiry[6]:

- Context
- Partnership
- Interpretation

- Focus

These four principles can be translated into:

- Going to the Linac Control Area
- Observing the participants performing their routine work
- Understanding the work of the participants
- Talking to the participants about their work during these observations

5.1.2 Selecting the Linacs

In this thesis, the environment to be observed is the Linac Control Area, therefore, Linear Accelerators were selected by consulting with Superintendent Radiographers, the senior radiographers responsible for staff workload. As part of their roles, the Superintendent Radiographers are aware of which Linacs are scheduled for patient treatment and are responsible for assigning Radiographer staff to these Linacs.

Therefore, with the agreement of the superintended Radiographers, three Linacs were selected:

- Linac A
- Linac B
- Linac 4

Although there are 6 Linacs at The James Cook University Hospital, it was unfortunate that 3 of these Linacs were not available for observation. This was because Linac 5 was undergoing decommissioning and Linac D was undergoing commissioning, meaning both Linacs were not in clinical use. Furthermore, Linac C was a struggle to gain access to for observations, due to availability of the observer and the Linac. This is interesting to note as there is sometimes a challenge for Healthcare Professionals in accessing the environments for observation, due to difficulties coordinating availability. Nevertheless, the other Linacs were able to be accessed and thus were able to be observed.

5.1.3 Selecting the Work

Two areas where MachineLog has the potential to be used are:

- The Morning Quality Assurance Session
- Routine use during patient treatment

Morning Quality Assurance (QA) starts around 07:30AM each morning on all Linear Accelerators that are schedule to be used for patient treatment. This QA is performed by at least one Radiographer. Simply, this includes warming up the beams on the Linacs and checking the beam outputs are within agreed tolerances. This was an obvious time to conduct the observations as it is this point a Radiographer may discover a fault.

After understanding the work of the radiographer for QA, further observations include QA leading into a patient treatment session were planned. It is important to note, patient treatment was not directly observed, only the work of the Radiographer within the Linac Control Area.

Both these areas of work have the potential for a fault to arise during use and requires the Radiographer to use MachineLog.

5.1.4 Selecting the Participants

There were 6 staff groups who participated in study:

- Therapeutic Radiographers
- Superintendent Therapeutic Radiographers
- Radiotherapy Assistants
- Clinical Technologists (Radiotherapy Engineers / Machine Technologists)
- Clinical Scientists (Medical Physicists as Machine Physicists)
- Student Radiographer (Minimal Participation)

The Radiographers were selected as they were the users of the Linear Accelerators (Linac) and are most likely to be present during a Linac fault, requiring them to use MachineLog.

Some but not all participants were selected as they had been identified as stakeholders in Machine Log. The Primary Stakeholders are both the Machine Technologists, being the users who use MachineLog for metrics and tracking faults, and the Radiographers, as they are being requested to use MachineLog to report faults and metrics. Machine Physicists were selected as secondary stakeholders as they have an interest in metrics although do not actively use Machine Log. Also included were Radiotherapy Assistants and Student Radiographers who do not use machine log but form part of the Radiographer's working activities by supporting the Radiographers use of the Linear Accelerator.

In total, over 7 observations, there were 33 directly observed participants which consisted of:

- 20 Therapeutic Radiographers
- 3 Superintendent Therapeutic Radiographers

- 3 Machine Technologists
- 1 Head Machine Technologist (Lead Engineer)
- 1 External Machine Engineer
- 1 Medical Physicist
- 3 Radiotherapy Assistant
- 1 Student Radiographer

All the participants were observed on one of the three Linear Accelerators (Linacs) at The James Cook University Hospital in Middlesbrough.

There were also 7 patients who were indirectly involved with the observation but do not form part of the scope because they were only present due to receiving the actual radiotherapy treatment. There were no direct observations of patients being treated as the focus of the observation was within the control area and not the Linac bunker.

It is worth noting that, although not directly observed during the study, from experience, Linacs can also fail during patient treatment which means the patient often needs to wait on the bed until the issue is resolved. This is so that the remainder of their radiation dose can be delivered. If a patient needs to be taken off the bed due to a fault, then their treatment would need to be re-calculated by Medical Physicists. Considering that the Radiographer has a great interest in the positive experience of the patient, this situation is not good and can often lead to high pressure working.

5.1.5 Collecting Data through observations

The primary source of data was obtained by using the contextual inquiry methods discussed in the Literature Review in Chapter 4, such as the master/apprentice method. The notes were made on paper during the observation for ease and very soon after converted into a timeline document. These timeline documents were used as the basis for the further analysis. An extract from one is given in Appendix C

During the first observation the initial 'cognitive load' meant that it was difficult to learn the activities by conducting only one observation. Therefore, the data was collected by using an iterative approach, building up a picture of common patterns over time and over several observations. After each observation was reviewed, a decision was made on whether to conduct another observation in a specific area if it was felt there could be more questions to explore and answer. This lead into multiple morning QA observations and multiple patient treatment observations. However, only one interview was needed for understanding the work of the Machine Technologists. This was because the understanding of the activities was sufficient enough to only need one interview.

5.1.6 Data Analysis - Reviewing the observations

Reviewing the data obtained from the observations led to the creation of Flow Models and Physical Models. These models were previously discussed in Chapter 4. These models visualised the complexities in interaction between people and systems, and visualise the environment.

Although other models were discussed in Chapter 4, such as the Artefact and Cultural models, it was felt that there was very little extra to capture by using these models. The observation focused on the use of MachineLog, the artefact of interest. The observations were aimed at capturing the work to give a sense of why Radiographers might not be using MachineLog, to solidify our argument that Radiographers should not use MachineLog to input fault information, in its current form. The observations, flow models and physical models sufficiently demonstrated that the work of the Radiographer is focused around patient treatment and the work of the Machine Technologist is focused around Linac maintenance and repair.

Furthermore, being aware of the intense nature of the work that Radiographers perform, and their influences, such as Senior Radiographers influencing the work, alongside documented procedures. it was decided there would be no more value added by using a cultural model to explicitly represent the lack of use of MachineLog.

The observations were outlined and discussed. Throughout, the observations built a picture of the goals of Radiographers and Machine Technologists. The goal of the Radiographers is to treat their patients and provide a good patient experience. The goal of the Machine Technologists is to repair and maintain Linacs when faults arise. These goals are important for unpacking the reasons why Radiographers might not be using MachineLog.

5.2 The Observations & Interviews

Each observation will be presented with an overview of what occurred during the interview and observation. The observations will include a flow model, which help to visualise the people and interactions and a physical layout diagram (where the physical layout differs between observations) in order to understand the ergonomics of the physical Linac control area.

However, before diving into the observations, the observations are presented in a table as an overview, displayed in Table 5.1, below.

5.2.1 Overview

All observations for this study were conducted in the Radiotherapy Department at The James Cook University Hospital in Middlesbrough, a hospital within the South Tees Hospitals NHS Foundation Trust.

Overview of Observations	
Observation	**Overview**
1) 17th of July 2018 on Linac B	This was first observation, lasting 1 hour and 15 minutes, with the purpose of understanding the activities of the morning quality assurance processes.
2) 8th of August 2018 on Linac 4	The second observation, lasting 50 minutes, uncovered multiple interruptions to Radiographers performing complex QA procedures. Furthermore, the observation suggests that Radiographers are focused on getting Linac 4 ready for clinical treatment.
3) 4th of September 2018 on Linac 4	The third observation, lasting 1 hour and 45 minutes observed a serious error that led the Radiographer to contact a Machine Technologist. This provided a good opportunity to expose the complexities in interaction during faults. This observation observes both morning QA and patient treatments.
4) 18th of October 2018 on Linac 4	The fourth observation, lasting 1 hour, observed activity during patient treatment only. It was clear that MachineLog is not useful during routine treatment activity.
5) 4th of September 2018 on Linac A	The fifth observation, lasting 40 minutes, observes activities during routine patient treatment. The observation suggested there was no situation where MachineLog would need to be used for recording faults.
6) 5th of November - Interview	An interview with a Machine Technologist, lasting 40 minutes, immediately leads into the fault/incident resolution process. I observe the point of view of the Machine Technologist.
7) 24th of January 2019 on Radiotherapy CT	A straightforward and uneventful observation of a CT scanner where MachineLog was not needed

Table 5.1: Summary of Observations

5.2.2 Linac Physical Layouts

Chapter 2 discussed the Linear Accelerator, its rooms and the IT ecology that helps drive Radiotherapy treatment. This section aims to illustrate the Linac Control Area, the area where the workstations that control the Linac and MachineLog are located. This visualisation is represented as a Contextual Design Physical Layout model.

Linac A (LAA) & Linac B (LAB) Control Area

Linac A, visualised in Figure 5.1, shares an identical layout to that of Linac B. Therfore, Figure 5.1 visually represents both Linac A & B's Control Areas.

This area consists of several clinical workstations that are used to operate medical software such as Mosaiq, and other workstations that are used to operate the medical imaging software and software that control the Linac. More of this can be seen in Figure 5.1.

The work performed in this area is discussed later, within the observations that were conducted.

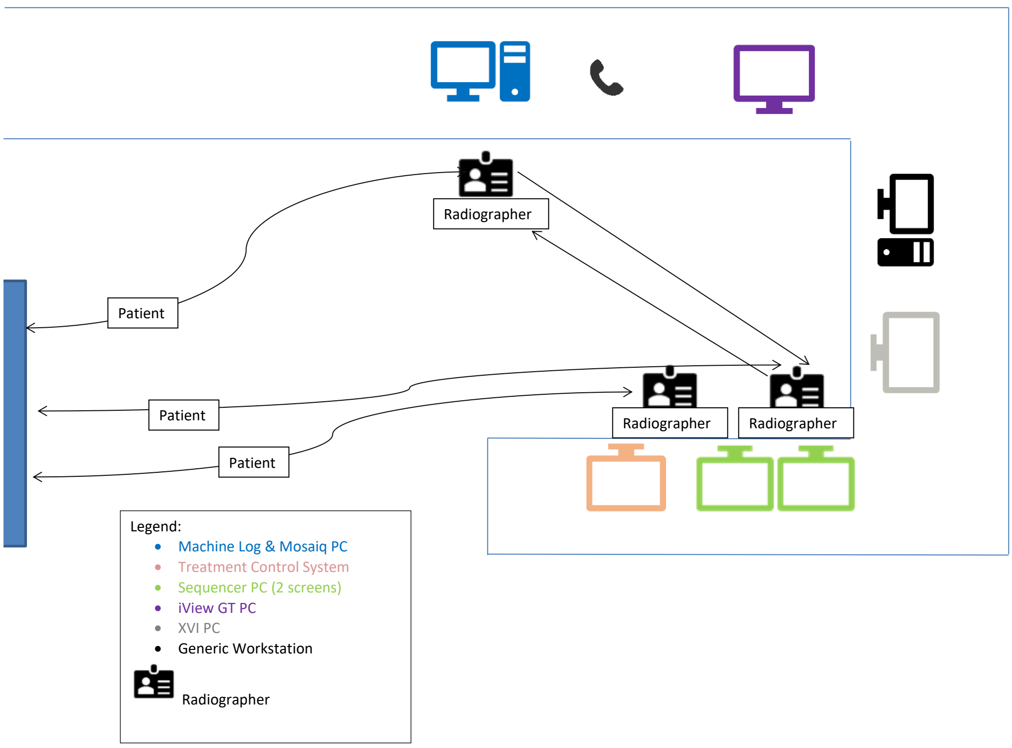


Figure 5.1: Linac A & Linac B Physical Layout Model

In this Layout Model, it is clear that MachineLog is located away from the main workstations that are used to control a Linac. The main workstations are the Mosaiq PC, Treatment Control System, XVI PC, etc. This is where the radiographer sits when operating the Linac and when treating their patients. MachineLog is indicated in blue on 5.1 and is important to note because the Radiographers are most likely to encounter an error using the workstations that control the Linac. MachineLog is out of view and behind the Radiographer whilst they are working in this area.

Linac 4 (LA4) Control Area

Unlike the previous Linacs that were observed, Linac 4 (LA4), visualised in Figure 5.2, is set out differently.

Nevertheless, the Linac consists of the same workstations that are used, with the exception of an additional workstation due to this Linac providing more specialist treatment options on top of standard treatment.

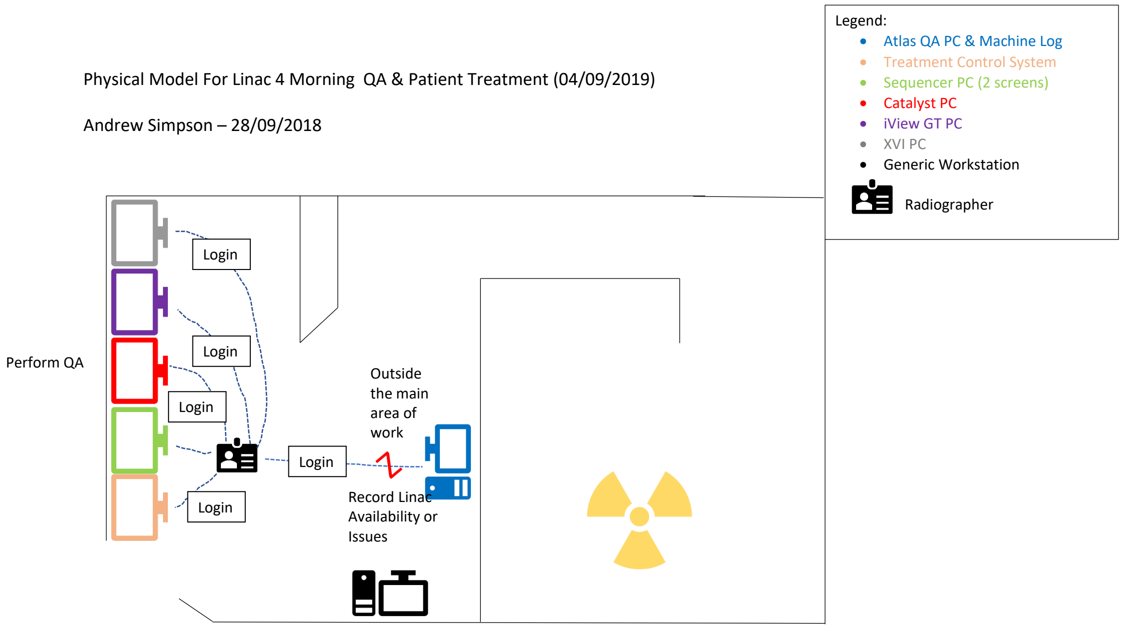


Figure 5.2: Linac 4 Physical Layout Model

Despite this layout being different to that of Linac A and Linac B, in this Layout Model, it is clear that MachineLog (in blue) is similarly located away from the main workstations that are used to control a Linac, and behind the Radiographers.

5.2.3 Observation 1: LAB - July 17th 2018

On July 17th 2018, during 07:30AM until 08:45AM, lasting 1 hour and 15 minutes, an observation was conducted for Linear Accelerator (Linac) B.

Earlier, in Chapter 2, it was mentioned that Radiographers perform basic morning safety checks for the Linac, ensuring that the Linac is safe to use on patients on their day of treatment. Therefore, the purpose of this observation was to discover the morning Quality Assurance process, in order to understand the workflows of the Therapeutic Radiographers. The mandatory morning QA is performed daily for compliance with the Ionising Radiation (Medical Exposure) Regulations and to check that the Linear Accelerator is safe to use for patient treatment on that day.

Usually, problems that may arise with Linacs are detected during this QA session and as such may provide insight into the interactions that occur when MachineLog should be used.

The staff directly involved and that were present in Linac B during this observation were:

- 4 Radiographers (RA1,RA2,RA3 & RA4)
- 1 Machine Technologist (MT1)

Other staff that were indirectly observed, i.e. not physically present in the Linac Control Area were:

- 1 Receptionist
- 1 Senior Medical Physicist (HMP1)
- 1 Lead Machine Technologist (HMT1)

The Observation

The radiographer logged into the Linear Accelerator's sequencer, which was a Windows 7 workstation. The workstation hosted the oncology information management system. The Radiographer also logged into several other workstations such as XVI. Eventually, the Radiographer logged into the QA workstation which has QA specific software such as Atlas QA. This workstation hosted the existing Machine Log.

Very quickly during this observation, one can see why morning Quality Assurance is essential. The radiographer notices that the Controlled Area 'Do not Enter' sign is not illuminating properly and reports this to the Machine Technologist over the phone. It became obvious that the radiographer preferred using the phone to report issues as opposed to an electronic system. The radiographer continues with the QA session until a Machine Technologist arrives. The Machine Technologist confirms that the sign needs a new bulb.

During the observation, the radiographer struggled to locate one of the phantoms, specifically, the phantom known as the Daily QA3™phantom (Figure 5.3). A phantom, in this context, is a technical term in Radiotherapy, used to describe an electronic device that accurately records the delivery of radiation, mimicking the properties and behaviour of a human. It is a device that supports Quality Assurance and in essence, it measures and verifies that the output of the radiation is as expected or planned. There are many different types of phantoms serving different purposes.

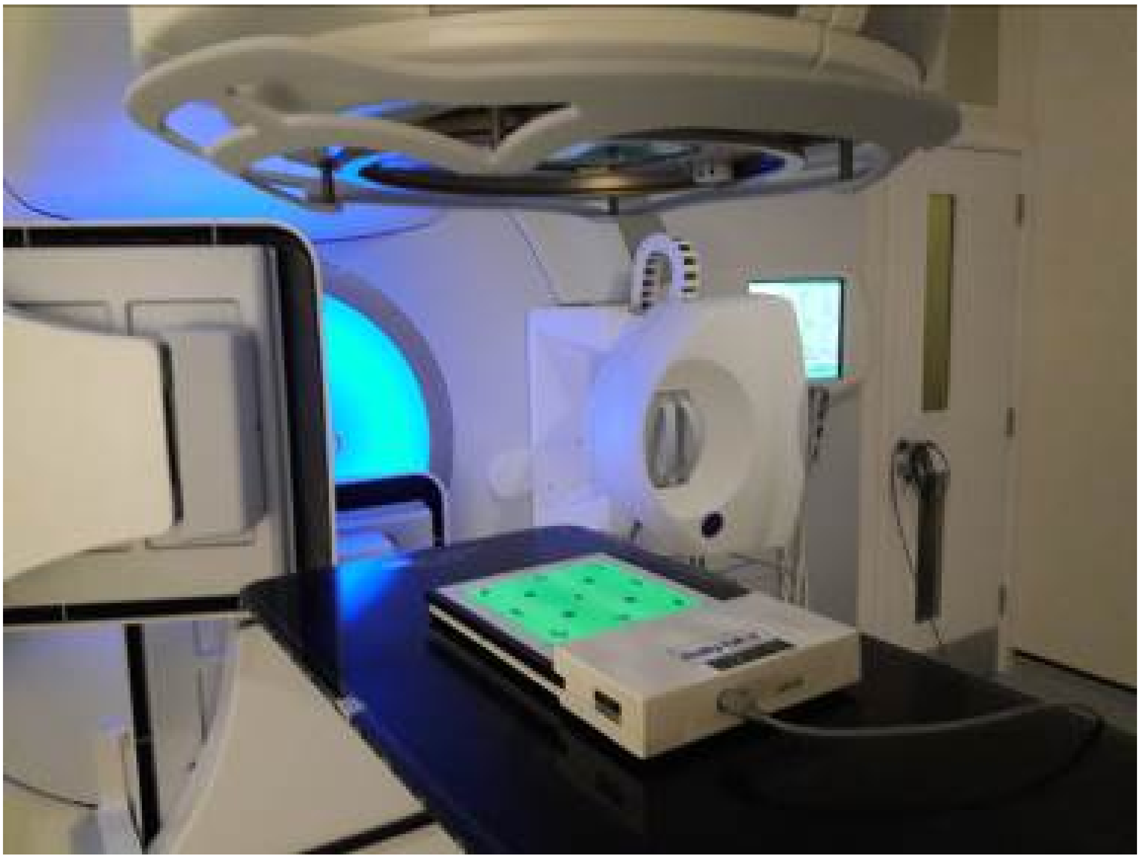


Figure 5.3: A QA3 Phantom. Source: The James Cook University Hospital

As the Radiographer was unable to locate this specific phantom, the Radiographer needed to borrow an identical phantom from another Linac. Therefore, the order of steps taken when performing Quality Assurance were done differently between the two Linacs, an interesting observation to note because the Radiographers should be following the steps in the same order as required in the documented procedure, on all Linacs. However, very interestingly the radiographer later discovers a QA3 phantom in the cupboard in the Linac Treatment room. Although, this tracking of phantoms is not managed by MachineLog.

It was observed that the radiographer received many interruptions from other staff, needed to work across multiple workstations and report issues with the Linac, whilst ensuring the Linac is ready for its first patient at 08:30AM. The observation concluded at 08:45AM.

Discussion

This observation can be visualised and represented as a Flow Model, displayed in Figure 5.4. Flow Models are visual representations of the work that is being performed [6].

The users of MachineLog are identified in the Ovals on the model and the devices/equipment and software that the users interact with, are identified in the rectangles of the model. Connecting the ovals (users) and rectangles (systems/devices/equipment) together are arrowed lines. The lines represent the interactions, and are captioned. The rectangular captions on these interaction lines represent a particular process, such as patient treatment or verification.

From the flow model in Figure 5.4, it is apparent that interaction during morning Quality Assurance is complex. The flow model also visually describes the interactions when the issue of the Linac Controlled Area Warning Sign arose during the observation. The handling of this issue should have been managed within MachineLog, instead it is apparent that the Radiographer calls the Machine Technologist (Radiotherapy Engineer). An early picture is built, suggesting that the Radiographer is highly concerned with performing morning Quality Assurance so that they can begin to treat their patients. There is no use of MachineLog during this observation. Furthermore, referring back to the physical layout model in Figure 5.1, it is clear that MachineLog is installed on a workstation away from where the Radiographer is performing their work.

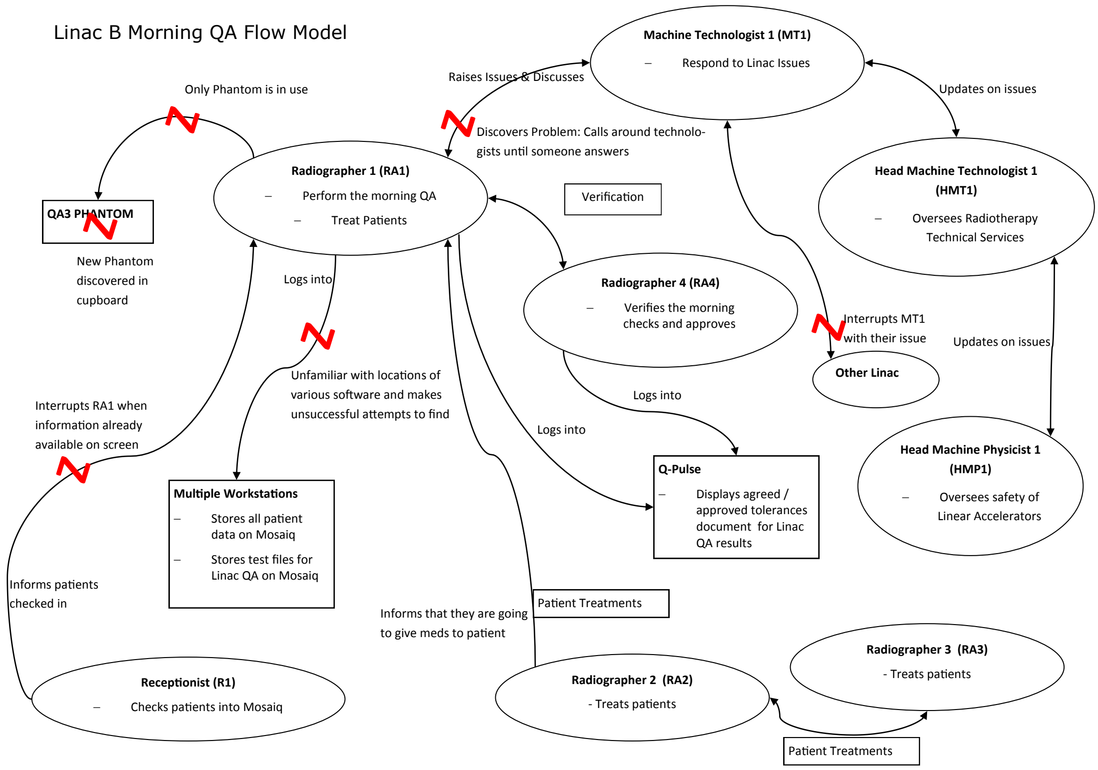


Figure 5.4: Observation 1: Flow Model for Linac B

Reviewing the flow model in Figure 5.4 highlights several breakdowns that add to the distraction of the Radiographer when performing their Quality Assurance. For example, the Radiographer is unable to locate a verification device (phantom) that is needed to perform their beam measurements. This results in the Radiographer contacting each Linac bunker for a spare device, without success. Therefore, the Radiographer must alter their working process to perform these measurements later. The Radiographer is being distracted by reception staff.

Furthermore, after the issue has been reported to the Machine Technologist, it is apparent that the Machine Technologist is receiving interruptions from other Linacs experiencing their own issues, initially suggesting that the work of the Machine Engineer is interrupted and perhaps not triaged. However, during this observation, the

Machine Technologists updates the Lead Engineer on their progress, whilst taking calls directly from other Linacs. This is important because the Lead Engineer is responsible for the Machine Technologists workload.

In summary, this observation suggests that the goal of the Radiographer is to complete the Quality Assurance and to begin treating their patients and that MachineLog is not being used when issues are discovered.

5.2.4 Observation 2: LA4 - August 8th 2018

On August the 8th 2018 at 07:24AM until 08:15AM, an observation was conducted for morning QA on Linac 4. The physical layout of Linac 4 can be found in Figure 5.2, earlier in this Chapter.

The people present during this observation were:

- 1 Radiographer (RA5)
- 1 Medical Physicist (MP1)
- 1 Radiotherapy Assistant (RAA1)

The Observation

The observation begins with the Radiographer 5 Logging into the many different clinical systems that they need for performing morning Quality Assurance. Interestingly, on this occasion, RA5 uses MachineLog to enter the start time for the QA session. According to the Machine Engineers, the recording of start time is something that does not happen without the Radiographers being reminded.

Similar to other observations, there is the possibility that RA5 was aware that I was there to observe the use of MachineLog, and thus may be explained by the Hawthorne effect, which is behaviour changes due to observation and is difficult to control [48].However, this was more apparant during this observation as RA5 appeared to be concerned by my observation, questioning whether it was for quality management auditing and as such, auditing of compliance to procedures. It was explained to RA5 that my role is to observe the use of MachineLog.

After logging in, Radiographer 5 (RA5) proceeded to the Linac Maze which leads into the treatment delivery area, and begins the setup of the alignment phantom, shown in Figure 5.5. This phantom is slightly different to the QA3 phantom discussed previously in Observation 1 (Figure 5.3) as this phantom is used to check the position of guidance lasers.

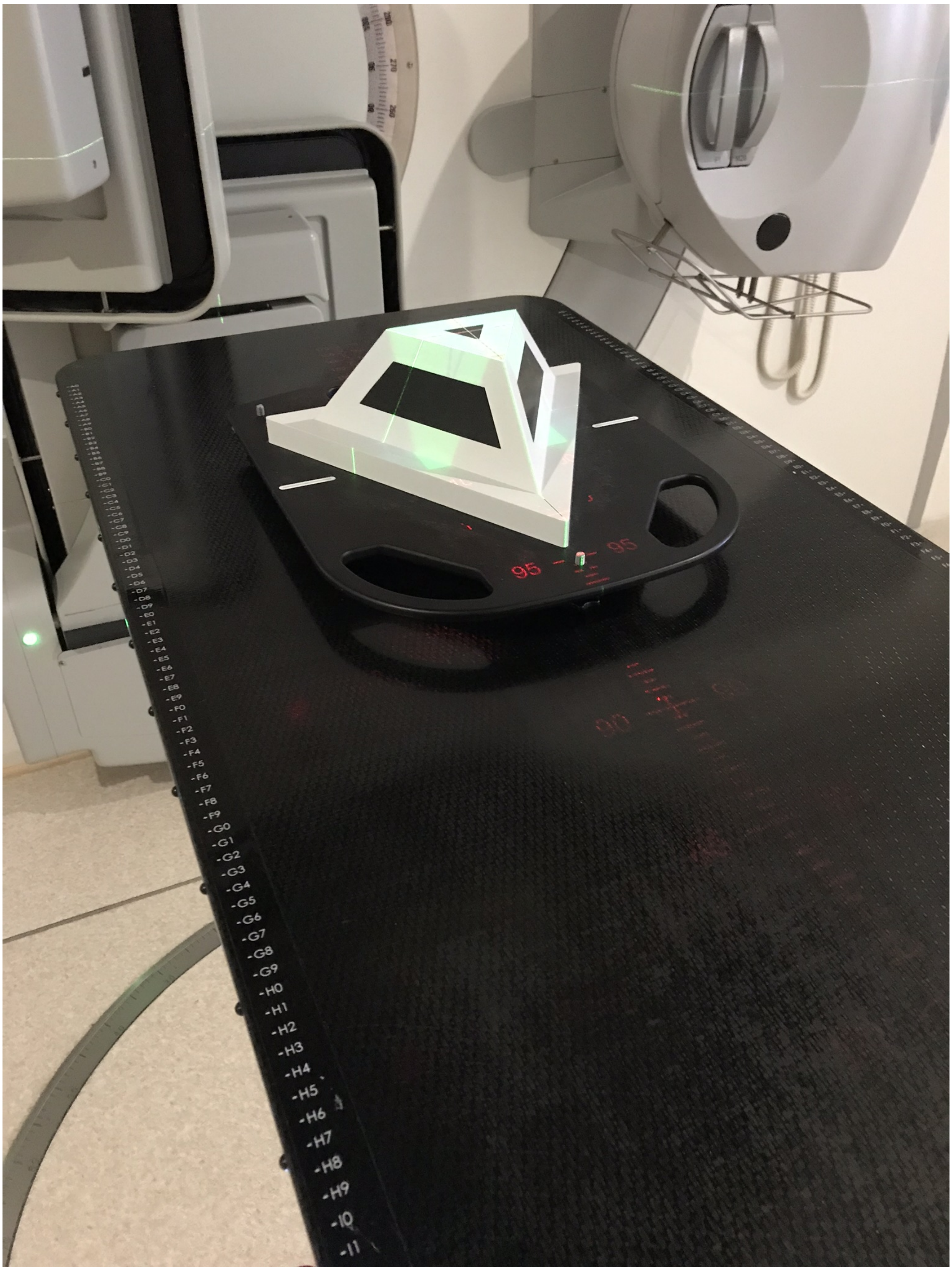


Figure 5.5: A Linear Accelerator Laser Alignment Pantom. Source: The James Cook University Hospital

Whilst RA5 was within the treatment delivery area, a patient entered the control area informing me that he has arrived 1hr early for his appointment and that he was unsure what to do but understands that he needs to undergo bladder filling preparation (a technique to fill the bladder with water in order to push the prostate into a good position). I then find myself interrupting RA5 by informing RA5 that a patient has arrived early and is seeking advice on bladder prep.

One of the questions I asked to Radiographer 5 at this point was "How do you know what to do?". RA5's reply was that they had been shown what to do a couple of times and there is a Standard Operating Procedure documented on Radiotherapy's document management system.

Immediately after, Radiotherapy Assistant 1 (RAA1) enters, asking if RA5 would like a cup of tea. RAA1 also asked RA1 if RA1 is happy for RAA1 to inform the early patient to start drinking water at 07:45. (The time was 07:35).

At 07:36, RA5 proceeds to load up Atlas QA, discussed previously in Chapter 2 as software involved in verifying the radiation beam. To load up Atlas QA, RA5 proactively minimises MachineLog. This is interesting because at this point, MachineLog is in the view of the Radiographer, but is not needed.

Unexpectedly, in this observation RA5 created an artifact, some scrap paper to draw a table in order to record the Dose Rate (DR) and Backup Monitor Units (MU) (Figure 5.6). This is important to note as it was decided that artefact models will not be used. However, this artefact was only created during this observation.

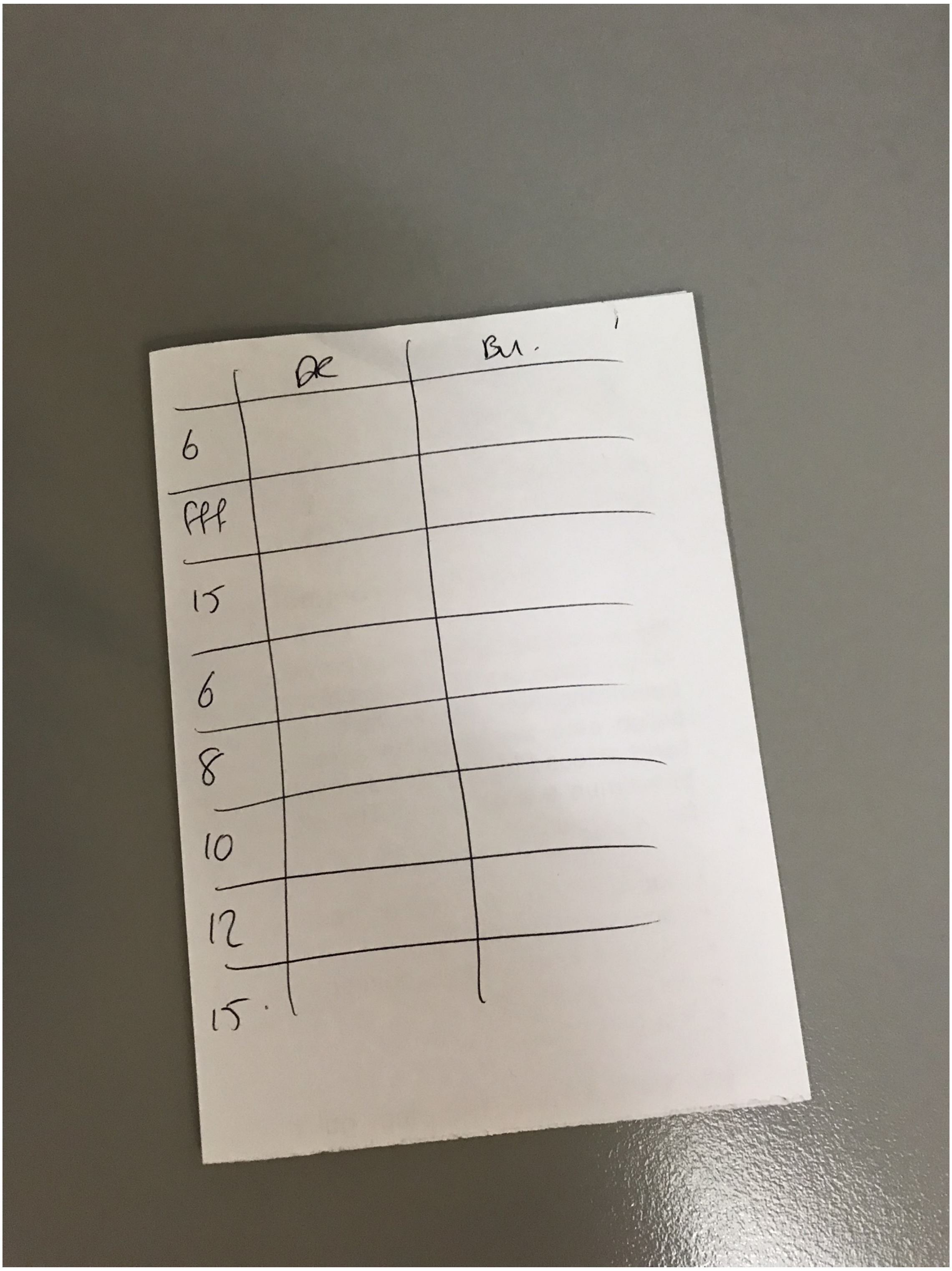


Figure 5.6: Dose Rate (DR) & Backup Monitor Units (BU) Paper Artifact

After creating the columns on the paper table shown in Figure 5.6, RA5 walked into the Linac treatment delivery area to setup the QA3 Phantom, a device which records the radiation (Figure 5.3). RA5 then watches the Linac Control screen which displays these values, and writes the values down after the beam has completed, shown in Figure 5.7.

