Big Science Politics and Global Development: The Case of Square Kilometre Array (SKA) in Africa

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Big science projects such as astronomy and space science have been framed in terms of a linear relationship to development. In depoliticisation language, scientists link answering fundamental questions about the universe, building large research infrastructures and technological advancement to discourses of development. Political questions of power are often suspended in this discourse and have received little attention, especially in the African context. This thesis brings to the fore these suspended issues or unintended effects of power, geopolitics, coloniality, dependency and neoliberalism which affect the projected impact of big science projects such as the Square Kilometre Array (SKA) and Development in Africa with Radio Astronomy (DARA) projects in Africa. The thesis utilises these case studies to put forth the idea that the creation of scientific knowledge and the development of related skills are crucial in maintaining the dependence of the Global South on the Global North. Science is not apolitical as scientists would portray but there is a correlation between science and power. The pursuit of big science is not just for the sake of knowledge generation and advancement, but it is an extension of influence from within states and beyond. The unique contribution made by the thesis is the use of different theoretical strands and disciplines, bringing them into conversation with each other to answer key questions on the political economy of science, technology, and innovation systems in Africa. The empirical evidence generated suggests a coproduction of big science and power and maintenance of scientific knowledge dependency in the Global South. In particular, the thesis unveils the side effects of big science development intervention and how ontological security is being built around big science at the individual, state, and transboundary levels.

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Introduction

1.1 Introduction

The 21st Century global development challenges ranging from political crises, climate change, increasing levels of poverty and of late the emergency of pandemics such as the outbreak of Corona Virus in 2019 have put science at the heart of evidence-informed decision making. In all these challenges confronting humanity, science is framed as a “panacea that carries the promise of curing socioeconomic ailments irrespective of the aetiology of these ailments” (Pfotenhauer and Jasanoff, 2017: 784). In international discourses on development and politics, hardly can conversations unfold without mentioning science, technology, and innovation. The development potential of science and narratives in these discourses is depoliticised and the politics embedded especially in big science infrastructures is regarded as a sphere of uncertainty that can impact outcomes therefore needs to be invisibilised (Venugopal, 2022: 1003). This has been referred to as an “anti-politics machine.”

The idea that development is an "anti-politics machine" has been popularised by Ferguson (1990) and refers to the tendency to simplify complex socio-economic problems into technical solutions that do not account for the political realities on the ground. As a result, development projects often fail because they overlook the local context and ignore the valuable knowledge and experience of the people who live there. Even the local knowledge sometimes tend to be overlooked by its owners, a development which decolonial thinkers are grappling with ((Ngũgĩ wa Thiong’o, 1986; Fanon and Lam Markmann, 1952; Ndlovu-Gatsheni, 2018). Western scientific knowledge is often prioritised over indigenous expertise, and technical expertise is sometimes used to suppress important social debates (Venugopal, 2022: 1002). Overall, the notion of development as an "anti-politics machine" suggests that a more nuanced and context-specific approach is needed to truly address the challenges of

development which this thesis explores using Ferguson's critique of development projects.

The genesis of international development using the discursive power of science and technology can be traced back to President Harry S. Truman's inaugural address to Congress in 1949 which is widely believed to influence the current approaches to the discipline of development and how it is deployed in the Global South. He pronounced the opinion that materialised in colonial and post-colonial relations to the developing world:

> We must embark on a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas. (Truman, 1949)

The statement impelled the economic and moral rationale of developed nations to give aid and technological transfers to 'underdeveloped areas'. As a result, governments have increasingly turned to intricate international collaborations as their preferred policy tool for enhancing their domestic abilities in science, technology, and innovation (ST&I), often in conjunction with foreign partners. Usually, these major initiatives are led mainly by practitioners and lack a thorough systematic comprehension of the various project design possibilities and compromises that are available (Pfotenhauer and Jasanoff, 2017). The available design options and trade-offs in this context refers to the policy considerations, operating social environment and the politics at play in both assisting and recipient nations. International partnerships and scientific collaborations also bring with them a whole lot of administrative and governance issues which their impact is often taken for granted. The broader societal and political impact of big science is perhaps the least understood, yet significant aspect, and systematic research is urgently needed (Autio, 2014: 6). This thesis seeks to make a scholarly contribution in this area which seem to have a dearth in literature, especially from the African perspective.

The advent of the Fourth Industrial Revolution (4IR) has also added the impetus to harness science and its accompanying technologies such as artificial intelligence and internet of things at the core for achieving the 2030 Sustainable Development Agenda. Astronomy is one of the scientific endeavours touted as an accessible field with

tentacles to other science, technology, engineering, and mathematics (STEM) subjects. The knowledge economy thinking and amassing of vast amounts of data and how they can be of use beyond the specialist's circles is something worthy interrogating.

The attractiveness of big science in governance by politicians has also been accentuated by the promises of ST&I as drivers of economic progress; equitable, humanitarian, and sustainable development; and evidence-based decision making and public policy development, which are regarded as hallmarks of good governance and responsible public administration (Copeland, 2015). Big science infrastructure projects arguably promote local and national capacity-building in science and technology (Academy of Arts and Sciences, 2022). They are claims of capacity-building through knowledge transfer, spill over effects and innovation (Scarrà and Piccaluga, 2022) which are enablers of a technologically advanced and competitive global economy. In scientific research, promises of future developments have always been integral. However, the implications of such promises can vary significantly depending on the context. Scientific promises formulated in peripheral scientific contexts (developing world) have different structures and consequences compared to those made in dominant or hegemonic sites (developed world) (Kreimer, 2023: 84). Although the intention of promises is to address important public problems, they also serve to position a particular scientific field or specialty as the most authoritative in solving these problems. In doing so, these promises can marginalize competing visions, challenge alternative actors, and establish the epistemic foundations required to understand and address these issues (ibid).

This study argues that besides the seemingly immediate gains of knowledge, evidence for decision making and contribution to economies, big science intentionally or unintentionally extent the bureaucratic power of the state following Ferguson's argument (Ferguson, 1990; Ferguson and Lohmann, 1994; Venugopal, 2022). The thesis surmise that the intentional blueprint for "development" and bringing down of poverty to a technical problem requiring technical solutions, big science projects end up straddling in sensitive political operations that involve institutional state power under the guise of a neutral technical assistance cover which no one can object to. Science and global politics are not only entangled but have always been co-productive of each other (Witjes and Olbrich, 2017:1). The co-productive nature of science,

technology, and global politics has always existed from ancient times to First and Second World War; independence movements among former colonies, from the Space Race during the Cold War to the processes of European integration. National prestige and ideological systems have been closely associated with science and technology (Witjes and Olbrich, 2017). Globalisation has impacted science, technology, and innovation, as it has improved the exchange of knowledge, resources, and talent worldwide, however, certain challenges remain (The Royal Society, 2011). The new entrants (China, India, Brazil, etc.) in the scientific powers league and the emergence of other scientific nations in the Middle East, South-East Asia and Africa pose a shift to an increasingly multipolar scientific world, where developed nations no longer retain control or are sole leaders in the field (Melchor, Elorza and Lacunza, 2020: 7). The current standoff between the giant Chinese telecommunications company Huawei and the Western powers is testimony to how science may be used to fuel superpower rivalries in a multipolar scientific world. Mascitelli and Chung described this standoff as the “start of the commercial and Cold War standoff with Huawei” (Mascitelli and Chung, 2019:2). They further argue that the rapid growth of China economically and scientifically could have unsettled the relations as illustrated in the statement.

> There were few cases in history where countries emerge economically with such gusto and haste as has China …. even threatening the position of the United States in such a short span of time (Mascitelli and Chung, 2019: 1).

The power that can culminate from science can be understood in terms of Lukes’s three faces of power. Lukes proposes that power is exercised in three ways: decision-making power, non-decision-making power, and ideological power (Lukes, 1974). The most prominent of the three dimensions is the first dimension, which pertains to decision-making power. This dimension centres on policy preferences that are made known through political action. The second dimension, non-decision-making power, concerns itself with setting the agenda in discussions and determining which issues are deemed unacceptable for discussion in "legitimate" public forums. This dimension provides a binary perspective on power, which enables analysts to examine both current and potential issues. This expands the focus on observable conflicts to include those that may be apparent either overtly or covertly. The third dimension, which is

ideological power, allows individuals to sway people's desires and thoughts, even compelling them to want things that go against their own self-interests. (Lukes, 1974: 15-24). Lukes' conceptualisation of power is an important analytical framework to this thesis as it explains the rationale behind participation in big science projects like the Square Kilometre Array (SKA) by African countries.

The pursuit of big science by states is not a neutral endeavour but reinforces the already co-productive nature of science and power (Bernard, 1949; Jasanoff, 2004).Nations in addition to physical security seek to achieve ontological security by routinising relationships with significant others and actors. Ontological security is the need to experience oneself, continuous person in time as being rather than constantly changing to realise a sense of agency (Laing, 1969; Giddens, 1991; Mitzen, 2006: 342). One way of routinising relationships in the global political arena is through scientific collaborations. The need for ontological security can be extrapolated from assemblages of individual identity, national identity and transnational or sometimes continental. The concept of ontological security has been applied in international relations and conflict studies and ever has it been applied in the politics of big science such as astronomy. The increasing role of science in Africa's development discourse requires a critical lens more so when regional bodies such as the African Union have endorsed a Space Strategy with astronomy as a flagship programme (African Union Commission, 2019). The thesis traces how ontological security is built from individual scientists, states, and transboundary levels besides the material and physical structures of the telescopes in the SKA project. The ontological security built around big science is similar to the unintended consequences of development.

One of the unintended effects of the "antipolitics machine," as conceptualized by Ferguson (1990), is the consolidation of bureaucratic power of the state. Development programs often rely on bureaucratic structures and mechanisms to implement their goals, and this can lead to the expansion of state power and the marginalisation of local communities and alternative perspectives. This can further entrench power imbalances and limit the potential for transformative social change. Therefore, the unintended effects of the "antipolitics machine" are not limited to the realm of development programs but can have significant implications for the broader political landscape. In this thesis there are some positive unintended effects of the SKA to the implementing countries and the African identity.

Branding a country is always a key factor in the creation of international image of a nation. The constant ideation of seeking ontological security and building capability in science is meant to project a better identity of the countries participating in the SKA to the world. Countries are resorting to harness “soft-power” tools or intangible assets such as culture, tourism, cuisine, cinema, or science, technology, and innovation (Copeland, 2009) as a better way to act in contrast to the use of coercive means, such as military power or traditional “hard power” tools. Therefore, countries make a combination of strategically hard- and soft-power tools in what can be framed as "smart power" (Nye, 2004). The increasing role of science in global politics has also given rise to the discipline of science diplomacy which is also at the heart of projects such as Square Kilometre Array (SKA) and Development in Africa with Radio Astronomy (DARA).

This thesis draws on critical intellectual thought at the intersection of international relations, politics of development, and science technology studies disciplines to explain how science can bed with dimensions of power in radio astronomy projects being implemented in Africa using Ghana as a case study. The framing of big science projects, such as astronomy and space science, has been in terms of a direct correlation with development. Scientists have used a depoliticisation language that links answering fundamental questions about the universe, building of large research infrastructure in form of telescopes and technological advancement to discourses of development. Depoliticisation can be defined as ‘a governing strategy and process of placing at one, remove the political character of decision-making’ (Burnham, 2001: 128), ‘the art of suppressing the political’ (Rancière, 2007:11), and ‘the denial of the choice, agency, and deliberation that are necessary in any democratic society’ (Fawcett, Flinders and Hay, 2017:6). This language of depoliticization has led to some perceptions of a strong connection of big science such as space science to the discourses of development. Political questions of power are often suspended in this discourse and have received little attention, especially in the African context. This thesis brings to fore these suspended issues of power, geopolitics, coloniality, dependency and neoliberalism which affect the projected impact of flagship big science projects such as the Square Kilometre Array (SKA) and Development in Africa with Radio Astronomy (DARA) projects in Africa. The unintended consequences of the discourse of development through science builds ontological security (OS) and this

thesis shows how OS, ideational power and capability interact in relation to African identity at three levels (i) individual, (ii) state/corporate and (iii) transboundary level. In this process the thesis unveils the yearn to position Africa as a continent with positive influence, an aspiration to be part of framing the intellectual agenda rather than being narrated to in this 'racialised' International Relations (IR) discipline, and the vulnerabilities of this OS. The thesis summarily argues that the production of scientific knowledge and associated capacity building play an important background role in the maintenance of dependency (epistemological and material resources) between the Global North and South.

1.2 Space science and astronomy as big science

This section contextualises big science and explain why the space science and in particular radio astronomy project, qualify as such. Space science is the study of the universe beyond Earth's atmosphere. It includes the study of astronomy, astrophysics, cosmology, and the exploration of space (know.space, 2021). It also includes the study of the physical and chemical properties of celestial bodies, such as planets, stars, and galaxies. Space science also involves the study of the origin and evolution of the universe, and the search for extra-terrestrial life. Space science is considered as a form of big science. Although the thesis uses radio astronomy as a case study it broadly refers to space science as the overarching term to cover all the upstream and downstream applications that are used in the projects.

The thesis broadly uses the term science purposefully to capture all the processes involved in knowledge generation to innovation cognisant of the fact that there are many conceptualisations of the term. Science is a systematic and empirical approach to understanding the natural world, encompassing all processes from research to innovation. According to the National Academy of Sciences (NAS), science involves the application of rigorous and objective methods to generate knowledge, test hypotheses, and develop theories (National Academies of Sciences, 2019). This includes the formulation of research questions, the collection and analysis of data, and the interpretation of findings. Science also involves a collaborative and iterative process of peer review, critique, and replication to ensure the validity and reliability of scientific knowledge (National Academy of Sciences, 2019).

Furthermore, the Organization for Economic Cooperation and Development (OECD) highlights that science includes the translation of research findings into practical applications and the dissemination of knowledge to the wider community (OECD, 2015). This process of knowledge translation and dissemination is crucial for ensuring that scientific knowledge is accessible and applicable to real-world problems. Overall, science is a dynamic and ongoing process of inquiry that seeks to advance our understanding of the world and improve our ability to address real-world problems. So, in this thesis when science is mentioned it will be referring to all the processes involved in knowledge generation and its translation.

The qualification of the case studies used in this study follows this synopsis of understanding large infrastructure and attendant human capital development projects as big science. There are several conceptualisations of big science. The terms ‘Big science’ or "Mega Science" are often used interchangeably to describe scientific collaborations that are characterized by their large scale and significant capital investment. These collaborations rely on shared scientific resources, which may include facilities for measurement, observation, experimentation, and research, as well as data resources and supporting infrastructure ‘(Autio, 2014:13). In 1961, Weinberg coined the term "big science" in a commentary regarding the influence of large-scale scientific endeavours on the economy of the United States. He made analogies between the pyramids of Egypt and the cathedral of Notre Dame, positing that grand structures of big science, such as particle accelerators, space vehicles, and rockets, also serve as symbols that reflect the most significant values and profound aspirations of contemporary culture. (Weinberg, 1961: 161).

During this time when he made a commentary, Weinberg was also worried about what would happen if science continued to grow in terms of teams, organisations, large institutional organograms, administrators, and warned about the inevitable bureaucratisation of science. This had a potential to overshadow classic academic science and eventually extinguish its natural (and crucial) creativity and serendipity (Weinberg, 1961: 162). Contrary to Weinberg, Price used the term big science to describe general growth of science in every aspect. However, he made references to growth of instrumentation, research teams and organizations to extreme sizes but Price did not see these as part of big science definition but rather as by-products of a

science otherwise growing in most respects (Price, 1986: 28-29). Further developments in the understanding of big science have defined the term as science made big in three dimensions: big organisations, big machines, and big politics (Olof, 2016: 17). This thesis adopts this transformed definition to suit the overall discussion throughout the chapters about power and its big politics in science.

The dimensions of the definition are considered individually. First, big organizations. The oldest known astronomy is aboriginal astronomy, dating back at least 40,000 years (Haynes *et al.*, 2011). Around the middle of the nineteenth century, astronomy was regarded as 'little science' in the sense that it was practised by individuals looking up at the night sky using the naked eye. From then on, post-World War II, there is a huge institutional transformation that happened in astronomy. Small single instrument observatories were replaced by large, complex observatories led by powerful directors, large institutional structures and organograms, transforming into big organisations (Lankford, 1997 cited in Howard, 2004: 71).

The second component of big science involves the utilisation of large-scale machinery. According to the present definition, the physical enormity of such machinery is paramount, as it necessitates the creation of extensive organisations with physically arranged parts or divisions. In fields that rely on data-driven scientific inquiry, such as radio astronomy, it is imperative to have access to sophisticated instruments capable of generating data for the purpose of addressing astronomical issues (Lankford, 1997). The instruments used and technology are expensive and available in a limited number of observatories. Due to massive infrastructure required in astronomy, no country single handed can construct and therefore requires collaboration with other countries. However, what constitutes "big" machines is of course relative (Hallonsten, 2016).

The third element pertains to the significant role of science in politics, referred to as "big politics." This involves the heightened prominence of science within political arenas, which results in increased attention from policymakers, governmental documentation, and news stories (Hallonsten, 2016: 19). Although the allocation of funds to big science in national Research and Development (R&D) budgets is relatively small when compared to universities and institutes with smaller-scale scientific programs, big science holds significant visibility and thus carries naturally elevated political stakes. This has been noted by researchers (ibid), who have

observed that the term "big science" is often strategically utilised by scientists and lobbyists to gain political support (Westfall, 2003: 32-33). This implies that there is political weight associated with both the concept of big science and its physical manifestations. Big science attracts political interest and seems to carry a symbolism that can give it some privilege i.e., special treatment in science policy. This was most evident after World War II, when nuclear physics was enough to get big science on the arena of superpower competition.

The simple fact derived from the three dimensions of big science in this definition is that thinking big in terms of projects is more likely to result in a successful outcome in terms of both funding, political support, and influence partly because a big project is more likely to get the attention of someone high up at decision making level. There is a profound relationship between size of projects and importance in the minds of decision makers. Astronomy and space science qualifies as big science in the sense that it involves big organisation of a multilateral scope, big telescopes at observatories and big politics in rationale, negotiation, and implementation especially the SKA project understudy.

1.3 Background to the SKA and DARA projects

The African continent has shown a great deal of interest and willingness in developing its member countries' economies driven by science, technology, and innovation. This interest is evidenced by Agenda 2063 and the Common African Position on Agenda 2030 that identified ST&I as key enablers to achieve development blueprints (ACBF, 2017: 1). The African aspiration for development using ST&I was expressed in the following statement of the Agenda 2063 document.

> We aspire that by 2063, Africa shall be a prosperous continent, with the means and resources to drive its own development, and where… well educated and skilled citizens underpinned by science, technology, and innovation for a knowledge society [, are] the norm…This will be attained through strategies of inclusive growth, job creation, increasing agricultural production; investments in science, technology, research, and innovation…. (African Union Commission, 2015).

A ten year Science, Technology and Innovation Strategy (STISA, 2024) has been formulated and adopted by the African Union to guide ST&I initiatives among member countries (African Union Commission, 2015). STISA-2024 identified six pillars of ST&I focus necessary for Africa's acceleration to an innovation led and knowledge-based economy. The six priorities are: eradicate hunger and achieving food and security; prevention and control of diseases; communication (physical and intellectual mobility); protect our space; live together –build the society and create wealth (STISA, 2024: 22-23). The fourth priority on protecting Africa's space is of interest to this study as astronomy is specifically mentioned in the STISA-2024 as one of the strategies to address the continent's socio-economic development issues.

> Space presents a unique opportunity for the continent to collectively address socio-economic development issues through derived services such as Earth Observation, Navigation and Positioning, Satellite Communication Space Science and Astronomy. (STISA, 2024, African Union Commission, 2015)

This sudden attention to space science raises a question on how specifically astronomy is linked to development, distinguishing it from other traditional science in Africa which this thesis will examine. The available literature does not give a clear synopsis of how the initial focus on fascinating science that studies the universe by detecting radio emission from celestial objects like the Sun, the Milky way, planets, galaxies, and nebulas has widened its scope to include development in Africa. Since the beginning of the space age, geopolitical considerations have played a dominant role in shaping space programmes and government buy in (OECD, 2016: 22). This study will endeavour to analyse the sudden attention given to space science by African countries whether it has any links to geopolitical considerations and power brokerage.

The SKA project is an international effort to build the world's largest radio telescope co-hosted by Australia and South Africa. South Africa is participating in this project with eight African partner countries that include Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia. The SKA is envisaged to answer fundamental questions of science and about the laws of nature such as: how did the universe, stars, galaxies form and evolve? Was Einstein's theory of relativity correct? What is the nature of 'dark matter' and 'dark energy'? What is the origin of cosmic magnetism? Is there life somewhere else in the Universe? (SKA, 2019). Figure 1 shows the location of countries participating in the SKA in Africa

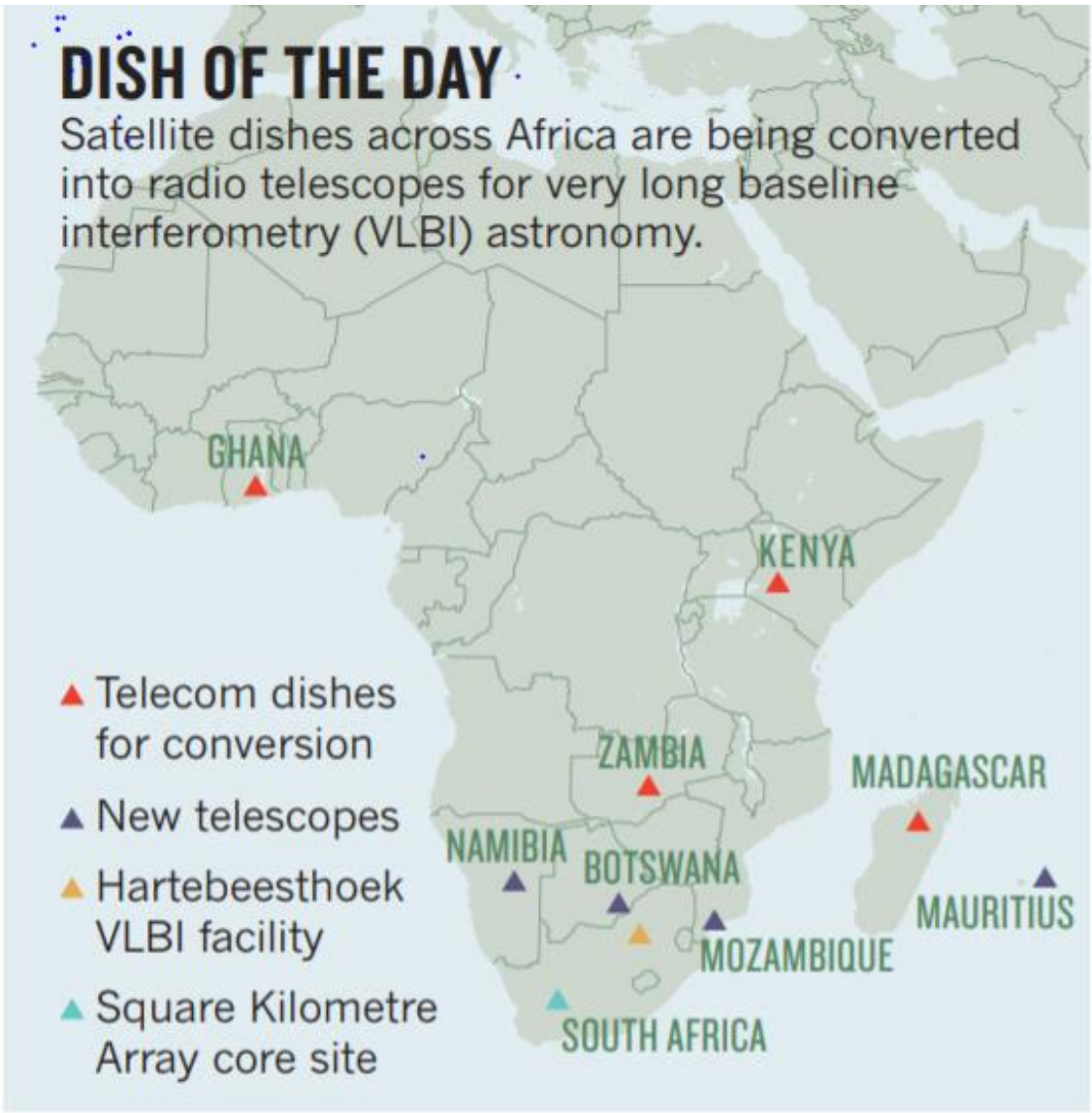

Figure 1.1: VLBI Network in Africa ***Source: Nordling, 2012 Nature, pp 488, 571***

1.4 Chronology of events for the SKA Project

It is important to understand the genesis of the project and its historical context to inform the subsequent narratives, debates around mega-science projects and western hegemony in science. The historical background of the SKA began in the early 80s but formally in 1993 when the International Union of Radio Science (URSI) established the Large Telescope Working Group to begin a worldwide effort to develop the

scientific goals and technical specifications for a next generation radio observatory (SKA, Official Website, 2019).

The Large Telescope Working Group's efforts resulted in the signing of a Memorandum of Understanding (MoU) during the International Astronomical Union (IAU) meeting in Manchester, UK in 2000 (according to the SKA website). Eleven countries (Australia, Canada, China, Germany, India, Italy, the Netherlands, Poland, Sweden, the United Kingdom, and the United States) were represented, and the agreement was followed by a Memorandum of Agreement in 2005. This agreement facilitated the expansion of the Steering Committee to twenty-one members, with seven members each from Europe, the USA, and the Rest of the World. Additionally, it led to the establishment of the International SKA Project Office, and several further agreements were created. Of relevance to this study is the 2007 agreement, which established the SKA Programme Development Office (SPDO). This agreement served as the foundation for internationalizing the technology development and design efforts of the SKA project, with Africa's involvement through the National Research Foundation of South Africa (SKA, 2018). The SKA Organization was founded in 2011 as a not-for-profit company, with the headquarters located at Jodrell Bank Observatory, near Manchester, UK. The goal of the organization was to formalize relationships between international partners and centralize leadership of the project. In 2019, the SKA Observatory Convention was signed by multiple countries to establish an intergovernmental organization (IGO).

Table 1.1 is a summary of the major events that have led to the establishment of the SKAO.