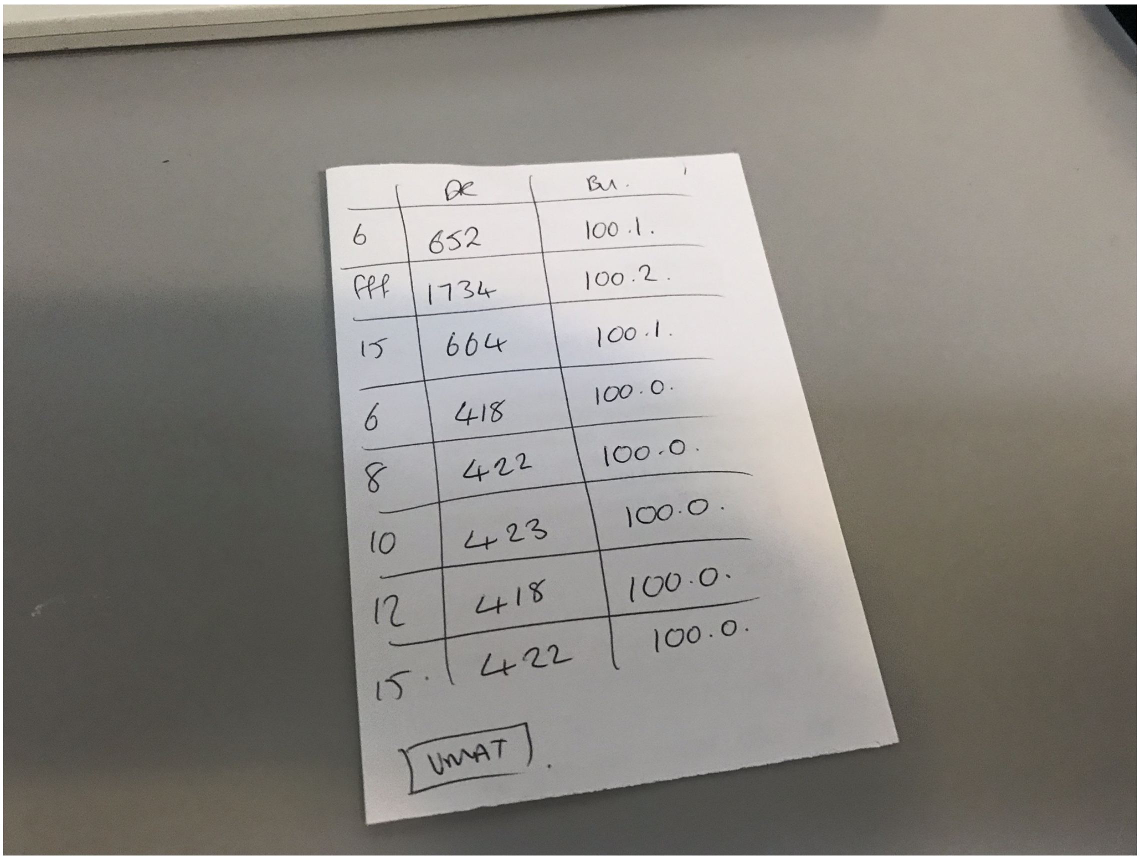


Figure 5.7: Dose Rate (DR) & Backup Monitor Units (BU) Paper Artifact Completed

RA5 then uses the QA software which is connected to the QA3 Phantom, to check whether the beam has passed or failed (Figure 5.8). This is done as a manual and software check. These checks were completed at 07:50.

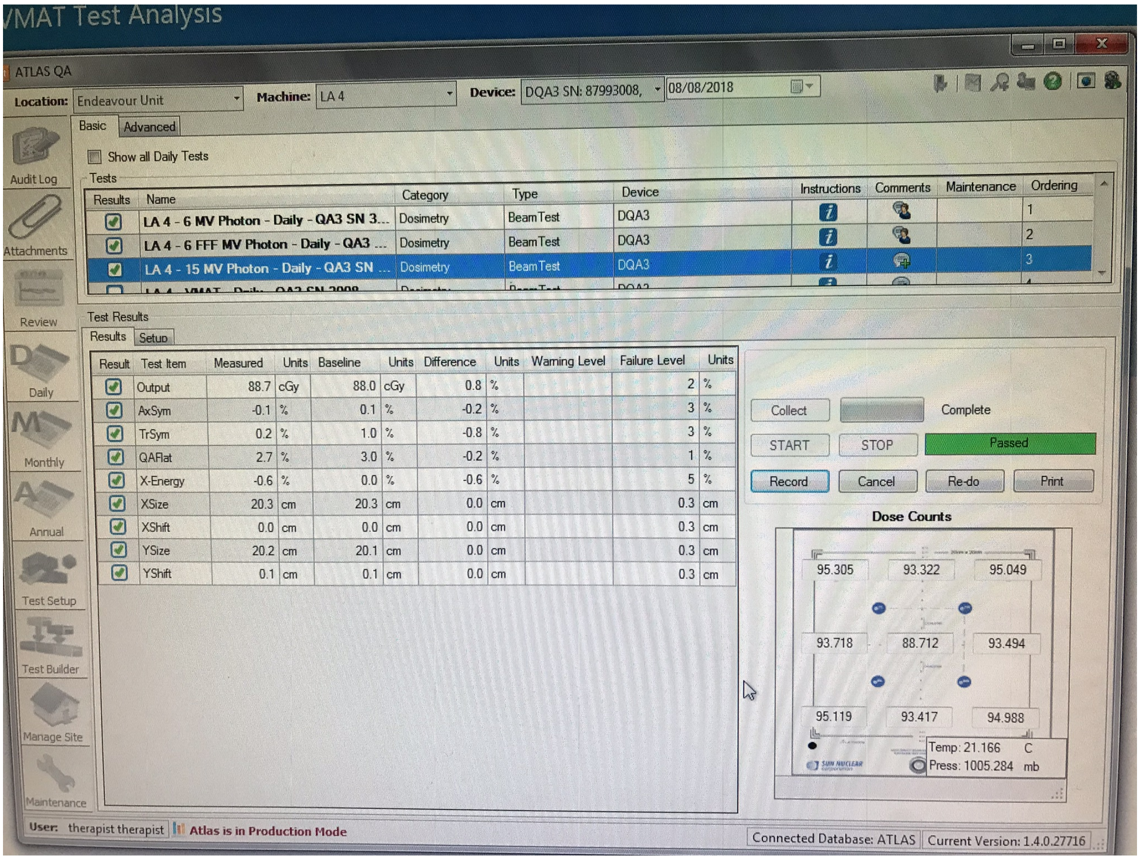


Figure 5.8: Beam Passing tolerance checks

At 07:52 RA5 warms up the imaging beams on the Linac in preparation of scanning the pentaguide, another type of phantom that is used for checking medical image quality on Linacs. Whilst this beam warm-up is in progress, the Radiographer opens up a checklist on the Mosaiq Sequencer PC (location shown in Figure 5.2).

The Radiographer completes this checklist (Figure 5.9) whilst waiting for the beam to warm up.

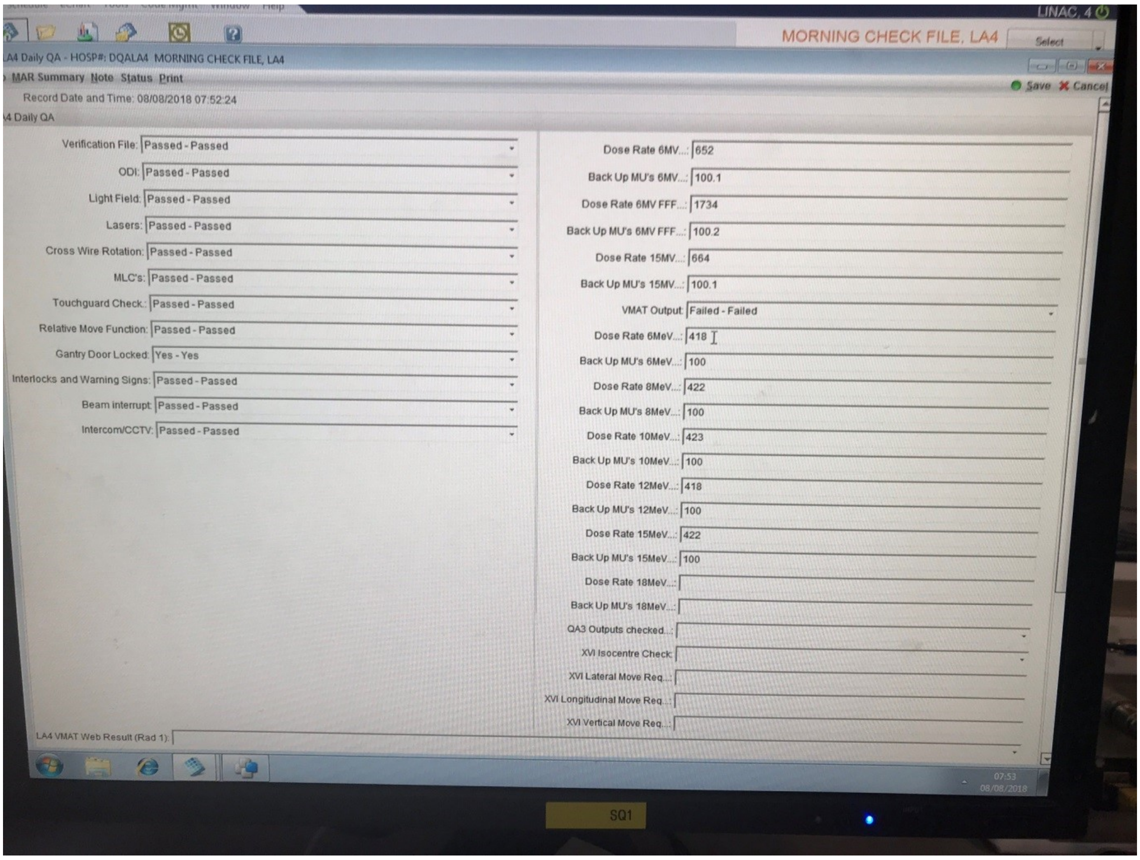


Figure 5.9: Morning QA Checks Checlist

At 07:55AM, the beam has warmed and RA5 enters the Linac Maze to setup the pentaguide and returns. RA5 loads up another file on the Mosaiq Sequencer PC. However, I noticed an error and questioned RA5 regarding this error. RA5 was unable to recall the error but re-loaded the file and the error displayed "Ensure there are no patients on the bed".

At 08:04, MP1 arrives and begins to use the workstation that hosts MachineLog. MP1 leaves at 08:10 and maximises MachineLog, bringing MachineLog into full view.

At 08:10, RA1 begins to treat their patient and as such, the observation concludes.

Discussion

The data from the observations was used to produce a flow model (displayed below in Figure 5.10), which allowed for visualising the interactions that occurred during the observation. The flow model highlights the breakdowns in interaction by using a red coloured Z. In this case, the breakdowns were that the Radiographer was interrupted several times during their morning Quality Assurance (QA) Session. For this observation, the researcher is represented on the Flow Diagram as a blue dashed circle. This is because the researcher needed to interrupt the Radiographer due a patient entering the Linac Control Area seeking clinical advice. Including this on the diagram provides a sense of the interruptions a Radiographer might experience whilst performing QA.

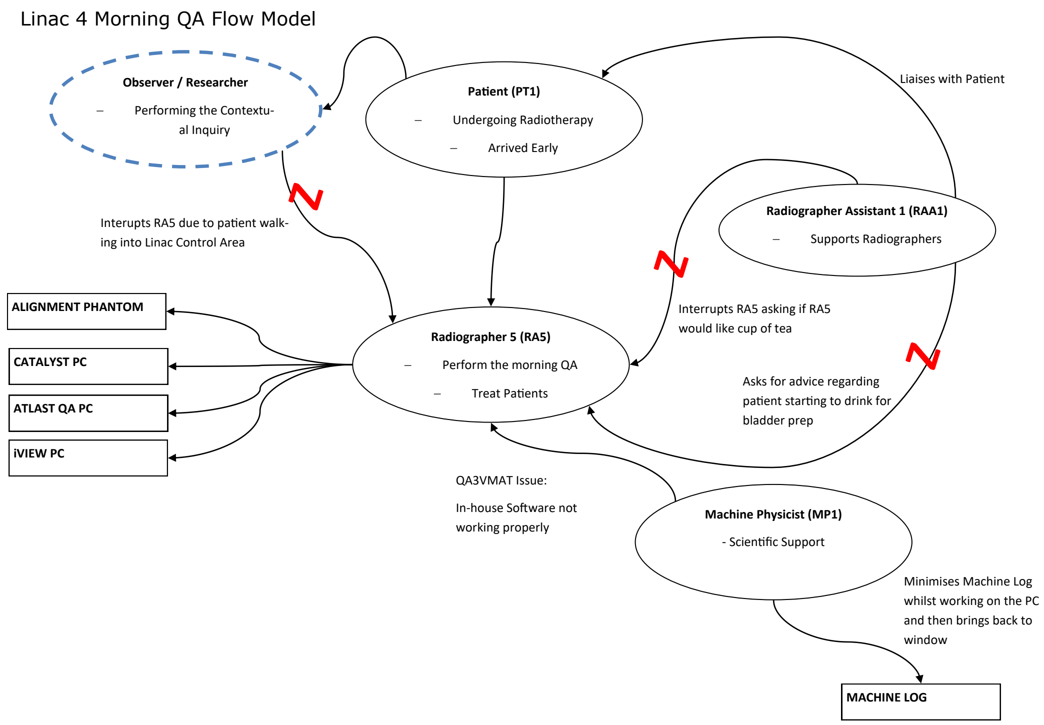


Figure 5.10: Observation 2: Flow Model for Linac 4

It is important to note that throughout this observation, Machine Log was used once to enter the start time by the Radiographer. However, similarly to previous observations, this could have been done as the radiographer was aware that I was observing how MachineLog is being used [48].

Previously, in the literature review (Chapter 4), it was mentioned that design experts experience challenges in observing healthcare professionals. In this instance, the observer experienced a similar challenge shared by design experts, the wariness of healthcare professionals undergoing observation due to blame [19]. There was concern that the observer was there to observe practice and report this practice. Nevertheless, the observation was able to be performed, although this may have introduced a behaviour change, prompting the radiographer to use MachineLog at the very start of the observation. However, MachineLog was not used again to input data during the observation, it was only minimised and maximised, therefore, the end of the QA session was not recorded in MachineLog.

During the observation and visualised in the flow model, there did not appear to be a situation where MachineLog would need to be used. The recording of the start time is of interest as the Machine Technologists are interested in the uptime and usage time of the Linacs. However, the goal of RA5 was to perform morning QA so that RA5 could begin to treat the patients scheduled on Linac 4 for that day.

5.2.5 Observation 3: LA4 - September 4th 2018

On September the 4th of 2018 at 07:15AM until 09:00AM, a further observation was conducted for the Morning QA on Linac 4. This observation differs to the previous two observations, as both morning QA is observed and the work of the staff is observed during patient treatments.

The staff involved in the observation were:

- 4 Radiographers (RA6,RA7,RA7 & RA9)
- 2 Superintendent Radiographers (SIR1 & SIR2)
- 2 Machine Technologists (MT1 & MT2)
- 1 Student Radiographer (ST1)

The Observation

The observation begins with the morning QA at 07:15AM. Radiographer 6 (RA6) logs into the sequencer machine to load the QA check file. Whilst doing this, one of the workstations freezes so RA6 heads into Linac 4's treatment delivery area to set up the laser alignment phantom, which was previously displayed in Figure 5.5. After the alignment tests have been performed with this flag phantom, RA6 then configured the QA3 Phantom (Figure 5.3).

Whilst observing RA6 setting up the alignment phantom, RA6 mentioned some issues around XVI that are on-going as a separate project, and the progress of this project. This is interesting to highlight because it demonstrates that NHS staff observing NHS staff are able to observe one another under the context of daily working activities.

After the alignment phantom has been set up, RA6 returns to the Linac Control Area and begins to warm up the clinical beams on the Linac. Interestingly, RA6 creates an identical grid, on paper, to that of the previous observation (Figures 5.6 and 5.7). At 7:30AM, RA6 loads up the morning QA checklist stored on the Mosaiq Sequencer PC and logs into other systems such as AtlasQA (Figure 5.2).

Whilst these workstations were loading various software, I asked the Radiographer "How do you know what to do for daily QA?". RA6 mentioned that there are various policies and procedures documented in the Quality Management System, and those are followed with a mixture of on the job training. RA6 also mentioned that they had learned a 'few tricks on the way'.

At 07:50, RA6 encounters a critical error with Linac 4 (Figure 5.11). This error has occurred a few times previously so RA6 is aware of what the error could be.

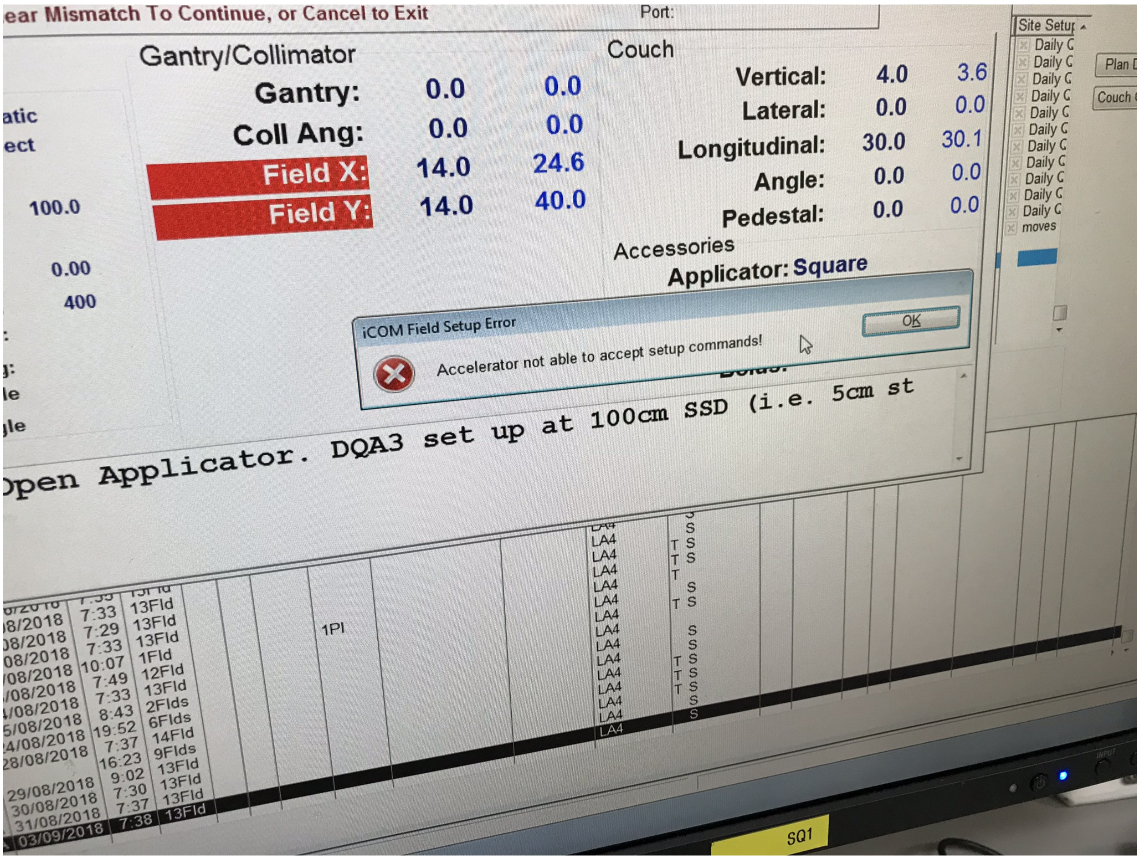


Figure 5.11: An error on LA4

Whilst RA6 set up the QA3 Phantom earlier, RA6 attached a device known as an applicator, a device designed to reduce radiation scatter (Figure 5.12).

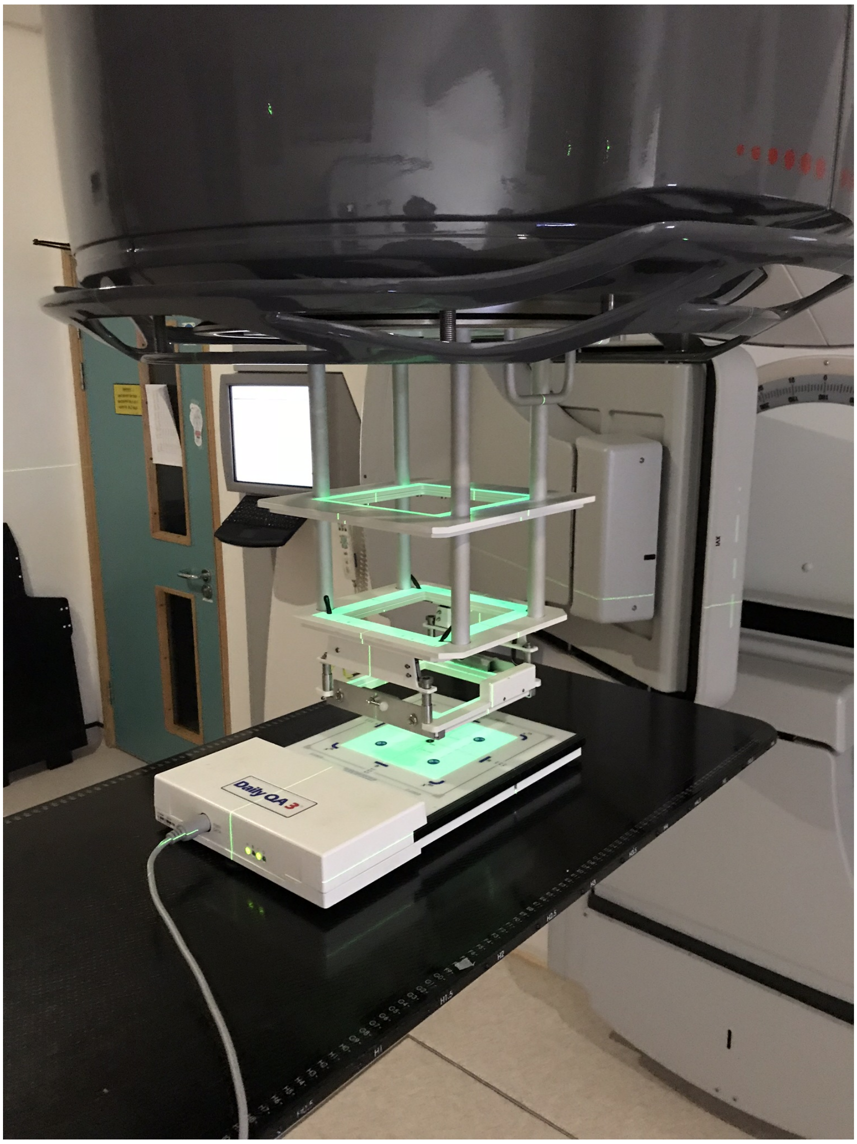


Figure 5.12: A Linear Accelerator Applicator slotted into the Gantry reducing scatter to a phantom with a QA3 phantom below

RA6 suspects that the error is caused by the Linac thinking that this metal applicator is colliding with something. The Radiographer attempts to solve this by wobbling the applicator to ensure it is secured in place and attempts to fix it themselves. However, this attempt was futile as the error persisted. at 07:55, RA6 attempts to locate the contact numbers for the Machine Technologists. However, RA6 can not find the telephone numbers and flagged down a passing 3rd party radiotherapy engineer (who works for the manufacturer).

The 3rd party Radiotherapy Engineers then contacts a Machine Technologist (MT2), who is a trainee. MT2 then proceeds to contact MT1, an experienced Machine Technologist and MT1 instructs MT2 to deal with another issue that MT2 was previously working on. At this point, there is no involvement of the Lead Machine Technologist, who is responsible for allocating tasks to their Machine Technologists.

At 08:15, a Superintended Radiographer (SIR1) enters LA4 to check on RA6's QA. RA6 mentions the on-going issue which has a potential to cause delay to starting treatment. However, RA6 also mentions that LA4 is understaffed. RA8 who is yet to arrive, has been on leave for 6 weeks and needs extra support whilst phasing back into the work. SIR1 leaves LA4 in search of the Radiographer Rota.

At 08:20, SIR1 re-enters and informs RA6 that there is an urgent patient. SIR1 is frustrated as there are no Linacs that are ready to begin patient treatment, available. All linacs are undergoing there morning QA checks. It seems that all the Linacs are experiencing delays during their QA.

RA6 asks for an update from MT1 and both discuss the issue. At this point, I asked MT1 how they were made aware of the issue. MT1 mentions that MT2 received a phone call from the 3rd party engineer. MT1 was then contacted by MT2 on a different phone.

It is now 08:30, the time that patient treatment should begin and the issue is still unresolved. RA6 becomes frustrated that they are now running behind for treatment. However, minutes later at 08:31, MT1 informs RA6 that the issue is resolved.

At 08:30, student Radiographer 1 (ST1) also enters Linac 4 because the CT area is too busy to accommodate ST1, and is now unsure as to where they should be for the day. RA7 informs ST1 that they are welcome to observe them for the day if other areas are busy.

At 08:32AM, RA7 arrives to second check the morning QA results. This happens quickly and RA7 leaves. Shortly after, RA8 enters. At 08:34AM, RA6 contacts another Linac to ask for further assistance. RA6 has noticed that no one on Linac 4 is trained to perform Deep Inspiration Breath Hold (DIBH) radiotherapy, a skill reserved for senior Radiographers. A patient scheduled for the morning requires this technique.

At 08:35, RA6 and RA8 call in the first patient (PT1) for treatment and proceed to setting up PT1 on the bed, ready for Radiotherapy Treatment. at 08:40, treatment is delivered to the first patient.

At 08:40, RA9 arrives to support the other radiographers on Linac 4, for that day.

At 08:45, Superintended Radiographer 2 (SIR2) enters the Linac 4 Control Area in preparation for the DIBH patient (PT2). Once PT1 has completed their treatment, SIR2 and RA7 call for PT2 and lead them to the treatment bed and setup PT2 for treatment.

The observation was concluded at 09:00AM.

Discussion

Like previous observations, the data from this observation was able to be visually represented as a flow model (Figure 5.13).

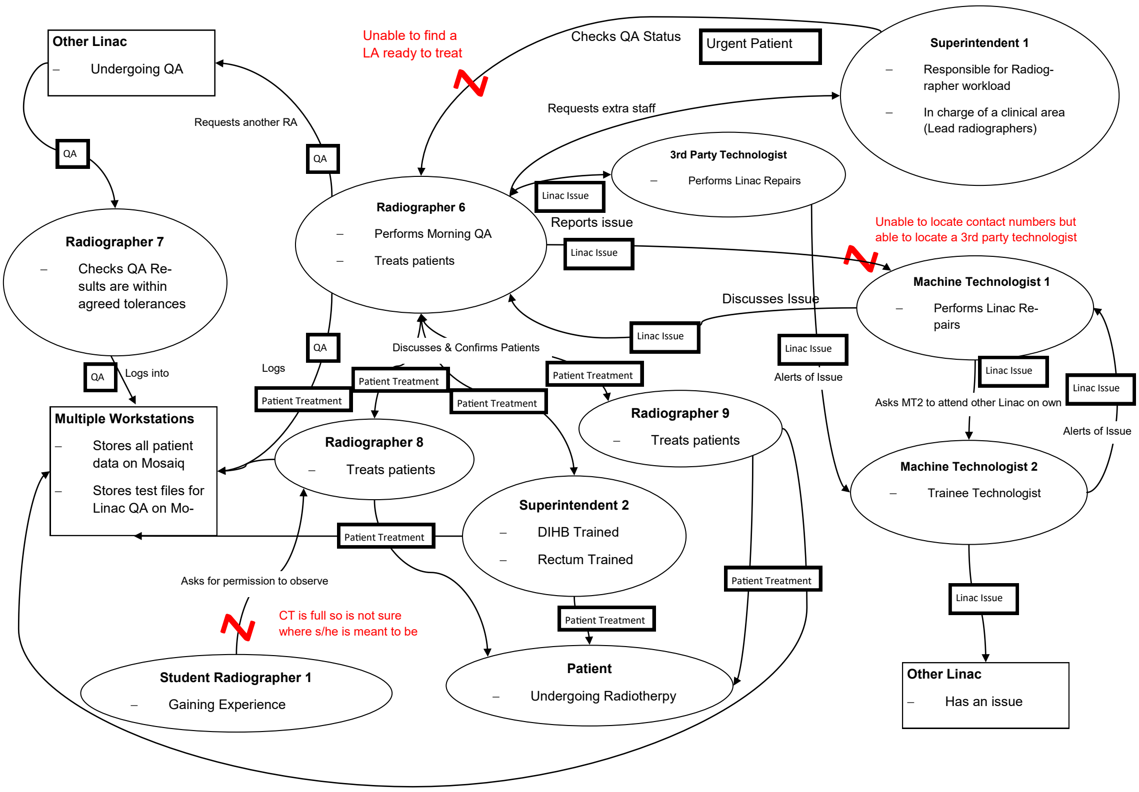


Figure 5.13: Observation 3: Linac 4 Flow Model

Reviewing the flow model demonstrates the complexities in interaction within Radiotherapy. The diagram shows that there were breakdowns (Red Z) when attempting to locate the Machine Technologist's phone number. At this point, MachineLog is something that should be used to report a fault. However, it was observed that MachineLog was not used for recording the fault that occurred during this observation.

Furthermore, SIR1 was unable to find any information as to which Linacs are available for patient treatment. However, MachineLog does not lack the function to record treatment availability, as was demonstrated in Chapter 3. However, it is clear that MachineLog is not being used for recording availability, or that SIR1 is not using MachineLog to check availability.

By capturing the areas of work that staff are working within (for example, QA and Treatment, identified in boxes on the flow mode), it can be visualised that much of the work of the radiographer during this scenario is to perform QA and begin treating their patients. The Linac issue is reported but the work to resolve that issue happens away from the Radiographer. Although, the Radiographer is kept informed with the progress.

5.2.6 Observation 4: LA4 - September 18th 2018

On September 18th 2018 at 13:40 until 14:40, a further observation was conducted in Linac 4 (Figure 5.2). Unlike the previous observations, this observation steps away from the morning QA and observes patient treatment activity only, on Linac 4. However, it is important to note that patients were not directly observed. The goal of this observation was to understand the work performed by the Radiographers surrounding the use of MachineLog, whilst treating a patient.

The staff involved in the observation were:

- 5 Radiographers (RA10, RA11, RA12, RA13 & RA14)
- 1 Superintended Radiographer (SIR3)
- 1 Radiotherapy Assistant (RAA2)

The Observation

When arriving at the Linac treatment unit, the Linac was already well into patient treatments and bustling with various different staff. Morning Quality Assurance had already been performed and the Radiographers were well within their routine clinical work. Radiographer's 10 and 11 were in the treatment delivery area positioning the patient for treatment. Others in attendance included a Radiotherapy Assistant 2 (RAA2) who performs administrative tasks such as finding patient notes in the Oncology Information Management System, and another two Radiographers (RA12 & RA13) there for support.

After the two Radiographers had returned from the Linac Maze after positioning the patient, they sat down at the Mosaiq Sequencer and confirmed the patients details. After both Radiographers agreed that the patient was the correct patient, positioned correctly and image matched, one of the Radiographer pressed the beam on button on the Function Keypad.

During the treatment of this patient, at 13:45, another radiographer requests some information relating to a different patient.

At 13:50, The patient treatment is complete and two of the radiographers head into the Linac Maze to retrieve the patient, assist them with their dressing and then call in the next patient.

A superintended Radiographer steps into the control area and asks if they can squeeze in an urgent patient. However, at this point, the next patient was already positioned on the bed by the Radiographers in the Linac Maze. This means the urgent patient would need to wait for this patient to finish treatment.

At 13:55, the next patient begins treatment. The Radiographers follow the same process of checking and verifiying the patient on the oncology management system. This happens for the remaining patients during treatment, a smooth process of checking in and checking out patients.

Discussion

This observation highlighted that, when Radiotherapy treatment is in process and the Linac fully operational, the delivery of radiotherapy is the key focus and goal for the Radiographer. There are no situations where MachineLog is needed to be used during these treatments.

The observation was visualised using a flow model (Figure 5.14).