Table 1.1: Chronology of the SKA Project

Time Period	Major Event
1993	International Union of Radio Science (URSI) established the Large Telescope Working Group to begin a worldwide effort to develop the scientific goals and technical specifications for a next generation radio observatory.
1997	Eight institutions from six countries (Australia, Canada, China, India, the Netherlands, and the U.S.A.) signed a Memorandum of Agreement to cooperate in a technology study programme leading to a future exceptionally large radio telescope.
2000	During the International Astronomical Union meeting in Manchester, UK, a Memorandum of Understanding to establish the International Square Kilometre Array Steering Committee (ISSC) was signed by representatives of eleven countries (Australia, Canada, China, Germany, India, Italy, the Netherlands, Poland, Sweden, the United Kingdom, and the United States).
2005 -2007	Memorandum of Agreement to Collaborate in the Development of the Square Kilometre Array came into force on 1 January 2005 and extended until 31 December 2007. This made provision for the expansion of the Steering Committee to twenty-one members (7 each for Europe, USA, and the Rest of the World) and the establishment of the International SKA Project Office.
2007	Call for proposals to host the International SKA Project Office (ISPO) and out of the three bids. University of Manchester was chosen to host the ISPO
2010	South Africa and Australia bid to host SKA Telescope
2011	SKA Organisation was established, and the UK won the bid to host the Headquarters
2012	Results of the bid to host the SKA telescope announced Australia and South Africa became co-hosts of the SKA Telescope
2019	Countries signed the Convention to establish SKA Observatory as an Intergovernmental Organisation (IGO)
2021	SKAO came into being as an IGO with the official launch of the first meeting of the newly formed Council

Source: Author's table based on SKA History (https://www.skatelescope.org/history-of-the-skaproject/)

The move to establish the SKAO has been interpreted as a consolidation of power. The rationale to establish the IGO according to the organisation's claim pertains to 'global and trans-cultural collaboration' or framework to 'internationalise the technology development' which deserves a critical lens of observation given current post-colonial debates about 'decolonising knowledge' and persistence of asymmetrical power relations in contemporary north-south and south-south relationships (Walker and Chinigo, 2018:10). Reversal in unequal north-south partnerships and 'brain drain' of promising 'southern' scientists to institutions in the north will see global scientist moving to African sites (ibid). These perspectives tend to depoliticise and de-historicise the deeper complex power dynamics inbuilt within global science (MacKenzie and Wajcman, 1999).

The governance of transnational science is made complex and gives rise to uncertainty by the disaggregation of authority and decision-making in global spaces (Legrand Timothy and Stone Diane, 2018: 10). Generally, science cooperation is based on disciplines and values that transcend politics, languages, borders, and cultures (Hormats, 2012: 2). The establishment of the SKAO has been viewed as strengthening science diplomacy among the participating nations. Science diplomacy in the context of global science is becoming a formidable dimension of these deeper complex interstate power dynamics which involve 'political intercostalities' of state actors, scientific communities and other transnational actors within the new architectures of global governance (Legrand Timothy and Stone Diane, 2018: 1). Federof (2008) defines science diplomacy as "the use of scientific collaborations among nations to address the common problems facing the 21st century humanity and to build constructive international partnerships." Legrand and Stone argue that the definition is narrowly cast to only reflect the exchange of knowledge between nations, yet science diplomacy has evolved to have wider transnational policy ramifications that impinge on governance networks and in other ways maintain asymmetrical power relations.

The hosting of the SKA telescope between South Africa and Australia came because of political decision-making and conflicts rather than a scientific endeavour. Two groups of countries, one consisting of Australia and New Zealand and the Sub-Saharan Region led by South Africa had cast their rival bids to host the big telescope

(Economist, 2012). In Africa, South Africa is partnering with Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia.

The resultant split in hosting between Australia and South Africa announced in 2012 has been described in a statement: “science has never been immune to the ugly reality of politics” (Nature, 2015). In her official statement, Naledi Pandor, who was the Minister of Science and Technology at the time, emphasised that the decision to divide the hosting of SKA was driven by geopolitics rather than scientific considerations. She further noted that in Africa, the SKA was regarded as a positive development, as it provided hope to a continent that was grappling with a reputation for violence and instability. (Economist, 2012). In terms of scoring in the ‘other selection factors’ (non-technical) for South Africa’s bid ‘much of the concern was the difficulties of coordinating the laws and procedures among the six partner countries in Southern Africa, as well as the security and political challenges in the region’ (Moran *et al.*, 2012: 4).

To the South African government, SKA meant the revival of the African continent. Gastrow (2014:83) states that, the investment in astronomy projects portrays a favourable image, one of ‘modernity, international standing and validation for African scientific and intellectual capabilities.’ Earlier in 2005, Gottschalk believed that investment in astronomy was the African National Congress (ANC) government’s rationale to prop up national prestige and dignity of the African continent (Gottschalk, 2005: 33). This idea by the ANC leads to African renaissance, a concept that African people and nations shall overcome the current challenges confronting the continent and achieve cultural, scientific, and economic renewal. Thabo Mbeki former President of South Africa in his speech “I am an African” delivered on May 1996 said,

> The evolution of humanity says that the Africa reaffirms that she is continuing her rise from the ashes. Whatever the setbacks of the moment, nothing can stop us now! Whatever the difficulties, Africa shall be at peace (Thabo Mbeki, 1996) (Mbeki, 2005).

The speech and beliefs contained feed into the broader African development discourse that underpins some of the key discussions in the subsequent chapters of this thesis. Whitelock (2009: 590), made a comment in line with this perspective of

African prestige based on the Department of Arts, Culture, Science and Technology's 1996 White Paper which pointed out that,

> Scientific endeavour is not purely utilitarian in its objectives and has important associated cultural and social value. It is important to maintain a basic science competence in 'flagship' sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future - the view that we are second class nation, chained forever to the treadmill of feeding and clothing ourselves (Whitelock, 2009: 590).

The statement has connotations of the emancipation of the African people from basic thinking to advanced scientific frontiers just like the developed countries. This thesis argues that this entrapment into modernity and neoliberal pathway to development plays a background role in maintaining the divide between the Global North, i.e., countries of the world which are characterized by a high level of economic and industrial development, and the Global South, countries that are typically located to the South of the industrialized nations.

Much of the literature and scholarly work on the SKA project in Africa has been centred on South Africa(Gottschalk, 2005; Gastrow, 2015; Atkinson *et al.*, 2017; Walker, Chinigò and Dubow, 2019) and void of other eight countries that are part of the initiative. This study seeks to fill in this gap by focusing on Ghana in the Western part of Africa and add to the critical mass of knowledge required to inform strategic decisions at the national level for different countries participating and at the continental level regarding astronomy and development as well as broader science, technology, and innovation system.

1.5 Ghana Radio Astronomy Observatory

Ghana is the first partner country of the African Very Long Baseline Interferometer (VLBI) Network (AVN) to complete the conversion of a communications antenna into a functioning radio telescope (SKA Africa, 2017). The 32-metre converted telecommunications antenna at the Ghana Intelsat Satellite Earth Station at Kuntunse will be integrated into the African VLBI Network (AVN) in preparation for the second phase of the construction of the SKA in Africa. The telescope is located at Kuntunse, a small town in the Ga West Municipal District of the Greater Accra Region. Ghana's

location at 5° north of the Equator is a vantage point for viewing the entire plane of the Milky Way, a galaxy that contains the solar system, nearly the whole sky, proximity to the African Undersea Cables spanning the east and west coasts of the continent that link Africa to the rest of the World (Asabere *et al.*, 2014: 4).

The political leadership in Ghana welcomed the development with great enthusiasm as noted from the speech delivered by the relevant Minister in Ghana.

> The Ghanaian government warmly embraces the prospect of radio astronomy in the country and our radio astronomy development plan forms part of the broader Ghana Science, Technology, and Innovation Development Plan, says Professor Kwabena Frimpong-Boateng, the Ghana Minister of Environment, Science, Technology, and Innovation. (MESTI, 2017)

The work of upgrading the antenna was a collaborative effort between SKA South Africa (SKA SA)/ Hartebeesthoek Radio Astronomy Observatory (HartRAO) group and a team of scientists from Ghana Space Science and Technology Institute (GSSTI) which is under MESTI. The South African Department of International Relations and Cooperation (DIRCO) funded a large part of the conversion project through the African Renaissance and International Cooperation Fund (ARF). The African Renaissance Fund is aimed at strengthening cooperation between South Africa and other African countries to support the development of skills and build institutional capacity on the continent (SKA, 2017). South Africa's investment in SKA was summed up Walker and Chinigo as a dual role of being by historic and geographic consequence, a 'big brother' and would be an equal partner(Walker and Chinigò, 2018a). This may culminate into a simmering tension among other partners in the SKA. While the SKA has its own human capital development strand, a separate related programme is also operational in Ghana which is described below.

1.6 DARA Project

Development in Africa with Radio Astronomy (DARA) is a human capital development programme within the people strand of the Newton Fund to develop high-tech skills through radio astronomy in several African countries in partnership with South Africa. DARA is an associate project to SKA and a joint venture between the UK, South Africa and African partner nations, aimed at providing development, education, training and

careers advice to Africans through radio astronomy and related technical disciplines (Hoare, 2018: 1). Astronomy training received by African students at various levels, including Masters, PhD, and basic training for physics graduates, equips them with skills and experience in research, computing, technology, digital signal processing, and big data. These skills are expected to be applied towards the development of high-tech industries and to contribute towards economic development. Furthermore, projects related to the DARA initiative support outreach activities aimed at encouraging school children to pursue science, technology, engineering, and mathematics (STEM) subjects, with the aim of propelling future development (Hoare, 2018:2). The human capital development started in August 2014 with the training of at least 10 trainees per year as well as a PhD student at the University of Ghana with funding from the Royal Society Africa Award.

The opportunity to use radio astronomy as a development vehicle in Africa is the cornerstone of DARA. DARA is under the leadership of the University of Leeds in partnership with other UK-based institutions and South Africa. The project aims to address Sustainable Development Goals (SDGs) specifically SDG 4: Quality Education; SDG 9: Industry, Innovation and Infrastructure and SDG 17: Partnerships for the Goals. Radio astronomy encompasses all the science, technology, engineering, and mathematics (STEM) skills that underpin the emergence of a strong developed economy. The modern astronomer needs knowledge in physics, mathematics, chemistry, and computing (DARA Website, 2019).

The aim is to inspire and train a new and diverse generation of young people to engage with these skills. Training will engender a research ethos as well as communication and diagnostic skills that are transferable to many aspects of a developing economy (DARA, Phase 2 Proposal). DARA has identified three main impact pathways under the current Newton Fund which are: knowledge exchange, commercialisation, and collaboration with industry. However, in the impact pathways identified in DARA, there are some missing ontologies especially the social aspects of addressing inequality, race, and power relations which this thesis seeks to understand why these are omitted in 'big science' projects. The following infographic produced by the University of Leeds on behalf of the project summarises the DARA project in terms of the SDG framework informing the project, scientific aims, nature of training provided, participating countries and the target numbers for the training.

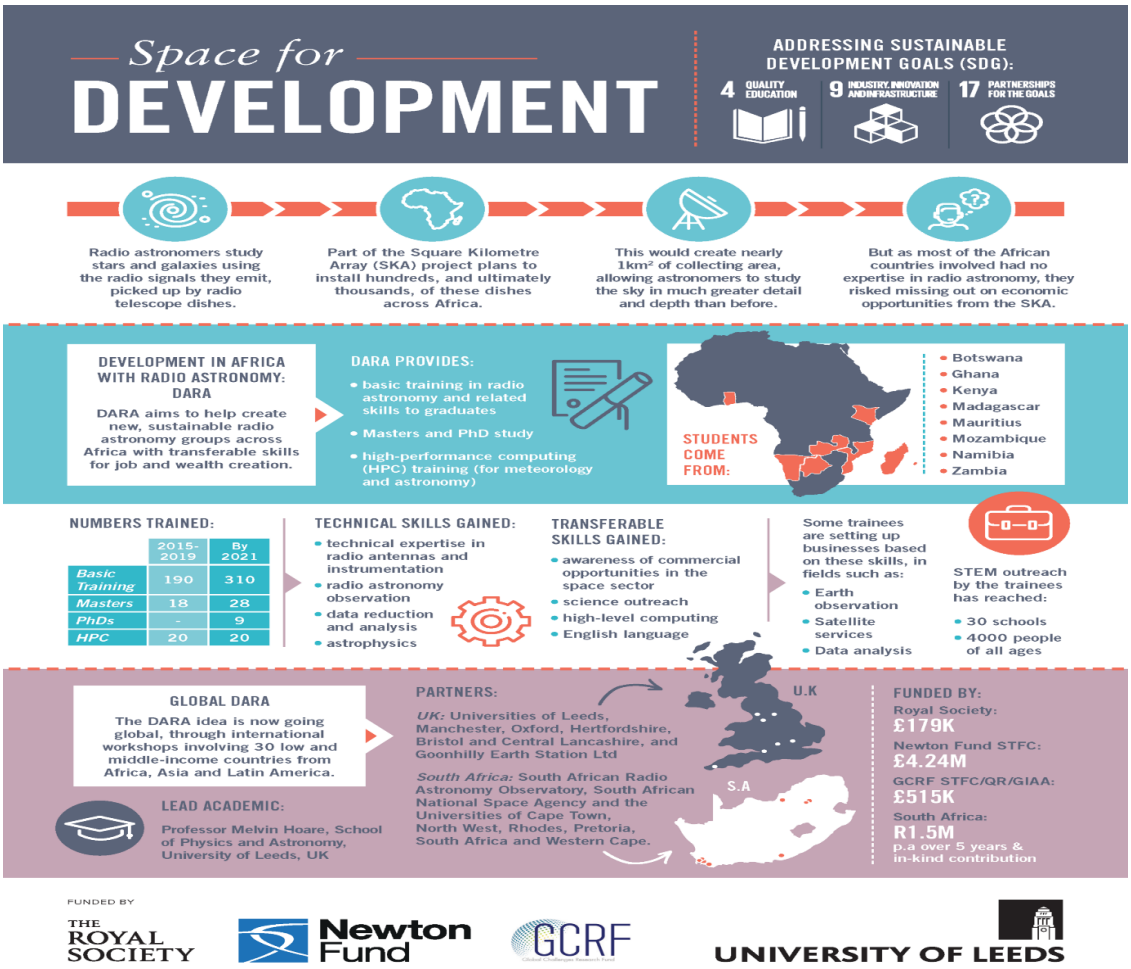

Figure 1.2: University of Leeds DARA Project Infographic. Source: University of Leeds, 2019

The DARA project is implemented in the eight African countries that constitute the SKA in Africa but the political context in which they operate needs exploration as well as some background and historical information which helps in understanding the rationale for participation. The next section moves on to give the political landscapes of Ghana and South Africa as the two countries currently at the forefront, as far as the set targets for the implementation of the project are concerned.

1.7 Political contexts of Ghana and South Africa

The preceding section has examined the evolution of the SKA infrastructure project and the associated human capital development programme (DARA) to its present state. However, it is important to understand the political context in which the project is implemented. The incorporation of scientific knowledge depends on the values and

beliefs already held by the society, political ideology and systems prevailing (Stanford Encyclopedia of Philosophy, 2019). The history of science, technology, and innovation in the SKA implementation countries is equally important in shaping the current situation. Reference is paid to Ghana's politics and science landscape. The discussion will also focus on South Africa as well since they are assuming leadership role of the project in Africa.

In 1957, Ghana became the first nation in Africa to gain independence from colonial rule (Gallagher, 2018). Nkrumah`s Pan-African ideology whose vision was to have a United States of Africa and policy of non-alignment were and continue to be the main pillars of Ghana`s foreign policy agenda in Africa and beyond as Nkrumah posited in 1963 cited in Sanusi and Adu-Gyamufi (Sanusi and Gyamfi, 2017: 599). However, the values of togetherness and one united Africa had challenges of foreign rule that left Africans with a 'crisis of conscience', a 'loss of identity' (Nkurumah, 1964 cited in Gallagher, 2018: 883). Not only did Ghana felt loss of identity but also had a feeling of emptiness, alienated, and lacked proper self-consciousness (ibid). The feelings amount to a struggle for recognition (Schaap, 2003) which most if not all African countries are experiencing in the International Relations (IR) discipline.

There is general ambiguity around Africa's position in the study of IR and international political hierarchy. The first level is that of Africa in a precarious position within the IR discipline pushed to the margins of some mainstream approaches and focus is on great powers, 'the states that make the most difference' as propounded by Waltz (Waltz, 1979: 73). Africa, therefore, "is IR's permanent 'other', serving to reproduce and confirm the superiority and hegemony of Western knowledge, epistemologies, and methodologies." (Abrahamsen, 2016: 126) On the second level marginalisation of Africa give rise to an unbridgeable divide between 'mainstream' IR and Africa, punctuated with hegemonic and exclusionary traits. Conceptually and theoretically, the argument is that 'western' origins and focus of IR implies Africa will always be a problematic 'other' in the discipline, at conflict with a western norm (Brown and Harman, 2013:1). At the same time Africa is increasingly becoming a significant player in IR, occupying a geographic space where major international events from colonial rule to resource competition to post-conditional aid dependency have played out (ibid). This precarious position of Africa in IR forms one of the arguments of this thesis on the quest by the continent for recognition and restoring the 'lost identity' and science

is viewed as one of the strategies in the process. Ghana plays a significant role in shaping the continental politics particularly the science policies adopted by the continent as subsequent paragraphs shall indicate.

The initial years of Ghana's independence and democratic progress were undermined by a series of coup d'états which retarded the country's economic and social development. Ghana traced back to democratic rule in 1992 (Abdulai and Crawford, 2010). Since 1992, the country has experienced a rapid growth in democracy and rule of law to an extent that it is envy for many, receiving international praise as an icon for other African nations in the Sub-Saharan Region (Langdon, 2011). Ghana witnessed four democratic experiments since her independence in 1957, with the current one starting on January 7, 1993. The democratic experiments have centred around two stable political parties. Ghana has always had a two-party national system during its often-interrupted democratic history (Austin, 1970; Chazan, 1983). The current 'fourth republic' political landscape in Ghana is comprised of two traditional political liberal New Patriotic Party (NPP) and the populist National Democratic Congress (NDC) with smaller parties of very insignificant membership rounding out the picture. The NDC and NPP have dominated the fourth republic elections and have taken turns to occupy office (Fobih, 2010).

A review of the evolution of ST&I policy in Ghana reveals three patterns: (i) the era of Ghana's First President, Kwame Nkrumah (1957-1966); (ii) the era immediately after Kwame Nkrumah (1966 to the 1990s); and (iii) the era of the 'new dawn,' begins in 2000 onwards (Amankwah-Amoah, 2016: 136). Each one of the epochs has its own impact on the evolution of science, technology, and innovation to present day Ghana. Padilla-Pèrez and Gaudin suggests that though there has been much interest in ST&I in developing countries, understanding of political upheavals lor changes and their impact on government policy is limited (Padilla-Pérez and Gaudin, 2014). In Africa there is a growing phenomenon of political cycles and development strategies where every new political order and development strategy unsettles the ST&I policy resulting in thinly spread effort and resources (Chataway *et al.*, 2019). This thesis pays attention to such political changes and how they influence the conduct of science.

At independence and few years after, referred to as the Nkrumah era Ghana recognised the importance of, and the need for, science and technology in the nation's

development process. In 1957 presenting himself to the legislative assembly Nkrumah said:

> Our whole educational system must be geared to producing a scientifically-technically minded people. Because of the limitations placed on us, we must produce, of necessity, a higher standard of technical education than is necessary in many of the most advanced countries of the Western world … I believe that one of the most important services which Ghana can perform for Africa is to devise a system of education based at its university level on concrete studies of the problems of the tropical world. The University will be the coordinating body for education research, and we hope that it will eventually be as- sociated with Research Institutes dealing with agriculture, biology, and the physical and chemical sciences which we hope to establish.(McWilliam and Kwamena-Poh, 1975: 94).

Nkrumah also has a notion that the challenges that the country was facing could be overcome by science led by Africans. He also acknowledged in his speech the limitations placed on the African people by colonial systems. This background information of Ghana at the dawn of its independence in 1957 gives an important insight into the core arguments of this thesis especially the decolonisation efforts, acknowledgement of limitations inherent in African scientific knowledge production and the quest for Africans to mould scientifically and technically minded people to solve development challenges.

The passing of the Research Act 21 of 1958 marked the establishment of key scientific institutions that included National Research Council now reconstituted into Council for Scientific and Industrial Research (CSIR) with 13 institutes (Amankwah-amoah, 2016: 137) , Ghana Academy of Learning in 1959, a learned society that transformed into Ghana's Academy of Sciences in 1961 (Quaye *et al.*, 2019a). In 1963 the National Research Council merged with the Academy and assumed responsibility for ten full-time research institutes and projects whose programmes were directly related to the nation's economic and social development (ibid).

The same year, 1963 during the foundation summit of the Organisation of African Unity (OAU), Nkrumah shared his vision on the potential of science, technology, and innovation in transforming Africa into a self-sustaining industrialised continent. Fast forward to 21st Century, Nkrumah's socio-political thought shaped much of the thinking

in the African Union's Agenda 2063 and science strategy. The African Union Science, Technology & Innovation Strategy for Africa (STISA-2024) prominently quotes Nkrumah's speech of the inaugural OAU summit in its vision statement as follows.

> We shall accumulate machinery and establish steel works, iron foundries and factories; we shall link the various states of our continent with communications; we shall astound the world with our hydroelectric power; we shall drain marshes and swamps, clear infested areas, feed the undernourished, and rid our people of parasites and disease. It is within the possibility of science and technology to make even the Sahara bloom into a vast field with verdant vegetation for agricultural and industrial developments. (Nkrumah, 24 May 1963 cited by African Union, 2015)

The vision statement by Nkrumah embodies the comprehensive plan for continental development in the context of decolonisation and self-governance (Sackeyfio-Lenoch, 2016: 252) but also heavily influenced by modernisation perspectives. Moreso, it was an outcry by Nkrumah to shape the postcolonial knowledge production and to give ambition to the African mind that impossibilities can be possible if an enquiring mind is wired towards overcoming development challenges. Earlier analysis of the failures of science for development during Nkrumah era is summarised by Cobern's statement that.

> accepting the tight, linear science –technology-economic development (STD) model squeezes out non-scientific ways of knowing and in doing so, creates for science (in its scientific form) a privileged status in society. As this occurs there is increasing pressure for other aspects of culture to conform to scientific thinking. Any areas of resistance come to be viewed as deficiencies because the areas of resistance impede the takeover by scientific rationality. (Cobern, 1998: 20-21)

The analysis by Cobern is crucial to the thesis in the sense that in as much as Nkrumah wanted development driven by Africans but its basis was and is still deeply immersed in the Global North modernisation and this forces the many other aspects of African culture to conform to this scientific way of looking at things.

In addition to the establishment of these institutions to pursue science and technology for national development, the era of Kwame Nkrumah also saw the establishment of the Ghana Atomic Energy Commission (GAEC) which hosts the GSSTI in early 1960s,

currently driving astronomy projects and educational institutions in Ghana (Brown-Acquaye, 2006). These strategic national institutions were established to support academic institutions established earlier. The universities were meant to supply manpower to advance the nation's pursuit of science and technology for economic development. Among the key universities established were the University of Science and Technology (now called Kwame Nkrumah University of Science and Technology [KNUST]) the University College of Science Education (now called University of Cape Coast). Despite the many institutions established during this era, there was no single coordinated policy on science and technology (Amankwah-Amoah, 2016). Legal instruments enacted were acting as proxy policy directions for science and technology at the time.

The second era from 1967-1979 of science and technology development in Ghana is comparable to the "dark ages" in Europe. The period was characterised by "seeds for 'destruction' and disruption of science and technology…" during (Amankwah-Amoah, 2016: 137). The policy direction of science and technology was largely dictated upon by the successive coups that happened after Nkrumah was toppled. The decades were punctuated with political instability, economic decline, and diversion of expenditure on research and government commitments to science towards politically driven projects that had nothing to do with science. General Acheampong's leadership as president from 1972–1978, is said to have lacked experience and vision that drove the country to stagnation in innovation and scientific development (ibid). The main goal of the regime was to control universities in terms of politics and ideology.

The third era of ST&I development in Ghana at the turn of the 21st Century because it was in 2000s that the country attempted to produce a coordinated policy on S&T. Under the leadership of John Kufour (2001–2009) and the New Patriotic Party, there was a retracing to some of the scientific and industrial principles outlined by the Nkrumah era in response to downward path and stagnation of R&D. The first coordinated policy of 2000, though it was not operationalised because it never made it to Cabinet, was reviewed in 2009 (MESTI, 2010). From this period, Ghana has had two S&T policies and at the time of the study the third policy drafted in 2017 was under cabinet review. The cabinet review wanted the policy to reflect developments in S&T with wide applications, such as innovations in ICT and internet applications as well as emerging technologies. SKA resonates well with the new thrust of emerging

technologies and innovations in ICT. Key challenges noted were lack of implementation plan, monitoring and evaluation of the policy, lack of funding, lack of political will by institutions and agencies who are meant to lead or collaborate in implementing programmes and projects, amongst others (Quaye *et al.*, 2019b).

The new dawn of ST&I policy places science and technology as the cornerstone of Ghana's national development agenda. Although the policy was before cabinet, it has served as a reference document in crafting Ghana' 7-year Co-ordinated Programmes of Economic and Social Development Policies, with a vision to establish a solid economy that generates opportunities for its people, inspires entrepreneurship, allows growth of existing businesses, and, resultantly, creates jobs, and increased economic productivity. Alongside the development of the ST&I policies over the years Ghana's ST&I system witnessed some key milestones that have a potential to transform the whole outlook of the R&D landscape of the country.

The key milestones include, an ST&I policy review conducted jointly by development partners UNCTAD, World Bank, and Ghana CSIR-STEPRI in 2009; production of a national ST&I outlook in 2010 and 2012; national ST&I baseline study in 2016 to establish key indicators. The most important development was the establishment of the ST&I Advisory Council in the Presidency (Presidential Advisory Council on Science, Technology, and Innovation [PACSTI] in 2018 (Quaye *et al.*, 2019a). The PACSTI is a council comprised of eminent Ghanaian scientists picked from diverse fields, charged to advise the President on ST&I matters and keeping him posted on current advances in ST&I, and relevant applications to aid national development (Ghana Communications Bureau, 2019). The Advisory Council emphasises collaboration among various sectors both in government and the private sector. There are current efforts to establish the National Innovation/Incubation Programme and of National Research Fund, all key institutions for implementation of the ST&I policy.

South Africa on the other hand is arguably among the last countries to gain independence from colonial rule after being strongly supported by regional and international actors (Clarke and Bassett, 2016). Post-apartheid, immediately after gaining independence, South Africa's foreign policy was pro-African driven by nationalistic views with the main goal to wade off the burden of colonialism and the key figure driving this policy was Thabo Mbeki, the successor to Nelson Mandela (Habib, 2009). South Africa's foreign policy is a difficult one to understand because at

some point it is combative to the West, and other times it strategically positions itself to gain from the international institutions (ibid). However, the basic tenets of South Africa's foreign policy were summarised by Lipton that: South Africa is anti-racism and against imperialism and express solidarity with countries of the South to secure economic development, and overcome negative images of, Africans; aspires to play a leading role of promoting ambitious plans for African unity and an African Renaissance through establishing and strengthening continental bodies like the African Union (AU), the Southern African Development Community (SADC), the New Partnership for African Development (NEPAD) now the AU's development agency; strongly supports state sovereignty and multilateralism, but emphasise that external interventions in sovereign states be done under the aegis of the UN or regional institutions like AU or SADC (Lipton, 2009: 332-333).

These three main pillars of the South African foreign policy have put the country in an ambivalent position among some African countries. South Africa is viewed as a pawn of imperialism especially among countries which also aspire to play leading roles in Africa, such as Nigeria, Angola, and Libya (ibid). To support their point they have often paid reference to South Africa's inclusion among an insignificant number of countries from the Global South invited to meetings such as G8 annual meetings (Lipton, 2009). This hegemony by South Africa agitates weaker African states. More often, South Africa has performed a balancing act between countries in the Global South and Global North. The aggressive transformational and developmental foreign strategy pursued by Mbeki had a goal of creating equity and equality on North-South relations (Landsberg, 2010). Landsberg further argues that Mbeki's aim is to change the global economic order of power countering the hegemony of the North trading blocs and extract from them financial resources for the development of the Global South. With this background of South African foreign policy, its science, technology, and innovation policies mirror those cardinal points discussed.

The history of science, technology and innovation can be divided into pre-independent and post-independence time periods. During apartheid era, science and technology was in the interest of the colonisers, racial in nature and was tilted towards the defence industry. The change of political configuration represented a shift from pro-white system of discrimination even at the level of the science, technology, and innovation (ST&I) system to a democratic black majority government (Marais, Pienaar and

Plalliling, 2010: 83). As a young democracy coming from apartheid system, South Africa wanted a delightful story to tell the world. South Africa ‘s foreign policy ideals of playing a leading role in African Renaissance, astronomy as a high-end science would be one of the flagship projects with wider continental and global influence.

The motivation for South Africa’s participation in SKA was largely influenced by the Department for Science and Technology (DST) ‘s 1996 White Paper on S&T. The White Paper identified astronomy as a strategic subject in South Africa’s science, technology, and innovation (ST&I) sector (Department of Science and Technology 1996). South Africa had “good access to Southern skies” and thus a natural geographic advantage for astronomy (Department of Science and Technology, 2002). In addition, DST perceived astronomy as a fundamental science which could enhance national skills and capacity-building and by extension contribute to the development of a South African knowledge society.. Science and technological innovations were largely centred on defence during apartheid, so radio astronomy was another way of diversifying the economy.

The bid to host the SKA by South Africa was an act of ambition because in the early 2000s, there was no capacity in astronomy. The majority of the SKA steering committee members were not convinced of South Africa’s scientific and technical abilities (Reich 2022 cited in Rüland, 2022). Global North SKA partners were pessimistic about Africa participating in such a project that required already inbuilt capacity in astronomy. The story of South Africa is best described as one of coming from an ‘afro pessimism to afro-empowerment’ where as a country later managed to build a remarkable pool of astronomers and capacity to host the SKA (Rüland, 2022). The co-option of the other eight participating countries including Ghana can be viewed as an act of paying gratitude to fellow African countries who stood by South Africa during difficult times in its struggle for independence. South Africa’s leading role and as a pacesetter forming institutions for Africa’s development, international advocacy for treatment of the Global South equally and international governance reforms (Lipton, 2009) gives the confidence that it would want to see all the African participating countries in the SKA prosper. It is against this context and backdrop that the thesis explores the political significance of the SKA project in the African continent using Ghana as a case study.

1.8 Research questions

The preceding section about the background to SKA, DARA and their corresponding debates focused on claims to boost development of participating nations versus the social, political, and economic realities of those nations. The main research question or central research problem is What are the political dynamics of big science initiatives in Africa?

The sub-set of questions is as follows:

- How do theoretical and power dynamics shape understandings of the science-development nexus?
- What are the underlying assumptions of SKA and DARA investments for development in Africa?
- What is the role of SKA and DARA in bridging the knowledge and power gap between the Global North and Global South?
- How do the SKA and the DARA projects address issues of race, class, power, and inequality in their implementation?
- What are the implications of large-scale science projects on the ontological security of African societies?

The discursive power in the discourse on the broader societal impact of astronomy beyond the scientific agenda by SKA and DARA project shapes the perceptions about the relationship between ST&I and development. The thesis gives a critical evaluation of this technology, development, and power discourse to assess the impact of SKA and DARA projects in Africa. The discourse also illuminates 'big science' and social sciences intersections or lack thereof in the design of projects in the developing world. This gap is hereafter referred to as the 'missing social science ontologies.' Missing social science ontologies in this thesis refers to the earlier on alluded deeply rooted power structures that reproduce class, racial differentials, contextual understanding of development and other forms of inequality.

The focus for this study is influenced by Ferguson's Antipolitics Machine. Depoliticisation can be a management strategy in situations where one wants to get practical issues organised without complications (Nuijten, 2004: 53). At the same time, it can be detrimental when it is used to deny existing power relations that will fundamentally affect the implementation of the developmental programme (ibid: 54). Big science projects have emerged as sources of power and influence in the geopolitical arena. Legrand and Stone contend that scientific partnerships have

generated a distinct and new transnational political dynamic discernible in research networks that operate as mechanisms through which science become entwined with governance ambitions of international organisations and foreign policy concerns of governments (Legrand Timothy and Stone Diane, 2018: 2). Ontological security concept also buttresses this hidden source of scientific power which projects in big science normally pay little attention to.

Researchers within the field of science and technology studies (STS) state that science is not as pure as it claims to be and that what makes science important is that it is messy, impure, and political (Lidskog, 2015: 1). Ferguson argues that the agricultural intervention project in Lesotho was not a machine for eliminating poverty but was meant to reinforce and expand the exercise of bureaucratic state power that incidentally took 'poverty' as an entry point (Ferguson, 1990: 255). This thesis hypothesises that the intentional blueprint for "development" and reduction of poverty to a technical problem in need of technical solutions, big science projects end up performing extremely sensitive political operations involving institutional state power under the neutral technical mission cover which no one can object to.

Development is characterised by continuously shifting programmes and every new concept or model is presented as panacea, the new 'magic charm' that will radically change the world (Benda-Beckmann, 1993:116-34). However, results of development interventions do not always bring what was expected most of the time but new programming and models are presented in a continuous flow with high hopes described as a "hope-generating machine" (Nuijten, 2004: 52). Nuijten further explains that the 'hope-generating machine' like Ferguson's anti-politics machine, is related to the bureaucratic system in which most of the time limitations and failure of past programmes are admitted together with projects that indicate the 'new way forward' creating a never-ending cycle of high hopes and expectations. The hope-generating machine suggests that the 'missing factor' has been found and the desired knowledge is being produced and will make a difference. The SKA project in Africa described the benefits to society 'beyond science' couched in a typical 'hope-generating' fashion.

1.9 Contributions of the thesis

The thesis contributes to research on the political questions in big science infrastructure projects and accompanying human capital development activities.

Mainstream literature has focused on the relationship between investment in ST&I and development in Africa. The politics of science, knowledge production and language used has been invisibilised by the discourse of international development that underscores assistance by the developed nations to Africa for catch up. The study critically evaluates the projected developmental impact of the SKA including how and to what extent such projects contribute if at all to sustainable economic development and the expansion of African scientific expertise. The study draws from different disciplines to understand space science and how it shapes perceptions in the development discourses. However, it is important to highlight that what is considered as interdisciplinary is widely contested Interdisciplinarity is often described as the interaction across and between disciplines (Luri *et al.*, 2018). Crucially, the interaction is not aligned towards synthesis or a disappearance of disciplines. But interdisciplinarity comes through interferences between disciplines and other forms of knowledge (ibid). The thesis engages literature from international development, IR, science, and technology studies. The supervision of the project also straddled on politics and physics. The value brought by this interdisciplinary approach is that the complexity of development through science cannot be simply explained by one discipline but entails the researcher being conscious of multiple views out there. Interdisciplinary approach was adopted to capture the complexities of analysing the relationship between big science and development. The pulling of different disciplines is a way of opening and showing that disciplines can communicate and work together to answer research questions.

Theoretical contribution

The thesis makes theoretical contributions by analysing the power dynamics and theoretical frameworks that shape the science-development nexus. It also provides insights into the role of SKA and DARA in bridging or widening the knowledge and power gap between the Global North and Global South, and how these projects address issues of race, class, power, and inequality. Additionally, the thesis develops a critical framework for understanding the implications of large-scale science projects on the ontological security of African societies.

The thesis gives an analytical approach intersecting the disciplines of international development, international relations, and science technology studies. While scientists

have depoliticised science, the thesis ‘politicises’ the science projects in a positive way. The drive towards politicisation of scientific endeavours draws on Ferguson’s anti-politics machine, an anthropological approach to analysing development endeavours in developing countries. The development concept is generally construed as necessary and cast in a good way and that the Global North must institute it, to impoverished Global South (Ferguson, 1990).

The thesis traces the development discourse in Africa to understand the positionality of space science through a five-point story which begins with construction of African story of a place that is devoid of scientific expertise and lacks technology that justifies technical assistance and capacity building through projects such as SKA. Secondly, the African reality is that the continent has always been scientific with earliest forms of astronomy found in Egypt (Homer and Shewring, 2008). Iconic leaders such as Nkrumah already believed in the power of science to transform Africa and was visionary to place science as a strategic pillar in the founding stages of OAU in 1963 (Nkrumah, 1963). Therefore, science is not novel to Africa and should approach the capacity building initiatives with a view of Africans as co-contributors to knowledge production (Mavhunga, 2017). Thirdly, the African reality is inverted, leaving out the science potential inherent in the African societies as noted by Homer in Egypt. Effects of colonial education systems, neoliberal research funding policies and portrayal of Africa as recipients of knowledge and not as generators of knowledge, justifies assistance. Fourth, by leaving out all these power asymmetries, the discourse depoliticise science. Fifth, the depoliticization of science has effects of hope-generating (Nuijten, 2004) where development interventions may not deliver the projected outcome but are used to set the agenda for the next intervention which Ferguson referred to as antipolitics machine (Ferguson, 1990).

Implementation of development projects such as SKA in Africa leave unacknowledged or unintended effects in literature. These unacknowledged effects include the consolidation of bureaucratic state power, building ontological security, that is confidence and security of self (Mitzen, 2006; Steele, 2007), renegotiation of position in international political hierarchy, translation of political realities of power imbalances in knowledge production and other asymmetries into "technical" problems awaiting technical solutions by development agencies and experts. This project provided an important opportunity to advance the understanding of ontological security in the IR

discipline and unintended consequences of big science projects. Questions have been raised on ontological security as a concept in its application to explain state behaviour when it was originally meant to explain individual behaviour thus reducing state to individuals with psyches and emotions (Ned Lebow, 2016). This thesis makes a contribution to research on ontological security by demonstrating that it can be applied at three scales from individual, state/corporate, and transboundary levels. Scientists and astronomers are building their ontological security around radio astronomy, and that accumulates to the state as well as beyond the state to transboundary at continental level in Africa. Therefore, Mitzen and others who are proponents of OS, are correct in applying the concept at state levels.

At the intersection of international development and IR, the thesis politicise the development discourse flaunted in big science. The thesis proposes a conceptual framework that combines ideational power, ontological security, and capability (through science) in chapter six (Figure 6) to explain how Africa is negotiating a new identity in international politics. Ideational power is defined as the capacity of actors (whether individual or collective) to influence other actors' normative and cognitive beliefs through the use of ideational elements such as discourse, narratives and identities (Carstensen and Schmidt, 2015: 318). This conceptual framework helps to explain the politics embedded in astronomy as big science in Africa's development discourse. It also contributes to the IR debates on security studies, that besides the need for physical security, states also need a stable identity and favourable outlook which is brought by ontological security.

It is the political comprehensibility of these effects, along with the discourses that produces them, that this thesis illuminates through a detailed case study of the dealings of the SKA in Africa with reference to Ghana and by extension South Africa. The thesis utilises James Ferguson's anti-politics machine and pulls together an interdisciplinary approach that draws from global development, international relations, science, and technology studies to show that these theoretical approaches can communicate with each other. The approach reveals how the development discourse in big science projects conceals the historical and political realities of the intended beneficiaries in Africa. Such an interdisciplinary approach has not yet gained currency in the context of space science and in Africa contributing theoretically to the analysis and evaluation of big science projects.

Empirical contribution

Empirically, the thesis provides an in-depth analysis of the political dynamics of big science initiatives in Africa, with a focus on SKA and DARA. It examines the policies, institutions, and actors involved in their implementation, and contribute to the understanding of how these investments for development are perceived and understood by various stakeholders. Furthermore, the thesis examines the social, cultural, and political impacts of large-scale science projects on national and at continental level in Africa shedding light on their implications for ontological security. Overall, the thesis provides valuable theoretical and empirical insights into the political dynamics of big science initiatives in Africa, and their impact on development and society.

The originality of the thesis is anchored on its empirical approach. Research for the thesis was done during the Covid-19 pandemic. Under normal circumstances, qualitative research highly depends on the participant-researcher relationship and proximity between the participant and the researcher (Torrentira, 2020: 82). The thesis had to employ strategies of building rapport virtually via emails and professional social platforms such as LinkedIn, knocking the virtual doors and attending strategic meetings within the space science and radio astronomy circles. The use of these remote and online methods to perform the same function as the traditional ways is cost effective and has a potential to revolutionise the conduct of qualitative research.

The study conducted a total of forty-three (43) interviews with key informants and individual scientists who participated in the DARA and SKA human capital development projects, observed high level meetings of the projects as well as an extensive secondary literature review. The main advantage of key informant interviews, observing high level meetings, and interacting with scientists involved in the projects is gathering of informed perspectives about how they link big science and development, assumptions, contextual understanding of the thinking behind and ultimately how that relates addressing of country specific challenges such as poverty, unemployment, and better social amenities. Most importantly, the thesis shows how development challenges are reduced to technical problems that can be fixed with a technical solution in the form of training. Epistemological foundations of such linkages

are traced to the modernisation theories of development and anticipation of trickle down that if resources in research and development are concentrated in few key areas, the proceeds will eventually benefit the whole economy and uplift the general living conditions of people, thus development. This view has been challenged in this thesis because the link between science, technology and innovation and development is not straightforward. Power asymmetries which the thesis reveals in the implementation of big science projects which are thrown out of the generic development discourses prove to be fundamental in determining the impact of such investments in science. This empirical contribution adds to existing literature on the critique of development approaches that ignores such profound structural issues of power, dependency, and historical experiences of the African continent.

Main themes and chapter overview

The organisation of the chapters is along the main themes coming from the broader discourse and thematic analysis. The thesis is organised into eight chapters with the main themes and summary arguments for each chapter as follows:

Chapter 1: Introduction

The first chapter is the introduction that gives the rationale of the study, the main problem to be addressed, research questions, objectives, and hypotheses. The chapter sets the scene for a subsequent captivating critical analysis about science-development nexus and its political implications. The introductory chapter also gives the background information about the operations of SKA and DARA projects in Africa. Ghana is used as the case study; its science and technology system is located within its national and continental wide political context. It should be noted that throughout the thesis there will be a deliberate reference to South Africa because they are the lead country and focal point of contact for the SKA project in Africa. They have more influence on what is happening in Ghana in as far as the SKA project is concerned. The multiple core claims from SKA and DARA projects that ranges from knowledge transfer, strengthening STEM in Africa, preparation for the 4IR and development forms part of the preliminary themes in the chapter. The concept of power runs through all the chapters of this thesis and informs all the questions as well as the empirical interactions.

Chapter 2: Is big science a silver bullet to development?

The second chapter examines the literature on science and development focusing on Africa. It explores the broader assumptions underpinning investments in big science and what they can tell us about development strategies and the Sustainable Development Goals (SDGs) framework in the Global South. The chapter also lays the theoretical foundations and conceptual framework of this thesis problematising the depoliticisation language used by the proponents of big science as a tool for development in Africa. The main argument of the chapter draws inspiration from Ferguson's anti-politics machine, that the development discourse advanced in big science projects reduce challenges in the developing world to technical problems that can be solved by building technical capacity.

However, this discourse suspends the deep structural political issues of power imbalances in terms of who defines the 'development' process itself, coloniality of knowledge production and material challenges leading to dependency. Moreover, the fact that development has different meanings and is multifaceted gives a challenge to the proposals of technical solutions. The chapter also set the scene on the coproduction of science and politics scaffolding the main argument of this thesis that the underplayed ontological security and power derived from big science is the one which appeals more to states than the physical benefits enumerated by scientists. This analysis has potential contribution of adding literature and knowledge on the nuanced intersection of science and technology studies, development, and the discipline of International Relations (IR).

Chapter 3: Methodology

The third chapter lays out the methods employed by this thesis to arrive at the conclusions made at the end. The greater part of the fieldwork for the study was conducted during the extra ordinary time of Covid 19 pandemic and the whole plan for face-to-face interaction with research participants shifted to virtual platforms. The migration from physical interaction to virtual mode of data collection due to social distancing measures put in place and the experiences contribute to the existing knowledge and methods about conducting qualitative data collection under restrictive conditions.

The type of questions answered by the thesis, as well as the literature, theoretical and conceptual frameworks presented in chapter two informs the methodology adopted in this study. The thesis uses the constructivism research paradigm which entailed the adoption of qualitative methods and broader methodological approach of discourse analysis. Discourse in this thesis is concerned with firstly, meaning making as an element to explain the language used by scientists and decision makers in propagating big science projects; secondly, the language associated with the development discourse; and thirdly a way of construing a new world associated with big science (Fairclough, 2013). Discourse analysis brings into this study, the critical lens of social analysis into language of development in Africa through science and contributes to understanding relations between discourse and broader structural issues of power, ideologies, institutions, and identities. Discourse analysis, i.e., interpretation of the text and language used during interviews, speeches, conversations and meetings about the SKA and DARA projects informed the main themes. Thematic analysis was both computer-assisted using NVivo version 12 and interpretive using theory to consolidate new knowledge coming out of the research.

Chapter 4: Big science assumptions and perceptions about development

In chapter four of the thesis, the specific assumptions underlying the SKA and DARA projects in Africa are examined. The overarching assumption is that development is a meaningful term, but the diversity in the meaning of the development concept shows the complexity of linking and attributing certain actions as part of the concept. However, the thesis uses discourse analysis to identify specific assumptions linked to astronomy and space science, which include: (1) Africa's development challenges are technical and can be fixed by big science infrastructure projects; (2) Scientific knowledge distributed to individuals without significant parallel investments into the socioeconomic and political structures of the innovation system will translate into development; (3) Scientists understand the social needs of the countries of operation; (4) Innovation systems of the countries of implementation are coherent and have high absorptive capacity for knowledge generated.

The chapter examines these assumptions and shows that they reflect modernisation and neoliberal development pathways mimicked in the African context where space

science is among the top priorities in national and regional development blueprints. The analysis reveals that the SKA and DARA projects are situated within a particular worldview that links science and technology to economic growth and development and assumes that development can be driven by scientific knowledge and technological innovation. Additionally, the chapter enumerates the achievements recorded by the SKA and DARA at the project level as well as from the implementers' perspective. It highlights the positive impacts of the projects, such as providing employment opportunities and building scientific and technical capacity in Africa. However, the chapter also raises critical questions about the underlying assumptions and the long-term sustainability of these projects in addressing the complex challenges of development in Africa.

Overall, the chapter provides a detailed analysis of the assumptions underlying the SKA and DARA projects in Africa and sheds light on the complex relationships between science, technology, and development in the African context.

Chapter 5: Power, knowledge production, and dependency in big science

Chapter five critically analyses the contribution of SKA and DARA projects in narrowing the knowledge and power divide between the Global North and South. The chapter examine the idea that big science like astronomy leads to newly trained scholars and new lines of enquiry that are African led as opposed to mere integration into European and global science. Chapter five engages with the main argument from the decolonial perspective inspired by Africanists like Ndlovu-Gatsheni that if the colonial legacies, power imbalances between Global North and South in decision making and research agenda setting, global structural issues that privilege certain epistemologies in knowledge production, material and funding resources skewed towards the Global North are not addressed, it is difficult to close the divide. Projects like DARA and SKA find themselves entangled into these structural issues despite their ‘good’ intention to build capacity in science. Astronomy has a colonial legacy in Africa where access to such elite subjects was along racial lines (Dubow, 2019). Critical Race Theory (CTR) argues that as long as resource allocation in knowledge production is still biased towards certain groups the rationale is that they are dominant and hold power; therefore, global resource allocation is structured to perpetuate the

status quo (López, 2006; Ladson-Billings, 2009; Pulliam, 2017) (O'Hara, 2022). This chapter further argues that if the status quo is maintained, the gap between the Global North and Global South further drifts and reinforces dependency. In summary, chapter five brings to surface the concealed aspects in the discourse of development through big science in Africa.

Chapter 6: Building ontological security around the discourse of science.

Chapter six advances the theoretical understanding of ontological security concept in the IR discipline and illuminates big science as a subfield that requires more empirical studies due to the role played by science and technology in contemporary politic. Africa is viewed as 'peripheral and uninteresting' in IR (Gallagher, 2016). With that position in the political hierarchy, Africa seeks to change that identity. This chapter using IR literature from leading scholars on ontological security (Giddens, Lang, Mitzen) ontological security is built around the discourse of big science at three levels: individual, national/corporate, and transboundary.

While the development discourse by scientists and decision makers at policy level depoliticises the big science astronomy projects in Africa, actors (students participating in SKA and DARA, national governments, and regional bodies) in the African continent are building confidence and tracing back biographical narrative of a continent that has the capacity to rise into the same league with the advanced economies. The chapter proposes a conceptual framework that explores the interaction of ideation power, ontological security, and capability to negotiate Africa's new identity. Since Africa feels insecure with its current identity, it always seeks ideas that can help to trace its biographical narrative and stabilise its ontological security. Capability is also a key factor in negotiating this identity because there should be a direct proportional relationship between the state's capabilities and the identity sought. In this case, Africa wants recognition as a continent leading in science and a force to reckon with in knowledge production so big science projects such as SKA are regarded as status enhancing endeavours.

Chapter 7: Pursuit of big science as a source of power

Chapter seven overlaps with the preceding chapter and focuses on how power is then constructed and reproduced around the discourse of big science in SKA and DARA projects. The chapter explores the co-production and co-existence of science and politics in the implementation of big science. The chapter argues that big science is not just for the sake of knowledge production, but it pervades the politics of modernity. This argument rides on science and technology studies (STS) literature on co-production where scientific knowledge is 'incorporated into identities, institutions, discourses, and representations' (Jasanoff, 2004, p. 275).

The chapter begins with an overview of different forms of power paying particular attention to Lukes's three dimensions of power and how it plays out in big science. The chapter proceeds by looking at Weiss's patterns on how science and technology can influence international relations (Weiss, 2015). The key trends that are emanating from space science such as commercialisation, democratisation, and militarisation of space poses significant challenges to the governance of space. The historical analysis of the Space Race is considered especially in view of these political entanglements of science and how astronomy throughout the 20th and 21st century has been used to demonstrate power. The current space race has new entrants like Africa who are now searching for a position of influence in global governance of space. The chapter also deals with the controversy which currently surrounds the question of whether elites of the global South and 'rising powers' genuinely have the intention to challenge the dominant structures of global capitalist development, or seek to support and reproduce these structures, while altering their global position in the system and enhancing their influence within the existing structures (Gray and Gills, 2016: 559). The chapter tries to partially address this controversy.

Chapter 8: Conclusion : Advancing in-depth knowledge imbedded in big science.

Chapter eight explores the implications of all the established findings of the thesis and synthesise them into theoretical and general conclusions. The study advances an in-depth knowledge about the intricacies of big science projects and their relations to development and power. The thesis argues throughout the chapters that the political issues taken out in the discourse of science and development through anti-politics are important determinants of the success of big science projects and achievement of projected impacts. The thesis demonstrates that radio astronomy and space science

in the African development trajectory has its epistemological basis in the assumptions derived from modernisation and neoliberal perspectives that underpin the science-development nexus. The chapter summarise the core arguments, gives the core contributions of the thesis, and concludes that the ontological position that building capacity in science, technology and innovation impulsively lead to development will not improve Africa's development status and position in the political hierarchy unless power imbalances perpetuating dependencies within the global knowledge production architecture are addressed. The thesis proposes ways of expanding the research in context specific areas and make suggestions for further studies in big science as a sub- field of IR.

Chapter 2
Is Big Science a Silver Bullet to Development?

2.1 Introduction

This chapter problematises the language used by the proponents of big science as a tool for development in Africa. Behind the simplistic and fixed view of theoretical framings of ST&I for development in Africa is an underlying assumption that science and innovation automatically represent development, without asking who is doing the science or innovating, for whom and what, and under what circumstances (Zheng and Yu, 2016). This chapter argues against this understanding of science as a 'silver bullet to development' and a technical fix, but views science as an assemblage that is embedded in ideologies, social norms, and power structures. The chapter contributes to this debate by tracing the development discourse like that of development experts by Ferguson (1990) in Lesotho beginning with construction of the African development position that justifies technical assistance, the discounted African reality, the inverted African reality, depoliticisation of science and non-fulfilment of development as a way of setting agenda for next development project. This five-point story outlines the "acceptable model of development for Africa in the eyes of those in the Global North whereby African economies are adjusted and aligned to the imperatives and demands of the international division of labour" (Ndlovu-Gatsheni, 2018: 31).

The relationship between space science and the context in which it is implemented has attracted a few studies conducted so far (Wild, 2017; Gastrow and Oppelt, 2018; Walker and Chinigò, 2018a; Dubow, 2019; Walker, Chinigò and Dubow, 2019). However, there is whole lot of literature on the relationship between science and development in Africa (Kahn, 2022; Ferguson, 1990; Mugabe, 2011; Smith, 2009). The ST&I and development connection is not linear but a complex one, dynamic and often influenced by the political forces and power structures at play in the global, regional, and national innovation systems (Chataway et al., 2007).

The main assumption that there is a straightforward progression from putting up big science infrastructure, scientific research collaboration for knowledge production to innovation i.e., transformation into modern technologies and development (in its

various forms) is problematic. The creation of scientific knowledge for development through big science infrastructures is bound to the intricate social, economic, and political institutions, practices and norms that sustain such institutions (Timmermann, 2014). Building on that argument, this chapter sets the scene on the coproduction of politics and science and scaffolds the main argument of this thesis that the underplayed ontological security derived from big science is the one which appeals more to policy makers than the 'physical and tangible' benefits of research capacity building in STEM subjects and knowledge production for development. In the African context such analysis has hardly been explored and this thesis potentially contributes to this body of literature and knowledge on the nuanced intersection of science, technology, development, and politics.

The chapter is organised as follows to untangle the science-development nexus. The first section begins by giving an overview of development theories underpinning science, its connections to development and role of international institutions and power in prescribing development driven by science. The second section of the chapter explores how Global North theoretical paradigms of development influence assumptions on science and development. The third section critiques the mainstream development theories, from modernisation to neoliberalism and bring together the insights of dependency theory and from post development which challenge the Western development templates of science as the sole tool for development. This section is also a precursor to the chapter that comes later in the thesis which deals with how the knowledge around science is produced, who controls that knowledge, and how that reinforces pre-existing dependant or unequal power relations in the global system. The fourth section introduces the discursive power of science, technology, and innovation in development. The concept of discursive power as developed by Foucault is an attempt to understand the relationship between language, social institutions, subjectivity, and power.

Post-development scholars such as Escobar and Ferguson inspired by Foucault's ideas are drawn into this analysis of discourse and discursive power of science using evidence from the flagship astronomy projects in Africa. Special focus will be given to the classical analysis of the development discourse in the Global South by Ferguson's main argument that "by uncompromisingly reducing poverty to a technical problem, and by promising technical solutions to the sufferings of the powerless and oppressed

people, the hegemonic problematic of ‘development’ is the principle means through which the question of poverty is depoliticised in the world today” (Ferguson, 1990: 256).