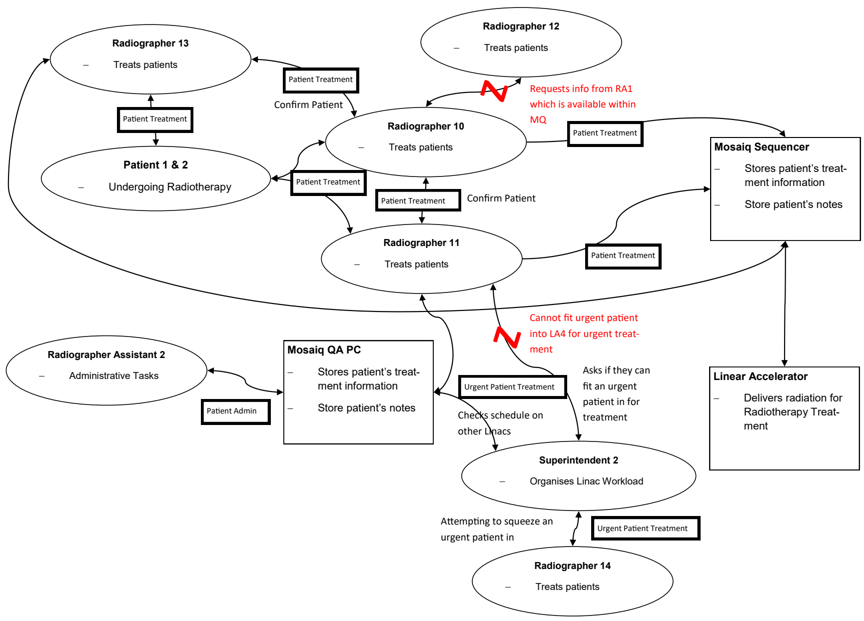


Figure 5.14: Observation 4: LA4 Flow Model

Reviewing the flow model shows that much of the processes are focused around patient treatment. This further suggests that the goal of the Radiographer is to treat their patients. While Radiotherapy treatment is working correctly, the Radiographers are not interested in how the Linac is function and therefore, not concerned with MachineLog during routine patient treatment.

5.2.7 Observation 5: LAA - October 3rd 2018

On October 3rd 2018 at 14:30 until 15:10, a further observation was performed. This time, the observation was performed at Linac A (LAA) (Figure 5.1).

Those participating in the observation were:

- 5 Radiographers (RA15, RA16, RA17, RA18 & RA19)
- 1 Radiotherapy Assistant (RAA3)

The Observation

Upon arriving, RA15 is operating the Mosaiq Sequencer Workstation (Figure 5.1) and RA16 & RA17 are within the Linac treatment room with a patient, assisting the patient on to the treatment bed.

However, this patient requires an oesephagus scan. Therefore, at 14:36 RA16 contacts a Superintendent Radiographer, who then organises to send another Radiographer for assistance. Not all Radiographers are trained in performing these scans.

At 14:40, RA18 arrives to assist the other Radiographers. RA15 and RA16 confirm the patient details are correct and verified within the oncology information management system.

At 14:44, the patient treatment is complete. However, RA19 enters and leaves as RA19 was sent to Linac A, but was not needed. The patient then leaves Linac A.

RA16 is concerned about one of their other patients that they are due to treat that day. The patient has received two scans. However, for a patient to receive another 3rd scan, special permissions needs to be given by Medical Physicist (Clinical Scientist), due to radiation protocols.

At 14:54, the next patient is called in for treatment and assisted into the treatment room by the RA15 and RA16. Whilst this is ongoing RA15 contacts RAA3 to re-arrange ambulance drop-offs for patients.

At 15:08, treatment has competed for this patient and at 15:10, the observation is concluded.

Discussion

This was a shorter observation as treatment delivery was progressing without issue. The data from this observation informed a flow model (Figure 5.15).

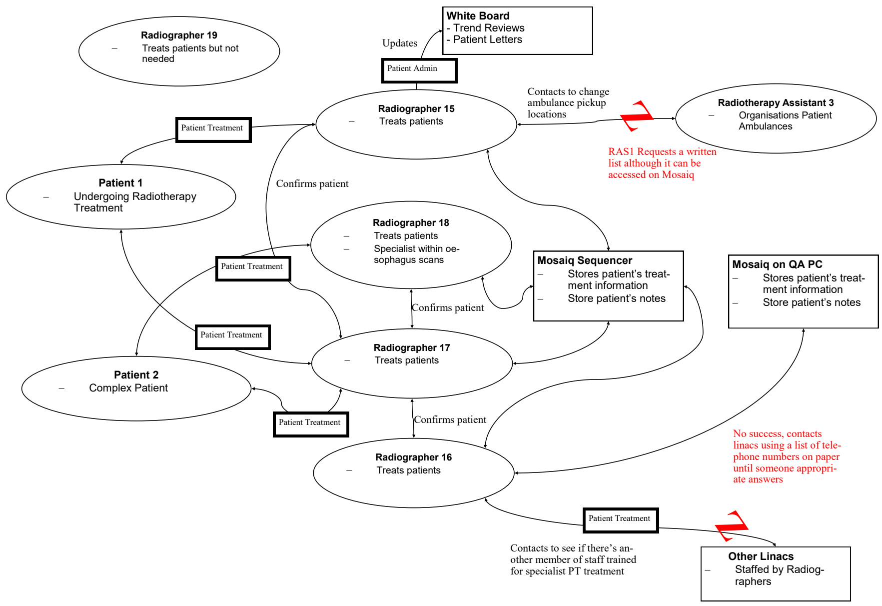


Figure 5.15: Observation 5 LAA Flow Model

Reviewing the flow model shows that much of the work of the Radiographer surrounds patient treatment. The only breakdown on the flow model was that the Radiographer struggled to find a contact number for a superintended Radiographer. In this case, MachineLog would not need to be used. Therefore, the flow model suggests that the goal of the Radiographers are to treat patients.

5.2.8 Observation 6 & Interview 1 with MT1 - November 5th 2018

On November 5th 2018 at 14:35 until 15:15, an interview with Machine Technologist 1 (MT1) was conducted. The aim of this interview was to perform a question and answer session.

Questions were prepared in advance. However, the interview was immediately cut short due to an urgent issue on Linac A (LAA).

Those involved in the observation were:

- 1 Machine Technologist (MT1)
- 2 Radiographers (RA19 & RA20)

The Interview & Observation

At 14:36, MT1 immediately received a call from LAA. Brief information was provided but it was suggestive that there is an issue with an XVI panel on Linac A.

Immediately, we walk to LAA. LAA is located opposite the Machine Technologist's office and is not far to walk. Upon arrival MT1 questions RA19 over the issue, in an attempt to tease more information from RA19. RA19 explains the issue. RA19 was concerned that there is a patient waiting for treatment. Although, there was no patient on the bed currently. MT1 began to work quickly to resolve the issue and acknowledged that this is a frequent issue.

At 14:43, MT1 has resolved the issue. Interstingly, at this point, MT1 heads over to the Linac Control Area workstations and checks to see if the Radiographers have used MachineLog to record the fault. It is apparent that the Radiographers have not completed MachineLog, much to MT1's frustration.

MT1 prompts RA19 to complete MachineLog. However, RA19 is busy and asks RA20 to complete MachihneLog. RA20 asks RA19 what time the incident start and RA19's response was "around 5 minutes ago". This suggests that even if MachineLog is now used in this observation due to MT1s requirement, MachineLog is not accurate.

Observation Discssion

The observation was visually represented as a flow model (Figure 5.16).

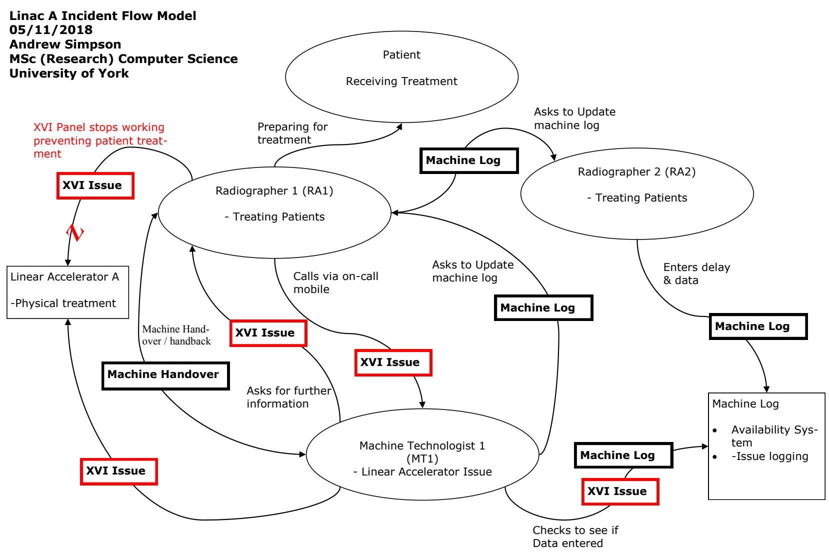


Figure 5.16: Observation 6 Interview with Machine Technologist Flow Model

Reviewing this flow model, it is clear that this is a situation where MachineLog should be used. However, MachineLog is only used when prompted by MT1. The work that happens to resolve the fault happens away from MachineLog and the Radiographers. The goal of the Radiographer is to treat their patients, and thus the Radiographers wait for Linac A to be fixed so that treatment can be resumed. Considering that MT1 demands that MachineLog be completed the Radiographers, much to their frustration, it is apparent that MachineLog is not something that is considered by Radiographers during faults or failures because they are concerned with ensuring that the patient is comfortable or informed during any delay.

The Interview

After the incident, the interview begins with MT1. Questions were prepared in advance. The interview lasted from 14:55 until 15:15, due to time constraints.

The interview uncovered frustrations experienced by Machine Technologists. The Machine Technologist has the option to discuss issues at a Machine Meeting, a meeting where Machine Technologists, Medical Physicists and Senior Radiographers gather to discuss Linac issues.

The interview suggested that Radiographers also attempt a first-fix of the Linacs. Some of this self-troubleshooting of the Linacs does resolve an issue, for exmaple, a reboot of a workstation. However, this frustrates the Machine Technologists as they are not able to keep a track of these types of issues and faults because they are not reported at all.

On the other hand, Machine Technologists are aware of faults despite the lack of use of MachineLog because the Radiographers need to call them for help. It is clear that during the interview, the Machine Technologists are frustrated that the Radiographers are not using MachineLog to record faults properly and a great deal of blame is placed on Radiographers for the inaccuracy of recording faults.

During the interview, The Machine Technologist suggested that the work to improve MachineLog would be to ensure Radiographers used MachineLog. This demonstrates that Machine Technologists are convinced that the recording of faults should be performed by Radiographers.

Furthermore, it became clear that the Lead Machine Technologist was very interested in improving the coordination of the work for Machine Technologists, suggesting that there is a need to triage and assign faults to the most appropriate member of the team. This is because the Machine Technologists feel that some members of their team are getting more of the interesting work and that the Radiographers on the Linacs are contacting their personally preferred Machine Technologists.

However, despite MachineLog having the functions to record faults, it appears the Machine Technologists are keeping their own records of faults and as such, are not using MachineLog to do this, despite demanding Radiographers enter fault information into MachineLog.

During the interview, there was a whiteboard on the wall (Figure 5.17). This whiteboard had information around faults. This suggests that MachineLog is not used by the Machine Technologists in this respect, although the functionality in MachineLog exists.

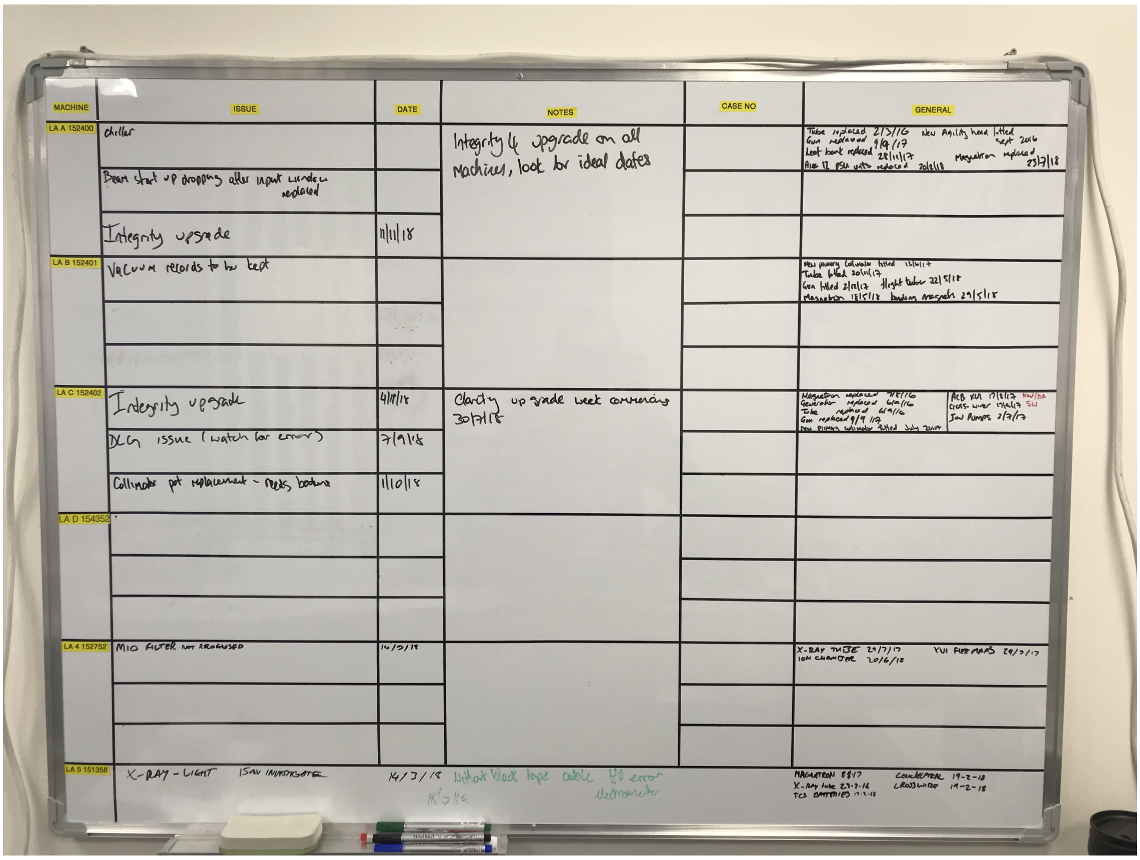


Figure 5.17: Whiteboard inside the Machine Technologist's Office

5.2.9 Observation 7: CT - January 1st 2019

On January 1st 2019 at 10:30AM until 11:30AM CT was observed. The observation showed a routine and uneventful scanning of patients. CT is an area which potentially could use machine log, however during this observation it was evident that there was no situation for using machine log. The repair and maintenance of CT scanners is beyond the scope of the Machine Technologist. This is performed by an external contractor.

As MachineLog is not used for Radiotherapy CT, the observation was not represented in a flow model.

5.3 Discussion

The contextual inquiry study involved performing seven observations for learning and understanding the complex work and goals of the Radiographers and Machine Technologists. In summary, the observations suggest that the goal of the Machine Technoogist is to resolve faults that arise when operating Linacs. The goal of the Radiographer is to treat patients using the Linac. The Machine Technologists are not directly involved with the work of the Radiographers. However, Machine Technologists demand that the Radiographers use MachineLog.

When a fault occurs, the Radiographers' goal shifts towards coordinating the care of their patients whilst treatment is delayed. The Radiographers need to sit at a workstation to enter fault information into MachineLog, taking the Radiographers away from the coordination of their patients. This could explain why Radiographers do not use MachineLog, because it does not align to either of their goals.

5.3.1 The Users and Types of Activity

The observations identified the staff (users) who are using MachineLog and highlighted the activities that are performed by the users while they are using MachineLog. The users and activities were visually represented as flow models. Furthermore, the observations identified that the physical layout of each Linac can differ. Although, some Linacs share identical layouts. There is no standard layout for Linacs.

The first intended user is the Radiographer. The goal of the Radiographer is to first, ensure that the Linacs are safe to use for their daily treatment schedule by performing morning Quality Assurance, and secondly, treat their patients with the Linac.

Each morning, Quality Assurance safety checks are performed. This procedure is documented and governed by the Quality Management System. However, Radiographers have developed their own style of Quality Assurance. Sometimes, breakdowns such as locating phantoms for beam verification, lead to this procedure being altered. However, MachineLog is not intended to manage the availability of these phantoms. Furthermore, other factors influence the order in which Quality Assurance checks are performed, such as resource allocation (staffing) or failures of components that do not prevent the Radiographer from performing other safety checks.

For patient treatment, the Radiographer uses multiple workstations, an example of which can be found in the physical model Figure 5.2. These workstations have different purposes, each with different software that is involved with delivery radiation. These workstations also have a mixture of single monitor and dual monitor, so the Radiographers are monitoring various different screens at each stage of treatment. Furthermore, software is a mixture of desktop software and web application.

These activities were visually represented by using flow models, using the methods discussed in both Chapter 4 and Section 5.1 of this Chapter, by reviewing the observation notes. The diagram identifies the complexity in interactions between people, work processes and software.

The Radiographer has little interest in 'how' the Linac works, unless this surrounds using the Linac's different settings for patient treatment. Ultimately, their goal is to ensure that their patients recieve a good treatment experience whilst treating their cancer patients with radiation. However, when a Radiographer attempts a first fix of a Linac, they do so with the goal of making it work so that they can start treating their patients. Although, this is much to the frustration of the Machine Technologists, the second intended user of MachineLog, because these type of faults go completely unreported if the Radiographer manages to resolve the fault.

The Machine Technologist expects that the Radiographer will input detailed information surrounding a Linac fault. The Machine Technologist's goal is to resolve any faults that might arise from using the Linac. The Machine Technologist is interested in 'how' the Linac works. Although, they are not as interested in how the patient is cared for during their treatment, on the Linac. As Engineers, they are problem solvers and like to have an overview of how their machines are performing, including on-going issues.

There are other staff members that are observed. However, these staff do not use MachineLog as their roles are to support the Radiographers with their provision of care for their patients. Therefore, the goal of these staff is similar to that of the Radiographer, providing, assisting with or learning to provide a good treatment experience for their patients.

The observations suggest that the intended users of MachineLog have different goals and motivations, performing a range of technical and clinical activities.

Of interest, MachineLog is not used in any observation for its intended purpose of recording Linac faults. It is used to record the start time of a QA session. However, this recording may have been prompted by the Radiographer's awareness of the role of the observer. All staff are performing complex activities. However, MachineLog, demonstrated by the physical layout diagrams, flow diagrams and observations, is quite literally a piece of software installed on a workstation, away from where most of the staff perform their activities, that is of low priority.

5.3.2 The Types of Breakdown

The observations showed that there are a lot of staff involved at different points during different activities. Morning QA can be performed by 1 or 2 Radiographers, patient treatment involves at least 2 radiographers or more depending on expertise needed. However, during these activities, breakdowns were observed.

During the first observation, the Radiographer struggled to find a device known as a phantom, that detects and records Linac beam outputs. However, this breakdown is related to their morning Quality Assurance process. It is not related to the use of MachineLog. Interestingly, this causes the Radiographer to adjust the steps that they perform when performing QA, and instead, perform other safety checks whilst waiting for a phantom to become available. Eventually, the Radiographer realises that there is a phantom in the treatment area of the Linac. However, the phantom was stored in the wrong cupboard. In this instance, MachineLog would not need to be used.

Further observations identified breakdowns that occur but are beyond human control, for example, Linac faults. Interestingly, these breakdowns present scenarios where MachineLog should be used, yet it is not used for recording these faults.

Other observed breakdowns appeared to be due to interruptions or difficulty locating resources. Some of these difficulties, such as contacting a Machine Technologists present a scenario where MachineLog should be used, yet it is not used. Therefore, there are scenarios where MachineLog may have prevented a breakdown, displayed in the flow models. For example, MachineLog could have been used to report a fault directly to a Machine Technologist. However, the current MachineLog does not inform Machine Technologists whilst they are on the move. It requires the Machine Technologists to be sat at the desk.

5.3.3 The Software

To support the users of MachineLog in their activities, other software is used and is captured during the observations, and visually represented in flow models. This software was previously introduced in Chapter 2.

It was observed that Radiographers are interacting with several different clinical systems during Quality Assurance and Patient Treatment. During the observation, an interesting use of other software was uncovered. AtlasQA, commercial software, has been modified to purposely fail a safety check. This failure is designed to prompt the Radiographer to use QA3VMAT, software that has been in-house developed by Medical Physicists at The James Cook University Hospital. There are instances where commercial software is being changed or being set in such a way that it is not intended to be used, to alter the work of other staff. Therefore, not only is in-house software being developed to shoehorn staff into a certain activity, commercial software is being altered or set to shoehorn staff into certain activities.

Nevertheless, observation of the use of other software matters because it demonstrates that Radiographers are immersed in both complex activities and a complex IT ecosystem. It is difficult to see where MachineLog fits in with this work and ecosystem, suggesting that MachineLog sits outside and may explain its lack of use. Afterall, MachineLog is installed on a workstation away from where Radiographers perform most of their work. It is not in direct sight of the Radiographers. This initially suggests that a prototype should be nearby to the work of the Radiographers. Interestingly, all commercial software involved in directly treating patients, during patient treatment activity, was used as intended by the Radiographers.

5.3.4 The Use of Machine Log

The observations show that MachineLog is an overlooked piece of software, installed on a workstation that is not located nearby to the Radiographers main areas of work within the Linac Control Area, for example, Figure 5.2.

MachineLog is a clunky desktop application that requires Radiographers to move away from the other software that the Radiographers use. This other software fits well into their working activities and is essential for the Radiographers delivery of radiation to a patient.

It is acknowledged that on some occasions, MachineLog was used to enter the start time of morning QA. For example, in Observation 2. However, this may have been influenced by the observers presence. This observational effect is known as the Hawthorne Effect, suggesting that participants involved in observations can adjust their working practices due to their awareness of being observed [48]. This is important because the use of MachineLog during the observations may have been influenced by the observers presence. If there observer was not there, this may have meant MachineLog may not have been used during the events that took place during the observation.

Further use of MachineLog during observations appeared to prompted by a Machine Technologist, demanding that a fault be reported using MachineLog. This usually happened some time after a fault has occurred and had been resolved. Nevertheless, MachineLog is not being used as intended.

5.4 Conclusion

This contextual inquiry study sought to discover why MachineLog is not being used by the Radiographers of the Radiotherapy Department at The James Cook University Hospital. Performing the contextual inquiry observations allowed for an understanding of the goals of the Radiographer and Machine Technologist.

It is apparent that the goal of the Radiographer is to treat their patients safely and effectively, whilst providing a good treatment experience to their patients. MachineLog does not facilitate the Radiographers when they are treating their patients. However, when faults arise, there are scenarios where MachineLog should be used, yet it is not. This may be due to MachineLog being installed away from the Linac Control Area, out of easy reach of Radiographers. The activities and the goals of the Radiographers suggest that during routine use of the Linac, there is no need to use MachineLog. However, at the times where MachineLog should be used, the

Radiographers become concerned with ensuring their patients are informed with up to date information surrounding the delay of their treatment. At this point, the Radiographer is not interested in why the Linac is not working and thus their goal is to continue to ensure their patients receive a good standard of care or good patient experience despite the delay.

Therefore, MachineLog, in its current form does not align to the goals of the Radiographers and the Radiographers will not use MachineLog unless it is improved. This misalignment of goals is perhaps a factor that influences the usability and acceptability of Medical Infrastructure Software.

The staff group that should record Linac faults are the Machine Technologists and not the Radiographers. Despite Machine Technologists demanding that Radiographers record the information surrounding a fault, it should be the Machine Technologists who inputs the detailed information surrounding a fault, taking this responsibility away from the Radiographer. This will allow the Radiographer to focus on their goal of ensuring the patient continues to receive a good experience despite the delay. However, the Radiographers should still be able to quickly raise a fault where needed.

As the Lead Machine Technologist is responsible for the workflow of the Machine Technologists, the Lead Machine Technologist should be able to triage and assign faults to members of their team.

The results of this contextual inquiry study were used to develop personas and new scenarios of use, to inform the design of a new prototype named LinacLog, aimed at addressing the lack of use and frustration experienced by Radiographers and Machine Technologists.

Chapter 6

Personas and Scenarios

Personas, previously discussed in Chapter 4, are a way of representing the users. The usefulness of personas has been well-debated. However, for the purposes of this thesis, personas are a useful tool in communicating the requirements for the new prototype [49]. Importantly, as healthcare professionals developing software, we possess first hand experience of the users environment, which is an advantage when creating personas [37]. Furthermore, personas are useful for representing the users where the users can be involved in the design [36].

The personas in this thesis were developed by drawing from observations and the past experience of working with the Radiographers and Machine Technologists. The personas helped to bring the requirements to life by representing realistic actors within the scenarios.

Envisaging scenarios of existing and future use helped to clearly identify the problems with MachineLog and articulate future designs. For example, new scenarios where a new usable prototype would be used to report a Linac fault.

The focus for the Personas and Scenarios was directed towards being good communication tools for stakeholders, and in our case, the Radiographer and Machine Technologists, to see the problems with MachineLog and understand potential solutions. This allowed us to communicate to the Machine Technologists that the Radiographers should not use LinacLog to enter detailed fault information, when propsoing that the Machine Technologists instead use LinacLog to enter detailed fault information. Furthermore, the personas and scenarios were useful for communicating the requirements of LinacLog.

The goal of this chapter is to introduce the personas that were created, together with the existing and new scenarios of use.

6.1 Creating The Personas and Scenarios

The personas were created and used by following a persona lifecycle [49].

Firstly, personas were created by reflecting on and analysing the data gathered in the 7 observations of the contextual inquiry study of Chapter 5, and by using personal experience, whilst trying to avoid assumptions about the users. This is essential as it better to build personas based on data, than assumption [49]. Although, personal experience may introduce assumptions, any assumptions were reviewed by the users to help ensure that the persona is still representative of their role. Furthermore, each observation iteratively identified the different motivations and goals of each persona.

To introduce the personas into the organisation, the personas were shown to the users, who commented that they are able to identify with the personas as an accurate representation of their roles. This suggests that the personas may contribute to achieving a realistic, first iteration re-design of MachineLog, by helping to communicate the requirements that is based on the needs of the actual users of the system.

The personas were then used to develop a requirements specification in Chapter 7 and the requirements were able to inform an evaluation, completing the persona lifecycle [49].

Secondly, scenarios of existing use were captured. The scenarios were developed from the study in Chapter 5, as a reflection of practice. Incorporating the personas into the scenarios provided a hypothetical narrative around the existing use of MachineLog, envisaging a story and situation where MachineLog should be used, with the aim of uncovering the successful use of MachineLog and the problems that arise with MachineLog. The hypothetical narrative of the scenarios was based on the actual users and their activities by drawing from observations together with personal experience.

After creating scenarios of existing use and identifying the issues with MachineLog within these scenarios, scenarios of new use were created. The scenarios of new use provide insight into how the work could be simplified through the use of a new prototype. Therefore, these scenarios of new use are useful for informing the requirements for the new prototype.

6.2 Personas

6.2.1 Miriam - The Therapeutic Radiographer

By reviewing and reflecting upon all of the observations that included Radiographers, conducted in Chapter 5, Miriam, a Therapeutic radiographer, was created.

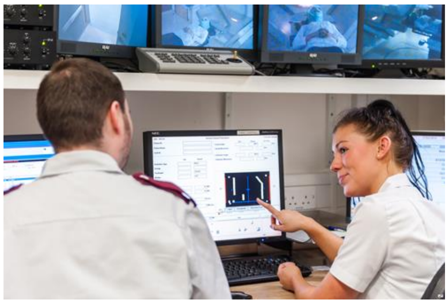
The key goals and tasks of Miriam were identified, and her interests and motivations were constructed and constructed her interests and motivations. Miriam, of course, is not a real Radiographer. Instead, Miriam is the archetypical representation of the radiographer who uses Machine Log. The persona for Miriam is displayed in Figure 6.1.

A snappy slogan was added: “Therapeutic Radiographer by day, fitness fanatic by night!”, allowing the persona to become more relatable and give it some life. Furthermore, a quote from a Radiographer was included, to highlight what Miriam enjoyed most about her work. The level of computer skills that a Radiographer possesses was also included.

Miriam – Therapeutic Radiographer by day, fitness fanatic by night!

"Making a difference to a patient by using constantly advancing radiotherapy technology and supporting them & their families in the best possible way gives me a real buzz!"

Employer: James Cook University Hospital
Computer Skills: Intermediate



Source https://www.healthcare.ac.uk/collaborative-effort-between-school-of-radiography-staff-and-students-leads-to-higher-engagement-and-new-research-articles/

Key Goals & Tasks

Miriam, who is 30 years old, is a Therapeutic Radiographer, who is a 'Highly technical healthcare professional whom is tasked with the actual delivery of radiation to an oncology patient'. For Miriam to be a radiographer she is required to have studied a BSc in Therapeutic Radiography.

She wants to be able to treat cancer patients and ensure a positive experience for her patients. Miriam is required to operate many different systems to do this, one of which is the Machine Log.

Miriam works within a procedural-driven environment, following agreed procedures and tasks. One of her main concern is to ensure the patient is safe and receiving the best care for them.

Interests

Miriam is interested in her work. At work, she strives to deliver radiation therapy to cancer patients with a patient-centric attitude.

She's interested in furthering her career by learning more about the advanced techniques in radiotherapy. Her career progression ambitions are to become a superintendent radiographer.

Miriam likes to keep fit and eat healthy; more especially as she needs to manual handling during the day, and needs to be able to concentrate for long period of times.

Motivations

Miriam is comfortable using advanced technology. Most of her work is done on a computer. However, Miriam isn't that interested in the latest consumer technology and views technology as a way of assisting her. Miriam does enjoy using work-related technology. Miriam tends to work in a way which she is familiar with, by using technology to achieve her goals.

Figure 6.1: Persona for the Therapeutic Radiographer

6.2.2 Dave - The Machine Technologist

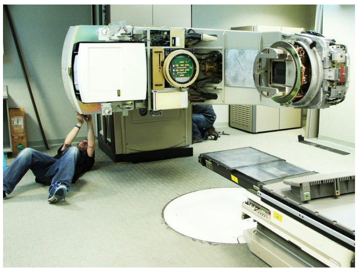
The key goals & tasks of Machine Technologists were identified to construct a persona called Dave. This included identifying the interests and motivations of Machine Technologists allowing for the further development of the persona and archetypical representation of a Machine Technologist using MachineLog.

The persona consisted of another snappy slogan "Clinical Technologist by day, DIYer by night." , designed to bring the persona to life. A quote from one of the Machine Technologist was added and so too was the level of computer based skills.

Dave – Clinical Technologist by Day, DIYer by night.

"Contributing to patient satisfaction by ensuring the linear accelerators are operating with no issues, or resolving issues fast is what makes me tick"

Employer: James Cook University Hospital
Computer Skills: Intermediate



Key Goals & Tasks

Dave, who is in his 40s, enjoys all things electronics. Dave likes to be able to keep track of the linear accelerator issues which are undergoing repair or require repairing. Dave response to faults in reactively but Dave would like to be able to predict when machines will fail.

Interests

Dave loves gadgets and technology. Dave is a jack of all traders. In his job he needs to know everything from basic IT to complex electronical engineering components and mechanics. He's a fixer; if something is broken Dave loves to fix it.

At home, Dave likes to switch off by caring for his hens! He also likes to make home improvements. There's no job too big or small for Dave, and he is always happy to help. Dave is eager to please!

Motivations

Dave is motivated by the diverse range of challenges that he encounters. Linear Accelerators are complex machines which need to be maintained within regulations. Each day is a different day with a new challenge. From routine services to catastrophic failures, Dave loves coming into work each day.

Dave has some computing skills, he can build an access database but nothing 'fancy'! He can troubleshoot basic IT issues with PCs. He likes gadgets and learning more about the computing technology which supports the Linear Accelerators, as well as the day to day electronics and physics.

However Dave is frustrated that he can be pulled 'left-right and centre'. Although he is used to this, his frustrations lay within the organisation of this pulling. His planned work suffers because of this. He is the go-to person although he works within a team. He has become an accidental first person of contact, much to the frustration of Jennifer. Dave doesn't mind this though, he loves his job and will always help when asked, whoever asks!

Figure 6.2: Persona for the Machine Technologist

6.2.3 Jennifer - Lead Machine Technologist

Following similar approaches to creating the earler personas and by reviewing the observations conducted in chapter 5, the persona for Jennifer, the Lead Machine Technologist, was created.

Jennifer

"Maintaining complex machines which treat patients is one of the best jobs I can think of!"

Employer: James Cook University Hospital
Computer Skills: Intermediate

Source
https://www.timeshighereducation.com/blog/culture-engineering-does-not-take-women-seriously

Key Goals & Tasks

Jennifer, who is in her late 40s years old, is a Senior Clinical Technologist who leads the Radiotherapy Linear Accelerator Engineering group. Jennifer is well organised and likes to be kept update with all issues, developments and projects that her team is working on.

Jennifer needs to be able to report these issues and faults to her senior managers, including the usage of the Linear Accelerators.

Jennifer is quite new in her role however, and is leading her team into proactivity and promoting her team across the department.

Interests

Jennifer loves all things electronics. At home she enjoys spending time with her children who are now grown up and at university. She's a family person. At work, she's a born leader and enjoys leadership. Jennifer projects this into work and her subordinates are her family. Jennifer is interested in developing her team. She knows her team; she has worked alongside them before becoming their line manager. Sometimes this comes with its difficulties.

Jennifer enjoys reading and aims to read at least 2 books a week.

At work, Jennifer is interested in growing her team's responsibility. She wants her team to become recognised as Engineers, not technicians.

Motivations

Jennifer is motivated by working with advanced electronics and technology. The technology Jennifer works with requires deep understanding of aspects of engineering, electronics and physics. The challenges of maintaining a linear accelerator are complex and she is motivated by the opportunities to continuously learn.

Jennifer however, isn't one for buying the latest gadgets or spending time on a computer. She can work her way around a computer and maintain some computer hardware, but when it comes to the software, she uses what she needs to get the job done. Jennifer is very much a practical hands on person interested in leadership. She is motivated by her vision of what her team can evolve into.

At work, Jennifer has reached the highest position in her career path. Jennifer manages people who are young professionals who she considered s her family. Jennifer is very much the mother figure of the team. Jennifer has a slight frustration whereby one of her staff becomes a frequent 'first point of contact' which is making it difficult for other members of the team to become involved in problems. Some of these problems are unreported and she really wants a way to fix this.

Figure 6.3: Persona for the Lead Machine Technologist

6.3 Scenarios of Existing Use

By reflecting on the work and practice of Radiographers and Machine Technologists (Engineers) from the observations in Chapter 5, two scenarios of existing use for each user group (Radiographers, Machine Technologists and Lead Machine Technologist), were created. The scenarios envisage a story and situation where MachineLog should be used, aiming to uncover the problems that arise with the existing MachineLog. Incorporating the personas into the scenarios provided a hypothetical narrative, based on the activities of the actual users, around the use of MachineLog.

6.3.1 Radiographer Scenarios

Scenario 1

Miriam begins her morning QA under time pressure. She starts at 07:30 and her first patient is due at 08:30. QA is a legal requirement and there is a lot to go through in 1hr, providing it runs smoothly this is achievable for Miriam. However, the Linac fails and Miriam tries to work out why. There's an error on the screen saying "Accelerator not able to accept setup commands". Using her knowledge she attempts a 'first line fix' Miriam does this to see if she can get the Linac working again without needing to find a Machine Technologist. Miriam tries rebooting the PC which controls the Linear Accelerator and it still has not worked. Now Miriam is really time pressured, she has her first patient at 08:30 and there is now a delay in her morning QA. Her fix did not work, the Linac is still not responding properly. The time is now 08:10AM.