The chapter concludes that the co-option of development in big science is an extension of hegemonic power by the Global North by classifying the Global South as undeveloped through the absence of technical capability and needs assistance. Such classification further alienates the Global South especially Africa from its realities, geographic advantages, social, cultural, and historical contexts. Focusing on human capital development alone without paying attention to the macro-environment may not yield the desired outcomes. However, the failure to achieve the desired developmental outcomes can have unintended outcomes which can work in favour of states such as ontological security and consolidation of bureaucratic power. These concepts will be explored and dealt with in subsequent chapters.

2.2 Modernisation Theory

Modernisation theory present development as a homogenous evolutionary route followed by all societies from primitive to modern forms (Chirot and Hall, 1982; Bradshaw, 1987; Escobar, 1995; Shrum, 2000). The major assumptions of modernisation theory are that; development is a phased process as suggested by Rostow. Modernisation is based on five main phases of development which are: traditional society, precondition for take-off, the take-off process, drive to maturity and a high mass consumption society (Rostow, 1960: 4-16). As a homogenising concept modernisation produces tendencies towards convergence among societies. maintains that patterns of modernisation are such that the more modernised societies become, the more they resemble one another (Levy jr., 1967: 207).

Developing nations emulate the political systems, economics, and leadership of Europe and America (Tipps, 1973: 14). As an irreversible process, modernisation assumes that once third world countries encounter the West, there is less probability to resist the impetus towards modernisation (Reyes, 2001: 2). Applying the theory to developing nations, modernisation regards African societies as witnessing a process of being modern rational entities where efficiency and scientific logic replace traditional values and belief systems (Chazan *et al.*, 1999). Modernisation as a progressive

process has a capacity to deal with the function of national identity, legitimacy, penetration, participation, and distribution than traditional political systems (Reyes, 2001: 2-3). The theory focuses on internal sources of socioeconomic development for instance formal education, market-driven economy, democratic and secular political systems (Ynalvez and Shrum, 2015). External sources of economic development and social change are not totally ruled out (Jenkins and Scanlan, 2001) but among the external forces, science is regarded as exceptional as it benefits developing countries through knowledge and technology transfer from advanced economies (Shrum, 2000). Development is viewed as simply a question of knowledge and technology transfer that is unproblematic and straightforward, context free, and does not affect existing cultural and social settings in developing countries (Herkenrath and Bornschier, 2003). Modernisation seems to overlook the fact that much of the knowledge and technology required for national development and competitiveness is within the domain of proprietary knowledge production often controlled by developed countries (Ynalvez and Shrum, 2015:151).

Lewis contend that modernisation is premised on the ‘trickle-down effect’ which theoretically envisages the effects of investment in a few sectors to spread through the economy at all levels of the population creating a self-sustaining economic growth cycle and reinforcing political institutions (Lewis, 1980; Lewis, Wood and Gregory, 1996). Short-term worsening of income inequalities is a necessary transition to long term growth and democracy. However, in contrast real wages and incomes of the majority have stagnated and regional inequalities have increased. Instead of strengthening democracy, development programmes based on the 'trickle-down' paradigm synonymous with modernisation have contributed to social unrest and upheavals (ibid).

Modernisation has been criticised on the basis that development is not necessarily unidirectional, like Rostow’s proposed phases for example (Reyes, 2001: 4). The theory also shows one possible model of development with the United States as an example, but there have been development advances in other nations such as Taiwan and South Korea, which had admittedly occurred within their current development levels under strong authoritarian regimes (Killick, 1997: 45-56). Another critique of modernisation is with regards to the need to eliminate traditional values. Redfield argues that third world countries do not possess a homogenous set of traditional

values; their value systems are highly heterogeneous (Redfield, 1967: 35-43). Reyes gave a critical analysis of the fact that traditional and modern values are not necessarily always mutually exclusive with China as an example. China, despite its advances in economic development, continues to operate on traditional values(Reyes, 2001). Linked to the modernisation theory is neoliberalism or neo-institutional theory which explains development agendas informed by science in developing countries described in the next part of this section.

2.3 Neoliberalism/ Neo-institutional Theory

The period between 1980 to the 1990s was characterised by neoliberalism as continuation of western modernisation approach to development with a focus on the market, where governments were encouraged to retreat from direct involvement in economic activities and considering grassroots approaches, local context and indigenous knowledge, gender, and development (Willis, 2011: 28). Ferguson describes neoliberalism as a macroeconomic doctrine with key elements of valorisation (stabilisation of prices) of private enterprise and suspicion of the state, “free market fetishism” and the advocacy of tariff elimination, currency deregulation and deployment of enterprise models that would allow the state to be ‘run like a business’ (Ferguson, 2010: 170). In this context, neoliberalism is described as a depoliticised and technocratic policy agenda. Neoliberalism also referred to as Neoinstitutional Theory in this thesis, though in some literature they are often separated the former being the umbrella term and the later focused more on analysis of international institutions. Neoinstitutional theory endeavours to explain the urge by developing countries’ adoption of scientific approaches to development regardless of the unpredictable consequences.

The Neoinstitutional theory analyses the role of international economic and financial institutions such as the World Bank, IMF, UNESCO, and other multilateral organisations in espousing science and deploying the rhetoric that it is a core instrument for development (Drori, 2003). Western development experts played a significant part in advancing the universality of science as a vehicle for national development. Technical assistance programs, monetary lending policies of international financial institutions, and international policy making propagate this

science-development discourse and transmission is done through Western education systems (Schofer, Ramirez and Meyer, 2000). The processes of professionalisation and institutionalisation strengthened the faith in science as an instrument for development (Escobar, 1995; Schofer, 2004). Professionalisation is the process that pulls developing nations into the politics of expert knowledge and Western science. Institutionalisation is the creation of institutions such as development banks for example African Development Bank (ADB) where the development discourses are generated and disseminated to member countries (Escobar, 1995). There are power dynamics inherent in those discourses and ST&I framing which the next section explores.

2.4 Power dynamics and role of international institutions in ST&I Framing

As aforementioned in the preceding introduction of neoliberalism, organisations like the OECD, World Bank and UNESCO are playing a major role in shaping national discourses on ST&I and its link to development (Schwachula, Seoane and Hornidge, 2014: 3-4). All the three organisations take it upon their mandates to advise national governments regarding ST&I policy options and their impact on development (OECD, 2013). UNCTAD and UNESCO's work in ST&I policy for development focusing on supporting the integration of STI in national development strategies and building-up ST&I policy-making capacity in developing countries. The advice on ST&I policy to national governments by these international institutions for instance OECD on Space and Innovation and its impact to the larger economy (OECD, 2016), the African Union initiatives on ST&I indicators prescribed seem to draw on 'Western' conceptualisations of development which are in favour of innovation driven by research and development (R&D) in formal institutions, and advanced science and technology (Daniels, 2017: 172) excluding innovations that happen at grassroots level yet in Africa, most economies are largely informal (Charmes, Gault and Wunsch-Vincent, 2018).

Economic prescriptions of World Bank and IMF have paradoxically left most of developing states in abject poverty (Ayelazuno, 2013). Many countries in the developing world have witnessed growth and assumed middle income status albeit without development and have failed to diversify economies towards industrialisation.

The domination of international institutions in the African continent and Third World in general is logic of unequal power relations, obstructed development, and unpropitious incorporation into the global economy. The nature of ST&I ushered in Africa can be similar to the dynamics of structural adjustment and conditionality-based development aid and reproduces the deeply unequal and coercive relationship between rich and poor countries (Venugopal, 2015: 10)

It is therefore apparent that the meaning of ST&I in Africa must therefore shift from the current understanding to a broader and more inclusive sense of innovation for development in line with the needs, concrete realities, and aspirations of the continent (Daniels, 2017: 180). The evolution of scientific ideas regarding science, technology, and innovation has corresponded with adjustments in policies related to these fields. Governments have created specific policies aligned with their national development goals, drawing on the concepts of the knowledge society and economic innovation. (Hornidge, 2011). To a large extent, ST&I policies and programmes linked to the 'development' discourse have remained at technocratic level with little inclusivity of grassroots or local level realities.

Science, technology, and innovation are important tools that can contribute to growth and development (Kraemer-Mbula and Wamae, 2010). However, it is also widely acknowledged that advances in ST&I can lead or perpetuate exclusion and inequalities in the society (Cozzens *et al.*, 2009; Cozzens, 2010; OECD, 2013; Mhula, Hart and Jacobs, 2015). Hart et al., (2013) maintained that there is a continued presence of high levels of poverty, inequality and unemployment in South Africa which has remained a challenge despite the country being one of the frontiers of science, technology, and innovation in the African continent. Therefore, if the purpose of STI is to improve quality of life then perhaps this persistence of inequalities calls for reconceptualisation of ST&I in a manner that broaden the concepts, enhances inclusivity and ensuring that it addresses the needs of the wider segment of the society (Daniels 2017: 180). Neoliberal policies were also criticised for being excessively technical, economistic, 'cookie-cutter', context-blind, and politically naïve (Venugopal, 2015: 10). The critique questions and problematises the narrowness of defining development in terms of the 'means' (economic growth) rather than the 'ends' of looking at whether poverty alleviation has taken place, health, education, or other

measures such as democracy, human rights, and gender equality have been addressed (Streeten, 1994; Sen, 1999; Jolly, 2003; Fukuda-Parr, 2011). Neoliberal and neoinstitutional theory insights are helpful to explain the scientific pursuits in African countries due to external influence of international technical, economic, and financial institutions that validate and fortify the idea of science as a panacea to development.

2.5 How do theoretical and power relations influence science-development assumptions?

The nexus between big science and development has been discussed with macrolevel orientations of national economic growth and scientific capacity (i.e., knowledge production, technological development, technical innovation, and scientific discovery) as empirically associated with each other (Castells, 2000; Schofer, Ramirez and Meyer, 2000; Grammig, 2002; Schofer, 2004; Malmgren, Ottino and Nunes Amaral, 2010). Over the past years science has also gained a position of centrality of providing the knowledge base required in facilitating work towards achievement of Sustainable Development Goals (Schmalzbauer and Visbeck, 2016). Major research funding agencies such as the UK Research and Innovation (UKRI), Global Challenges Research Fund (GCRF) and Newton Fund have focused on initiatives to support research that address the most pressing challenges of developing countries and progressing the United Nations SDGs (UKRI, 2021). On the contrary monopolisation of knowledge production, science, technology and innovation by the most advanced economies in the world i.e., G7 and OECD countries bears testimony to the importance put on macrolevel science-development nexus (Mormina, 2018).

There is again world-wide recognition and acknowledgement that the science and technology (S&T) capacity is unequally distributed between advanced economies in the Global North and those in the Global South. Ambitions to enhance scientific research and upgrade the technological capabilities of Low- and Medium-Income Countries (United Nations, 2015) has led to the adoption of research capacity building (RCB) and human capital development (HCD) projects as cornerstones of international development assistance (Colglazier, 2015). The capacity to generate scientific and technological knowledge (S&T) and ability to produce goods and services are regarded as levers for economic growth and development. Much of the

understanding of capacity to generate scientific knowledge is based on Western-centric notions largely borrowed from concepts such as performance management and organisational development (Morgan, 2006) with less emphasis on empowerment, community participation and development. Capacity building is therefore a grey area which leaves practitioners in development with varied interpretations where some take it as a human resource issue while for others is a systems approach that looks at institutions and how they are governed (ibid). In the case of big science research infrastructures and research collaborations between the Global North and Global South, capacity building in research is viewed as an ethical obligation to level up among collaborators with unequal capacities and resources, hence the focus on skills development for local scientists (Parker and Kingori, 2016) with insufficient attention to the structure and social factors that facilitate or are barriers to local knowledge production (Mormina, 2018).

There is a gap in literature on assumptions made by scientists in constituting big science projects and associated human capital development projects and collaborations in Africa especially radio astronomy. Connections between big science and development are made but a systematic understanding of how science contributes to development and assumptions underpinning the relationship is lacking. Kaplan suggested several assumptions which seem to have much resemblance to theoretical paradigms of development which are:(1) development can be created and engineered. Interventions are therefore deigned to bring development amongst those lacking; (2) development is something which is brought to and for some, by others who presumably are more developed; (3) Development is done on behalf of third parties. The development practitioner is the one deemed to bring development interventions which are designed and bankrolled by third parties not the intended beneficiaries who are subject of the intervention; (4) the development practitioner works from their understanding of the world rather than the others; (5) the ‘development project’ is a short term, time bound and limited in resources; (6) knowledge and understanding will create change and takes less account of culture, traditional processes. Hence, emphasis should be put on training and technical assistance; (7) development is linear and predictable. In other words , there is a direct cause and effect relationship, between inputs and outputs. If correct assumptions and inputs are put in place initially the output is predictable; (8) development itself, then, has a beginning and an end and

the assumption is that the end can be defined and provided for at the beginning; (9) development places far more emphasis on technical experts and 'advisors' and on trainers, than it does on change facilitators; (10) development assumes a preferred culture or value system. The presumption is that there is something wrong, and we intervene to change it. the results are judged according to our own norms and standards; and (11) development interventions are generally implemented in terms of the goals enshrined in the project document, not in terms of the myriad other outcomes which may (or may not) have been forthcoming in terms of the individuals, communities, or organisations with whom the development intervention had been entered (Kaplan, 1999: 5-7).

The assumptions by Kaplan were not targeted to any development project initiated in communities but were general assumptions. They give a generic picture of what goes into a project before it is implemented. There are a lot of similarities in the framing of these assumptions with modernisation and neoliberal thinking of development and a logical conclusion can be ascertained that development is a Western project which is fundamentally transfer of resources from a point of endowment in form of financial, equipment, technical know-how, skills, political clout, to those regions deemed under-developed that lack those resources. This discussion on development assumptions leads to a complex dynamic on science and its links to development paradigms.

2.6 Science and paradigms of development

The initial step in the relationship between science and development is to go through terminology as a sign of acknowledging the complexity of science itself before it relates to development which further complicates the discourse. Terminology is also important in any discourse. The terms science, technology and innovation are equally open to multiple definitions and interpretations along their way to contribute towards ‘development’. Much hope is resting on ST&I and its potential to impact on various sectors in terms of development as encapsulated in the Science, Technology, and Innovation Strategy for Africa 2024 (STISA, 2014: 10). Barnes (1982: 166-172) noted the blurriness in the terms, science as production of new knowledge and technology as the practical application and proposed not to differentiate them . He suggested the use of the words on equal terms. In the context of ‘development’ ST&I and its role has

revolved around innovation defined as the commercial usage of scientific knowledge thus putting emphasis on knowledge as a competitive factor (Schwachula et al., 2014: 2). Post-World War II, the US government declared its need to strongly support science for achieving different economic and social goals (Arond et al., 2011).

The initial emphasis placed on research, which subsequently evolved into the 'science-push' innovation model, posited that the generation of scientific knowledge, regardless of its immediate applicability, yields beneficial outcomes for society. The 'science-push' model was later succeeded by the 'problem-solving paradigm' or 'demand-pull' approach, which prioritizes addressing challenges, resolving technical difficulties, and promoting economic progress (Schwachula et al., 2014: 6). Subsequently, the concept of 'science as a source of strategic opportunity' emerged, which links research outputs with broader national policy objectives, such as international competitiveness, through the encouragement of international research collaboration and the establishment of knowledge transfer mechanisms to disseminate academic knowledge to other actors (Ruivo, 1994: 157-164). An alternative perspective, more nuanced than the linear relationship between ST&I and development, has emerged that acknowledges the complex and interactive nature of the research system. Since the 1970s, there has been a shift in terminology, reflecting a corresponding change in concept: the term "science policy" has become less prevalent and is increasingly being subsumed under the wider rubric of "innovation policy" or "science, technology, and innovation policy," or other related terms where innovation takes centre stage (Schwachula, Seoane and Hornidge, 2014: 6-7).

Two main paradigms of the relationship between ST&I and development that comes from the discourse are: ST&I for economic development, ST&I for sustainable development. These paradigms clearly come out from the development discourse that links science and development in Africa’s economic blueprints in a chronological order at the turn of the millennium and sustainable development in 2015.

2.6.1 Science for Economic Development

The first paradigm is based on the economic growth which is the core of most countries’ development strategies. ST&I policies are therefore tailor made in a way

potentially to contribute to such a broader aim. Knowledge and innovation are considered as comparative advantages on the world market (Drucker, 1993). As a result, economic innovation thinking has become a 'standard recipe' of growth, which is based on the idea of a free-market economy and on a top-down policy promotion for technology production (Röling, 2011). The linkage between development and ST&I gained prominence in the 1960s, when scholars postulated that disparities in worldwide development reflected technological differences, and therefore technological capacities needed to be developed to close the technological gap and to stop countries from 'lagging behind' ((Fagerberg *et al.*, 2009) cited in Shwachula, (2014: 8). Related conceptually to science and technology-based economic innovation is the concept of the knowledge economy, which is assumed to emerge because of technological developments. Most concepts of the knowledge society focus on the economic aspects, but simultaneously acknowledge the crucial role of information and communication technologies for the distribution and diffusion of that knowledge (Hornidge, 2011). The paradigm which seems to drive most of the scientific endeavours in the 21st century is sustainable development. SKA and DARA projects were also expressed in the language of SDGs.

2.6.2 Science for Sustainable Development

The second paradigm is on sustainable development. Sustainable Development Goals (SDGs) also referred to as the Agenda 2030 is a shared blueprint by United Nations (UN) Member States adopted in 2015 which is more like a critique to ST&I for economic development. The Agenda recognises the eradication of poverty as the greatest global challenge and an indispensable requirement for sustainable development. It also acknowledges the role of ST&I as a key driver enabling and accelerating the global transformation towards prosperous, inclusive, and environmentally sustainable economies in developing and developed countries. The Sustainable Development Goals acknowledges the importance of science, technology, and innovation (ST&I) in achieving sustainable development, particularly in eradicating poverty and promoting inclusive and sustainable industrialisation. Goal 9 specifically highlights the need to foster innovation and technological progress to achieve sustainable industrial development, while ST&I are seen as key drivers towards achieving all the other goals. Additionally, Goal 17 emphasises the

importance of international cooperation and partnerships for development, with ST&I as a central component. (UNCTAD, 2018: 3). The SKA and DARA projects can be examples of this cooperation on ST&I for development.

Prior to the SDGs, the international community had the Millennium Development Goals (MDGs). The MDGs were also a set of ambitious goals which galvanized unprecedented efforts to meet the needs of the world's poorest. There has been a growing recognition that technology and innovation have a role to play beyond industrial growth. Acknowledgement of this growing role begs the question of how countries can harness the strong linkages between technology and innovation policies for overall sustainable development and welfare. This issue is a pressing concern for all countries (UNCTAD, 2014: 2). The first challenge where ST&I have a critical role to play is the multidimensional nature of poverty. In addition to income, various factors comprise the deprivation experienced by the poor, including lack of education, health, housing, empowerment, employment, personal security and more. ST&I have a huge potential to contribute to tackling these multiple dimensions of poverty through a variety of channels. For instance, ST&I is envisaged to facilitate the creation of jobs, enhance delivery of basic public services, improves access to knowledge and education, and empowers the marginalized sections of society.

Inclusive and pro-poor problem solving in the context of sustainable development incorporates a social and human dimension. Non-economic, non-market driven, or profit-oriented approaches have been developed for ST&I initiatives. This perspective suggests that innovation systems in developing nations should not only focus on economic goals, but also on social development. Thus, investments in ST&I in developing countries are deemed valid only if they aim at both economic and social aspects of development (Arocena and Sutz, 2012). Drawing from debates in political ecology and economy, alternative perspectives challenge conventional economic notions of innovation by examining the distribution of benefits and costs of different types of innovation, the diverse interests pursued, and power relations. Bozeman and Sarewitz suggest that ST&I policies that exclusively prioritize market-driven approaches tend to neglect important social and environmental dimensions. (Bozeman and Sarewitz, 2005). They therefore propose to conceptualise ST&I and its policies around the idea of 'public failure', instead of 'market failure' to stress the

accountability of policies towards the public. The following section gives a critique of modernisation and neoliberal antiques of science and development from a dependency and world systems perspectives.

2.7 Dependency Theory and World Systems Perspectives on Science and Development

This thesis critiques these traditions of modernisation, neoliberal and the power exerted by international institutions together with the associated development assumptions. In this critique, the thesis uses dependency theory and post-modernism as anchors for the arguments. The Dependency Theory and World Systems Perspectives emerged as the critique of the assumptions of Rostow, knowledge base that the Global South, Africa, and Latin America was underdeveloped and simply needed Western expertise to make it developed or modernised. Dependency theorists suggest that there is a close, and perhaps even a causal, relationship between development in some areas, and the underdevelopment in others. Influential writers (including Frank, Cardoso, Theotonio Dos Santos, Walter Rodney, Samir Amin, Arghiri Emmanuel, and Wallerstein) generally agreed on the basic point that capitalism had to be theorised as a world-system, in which there are constituent parts or regions, some of which (cores or metropoles) served to exclude, dominate, or subordinate satellite, peripheral, or dependent regions of the world economy. Dependency can be defined as an explanation of the economic development of a state in terms of the external influences--political, economic, and cultural--on national development policies (Sunkel, 1969:23) Dos Santos emphasized the historical dimension of the dependency relationships in his definition:

> [Dependency is]...an historical condition which shapes a certain structure of the world economy such that it favours some countries to the detriment of others and limits the development possibilities of the subordinate economics...a situation in which the economy of a certain group of countries is conditioned by the development and expansion of another economy, to which their own is subjected. (Dos Santos, 1971: 226)

Dos Santos further acknowledges the link established by international division of labour between the economic achievements of the centre (industrialised) and those of the 'periphery' (LDCs) with the former reaping benefits of technological progress and

the latter left with primary sector activities hence the need to transfer capital from the developed to the developing countries (Santos, 1973: 76). Science within the dependency thought is a conduit for world economic domination and preservation of geopolitical hegemony by developed countries. Baran described underdevelopment of those countries in the 'periphery' as a stagnant, decaying, monopoly capitalism, which, "far from serving as an engine of economic expansion, of technological progress and of social change" actually represents "a framework for archaic technology, and for social backwardness" (Baran, 1957: 163-4).

Frank (1969) extended Baran's theory of economic surplus, which argues that developed countries became wealthy by extracting surplus from poorer nations. According to Frank, this process of surplus extraction occurred not only within nations, but also between wealthy metropolitan centres and less developed satellite countries. This hierarchy of exploitation can be applied to the divide between economically rich and poor nations. Thus, "satellites remain underdeveloped for the lack of access to their own surplus" (Frank, 1969: 9), as capitalism "has at all times and in all places […] produced both development and underdevelopment" (1969: 240). Frank argued that capitalism was present globally, regardless of the relations of production in a specific area. In contrast, Baran believed that non-capitalist relations of production remained, but were subordinate to the needs of the broader international economy dominated by capitalism.

Wallerstein brought in the world-system approach and argued that the world had been capitalist since at least the sixteenth century, and the basis for this was a division of the world into core, peripheral, and semi-peripheral areas. He argued that the core areas have, since at least 1640, specialized in higher value production and appropriated a surplus from the periphery and semi-periphery (Wallerstein,1979: 18-19). Amin described and analysed how Africa as a continent was incorporated into the world system tracing the historical stages that involved colonisation as key source of underdevelopment and three patterns of integration. The three patterns of integration into the global system included colonial trading economy, mineral resource oriented economy (in the Eastern and Southern parts of Africa) and the concession owning companies mainly in the central part of Africa (Amin, 1972: 523). He argues in the same vein with Wallerstein that capitalism is one system comprising of unequal and combined development between the two sides of the coin, centres, and peripheries.

The organisation of that unequal asymmetric relation was based on the countries of Africa being exporters of many raw agricultural produce, and mineral ores. That export orientation to Amin did not allow any type of industrialisation, and has led to conditions where Africa remains passive, and is continuously adjusted to the demands of the global system, that is, acceleration of growth and accumulation in the centres (Amin and Bush, 2015: 3).

The lessons that this project will take from the Dependency Theory is that the world is still divided into the centres and peripheries. If Africa remains the recipient of knowledge and technology transfer through big science, the more the centre (Global North) develops. Dependency theory views the link between science and development as being derived from both neoclassical and Marxist economics. The relationship between science and development according to dependency theory can be explained by the amalgamation of neoclassical and Marxist economics. Neoclassical economics argue that knowledge producers, like capitalists, are rational and are primarily interested in maximizing their own profits. On the other hand, Marxist economics hold that knowledge producers are more attracted to research areas that offer high rewards and profits. Based on this perspective, it can be argued that the production of scientific knowledge and associated capacity building play a crucial role in the persistence of the dependency between the Global North and South. This dimension of scientific dependency will be dealt with in chapter four and five. The other lesson is that the so called 'underdeveloped' Global South does not simply require the touch of Western modernity and expertise to develop but rather a proactive thinking about co-option into the world system on mutual benefit terms. However, critical to this thesis is combining these insights from dependency theory with the insights around knowledge and power that can be gleaned from the Post –development theorists explored in the next section.

2.8 Post-development Theory

Post-development is premised on the argument that, ideas about 'development' from a Eurocentrism perspective must be challenged from the grassroots, and increased awareness of how different social and cultural groups are affected by development processes is a priority. The theory challenges the long-established assumption of Western knowledge and science as authoritative, objective, reliable, applicable universally and value-free (Ynalvez and Shrum, 2015: 154). Post development

scholars like Escobar (1995) argues that the development process, as it has been experienced by the Global South, is based on Eurocentric assumptions, and reflects prevailing power relations which enables some ideas of 'development' to be presented as 'correct' while others are dismissed. Escobar gives an example of the Colombian society and economy which was magnified as 'lacking development' and the lack could only be addressed by adopting Northern forms of 'development' justifying numerous interventions in form of aid and technical assistance. Rasekoala throws her weight in the argument by suggesting that science must give up male dominance, eurocentrism, and idea that it is the only answer to all humanity's problems (Rasekoala et al, 2015).

Foucault has a lot of influence on the post development theorists. In the Foucauldian analytical framework, development is viewed as a specific way of visualising the world and as a particular form of knowledge which is not a reflection of reality but instead constructs reality and in the process forgoes alternative ways of thinking and therefore wields power. Escobar has adopted Foucault's analysis of power, knowledge, and discourse in relation to development as evidenced by how discourses of Western countries about the Third World have become means of instituting dominance (Kippler, 2010: 9). The discourse has given birth to the professionalisation of development and made it possible to remove all problems, including poverty from the political and cultural realms and recast them in terms of the apparently more 'neutral' realm of science. Consequently, development is viewed as a system of universally applicable technical interventions intended to deliver solutions on identified problems to "target" populations (Escobar 1995: 44) with the idea of 'progress' dominating the discourse.

The nerve of 'progress' as described by Shanin "sees all societies as advancing naturally up on a routine from poverty, barbarism, despotism and ignorance to riches, civilisation, democracy and rationality, the highest expression of which is science" (Shanin, 1966, 1997:65). The net effects of such magnification of development as 'progress' in contemporary societies is that it has become the popular common sense and acts as a shield to challenge. Blueprints of 'progress' and 'development' have given legitimisation to repressive bureaucracies both on a national and international level, to act on behalf of science, presenting as technical problems and objective matters those which are essentially political and thereby taking away choice from those influenced most by decisions taken by these institutions (Shanin 1997: 69).

Ferguson's furtherance of the post development theory is the classical analysis of the 'development discourse' on Lesotho and the ways in which the development agencies portrayed the country's economy and society. The Thaba-Tseka Project which was meant to bring transformation in livestock practices that would result in commercialisation and modern paddocks failed by ignoring the traditional political and economic structures that governed livestock keeping in Lesotho where non-commercial livestock rearing supported local power relations (Ferguson 1990). Development practitioners in their portrayal presented Lesotho's economy and society as lying within the control of neutral leadership perfectly responsive to the blueprints of planners who visualised "the government as a machine for providing social services and engineering growth" (Ferguson, 1990: 226). Ferguson argues that this misinterpretation of the underlying role and power of the state contributes to the failure of development projects in general but most importantly the myopia to see the instrumental effects of the consolidation of bureaucratic state power. Linking to technology 'big science' projects may bring or may not bring the desired effects of 'development' but instrumental effects of such investments can have some trail of power relations on the African continent through projects such as SKA and DARA. Instead of focusing on the development or its potential in the big science infrastructure project effort should be on what it achieves through its "side effects." The next section gives the development discourse driving big science projects in Africa.

2.9 The development discourse in big science

The concept of development is multi-layered and has many dimensions as highlighted earlier on in this chapter. Pieterse identified a generic multi-layered pathway that a development discourse takes (Pieterse, 2010). Firstly, it occurs in a particular historical context and political circumstances. Visualising development in context is an acknowledgement that it is a natural response to challenges at the time. Secondly, explanations or assumptions about causal relationships in this case between science and development are set. Third epistemology or rules of what constitutes knowledge. This implies going beyond handling development as ideology, or interest articulation. but invokes meticulous attention to development texts and utterances. Thus, it involves the sociology of knowledge not only in terms of class interests (as in ideology critique)

but also in terms of what makes up an underlying 'common sense'. Fourth, the development discourse defines methodology, indicators, and research methods to be employed to measure success of an intervention. Fifth, development thinking performs a role of representation, of articulating and privileging political and class interests and preferences. Sixth, development discourse reflects images of improvement or desirable change to the lives of the people targeted by the intervention. Seventh is the agenda-setting role of development theory, as a set of policy implications and a future project. Figure 2.1 gives a summary of this development discourse pathway.

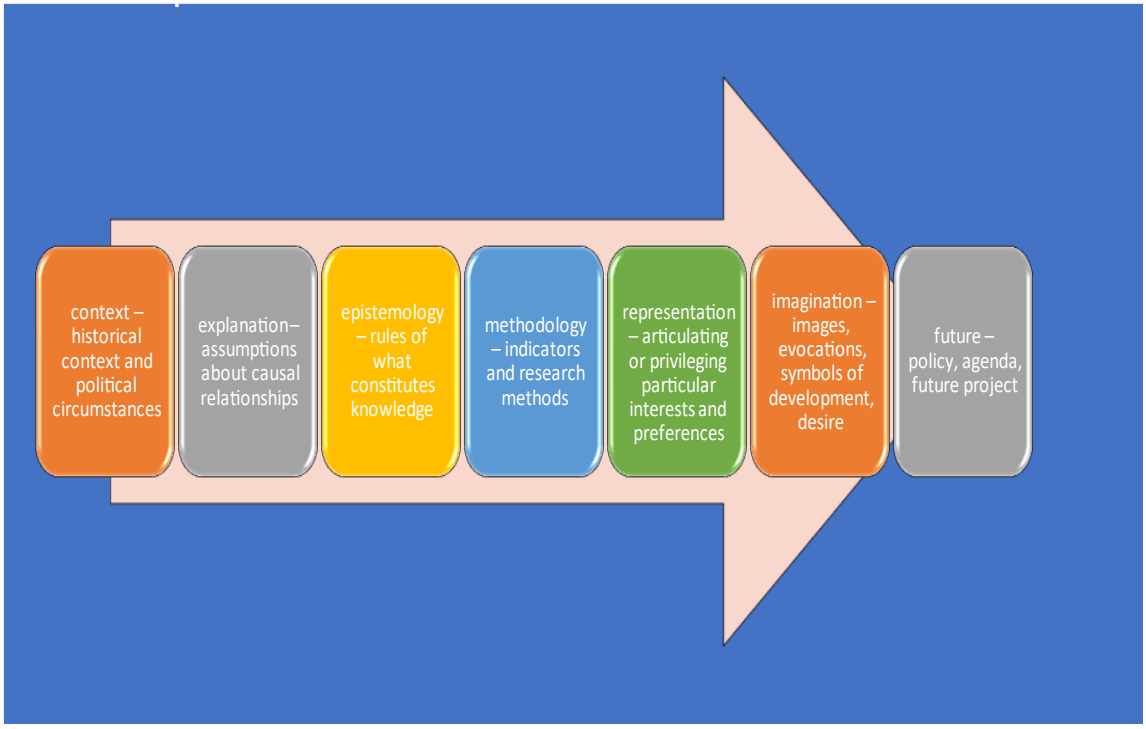

Figure 2.1 Author's diagram with development discourse (Adapted from Pieterse, 2010)

The multi-layered pathway described culminates into a story, hence the development discourse can be regarded as a myth or fairy tale (Rist, 2007), and a grand narrative that appeals to the circumstances with a skill of skirting around political issues of power on the ground. Another perspective is that development can be seen as a construct, representing a Western modernist ideal that imposes its values on other societies. This results in a pursuit of material progress that negatively impacts people in the Global South. In this view, development is considered to be a misleading and deceptive concept (Pieterse, 2010). This argument takes the post development line of

thinking (for example, Escobar 1992b, Sachs 1992a). Like the pathway simulated by Pieterse above, the SKA and DARA projects development discourse took the Ferguson's antipolitics machine route in a Southern African country, Lesotho where development projects failed to achieve intended objectives. Narratives by development experts however justified intervention. In the case of the SKA project the development discourse in Africa seem to lean towards the Lesotho experience. The first stage is the construction of a story about Africa, secondly discount the African reality, thirdly rearrange the reality to justify funding, fourth depoliticise the project, fifth, non-fulfilment of development promise and embracing the side effects for future projects.

2.9.1 Construction of an Africa story

The justification of human capital development and building big science infrastructure in Africa starts with a narrative about the continent. The narrative in the SKA project is that the backwardness of Africa is due to lack of cutting-edge technology, its young population is not excited to take up STEM subjects and currently there is no capacity for radio astronomy. This narrative suits the funding agencies to portray developing countries in terms that make them suitable targets for technical assistance for instance the main reason that South Africa was awarded the bid to host part of the €650M Square Kilometre Array (SKA) next generation radio telescope was put across as a tremendous opportunity to use radio astronomy as a catalyst for wider development across the emerging economies of the African continent. Science in this case is flaunted as the only way to modernise economies and ultimately develop and that Africa itself has no clear development action plan. The following statement by the SKAO sums the narrative.

> Mega-science projects such as the SKA have the potential to seed or boost significant technological development, enhance capabilities and efficiencies across myriad of industrial and educational sectors, as well as generate economic and social benefits to society…. Moreover, the aim is to establish astrophysics education and research communities in these countries as a springboard for wider development. (SKAO, 2021)

However, a scan of the development plans of the African nations and their "country profiles" on which the astronomy projects base their interventions frequently bear little or no clear relation to economic and social realities. The construction of the Africa story is participatory with governments of the eight African countries in the SKA welcoming the project for its transformation potential beyond astronomy in terms of driving development in the areas of education, skills, and technological innovation. For instance, South Africa's then Minister of Science and Technology, Naledi Pandor addressing the 2nd Ministerial Meeting of SKA African partner countries said that:

> We hope that through human capital development, innovation, value addition and industrialisation in alignment with STISA, we will be able to uplift large sections of Africa's people. Diversifying our economies and broadening our sources of growth and sustenance will help us to address poverty and foster both social transformation and economic competitiveness on the continent. As an excellent vehicle for human capital development, as well as for innovation, key technologies such as the ICT and most notably for the big data economy SKA Africa have a key role to play in supporting the implementation of STISA. (South African Government, 2019)

Similar sentiments were also echoed by the Zambian Minister of Education, Science, Vocational Training and Early Education, Dr. Michael Kaingu who said:

> SKA project will contribute to human capital development through training in cutting-edge technology that will be required during the construction process and manning of what will be the world's largest radio telescope...This project is important to Africa as it will help our researchers with data especially for those countries with shortages of academic staff. (Press Secretary, Zambia High Commission, March 2015).

In Ghana, the SKA project was warmly embraced as part of the broader Science, Technology, and Innovation Development Plan. The President of Ghana, Nana Addo Dankwa Akufo-Addo, described the development as

> The beginning of a new era in the country's quest to harness the potential of space science and technology for accelerated national development. (Ministry of Environment, Science, Technology and Innovation, 2017)

During the launch of the Ghana Radio Astronomy Observatory, President Akufo-Addo reiterated his government's support for ST&I through the Presidential Advisory Council on Science, Technology, and Innovation (PACSTI). The Council would among other things significantly increase funding for research and development (R&D) in science, technology, and innovation from 0.25 per cent of GDP to one per cent of GDP in the short to medium term and increased further to 2.5 per cent of GDP in the long term.

> It will form the National Science, Technology, and Innovation Fund to support R&D in all research institutions and universities, both public and private. At the same time, the government will make efforts to increase collaboration among research institutions, industry, especially the private sector, and political authorities at all levels. These measures, I hope, will make the transition from research to product development and industrial production much easier. President of Ghana, Nana Addo Dankwa Akufo-Addo (Graphic.com.gh, 2017)

The then SKA Africa representative Ms Anita Loots, Head of Africa Planning Office, central in the upgrading of Ghana's observatory viewed it as a timely facility that would help in the efforts of African scientists finding solutions for Africa. She exhorted African countries step up their capabilities in data collection and processing in the following statement.

> Attaining the SDGs depends very much on Africa's ability to gather data on health, education, agriculture, sanitation and the economies to make informed decision, and that was what the observatory would help in attaining as part of the broader intellectual capacity development. (SIRJAMES, 2017)

The claims regarding the impact of a big science from key stakeholders point towards an underlying presumption of inherently positive relationship between astronomy and loosely defined notions of 'development' (Walker and Chinigò, 2018: 2). However, the potential impacts of ST&I on society is complex and take place on multiple scales (Schwachula, Seoane and Hornidge, 2014: 2). The theoretical debate over the relationship between science, big science and nature of development is broad, and contains many strands which address different purposes and concepts (Pieterse, 2010).

The dominant strand in the relationship is ST&I for economic development based on the innovation systems approach which emphasise linkages between knowledge

creators, firms and the state with the aim of sharing technological innovations (Schwachula, Seoane and Hornidge, 2014: 8). The term innovation was first introduced by the Austrian economist, Schumpeter who defined innovation as a new combination of factors that lead to a commercial or industrial application of a new product, process, or the opening of a new market, the conquest of a new supply source or an organisational change (Schumpeter 1934; Fagerberg 2006). The concept has been subjected to constant changes and redefinitions. The innovation concept is wedded to an economic ideology to the extent that its history of being a political and contested concept is forgotten (Godin, 2015: 1). Prior to the 20th Century, innovation was regarded as a vice, something forbidden by the law and a linguistic weapon by opponents of change (ibid). Today innovation is a word of honour, everyone likes to be called an innovator, every firm innovates; governments legislate to make whole nations innovate (Godin, 2015: 219). Godin believes the innovation concept gained currency because of its instrumental function to political, social, and material progress of societies.

For a lengthy period of time, 'linear models of innovation' were in use, which suggested that the process from idea to product is a straightforward one: new knowledge is created in a laboratory and then transformed (though with feedbacks from the market) into a product (Schwachula, Seoane and Hornidge, 2014: 8). There are two theoretical perspectives, the economic (technological) and policy, that served a market ideology and subsequently got government hearing (Godin, 2015: 224) In the 1980s it became clearer that technology was not something simply available to everyone as an external input, developed in a mechanical way as neoclassical economics assumed (Nelson 1995). Development scholars question economic approaches to innovation based on past research which proves that growth does not necessarily go hand in hand with improved living conditions for all and does not 'trickle down' per se or lead to social inclusion (ibid 2014: 24).

The development path depicted by President Truman's inaugural address in 1949 seems to use the economic growth potential of ST&I as a discursive construction for opinion setting as well as easy acceptance in a highly competitive space of priorities. Ferguson in his famous anti-politics machine, explored how the "development discourse" worked in a developing country Lesotho, particularly, the language and practices used by specialists to influence the *modus operandi* in which development

is purveyed, and the unintended consequences it fosters (Ferguson, 1990: 18). The net effect of development, he argues, has been to "de-politicize" questions of inequality, power and resource allocation and consolidation of bureaucratic power.

Alternative concepts developed mainly ST&I for sustainable and social development discussed earlier seem to inform the current thinking on Sustainable Development Goals (SDGs), that a tighter link be established on science, policy and society and integrate scientific understanding with action (ISSC and UNESCO, 2013: 6-9).

Successful implementation of the broader African vision to catapult the continent's development through ST&I largely depends on a number of factors at member state level, which include infrastructure development, technical competence, entrepreneurship development and enabling environment for ST&I growth (Juma and Serageldin, 2016: 9-10). An enabling environment in this instance refers to a political will and governance of a coherent national framework for promotion of ST&I, increased investment, strengthened legal and regulatory systems.

A critical analysis of the contributions of SKA to development is therefore coming at an opportune time where huge investments have been put in place, and Agenda 2030 on Sustainable Development Goals (SDGs) underpins its hopes on the catalytic role of ST&I for successful implementation, amid big debates on the complex relationship between ST&I and development. There are missing ontologies in governance and policy understanding of the various mechanisms through which big science contribute to society, economy, and politics (power relations) beyond scientific agenda. This thesis seeks to understand the intersection of investment in science, the power dynamics that come to play and 'development' at both national aggregate and local levels. The study has the potential to contribute to the literature though minimally to the bigger debates on Africa's position in the world, its renaissance, and intellectuality. All this is linked to Modernisation theory of development that informs development discourse of the Global South.

2.9.2 African Reality

As far back as 1963 during the foundation summit of the Organisation of African Unity (OAU), the then President of Ghana, Kwame Nkrumah realised the potential of science, technology, and innovation in transforming Africa into a self-sustaining

industrialised continent. The founding ethos in as far as development is concerned were reaffirmed by the Africa Union in its ambitious Agenda 2063 and the Science Technology and Innovation Strategy for Africa 2024 that the continent will be a prosperous one underpinned by science, technology and innovation driven by own resources (Africa Union Commission, 2015). So as early as 1963 and even beyond Africa already had a vision for its future in terms of science. Africa is resident to earliest forms of astronomy in Egypt among other scientific discoveries in architecture, medicine, and mathematics. Africans should therefore approach "Western" ST&I not as outsiders looking in but as co-contributors of a knowledge pool monopolized through imperialistic power (Mavhunga, 2017: 2). In modern day science there are some notable deficiencies that can be enumerated in Africa. The Africa Capacity Report (2017) posits that despite the growing emphasis on STI for Africa's development effective use has been hindered by low investment by governments, lack of specific capacities, critical technical skills, and resources to promote research and development (R&D) improve higher education and foster growth. Deficits of capacities only reflect conditions that are exogenous to the development of STI, and the missing ingredient is the understanding of STI as a social system influenced by culture and beliefs (Saidi and Douglas, 2018). The incremental reliance of modern states and societies on science and technological systems has redefined relationships between science and technology, government affairs, and political power in a broad range of issues underpinning the development of the modern world (Fisher, Pearce and Molfino, 2016). Therefore, Africa as continent thrives to fit in this modern world to conform to the norm.

2.9.3 Inverted African reality.

The scientific ambitions and prior capacity of Africa in science subjects such as astronomy is not mentioned in the narrative of big science infrastructure projects. Presenting Africa as a place with prior association with technology, roots to modern day astronomy and a co-contributor to knowledge would not convince justification for capacity building projects. Some of the exogenous factors such as colonial history, dependency, and effects of neoliberal policies towards funding of research are deliberately left out in the narrative since their inclusion will be construed as acceptance of the Western hand in Africa's underdevelopment. The issues of bridging

the knowledge divide between the Global North and Global South are subtly mentioned but all the capacity development is focused to the successful implementation of the SKA project in Africa. The portrayal of Africa is that of recipients of knowledge and not generators of knowledge so that capacity building and human capital development projects are neatly packaged.

2.9.4 Depoliticisation of science

Science can be utilised to repose political questions of land, resources, jobs, or wages as technical 'problems' responsive to technical development interventions as noted by Ferguson that.

> By uncompromisingly reducing poverty to a technical problem, and by promising technical solutions to the sufferings of the powerless and oppressed people, the hegemonic problematic of 'development' is the principle means through which the question of poverty is depoliticised in the world today (Ferguson, 1990: 256).

In the SKA, the project is presented as a purely scientific venture to answer the fundamental questions about the universe. The SKA will be the world's largest radio telescope, many times more powerful and faster at mapping the sky than today's best radio telescopes.

The SKA drivers stress the importance of answering the fundamental questions and about the laws of nature, such as: how did the Universe, and the stars and galaxies contained in it, form and evolve? Was Einstein's theory of relativity correct? What is the nature of 'dark matter' and 'dark energy'? What is the origin of cosmic magnetism? Is there life somewhere else in the Universe? So, the focus is science. The development discourse about SKA forgets that the magnitude of the project and its involvement of different countries brings its own politics of power and hegemony. National governments are not neutral entities that facilitate science for the sake of science, there are local and international collisions in terms of expectations, administrative regimes with own priorities, epistemic tensions, and politics of knowledge production are all suspended in the discourse. Such omissions are not a

manifestation of naivete but a skill by project managers and advocates to get unanimous support for the project across the social and political divide in settings of limited resources especially in Africa.

2.9.5 Non-fulfilment of development and side effects

Results of development interventions are not guaranteed, but new programs and models are presented in a continuous flow with high hopes described as a 'hope-generating machine' (Nuijten 2004: 52). Nuijten further explains that the 'hope-generating machine' like Ferguson's antipolitics machine, is related to the bureaucratic system in which most of the time limitations and failure of past programmes are admitted together with projects that indicate the 'new way forward' creating a never-ending cycle of high hopes and expectations. The SKA project in Africa described the benefits 'beyond science' in a typical 'hope-generating' fashion. In Ghana and other participating countries, SKA and DARA may not develop the economies, address inequalities, bridge the knowledge divide between the Global North and Global South but can change the identity of Africa, spruce up the image and change the terms and conditions of the continent in the global knowledge system. These unintended consequences and how the settings for communicating them to the society are controlled by ideas and language which will be dealt with in chapter six that look at ontological security in big science later in this thesis.

2.10 Conclusion

This chapter analysed the relationship between ST&I and development as well as the major assumptions underpinning this nexus. The above sections have given various angles of development and how it is understood by different practitioners forming a discourse. The concept of development has been contested and multiple characterisations proffered and on the other hand the terms science, technology and innovation have evolved giving a complex matrix of a relationship. A detailed empirical case study of what ST&I mean from an African perspective may partially assist to explain Africa's place in the world, renaissance, and its intellectuality. The different notions of development pose a challenge to the SKA and DARA projects as to which form of development is being addressed by the intervention amid structural power

relations between the Global North and the South. The ontological position that investment in science, technology and innovation automatically translate into various facets of 'development' needs careful analysis of its epistemological foundations which the approaches to development have endeavoured to explain especially from a modernisation perspective and neoliberalism. The discourse of development chronicled through the five-point story continue to condition Africa to the dominant logic of capitalist accumulation that relegates the continent to the periphery.

Modernisation and neoliberalism theories have been criticised for their knowledge base and assumptions of the Third World which were more of a technocratic framing of the challenges posed by underdevelopment such as poverty and in need of technical intervention mainly from the Global North. This idea about ST&I as a 'silver bullet' to development is a perpetuation of modernisation theory and neoliberalism. The chapter has also brought together the insights of dependency theory that the world is divided into centre and periphery where knowledge around big science is controlled by the centre and how that reinforces pre-existing dependant or unequal power relations in global capitalism and insights from post development which seeks to challenge the genealogy of that knowledge. This thesis is concerned with intellectual traditions of dependency theory, post development theory and those that seek to challenge this techno-fix approach to development. Globally, countries rely on each other's technology, but it's not necessary for every place to adopt a universal model for technology production. Although astronomy may seem promising in the scientific field, there's no guarantee that supporting it will solve economic problems for every country, especially if they lack prior experience in the field. It's worth considering tailoring development to the local context and aligning it with the existing science, technology, and innovation system.

Development policies based on science, technology and innovation cannot be reduced to mere technical operations whose sole objective is to increase the efficiency or productivity (Lewis et al 1992: 14). Technological change and innovation may not have socially beneficial effects if the cultural and political contexts are not prepared to absorb and incorporate them. Building capacity of individuals without giving attention to the system of innovation they operate in may not give the desired outcomes of development. Substantial gaps remain in Africa especially knowledge of suitable approaches to addressing challenges in areas such as ST&I understanding, definition

and conceptualisation (Foster and Heeks, 2013); innovation ecosystems, landscape dynamics, and actors which can ensure effective interactions and partnerships (Adebowale *et al.*, 2012); and the capabilities, knowledge and learning required to achieve Africa's ST&I aspirations. This dimension brings to fore what then science, technology and innovation mean in the African context. Daniels (2017: 171) argues that the potential of ST&I to contribute to Africa's socioeconomic development depends on what it signifies, how it is conceptualised, operationalised and its impact on policies targeted, what is included or excluded in the ST&I black box in Africa? Who controls the narrative? What development trajectories have been identified and how are they being addressed? The meaning of science from an African perspective is still an area that needs research effort.

Science is not purely sanctified from politics. Literature has shown that any attempt to suspend power and politics from the study of development and its relationship to science, technology and development is a political gimmick. The language used by development practitioners under the cover of science and its fixing capability of economic failures can pass the 'litmus test' in the development discourse but in fact issues of power and politics do not disappear, they are simply hidden, made tacit or recast as technical problems. The participation of states and subsequent investment in big science initiatives is beyond the economic benefits but has become a sign of power. The avenue (state) in which science, technology and innovation is delivered to achieve 'development' is not neutral as portrayed by techno-fixers. The underestimated role of state has instrumental effect of consolidating bureaucratic power and de-politicisation of otherwise contested decisions on the allocation of resources which Ferguson refers to as 'the anti-politics machine.' The side effects of failure to give development of big science can have a positive impact to the people in other spheres of their lives such boosting their confidence, ontological security, identity consolidation and national branding which are rarely mentioned on impact pathways of big science infrastructure projects.

The SKA and DARA projects have the potential to foster international partnerships, regional integration, and national human capital to address shared challenges of the 21st century. However, governing transnational issues is complicated by a division of power and decision-making. Navigating governance networks can be difficult without considering the different contexts and capabilities involved. A new approach is needed

that investigates the connections between science and development in a more contextualised way. This approach blends global systems theory and reagency, with some modifications. While it focuses on global movements of capital, culture, knowledge, and technology, it also recognizes that there may not be uniformity in the dynamics, nature, orientation, style, and practice of science across the world. Understanding of the context which is not always given on a silver platter may ultimately assist in the assessment of overall developmental impact of science, technology, and innovation. The subsequent chapters after the methodology goes at length to understand context and realities of development in Africa using Ghana as a case study beyond the technofix approach of big science projects.

Chapter 3
Methodology

3.1 Introduction

The main research question for the study seeks to extend knowledge on the politics embedded in large research infrastructure projects in the development discourses especially in the African continent. The sub-set of questions or objectives are as follows: (1) How do theoretical and power dynamics shape understandings of the science-development nexus?; (2) What are the underlying assumptions of SKA and DARA investments for development in Africa?; (3) What is the role of SKA and DARA in bridging the knowledge and power gap between the Global North and Global South?; (4) How do the SKA and the DARA projects address issues of race, class, power, and inequality in their implementation? and (5) What are the implications of large-scale science projects on the ontological security of African societies? Based on these research questions, the thesis takes a Constructivism paradigm stance which has roots in Interpretivism. Constructivism paradigm posits that knowledge is constructed through own understanding of the world, day to day experience and reflection of those experiences. The choice of the Constructivism naturally leads to the conceptual basis for the selection of qualitative methodological approach linked to the paradigm as suggested by Wagner (Wagner, Kawulichi and Gardner, 2019). This chapter therefore gives in detail the research paradigm, methodological approach adopted for this study, research design, methods used for data collection, data analysis, limitations, and adaptations during the Covid 19 pandemic period.

3.2 Constructivism Paradigm

The study is premised on the Constructivism philosophy, a research paradigm which views reality as a human construct with subjective interpretations of the world (Lincoln, Lynham and Guba, 2018:111). Due to the nature of the research questions of the study which seeks to understand the discourses of development from the world of big science, an interpretive research paradigm was best suited to explore ontological and epistemological assumptions of connections between science and development.

Crotty defines ontology as the ‘study of being’ (Crotty, 2003: 10) and the reality of the world being investigated. The assumptions of the big science world and its associations with development have been discussed in chapter two. The ontological assumptions that big science infrastructures and capacity to do cutting edge science translate into development underpins investment in radio astronomy skills in the SKA project in Africa. The widely held reality in this context is that Africa’s development is stalled because of lack of science and technology capacity. A causal-effect relationship is drawn between big science investment, capacity building and ‘broad based development’ of the continent.

The thesis analyses the ontological assumptions and seeks to understand why the causal relationship of science and development is a reality and makes epistemological assumptions. Epistemology can be defined as ‘a way of understanding and explaining how we know what we know’ (Crotty, 2003: 3). The study takes the interpretivism and constructivism epistemological stances. The interpretivism stance takes the hermeneutics approach (Heidegger, 1962) which is associated with interpreting and understanding texts or documents and the deeper meaning in them (Alan Bryman, 2012). Interpretivism argues that the ontology and existing knowledge are subjective, culturally, and historically situated, based on people’s experiences and their understanding of them (Ryan, 2018: 8). Therefore, as a researcher my experience and understanding of Africa can never be separate from the values and beliefs that the continent beholds. In one way or the other that informs the collection, interpretation, and analysis of data (ibid). The constructivist paradigm acknowledges and assumes that there are multiple realities of big science interventions which are subjective hence, a subjectivist epistemology (knower and respondent cocreate understandings), and a naturalistic (in the natural world) set of methodological procedures (Denzin & Lincoln, 2005a: 24). In summary the research examines the ontological position held by astronomers in their world and then interpret in relation to historical and obtaining geopolitical contexts of the research respondents.