Miriam calls a Machine Technologist; she's not able to find one at their desk. She then grabs her sheet of paper with telephone numbers on and calls around. Miriam then calls the shared mobile phone and reaches someone at 08:15AM. She explains the problem and 5 minutes later at 08:20AM the technologist turns up. Her goal is to get the first patient in at 08:30 so that the treatment day does not over-run, leaving her patients with a good experience. This leaves the Machine Technologist only 10 minutes to fix the problem so that Miriam stays on schedule.

The Machine technologist quickly works to fix the problem. The problem is fixed with 5 minutes to spare, Miriam continues her QA albeit a little quicker to get the Linac up and running. In the panic and the rush she forgets to update the Machine Log. Unfortunately, Miriam is only able to get the first patient for treatment at 08:45, 15 minutes past their appointment. Miriam is frustrated as all her patients on that day will be delayed over 15 minutes each.

Scenario 2

Miriam welcomes her next patient. The patient is a planned patient for prostate cancer treatment. Miriam works with the other radiographers to assist the patient into the room and onto the Linear Accelerator couch.

Miriam leaves the patient on the couch and heads over to the Treatment Control System. After confirming with her colleague that the patient's details are correct, the correct treatment plan has been loaded and the correct setup information is loaded, she delivers the radiation treatment to the patient. After several minutes, the fraction (the term used for an episode of radiation delivery which is a fraction of the patient's total dose over the entire course of treatment) is complete and the patient is assisted off the couch and out of the Linear Accelerator. Miriam then greets her next patient. The treatment ran smoothly with no issues.

6.3.2 Machine Technologist Scenarios

Scenario 1

Dave gets a call from Linac A, they are struggling to explain the problem but have mentioned that they have tried to fix it themselves. This frustrates Dave because he feels the Radiographers have been tinkering without asking for the proper help to begin with. Dave takes the short walk to Linac A to figure out what is going on. It looks like there's an issue with the XVI panels. All the radiographers did was waste time by rebooting the XVI computer. Dave unscrews the panel. Dave is time pressured though, there's a patient waiting to be treated that is now becoming unhappy over the delay.

Dave does his magic; he fixes the panel and screws it back on. The whole job took around 10 minutes. Dave feels this is a job well done. Dave asks the lead radiographer if they have completed Machine Log. The answer is of course, no! Dave gets slightly frustrated by this and asks the Radiographers to complete Machine Log. Dave heads back to his desk to check machine log and notices that it has not been completed correctly. Dave jots down the problem, the fix and the times of the problem on his own excel spreadsheet for his own reference, instead.

Scenario 2

Dave is walking past Linac 4 and immediately, a Radiographer runs out and in frustration, mentions that they have huge problem and can not find any of the Machine Technologists to help her.

Dave apologises for this and asks for more information around the fault. It becomes clear that the problem is that the Linac is not rotating properly. After ascertaining the fault, Dave begins to investigate.

However, this issue is complex and requires extra help. Dave calls another Machine Technologist using a private mobile number. The other technologist leaves their work and provides assistance to Dave. They both strip the plastic coverings from the Linac to try and resolve the problem. Meanwhile, the Radiographer is worried that her patients are being delayed. Dave is too busy to talk to the Radiographer now and is not able to give an estimated timeframe for fixing the problem. Dave also asks the Radiographer to input the fault information into MachineLog so that the delay can be recorded.

Unhappy with this response, he Radiographer contacts Jennifer, the Lead Machine Technologist. Jennifer approaches Dave and in frustration, questions why she was not told of the major fault and questions why the other technologist is there without her knowing. Jennifer then contacts the senior Radiographers requesting that the patients be moved to another Linac so Dave can continue to fix it. However Jennifer sends the other Technologist back to their original activity.

6.3.3 Lead Machine Technologist Scenario

Scenario 1

Jennifer finds out that there may be a possibility of expanding her team. The Head of Radiotherapy Physics has asked Jennifer to provide him with a report that they can take to their leadership team, which can demonstrate average weekly hours spent fixing problems, average time it takes to fix common issues, and the average clinical treatment delay caused by these issues. Jennifer looks into machine log and can't find a way to do this. The data in MachineLog does not match Jennifer's experience and she feels that it does not reliably reflect the actual workload of her staff. Some faults are entered retrospectively after some time has passed, with estimated start and finishing times.

Scenario 2

Jennifer needs to report uptime metrics to the Head of Radiotherapy Physics who in turn feeds this into higher leadership of the Trust. These uptime statistics can be used as a metric for decision making on staff, procurement and cancer performance. Jennifer looks into Machine Log and cannot find anything that allows her to do this. Panic ensues! Jennifer then assigns the task to her subordinate, thus using their own valuable time hand generating uptime statistics by manually going into MachineLog and estimating the time, from memory, on how long the fault had taken to fix. Jennifer gets frustrated by this.

6.4 What are the problems?

The scenarios demonstrate that Radiographers are immersed in performing their duties towards patient care. The Radiographers are motivated by providing an excellent patient experience whilst delivering radiotherapy treatment. Most of the Radiographer‘s work is performed by interacting directly with patients. The Radiographer then delivers the radiation at a console. Sometimes patient treatment is delayed which reflects badly on the Radiographer so there is a strong motivation to resolve issues quickly. However, MachineLog does not fit into the workflow of the Radiographer. MachineLog is hosted on a PC away from the treatment console. When something does go wrong, the Radiographer reaches for the phone to report the fault, forgetting about MachineLog. Furthermore, MachineLog has no facility to alert the Machine Engineers, so the Radiographer has no real motivation to use MachineLog.

This is much to the frustration of the Machine Engineers. The Lead Engineer is required to report uptime metrics to their superiors. However, as the uptime metrics are not being recorded by the Radiographer, who has no interest or motivation in using MachineLog, these metrics are difficult to track and provide. MachineLog has no easy and usable way of recording these metrics.

There is sometimes an attempt by the Machine Engineer to persuade the Radiographer to complete MachineLog. Although this does sometimes happen, where the Radiographer retrospectively enters the fault information from their own memory, and is shown to be done by a Radiographer sometimes not involved with the fault, the information becomes inaccurate and adds to the frustration of the Radiographer.

During a major fault that renders the Linac unusable, the Radiographers remain concerned with coordinating the care of their patients, by ensuring that patients are moved to a working Linac. However, during this point, the Radiographers are asked to update MachineLog. This frustrates the Radiographers because they need to ensure that their patients continue to receive a good experience whilst receiving treatment. The Radiographers can not do this when they are entering fault information into MachineLog, when they instead need to move patients to a new Linac.

Therefore, the scenarios of existing show that there is a problem with MachineLog in its current form because it does not get used, despite there being a situation where it should and could be used. For example, Miriam in Scenario 1 (Section 6.3.1) frantically tries to find an available Machine Technologist to resolve a fault. Miriam experiences difficulty in finding a Machine Technologist but should have used MachineLog to record the fault, first. However, in all the panic and the pressure to begin treating a patient, Miriam forgets to update MachineLog. The Radiographers want to help their patients and the Machine Engineers want to know more about faults. However, the Radiographers do not want to use MachineLog because it does not fit in with their work or their goals. Therefore, MachineLog should be re-designed so that the Machine Engineer enters fault information whilst they are on the move, responding to faults. The Radiographer should be able to raise a fault and await feedback from a Machine Technologist and not need to stop their work whilst trying to find support for Linac faults.

The scenarios reflect the problems that were previously observed in Chapter 5, in a communicable form, that does not point the finger of blame towards an individual. The scenarios, although realistic, are fictional and cannot be used to blame people for not using MachineLog. This may mean that the scenarios are more likely to be listened to and are better received, especially when proposing the new prototype and communicating the problems to the existing users.

6.5 Scenarios of New Use

To capture how a re-designed MachineLog prototype might fit in with the work and goals of staff, scenarios of new use were created. The scenarios incorporated the personas and aimed to envisage the work being performed whilst using the a prototype, demonstrating how the newrototype may facilitate the work.

The new scenarios of use were used to introduce a new workflow that captures the faults and problems with the Linacs whilst also being a part of the solution to the lack of use problem. By introducing a new prototype into the new scenarios, informal channels of communication are removed and are replaced with formal channels of communication that provides a more reliable service. This formal channel of communication also logs and records the nature and impacts of Linac problems. It puts the responsibility for inputting detailed fault information with the Machine Technologists.

6.5.1 Scenario - Bulb Failure

It is 10:45AM and Miriam is treating her patients, all is running smoothly until she notices that there is a warning light not working. Miriam thinks it could just be a bulb. Miriam walks over to the fault screen and presses the Fault Button as normal procedure states that all faults must be reported.

Jennifer receives the fault alert and acknowledges it. Miriam sees that the screen has now changed to acknowledged and within moments, answers the phone. Jennifer has called Miriam to find out some more information to assist with her triaging. Jennifer logs the discussion and assigns the fault to Dave. Dave sees the alert pop up on his smart device with the description "LAB Warning bulb not working". Dave has the option to either queue the incident or call Miriam for further information.

Just to be safe, Dave calls Miriam to gather some further information and to let her know he is working on it. Miriam explains that a warning bulb appears to have stopped working for the Controlled Area light. This light warns that the device is delivering radiation and has become a controlled zone defined by the Ionising Radiation (Medical Exposure) Regulations, meaning no one can enter unless specifically authorised to do so by the radiation protection adviser, or the patient themselves. Dave notes this and said this is not urgent and can be fixed at the end of the day, so that he does not delay patient treatments. This is because the room is sealed when the beam is on, and all staff are outside of the room.

Dave marks the fault as pending and adds a note that he will fix it after patient treatments have finished. Miriam receives a notification letting her know this, too, and Jennifer can see this in the jobs overview dashboard.

6.5.2 Scenario - XVI Panel Failure

It is 11:30AM and Miriam, the Radiographer, is about to deliver treatment to a patient using 3D imaging. Suddenly, an error appears which suggests that the 3D imaging panel has failed. Miriam immediately calls Jennifer, the lead machine technologist and reports the issue. This is an urgent issue as there is a patient waiting for treatment.

Jennifer logs the details, flags it as urgent and assigns it to Dave. Dave receives the alert on his smart device, with a brief description. Dave realises this is an urgent issue. Dave calls Miriam to investigate further and logs the discussion of the call. Dave arrives at the Linear Accelerator and confirms the panel has failed. Unfortunately, there is not much Dave can do as Dave needs to order a replacement panel, which takes 1 working day. Dave informs Miriam that she can continue to treat patients but is only able to use 2D imaging. If the patient requires 3D imaging, the patient will need to be moved. This becomes a Radiotherapy issue and Miriam consults her superintendents. Dave enters the details into his smart device and marks the job as in-progress. Dave alerts the manufacturer who dispatches a replacement panel. Dave returns the next day to resolve the problem.

6.5.3 Scenario - QA Issue

It is 07:30AM and Miriam, the radiographer tasked with performing morning QA, begins her QA. All is well until, at 08:00AM Miriam discovers that there is an issue. The device is displaying "Accelerator is not able to accept setup commands". After a slight panic, Miriam hits the 'Fault' button on the fault screen located on the wall. It changes to show that the alert has been sent to confirm it has been sent.

Jennifer, the lead machine technologist immediately receives the alert. Jennifer springs into action. Jennifer calls Miriam. Miriam explains the problem allowing Jennifer to triage the fault. Jennifer, with her expert knowledge, quickly realises that this fault is critical and requires urgent resolution.

At the same time, the fault screen display on the wall changes to 'Acknowledged' as Jennifer has hit the acknowledged button on her fault management interface. The other radiographers starting their morning shift glance at the screen and notice that it has a fault acknowledged message, so they don't disturb Miriam whilst she's dealing with this. Jennifer assigns the job to Dave, one of the machine technologists. Dave receives the alert on his smart device. Dave sees that the fault has been assigned to him by Jennifer as urgent, and clicks the call button which puts him into direct contact with Miriam. Dave liaises with Miriam to discover what the issue is in detail.

After the conversation, Dave records a quick summary of what was discussed by typing it into the Call Log box in his smart device, using the keypad. This sets the fault to the next stage, 'In-progress' or 'Pending' on all interfaces. This allows Jennifer to see that Dave is dealing with the job and provides Jennifer with an overview of what was discussed on the web interface should Miriam need to check, it shows the other radiographers via the fault screen display and all other staff via the fault management web interface. Dave heads down to Linac 4 and uses his expert knowledge to resolve the issue, providing updates as he goes, using his work smart-phone. If Dave gets stuck, he can call for help or access resources on his smart-phone.

Meanwhile, Jennifer has a complete overview of her staff resources, and Miriam has constant feedback throughout the incident.

Dave resolves the fault, updating the fault with information that the fault has been resolved enters the details on his smart device and flags the fault as resolved. Jennifer reviews the fault and closes it once she is satisfied it has been fully resolved.

6.5.4 Scenario - Total Linac Failure

It is 07:15AM at Linac 4 and Miriam is performing her routine morning QA. Suddenly, the workstations display critical errors. The Linac is no longer rotating and a mechanical fault means that the movement is jammed.

Miriam presses the Raise Fault button on the tablet, located on the desk near the workstation and phone. Immediately, Jennifer receives the alert. Jennifer calls Miriam and discusses the issue. It is clear that this issue is serious.

At 07:20AM, Jennifer assigns Dave to resolve the fault. Dave Calls Miriam for some further information and to re-assure Miriam that help is on the way. At this point. Miriam is able to call her senior radiographers and alert them of the situation. The senior Radiographers together with Miriam, coordinate the moving of patients from Linac 4 to Linac B. The patients will need to be moved from the main hospital to the Endeavour Unit. However, patients are unhappy. As Miriam does not need to input the fault information herself, she is able to interact with the patients and explain what is happening, re-assuring the patients and allowing Miriam to achieve her goal of coordinating the care of her patients during the time of this fault.

Dave arrives at 07:25AM and begins to work on resolving the issue. Dave enters further updates into his smart-phone app, allowing Jennifer to see his progress. Dave attaches pictures of the fault and records into his smart-phone app, that the new part needs ordering. Jennifer assigns this ordering to another member of her team whilst Dave works on removing the failed part.

6.6 Discussion

The goal of the Radiographer is to provide a good standard of care to their patients. When a Linac breaks, the Radiographers goals shift to providing a smooth experience to their patients, such as explaining delays and moving patients to another Linac if the broken Linac is not easily fixable. The goal of the Machine Technologist is to fix the broken Linac.

Replacing MachineLog with a prototype that puts the issue of recording Linac faults with the Machine Technologist, appears to be a viable solution. Informal channels of communication are removed and replaced with formal channels of communication. The scenarios suggest that there is a need for a quick way for Radiographers to report faults and receive re-assurance from the Machine Technologists, which could be in the form of a phone call. A button that alerts Machine Technologists to a fault appears to be a useful approach because the Radiographers can press this button and immediately alert the Machine Technologist, who are interested in resolving the fault. This eliminates the need for the Radiographer to sit at a workstation to enter detailed fault information. Instead, a Machine Technologist would be responsible for entering the fault information after a discussion with the Radiographer.

The Personas and Scenarios in this Chapter are able to communicate the requirements of a new Prototype, LinacLog. These requirements were formalised in Chapter 7, as a Software Requirements Specification.

Chapter 7

Prototype Software Requirements Specification

Within the software development domain, a Software Requirement Specification is generally accepted as useful document tool allowing software engineers to capture the requirements for software development. It is normally the case that these requirements are agreed between a client (customer) and a Software Engineer or consultant on behalf of an organisation. The Software Engineer then uses this requirement specification document to inform the software development team of the components that a software should contain.

However, as this thesis is a Human-Computer-Interaction project at its core, this will not be a full and detailed requirements specification. Nevertheless, the motivation for this thesis is to produce a new design using HCI methods. Therefore, it is sensible to create a requirements specification.

The new prototype will be named 'LinacLog'. The previous name, MachineLog, did not capture the focus of the software. That is, the connotation of Machine was not specific enough to explicitly refer to Linacs. For example, when one thinks of a Machine Log, one might feel that this covers all types of Machines, such as the CT scanners, etc. Therefore, appending Linac with Log was decided upon to explicitly refer to Linear Accelerators. Furthermore, by selecting a new name, may infer that this is a fresh new product, that steps away from the old MachineLog.

LinacLog will consist of different modules that fit into the workflows of the different staff groups. Namely, LinacLog Bunker for the Radiographers, LinacLog Response for the Machine Technologists and LinacLog Triage for the Lead Machine Technologist, and the consideration of a future LinacLog Hub which displays metrics that are useful to the Machine Technologists. All of which are designed as an attempt to address the challenge of recording Linear Accelerator faults.

7.1 A New Workflow

In order to specify a prototype addressing this challenge new workflows were created. By using the scenarios of new use found in Chapter 6, it became possible to envisage how the new work will be performed and map this work out in the form of a traditional and well known flow diagram which is displayed in Figure 7.1. The new work flow alters the Machine Technologist's existing working practices.

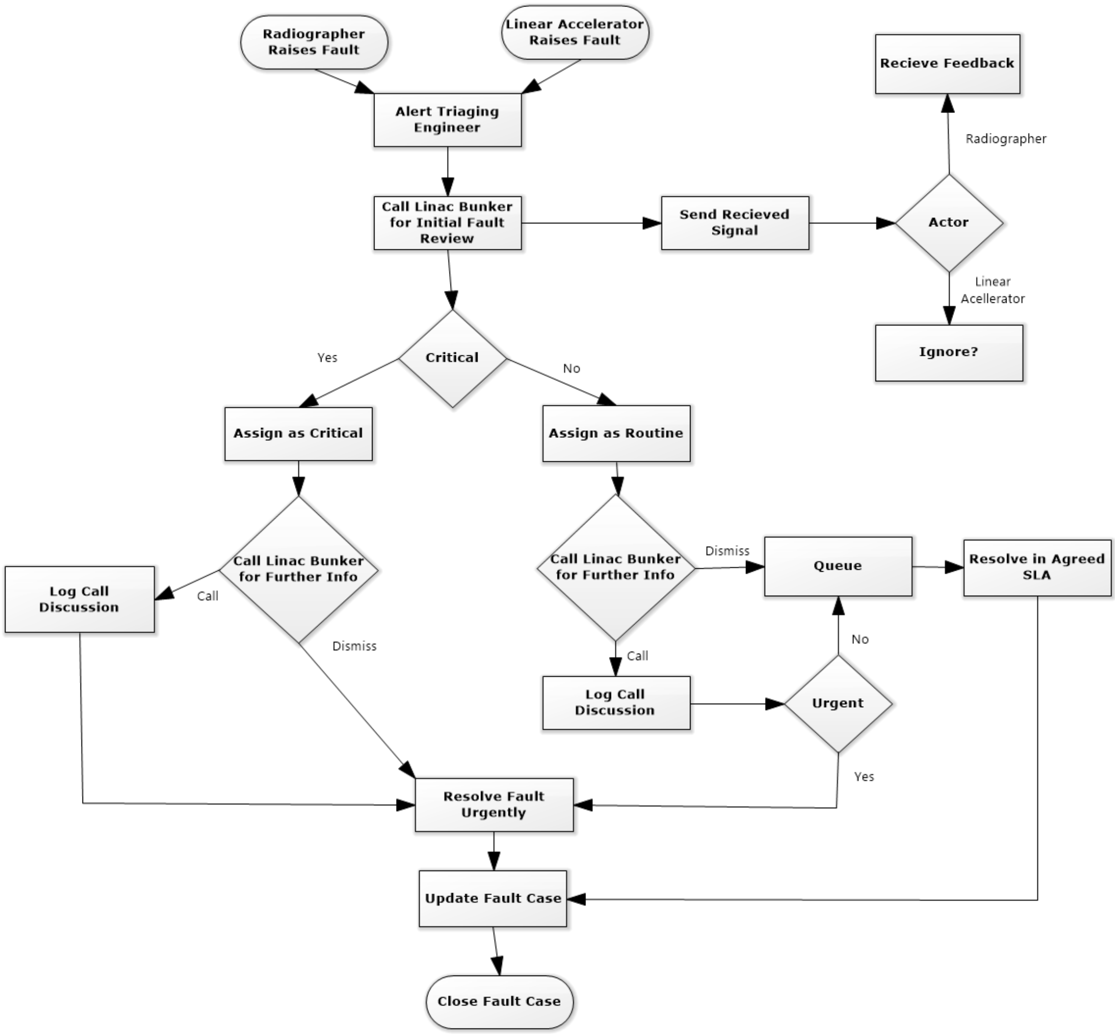


Figure 7.1: The new work of the Machine Engineers

One of the major changes in the workflow for the Machine Technologist was the addition of a Triage Engineer. The Triage Engineer will be the Lead Machine Technologist, becoming responsible for assigning faults to a specific engineer. The Triage Engineer is involved from the moment a fault is raised. It is worth noting that on the flow diagram there is a process kick off entitled "Linear Accelerator Raises Fault". The Linac does not directly notify MachineLog of a fault. It does show that there could be an opportunity for the Linac to directly alert the Machine Technologists however this fits within the domain of Cyber-Physical Systems and outside the scope of this thesis.

Although the core focus for re-designing the work surrounded the Machine Technologists as they should be the primary users of LinacLog, it is important to highlight the simplification of raising faults by a Radiographer. This new work is displayed as a workflow diagram in Figure 7.2. When a fault occurs the Radiographer will raise the fault and await a call from a Machine Technologist. The Radiographer can then discuss the issue with the Lead Machine Technologists (The Triage Engineer).

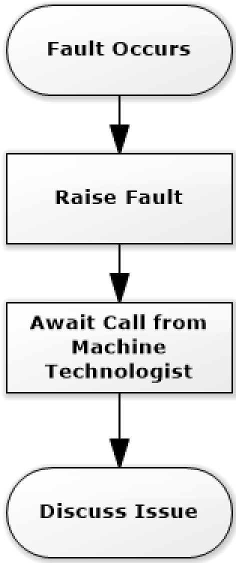


Figure 7.2: Radiographer Workflow for raising a fault

It is also beneficial to include the new work of the Radiographer to highlight the simplification of changing the Linac Mode. This changing of mode is used as a metric for recording the times that when the Linac is undergoing QA or being used for clinical treatments. This is displayed in Figure 7.3.

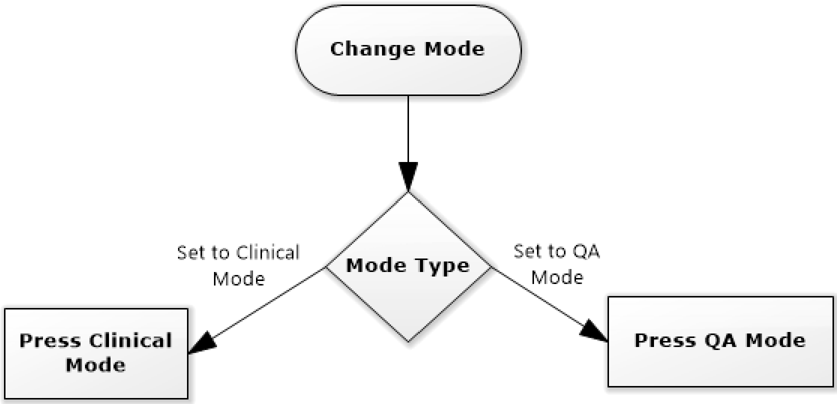


Figure 7.3: Radiographer Workflow for changing Linac Mode

7.1.1 Initial Workflow Feedback for Machine Technologists

This workflow was presented to the Lead Machine Engineer and the feedback from the Lead Engineer was that they were pleased with the new work flow as it gives the Lead Machine Engineer greater control over how they are able to assign faults to specific Machine Technologists by becoming a Triage Engineer. This was an early sign that the workflow will be accepted by the Machine Technologist.

7.2 Functional Requirements

Using these workflows and the data from the personas and scenarios in Chapter 6 helped to set out the high level requirements for LinacLog‘s first prototype design iteration. The first set of these requirements is known as Functional Requirements, which are the behaviour and components of a system. A functional requirement describes what the system is supposed to do [1].

The functional requirements for LinacLog are separated into priorities. These are Low Priority and High Priority. The high priority requirements are requirements that need to be implemented for LinacLog to address the lack of use problem for the current MachineLog.

The LinacLog prototype will be a mixture of different smart devices and will be delivered as modules comprising of:

- LinacLog Hub
- LinacLog Bunker
- LinacLog Triage

- LinacLog Response

Each of these modules will be used by the different staff groups respectively and separates the LinacLog into well defined areas of intended use.

7.2.1 LinacLog Hub

It is envisaged that LinacLog must incorporate a Web Application which acts as a hub and an Application Programming Interface (API). This will allow the Engineers to review metrics and perform administrative tasks such as auditing Linac faults.

However, the core problem is that MachineLog is not being used at all, thus LinacLog hub sits outside the scope of this thesis, and the first iteration of the prototype. LinacLog Hub is a 'nice to have'.

7.2.2 LinacLog Bunker

The application will allow for the logging in to a specific Linac bunker and display a summary of the most recent open fault and the status of the open fault. The Radiographer will be able to scroll through the open faults to track the status. The Radiographer must be able to see a summary of the most recently resolved faults so that they are able to check faults have been resolved or are being addressed. Figure 7.4 shows the Use Case UML diagram for viewing Linac information, changing Linac status and raising a fault on the LinacLog Bunker Tablet.

The application must display the availability of the Linac. It will show whether the Linac is in Clinical Mode or Quality Assurance (QA) Mode. It will also show if there is a restricted use certificate issues for the Linac.

The App must allow the Radiographer to switch between Clinical and QA mode, which will record a time stamp in the system for reporting purposes. The App will allow the Radiographer to raise a fault and alert the radiographer that this fault alert has been successfully delivered to a Machine Technologist.

This overview of requirements can be visualised as a Use Case, shown in Figure 7.4.

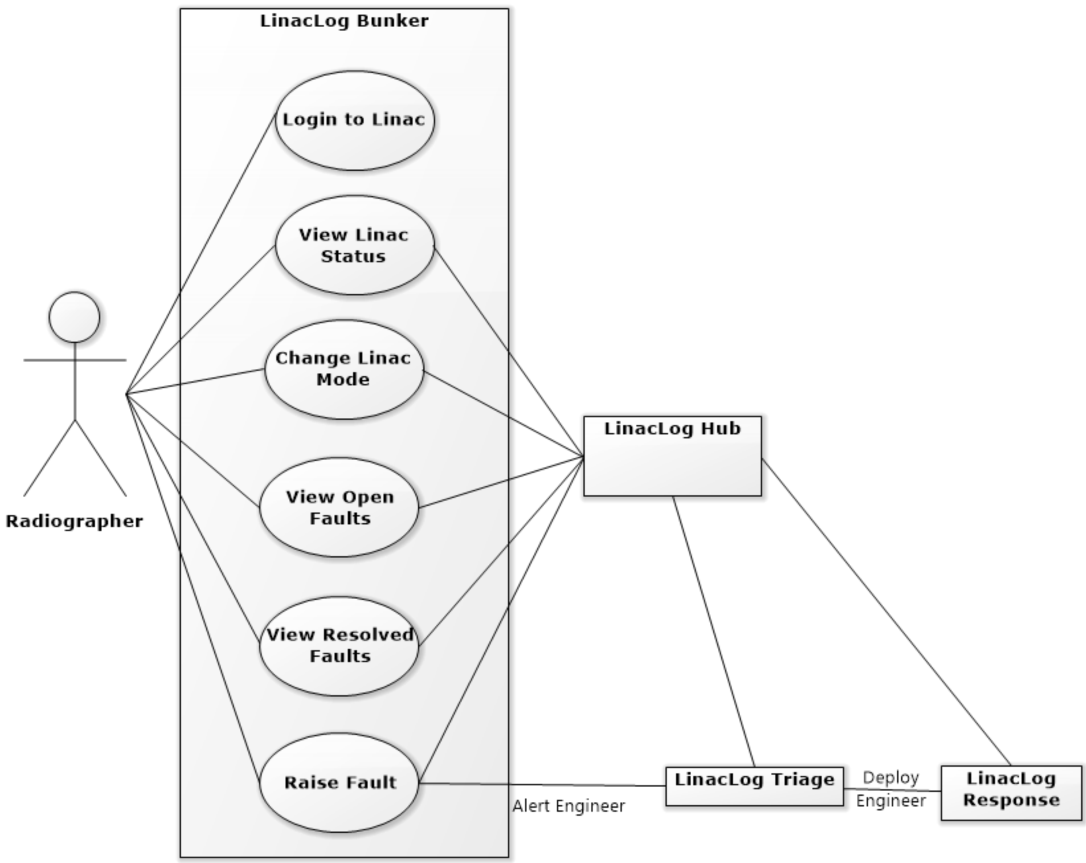


Figure 7.4: Use Case: Viewing and raising faults on Linac Bunker

The Use Case in Figure 7.4 can be translated into a list of high priority and low priority requirements such in Tables 7.1 and 7.2, respectively. These requirements are able to inform the design of LinacLog Bunker and its evaluation.

High Priority Requirements	
Requirement No	Description
LB1	Login to a specific bunker
LB2	Display summary of unresolved faults
LB3	Display summary of recently resolved faults
LB4	Display whether Linac is in QA model or Clinical Mode
LB5	Be able to switch from QA mode to clinical mode and vice versa
LB6	Button to raise and record fault.

Table 7.1: LinacLog Bunker High Priority Requirements

Low Priority Requirements	
Requirement No	Description
LB7	Display Restricted Use Certificates

Table 7.2: LinacLog Bunker Low Priority Requirements

7.2.3 LinacLog Triage & Linac Response

LinacLog Triage must inform the Triage Machine Technologist (Engineer) that a new fault has been raised by a Radiographer, from LinacLog Bunker. The App must then allow the Triage Engineer to accurately enter fault information and set a priority flag. The flag will be either Low or Critical. The App then must allow the Triage Engineer to assign the fault to a specific Machine Technologist (Engineer). LinacLog Triage will be an extension of LinacLog Response.

LinacLog Response must alert the Machine Technologist (Engineer) that they have been assigned a new fault by the Triage Engineer. The Machine Engineer needs to be able to telephone the Linac bunker. After the call, the Machine Engineer then needs to be able to enter some more information surrounding the fault.

The Machine Engineer needs to be able to access a list of faults so that the Machine Engineer can manage their fault workload. The Engineer also needs to be able to open up a specific fault record, be able to view information of the fault, update the fault and then request that the fault is resolved by pressing on a 'Resolve' button. When the resolve button is pressed, this will then send a request to LinacLog Triage to close the fault completely. Figure 7.5 also demonstrates the Use Case for LinacLog Response.

The App must include the ability for the Machine Engineer to sign out when they are off duty so that LinacLog Triage is able to exclude them from a list of available Machine Engineers.

This overview of requirements can be represented as a Use Case, shown in Figure 7.5.

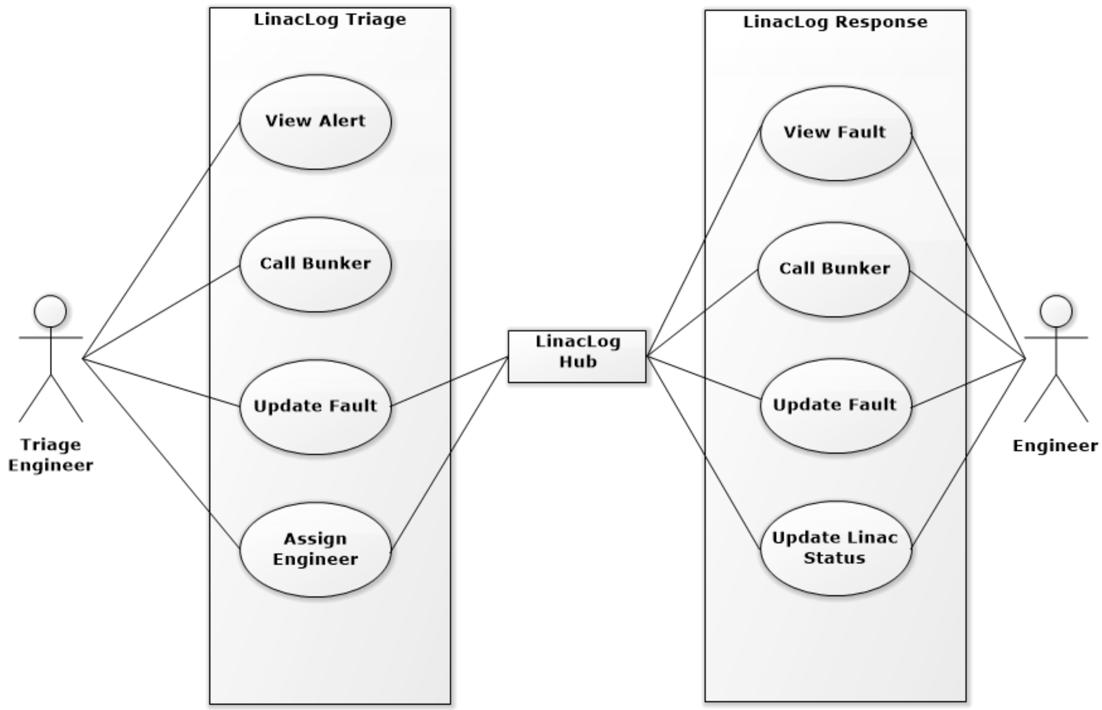


Figure 7.5: Use Case: Triaging Faults and Managing Faults

The Use Case of LinacLog Triage can be translated into a list of high priority and low priority requirements in Tables7.3 and 7.4, respectively.

LinacLog Triage High Priority Requirements	
Requirement No	Description
LT1	View Linac Alert
LT2	Call Linac Bunker
LT3	Update Fault
LT4	Assign Engineer to fault

Table 7.3: LinacLog Triage High Priority Requirements

LinacLog Triage Low Priority Requirements	
Requirement No	Description
LT5	View all open Linac Faults

Table 7.4: LinacLog Triage Low Priority Requirements

The Use Case of LinacLog Response (Figure 7.5) can be translated into a list of high priority and low priority requirements in tables , respectively.

LinacLog Response High Priority Requirements	
Requirement No	Description
LR1	Accept or Queue Assigned Fault
LR2	Call Linac Bunker
LR3	View Fault
LR3	Update Linac Fault Status
LR4	Change Linac Fault Priority
LR5	Request to re-assign fault to another engineer
LR6	Mark fault as resolved

Table 7.5: LinacLog Response High Priority Requirements

LinacLog Response Low Priority Requirements	
Requirement No	Description
LR7	View all open Linac Faults
LR8	View all faults assigned to specific engineer

Table 7.6: LinacLog Response Low Priority Requirements

7.3 Non-Functional Requirements

After identifying the functional requirements, the non-functional requirements were considered. Non-functional requirements outline the constraints there are on the system and its development [1]. MachineLog in its current form is unusable and as one of the goals of this thesis is to re-design MachineLog so it is usable, the usability aspects of non-functional requirements were focused upon.

7.3.1 LinacLog Bunker Usability

LinacLog Bunker must be a smart tablet that can be fixed to the desk. It should be able to be removed for servicing when required. It must be placed in the Linac Control Area next to the Function Keypad (Figure 2.3) so that it is easily accessible and noticeable to the radiographers whilst they are performing their work. This ensures that the Radiographers do not need to leave their area of work to raise a fault. The camera must be disabled or hidden so that that the area around the Linac is protected.

The design of the app should include reliable information such as displaying accurate information on fault updates. This information display will utilise a visible fault status indicator. The Radiographer must be presented with the information that they are required to know in order to perform their role, they do not necessarily need to know the absolute status of a fault, only an overview of what is being addressed. For example, the Radiographer does not need to know that Machine Technologist Dave needs to change the screw that holds the bulb holder in place and is currently awaiting delivery of the new screw from their specialist supplier. They do however need to know that Dave is working on fixing it.

The Radiographer must be able to clearly view that their fault has been raised and acknowledged and provide an interface which demonstrates this as feedback. It must not happen behind the scenes, it must be clearly displayed to the Radiographer so that the Radiographer has the same confidence as they would of someone answering the phone when they previously raised fault.

The non-functional requirements are shown in Table 7.7.

LinacLog Bunker Non Functional Requirements	
Requirement No	Description
LBNF1	Smart tablet that can be fixed to a desk
LBNF2	Placed next to the Function Keypad
LBNF3	Camera must be disabled
LBNF4	Able to login and logout as different Linacs

Table 7.7: LinacLog Bunker Non Functional Requirements

7.3.2 LinacLog Triage Usability

LinacLog Triage must be a smartphone app. This will allow the Triage Engineer to remain mobile and respond to faults. Fault response is ad-hoc and reactive in nature, meaning that a fault can occur anytime and the Triage Engineer is not actively sitting at their desk waiting for faults to arrive. The Triage Engineer is also involved in resolving faults. However, the Engineer needs to be alerted to a fault as it is now their role to respond first and coordinate a response to a fault. A mobile smart device will allow the Triage Engineer to respond to faults and continue to work on prearranged and planned work.

The Triage Engineer must be able to see information on the Linac that has reported the fault. This will be in the form of an alert box. The box will display the Linac location and an option to Call the Linac. As it will be the responsibility of the Triage Engineer to respond to faults and thus triage faults, the Triage Engineer will only have the option to call the Linac. The device will continue to make an audible alert whilst vibrating until the Call button is pressed.

The Triage Engineer must then be able to record brief information surrounding the fault and then assign the fault to an engineer with a priority. The Triage Engineer will be presented with a list of Engineers and a slide-able Priority indicator. In the event that a Linac has raised a fault on behalf of another Linac, the Triage Engineer must be able to change the Linac that the fault will be assigned to. The Triage Engineer can not exit this screen until this has completed, ensuring that the Engineer performs this task before moving on to their next task.

The non functional requirements are displayed in Table 7.8.

LinacLog Response Non Functional Requirements	
Requirement No	Description
LRNF1	Smartphone App
LRNF2	Login and Logout

Table 7.8: LinacLog Response Non Functional Requirements

7.3.3 LinacLog Response Usability

LinacLog Response must also be a smartphone app. This will allow the Machine Engineer to remain mobile whilst responding to faults. It could be that a Machine Engineer is already responding to a fault and by developng LinacLog Response as a mobile app, it allows the Machine Engineer to respond to faults on a ad-hoc reactive basis, whilst still being able to perform their own planned work. However, the planned work for resolving faults must be captured within LinacLog Response.

Machine Engineers can be compared wih Field Engineers, the work of the Machine Engineer is performed in the 'field', or in this case the Linac. It is sensible to have a mobile app so that the Machine Engineer can update fault information 'on the go' as opposed to needing to enter the information directly on a PC in an office, hours after the fault has been addressed.

Currently, MachineLog is a desktop based application. As the Machine Engineers work is on the field, by the time they return to their desk to complete Machine Log, information and updates may have been forgotten. By changing this to a mobile app it may help to ensure that entering data within LinacLog is not another task that is forgotten.

The Machine Engineers must be presented with a default interface that shows them:

- A number indicating the amount of new fault updates
- A number of All faults that the Machine Engineer has assigned to them
- A list of the most critical faults
- A list of the most recent fault update

The Machine Engineers must be presented with a visual notification, an audible alert and vibration, alerting the Engineer that there is a new fault that has been assigned to them. The Engineer must be able to 'Accept and Call' the Linac or request to Queue the job if they are unavailable. They must not be allowed to re-assign the job to someone else.The Machine Engineer must be presented with an interface which allows them to manage and update the fault.

The non functional requirements are displayed in Table 7.9.

LinacLog Triage Non Functional Requirements	
Requirement No	Description
LRNF1	Smartphone App
LRNF2	Login and Logout

Table 7.9: LinacLog Triage Non Functional Requirements

7.3.4 Infrastructure Requirements

The smart devices must communicate with a Microsoft SQL Server Database Server and IIS on the Hospital‘s IT Network to enable seamless interaction between software and devices. To achieve this, the smart devices must be connected to the Wireless Local Area Network with access to the web service & Microsoft SQL Server. This requires Hospital IT Network teams to connect the tablets and smartphones to the hospital Network, upon Information Governance approval.

The devices will need to connect to the Hospital‘s Mobile Device Management software.

The non functional requirements are displayed in Table 7.10.

Infrastructure Non Functional Requirements	
Requirement No	Description
INF1	Access to SQL Server Database
INF2	Connected to hospital WiFi using Mobile Device Manager

Table 7.10: Infrastructure Non Functional Requirements

Chapter 8

Prototype Design

One of the goals of this thesis is to re-design MachineLog so that it is used properly by the Radiographers. To achieve this goal, by using the specification in Chapter 7, the prototype can move on to the next stage in the design process: designing a prototype.

The prototype consists of low-fidelity user interface sketches, sketched in software called Adobe XD, for each suite of the software, which are:

- LinacLog Bunker
- LinacLog Triage
- LinacLog Response

The sketches were used to visualise and envisage what the first iteration of how the application might 'look and feel' to the user.

8.1 LinacLog Bunker

LinacLog Bunker is a smart-tablet application. It is intended to be used by the Radiographer. The Radiographer is to use LinacLog bunker to primarily raise faults, change the clinical mode from QA to Clinical and vice versa, and to view essential information for the Linac, such as:

- Linac Availability (Clinical Mode or QA Mode)
- Restricted use for the Linac, for example a specific beam can not be used.
- Current unresolved faults that can be scrolled through, so that the radiographers can be made aware of the status of a fault.
- Recently resolved faults that can be scrolled through.

A key feature of LinacLog Bunker is presenting the status of a fault in a quick and meaningful way, whereby the radiographer glances at the screen to quickly determine where a fault is in the resolution process. To do this, a Fault Status Indicator was developed.

8.1.1 Fault Status Indicator

Displaying information on a tablet screen is a challenging. One piece of useful information is the status of a fault. A Fault Status Indicator was sketched, designed to allow the Radiographer to quickly glance and view the status of a fault, allowing us to achieve one of the non-functional requirements in Chapter 7.

Figure 8.1: LinacLog Bunker: Fault Status Pathway Indicator

The status indicator is displayed on the default interface, which includes a summary of fault status.

8.1.2 Default Interface at Idle

At the top of the default interface shown in Figure 8.2, the interface shows the overall treatment status of the Linac. The Unrestricted Use indicator will change amber if there is a restricted certificated issued. The restricted use certificate is issued by a Medical Physicist stating that the Linac can only be used for certain radiation beams. If there is a major fault preventing the Linac from being used, the indicator will change to a red colour with the label 'Offline'.

The 'Operating Clinically' label shows whether the device is being used clinically. If the device is placed into Quality Assurance (QA) Mode, the label will change to display QA Mode (Right) is independent from the status indicator (Left).

The default screen also displays a summary of Unresolved Faults. This is to inform the radiographers of faults which are currently unresolved, or being dealt with by the Radiotherapy Machine Engineers. The information displayed consists of: The date and time the fault was logged, the title of the fault and a fault status indicator which displays the fault resolution pathway. Below the fault status indicator are two buttons with arrows. These buttons allow the radiographer to scroll through unresolved faults. However, the faults will self-scroll on a timer if there is more than one fault, so that the list of unresolved faults are displayed in order of priority and submission date.

Below the unresolved faults section of the default interface is the recently resolved faults. This section displays the date and time that the fault was resolved, with a brief title of the fault. There are two buttons below this which allows the radiographers to scroll through the last 3 faults that were resolved.

There are two buttons at the bottom of the interface. The Change to QA mode (Bottom right) will be used when Radiographers are performing QA in the morning. If QA mode is already selected, the button will display Change to Clinical Mode. This button is used for time stamping, removing the need for radiographers to enter the start time and dates manually. The Raise Fault button (Bottom Left) is a button which is pressed that 'kicks off' the fault process, allowing the radiographer to quickly raise a fault with the least amount of interaction.

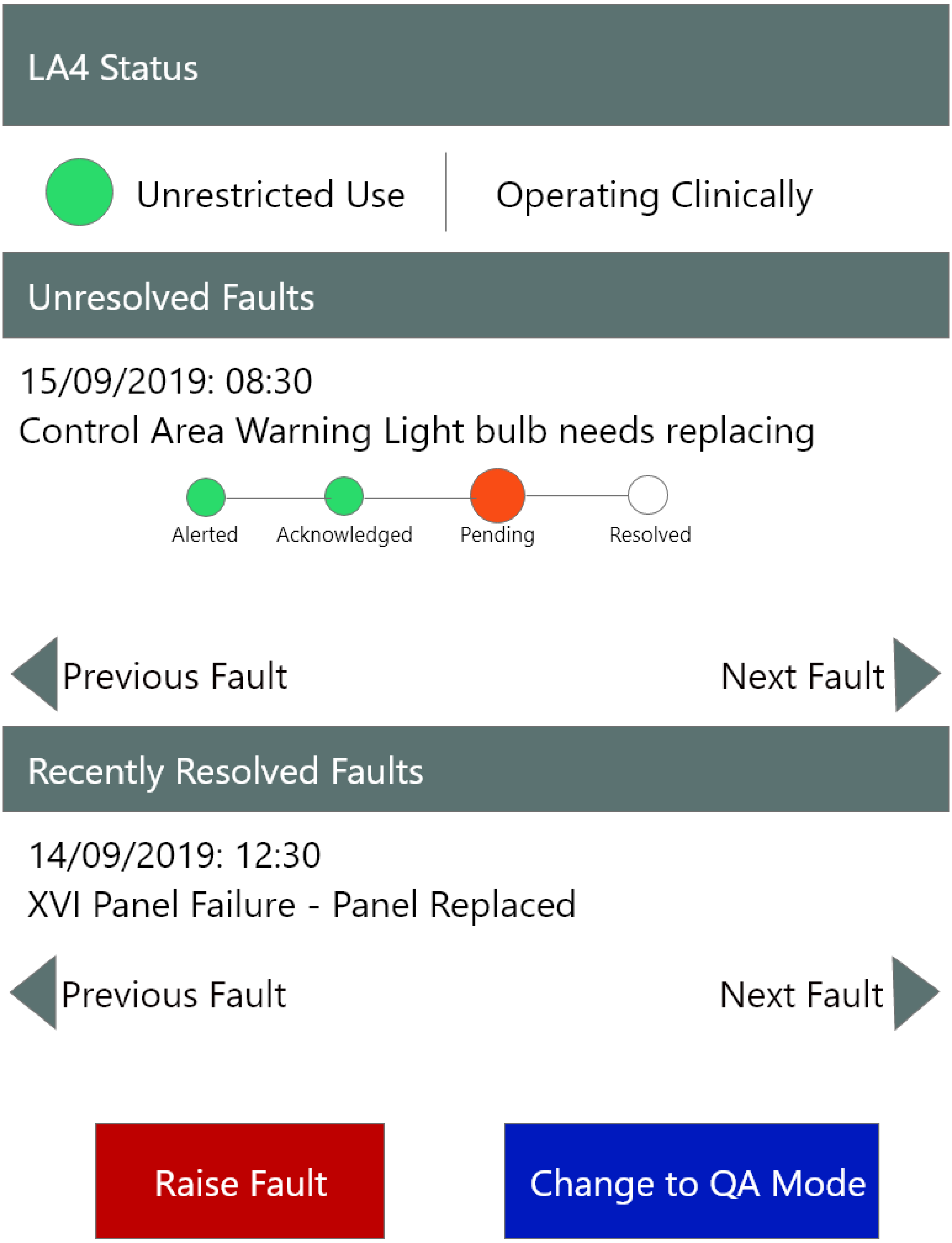


Figure 8.2: LinacLog Bunker: Default screen sketch

8.1.3 Raising a New Fault

When the Raise Fault button is pressed in Figure 8.2, a new interface shown in Figure 8.3 is displayed to the radiographer. The top of the interface remains the same as the default interface which allows the radiographers to see the status of the Linac.

However, the unresolved faults section changes to display the current fault and its acknowledgement status. The radiographer can clearly see that the fault has been raised by using a ‘Fault alert has been sent’ box. The radiographer can also view the status of the fault alert

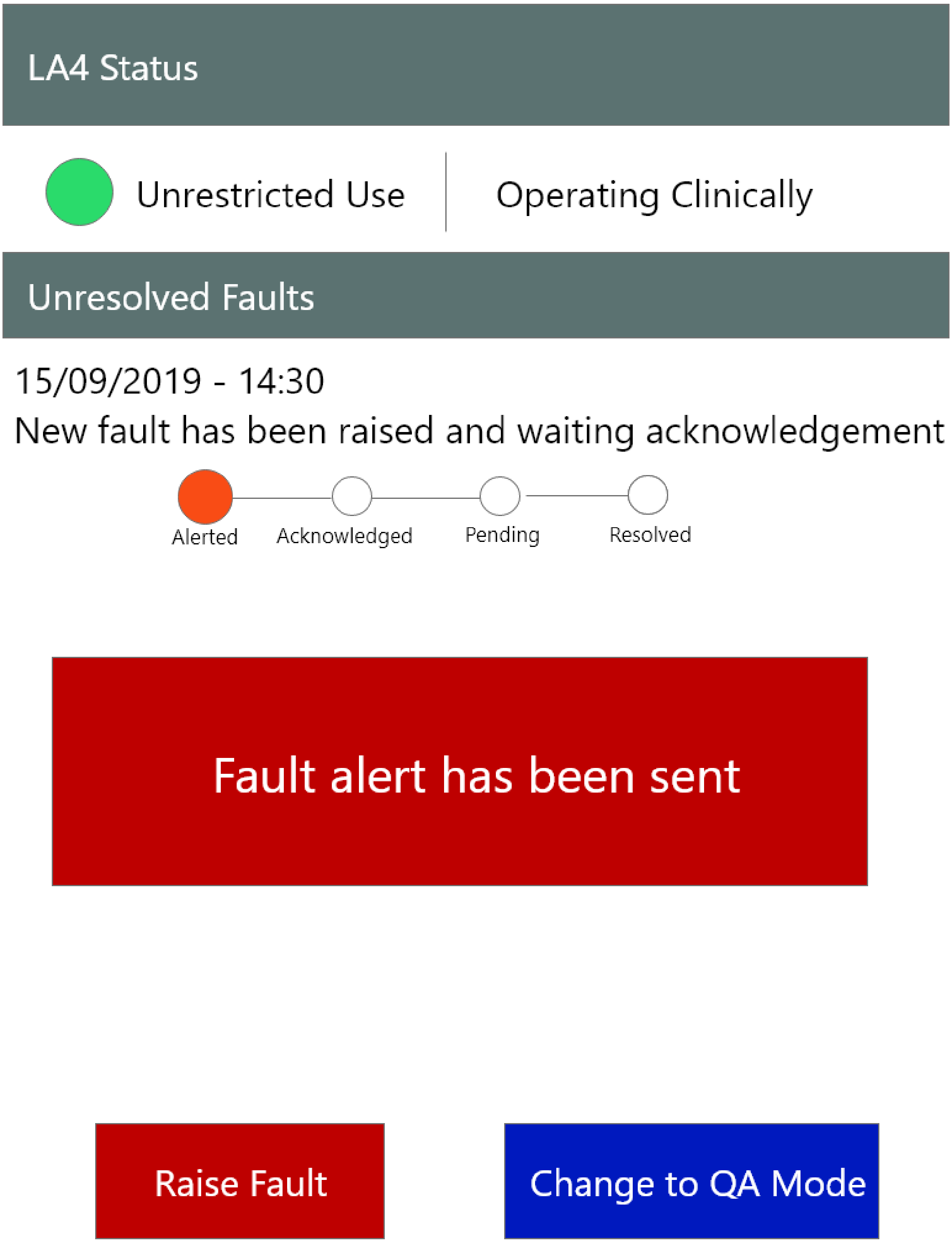


Figure 8.3: LinacLog Bunker: Raising a fault sketch

8.1.4 New Fault Acknowledgement

After the Radiographer has pressed the Fault button, they are presented with a Fault Acknowledgement alert. Shown in Figure 8.4, The ‘Unresolved Faults’ section updates to reflect that the Fault has been acknowledge by the Triage Engineer. The Fault Pathway Indicator changes to display a green circle with the subtext ‘Alerted’ and a larger amber circle displaying the subtext ‘Acknowledged’. This provides an easy way to differentiate between the other indicators within the fault pathway. The uncoloured circles represent the pathway which has not been complete.

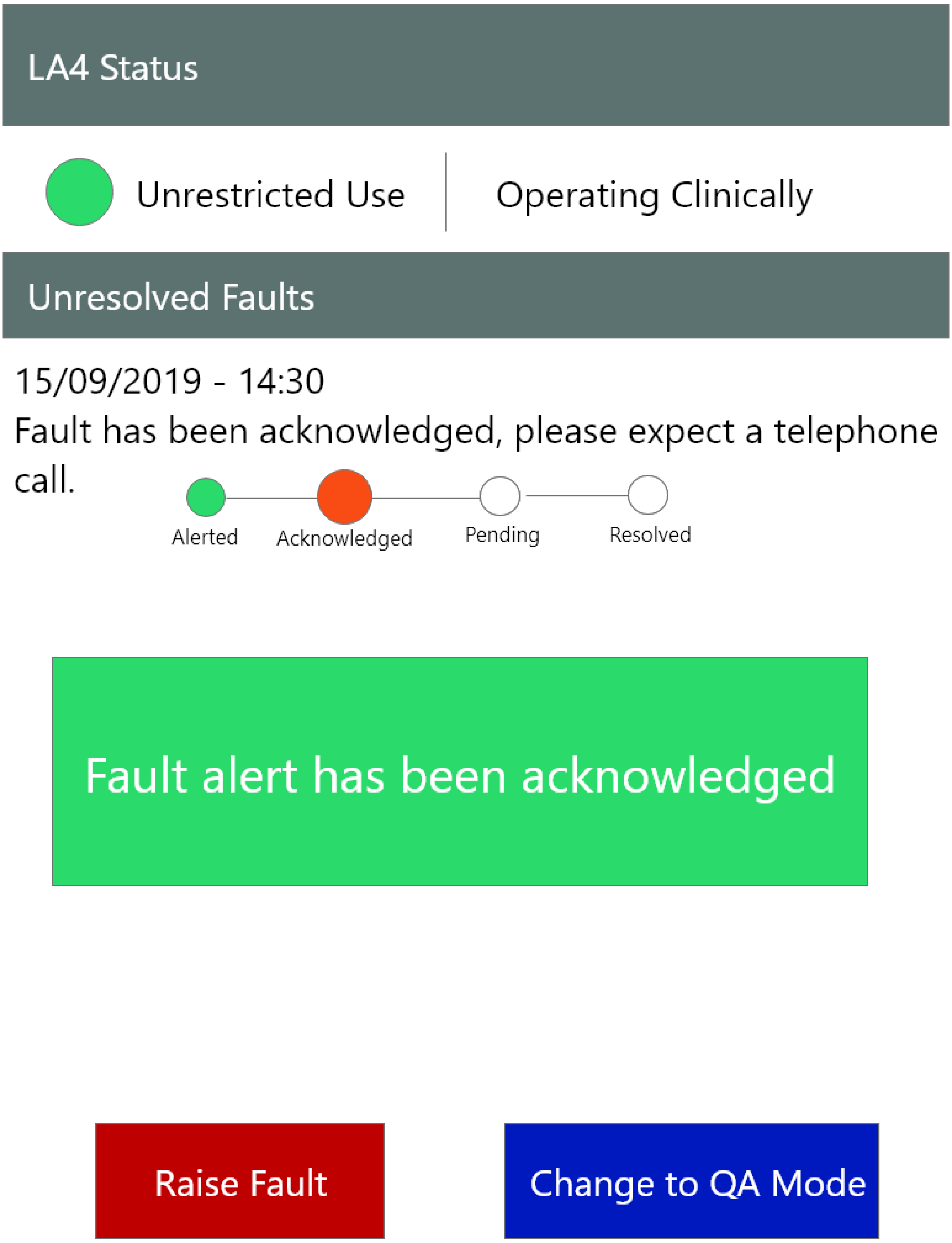


Figure 8.4: LinacLog Bunker: Receiving fault acknowledgement

8.1.5 Bespoke Desk Mount

One of the non-functional requirements in Chapter 7 required that the tablet be fully secured to the desk. There are commercial and off the shelf solutions for this. However, none of them met the requirement for covering the camera and ensuring that the user could not access the button navigation menu and the top menu settings within the Android OS.

One option could be to use a commercial app that disables these features. However, a simpler solution would be to extend the plastic covering over the tablet and adjust the interface size. It is a nice elegant physical solution resolving a technical challenge.

Therefore, a bespoke tablet desk mount, displayed in Figures 8.5 and 8.6 was designed, which conformed to the non-function requirements specification. The mount allows for secure fixing to the desk and can only be removed using a specific screw key.

Figure 8.5: LinacLog Bunker: LinacLog Bunker Tablet Mount Front

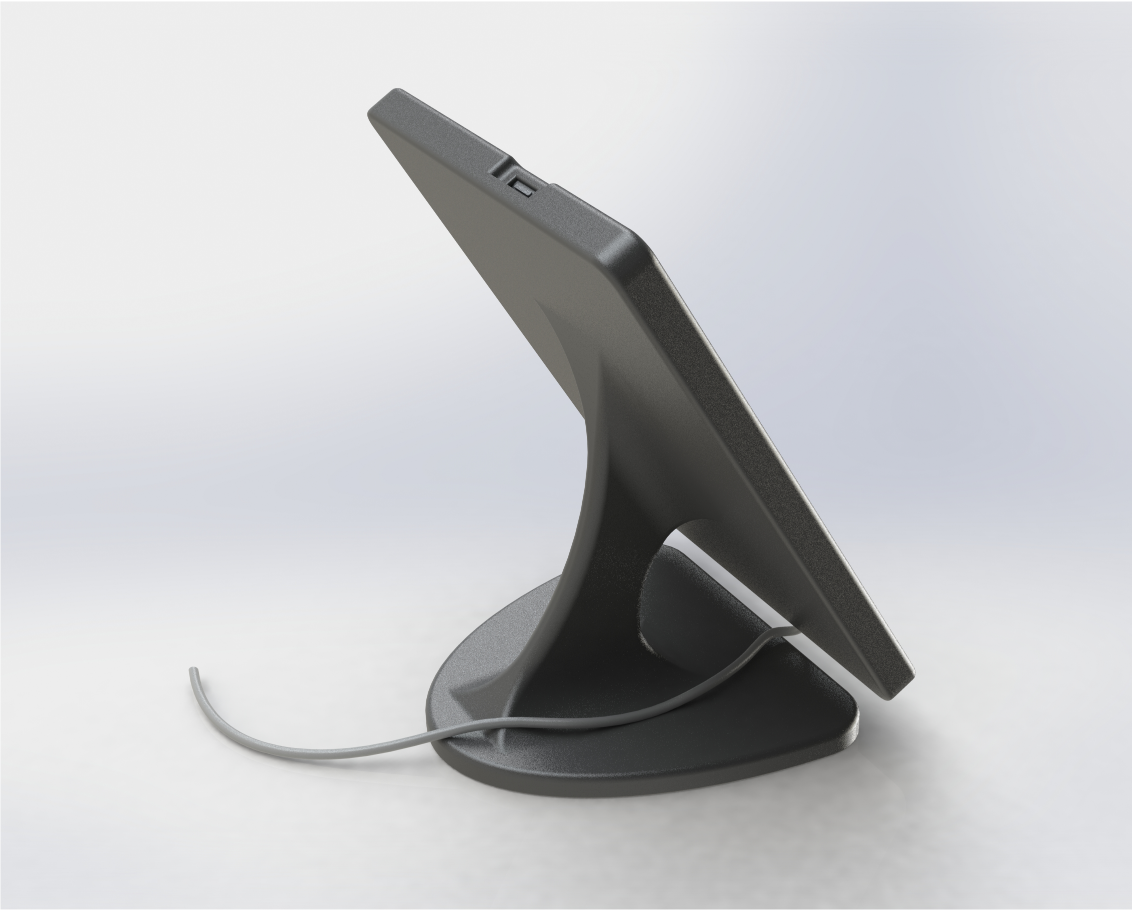


Figure 8.6: LinacLog Bunker: LinacLog Bunker Tablet Mount Back

8.1.6 Environment Renders

By creating renders of the prototype it possible to envisage how the LinacLog Bunker tablet would be positioned in its physical environment. The LinacLog Bunker tablet was virtually placed next to the 'Function Keypad' (FKP), a device which the Radiographers use to activate the radiation beam, and thus 'kick-off' the radiotherapy treatment to a patient. This way if there is a fault, a radiographer can quickly hit 'Raise Fault' if a fault becomes apparent. LinacLog becomes a piece of software (and hardware) which is directly placed within the area that Radiographers perform most of their work when controlling the Linac, instead of a piece of software on a PC located in the corner, away from the work. This is in line with the non-functional requirements for LinacLog Bunker in Chapter 7.

Figure 8.7: A wide view of LinacLog Bunker in the control area positioned next to the Linac Control device

Figure 8.8: LinacLog Bunker: A close up of LinacLog Bunker in the control area positioned next to the Linac Control device

8.2 LinacLog Triage

LinacLog Triage is a mobile app that is installed on an Android smartphone. The app allows the Triage Engineer to receive a fault alert from a Linac Bunker and assign the fault to Machine Engineers.

8.2.1 New Fault Alert

Figure 8.9 shows a simple alert on LinacLog Triage, the smartphone app for the Triage Engineer. The alert informs the Triage Engineer that a Radiographer has pressed the fault button on Linac Bunker, as shown in figure 8.3. The Triage Engineer must then press the 'Call' button. The button then calls the LinacLog Bunker tablet, giving the radiographer direct verbal communication with the Triage Engineer, as a first line response, as discussed in Chapter 7 section 7.2.2.

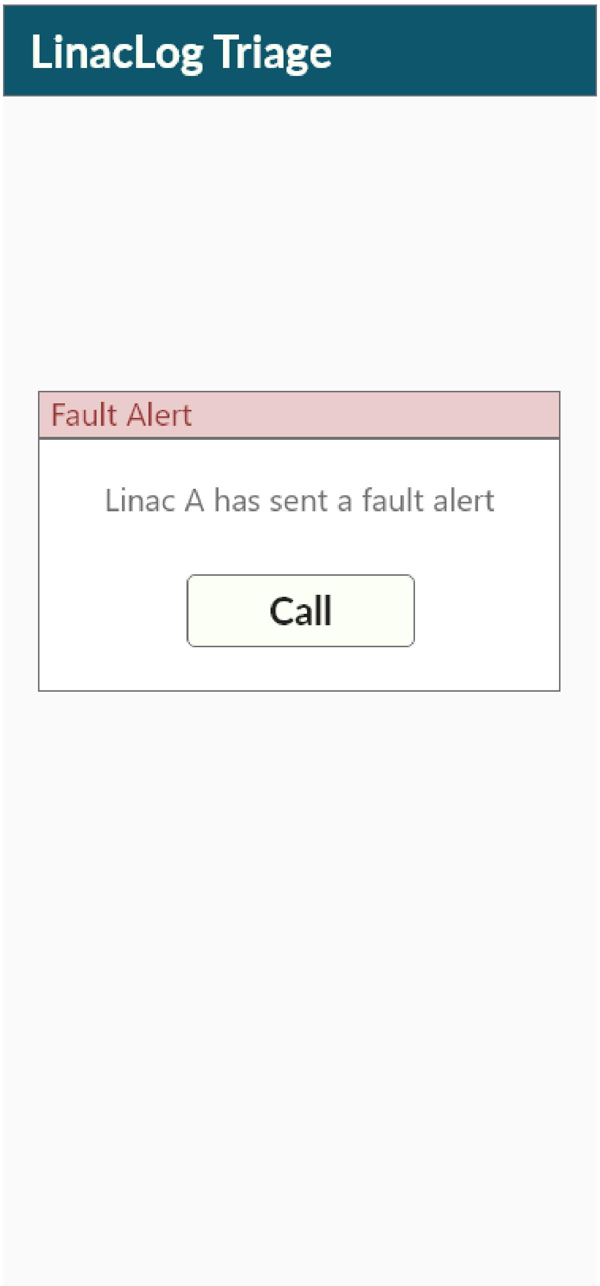


Figure 8.9: LinacLog Triage: Receiving a fault alert from a Linac Bunker

8.2.2 Assigning an Engineer

After the Triage Engineer has completed the call to the Linac Bunker, the Engineer then needs to be able to record some basic information and assign an Engineer to respond to the fault.

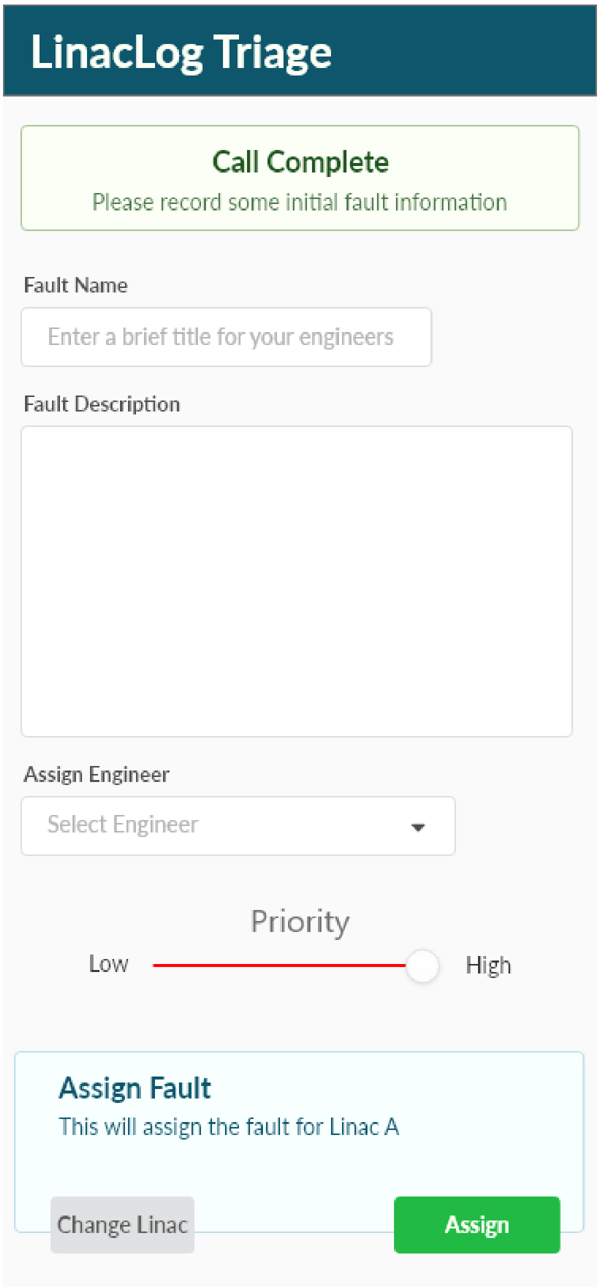


Figure 8.10: LinacLog Triage: Assigning the engineer

Figure 8.10 allows the Triage Engineer to provide a title for the fault and a brief description so that the engineer is aware of the type of Fault. The Triage Engineer can then assign the fault to a specific engineer using the drop-down menu. The Triage Engineer can then select the priority of either 'Low' or 'High' depending on the fault type by sliding the slider towards High. By selecting a low priority it will assign the fault to the engineer's fault queue for the engineer to investigate the fault when they are available to do so. However, by selecting the high priority, the engineer would only be given the option to call the Linac Bunker ensuring that the engineer responds to the issue as soon as they recieve the alert.

Towards the bottom of the interface is an information box drawing attention to which Linac the Triage Engineer is assigning the fault to. There is a 'Change' button allowing the Triage Engineer to override the default selection in the event that a Radiographer has raised a fault which applies to a different Linac Bunker, from a different Linac Bunker tablet.

The Triage Engineer is then able to press the 'Assign' button which assigns the fault to the selected Engineer.

It is worth noting that there will become a natural point where the Triage Engineer will want to assign a fault to a particular category of fault. For example, the Triage Engineer may want to assign an XVI panel fault to an 'Imaging Faults' category, or a linac bunker control area PC failure to a 'Control Equipment' category. This category assignment has not been captured within this sketch.

8.3 LinacLog Response

LinacLog Response is a mobile app installed on an Android smartphone. The app allows the Machine Engineers to receive fault alerts, respond to faults and track fault information. The prototype consits of two default interface sketches, an interface displaying a 'New Fault Alert' notification and an interface for viewing a fault.