3.2 Qualitative Methodological Approach

The adoption of the Constructivism research paradigm dictated the use of qualitative methodological approach. The term qualitative methodological approach has a wide

range of meanings but this study considers the definition by Hammersley that qualitative research methodology is a form of social inquiry that tends to adopt a flexible and data-driven research design, to use relatively unstructured data, to emphasize the essential role of subjectivity in the research process, to study a number of naturally occurring cases in detail, and to use verbal rather than statistical forms of approach (Hammersley, 2013:12). The main advantage of qualitative methodological approach in this study is that it provides intricate and in-depth understanding of meanings, actions, non-observable as well as observable phenomena, attitudes, intentions, and behaviours, and these are well served by naturalistic enquiry (Gonzalez, Brown and Slate, 2008:3). At the same time qualitative methodology gives an opportunity for research participant voices and simultaneously probing underlying issues of presenting behaviours and actions. This is central to the thesis because the meanings attached to big science and the presenting behaviours of actors requires an understanding of what lies beneath the surface and motives behind. Ontological and epistemological assumptions of big science described earlier informs the research design for the study and the next section describes the design adopted.

3.3 Research Design

The thesis takes the case study research design. A case study is an empirical method that investigates a contemporary phenomenon (the “case”) in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clear (Yin, 2018: 45). Bryman (2012: 66) also described a case study as a detailed and intensive analysis or examination of a single case. Case study designs are part of the comparative research method and in this study, this might appear as a contradiction in terms of where the comparison is drawn if the focus is on Ghana. The nature of the main research question requires a detailed case study to interrogate issues using multiple sources of evidence. A case study design copes with the technically distinctive situation in which there will be many more variables of interest (Yin, 2018) like in the SKA project. The case of Ghana and by extension South Africa in as far as the SKA and DARA project is concerned can have wider intellectual relevance, applicable to other AVN partner countries and to Africa as a continent. According to Halperin and Heath, case studies have the ability to make inferences that apply to countries beyond the original case (Sandra Halperin and Oliver Heath., 2012:

205). Gathering of evidence was done in two stages, first document analysis of existing information about the SKA and DARA and qualitative data collection in the field. The following is the rationale for choosing SKA and DARA

3.3.1 Rationale for choosing SKA and DARA Projects

The SKA and DARA were chosen because they are the contemporary astronomy projects in Africa presenting multiple core claims embodied in the design framework of their implementation which vary from strengthening the educational front (STEM subjects) with practical utility in areas of meteorology, health imaging, navigation, and general understanding of the universe. Development is another core claim running through the projects which may have been loosely constructed given its variable meaning as postulated by Walker and Chinigò (2018: 2). Astronomy by nature and design is a collaborative and networked science. Central to this thesis, is the power dynamics that come into play in hosting such collaborative projects. The interaction of overseas, local expectations and demands or, rather, the balance between northern and southern hemispheric power (Dubow, 2019: 664) present tensions and competitiveness which can be finely illustrated by SKA and DARA projects. The wider political terrain starting from the individual, institutional, national, and transboundary in which astronomy is pursued is an area which has been downplayed by the sequential, technically, and development-oriented narrative. The historical association of astronomy and colonial activity in Africa is of interest to this thesis. Astronomy supported African sub-imperial ambitions in the early decades of the 20th century. Practically, the determination of the Arc was essential for accurate cadastral mapping and geodetic surveying, a precondition for laying out colonial frontiers and patterns of landownership (Dubow, 2019: 665). The implementation of the SKA project presents an opportunity to decolonise in many respects.

3.3.2 Why Ghana?

Many studies on the developmental impact of SKA in Africa and scholarly work has been centred on South Africa (Gastrow, 2015, Atkinson 2017, Walker, and Chinigo, 2017) and there is a void of the other eight countries who are part of the initiative. The choice of Ghana in the SKA project is largely influenced by the fact that the country is

first among other AVN partner countries to convert its existing communications antenna into a radio telescope (SKA, 2019). In addition, Ghana has been running the Basic Training on Astronomy from 2014 to 2018 funded by the Royal Society and DARA took over in 2018. This gives a 'reasonable' time to assess the potential impact, and in some cases real traces of human capital development impacts on the innovation system.

3.4. Research Participants

The study involved data collection from various levels of respondents to corroborate or confirm findings from the document analysis. The widely held concept in qualitative research is saturation but this thesis uses the information power concept (Malterud et al, 2016) Various levels of respondents gives this information power. Information power holds that the amount of relevant information needed for the study determines the levels, numbers, and range of respondents (ibid). The study targeted policy makers for semi-structured and unstructured interviews from the following ministries/departments: Ministry of Environment, Science, Technology, and Innovation (MESTI), Ghana Atomic Energy Commission (GAEC), Ghana Space Science and Technology Institute (GSSTI), Council for Scientific and Industrial Research (CSIR), ministries of industry, finance, higher education, universities, telecommunications, and local government. The ministries were chosen based on their influence in terms of the SKA and DARA project. Selected elite interviews were considered especially with the Ministry responsible for ST&I. Pierce define elites as people 'who exercise disproportionately high influence on the outcome of events or policies in a research area'(Pierce, 2008:119). Difficulties associated with securing appointments for such high-profile elites was experienced and use of personal contacts from previous professional work in Ghana was reactivated with the relevant ministry.

Sampling Procedure

A non-probability sampling procedure was adopted for this study and in particular purposive sampling. Yin defines purposeful sampling as the selection of participants or sources of data to be used in a study, based on their anticipated richness and relevance of information in relation to the study's research questions (Yin, 2018). Purposive sampling allows researchers to pick the cases to be included in the sample

based on their judgement of their typicality or possession of the characteristic(s) being sought. The sample is constituted to meet specific needs. In this study, research participants were chosen based on their knowledge of the SKA and DARA project as well as their understanding of governance and innovation systems in Ghana.

3.5 Data Collection Methods

The study utilised qualitative data collection methods which, as already mentioned, were adjusted to suit the conditions imposed by Covid-19 pandemic of social distancing. The methods included document analysis, interviews, and observation of meetings. The following sections describe in detail the methods used and rationale for using them.

3.5.1 Document Analysis

Document analysis consists of analysing various types of documents including books, newspaper articles, academic journal articles, and institutional reports (Morgan, 2022: 64). The term document refers to a wide variety of material including visual sources, such as photographs, video, and film (Merriam & Tisdell 2016). Document analysis offers valuable information and advantages in difficult circumstances (Morgan, 2022). Fieldwork was difficult to carry out during the Covid 19 pandemic and document analysis became a complementary data collection in addition to interviews and observation methods. Documents analysed included African Union Agenda 2063, Space Policy and Strategy, SKA and DARA project documents, ministerial meetings for the SKA, country level ST&I policies (Ghana and South Africa), speeches made during events. Continental policy documents, ministerial meeting outcome documents for the African countries participating in the SKA, Ghana ST&I policy, the South African White Paper on Science and Technology (1996) and a sample of speeches made at major events such as award to host the SKA by South Africa in 2012, launch of the Ghana Radio Astronomy Observatory in 2017 and the African Space Strategy in 2017. All the documents were purposively sampled. As part of the discourse analysis, the data extracts from documents provided illustrative examples for analysis. In the next part each data collection method is explained together with a description of the processes followed.

3.5.2 Interviews

An interview is a qualitative research method which involves exchange between two people where the interviewer elicits information, opinions or beliefs from another person (Lincoln, Lynham and Guba, 2018). Interviews provide flexibility to explore new ideas and issues that had not been anticipated in planning the study but that are relevant to its purpose are part of qualitative data collection methods. conducted using interview guides that list the topics and issues to be covered during a session (Kumar and Analyst, 1989). The actual questions were framed by the interviewer during the interviews. The atmosphere was generally informal, resembling a day-to-day normal conversation. The main advantage of the interviews is that they 'provide flexibility to explore new ideas and issues that had not been anticipated in planning the study but that are relevant to its purpose' (Kumar and Analyst, 1989: 3). Such flexibility may not be given in other methods of data collection. Key informant interview guide was developed for this group of respondents with questions on: governance and coordination of ST&I system in Ghana; policy coherence, adoption and adaptation of new technology; investment levels by both government and private sector; how the agenda for development is set and its linkages to ST&I; lines of authority; who is deciding who gets the job in ST&I programmes; how decisions on students enrolled are arrived at; co-creation and commercialisation of knowledge, gender considerations and power dynamics involved in the SKA and DARA projects.

The study conducted interviews with incoming and exit trainees of both SKA and DARA to answer the core research question *'To what extent do the SKA and DARA projects contribute to narrowing the knowledge and power divide between the Global North and Global South?'*

Beneficiaries targeted in this thesis were those who received the SKA and DARA trainings (direct beneficiaries) and I used the training database from SKA and DARA to identify the trainees. The trainees were asked about their, processes of enrolment, experiences in participating in the trainings, how the training has improved their knowledge, development aspirations and their envisaged contribution to the country's economy. The beneficiary interviews helped to gauge the direct impact of the project simultaneously testing whether knowledge transfers in big science projects represent a central tenet of broader commitment to the redistribution of power in the service of

modernisation or progress that would benefit people everywhere, not just the Western industrial nations (Narayanaswamy, 2017: 5). The other core research questions on race, inequality, and other social science ontologies were partially answered by these beneficiary interviews. Access to the training database was sought from the relevant authorities.

Interviews were contacted with respondents from government ministries in Ghana, the private sector companies who can benefit from downstream applications of astronomy (for instance ICT industry, health, geo-informatics) , local leadership (Chiefs, Councillors and Members of Parliament who represent local development aspirations), regional and international organisations (e.g. World Bank, UNCTAD, UNESCO who advise governments on ST&I in Africa and power dynamics involved), SKA Organisation Headquarters and Africa Office and DARA representatives as well as universities. Key informants are those whose social positions in a research setting give them specialist knowledge about other people , processes or happenings that is more extensive, detailed or privileged than ordinary people, and who are therefore particularly valuable sources of information (Payne, 2004)

3.5.3 Observation of SKA and DARA Meetings

Observation is defined as the systematic description of the events, behaviours, and artefacts of a social setting (Marshall and Rossman, 1989: 79). This fall under

ethnography where the researcher study people in ‘naturally occurring settings’ (Brewer, 2000:6). Ethnographic methods tend to be overlooked as tools for research in politics and IR (Sandra Halperin and Oliver Heath., 2012: 305) But there is a growing realisation that ethnography is best suited to give more insight into what people do i.e., checking the differences between what people say they do and what they actually do. The study adopted the observation method of data collection to triangulate data from interviews and understand the research participants’ world. The SKA and DARA organises international seminars and annual meetings where students, distinguished academics in astronomy and the corporate world interact in the same room. Such condensed wealth of data and voices has been missing in the literature that analyse big science projects especially the SKA project. In those meetings I took the position of “observer as participant” where I participated in the

social setting under study but not as a group member. Group members were aware of the purpose of the research and were more open to share their experiences. Permission was also sought from the meeting organisers and the participants. The meetings attended include DARA Annual Meeting in Goonhilly, UK 2019; Benny Fanarroff Annual Lecture in Manchester, 2020, UK; Space Generation Council Meeting in Accra, Ghana 2021, African Union Meeting. The following table is a summary of all the methods used research participants and the research questions that were answered.

Table 3.1: Fieldwork data collection matrix

Method	Category	Target No of Interviews/documents/ observations	Rationale/Research Question to be answered	Main Research Question
Document analysis	Strategies	Economic blueprints, space strategies, speeches, outcome documents for ministerial meetings	How do theoretical and power dynamics shape understandings of the science-development nexus? All questions	**What are the political dynamics of big science initiatives in Africa?**
Interviews	Government Ministries, Departments and Agencies	8	To what extent do 'big science projects' in the developing world consider the ontological concerns of the social sciences?	
	Local leadership in Kuntunse (Chiefs, Councillors and Member of Parliament)	3	How do the SKA and DARA projects engage with issues of gender, class, power, and inequality in Ghana?	
	Private Sector Firms/Companies (downstream astronomy applications)	5		
	National, Regional and International Organisations	5	What are the implications of large-scale science projects on the ontological security of African societies? To what extent do the SKA and DARA projects contribute to narrowing the knowledge and power divide between the Global North and Global South?	
	SKA and DARA Representatives	5		
	Universities and Research Institutes	5		
	PhD Students	4		
	Master's Students	4		
	Basic Training for Physics Graduates	4		
Total No for Interviews		**43**		
Meetings Observed		4		

Note: The link between data collection method and research question was not casting stone and some issues were cross-cutting among the respondents. All the questions combined help to answer the main research question. The numbers of interviews were mainly determined by time, availability of respondents, and cognisant of the point of saturation in qualitative data collection.

3.5.4 Typologies of power in data collection

During data collection, power is constantly negotiated and constructed between participants (Thornborrow, 2014). Fairclough defined power in research as synonymous with controlling contributions of non-powerful participants in discourse by powerful participants (Fairclough, 1989). In the context of interviews there is bound to be dominating views and suppression of others' views (Wang, 2006). Power during interviews was derived from socioeconomic status, educational attainment or professional background, political standing and identities of research participants Lukes identifies covert and overt power shifts (Lukes, 1974). During the interviews power was overtly displayed where some interviewees would make attempts to indefinitely postpone the interview, discontinue the interview and showed reluctance in answering some of the questions. The other dimension of Lukes' faces of power is agenda setting, where powerful respondents especially with higher positions in government and heads of institutions tried to change the questions forwarded to them so that they are 'politically correct.'

During the interview some key informants would rebuff the researcher in many ways so that questions in a certain category are not asked and this Lukes referred to as deterrence power. In this way, attempt is made to control the context and scene of the discussion and the interviewer is somehow disempowered. There are also scenarios where the interviewer assumed the power by swaying the discussion away from what the respondent wanted to focus on which was deemed out of scope of the research. This is how power oscillated between interviewer and interviewee. However, the researcher noted how interviewees could shy away from these power dynamics and merely say what I wanted to hear. This same observation was noted by Kvale (2006) who asserted that during fieldwork respondents talk about what the interviewer wants to hear than what is asked. Follow up interviews and informal meetings with respondents in a relaxed environment were done to ensure the information was balanced and to seek additional insights.

3.5.5 Data Management and Storage

Data collected through the interviews was transcribed, stored, and uploaded on the University of Leeds server. A field diary was used to record notes and observations of

specific phenomenon important to the study. Field notes are categorised into two components, descriptive information, and reflective information. Labaree (2019) refers to descriptive information as factual data (time, date, physical setting, social environment, descriptions of research participants, and impact of researcher on the environment) and reflective information is the researcher's reflections about the setting and participants (it can either be further questions, concerns, and other related thoughts). The field diary was an important asset in the analysis of data and formulation of themes.

NVivo version 12 (latest version so far), a qualitative data analysis software was used based on its ability to analyse both audio information and text as well as discourse analysis. During fieldwork the university rules and regulations on data protection were upheld and the general research ethics. All data collected that is field notes, audio files of interviews was secured through use of passwords and locked in filing cabinet accessible to the researcher and permitted individuals. Respondents were protected by anonymising the data and not mentioning any identifiable information, such as names. Prior to the fieldwork the study received a favourable ethical opinion from the University of Leeds Ethics Committee (letter of approval attached in the appendices).

3.6 Discourse Analysis

Discourse analysis was used mainly to answer the main research question. Both SKA and DARA SKA claims that science has the potential to transform nations economical and socially. The following is an extract from the SKA website that point towards the immense contributions anticipated from the project.

> SKA Project is expected to deliver significant benefits for Member States' research landscape, economy, society, sustainability, and culture. These impacts span industry research and innovation, human capital development, inspiration and education, geopolitics, and diplomacy. (https://www.skao.int/en/resources/402/key-documents)

DARA on the other hand also make claims of investment in science as a key ingredient for development.

> Radio astronomy encompasses all of the science, technology, engineering, and mathematics (STEM) skills that underpin the emergence of a strong developed economy. (https://www.dara-project.org/)

The interventions by SKA and DARA in the developing nations have a power dimension that the only pathway for development in the Global South must follow the modernisation template and that partly gives a clue to the position they enjoy in development discourses. Lata supports this point when she highlights that there is a 'historical tendency to privilege science and technology education and knowledge to foster development……. inextricably linked to power' (Narayanaswamy, 2017: 5). The claim of development creates a discourse about the discursive power of science to stimulate 'development.' In this thesis, the technical capability of scientific knowledge brought to Third World countries to spur development is analysed in relation to addressing development aspects of class, power, race, and inequality. The advantages of using discourse analysis for a topic that analyses power imbalances and politics behind science is that these are not simple issues which are clear on the surface, they require the researcher to unmask the motivation behind the speech or text, to understand the undertones of a spoken or written speech putting the historical and social contexts (Shaw and Bailey, 2009). Few studies as noted in chapter two have employed discourse analysis in big science projects.

A discourse consists of ensemble of ideas, concepts and categories through which meaning is produced and reproduced in a particular historical situation (Sandra Halperin and Oliver Heath., 2012: 309). Foucault defines a discourse as "ways of constituting knowledge, together with the social practices, forms of subjectivity and power relations which inhere in such knowledge and relations between them." Elements of a discourse are brought to focus through the analysis of language, latent meanings in text and conversations found in the variety of written, oral, and visual 'texts. Discourse analysis was used to handle all the 'developmental' claims of SKA and DARA. Discourse analysis was also used to answer the key sub-questions on

power relations in SKA and DARA, Global North, and South political dynamics as well as local power dynamics in Ghana. The study used existing information about the project which involved Ghana's specific national development strategies, SKA and DARA documentation, reports, and event speeches. The existing information helped to catalogue all the 'development' claims made by the SKA and DARA projects. Since, the study is also looking at power relations, developmental claims made constitute a discourse.

The thesis analyses the public speeches made by government officials in the media and from official documents, SKA Management in Africa, private firms and universities, South Africa as the lead country in the bid to host the SKA and from Ghana as well which formed the basis of subsequent action on the project. In terms of a time frame, the thesis looks at conceptualisation of the SKA project phase in 1993 up to 2021. The year 2012 has special significance to the project specifically because that is when it was announced that South Africa and partners including Ghana won the co-hosting of the SKA project (Gastrow, 2015: 1). As for the DARA project, the period for analysis is also considered from 2014 to 2020, since the human capital development started in 2014 in Ghana although it used funding from the Royal Society and DARA took over in 2018 but the training is the same. The current DARA funding comes to an end in 2021 with prospects for renewal or extension.

The analysis of the discourse makes use of both inductive and deductive coding. Inductive analysis refers to approaches that primarily use detailed readings of raw data to derive concepts, themes, or a model through interpretations made from the raw data by an evaluator or researcher while deductive analysis refers to data analyses that set out to test whether data are consistent with prior assumptions, theories, or hypotheses identified or constructed by an investigator (Thomas, 2006: 238). Inductive coding begins with close readings of public speeches and other official documents considering multiple meanings that are inherent in the text. The researcher identified text segments that contain meaningful units and created a label for a new category to which the text segment is assigned. Additional text segments were added to the categories to which they are relevant. The coding adapts the six stages by Boyatzis which include: developing the code manual; testing the reliability of codes; summarising data and identifying initial themes, applying template of codes and

additional coding; connecting the codes and identifying themes and lastly corroborating and legitimising coded themes (Boyatzis E, 1998).

3.7 Generating themes for analysis.

In qualitative research, the researcher is often described as the research instrument in as far as the ability to understand, describe and interpret data to uncover meaning (Maguire and Delahunt, 2017). Thematic analysis was used to generate themes for analysis of data. Thematic analysis can be defined as a way of identifying patterns or themes within qualitative data (Braun and Clarke, 2006 cited in Maguire and Delahunt, 2017: 2). Two levels of themes usually emerge in qualitative research, semantic and latent (Braun and Clarke, 2006). In semantic theme, the researcher is not looking beyond what the interviewee provides while latent level looks beyond what has been said and 'identifies underlying ideas, assumptions and ideologies that undergird the semantic content of the data (Braun and Clarke, 2006: 84). The researcher adopted Braun and Clarke six step method of generating themes. The first step was of getting familiar with data, (2) generated initial codes, (3) searched for themes from NVivo generated data (4) reviewed the themes, (5) defined the themes, and (6) started the writing up. Generation of themes was more biased towards latent level where the thesis explored the underlying assumptions and ideas of respondents around big science infrastructures and development.

3.8 Shifting power at analysis stage.

At the data analysis stage power seems to return to the interviewer. The researcher tells the story in a new historical and socio-cultural context (Karnieli-Miller *et al.*, 2009). The opportunity and power to work with the interviewee or co-opting them at the writing stages resides with the interviewer. The interviewer has some privilege of interpreting and reporting what was meant by the respondents, considering the power that interviewees yield at data collection stage for instance not answering some of the questions (Kvale, 2006). Generally, few researchers give interviewees an opportunity to have the final say on what to report and what interpretations to present in their studies (ibid). However, some scholars such as Holstein and Gubrium (2004) argues that interviewees can add meaning construction rather than contaminating the

meaning construction, therefore interviewers need to be cautious when reporting their findings.

3.9 Positionality Statement

The data collection and analysis of this thesis should be read within the confines of the researcher's positionality. My position as a Zimbabwean from the Southern part of Sub-Saharan Africa, studying at an elite university in the Russell Group of Universities, United Kingdom and conducting research in Ghana, gave me an outsider status. The notion of conducting research at home tends to imply that researchers are insiders, whereas those conducting research away from home are considered outsiders (Bhattacharya, 2007; Breen, 2007; Court and Abbas, 2013; Hill, 2006). My status as an outsider researcher in relation to participants in Ghana inevitably influenced all aspects of the research process including research design, access, data collection and interpretation. As an outsider there are hurdles of credibility and approachability. In terms of credibility, I established myself as an academic professional researcher worthwhile to invest time through evidence of institutional affiliation with University of Leeds and ethical approval letter. One of my co-supervisors had a project in Ghana which assisted in establishing academic credibility within the researched community. However, this may have affected the responses given by interviewees especially those linked to the project. As a stop gap measure, I kept a Field Diary where I logged all my interviews, made reflections upon them, and made follow ups to get clarity on some responses.

As someone who has worked as a research coordination manager/deputy director for a national research council housed within the President's Office, I bring a unique perspective to the thesis on big science politics. My experience working in this role has given me first-hand insight into the complexities and challenges involved in managing large-scale research projects and the nuances of those involved in the projects. Prior to commencement of my PhD studies, I worked with our board to establish the Zimbabwe National Geospatial and Space Agency (ZINGSA) from 2016-2018. The work gave me a practical experience of debates that come with such large infrastructure projects and societal expectations.

Additionally, my positionality as someone who has worked closely with policymakers at the highest levels of government has allowed me to develop a nuanced

understanding of the political landscape in which big science projects operate. This understanding has informed my research, allowing me to explore the ways in which political considerations can shape the development and implementation of large-scale research initiatives.

Overall, my positionality as a research coordination manager/deputy director and someone with experience working in both scientific and the political spheres has equipped me with the knowledge and perspective necessary to make valuable contributions to the study of big science politics.

During fieldwork I remained approachable despite that background. Approachability of the researcher refers to the presentation of a researcher to the researched audience as non- threatening and safe (Mayorga-Gallo and Hordge-Freeman (2017: 381). The success in getting access to the researched is enhanced if the researcher "enters negotiations armed with connections, accounts, knowledge, and courtesy" (Lofland et al., 2006: 41). My position as an outsider to Ghana made me employ a socially acceptable incompetent strategy in which I took on the role of someone who was "ignorant" and therefore needed to be "taught" things that may even appear obvious without taking offense. This strategy assisted in getting the most out of the interviews.

As a male researcher, my position regarding gender issues and power dynamics in science can affect the responses and how I will deal with female scientists or respondents. My presentation to research participants avoided being labelled as 'one of the boys' perpetuating underrepresentation of women in science. Though the research was not going to delve into sensitive issues, as a researcher I gave room for such matters to arise in one way or the other and due care was invoked on the questions, degree of probing and a limit to 'shared' experiences.

3.10 Limitations and adaptation of methods during Covid-19

The Covid-19 pandemic has had a significant impact on the scope of the study, research methodology, and the conditions in which data collection was conducted. The scale of the study initially was to explore political dynamics policy levels right up to the local communities. That meant taking an ethnographic approach, staying in local areas around the telescopes and having conversations with the people. With the implementation of lockdowns this scale was reduced to higher levels. Social

distancing measures, and restrictions on in-person interactions meant that I had to adapt research methods to comply with health and safety guidelines. At the same time on my part there were added roles in terms of home schooling and the psychological effect of staying in same place performing academic and household management at once. This had a psychological impact as well. One major impact of the pandemic on research methodology has been the shift towards remote research methods. I had to rely more heavily on online or virtual interviews, and digital data collection tools to collect data. This shift has not only made research more accessible to a wider range of participants but has also allowed researchers to reach individuals who may have been difficult to engage with in traditional research settings.

Most of the interviews were contacted via Skype. Skype was chosen because of its voice over internet protocol which allowed contacting research participants in synchronous (real-time) connection and the ability to record the interview. Skype option saved a lot in terms of fieldwork budget, convenience, and flexibility of scheduling the interviews. Creating rapport with respondents was relatively easy but involved a lot of email exchange, first from introductory emails from supervisors and the second tier of myself setting up the meetings with the key informants. The downside of the Skype was connectivity issues. Interview participants were less worried about time and the tendency to share a lot of information was noted which one may not have on face-to-face interview. In some skype interviews interruptions were experienced due to internet challenges and would often cut the interview and reconnect again. The head and shoulder interaction on Skype could not capture the full body language, gestures and posture which could bring a rich experience and meaning to the data collected. Bayles (2012: 578) contents that in a head and shoulders presentation via Skype we lose the full range of postural, gestural, and expressive movement that the body conveys, as well as the intentionality that is carried and expressed in that movement.

Recruitment of participants through door knocking provides the researcher with the opportunity to apply his/her ethnographic imagination to the entire research process, from choosing areas to focus on and getting the bus to and from leaflet drops to meeting residents and arranging interviews (Davies, 2011: 292). In this case the research knocked virtual doors where professional profiles on social media platforms

such as LinkedIn were used. The use of social media platforms to perform research experience a boom during Covid 19 pandemic restrictions. LinkedIn platform was mainly used in this study LinkedIn is more of a ‘professional’ platform where people can control how much of their profile to show to the public and to connections (Skeels and Grudin, 2009). The belief is that members can explore the direct connections of their connections. The platform was interesting in the way the researcher was able to connect, communicates and manage to broker interviews with people who ordinarily would find difficult under normal circumstances because of their professions. LinkedIn enabled me to keep a relationship with some of the key informants alive because of awareness of others’ activities. I would occasionally review connections and see their activities. Sometimes throwing a congratulatory message for milestone achieved by connections was a gesture, a reminder of past shared experience that reaffirmed interest. That way respondents were more willing to schedule interviews.

It was not possible to investigate the impact of the SKA project to the local communities in Ghana especially the area around the Kuntunse telescope. The local community voices could have strengthened the analysis on how development is construed at that level and the expectations from the big science infrastructure installed in their vicinity. Though the researcher managed to scrounge for these local voices from social media platforms like YouTube and news articles they were not robust enough to understand the underlying nuances. Such work, the researcher intends to pursue when preparing to covert the thesis into a book and journal articles.