8.3.1 Default Interface Sketch 1

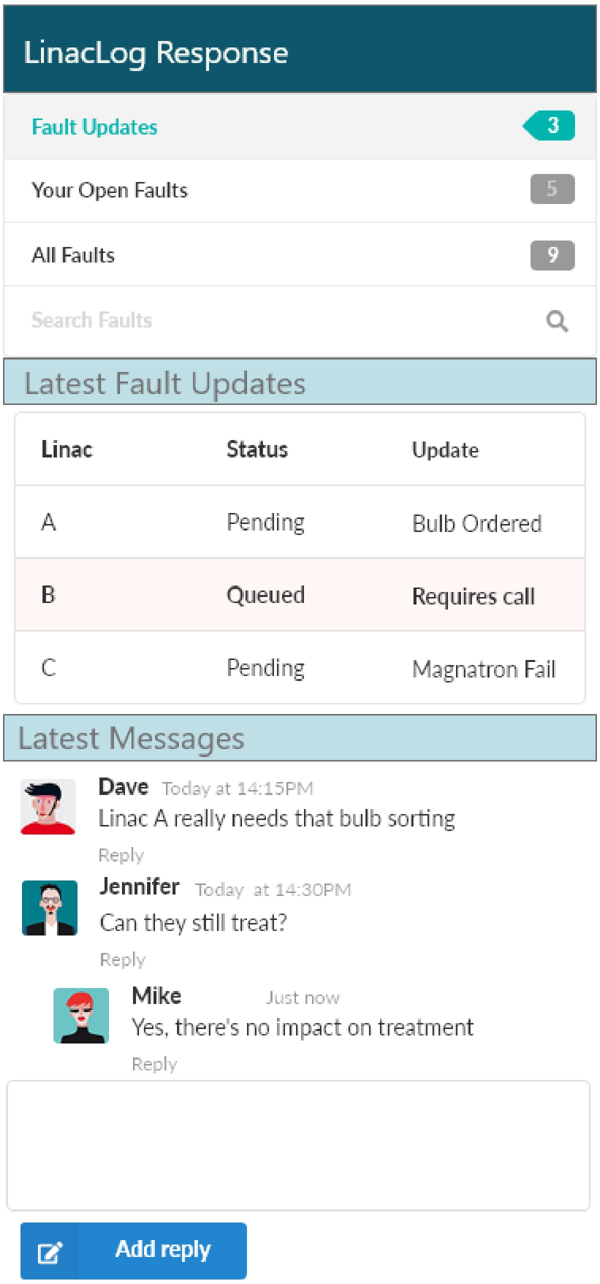


Figure 8.11: LinacLog Response: The default interface sketch 1

Figure 8.11 displays the first iteration of the default interface sketch. This interface includes a top menu that the Engineering presses on to view the latest Fault Updates, the Engineer's open faults and All faults that the team are currently working on. The menu also includes a 'Search Faults' search bar which allows the Engineer to search for a fault.

Below this menu is sketched a 'Latest Fault Updates' table. This enables the Engineer to press on a fault which contains a new unseen update. Faults which require urgent attention are highlighted in a pastel red.

Below the 'Latest Fault Updates' table is sketched we sketch a 'Latest Messages' message window. The Engineer can quickly send messages to other members of the team using this. However, this was not something investigated and could be identified as a feature creep. After re-visiting the specification and the study, I concluded that there was no obvious need for a messaging system to facilitate the work of the Machine Engineers, given that they can update the fault information. This chat feature could potentially duplicate work or encourage the Machine Technologists to update fault information outside of the controlled fault management aspects of LinacLog. Furthermore, it was not clear on what menu items can be pressed on the top menu as the top menu could appear as an information box as opposed to a clickable menu. Therefore, the default interface was re-sketched, as shown in Figure 8.12.

The sketch in Figure 8.12 includes a change in the information that is displayed. A new 'Most Critical Faults' table was sketched, so that the Engineer could view the most critical faults. These faults are usually something which prevents a Linac from delivering patient treatments and thus causes issues and delays in the patient treatment pathway.

8.3.2 Default Interface Sketch 2

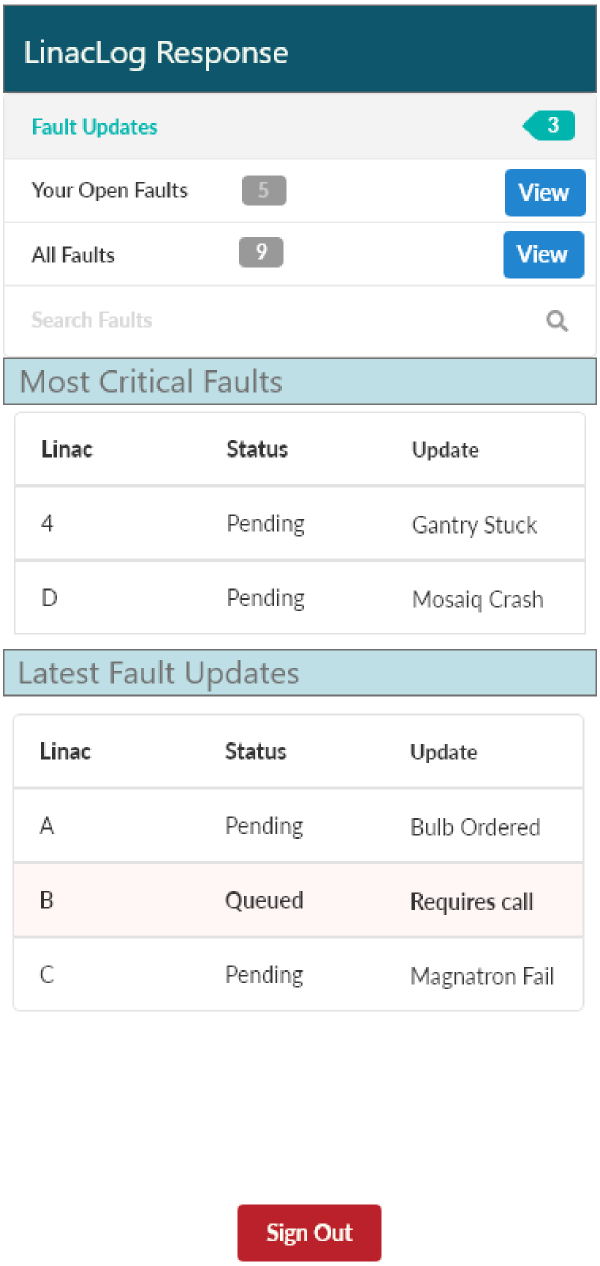


Figure 8.12: LinacLog Response: The default sketch 2, interface in line with requirements specification

8.3.3 New Fault Alert

Figure 8.13 demonstrates how the Machine Engineer will receive a popup alert. This notifies the Machine Engineer that they have been assigned a new high priority fault by the triage Engineer and the smart device will vibrate and play an audible tone until the notification is dealt with. The Triage Engineer‘s name is displayed, their role and a picture of the Triage Engineer. Below this is a brief summary and an option to ‘Accept & Call’ or ‘Queue’ the fault job depending. Queuing will alert the Triage Engineer, who can override the Queue, or re-assign the fault to another engineer. The alert box is central to the screen, drawing the Machine Engineer‘s attention. The smartphone device will play an audible alert tone and vibrate.

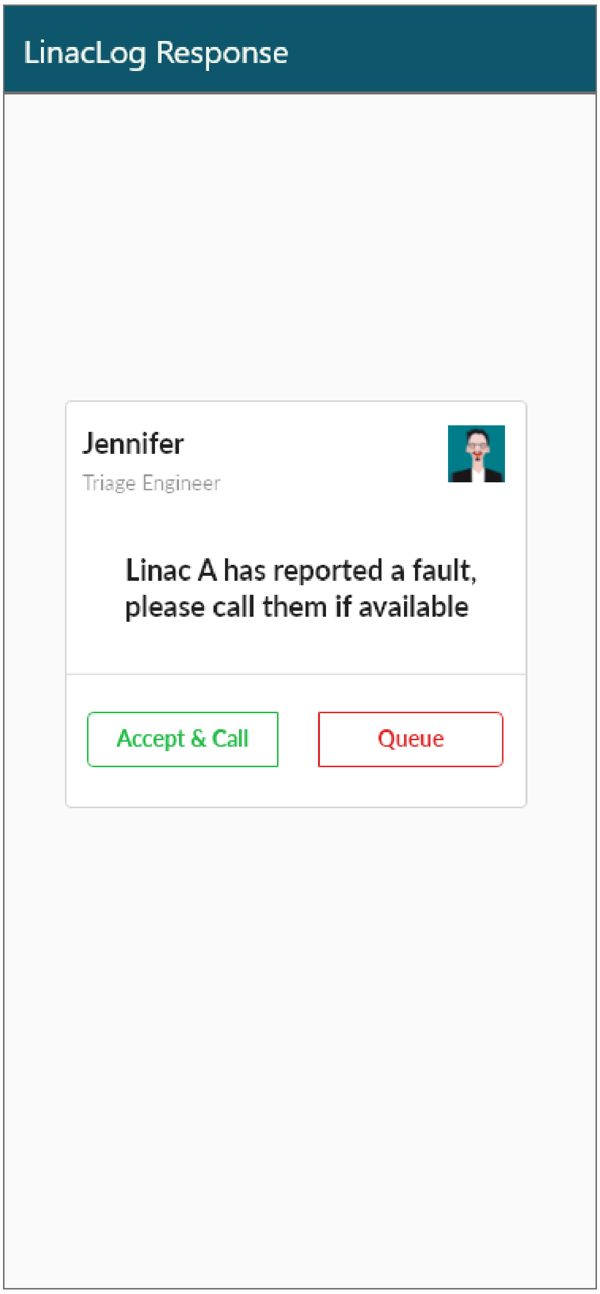


Figure 8.13: LinacLog Response: Receiving a fault alert from the Triage Engineer

8.3.4 Viewing a Fault

The Machine Engineers need the ability to manage faults whilst mobile. The LinacLog Response smartphone app will include an interface which provides this feature, as shown in Figure 8.14. The interface displays the Linac which the fault is assigned to and a brief title of the fault next to a picture of the assigned Engineer.

Below this, the Fault Description can be seen and a button available which allows the Engineer to read further information and images relating to the specific fault. In Figure 8.14, a 'Recent Update' box displays the most recent update and information about the date and time the update was added, and the Engineer who added the update. This includes an 'Add Update' button which allows the Engineer to add further updates on the fault.

A collection of three buttons provides the Engineer further options such as 'View All Updates' which allows the Engineer to view all of the Update history associated with the fault, and a 'Re-Assign' button which allows engineers to request that a fault be re-assigned to a different Engineer. This is useful for when Engineers are unavailable due to planned leave. However, it is important to emphasise that this feature is a request for re-assignment. The Lead Engineer would need to approve the request, in order to meet the requirement of greater control over Engineer workload, as described in Chapter 7.

If the fault is ready to be completed by the Engineer, the Engineer can touch the Resolved button. This flags the fault as resolved and sends the fault to the Triage Engineer for review. Once the Triage Engineer is satisfied, it would be the Triage Engineer responsible for closing the fault completely. If the job is not ready to be completed, the Engineer can touch the Exit button. Careful consideration was taken when designing this button. The word Exit was chosen over Close as Close could represent the closing of a fault as opposed to the closing of the interface.

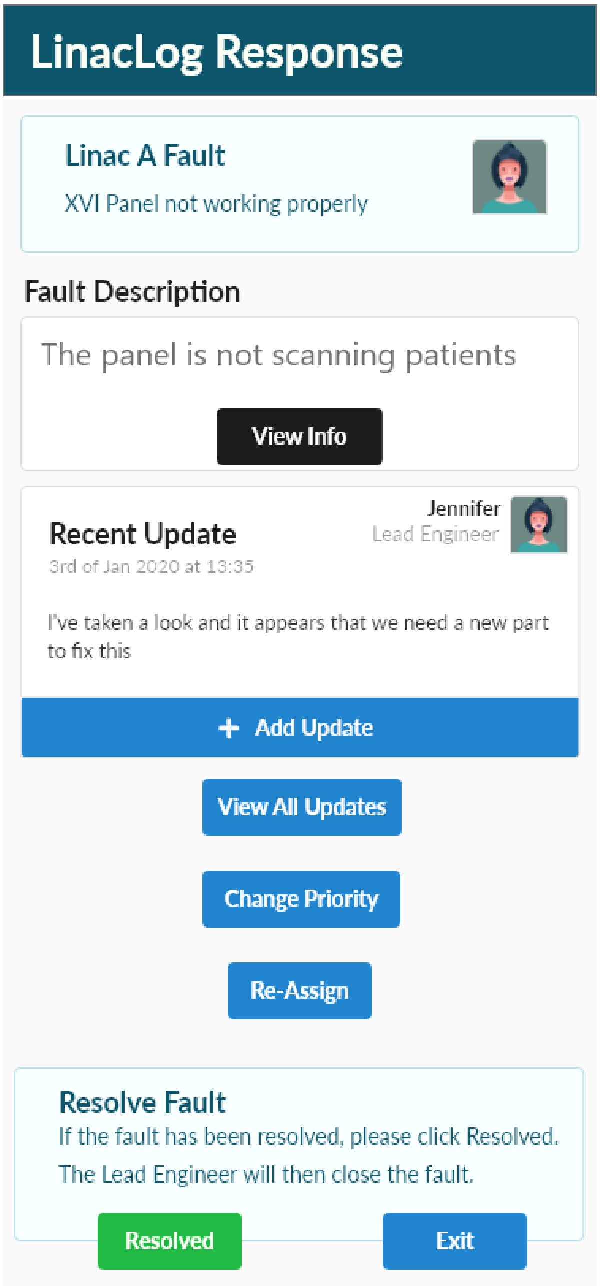


Figure 8.14: LinacLog Response: Receiving a fault alert from the Triage Engineer

Chapter 9

Prototype Evaluation

The work in Chapter 8 focused around the development of a low-fidelity prototype, named LinacLog, that can be evaluated. Therefore, the goal of this chapter is to discuss the work around the evaluation of this prototype.

However, evaluating prototypes in the NHS is a difficult task. Design experts experience difficulties in recruiting NHS staff for evaluation [41]. Furthermore, NHS staff lack awareness of HCI and lack the awareness for the need of design [7]. Moreover, many HCI design evaluations, such as Cognitive Walkthroughs, must be performed by design experts [43].

Nevertheless, HCI methods frequently mention the need to include the users during the design of software. For example, Rieman, et al. [42] mention that the users should be involved in the early stages of prototyping. Despite not being design experts, Healthcare Professionals, who are developing Medical Infrastructure Software, are still able to evaluate the software that they have developed [41].

In the context of this thesis, Usability Testing would allow us to perform evaluations of software as non-design experts [8]. These methods can be used as an attempt to address lack of use problems such as those exhibited by MachineLog.

Specifically, user testing can be a good method for evaluating and iteratively refining user requirements and improving acceptance of a system [50] [51].

Furthermore, according to Cassano-Piche, et al. [8], one must understand the environment of use, the users and work. The advantage as Healthcare Professionals is that we are immersed in and understand the complex environment of use, when developing software solutions to solve problems in this environment.

The understanding of the activities was aided by the contextual inquiry observations discussed in Chapter 5. This was important for planning the evaluation tasks, especially where there is a lack of design expertise within the NHS, or difficulty accessing design experts. The activities helped to inform the scenarios in Chapter 6 which in turn helped to inform the user testing tasks, discussed later in this Chapter.

However, before diving into a user test, it seemed sensible to review the design meets the requirements set out in the software requirements specification discussed in Chapter 7. The design reviewed aimed to uncover issues that may arise before testing with users who are time constrained.

Fortunately, a design review does not require the reviewer to be a design expert. However, the design review can not identify how usable LinacLog might be and therefore should not be used on its own to determine usability [52]. Therefore, the design review of LinacLog served as a 'first check' that the requirements for LinacLog have been met before performing a user test.

Therefore, LinacLog was evaluated, as non-design experts, by performing a design review and then by performing user testing.

9.1 Evaluation Method

The evaluation consisted of three phases:

- Phase 1 - Design Review
- Phase 2 - Presentation to the users
- Phase 3 - User Testing

The first phase involved investigating whether the design has met the specified requirements set out in Chapter 7, as a design review. The design review served as a summary to ensure the design meets the criteria before evaluating it with the actual users.

After the design review has showed that the prototype meets the specification, the second phase was considered. Phase 2 involved presenting LinacLog Bunker to the Radiographers and presenting the new work of the Machine Technologists to the Lead Technologist, as an initial form of user testing.

Phase 3 involved evaluating the interfaces of LinacLog with the actual users. The users were provided with a task list based on the scenarios of new use created previously in Chapter 6.

These tasks were printed out and handed to the users of each module respectively. The user was given a verbal instruction "to follow the tasks listed and say out loud any issues or comments".

Along with the printed task list, print outs of the interfaces were provided. The interfaces were printed because of the challenges and limitations of implementing a working solution. Particularly, it was not possible to connect the smart tablet and smartphone to the hospital WiFi for developing and prototyping, during the limited time-frame of this thesis, hence this style of paper prototyping.

The user was instructed to pretend that they were interacting with a smartphone or tablet app, using the paper interfaces. Where a button action press leads into another interface, the paper was replaced with the sketch of the relevant interface. This is known as an animated paper prototype [53].

9.1.1 Special Acknowledgements during Covid-19

At the time of writing this thesis and performing the usability evaluation, the COVID-19 outbreak occurred and rapidly became a global pandemic causing major disruption across the United Kingdom, and placing extreme pressure on the National Health Service. Therefore, access to staff become very difficult, even as Healthcare Professionals. I wish to formally recognise and express gratitude to my colleagues who spared their time to participate in the evaluation of LinacLog, despite the demands during Covid.

9.2 Phase 1: Design Review

It is good practice to investigate that the design has met the specified requirements and workflows set out in Chapter 7. The Design Review serves as a summary to ensure that the design meets the criteria of the Software Requirements Specification, prior to performing user testing. By not performing the design review prior to evaluating with users, possible usability problems that are able to be fixed prior to evaluating with a user, may go unidentified.

9.2.1 LinacLog Bunker

Table 9.1 below summarises whether the requirements (from Tables 7.1 and 7.2 in Chapter 7) for LinacLog Bunker, have been met.

LinacLog Bunker Requirements	
Requirement	Requirement Met?
LB1 - Login to a specific bunker	Yes (Figure 8.2)
LB2 - Display summary of unresolved faults	Yes (Figure 8.2)
LB3 - Display summary of recently resolved faults	Yes (Figure 8.2)
LB4 - Display whether Linac is in QA model or Clinical Mode	Yes (Figure 8.2)
LB5 - Be able to switch from QA mode to clinical mode and vice versa	Yes (Figure 8.2)
LB6 - Button to raise and record fault.	Yes (Figures 8.2, 8.3 & 8.3)
LB7 - Display restricted use status.	Yes (Figures 8.2, 8.3 & 8.3)

Table 9.1: Confirming LinacLog Bunker's requirements have been met

The default interface (Figure 8.2) allows the radiographer to view information on the clinical status of the Linac at the top, stemming from the low priority requirement 'LB7' shown in Table 7.2 in Chapter 7. Radiographers are interested in this status as they are required to be aware of any restricted use certificates that are issued. For example, the Linac may not be able to operate a specific beam and is therefore placed in restricted use mode. However, this requirement does not address the immediate lack of use issue, and was considered a nice to have. Nevertheless, this requirement was incorporated into the design.

The Radiographer can view the latest fault information and the latest resolved fault information, and scroll through this information using arrows. A fault pathway navigation aid (Figure 8.1), specified as a non-functional requirement, visually displays the status of an open fault succinctly. A radiographer can quickly glance at the latest unresolved fault and observe the fault's current status using this pathway aid. The aid consists of circles of different colour, with green representing complete, orange representing pending and white representing that the next status has not yet been reached. The use of a smaller circle to symbolise a complete status and a larger circle to highlight the current status provides an easy visual method of identifying the current status of a fault.

There are two buttons at the bottom of the interface displayed in Figure 8.2 which allow the radiographer to either Raise a Fault or change the Linac to QA mode. By clicking the Raise Fault button which is displayed as a red box with white text for easy identification, this alerts the radiographer that the fault has been sent to an engineer by displaying a red alert box as seen in Figure 8.3. This will later change to display a green alert box as seen in Figure 8.4. At this point, the Engineer will call the Linac Bunker and the screen will return to its default view shown in Figure 8.2.

Chapter 7 stated that for the non-functional requirement of LinacLog Bunker, LinacLog Bunker should be a smart tablet within easy reach and view of the Radiographer. This was met by introducing a Bespoke Desk Mount in Section 8.1.5 of Chapter 8 and is shown in Figures 8.7, 8.8, 8.5 and 8.6.

The design review concludes that the design has met the required specification for LinacLog Bunker.

9.2.2 LinacLog Triage

Table 9.2 summarises whether the requirements (from Tables 7.3 and 7.4 in Chapter 7) for LinacLog Triage, have been met.

LinacLog Triage Requirements	
Requirement	Requirement Met?
LT1 - View Linac Alert	Yes (Figure 8.9)
LT2 - Call Linac Bunker	Yes (Figure 8.9)
LT3 - Update Fault	Yes (Figure 8.10)
LT4 - Assign Engineer to fault	Yes (Figure 8.10)
LT5 - View all open Linac Faults	Yes (Figure 8.12)

Table 9.2: LinacLog Triage Requirements

The LinacLog Triage design allows the Triage Engineer to manage alerts raised by LinacLog Bunker. When the radiographer presses the Raise Alert button on the tablet, it then alerts the Triage Engineer on the LinacLog Triage App. The interface in Figure 8.9 shows the alert in the form of a pop up box, ensuring that the Triage Engineer responds by calling the Linac. This calling then drives the LinacLog Tablet to display the Fault Acknowledgement alert box as displayed in Figure 8.4.

After the call has taken place, the LinacLog Triage Engineer can enter a fault name and brief description of the fault (Figure 8.10). The Triage Engineer is able to press the drop-down input menu allowing the Triage Engineer to assign the fault to a specific Engineer.

The Triage Engineer is then given the option to select a priority and is presented with a disclaimer alerting the Triage Engineer that this fault will be assigned to a specific bunker. If by chance that a Radiographer has reported this fault from a different bunker, the Triage Engineer has the option to change which Linac the fault will be assigned to. After the Triage Engineer has entered all of the information required, the Triage Engineer will then be able to click the Assign button at the bottom of the interface, and assign the fault to the selected Engineer.

To view all open faults, the Triage Engineer can use LinacLog Triage to open Linac Response. Linac Triage is an extension of LinacLog Response, giving access to higher functionality to those who are assigned as Triage Engineer, whilst being able to respond to faults.

The design review concludes that the design has met the required specification for LinacLog Triage.

9.2.3 LinacLog Response

Table 9.3 summarises whether the requirements (from Tables 7.5 and 7.6 in Chapter 7) for LinacLog Response, have been met.

LinacLog Response Requirements	
Requirement	Requirement Met?
LR1 - Accept or Queue Assigned Fault	Yes (Figure 8.13)
LR2 - Call Linac Bunker	Yes (Figure 8.13)
LR3 - View Fault	Yes (Figure 8.14)
LR3 - Update Linac Fault Status	Yes (Figure 8.14)
LR4 - Change Linac Fault Priority	Yes (Figure 8.14)
LR5 - Request to re-assign fault to another engineer	Yes (Figure 8.14)
LR6 - Mark fault has resolved	Yes (Figure 8.14)
LR7 - View all open Linac Faults	Yes (Figure 8.12)
LR8 - View all faults assigned to specific engineer	Yes (Figure 8.12)

Table 9.3: LinacLog Response Requirements

After the Triage Engineer has assigned the fault to a Machine Engineer, the Engineer is alerted to the fault. As seen in Figure 8.13, a popup box appears. The popup box contains information on who has assigned the fault, and a brief summary of which Linac Bunker has reported the fault. The Engineer is then able to accept and call or queue the fault. After the Engineer has selected their option, they are either greeted with the default interface displayed in Figure 8.12, or greeted with the interfaced displayed in Figure 8.14. The interface displayed in Figure 8.14 allows the Engineer to view a brief summary of the fault. The Engineer can view information about the fault by clicking the View Info button. The Engineer can then view the most recent update associated with the fault. Below this information, the Engineer has the option to submit a new update by touching the '+ Add Update' button.

To assist the Engineer, there is a button which allows the Engineer to View All Updates, allowing the Engineer to view every update associated with the fault record. Below that, the Engineer has the option to Change Priority of the fault. For example, the fault may have been flagged as high priority and the Engineer may have resolved part of the fault which now makes the fault a lower priority. The engineer can hit the change priority button which will select either Low or High depending on the existing priority. The Engineer also has the option to Re-Assign the fault to another Engineer. The Engineer will not be able to select another Engineer, instead this button alerts the Triage Engineer that the current Engineer wishes to re-assign the fault.

At the bottom of the interface, the Engineer has the option to resolve the fault. If the fault is resolved, the Engineer can touch the Resolved button which will flag the fault as resolved. The Triage Engineer would be responsible for the final closing of the fault. However, if the fault is not ready to be closed, the engineer has the option to Exit the fault record.

The Engineer is then presented with the default interface displayed in Figure 8.12. At the top of the interface, the Engineer can view a number of open faults, and a list of all open faults for the entire team. The Engineer can also search for a fault, open or closed. The Engineer can then see a list of most critical faults as a table and touch the fault to open the fault information interface displayed in Figure 8.14. Below this table is another table displaying the faults with the latest update. Again, the Engineer can touch the fault and open the information as displayed in Figure 8.14.

At the bottom of the interface, the Engineer can touch the Sign Out button at the end of their working day to sign out from LinacLog Response, and mark the Engineer as unavailable.

9.2.4 Design Review Summary

In summary, the prototype designs for all interfaces match the requirements set out in Chapter 7. Furthermore, the review suggests that LinacLog Response and LinacLog Triage matches the workflow displayed in Figure 7.1. Moreover, LinacLog Bunker matches the workflow displayed in Figures 7.2 and 7.3.

This design review has been useful as a self-appraisal against the requirements specification in Chapter 7. This was especially useful due to the additional time constraints placed upon staff during the Covid-19 pandemic. By reviewing the design, potential issues could be identified and rectified prior to performing a user test. Fortunately, the design review demonstrated that the requirements were met.

However, design reviews should not be performed as a sole basis of establishing usability and acceptance [52]. Therefore, user testing was performed.

9.3 Phase 2: Presenting the Prototype

Prior to conducting a formal user testing (by asking a user to follow a set of tasks), the prototype and workflows were presented to the users in a meeting. This was particularly useful because it is recommended that evaluation takes place in the early stages of prototyping [42] and served as an initial informal user test, again with the aim of identifying potential issues prior to formal user testing with time constrained users.

The initial presentation of the LinacLog Bunker prototype aimed to elicit initial feedback before asking the Radiographers to formally test LinacLog Bunker. Previously, the users were frustrated with MachineLog. Therefore, care needed to be taken in involving the users in the design of LinacLog. The presentation aimed to encourage the users to buy into the new LinacLog.

Presenting the new workflow to the Triage Engineer aimed to further strengthen the evaluation of LinacLog by providing an early indication on whether the workflow may be accepted.

9.3.1 Presenting LinacLog Bunker to Radiographers

The new prototype, LinacLog Bunker, was presented to the Radiographers at James Cook University Hospital in the form of a slideshow which can be seen in Appendix A. The presentation occurred during the regular Quality Forum, a meeting where various healthcare professionals meet to discuss quality issues. In attendance were 6 Radiographers, which includes 2 Superintendent Radiographers (decision makers), and 4 Medical Physicists, which includes the Senior Medical Physicists responsible for the Machine Engineers. However, no Machine Engineers attended, despite being invited.

The first 30 minutes was dedicated to reviewing The Study that was conducted, sharing some of the results including the flow models generated from The Study. Early conclusions were discussed such as the Radiographers not being the most appropriate staff to enter fault information into Machine Log. The sketches and how the prototype would work were revealed to the Radiographers and Medical Physicists.

The presentation was well received. The Radiographers saw the value in changing their workflow to match the prototype design. Feedback from senior Radiographers was positive, with a senior Radiographer making a comment on how much better he thought the solution would be compared to the existing solution. The idea that Radiographers should not use Machine Log in its existing form was met with agreement and positive discussion from the Radiographers and the Medical Physicists. It was noted however, that no Machine Engineers were available during this presentation so it was difficult to obtain a collective set of feedback from all staff groups in one room. However, the Medical Physicist responsible for the Machine Engineers overall work felt that the new workflow for Machine Engineers would be a positive change.

9.3.2 Presenting The Change of Work To The Lead Engineer

A meeting was held with the Lead Engineer with the primary goal of demonstrating how the new workflow would operate within their team by using the workflow diagram displayed in Figure 7.1. The Lead Engineer felt the changes would be very positive and resonate with how she would like to manage her team. The idea of being able to triage faults and assign them to the most appropriate staff was well received by the Lead Engineer.

The outcome of the discussion was overall positive and demonstrated that the new work system designed will meet the expectations of the Lead Engineer.

9.3.3 Discussion

By involving the users at an early stage [42], it was possible to receive initial positive feedback and therefore strengthened the evaluation, by providing an early indication that the new LinacLog is something that may be accepted by the users, prior to performing a formal user test.

It is acknowledged that during the Quality Forum presentation,, there were no Machine Technologists present to offer feedback. However, the workflow was presented to the Lead Engineer in a separate one-to-one session, who provided positive feedback on the workflow. Furthermore, during the Quality Forum presentation, the Medical Physicist responsible for the Machine Technologists felt the LinacLog sketches appear to make a good effort towards tackling the lack of use of MachineLog. Considering this, the aim was to perform a formal evaluation as a user test, with the users of LinacLog Bunker, LinacLog Response and LinacLog Triage.

9.4 Phase 3: Evaluating with Users

It was earlier discussed that a design review is not sufficient enough to determine usability and acceptability [52]. Therefore, user testing was performed, with the actual users (The Radiographers and Machine Technologists) of the new prototype, LinacLog.

9.4.1 LinacLog Bunker User Testing Tasks

The users identified for LinacLog Bunker are the Radiographers. The aim of the LinacLog Bunker user test was to allow the Radiographers to perform a set of tasks and be able to supply their feedback by thinking aloud when performing the tasks. Their feedback was captured and then reviewed.

The actions shown in Table 9.4, were printed on paper and supplied with printouts of the prototype. The paper interfaces served as a storyboard. Where required, any interface that loaded another interface was placed in front of the Radiographer to simulate the changing of interfaces. One Radiographer participated in this evaluation, taking fifteen minutes to complete.

Task	
Action	**Action Sequence**
Action 1 - Check LinacLog Status	1. Look at the top of the interface 2. Observe Restricted Use Status
Action 2 - Scroll through open faults	1. Touch the arrow pointing to the right
Action 3 - Scroll through previous faults	1. Touch the arrow pointing to the right
Action 4 - Raise a new fault	1. Touch the Raise Fault button
Action 5 - Change Clinical Mode	1. Touch the Change to QA Mode Button

Table 9.4: LinacLog Bunker Evaluation Actions

9.4.2 LinacLog Bunker User Testing Results

The Covid-19 pandemic meant that rightfully, the Radiographers' highest priority was to continue to care for those patients who were undergoing Radiotherapy treatment for their cancer during the extreme circumstances surrounding the NHS due to Covid-19.

Despite this, one Radiographer was able to evaluate LinacLog Bunker by following the tasks in Table 9.4.

When completing Action 1, the Radiographer commented whether the Restrictive Use Status would then display what use was actually restricted. The Radiographer mentioned that this is currently done by reading a certificate in a log book.

This was very interesting feedback that can inform a second iteration of LinacLog. It appears that, although LinacLog Bunker displays that there is a restricted use certificate issued, it does not actually indicate what the restricted use is. However, this Task derives from LinacLog Bunker Function Requirement Number LB7 (Table 7.2), a low priority requirement, that does not need to be included in the first design, because it does not address the immediate problem of lack of use. Nevertheless, Task 1 is important because it was useful for being able to establish what this feature was requested for and can inform future requirement and is a good example that by involving the user in the early design of LinacLog, we can address issues [42].

The Radiographer completed Action 2 and 3 without issue and as such, tapped on the arrow to scroll across the open faults. The Radiographer commented that these features were really useful.

Completing Action 4, the Radiographer managed to raise a fault which would then display the interface in Figure 8.3, then the interface displayed in Figure 8.4 once the fault has been acknowledge and then finally return to the default interface displayed in Figure 8.2. However, the Radiographer questioned what happens when the fault has been Acknowledged, suggesting that the next iteration of the prototype could incorporate a description of what happens next, within the acknowledgement alert box.

The Radiographer completed Action 5 without issue and made further comment that this could be potentially useful for someone who wanted to be able to view the status of all Linacs.

In summary, the user testing proved useful in ascertaining whether this is something that would be used. Together with the early presentation in Section 9.3, the feedback suggested that LinacLog Bunker, is something that will address the lack of use problem this thesis set out to address.

The feedback from the user testing can be used to specify the requirements for the next iteration of LinacLog, although the next iteration of LinacLog is beyond the scope of this thesis.

9.4.3 LinacLog Triage User Testing Tasks

The main user identified for LinacLog Triage is the Lead Machine Technologist who is responsible for the workload of all Machine Technologists. The aim of the LinacLog Triage user test was to allow the Lead Machine Technologist to perform a set of tasks and be able to supply their feedback by thinking aloud when performing the tasks. Their feedback will be captured and then reviewed.

The actions displayed in Table 9.5, were to be printed on paper and supplied with print-outs of the prototype. The paper interfaces served as a storyboard. Where required, any interface that loaded another interface was placed in front of the Lead Machine Technologist to simulate the changing of interfaces.

Task	
Action	**Action Sequence**
Action 1 - Call the Linac Bunker	1. Touch the call button
Action 2 - Enter the details of a high priority fault and assign an engineer	1. Touch the Fault Name input box 2. Enter the fault information by touching the characters on the keyboard 3. Touch the Fault Description text area 4. Enter the Fault Description by touching the characters on the keyboard 5. Touch the Select Engineer drop-down menu 6. Select the most appropriate Engineer 7. Slide the priority to High 8. Touch the Assign button
Action 3 - Assign the new fault to a different bunker	1. Touch the Fault Name input box 2. Enter the fault information by touching the characters on the keyboard 3. Touch the Fault Description text area 4. Enter the Fault Description by touching the characters on the keyboard 5. Touch the Select Engineer drop-down menu 6. Select the most appropriate Engineer 7. Touch the Change Linac button

Table 9.5: LinacLog Triage Evaluation Task Actions

9.4.4 LinacLog Triage User Testing Results

The user test was difficult to perform due to the Covid-19 pandemic which placed strain on the NHS.

The Lead Engineer became, understandingly, very busy during this period as there is only one Lead Engineer, responsible for the coordination of all Machine Technologists. Whilst the user testing was scheduled to happen with the Lead Machine Technologist, the Machine Technologist was prevented from attending due to a situation where a suspected Covid-19 patient had attended for Radiotherapy and the a Linac needed to be deep cleaned before being available for the next patient.

Therefore, the formal user testing for LinacLog Triage was unable to progress and LinacLog Triage was not tested by the Lead Machine Technologist, and was therefore, a constraint and limitation experienced during this thesis.

9.4.5 LinacLog Response User Testing Tasks

The users identified for LinacLog Response are the Machine Technologists. The aim of the LinacLog Response user test was to allow the Machine Technologists to perform a set of tasks and be able to supply their feedback by thinking aloud when performing the tasks. Their feedback will be captured and then reviewed.

One Machine Technologist participated in the user testing. The tasks, shown in Tables 9.6 and 9.7, were printed on paper and supplied with print-outs of the prototype. The paper interfaces served as a storyboard. Where required, any interface that loaded another interface was placed in front of the Machine Technologist to simulate the changing of interfaces.

Unlike the previous tests, for LinacLog Response, there were two sets of tasks identified:

- A task for responding to a fault
- A task for managing faults

This is because LinacLog is directed towards the work of the Machine Technologists and is therefore, centred towards to use of recording Linac faults by the Machine Technologist instead of the Radiographer. As such, the interfaces of LinacLog Response contain more input boxes, buttons and options compared to LinacLog Bunker and LinacLog Triage.

Tasks for Responding to a fault	
Action	**Action Sequence**
Action 1 - Accepting a low priority call	1. Touch Accept & Call
Action 2 - Queue a low priority call	1. Touch Queue
Action 3 - View fault description	1. Touch View Info
Action 4 - Add an update to a fault	1. Touch Add update
Action 5 - View all fault updates	1. Touch View All Updates
Action 6 - Change the priory of a fault	1. Touch Change priority
Action 7 - Re-Assign a fault to another Engineer	1. Touch Re-Assign
Action 8 - Flag the fault as resolved	1. Touch Resolved
Action 9 - Return to the fault list interface	1. Touch Exit

Table 9.6: LinacLog Response Evaluation Task Actions: Responding To A Fault

Tasks for managing faults	
Action	**Action Sequence**
Action 1 - View your open faults	1. Touch View
Action 2 - View all your faults	1. Touch View
Action 3 - Search for a fault	1. Touch the search fault area 2. Enter the name of the fault 3. Click the magnifying glass
Action 4 - View one of the critical faults in your work list	1. Touch one of the faults
Action 5 - View one of the faults with a recent update in your work list	1. Touch one of the faults
Action 6 - Sign out of LinacLog Response	1. Touch Sign Out

Table 9.7: LinacLog Response Evaluation Task Actions: Managing Faults

9.4.6 LinacLog Response User Testing Results

Task 1: Responding to a Fault (Table 9.6)

This task was performed by one Machine Engineer, taking 30 minutes to complete. Immediately, the Machine Technologist noticed that for Action Task 1, there is no way for him to recognise the priority of the job assigned to him from the interface displayed in Figure 8.13. The Machine Technologist‘s response for Action 1 was "How do I tell what the priority is?" suggesting that the Machine Technologist would actively seek the priority of the fault before contacting the Linac Bunker. This is something that must be addressed in the next iteration of LinacLog.

The Machine Technologist proceeded to follow Actions 1 to 9 and completed the tasks successfully and seemed to have no issues with the interface displayed in Figure 8.14.

Task 2: Managing a Fault (Table 9.7)

The second task for managing faults was performed by one Machine Engineer, by performing the actions in Table 9.7. This took 20 minutes to perform.

For Action 1, the Machine Technologist noted that the interface in Figure 8.12, it was not clear if 'All Faults' meant that this was a list of all the Machine Technologist's own faults, or a list of all the team's faults assigned to all Machine Technologists.Action 2 was completed without any issue.

The Machine Technologist struggled with Action 3 - Search for a Fault. The Engineer could not locate the search bar. When the Engineer did eventually find the search bar, he noted that the search bar was too faint and the text, box and icon was not obviously notable.

For Action 4, it was reassuring to observe the Machine Technologist automatically touching one of the faults displayed on the interface in Figure 8.12, with their finger. This shows that the Machine Technologist automatically recognised the non-obvious call to action for the fault displayed in a table. It does not show a button to open fault yet the Engineer was able to very quickly perform the action of opening a fault to discover more information on the fault. Touching the fault opens the interface displayed in Figure 8.14.

The Machine Technologist successfully performed the remaining actions 5 & 6.

9.4.7 User Testing Discussion

The Covid-19 pandemic is an example of an exceptional situation, of which there may be others, for example, industrial disaster, which can interfere with the normal running of a hospital over a long period of time. These situations make it extremely difficult for design experts to access healthcare staff.

An advantage of performing user testing as a healthcare professional is the continued access to some staff despite these exceptional situations arising. In this thesis, a Radiographer and a Machine Technologist were able to participate in the user testing for the prototyping of LinacLog.

However, during these exceptional circumstances due to covid-19, LinacLog Triage was unable to be tested by the user as the Lead Machine Technologist was unavailable. Therefore, there are instances where healthcare professionals developing software also experience difficulty in accessing staff similarly to design experts [19], during exceptional situations.

Nevertheless, the participation of the Radiographer and Machine Technologist provided interesting feedback and results.

The user testing appears to suggest that LinacLog Bunker can be used by the Radiographer to report faults. The feedback for LinacLog Bunker was positive with Radiographers commenting on its better design.

However, LinacLog Response requires more work. Despite LinacLog Response meeting the functional requirements, there are some issues surrounding usability that need to be further investigated and addressed in the next iteration of LinacLog.

9.5 Discussion

Despite the challenges of evaluating Medical Infrastructure Software that has been developed by Healthcare Professionals, as non-design experts, the evaluation of LinacLog in this thesis demonstrates that a Design Review, Initial Presentation and User Testing can inform the iterative development of Medical Infrastructure Software.

This is important because it is recommended that users be included in the early stages of the prototype. This involvement highlights that without user input, LinacLog could potentially be another system that exhibits a lack of use problem. This is because during the user testing, the users have identified issues with the prototype. These issues can be corrected an re-evaluated. If this process didn't occur and LinacLog was deployed with these issues going overlooked, LinacLog may not be used.

The issues can translated into a table of suggested changes for the next version of the LinacLog Prototype.

Suggested Changes - LinacLog Bunker	
Change No	Description
LBC1	Display what use is actually restricted
LBC2	Better indication of what happens when a fault is acknowledged

Table 9.8: LinacLog Bunker Suggested Changes

Suggested Changes - LinacLog Response	
Change No	Description
LRC1	Better recognition of fault priority
LRC2	Clearer buttons to display and differentiate between Machine Technologists own faults and faults assigned to their colleagues
LRC3	Clearer and more obvious search bar

Table 9.9: LinacLog Response Suggested Changes

It is therefore that this evaluation has identified issues that can be corrected and re-evaluated in the future, and therefore, this thesis has succeeded in involving the users in the design, as recommended, despite the lack of access to design experts.

Chapter 10

Conclusion

The goal of this Chapter is to summarise the work done in this thesis to understand the factors that influence usability and acceptability of Medical Infrastructure Software, by investigating the lack of use of a real-world piece of Medical Infrastructure Software, called MachineLog. The Chapter discusses the limitations encountered and future work that can be built upon from this research.

10.1 Summary

Healthcare Professionals in the NHS are developing software as a tool to support their work. This software is not always used for treating patients, as it sits behind the scenes, supporting the Medical Infrastructure.

An example of this software is MachineLog, introduced in detail in Chapter 3, a piece of Medical Infrastructure Software used within the Radiotherapy Department at The James Cook University Hospital. MachineLog was developed by Healthcare Professionals at the Northern Centre for Cancer Care and diffused into The James Cook University Hospital, with the expectation that Radiographers use MachineLog to input detailed information surrounding Linac faults. However, this software exhibits a lack of use problem (the Radiographers are not using MachineLog as intended), a problem that HCI methods aim to address.

To address this lack of use, this thesis aimed to understand the factors that influence the usability and acceptability of medical infrastructure software. This was achieved by:

- Investigating how people are, or more precisely, not using Machine Log in the way it was intended, by using HCI methods.
- Producing a new design prototype for MachineLog, called LinacLog.

To investigate the lack of use of MachineLog, HCI literature was reviewed in Chapter 4, as a non-design expert. However, the discourse of the literature in the context of healthcare appears to be directed towards patient safety and patient care. Furthermore, the discourse is directed towards regulated software and medical devices. In essence, the research seems to be focused on the 'pointy-end' software, software that is heavily involved with patient care, and not towards the mundane and 'boring' software like MachineLog.

MachineLog does not fit with this discourse as MachineLog is not used for patient care. MachineLog is Medical Infrastructure Software that is designed to support the medical infrastructure that is used to deliver treatment. For example, Linacs and Linac software.

Nevertheless, HCI methods such as Contextual Inquiry provided tools for performing observations, allowing us to investigate the lack of use of MachineLog, by observing staff when using MachineLog. The contextual inquiry study was discussed in Chapter 5.

As suspected, it was found that MachineLog was rarely used. In scenarios where MachineLog is intended to be used and intended to be most useful (reporting faults), MachineLog was not used.

The 7 observations in Chapter 5 informed the development of Personas, Scenarios of Existing use and Scenarios of new use, discussed in Chapter 6. The personas and scenarios were then able to inform a requirements specification discussed in Chapter 7, allowing for the design of a prototype, discussed in Chapter 8.The prototype was evaluated in Chapter 9, by performing a design review and then user testing.

Throughout, this thesis explored the aspects of HCI and Human Factors that can make software usable in Medical Infrastructure Software and advocated the use of HCI and Human Factors in the development of Medical Infrastructure Software by Healthcare Professionals.

10.2 Investigating The Use of MachineLog

The work in this thesis surrounded unregulated Medical Infrastructure Software called MachineLog, developed by Healthcare Professionals. The use of MachineLog was being directed by Machine Technologists, towards Radiographers. However, the Radiographers were not using MachineLog as intended. The primary intention of MachineLog was to record faults so Machine Technologists can manage these faults.

To conclude, the Radiographers should not be recording detailed fault information because it does not align with their goals, to treat their patients and provide a good patient experience and coordinate their patients care. Instead, the Machine Technologists should input detailed information into MachineLog. The Radiographers should be able to raise a fault by pressing a button that alerts the Machine Technologists to the fault. The managing of this fault is then coordinated between the Lead Machine Technologist and the Machine Technologists, taking this responsibility away from the Radiographers.

This conclusion was reached after performing a contextual inquiry study (Chapter 5), a method for discovering the existing work performed by users of an existing system. The advantage of Healthcare Professionals performing a contextual inquiry is that they are already familiar with the environment, although, need to build a better picture of the work that their colleagues (users) are performing.

The contextual inquiry consisted of seven observations on three Linacs:

- Linac A
- Linac B
- Linac 4

Due to limitations surrounding availability, Linacs C, D & 5 were not observed.

The contextual inquiry was visualised by using physical layout models, which represented the environment and physical layout of the Linac Control Areas, and flow models, that represented the interaction of staff between software and other staff. The physical models identified that MachineLog is installed on a workstation behind the Radiographers (Figures 5.1 and 5.2), away from where the Radiographers are performing most of their work.

The flow models were useful in identifying the goals of staff and breakdowns. Accordingly, these models and observations demonstrated that the Radiographer's goal is to treat their patient. Most of the work that the radiographer performs is related to patient treatment, it is not related to maintaining a Linac.

When faults arose, the Radiographer's goal then became one of coordinating patient care, ensuring that patients were transferred to an available Linac, or explaining to patients what is causing their delay. It is at this point, the goal of the Machine Technologist is to respond to and repair a fault.

Reviewing the observations allowed us to create Personas and Scenarios. Despite the usefulness and validation of personas being widely debated [36] [37], together with scenarios of use, the personas were useful in this thesis for communicating the requirements for the new prototype, LinacLog. Furthermore, these Personas were shown to the users, who commented that the personas were close representations of themselves.

Reviewing the observations and scenarios, we concluded that MachineLog in its existing form, should not be used by the Radiographers. Instead, it should be re-designed.

10.2.1 HCI Methods for Investigating Lack of Use

Performing the contextual inquiry for investigating lack of use established that this is a useful technique that can be used to investigate the lack of use of Medical Infrastructure Software, as a starting point for re-designing software as a non-design expert, where design expertise is not available.

Other frameworks, such as SEIPS 2.0, are directed towards patient treatment and safety [21]. These frameworks are useful for ensuring safety within regulated medical software. However, Medical Infrastructure Software such as MachineLog sits behind the scenes as a tool for maintaining the medical infrastructure and does not inform patient treatment or safety. Medical Infrastructure Software is not regulated software.

Research suggested that healthcare professionals are difficult to observe due to various factors [19]. However, this thesis demonstrates that there is advantage in developing software as Healthcare Professionals. I did not experience barriers in observing staff performing their work. This may perhaps suggest that design experts could access healthcare professionals through other healthcare professionals, such as Clinical Scientists, who are developing software. Clinical Scientists may perhaps be able to act as an intermediary, improving access between design experts and other Healthcare Professionals.

However, from experience, there is still a lack of design awareness within the NHS [7].

10.2.2 Limitations When Investigating Lack of Use

When organising time to observe staff on the Linacs, it appeared that Linac C was not offered as an option. Although, Linac C was fully operational the time of observations.

Linac 5 was undergoing decommissioning during the time of observations and was in the process of being sold. Therefore, Linac 5 was not able to participate in any observations. Furthermore, Linac D was undergoing commissioning during the time of observation and was not in full clinical use. Due to this, the staff were busy becoming accustomed to the layout of Linac D and therefore we were unable to observe Linac D.

The layouts of these three Linacs vary considerably. The limitations on observing these Linacs may not capture whether MachineLog is used as intended in these Linacs. Considering that Linac D was undergoing commissioning, it could be speculated that MachineLog forms part of this commissioning and that the Radiographers may perhaps be trained to use it, or the use of MachineLog may be advocated. It would be useful to re-visit Linac D in the future to explore this. Nevertheless, MachineLog is not used as intended in the other Linacs and this required addressing.

During the observations, it is possible the Radiographers had a greater awareness of being observed and as such, may have adjusted their working practices [48] and is a limitation of the study. One example was discussed in Observation 2, where it was observed that a Radiographer entered the start time of Linac QA, perhaps because that the Radiographer was aware of being observed on their use of MachineLog.

10.3 Re-designing MachineLog

To inject a sense of 'newness', MachineLog was re-branded as LinacLog. This was done to focus the software on recording faults for Linacs, hence LinacLog. It was felt MachineLog was too ambiguous. LinacLog was re-designed as a non-design expert and to communicate the requirements for LinacLog, I drew from HCI literature surrounding personas and scenarios. The personas and scenarios were introduced and discussed in Chapter 6.

To develop the personas, I followed a persona life cycle [49], discussed in Chapter 6. The usefulness of personas has been well debated [36]. However, in this thesis, personas were a useful tool for communicating the requirements of LinacLog. Bowen, et al. [36] mention that personas can be useful when users can be deeply involved in the design. The advantage of developing software as a Healthcare Professional, is that we can involve other Healthcare Professionals in the design. In the case of this thesis, the users are the Radiographers and Radiotherapy Engineers, who are able to understand their requirements and articulate them. Together with the observations and experience of these staff groups, we were able to create personas that accurately represented the users, concluding that personas are useful for assisting in the communicating of the requirements for a re-designed prototype Medical Infrastructure Software, to be used by other staff groups.

The personas were then used within scenarios of existing and new use. The scenarios were developed from the contextual inquiry study within Chapter 6, by reflecting on the activities and practice of the Radiographers and Machine Technologists (Radiotherapy Engineers). The scenarios provided a hypothetical narrative around the use of MachineLog, envisaging situations where MachineLog should be used.

After creating scenarios of existing use, scenarios of new use were created, providing insight on how the work could be simplified by a new prototype, known as LinacLog.

10.3.1 Formalising the Requirements

The personas and scenarios assisted with the development of a formal specification, outlined in Chapter 8. The specification was useful for informing the design of LinacLog.

The specification included a new workflow for the Machine Technologists. This was initially presented to the Lead Machine Technologist before proceeding further. This early feedback was useful in understanding that the new workflow is something that will work and will be accepted by the Lead Machine Technologist, who is responsible for the team's workload. Research has shown that it is important to involve the users at an early stage [42]. This involvement has demonstrated that eliciting early feedback surrounding the new Machine Technologists is a factor that influences the acceptability of Medical Infrastructure Software.

The specification outlined functional requirements and non-functional requirements for LinacLog, which was separated into three apps:

- LinacLog Bunker
- LinacLog Triage
- LinacLog Response

The apps were designed differently to promote separate use. For example, the Radiographers now only need to use LinacLog Bunker within the Linac Bunker. The Machine Technologists can use either LinacLog Response for responding to faults and LinacLog Triage for organising the response to faults, as the Triage Engineer. This separation clearly identifies the differences between reporting and recording faults.

10.3.2 Limitations on Development

The thesis set out to create a high-fidelity working prototype for LinacLog so that the users could be immersed in LinacLog. However, barriers to accessing the Trust IT network, were encountered. Therefore, it proved difficult to get the smart devices on the WiFi so that LinacLog would communicate with a database server hosted on the internal network.

Alternatives were explored such as hosting the database off site as a cloud solution. However, access to the servers were blocked by the Trust‘s firewall and it was sensible not to delay the thesis due to technical limitations. Interestingly, it is an NHS Digital policy for ‘Internet First’ or ’Cloud First’ [54]. Thus while there is a desire and policy to support the kind of work I envisaged, there are practical obstacles when it comes to actually implementing the policy. By the time all approvals were granted, approximately 18 months into the thesis, it was too late to develop a working prototype for evaluation, within the remaining 6 months. Therefore, Hospital IT was a significant limitation and subsequently, the prototype was designed as a low-fidelity sketch of digital interfaces by using interface design software known as Adobe XD.

To plan the design of the interfaces, HCI techniques from literature surrounding sketching ideas [39], were utilised. This was useful for overcoming constrained thinking due to the limitations of Hospital IT.

10.4 Evaluating LinacLog

Despite the difficulties experienced by design experts recruiting NHS staff for evaluation [41], as a non-design expert working within the NHS, it was possible to perform an evaluation of LinacLog, with NHS staff.

The evaluation of LinacLog was performed in three phases:

- Phase 1 - Design Review
- Phase 2 - Presentation to the users
- Phase 3 - User Testing

By performing a design review for the prototype, it was possible to ascertain that the prototype met the requirements specified in Chapter 7. The design review was performed by reviewing the interfaces in conjunction with the list of requirements for LinacLog Bunker, LinacLog Response and LinacLog Triage. The results of the design review were discussed in Chapter 9.

It was possible to initially present the LinacLog Bunker to the Radiographers at a Quality Forum, a meeting which brings together Radiographers, Medical Physicists and Machine Technologists, to discuss quality related issues. Feedback from this presentation suggested that LinacLog Bunker is something that would be useful for the Radiographers, as a replacement to MachineLog. During this presentation, no negative feedback was received. This was discussed in Chapter 9.

It was also possible to present the new workflow, that LinacLog would support, to the Lead Machine Technologist. The Lead Machine Technologist indicated that the workflow is a significant improvement, allowing for the better allocation of Machine Technologists.

Moving into Phase 3, a user test of the interfaces from Chapter 8 was performed, by designing a set of tasks and actions. The tasks and interfaces were printed as a storyboard, with interfaces being swapped manually.

The tasks were explained to the users and the users were encouraged to think aloud and provide feedback as they progressed through the tasks.

The feedback suggested that there was more improvement needed, which was displayed in Tables 9.8 and 9.9, as suggested changes. These changes can be considered in future versions of LinacLog.

10.4.1 Limitations on Evaluation

Due to Covid-19 restrictions, I was only able to recruit 1 Radiographer and 1 Machine Technologist to perform the full user testing. Unfortunately, the Lead Machine Technologist became unavailable due to the demands of Covid-19.

10.5 Factors That Influence Usability and Acceptability

This thesis aimed to understand the factors that influence usability and acceptability of Medical Infrastructure Software that has been developed by Healthcare Professionals such as Clinical Scientists, who are not design experts but are able to develop software. This was achieved by investigating the lack of use of MachineLog and used HCI methods to re-design MachineLog, so that it is used as intended.

Specifically, the influencing factors are:

- That Medical Infrastructure Software aligns with the goals of the users and is goal-oriented
- That the users are involved in the design and evaluation of Medical Infrastructure Software

- There is good access to the users (Healthcare Professionals) when developing Medical Infrastructure Software

The remainder of this section gives further details of these three points.

It is important that Medical Infrastructure Software aligns to the goals of its users. MachineLog, for example, did not align to the goals of the Radiographer, which is to treat patients or provide a smooth patient experience. This goal is common amongst most Healthcare Professionals involved in direct patient treatment. The use of Medical Infrastructure Software to provide detailed information should be directed towards the users that require detailed information. For example, detailed fault information should be entered by those interested in fixing the fault.

Actively forcing Healthcare Professionals to use Medical Infrastructure Software to enter detailed fault information prevents them from achieving their goals. In our example, Observation 6 in Chapter 5 demonstrates a situation where one Radiographer is being told to enter fault information, retrospectively, after the fault has occurred and has been resolved, by the resolving Engineer. Although this situation leads to Medical Infrastructure being used for entering information, the data inputted is not accurate because the Healthcare Professional wants to get back to treating their patient. Observation 6 demonstrated that the Radiographer estimated the time the fault occurred. Furthermore, this guessing prevents Engineers, or the ones who are interested in using the Medical Infrastructure Software to maintain the Medical Infrastructure, from logging accurate downtime metrics.

However, Healthcare Professionals using the Medical Infrastructure still need a way of reporting a fault and receiving feedback and re-assurance that someone is on their way to deal with the fault. For LinacLog, this was achieved by a 'Raise Fault' button, shown in Figure 8.2. This button alerts an Engineer to call the staff, to find out more information. The Engineer then enters the detailed fault information, with the system automatically capturing a more accurate time of when the fault occurred, and thus providing an ability for a more accurate downtime metric. Therefore, ensuring that Medical Infrastructure Software aligns to the goals of all its users is a factor that influences the acceptability and usability of Medical Infrastructure Software.

To help align to the goals of the users, it is important that the users are involved in the design and evaluation of Medical Infrastructure Software. By involving the users it was possible to gain initial feedback on the development of prototypes. This feedback can inform the iteration of the prototype/Medical Infrastructure Software. Therefore, involving the users in the design is a factor that influences the acceptability and usability of Medical Infrastructure Software.

It has been acknowledged that for design experts, there is difficulty in accessing Healthcare Professionals when designing all types of software. However, involving users in the design process is not difficult for Healthcare Professionals such as Clinical Scientists who are designing Medical Infrastructure Software. This is because there is easy access to the staff that they help to supporting during their routine work, most of the time, the different staff groups are already engaged in discussions with one another due to ongoing projects and multi-disciplinary working. This is an advantage for staff such as Clinical Scientists who are able to develop software such as Medical Infrastructure Software. However, there are some challenges when accessing other Healthcare Professionals during times of exceptional circumstances such as the Covid-10 pandemic. Therefore, good access to Healthcare Professionals when designing software is a factor that can influence the usability and acceptability of Medical Infrastructure Software.

10.6 Future Work

10.6.1 Developing A Working Prototype

This prototype has the potential to be used in the real world and replace the existing MachineLog.

Despite the significant limitations due to Hospital IT, preventing the development of a high-fidelity working prototype, within the time-frame of this research, it is possible to connect prototype devices to the Hospital IT Network as eventually, IG approval was given and Hospital IT were prepared to connect the devices to the network, after lengthy discussion and an approximate 18 month wait.

Therefore, this prototype design could be iterated by taking on board the suggested changes from Tables 9.8 and 9.9, and by translating the interfaces into smartphone and tablet applications.

This prototype could be further evaluated with more of the users, post-covid pandemic. Any further issues that are identified can be collated and used to inform another re-design or next iteration of the prototype. The evaluation could follow the three phase approach taken in this thesis, iteratively informing the design until LinacLog is fully functional.

It may also be useful to continue development and evaluation of LinacLog alongside design experts. Design experts are able to perform some of the more difficult evaluations such as Cognitive Walkthroughs. However, if design expertise continued to be unavailable, further evaluations can be performed by performing user testing during each iteration of design, which may minimise the time spent on developing LinacLog.

The advantage of developing LinacLog as an employee meant that the development and deployment can occur as routine work, in the same way that the original MachineLog was developed and deployed. However, it would be useful to undertake a full service improvement evaluation to demonstrate how LinacLog could improve the efficiency of the reporting and recording of LinacLogs. This service improvement evaluation could further strengthen the justification for replacing MachineLog with LinacLog and demonstrate that Medical Infrastructure Software that is designed with a user-orient approach such as LinacLog, with proper evaluation, may improve the non-clinical work of Healthcare Professionals who are tasked with supporting the Medical Infrastructure that they use to deliver treatment to patients.

10.6.2 A NHS Network of Design Experts

There could be work to be done in creating a NHS Network of Design Experts. This could address the problem of NHS software developers gaining easy access to design expertise. Perhaps one day we might see NHS Design sitting alongside NHSx and NHS Digital. If there was a mechanism whereby Clinical Scientists developing software could can send in a piece of software to be evaluated by design experts, and they were afforded the access to the users as NHS employees, we might find this established a proper evaluation method.

Research has suggested that NHS staff are difficult to access for evaluation [19]. However, a network of Design Experts working with Healthcare Professionals such as Health and care Professions Council (HCPC) registered Clinical Scientists, who are developing and being trained to develop software in the NHS for other healthcare professionals [4] [12], we may be able to improve access to design expertise in the NHS for both regulated and unregulated software.

10.6.3 Will LinacLog work in another Trust?

The question "Will our LinacLog Work in another Trust?" or, "Could there be a central LinacLog for all Radiotherapy Departments?", could be explored.

The work in this thesis focuses on MachineLog at The James Cook University Hospital. There is evidence from Chapter 2 and Chapter 3 that the challenges of managing Linac faults is shared by all Radiotherapy Departments. Yet, it was apparant that each centre developedevelop their own independent solutions to this challenge. Could the new LinacLog address this challenge for the entire NHS?

Contextual Inquiry studies and evaluations in other centres may highlight differences in activities which could suggest that LinacLog is not able to be a 'one size fits all' solution, or it could result in a similar looking LinacLog to the one in this thesis, by performing a contextual inquiry and user testing to inform the re-design of their own version of MachineLog,

10.6.4 A HCI Toolkit for Healthcare Professionals

The work in this thesis can be taken further by performing more research into the development of Medical Infrastructure Software by Healthcare Professionals who are able to develop software, but are unaware of how HCI can address issues such as lack of use.

From experience, there are some Healthcare Professionals such as Clinical Scientists who are now being taught Software Development skills as part of their formal 'Scientist Training Programme' (STP) [55], equipping newly qualified registered clinical scientists with both scientific, clinical and software development skills. An example of one competency is to "Specify, design, develop and test a small database, web application or image processing solution.". The competency can be found here: `https://curriculum.nshcs.org.uk/programmes/stp/`

module/SPE300/competency/13.

However, the STP curriculum does not include specific teaching on HCI. There is a huge potential for Computer Scientists and Design Experts to contribute to this learning of Clinical Scientists.

This could perhaps lead into a toolkit for Healthcare Professionals developing software. The toolkit could include guides on methods for design and evaluation such as contextual inquiry for non-design experts.

10.7 Final Thoughts

In this thesis, I was able to explore a real-world problem, apply HCI knowledge and methods to this problem and begin to address the problem within the domain of Healthcare. By re-designing MachineLog and evaluating LinacLog, this thesis has demonstrated that it is possible to re-design and evaluate mundane behind the scenes Medical Infrastructure Software that exhibits a lack of use problem, by using HCI methods, despite the lack of awareness of HCI in the NHS and the difficulty accessing Healthcare Professionals, as a non-design expert.

From experience, there are many other behind the scenes Medical Infrastructure Software exhibiting a similar problem. This software goes overlooked yet it impacts the work of Healthcare Professionals, shoehorning Healthcare Professionals into systems that do not align with their goals. This misalignment of goals is a factor that influences the acceptability and usability of Medical Infrastructure Software.

It appears the unregulated software gives rise to flexible development practices which may contribute to the lack of use problems experienced by unregulated Medical Infrastructure Software. Furthermore, there appears to be little research surrounding the design and evaluation of Medical Infrastructure Software developed by Healthcare Professionals.

It also appears that the discourse of the research within Health IT is directed towards the 'pointy-end' of patient treatment software and regulated medical device software, which does not fit with Medical Infrastructure Software, although Medical Infrastructure Software is equally as important as patient treatment software, helping to ensurethat equipment used to deliver treatment, is well-managed.

Clinical Scientists who are registered Healthcare Professionals, developing both unregulated and regulated software on the boundaries of regulated and unregulated healthcare activities, appear to have an advantage in developing software because they have good access to other Healthcare Professionals. Some of this software tends to be directed towards themselves, for example, software that calculated or checks radiation doses, developed by Medical Physicists for use by Medical Physicists.

Due to the new Medical Device Regulations, this software can be built with slight flexibility because it does not need to be CE marked by an external authority, providing that the software is only being used within the hospital that has developed it. This is also providing that the development of this software is done in accordance to a Quality Management System (QMS). However, in the hospital, the QMS appears to be developed/outlined by those Healthcare Professionals developing the software.

Despite the stricter requirements of this software, there are rare instances where this software is not used as intended. Investigating the lack of use of this type of regulated medical software may be an interesting area to investigate, as this is a case of Healthcare Professionals developing regulated software, with lack of awareness of HCI, that is used for patient treatment, but does not undergo the rigours of commercial software CE marking.

I hope this thesis can be used to guide the better design of Medical Infrastructure Software developed by Healthcare Professionals, helping to ensure that this type of under-researched software does not exhibit lack of use problems.

Appendix A

Appendix A: Presenting LinacLog Bunker to Radiographers

Continued on next page..

NHS
South Tees Hospitals
NHS Foundation Trust

Linac Log

Redesigning and improving the recording and usage of a hospital linear accelerator fault logging system

Andrew Simpson

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Introduction

- Working for the past 18 months on my MSc, 6 months to go!
- MSc (By research) Computer Science, focused on Human-Computer-Interaction
- Most of the work has been thesis-writing / theory
- Finally getting to the end-product stage – a prototype
- Investigating why radiographers don't use machine log
- Re-designing the work
- Re-designing Machine Log

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Disclaimer(s)

- Please don't share any of this information outside of the Trust due to Intellectual Property and copyright
- Currently in talks with University of York & South Tees surrounding IP, etc. As other Trusts are interested in this work.
- Please remember that the research work is part of my MSc and is still a work in progress

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The Study

1 Study of 6 observations

Observations	
Observation	Summary
1	The first observation with the main purpose of gaining knowledge of the morning quality assurance processes. Immediately, breakdowns come to light.
2	Multiple interruptions to Radiographer performing complex QA procedures. RA heavily focused on getting LA4 up and running for the clinical treatment day. Machine Log not used in this one.
3	A serious error lead the Radiographer to contact a Machine Technologist provided a good opportunity to expose the complexities in agent interaction. More participants observed compared to other observations. This observation observes both morning QA and patient treatments (not the patients themselves, however.)
4	Observing patient treatment only which shows Machine Log was used at some point to record availability. Shows difficulty in finding a use for Machine Log in the scenarios in the observation
5	Observation was conducted during routine patient treatment showing no situation where machine log would actively be used.
6	An interview with a Machine Technologist immediately leads into the fault/incident resolution process. We observe a the point of view of the Machine Technologist.