3.11 Conclusion

The chapter has given an overview of the research paradigm, research design, data collection methods and the analysis of data which resulted in following empirical chapters. Evidence from the chapters is anchored on the methodology used. This chapter also gave the positionality of the researcher in relation to this study, the professional work on national innovation systems and research management that he has been exposed to prior to this PhD which makes some of the arguments to be based on experiences rather than just information from research participants. The study employed a constructivist research paradigm and qualitative data collection methods to explore the complex nature of big science infrastructure projects in

developing countries. The study utilized a range of data collection methods, including secondary document review, key interviews, meeting observation/ethnography, and discourse analysis, to gain an in-depth understanding of the phenomenon under investigation.

The use of a constructivist research paradigm facilitated the exploration of multiple perspectives and interpretations of the research phenomenon, allowing for a nuanced understanding of the research context. Furthermore, the use of qualitative data collection methods enabled the capture of rich, detailed data, which facilitated a deep exploration of the research phenomenon. Secondary document review was particularly useful in providing context and background information about the research phenomenon, while key interviews provided valuable insights from key stakeholders. Meeting observation/ethnography, on the other hand, facilitated an understanding of the research phenomenon in its natural setting, and discourse analysis enabled an exploration of the underlying power relations and discourses shaping the big science and development nexus.

In combination, these data collection methods provided a comprehensive and holistic understanding of the research phenomenon, allowing for the identification of key themes and patterns in the data. The use of multiple methods also facilitated a validation of the findings and increased the reliability and validity of the research. Overall, the use of a constructivist research paradigm and qualitative data collection methods enabled a rich exploration of the research phenomenon, providing valuable insights into the complexity of the research context. The findings of this study in the coming chapters have important implications for theory, practice, and future research in the field, highlighting the importance of considering multiple perspectives and utilizing a range of data collection methods in research.

Chapter 4
Big Science Assumptions and Development

4.1 Introduction

The chapter focuses on the assumptions underpinning investment in ST&I, specifically big science astronomy infrastructure projects and how it links with development in Africa. The meaning of development to people making connections between big science like astronomy to development is one of the questions that runs through the discussion in this chapter. In the SKA and DARA projects astronomers project that their work will have a broad-based development impact. The chapter argues that the frequency of space science in the development discourse is influenced by modernisation and its assumptions of developing nations' challenges that are reduced to technical challenges. The chapter answers one of the key research questions of the thesis on what assumptions underpins SKA and DARA investments to aid development in Africa.

There is a gap in literature on assumptions made by radio astronomy and space science in constituting big science projects, associated human capital development projects and collaborations in Africa. There are general assumptions about science and development. Kaplan suggested several assumptions but four of them apply to the projects under study which are (1) development is created and engineered by technical intervention and training brought for others by those who are more developed; (2) the practitioner works from their understanding of the world rather than the others; (3) this initiates the 'development project' which is short term, time bound and limited in resources; (4) assumes knowledge will create change and takes less account of culture, traditional processes (Kaplan, 1999).The assumptions by Kaplan were arguably generic to any development project initiated in communities. This thesis identifies and applies specific assumptions made from the two projects (SKA and DARA) and how they can help in understanding rationales accepted as 'true' connections between big science and development. Such contextualisation of big science assumptions is missing in literature.

The chapter is organised into three main parts. The first part identifies the main assumptions inherent in big science projects and how they relate to SKA project in

Africa. The following development assumptions were identified: (1) Africa's development challenges are technical and can be fixed by big science infrastructure projects; (2) Training given to individuals and building science infrastructure will translate into development (3); Scientists understand the social needs of the countries of operation, and (4) Innovation systems of the countries of implementation are coherent and have high absorptive capacity for knowledge generated.

The second part is about space science and development. The science-development nexus gives radio astronomy and space science a privileged position in the development discourses in Africa. The chapter argues that the modernisation assumptions in development gives space science a special place in the development discourse. The third part identifies key achievements that the SKA and DARA projects have registered to date in their implementation and potential impact.

The chapter concludes that assumptions about big science and development valorise disciplines such as astronomy and space science and help them occupy a position of centrality among the top priorities of solutions in the development discourses. Modernisation and linear development thinking influence assumptions on big science even though contexts in developing countries are not the same as developed nations.

4.2 Theoretical underpinnings of the development assumptions

The overarching idea behind the big science -development linkage is the view that: development as a concept is meaningful and science is neutral-. All the four assumptions sit under this bigger framework This ideation setting is at the core of analysis and constitute the main argument of this thesis that big science uses development as an agent to legitimate itself. Defining development brings in power dynamics with those already convinced to be developed helping those developing. There are different ideas about what 'development' looks like (Adams, 2009: 7-8) and it is regarded as a process rather than an outcome. Development is dynamic in that it involves a change from one state or condition to another and is often regarded as something that is done by a certain group to another. This invokes a political process, raising questions about who has the power to do what to whom? Development remains an ambiguous and elusive concept, 'a Trojan Horse of a word' (Frank, 1987: 231), meaning a term that can be filled by different users with their own meanings and intentions. Howard described development as a 'slippery value word' (Howard, 1978:

18) that can be used by ‘persuaders’ (such as politicians or planners) to sway people in the direction they want them to go. Advocates of big science make explicit use of many meanings of the word ‘development’ to justify existence.

> Global mega science infrastructure such as the SKA drives development especially in Africa where technology gap is huge. Our backwardness in science is a cause for our situation in terms of our economy and development status. Economies are being sustained by advances in science and astronomy provides an open environment for several beneficial innovations. (Astronomer, Ghana)[1]

This statement from the astronomer in Ghana combined with other quotes from assumption one to four gives an impression of development as a meaningful term in the sense that it can easily be understood and discerned upon. As noted by Frank, the term is elusive especially in the developing world where there are so many challenges to overcome. The discourse of development promotes specific interventions in people’s lives, and does not hang in an academic abstract, but is inextricably linked to sets of material relationships, to specific policies and to the exercise of power (Crush, 1995). Mega science projects embody multiple, cross-cutting understandings of ‘development’ that arise from different historical, political, and socio-economic contexts that they straddle as well as the reflexive practices entangled in defining ‘development’ (Walker and Chinigo, 2018: 1980). The next part of this chapter explores different meanings of development from the understanding of respondents.

The SKA project makes strong claims of connections between astronomy and development. Respondents from key informants to beneficiaries of the studentships were asked their understanding of development. There were different meanings of development among the respondents and there was no consensus to one single definition. However, the different understandings of development fell into the domains of already established theories of development e.g., modernisation, neoliberalism, and

[1] The astronomer in Ghana was one of the central people in driving the SKA and DARA projects and an advocate of science for development. He holds influential positions in the national ST&I System

the SDGs framework. The diversity in the meaning of development shows the complexity of linking and attributing certain actions as part of the concept. The following section gives the different assumptions, understandings, and definitions of development from the research participants and how they were linking science to the development process.

4.3 Big science assumptions for development

Assumption 1: Africa's development challenges are technical and require a technofix.

The first assumption is that Africa's development challenges are technical and can be fixed by big science infrastructure projects. The portrayal of subjective 'backwardness,' 'underdevelopment,' and general 'lack of progress' in the Global South has been attributed to weak technological advancement in the region (Fabayo, 1996; UNCTAD, 2003; African Development Bank, 2014). Therefore, poverty and other challenges have been reduced to technical problems that require a technical fix and science is viewed as a 'silver bullet' that provides the most efficacious solutions. This assumption gives rise to a tension in the development process pertaining to the role of science, technology, and innovation that any technological innovation is flouted as a quick fix solution to multi-layered and complex problems (Smith, 2005: 648). The instrumental effect and potential use of knowledge and ripple effects in the economy can be underestimated, overestimated, or misunderstood due to a mismatch between project level ambitions and the contexts within which knowledge and technology are generated, diffused, and applied. The SKA project in its justification in terms of benefits to the countries involved and at global level mentioned this on their frequently asked questions section of their public website.

> Mega science projects such as SKA have the potential to seed or boost significant technological development, enhance capabilities and efficiencies across myriad industrial and educational sectors, as well as generate economic and social benefits to society. (SKA Website FAQs section, accessed in 2019)

Key informants interviewed echoed the same sentiments about science as a technofix to Africa's development challenges. The way SKA explicates development seem to

lean towards modernisation as reflected in the following extract of the interview with a senior member of management.

> The demands of the SKA will help drive technology development and contribute to and be a stimulant for invention and innovation within global industries. In conjunction with market forces, they will lead to benefits to society that will be widely applicable in other established fields and will begin even before the astronomical discoveries that will eventually be made using the telescope. Countries that participate in the SKA could reap considerable socio-economic benefits by participating at the forefront of these developments. (SKA, Director Corporate Strategy)[2]

In Ghana, among the academic community driving the DARA project, they also conceive science and technology as a solution to help the country and the continent achieve its development aspirations. In an interview with a lecturer at one of the premier universities in Ghana, she said.

> There is more that comes after doing the job and in this case investing in science and technology. The work itself in science such as the DARA project will bring development in some way to the people of Ghana and the whole continent will benefit. (Lecturer, University of Ghana)[3]

There is a consensus among the key informants that science and technology is a solution to the development of Africa. The project level ambitions of the SKA and DARA projects are to build scientific capacity for the African continent and there is no doubt that this needs to be done but the developmental needs of the continent are not homogenous let alone individual countries.

Majority of respondents identified development as a technical process which was not a surprise given the Western ingrained pathways of 'progress' anchored on predetermined stages that countries pass through and that scientific thinking and capacity are important for transition to take-off following Rostow's development stages

[2] SKA Director of Corporate Strategy is an important position of the SKAO in terms of formulating the long-term strategy of the organisation and its international relations portfolio. He was instrumental in the transition of SKA from a private organisation to an international governmental organisation.

[3] The university lecturer in Ghana is a prolific scientist in atmospheric physics and a politician in the opposition, strong advocate of science for development and empowerment of women who once contested to be a member of parliament.

(Chirot and Hall, 1982). The basis for this thinking is that the problems faced in developing countries are due to lack of current or latest technology and the skills to utilise it. Otherwise, what is needed is just investment in scientific knowledge generation and skills or adopt already made technologies and apply into the economy which is a straightforward process. Sentiments from participants in the DARA project pointed towards modernisation as a hallmark of development. The following are quotes from interviews.

> Development means being modern like developed nations out there, and science is part of the solutions to the process. A country cannot develop without a sound science system that enables its economic growth. (DARA Basic Training Student)[4]

> To me development is about possessing and having the capacity to use high end technologies. The ambience of a developed environment and economy is felt through its science and technology and Africa especially our country Ghana must do a lot for science because it is our saviour. (PhD Student, Ghana)[5]

The modernisation bias of development brings the underlying unequal power dynamics and tension in terms of which part of the world is developed and that which is not. Modernisation argues that development is largely economic, and the same development path should be taken by all countries. In the case of the Global South, that development must be brought by the Global North through sharing the benefits of the 'bottomless' scientific and technical knowledge as enshrined in the Truman 1949 speech (Truman 1949 in Escobar 1995: 3). The aspirations by students for Ghana's course of development that is rooted in the Eurocentric approaches fails to recognize diversity, needs and expectations of local populations which shall analysed in the next chapter. The next related assumption looks at the relationship between individual skills and the innovation system.

Assumption 2: Training given to individuals and building science infrastructure translate into development.

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[4] The DARA Basic Training graduate was based in Ghana and had undergone a training by the project waiting to apply for a master's program in the UK.

[5] The PhD student in Ghana was a beneficiary of the DARA project and was working for the GSSTI responsible for the management of the Ghana Radio Astronomy Observatory.

The second assumption is that scientific knowledge distributed to individuals alone through the human capital development in research and constructing big science infrastructure without significant parallel investments into socioeconomic and political structures of the innovation system will translate into development. The impacts of human capital development are projected to reverberate in different sectors of the economy and the proponents of the project are convinced with that impact pathway. The SKA Development Office in 2010 and DARA project justified the investment in astronomy HCD in the following statements.

> "The SKA can provide long-standing benefits, proportional to the long-term investment it requires. The construction and operation of the SKA facilities will impact local and regional skills development in science, engineering, technology and in associated industries." (Crosby and Bowler, SKA Program Development Office, 2010)

> Big science — and the home-grown scientists that do it — can inspire future generations to study science. It is a simple equation: more scientists are good for an economy. Of course, not all those we train will become radio astronomy researchers. But the technical knowledge and additional skills they gain will open many other avenues, all of which can benefit them as individuals and the country. (Prof Melvin Hoare)[6]

The statements from the SKA and DARA projects point towards a simple connection of technical knowledge and development. The connection is firmed up by the current wave towards 4th Industrial Revolution where Africa needs to strategically position itself and invest in skills that are critical to participate in this revolution which is data intense, and technology driven. Developing capacities in these areas was viewed as getting ready for the future and realisation of industrialisation and development blueprints. In an interview with a key informant who is also an astronomer, she said.

[6] Prof Hoare is the principal investigator and lead scientist of the DARA project with a prolific profile in astrophysics and was instrumental in the human capital development in the eight African countries participating in the SKA project.

> The development needs of the 4th Industrial Revolution especially in Africa where major development blueprints such as the SADC Industrialisation Strategy and Agenda 2063 have acknowledged the role of science requires certain skills set such as big data manipulation and engineering which astronomy is bringing. (Astronomer)[7]

Intrinsic to this capacity building of individuals and building science infrastructure is a notion that there is a straightforward progression from scientific research (knowledge production) to innovation (its application into new technologies) and to development (economic and/or social) (Mormina, 2018: 6). The input to the chain in the form of trained scientists will result in greater knowledge production, more and better technological innovation and faster development (Mormina, 2018). The belief with building capacity to individuals is its link to human development and capability which they can diffuse into the economy and prime the development process. Tied to this linkage is another assumption that the individuals who acquire the capacity have knowledge about the development needs of their contexts which is the basis of assumption three.

The capacity building of individuals largely draws its inspiration from the Sustainable Development Goals (SDGs) framework, which is a global development target adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 the world enjoys peace and prosperity (UN, 2015). The achievement of these goals position science at the centrality of facilitating each goal laying the knowledge foundation for a sustainable world. Research participants linked the SKA and DARA projects to the SDG framework and defined development in that regard.

> Our project in astronomy and space science is addressing the Sustainable Development Goals, especially Goals number 4 (Quality education), 9 (Industry, Innovation, and Infrastructure) and 17 (Partnerships for the goals). To us development is about achieving the Sustainable Development Goals which are universal whether you are coming from a developed or developing

[7] The astronomer is also a co-principal investigator of the DARA project working on the big data analytics and artificial intelligence.

> country our role is to assist those countries with the capacity needed. (DARA Project, UK)[8]

The SDG framework unfortunately falls into the neoliberal approaches to development where the thrust is to view developed nations as assisting developing nations to achieve development outcomes. Analysis of the root causes of the inequalities between the Global North and Global South is missing in the SDG approach to development (Mccloskey, 2020: 84). Hickel pays reference to historical events such as colonialism, slavery, extraction of resources, and erosion of Indigenous people's cultures as inputs for development of the Global North (Galeano, 1973; Hickel, 2017). The suggestion is therefore, to discard the IMF and World Bank narrative that the Global North is developing the South and replace it with 'the colonies developed the North' (Hickel, 2017: 93).

Assumption 3: Scientists understand the development needs of the countries in which they are operating.

The third assumption is that scientists understand the needs of the countries they are operating in and their contexts. Despite the complications of streamlining societal needs in terms of development, evidence from the interviews gave the impression that scientists understand the development needs of their countries. The following extracts of the interviews with an advanced student and practising astronomer point towards the fact that they understand the needs of their society.

> Science, technology, and innovation is at the core of Ghana's development, and I feel as scientists we have the responsibility to help our communities achieve this. We know the challenges and we can research and give the much-needed solutions. (PhD Student, DARA project beneficiary, Ghana)[9]

A practising astronomer in Ghana added that by virtue of living with people they too are alive to the needs of the society.

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[8] The interview was done with a co-investigator of the DARA project based at one of the participating universities in the UK who had an insight into the whole project

[9] The PhD student interviewed was studying in the UK and working in Ghana at the Atomic Energy Commission.

> Besides working on the telescope and in the scientific laboratory I too am a social being coming from a family with needs and living in a society that has challenges which I experience daily and some of it I may have some solutions, but they must go through a bureaucratic system which is politically driven and its high time I develop skills on how to navigate that. (Astronomer in Ghana)[10]

However, in general, science researchers, even when socially committed, do not often have any specific skills that helps them to identify social needs or target their work toward social solutions (Bozeman, 2020). Scientists are more focused on the objectives of their research and what happens after becomes the role of the society to absorb according to their needs. This assumption is central to the question of missing social sciences ontologies in big science projects. Social science ontologies in this context refers to concerns and other factors within the operating environment of the big science projects such as political systems, inequalities, race, culture of the communities, power dynamics between western funded scientists and developing world communities which are discussed in chapter five. Due to missing ontologies in big science, it becomes difficult to complete the development story and role of science advanced by scientists.

The assumption under discussion underscores the appreciation of development needs by scientists for the contexts in which they operate at the same time they assume that the innovation system which they play an integral role is coherent to give solutions. The next assumption explores this postulation of a coherent innovation system.

Assumption 4: Science, technology and innovation systems are coherent and have high absorptive capacity of new knowledge.

The SKA and DARA projects assumes that the innovation systems of the countries of implementation are coherent and have high absorptive capacity of knowledge generated. A coherent system in this case refers to the seamlessly networked nodes

[10] The astronomer in Ghana had undergone the DARA training and was also an inventor who had designed a disinfectant chamber during Covid 19 pandemic and awaiting to patent it

of innovation that complement each other and find support in particular national contexts (Lundvall, 2007). In other words, a system which operates i.e., government, institutions of higher learning and industry working together towards common goals. Absorptive capacity on the other hand is defined as the ability of a system to recognise the value of new information, assimilate it, and apply to commercial ends (Cohen and Levinthal, 1990). The assumption of a coherent system of innovation in Africa is based on the probability that the more governments make significant investments in R&D, the greater the chances to fully appreciate the value of new knowledge. The scientific community especially those close to SKA project in Ghana assumes that the innovation system is coherent and ready for their knowledge. In an interview with an engineer in Ghana who worked on the telescope during its upgrade said

> Our innovation system is ready; it only needs inputs in form of the critical mass of skills from science and massive funding for it to function. The government and industry are always searching for solutions to their problems and innovations such as the ones we offer through radio astronomy can go a long way to help the system function. (Electronic Engineer)[11]

The SKA made a similar assumption on coherence of the ST&I systems for the countries that they are operating in the following statement.

> The Square Kilometre Array, as a large-scale global project at the forefront of science, necessitates international collaboration by scientists, industry, and governments from the earliest stages. It can provide leadership for the development and growth of national and international industry clusters. (SKA, 2010)

The potential of SKA to build national and international collaborations is high and Ghana is one of the countries with established ST&I institutions that form its innovation system and science is crosscutting in the key sectors of the economy. The Ministry of Environment Science, Technology, and Innovation (MESTI) is mandated to coordinate the ST&I policies and the Ministry of Education oversees the national ST&I education policies (Draft Ghana National STI Policy, 2017). The main challenge identified by respondents in the Ghana ST&I system was lack of a robust coordination and

[11] The Electronic Engineer based in Ghana worked on the satellite dish conversion at Kuntunse into a functional telescope who was optimistic of the benefits that can be accrued from radio astronomy.

governance mechanism which impacts the absorptive capacity of knowledge in the innovation system. A science policy expert interviewed expressed issues around weak coordination and poor communication in the following statement.

> Most of the projects do not reach their desired impacts and do not leverage on already existing structures. Projects themselves do not address the genuine issues in the immediate to medium term but they leave a legacy. Sometimes stakeholders are not even aware of projects such as SKA and there is lack of coordination among researchers and those funding them and sometimes people are not willing to share. We have all the institutions but for some reason they are not well coordinated, they operate as silos. (Science Policy Expert, Ghana)[12]

The relationships, partnerships and communication are important components of any innovation system because institutions on their own do does not translate knowledge into development. A researcher in Ghana emphasised the need for dialogue and sustainable relationships in the following quote.

> I can identify three clear communities the research community, operations community, and applications community. SKA and DARA is more of research and operations community but its connection to the applications community is an issue. The people leading development isolate themselves from the science and vice versa. Dialogue and sustainable relationships among the communities is always a challenge. (Researcher, Ghana)[13]

The challenges observed in the coordination and weak relationships reflect bigger issues around the innovation system and governance framework of Ghana and other developing countries in which will be dealt with in the next chapter. The assumption of a coherent ST&I system is influenced by linear development thinking that once the inputs are in place the system works out to produce the desired results (Kaplan, 1999, 2002). Instead, the ST&I system is complex in the sense that relationships and partnerships are political constructs that change over time and in contexts (Smith,

[12] The science policy expert was involved in high level discussions at the inception of the SKA project and sat in national advisory committees on science policy in Ghana. He had an insight into the ST&I system of Ghana.

[13] The researcher was involved in atmospheric physics and closely associated with the SKA project through the working groups on downstream applications of radio astronomy such as weather systems and felt that communication about the project could be improved about its development potential.

2005: 650). As a result, the assumed networked system turns out to be fragmented affecting the attainment of development through science and technology.

The section has discussed different assumptions and how they relate to meanings of development according to the respondents. The fact that they could not all agree on one single standard definition shows how problematic, elusive, and evasive is the term development. The multidimensional nature of the concept makes it difficult to pinpoint what it is and at any given point in time the probability of satisfying all the dimensions mentioned by respondents as expected is minimal. Despite this complexity of defining development, radio astronomy and space science has occupied a sizable portion in the development discourse based on the assumptions and meanings of development discussed in the preceding sections. The next section explores radio astronomy and space science and implications it has on the development pathway for Africa.

4.4 Space science, development claims and perspectives.

The Global Space Industry value was estimated at US$ 360 billion in 2018, with a projected view of growth to US$ 558 billion by 2026 (Global Space Industry Market and Technology Forecast, 2018). In Africa, the industry is estimated to be above USD 7 billion of annual revenues, has a projection of 7.3% annual growth rate and to date over USD 4 billion has been allocated towards satellite development and launch in Africa (*Reports – Space in Africa*, 2020).

Over the past years there has been a considerable increase in space science and astronomy services and products demand from both government and academic institutions due to an upsurge of investments in observatories and telescopes across Africa. An interesting trend is the growing involvement of governments and pledging towards national space projects, creation of new space agencies fully operational for instance Rwanda in 2020 (Africa Space Industry Annual Report, 2020). There are also claims that in the past two to three years Africa has accomplished SDGs projects on areas such as education, reducing inequality, industry innovation and infrastructure with the aid of space technology and applications (Africa Space Industry Annual Report, 2020; OAD, 2018). These claims are supported by the respondents in the previous section who defined development from the SDGs framework.

> Development comes in different angles. Education and scientific programmes are enablers. The economy needs a basis to sit on which science can provide. Social issues are parallel and can be dealt when economy is doing well. (Economist in Ghana)[14]

The African Union which is the supreme body for the continent has come up with an ambitious development blue print dubbed the Agenda 2063 and its aspirations overlaps with most of the SDGs, explicitly SDG 17 recognise the importance of global partnerships to achieve Africa's development ambitions (Alden, 2019). Astronomy presents such an opportunity for global partnerships. The African Union Commission has heightened its interest in space programs as evidenced by the enactment of the African Space Policy and approval of the African Space Strategy as well as plans at an advanced stage to operationalise the African Space Agency. There is also growing interest and strategies by foreign governments on Africa's space industry can be explained in terms of claiming a share on the promising market and, in a way maintain a geopolitical dominance of the sector as a vital diplomatic or military alliance. The Africa Space Industry Report mentions China, European Union, Japan, France, Russia, the United Kingdom, and the United States of America as case studies across commercial, development and diplomatic fronts in astronomy (Africa Space Industry Annual Report, 2020).

> Our narrative on the potential of astronomy is more inclined to economic benefits but the connection is weak at face value. We struggle as astronomers and scientists in general to make a case for blue skies research. (Astronomer, SARAO)

Astronomy from a scientific enquiry lens seeks to answer fundamental questions on human existence and current research focuses on questions like: "How old are we?," "What is the fate of the Universe?" "How unique is the Universe, and could a slightly different Universe ever have supported life?" (Rosenberg and Russo, 2013). A leading physicist in Ghana explained the importance of answering these questions and developmental implications.

[14] The economist once worked in the Ministry of Finance of Ghana and was now into government advisory as a consultant.

> We need to understand our universe, our safety as a country or continent is important to take care of. If we don't do it others will do it for us and we remain behind. We cannot cure hunger and poverty in one day and we cannot stop investments in high end science either because that's a beacon of development (Physicist in Ghana)[15]

The justification for engaging with SKA project from to the scientific community in Ghana was on scientific basis but also with an efficacious ability of science to bring development. The pursuit of such fundamental questions has demanded justification in a world faced with many immediate problems of pandemics, hunger, poverty, energy, and global warming. The main question has been how this purely scientific quest has entangled itself in the development world? The argument for astronomy has been that there are long term benefits that are equally as important to a society which are not only economic in nature, but cultural and indirectly benefit the population in general (IAU Strategic Plan 2010-2020). Astronomy is one of the scientific fields thought to interact directly with society and has always brought development. Among the scientists, astronomers and engineers interviewed the dominant paradigm of development was mainly from a technocratic perspective, linking development to technological advances and knowledge about the universe. According to an engineer from SKA South Africa who was part of the leading team that worked on the satellite dish conversion into a functional telescope in Ghana.

> Development is also about having knowledge about the universe we don't know. To see the development impact of astronomy is a belief and you need politicians who can visualise benefits in the long run (SKA Engineer)

Perspectives of what development looked like differed across the range of respondents.

> To me development means being abreast with technological advancements especially in this era of the internet of things. Astronomy has already played a lot in our lives especially internet. In addition, astronomy has a good way to

[15] The physicist in Ghana was a prominent lecturer in physics and sat on various scientific committees in Ghana and the African continental bodies. The perspective on development was very much focused on science and modernisation as markers of development.

> increase international collaborations that can help the economy.(DARA master's student)[16]

Not only transcending borders, but actively promoting collaborations around the world (Rosenberg and Russo, 2013). During the so called 'birth' of international development post World War II, 1945 onwards, the scientific and technological development of a country or region was deemed to be closely linked to its human development index (HDI), a statistic that is a measure of life expectancy, education, and income (Truman, 1949). Linked to the HDI, the SKA and DARA claim to strengthen the scientific capacity of African countries participating in the projects and by extension the ST&I systems, attract young people to take on STEM subjects such as physics. When asked about their perception of development, a South African Radio Astronomy Observatory (SARAO) who had worked in the Carnarvon Region in Northern Cape where there had been tensions with local communities on land use and expectations from the project commented that.

> Above all the investment in big science infrastructure needs to bring tangible benefits to the communities. We need the communities to be with us and they need to see that development in their day to day lives e.g., schools, infrastructure, hospitals etc. That is progressing towards addressing societal challenges. We have had issues in our SKA South Africa where the farmers in the Carnarvon Region could not understand the value of astronomy in place of their sheep farming (SA Astronomer)

The development construed by astronomers clashed with the development that locals in the farming region expected. While he commented about South Africa he could see the same happening in Ghana where residents around the Kuntunse area visualised development from another lens different from astronomers as shall be discussed in chapter five.