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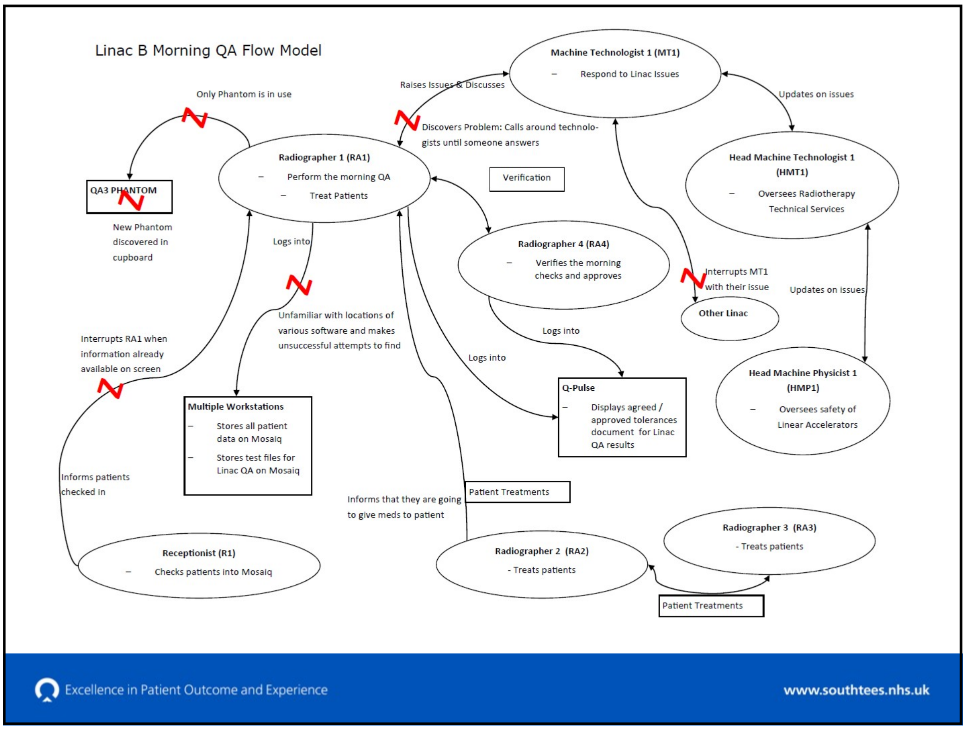
Linac B Morning QA Flow Model
Machine Technologist 1 (MT1)
– Respond to Linac Issues
Raises Issues & Discusses
Updates on issues
Only Phantom is in use
Discovers Problem: Calls around technologists until someone answers
Radiographer 1 (RA1)
– Perform the morning QA
– Treat Patients
Verification
Head Machine Technologist 1 (HMT1)
– Oversees Radiotherapy Technical Services
QA3 PHANTOM
New Phantom discovered in cupboard
Logs into
Radiographer 4 (RA4)
– Verifies the morning checks and approves
Interrupts MT1 with their issue
Updates on issues
Other Linac
Unfamiliar with locations of various software and makes unsuccessful attempts to find
Logs into
Interrupts RA1 when information already available on screen
Logs into
Head Machine Physicist 1 (HMP1)
– Oversees safety of Linear Accelerators
Q-Pulse
– Displays agreed / approved tolerances document for Linac QA results
Multiple Workstations
– Stores all patient data on Mosaiq
– Stores test files for Linac QA on Mosaiq
Informs patients checked in
Patient Treatments
Informs that they are going to give meds to patient
Radiographer 3 (RA3)
- Treats patients
Receptionist (R1)
– Checks patients into Mosaiq
Radiographer 2 (RA2)
- Treats patients
Patient Treatments
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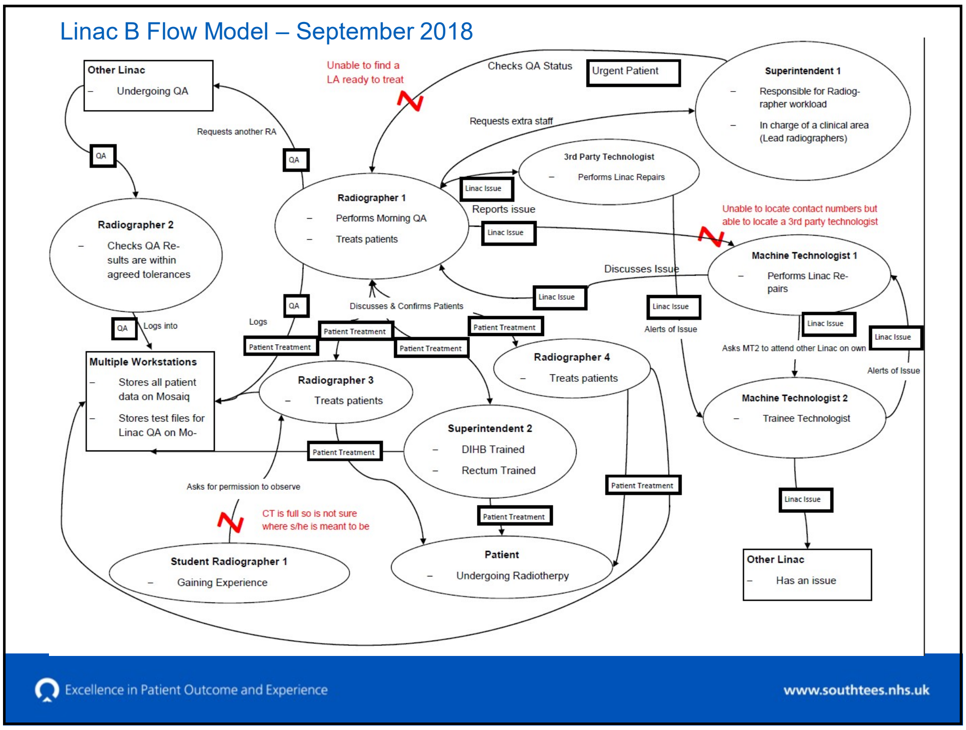
Linac B Flow Model – September 2018
Other Linac
– Undergoing QA
Unable to find a LA ready to treat
Checks QA Status
Urgent Patient
Superintendent 1
– Responsible for Radiographer workload
– In charge of a clinical area (Lead radiographers)
Requests another RA
Requests extra staff
QA
QA
3rd Party Technologist
– Performs Linac Repairs
Linac Issue
Radiographer 1
– Performs Morning QA
– Treats patients
Reports issue
Radiographer 2
– Checks QA Results are within agreed tolerances
Linac Issue
Unable to locate contact numbers but able to locate a 3rd party technologist
Discusses Issue
Machine Technologist 1
– Performs Linac Repairs
Linac Issue
QA
Discusses & Confirms Patients
Linac Issue
Alerts of Issue
QA
Logs into
Logs
Patient Treatment
Patient Treatment
Patient Treatment
Patient Treatment
Linac Issue
Linac Issue
Asks MT2 to attend other Linac on own
Alerts of Issue
Multiple Workstations
– Stores all patient data on Mosaiq
– Stores test files for Linac QA on Mo-
Radiographer 3
– Treats patients
Radiographer 4
– Treats patients
Machine Technologist 2
– Trainee Technologist
Superintendent 2
– DIHB Trained
– Rectum Trained
Patient Treatment
Patient Treatment
Linac Issue
Asks for permission to observe
CT is full so is not sure where s/he is meant to be
Patient Treatment
Patient
– Undergoing Radiotherpy
Other Linac
– Has an issue
Student Radiographer 1
– Gaining Experience
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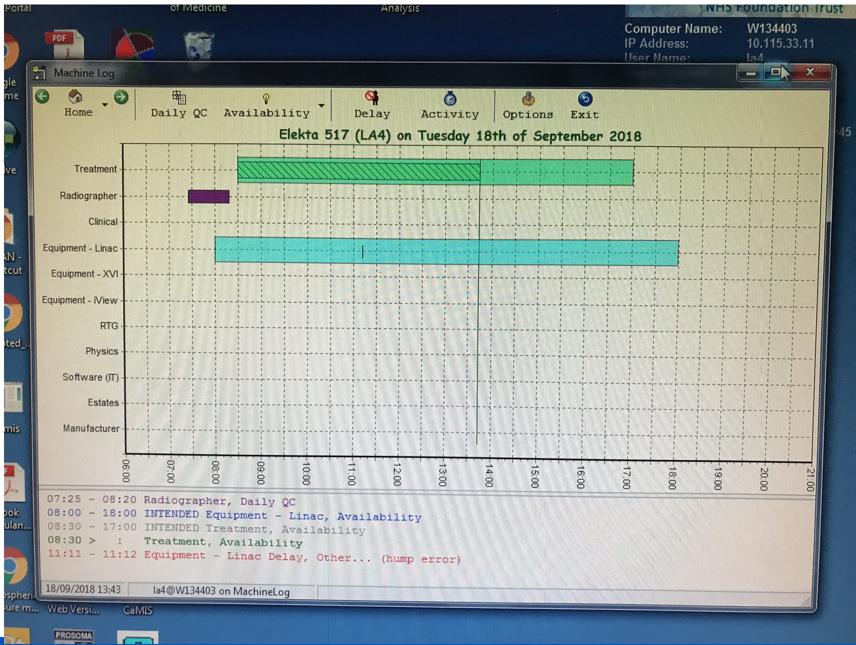

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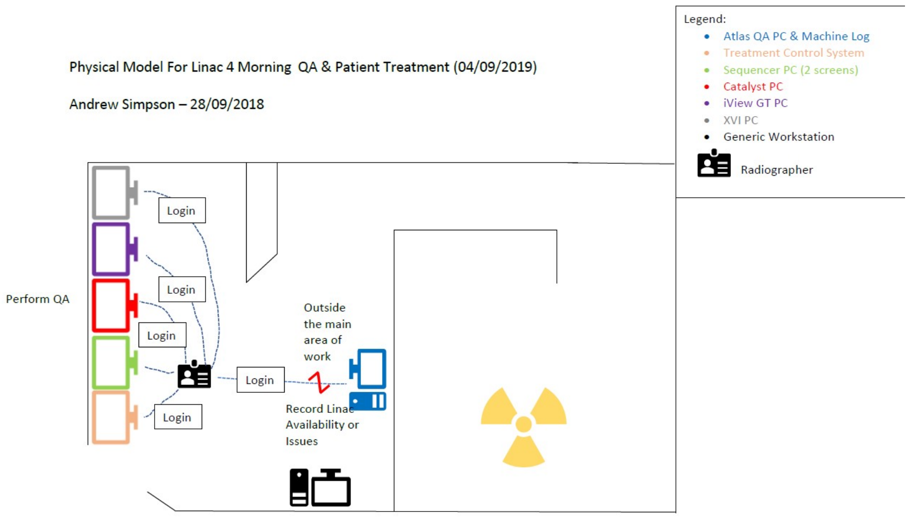
Physical Model For Linac 4 Morning QA & Patient Treatment (04/09/2019)

Andrew Simpson – 28/09/2018



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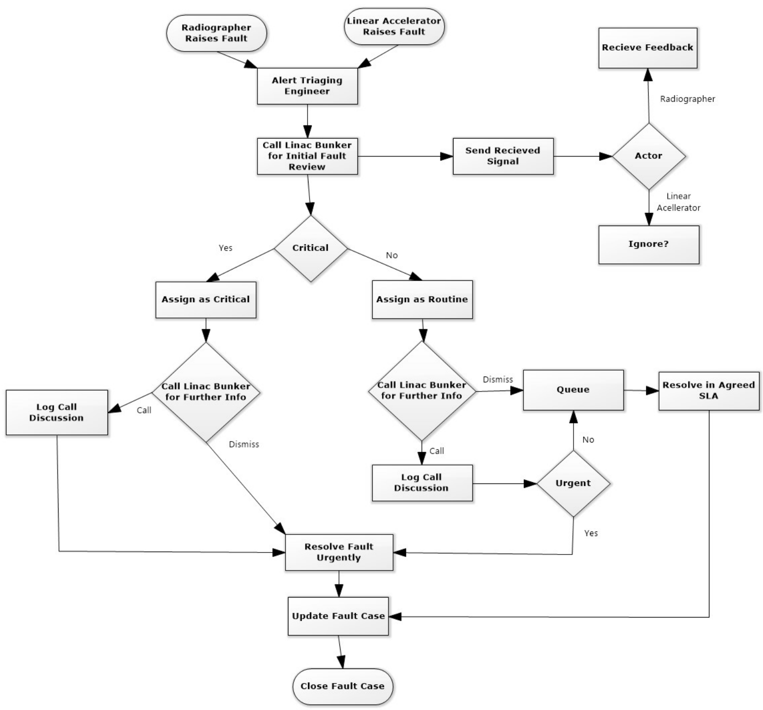
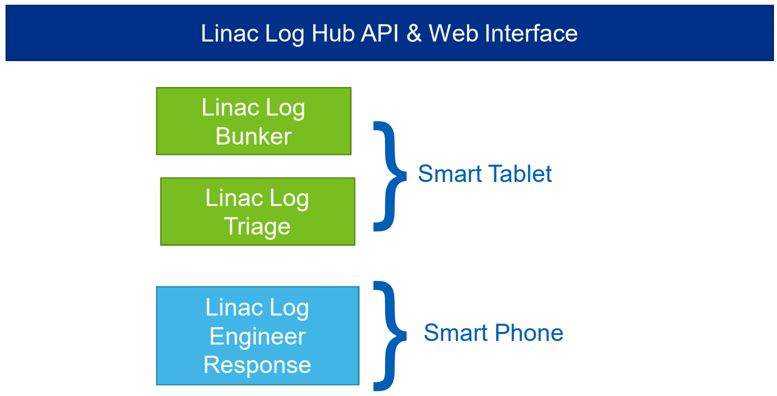
4

Machine Log

- Very much hosted on a PC in the corner
- Difficult to use
- Not aligned to the goals of a radiographer (To treat patients)
- Radiographer's *shouldn't* be using machine log
- Machine Engineers should be using and updating machine log
- Lead Engineer cannot properly oversee the work of the machine engineers
- No useful or accurate metrics from Machine Log



Linac Log – Prototype Overview



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LinacLog - Hub

- Web dashboard displaying metrics such as uptime
- Detailed overall fault log information
- Ability to view restricted use certificates (integrated with Q-Pulse)
- Assists with communication between Machine Engineers

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LinacLog - Bunker

- Tablet displaying key information to Radiographers
- Allows radiographer to raise a fault and receive feedback
- Allows radiographer to switch to QA mode & clinical mode instead of clunky menus

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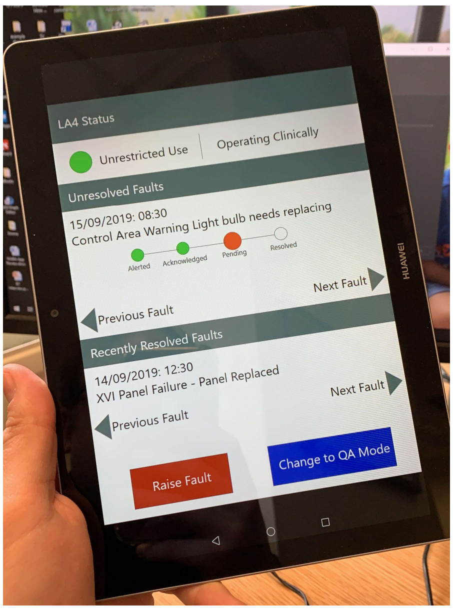

Huawei T3 10 Tablet for Linac Log Bunker Dashboard

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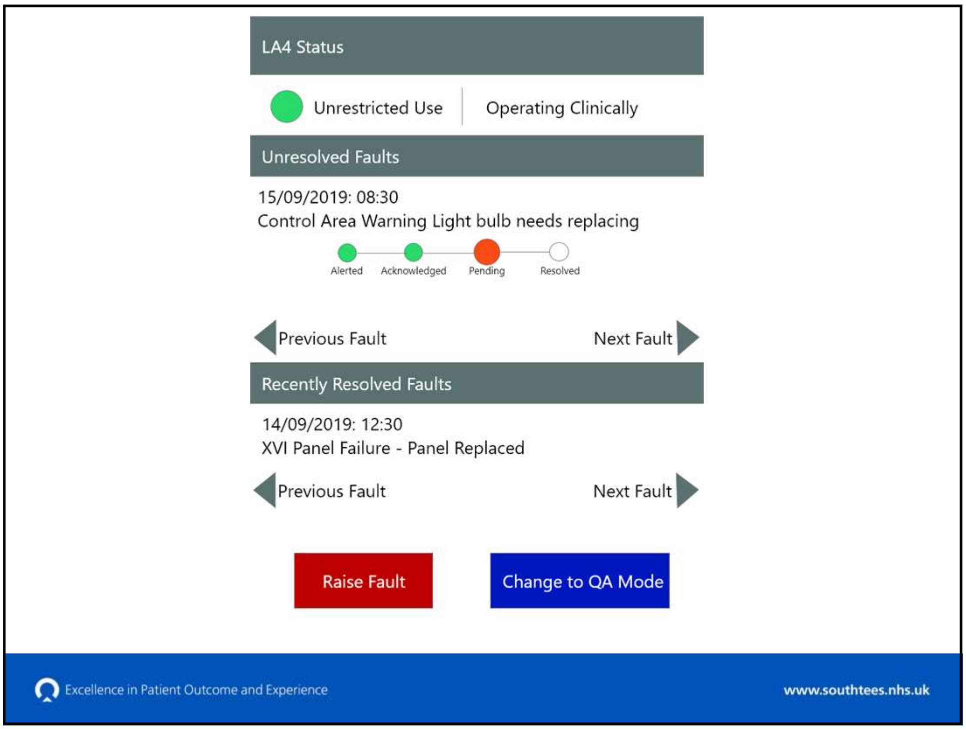
LA4 Status
Unrestricted Use
Operating Clinically
Unresolved Faults
15/09/2019: 08:30
Control Area Warning Light bulb needs replacing
Alerted
Acknowledged
Pending
Resolved
Previous Fault
Next Fault
Recently Resolved Faults
14/09/2019: 12:30
XVI Panel Failure - Panel Replaced
Previous Fault
Next Fault
Raise Fault
Change to QA Mode
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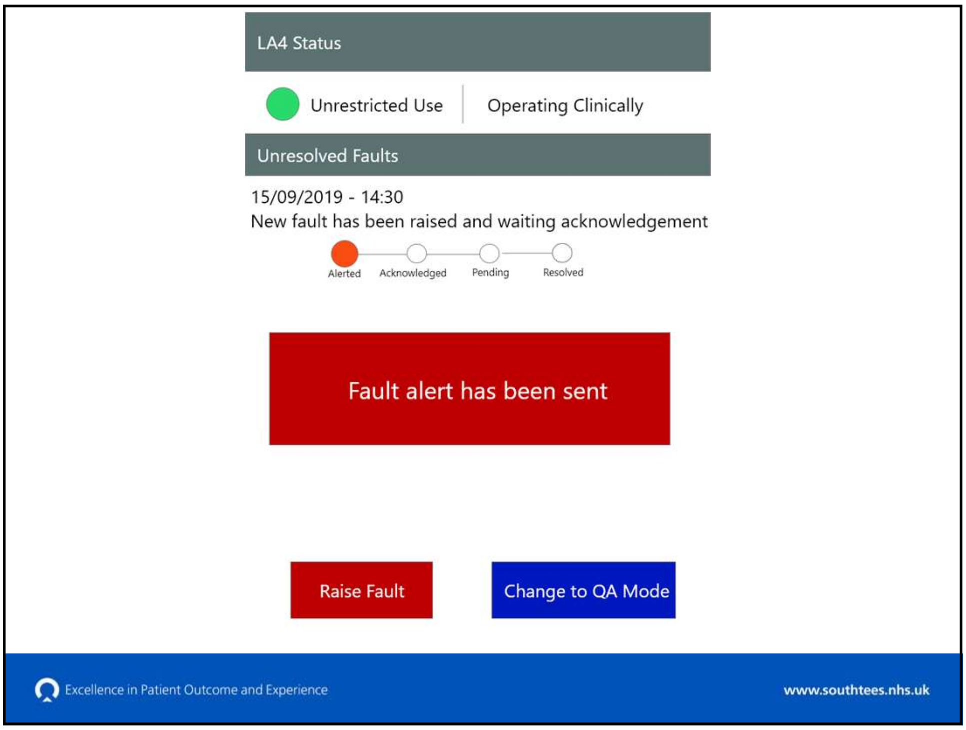
LA4 Status
Unrestricted Use
Operating Clinically
Unresolved Faults
15/09/2019 - 14:30
New fault has been raised and waiting acknowledgement
Alerted
Acknowledged
Pending
Resolved
Fault alert has been sent
Raise Fault
Change to QA Mode
Excellence in Patient Outcome and Experience
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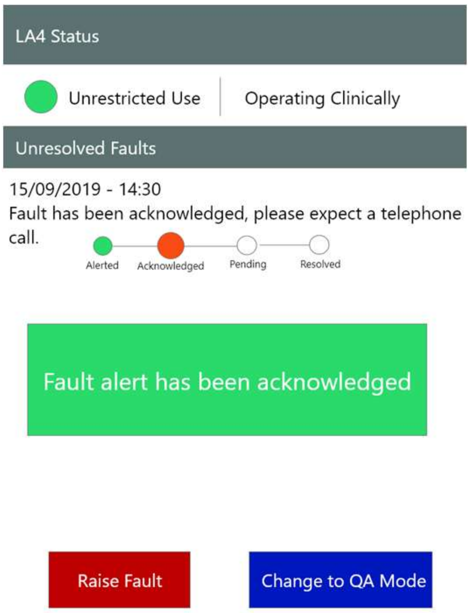

LinacLog - Triage

- Another Huawei T3 10 Tablet with Android App
- Allows Triage Engineer (Lead Tech) to:
  - Acknowledge Fault
  - Directly Call LinacLog Bunker to obtain further information
  - Assign Engineer to fault

LinacLog - Triage

New Fault Alert

Linac A has raised a critical fault

Call

LinacLog – Response

- Smartphone with App
- Allows Engineer to:
  - Respond to Faults
  - Call LinacLog Bunker
  - Log Fault information
  - Manage Fault workload
  - Queue non-urgent faults
  - Work on the move

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NHS
South Tees Hospitals
NHS Foundation Trust

Thanks for listening!

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Appendix B

Appendix B: Health Research Authority Approval Tool

Continued on next page...

Go straight to content.

Medical Research Council

NHS Health Research Authority

Do I need NHS REC review?

To print your result with title and IRAS Project ID please enter your details below:

Title of your research:

Improving the usability of medical infrastructure software: the redesign of a linear accelerator machine log

IRAS Project ID (if available):

Your answers to the following questions indicate that **you do not need NHS REC review for sites in England.**

This tool only considers whether NHS REC review is required, it does not consider whether other approvals are needed. You should check what other approvals are required for your research.

You have answered **'YES'** to: Is your study research?

You answered **'NO'** to all of these questions:

Question Set 1

- Is your study a clinical trial of an investigational medicinal product?
- Is your study one or more of the following: A non-CE marked medical device, or a device which has been modified or is being used outside of its CE mark intended purpose, and the study is conducted by or with the support of the manufacturer or another commercial company (including university spin-out company) to provide data for CE marking purposes?
- Does your study involve exposure to any ionising radiation?
- Does your study involve the processing of disclosable protected information on the Register of the Human Fertilisation and Embryology Authority by researchers, without consent?

Question Set 2

- Will your study involve potential research participants identified in the context of, or in connection with, their past or present use of services (NHS and adult social care), including participants recruited through these services as healthy controls?
- Will your research involve prospective collection of tissue (i.e. any material consisting of or including human cells)

from any past or present users of these services (NHS and adult social care)?
- Will your research involve prospective collection of information from any past or present users of these services (NHS and adult social care)?
- Will your research involve the use of previously collected tissue and/or information from which individual past or present users of these services (NHS and adult social care), are likely to be identified by the researchers either directly from that tissue or information, or from its combination with other tissue or information likely to come into their possession?
- Will your research involve potential research participants identified because of their status as relatives or carers of past or present users of these services (NHS and adult social care)?

Question Set 3

- Will your research involve the storage of relevant material from the living or the deceased on premises in England, Wales or Northern Ireland without a storage licence from the Human Tissue Authority (HTA)?
- Will your research involve storage or use of relevant material from the living, collected on or after 1st September 2006, and the research is not within the terms of consent for research from the donors?
- Will your research involve the analysis of human DNA in cellular material (relevant material), collected on or after 1st September 2006, and this analysis is not within the terms of consent for research from the donor? And/or: Will your research involve the analysis of human DNA from materials that do not contain cells (for example: serum or processed bodily fluids such as plasma and semen) and this analysis is not within the terms of consent for research from the donor?

Question Set 4

- Will your research involve at any stage procedures (including use of identifiable tissue samples or personal information) involving adults who lack capacity to consent for themselves, including participants retained in study following the loss of capacity?
- Is your research health-related and involving offenders?
- Does your research involve xenotransplantation?
- Is your research a social care project funded by the Department of Health and Social Care (England)?
- Will the research involve processing confidential information of patients or service users outside of the care team without consent? And/ or: Does your research have Section 251 Support or will you be making an application to the Confidentiality Advisory Committee (CAG) for Section 251 Support?

If your research extends beyond **England** find out if you need NHS REC review by selecting the 'OTHER UK COUNTRIES' button below.

OTHER UK COUNTRIES

If, after visiting all relevant UK countries, this decision tool suggests that you do not require NHS REC review follow this link for final

confirmation and further information.

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NOTE: If using Internet Explorer please use browser print function.

Appendix C

Appendix C: Extract from Timeline Document

Continued on next page...

It's now 08:14 and the radiographer has spotted an issue with the XVI PC. The screen seems to have gone strange and 'dotty'. The radiographer reboots the device.

08:15 and the radiographer discovers a QA3 device and appears confused as to why there is one in there, when there hasn't been at previous times.

08:16 the radiographer contacts the machine technologist by phone and asks whether she can use the QA3 device that was in the cupboard. The Machine Technologist gives the go ahead and the radiographer articulates her frustration that they weren't told that there was one available to use in the linac room.

08:17 and as the radiographer was walking to the linac room, the telephone rang. It was the receptionist informing her that there was a patient waiting in the waiting area. The radiographer mentioned that the receptionists schedule the patients and that they can see in the software.

The receptionist can obtain this information from the Clinical System Mosaiq, and see whether the patient has been checked in. She feels this phone call is unnecessary.

08:17 another radiographer (B) walks in, a member of the treatment team.

08:20 Radiographer B goes to give the patient some medication

The radiographers discuss their frustrations of not knowing that there was a QA3 device.

At 08:20 the radiographer attempted to login to a PC to find the Atlas QA software, she was unsuccessful and moves to another PC to attempt to find the software.

08:21 Radiographer A (the QA radiographer) mentioned that the Icon for Atlas QA is different inside the application and on the desktop, which makes it harder to find. She identifies the yellowness of the icon.

08:23 Radiographer A uses Atlas QA to record the beam profile (displays the information that the QA3 box collecs from the beam), and then they use QA3VMAT test web analysis for checking the position of the box is correct to reduce inaccuracies. The phone rings whilst she was explaining the process. The phone is the other linac bunker who is ready to release the QA3 device.

08:26 Atlas QA displayed the beam as failed (on purpose) to prompt the radiographer to check QA3VMAT. This is an interesting change to remind the radiographer to not forget the QA3VMAT step.

The radiographer is now quickly moving around the machines to run the tests, to meet the 08:30 clinical start time. It's now 08:27 and Radiographer C arrives.

References

[1] J. Preece, Y. Rogers, and H. Sharp, *Interaction Design: Beyond Human-Computer Interaction, 4th Edition*. John Wiley & Sons, 2015.

[2] The Ionising Radiation (Medical Exposure) Regulations 2017. (SI 2017/1322). [Online] Available at: https://www.legislation.gov.uk/uksi/2017/1322/contents/made[Accessed2020-05-06].

[3] Health Care & Professions Council. Professions and Protected Titles. [Online] Available at: https://www.hcpc-uk.org/about-us/who-we-regulate/the-professions, [Accessed 2019-10-24].

[4] I. C. Coulter, C. Kemp, I. J. S. Boddy, S. P. Marsden, N. Mukerji, and R. D. Strachan, "Real-time symptom reporting during elective intracranial pressure monitoring using an interactive handset," *British Journal of Neurosurgery*, vol. 32, no. 6, pp. 694–696, 2018, pMID: 29183151. [Online]. Available: https://doi.org/10.1080/02688697.2017.1409878

[5] J. Whitbourn, A. Simpson, and et al, "The winds of change for software regulation," *Institute of Physics and Engineering in Medicine (IPEM) Scope Magazine*, vol. 28, no. 2, pp. 10–13, 2019 (Online) Available at: https://www.ipem.ac.uk/Portals/0/SCOPE_JUNE2019.pdf?ver=2019-06-19-165346-813.

[6] K. Holtzblatt and H. Beyer, *Contextual Design : design for life*. Morgan Kaufmann, 2016.

[7] C. Acharya, H. Thimbleby, and P. Oladimeji, "Human computer interaction and medical devices," in *Proceedings of the 24th BCS Interaction Specialist Group Conference*. British Computer Society, 2010, pp. 168–176.

[8] A. Cassano-Piche, P. Trbovich, M. Griffin, Y. L. Lin, and T. Easty, "Human factors for health technology safety: evaluating and improving the use of health technology in the real world," 2015.

[9] NHS England. Compassion in care campaign hits new milestone. Feb 2nd, 2015. [Online] Available at: https://www.england.nhs.uk/2015/02/hellomynameis, [Accessed 2019-10-24].

[10] UK Accreditation Service (UKAS). Medical Physics and Clinical Engineering (MPACE). [Online] Available at: https://www.ukas.com/services/technical-services/development-of-new-areas-of-accreditation/current-pilot-projects/medical-physics-and-clinical-engineering-mpace/, [Accessed 2019-10-24].

[11] The Register of Clinical Technologists. About Clinical Technologists. [Online] Available at: http://therct.org.uk/info-for-public/about-clinical-technologists, [Accessed 2019-10-24].

[12] C. Kemp and A. Simpson, "Custom-built electronic referral system for home oximetry studies." *Abstracts of the 24th Congress of the European Sleep Research Society Basel, Switzerland*, vol. 27, no. S1, p. 137, 2018 Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1111/jsr.12751.

[13] EU, "Regulation (eu) 2017/745 of the european parliament and of the council of 5 april 2017 on medical devices, amending directive 2001/83/ec, regulation (ec) no 178/2002 and regulation (ec) no 1223/2009 and repealing council directives 90/385/eec and 93/42/eec," 2017.

[14] S. Donaldson, "Towards safer radiotherapy," *British Institute of Radiology, Institute of Physics and Engineering in Medicine, National Patient Safety Agency, Society and College of Radiographers, The Royal College of Radiologists, London*, 2008.

[15] J. J. Gibson, "The theory of affordances," *Hilldale, USA*, vol. 1, no. 2, 1977.

[16] A. Cooper, "The inmates are running the asylum. indianapolis, ia: Sams," 1999.

[17] S. Blomkvist, "Persona–an overview," *Retrieved November*, vol. 22, p. 2004, 2002.

[18] B. Groeneveld, T. Dekkers, B. Boon, and P. D'Olivo, "Challenges for design researchers in healthcare," *Design for Health*, vol. 2, no. 2, pp. 305–326, 2018.

[19] A. Blandford, E. Berndt, K. Catchpole, D. Furniss, A. Mayer, H. Mentis, A. A. O'Kane, T. Owen, A. Rajkomar, and R. Randell, "Strategies for conducting situated studies of technology use in hospitals," *Cognition, Technology & Work*, vol. 17, no. 4, pp. 489–502, 2015.

[20] M. H. Calp and M. A. Akcayol, "The importance of human computer interaction in the development process of software projects," *arXiv preprint arXiv:1902.02757*, 2019.

[21] R. J. Holden, P. Carayon, A. P. Gurses, P. Hoonakker, A. S. Hundt, A. A. Ozok, and A. J. Rivera-Rodriguez, "Seips 2.0: a human factors framework for studying and improving the work of healthcare professionals and patients," *Ergonomics*, vol. 56, no. 11, pp. 1669–1686, 2013.

[22] I. Habli, S. White, M. Sujan, S. Harrison, and M. Ugarte, "What is the safety case for health it? a study of assurance practices in england," *Safety Science*, vol. 110, pp. 324–335, 2018.

[23] H. Thimbleby, "Improve it, improve healthcare," *Computer*, vol. 50, no. 6, pp. 86–91, 2017.

[24] M. A. Sujan, I. Habli, T. P. Kelly, S. Pozzi, and C. W. Johnson, "Should healthcare providers do safety cases? lessons from a cross-industry review of safety case practices," *Safety science*, vol. 84, pp. 181–189, 2016.

[25] I. Habli, A. Al-Humam, T. Kelly, and L. Fahel, "Integrating safety assessment into the design of healthcare service-oriented architectures," in *5th Workshop on Medical Cyber-Physical Systems*. Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik, 2014.

[26] I. Habli, S. White, M. Sujan, S. Harrison, and M. Ugarte, "What is the safety case for health it? a study of assurance practices in england," *Safety science*, vol. 110, no. Part A, pp. 324–335, Dec. 2018, © 2018 Elsevier Ltd. All rights reserved. This is an author-produced version of the published paper. Uploaded in accordance with the publisher's self-archiving policy.

[27] Y. Li, P. Oladimeji, C. Monroy, A. Cauchi, H. Thimbleby, D. Furniss, C. Vincent, and A. Blandford, "Design of interactive medical devices: Feedback and its improvement," in *2011 IEEE International Symposium on IT in Medicine and Education*, vol. 2. IEEE, 2011, pp. 204–208.

[28] C. Wharton, J. Rieman, C. Lewis, and P. Polson, "The cognitive walkthrough method: A practitioner's guide," in *Usability inspection methods*, 1994, pp. 105–140.

[29] Interaction Design Foundation. Interaction Design, Interaction Design Foundation. [Online] Available at: https://www.interaction-design.org/literature/topics/interaction-design, [Accessed 2019-05-03].

[30] J. M. Carroll, Ed., *Scenario-based Design: Envisioning Work and Technology in System Development*. New York, NY, USA: John Wiley & Sons, Inc., 1995.

[31] C. J. Vincent and A. Blandford, "Usability standards meet scenario-based design: challenges and opportunities," *Journal of Biomedical Informatics*, vol. 53, pp. 243–250, 2015.

[32] A. Blandford and D. Furniss, "Dicot: a methodology for applying distributed cognition to the design of teamworking systems," in *International workshop on design, specification, and verification of interactive systems*. Springer, 2005, pp. 26–38.

[33] Interaction Design Foundation. Contextual Interviews and How to Handle Them, Interaction Design Foundation. [Online] Available at: https://www.interaction-design.org/literature/article/contextual-interviews-and-how-to-handle-them, [Accessed 2019-05-03].

[34] A. Cooper, R. Reimann, and H. Dubberly, *About face 2.0: The essentials of interaction design*. John Wiley & Sons, Inc., 2003.

[35] A. Cooper *et al.*, *The inmates are running the asylum:[Why high-tech products drive us crazy and how to restore the sanity]*. Sams Indianapolis, 2004, vol. 2.

[36] J. Bowen, H. Petrie, A. Hinze, and S. Samaddar, "Personas revisited: Extending the use of personas to enhance participatory design," in *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*, 2020, pp. 1–12.

[37] C. J. Vincent and A. Blandford, "The challenges of delivering validated personas for medical equipment design," *Applied Ergonomics*, vol. 45, no. 4, pp. 1097–1105, 2014.

[38] J. L. Martin, B. J. Norris, E. Murphy, and J. A. Crowe, "Medical device development: The challenge for ergonomics," *Applied ergonomics*, vol. 39, no. 3, pp. 271–283, 2008.

[39] B. Buxton, *Sketching user experiences: getting the design right and the right design*. Morgan kaufmann, 2010.

[40] Interaction Design Foundation. What is Ideation – and How to Prepare for Ideation Sessions. [Online] Available at: https://www.interaction-design.org/literature/article/what-is-ideation-and-how-to-prepare-for-ideation-sessions, [Accessed 2020-05-05].

[41] J. Nielsen, "Usability inspection methods," in *Conference companion on Human factors in computing systems*, 1994, pp. 413–414.

[42] J. Rieman, M. Franzke, and D. Redmiles, "Usability evaluation with the cognitive walkthrough," in *Conference companion on Human factors in computing systems*, 1995, pp. 387–388.

[43] T. Mahatody, M. Sagar, and C. Kolski, "State of the art on the cognitive walkthrough method, its variants and evolutions," *Intl. Journal of Human–Computer Interaction*, vol. 26, no. 8, pp. 741–785, 2010.

[44] D. E. Rowley and D. G. Rhoades, "The cognitive jogthrough: a fast-paced user interface evaluation procedure," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, 1992, pp. 389–395.

[45] T. Granollers and J. Lorés, "Incorporation of users in the evaluation of usability by cognitive walkthrough," in *HCI related papers of Interacción 2004*. Springer, 2006, pp. 243–255.

[46] R. J. Fairbanks and S. Caplan, "Poor interface design and lack of usability testing facilitate medical error," *The Joint Commission Journal on Quality and Safety*, vol. 30, no. 10, pp. 579–584, 2004.

[47] M. B. Weinger, C. Pantiskas, M. E. Wiklund, and P. Carstensen, "Incorporating human factors into the design of medical devices." *Jama*, vol. 280, no. 17, p. 1484, 1998.

[48] G. Wickström and T. Bendix, "The" hawthorne effect"—what did the original hawthorne studies actually show?" *Scandinavian journal of work, environment & health*, pp. 363–367, 2000.

[49] T. Adlin and J. Pruitt, *The essential persona lifecycle: Your guide to building and using personas.* Morgan Kaufmann, 2010.

[50] S. Kujala, "User involvement: a review of the benefits and challenges," *Behaviour & information technology*, vol. 22, no. 1, pp. 1–16, 2003.

[51] L. Damodaran, "User involvement in the systems design process-a practical guide for users," *Behaviour & information technology*, vol. 15, no. 6, pp. 363–377, 1996.

[52] Interaction Design Foundation. A Quick Guide to Conducting a Usability Review. [Online] Available at: https://www.interaction-design.org/literature/article/a-quick-guide-to-conducting-a-usability-review,[Accessed2021-02-23].

[53] C. Snyder, *Paper prototyping: The fast and easy way to design and refine user interfaces.* Morgan Kaufmann, 2003.

[54] NHS Digital, (2020). Internet First. [Online] Available at: https://digital.nhs.uk/services/internet-first/policy, [Accessed 2020-05-06].

[55] National School of Healthcare Science. Scientist Training Programme. [Online] Available at: https://nshcs.hee.nhs.uk/programmes/stp/ ,[Accessed2021-02-23].