In addition to discourse from the respondents, the thesis analysed a collection of documents that included African Union Agenda 2063, Space Policy and Strategy, SKA and DARA project documents, ministerial meetings for the SKA, country level ST&I

[16] The DARA masters student was from Ghana about to finish her studies at a South African university

policies (Ghana and South Africa), speeches made during events. A total of three continental policy documents, 6 ministerial meeting outcome documents for the African countries participating in the SKA, Ghana ST&I policy, the South African White Paper on Science and Technology (1996) and a sample of speeches (5) made at major events such as award to host the SKA by South Africa in 2012, launch of the Ghana Radio Astronomy Observatory in 2017 and the African Space Strategy in 2017. All the documents were purposively sampled. As part of the discourse analysis, the documents were analysed using NVivo version 12. A Word cloud is a visual representation of word frequency derived from written text (Atenstaedt, 2012). The more frequently the term appears within the documents analysed, the larger the word appears in the image generated. This part of analysis shows the frequency of the word 'development' and other claims in sections of the documents that discuss about astronomy and space science. The first one thousand words from the documents showed that 'development' was the dominant word appearing in the astronomy and space science text showing its exceptional treatment in the development discourse. The context of reference to development in the text analysed is the role of astronomy and space science in aiding Africa's development at various levels national, regional, and continental. Development can be at continental level represented by the word African or at national level through space science. The other words such as national, technology, innovation, space infrastructure, capacity, STI economy, knowledge and industry forms part of the broader claims made by the documents about the links between astronomy and development which have already been highlighted in the assumptions. The following image is the word cloud generated from the documents analysed.

Figure 4.1 Word Cloud of development claims of astronomy and space science

The illustration of development claims through word cloud gives a perspective on how space science relates to broader thematic areas of Africa's development and its position in the political hierarchy which builds the central question of the study on power dynamics in development discourses. These broader thematic areas are addressed in the coming chapters. Privileging space science in a way become part of linear development discourse. The linear development thinking stresses and reinforces the narrative of universal progress emanating from the outcomes of science and technology that underpins modernity (Pieterse, 1991; Buchanan, 1994; Walker and Chinigò, 2018a). This universal narrative of science and development calls for the deconstruction of the development discourse and zoom into the different circumstances and contexts in which big science infrastructures are implemented. But before taking into consideration, the national contexts especially of Ghana, the SKA and DARA projects have scored success stories which can validate potential of science in development which this last part of the chapter enumerates.

4.5 Major Achievements of the SKA and DARA Projects

The projects have registered major achievements during their implementation to date. The achievements noted are arguably according to the implementers' perspectives and key stakeholders driving the SKA. Among the notable achievements include the transformation of the SKA from an epistemic community to an intergovernmental organisation, skills transfer, linking students to industry and science outreach. Each one of the achievements is considered in detail in this last part of the chapter.

4.5.1 From epistemic community to an intergovernmental organisation

As mentioned in chapter one, the history of the SKA began in the 1980s and in 1993 through the International Union of Radio Science (IURS) established the Large Telescope Working Group which was more of an epistemic community of astronomy charged to work on scientific goals and technical specifications of the next generation telescope (SKA, 2019). The term epistemic community in international relations is associated with Haas who defined it as 'a network of professionals from a variety of disciplines and backgrounds with shared set of normative and principled beliefs, shared causal beliefs derived from their analysis of practices, shared notions of validity that is, intersubjective, internally defined criteria for weighing and validating knowledge and common practices associated with a set of problems to which their professional competence is directed (Haas, 1992: 3). Studies have noted several political and economic variables (such as power dynamics and aversion between stakeholders, economic disparities and politicisation of issues) that predicate epistemic communities' input in the decision-making process (Howorth, 2004; Verdun, 2011; Gornitzka and Holst, 2015; Kourtelis, 2020). However, in the case of the SKA epistemic community seem to have managed to manoeuvre these challenges.

The working group transformed in scope through various memoranda of agreements signed among members during the period 1997 – 2011. Beginning 2011 onwards until 2019, the SKA was operating as a not-for-profit organisation and that had limitations in terms of its influence and passing legislation (Wallace, 2020). The nature of scientific work involved in astronomy involves governments in different geographical locations with geopolitical tensions sometimes. Therefore, an Intergovernmental

Organisation (IGOs) would help with transition processes through influencing norms and practices in the policy domains where they have authority (Geels, 2011). In addition, IGOs operate within high level political frameworks that can create rules with impact on socio-technical regimes, defined here as "the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011: 27). The significance of the transformation of SKA from an epistemic community to a non-governmental organisation and now an intergovernmental organisation is a big achievement for the African continent. In February 2021 during the first Observatory Council meeting to mark the establishment of the Square Kilometre Array Observatory (SKAO), solidarity messages from the hosting nations attested to this, particularly from South Africa 's minister of higher education, science, and innovation. He had this to say.

> Establishment of the SKA Observatory enables the SKA project to enter an exciting phase – implementation of cutting edge scientific and technical designs that have been conceptualised by multinational teams, including many South African scientists and engineers, over the past few years. We are excited by the fact that the SKA Observatory will be the first, and only, science inter-governmental organisation where Africa will play a strategic leading role. The SKA project will act as a catalyst for science, technology and engineering innovation, providing commercial opportunities to local high-tech industry, and creating the potential to put Africa on the map as a global science and innovation partner. (Dr Blade Nzimande, Minister of Higher Education, Science & Innovation, South Africa, 4 February 2021)(SKAO, 2021)

The solidarity statement from South Africa's science minister has far reaching effect of rebranding the continent as a hub of science and assuming a strategic role in space. Participation of Africa in the newly formed SKAO is framed as a symbol of African achievement, assertion and validation of African capabilities, and importantly a sign of modernity and membership of the global scientific community (Gastrow, 2015: 17). This framing of achievement builds the ontological security of the continent, and the chapter six will discuss this in detail.

The two other countries United Kingdom and Australia, central in hosting the SKA project also conveyed their solidarity messages which shows the significance of this transition. The following are the messages.

> The SKA Observatory is one of the most ambitious scientific international collaborations of our time which could open unrivalled opportunities for the world's leading astronomers. Today's first meeting of the Observatory's Council, headquartered at the UK's own Jodrell Bank, is yet another pivotal milestone to provide our scientists with access to some of the world's most sophisticated telescopes, furthering our knowledge of the universe. **(**Amanda Solloway, Science Minister United Kingdom, 4 February 2021)(SKAO, 2021)

> Australia is delighted to be a founding member of the SKA Observatory. The Observatory will be a world leader in radio astronomy discovery for decades to come, bringing with it new technologies, human capital development and inspiration for future generations. Establishing the SKA Observatory is the culmination of many years of work and Australia greatly values the strong partnerships forged with fellow member countries during this time. **(**The Hon Karen Andrews, Minister for Science and Technology Australia, 4 February 2021)(SKAO, 2021)

An analysis of the solidarity messages from UK and Australia also points towards the importance of the SKA Observatory in advancing astronomy research globally. The messages are already simulating the level of influence that SKAO as an intergovernmental organisation will have in leading radio astronomy in terms of setting norms that guide researchers and other communities of practice. The level of such an influence is regarded as a major achievement in the history of radio astronomy. Besides the achievement at international level, the SKA and DARA have scored successes at project level in terms of the capacity building initiative targets and the following statistics evidence to that fact.

4.5.2 SKA Human Capital Development Programme

As of 2017, the SKA in Africa produced a total of 815 graduates comprising of postdoctoral fellows, postgraduate and undergraduate students from South Africa and eight partner countries through grants and bursaries under the program (Atkinson, Kotze, and Wolpe 2017: 42). Most of the bursaries (485) awarded were in the fields of physics, astrophysics, and astronomy. The remaining 330 were allocated to the field of engineering (ibid.). The other bursaries were given to the SKA partner countries, in preparation for the envisaged intra-African collaboration when the infrastructures are completed. Ghana received six bursaries; Namibia received sixty bursaries; Zambia 5

bursaries; Mozambique 4 bursaries; Madagascar 31 bursaries; Mauritius 17 bursaries; Kenya 18 bursaries; and Botswana 16 bursaries. Figure 4.2 shows the distribution of the bursaries among the distinct categories of recipients adding up to 815 by 2017.

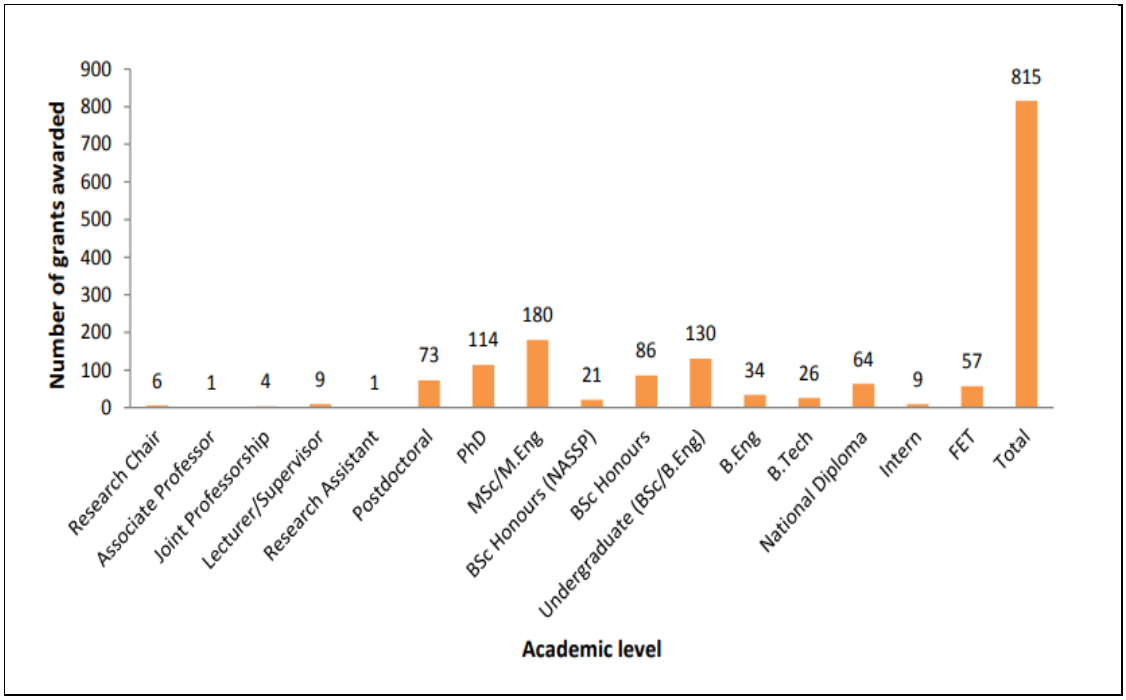

Figure 4.2 Number of SKA South Africa bursaries and grants awarded according to academic level.

Source: Socio-economic Assessment of SKA Phase 1 in South Africa, 2017

The assessment of the impact of the Africa's human capital development programme (HCPD) for the SKA Phase 1 concludes that since its inception in 2005, has produced impressive results. Success rates of students who received a bursary through the HCDP were on average much higher than national pass rates (ibid.). Most of the graduates have gone on to work in academia, for example as lecturers, supervisors, associate professors, or professors building on the critical mass needed in STEM fields. Resultantly, the capacity building programme has "contributed to the creation of an interactive, collaborating, and informed science community now comprising more than 200 practicing radio astronomy researchers in Africa", many of whom currently work for SKA (Atkinson, Kotze, and Wolpe, 2017: 44). The achievements presented are for the SKA programme only but associated projects such as DARA are also contributing to human capital development as indicated in the next section.

4.5.3 DARA Project Success Stories

The DARA project as highlighted in chapter one aims to help create new, sustainable radio astronomy groups across Africa with transferable skills for job and wealth creation (DARA, 2019). DARA provides basic training in radio astronomy and advanced training for masters and PhD study targeting the eight partner countries. Beginning 2014, DARA has trained a total of 362 students as of May 2022. Most of the students (329) are basic trainees, twenty-five are master's students and 8 PhDs. Among the eight AVN partner countries, Ghana has the majority trainees in basic and advanced training since it is the second country after South Africa that has made considerable progress in the SKA project. Most of the graduates are working in their observatories, universities and some have gone on to establish their businesses in fields such as data analytics. The advanced graduates are also participating in the basic trainings currently being contacted in Africa especially in Ghana and Kenya. In an interview with the principal investigator (PI) of the DARA project at the University of Leeds he praised the graduates for work they are already getting engaged in and stated that,

> The DARA graduates are slowly forming research networks among themselves and are assisting in training basic trainee cohorts. Some are even establishing companies which is a good thing in terms of commercialisation, and they are playing a key role in STEM outreach services to schools inspiring the next generation of radio astronomers, especially in Ghana. (Prof.Melvin Hoare)[17]

Based on the comments from the DARA leadership, there are traits of sustainable research networks among radio astronomers which are being formed in Africa though at a slow pace given the research conditions and contexts at national levels. Table 4.1 shows the distribution of trainees by country and type of training beginning 2014. Among the success stories is linkage with industry and commercialisation efforts in the DARA project.

Table 4.1 Number of DARA basic training, masters, and PhD students since 2014. Source: University of Leeds DARA Project Office Statistics, 2022

[17] Prof Melvin Hoare is the principal investigator and lead person for the DARA project in the UK.

4.5.4 Linking students with industry and commercialisation.

The DARA project in its design has an in-built mechanism of linking the students to the industry. Annually DARA advanced students (master's and PhD) meet either in one of the participating countries in Africa or in the United Kingdom at Goonhilly Earth Station to present their work and connect with the industry especially in space science.

Table 4.1 Number of DARA basic training, masters, and PhD students since 2014

Country	Period Operating	Basic Trainees	Masters	PhDs
Ghana	2014-2022	78	6	3
Kenya	2015-2022	62	5	3
Zambia	2015-2022	62	5	2
Namibia	2016-2022	23	1	
Botswana	2016-2022	25	-	-
Madagascar	2017-2022	39	3	-
Mozambique	2017-2022	40	2	-
Mauritius	2018-2022	-	3	-
Total		**329**	**25**	**8**
			33	

The connection with industry in the UK at Goonhilly seemed to be more popular with the students because of the clear connections of their work and industry especially synergies with space communications and radio astronomy. However, students were quick to compare the UK system and their settings, especially in Ghana. The linkage between academia and industry in Ghana was found to be not so strong in comparison with UK. Bartels and Koria in their ground breaking work on mapping and measuring innovation systems in Africa using Ghana as a case study found out that there was a lack of connectivity between universities and industry which had an impact on scientific knowledge's contribution to development (Bartels and Koria, 2015). Despite these weak linkages exceptional DARA students from Ghana pursuing their PhD projects in the UK formed their start-up company on data science aimed at training, supporting government and industry in Ghana. At the time of the study, they had secured funding

and awaiting signing a memorandum of understanding with the Ghana Space Science and Technology Institute (GSSTI) where they will be based. In a follow up interview with one of the students he reported that

> Yes, we have formed a start-up company on data science, and we want to train undergraduates, fresh graduates, and masters students as well as offering consulting services to government and industry on data issues. However, we are cognisant of the fact that science is not yet part of our DNA in Ghana and there is always this bureaucracy associated with dealing with government institutions. As we speak our MoU is still in the pipeline, but I am hopeful we will get there one of these days. (Ghana DARA PhD Student)[18]

In addition to the initiative by the students, the conversion of the Kuntunse satellite dish into a telescope involved local industries in engineering, welding and some skills transfer occurred. The conversion was done by engineers from South Africa with the host engineers in Ghana. In an interview with an engineer who worked on the conversion he gave the following remark,

> We had to learn how to do the conversion ourselves with Ghana industry being involved for example a lot of welding was required and we hired the locals to do it. Engineers in Ghana collaborated with us in many ways to do the job with funding from the African Renaissance Fund. (Mechanical engineer, SKA South Africa)[19].

While these are isolated cases of building relationships between knowledge generators and industry as well as commercialisation, the strength of such partnerships depends on the capacity of the broader economic system to nurture such inter-institutional linkages (Etzkowitz and Leydesdorff, 2000; Smith, 2005: 651), building support mechanisms and governance of the innovation system. Equally important is the understanding of the context and operating environment i.e., the general culture of the people, their needs, and the operating environment.

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[18] The PhD student was studying in one of the UK universities participating in the DARA project and has a soft spot for the project and actively worked with the Kuntunse telescope and GSSTI in Ghana, although his prospects of going back to work in Ghana were limited since he was actively seeking for opportunities in the UK.

[19] The mechanical engineer from SKA South Africa was part of the team helped Ghana to work on its satellite dish conversion building capacity for local engineers. He was very proud of the work they had done in Ghana.

4.6 Conclusion

The SKA and DARA projects have recorded remarkable success in training of radio astronomers and adjacent disciplines in eight participating African countries. Some of the trainees have gone on to form their companies that will partner with the national government in data analytics for instance the Ghana Data Centre to be hosted at the observatory. This impact pathway feeds into commercialization pillar of the DARA project that aims at strengthening academic and industry linkages. Other trainees who have completed their PhDs are working for the Ghana Space Science and Technology Institute (GSSTI) which is a direct transference of skills to the field. While remarkable success has been registered, the study noted that there is still need for investment in the entire system of Ghana's innovation system in terms of funding and governance.

The policies and strategies reviewed for Ghana's science and technology policy, African blueprints on science STISA 2024, Space policies and strategies confirms the exceptional position that big science such as radio astronomy occupies in the development discourse. The influence of Western modernisation and linear development thinking leads to linear science and development discourses.. The SKA and DARA projects have tangible results mainly at output level in terms of developing a critical mass with STEM skills. However, outcomes of bridging the knowledge divide between the Global North and South still requires further interrogation.

Space science is given a position of privilege in the development discourse. This contribution illuminates the pitfalls of discipline focused funding at the expense of other sciences and the whole innovation system in the Global South. Extraordinary focus on specific subjects has potential to neglect other areas that equally needs funding given that development itself is intersectional in nature. Policy making and development strategies that rely on science and technology in Africa have more to learn from using science as a strategy for development without understanding societal nuances. This chapter has also advanced knowledge in big science assumptions and has revealed the world of scientists as they link their efforts to contributing towards development as well as the tensions that arise from such oversimplification of causality.

This chapter has presented the assumptions underlying the drive towards investment in big science such as radio astronomy and space science from the perspectives of

leading astronomers, academics, policy makers, SKA and DARA projects management. Such empirical evidence on assumptions from the ground has been missing in literature. The thesis has contributed to understanding of the background thinking about connections that are made between space science and development. The assumptions are deeply rooted in modernisation neoliberal theories of development which may not match the contexts in developing countries. Capacity building is reduced to strengthening individual scientists' technical competencies through education and training without significant parallel investments to develop and sustain the structures that produce knowledge (Mormina, 2019). The case of Ghana shows that significant investment is required in the innovation system for science to contribute towards development.

Chapter 5

Power, Knowledge Production and Dependency in Big Science

5.1 Introduction

This chapter examines the structural issues identified that revolve around power imbalances, knowledge production and dependency which are suspended in the development discourse and assumptions of scientists in big science projects identified in chapter four. The main argument is that material challenges that preoccupy the Global South makes it difficult to translate knowledge into tangible development. In this argument the chapter engages decolonisation scholars such as Ndlovu- Gatsheni (2018) who interrogates the African post-colonial knowledge production with special attention on the crisis of epistemological, cultural, economic, and political dependencies, as well as Critical Race Theorists (O'Hara, 2022), Delgado and Stefancic (2017) that analyses racialisation of knowledge as the process of determining which social and material conditions are given to people based on race. The argument from Ndlovu-Gatsheni is on epistemic justice where African knowledges and ways of knowing have been relegated by Eurocentric epistemologies and decolonisation should therefore challenge this dominance (Ndlovu-Gatsheni, 2018).

The chapter also engages Foucault who uses the term 'power/knowledge' to convey that power is constructed through accepted forms of knowledge, scientific understanding, and 'truth' (Nola, 1998). He focused on the relationship that exist from language to discourse, knowledge, and power. Chapter 2 discussed how language used in science translate to a discourse of development and knowledge formed and in turn how power is constructed around the accepted forms of knowledge about the process of development. The language and discourses used in development seem to perpetuate existing power imbalances as evidenced by the underlying assumptions of a predetermined development path through science and maintaining hierarchies between the Global North and Global South (Martins, 2020: 140).

This chapter is organised as follows: first it explores the material conditions and challenges prevailing in the Global South in terms of the environment in which knowledge is produced. The chapter proceeds by analysing power imbalances in three main perspectives: firstly, the language used in framing development and the

dominating paradigms, secondly, knowledge production, and thirdly, the dependency of the Global South on the North.

In the process of examining the power imbalances, the chapter critically analyses the contribution of SKA and DARA projects in narrowing the knowledge and power divide between the Global North and South addressing one of the research questions for this thesis. The chapter gauges the extent to which big science like astronomy leads to newly trained scholars and new lines of enquiry that are advanced and African led as opposed to mere integration into European and global science. Other questions addressed are the extent to which big science projects consider ontological concerns of the social science and how SKA and DARA projects engage with issues of race, class, power, and inequality in Ghana. These questions provoke key discussions around coloniality of knowledge production, wider campaigns of decolonising knowledge and enduring dependency of the Global South. The chapter concludes that capacity building of individuals in big science should be accompanied with parallel address of these structural issues if Africa is to realise the projected impact of projects such as SKA.

5.2 Framing development and dominating paradigms in Africa.

The language used to justify human capital projects in Africa is anchored on developing the continent's economy through STEM skills which are believed to be critical for a developed economy as noted in chapter four. There are insinuations of development being brought to the developing settings by the developed. This conceptualisation of development reflects an epistemological perspective of 'progress' as universal in terms of intentions and outcomes (MacKenzie and Wajcman, 1985 cited in Walker and Chinigo, 2018). There is a link to the understanding of history that places the relative stage at which societies are in relation to their science and technology endowments (Marx, 1985). Modernisation from the Western perspective is therefore normalised as dominant paradigm through which the developmental trajectory of societies is to be applied universally (Walker and Chinigò, 2018a). The following quote from the DARA website prescribes training requirements for a developing economy to transform into a developed one.

> Development in Africa with Radio Astronomy, a joint UK-South Africa Newton Fund human capital development project to help drive economic development in Africa….Our training programme engenders a research ethos as well as communication and diagnostic skills that are transferable to many aspects of a developing economy. (DARA Home Page, no date)

The intrinsic assumption in the human capacity development programmes is that lack of technical knowledge is contributing to Africa's status in terms of development. However, archaeological evidence suggest that Africa is resident to the oldest astronomical site, Nabta Playa located in Southern Egypt, believed to be the dawn of modern-day observational astronomy (Malville *et al.*, 2007). This implies that Africa was already practising astronomy and if such technology was a catalyst to development, Africa would have been the most advanced technical powerhouse and most developed place today. The techno-fix approach to development is leaned towards modernisation and neoliberal approaches to development discussed in the preceding chapter. The simplistic view of development from modernisation and neoliberal approaches hides the deep structural issues of global politics in which big science find its space. The invisibilised local needs of Ghanaians for instance, who are the ultimate consumers of knowledge generated from SKA and the kind of development they want to see may not be taken on board and if by any means is considered. The absence of clear and objective parameters for measuring the developmental impact of human capital imbedded in big science projects compounds the situation in terms of attributing the effects of the scientific knowledge and what can be agreed as development. Representations of development from international to local settings are also important to understand the power dynamics underlying big science infrastructures in developing countries.

5.2.1 Representations of international, national, and local development in the SKA Project

In this section the relationship between the Ghana Observatory, the ideas of development from international scientific collaboration and the local conceptualisation development are discussed. The discussion unmasks some of the simmering invisible tensions of the different perspectives and expectations from such big science infrastructure projects emanating from power asymmetries in determining what the international SKA represents. There is general assumption by those implementing the

project that radio astronomy will have wide application and generalised benefits for society. But at the same time there is a caveat on industrial spill overs, where the proportion of funding each partner country has invested in the project will strongly influence sharing of benefits among the companies (SKA, 2019). The approval and backing of the SKA project in Ghana reinforce the international representation of SKA in the development discourse. Tensions to reconcile international and national representations of development are exposed at local level.

The Ghana Radio Astronomy Observatory is situated in Kuntunse 25 Km from the capital city Accra, a residential suburb in the Greater Accra Region under Ga West Municipal District. The station was commissioned in 1981 and operated under the Ghana Telecommunications Corporation up to 2008 when it was taken over by Ghana Vodafone (Asabere et al, 2006). Currently, Vodafone has donated the dish to GSSTI. Prior to the conversion of the dish into a radio telescope in 2017, residents of Kuntunse had already occupied the unused land surrounding the facility (Merron, 2020). Figure 5.1 shows the Kuntunse telescope surrounded by residential buildings.

Figure 5.1 Kuntunse Telescope. Photo Credit James Merron (Merron, 2020:78)

The current operations at the space infrastructure have brewed dispute between Vodafone (which still owns the land), the Ghana Atomic Energy Commission (which oversees the facility's operations), and the people of Kuntunse (ibid). As a residential place, the people had already been allocated pieces of land and some chiefs continue to give land to the area around the telescope. Open spaces near the Observatory were being converted by residents for small subsistence farming pieces of land and anecdotal information which could not be verified on the ground by the study about the area due Covid 19 pandemic suggest further advertisements for residential places was being done targeting Ghanaians in the diaspora. Perhaps these actions are descending voices by the people protesting against 'the asymmetrical power relations that persist allowing state elites and capital to marginalise voices calling for greater equity and social justice' (Beresford, 2016: 2). The kind of development assumed by residents is to have pieces of land, build their houses, access to better amenities such as roads and social services which may not be in synch with development pathway projected by the astronomers in the short-term. At the time of the study there was no law which designated Kuntunse as an astronomy advantage area. The Kuntunse Telescope management had this to say during the interview.[20]

> Our Minister of Science has managed to influence the government to enact a law so that Kuntunse can be left for astronomy purposes but that is still under consideration. The current challenge is that it was built in a residential area, the chiefs own the land in Ghana and the municipality also own the land through the state, land developers are also buying land en masse so there is always tension in terms of parcelling out land. Right now, the surrounding community was encroaching into the observatory, and it becomes political to resolve. However, despite these small challenges the station has brought some development for example the road to this telescope was in bad shape but has been fixed. (Kuntunse Telescope Management).

While the management celebrated infrastructure of the upgraded telescope and the new road, a scan of video clips on YouTube and news articles, though not verified on

[20] The Kuntunse management interviewed consisted of the incumbent in acting capacity and the substantive manager who was on sabbatical leave out of the country. They have tried to engage the Municipality of Ga West about encroachments and have not been able to resolve this and they felt it required a political engagement and process.

the ground indicated that the road was only constructed in 2017 because the president of Ghana was coming to inaugurate the Kuntunse telescope. In another interview with a close associate of the Municipality officials he dismissed sentiments that the road was constructed for inauguration purposes and praised the government

> Our government through partnerships with other developed countries are making significant efforts to uplift this area of Kuntunse in terms of development. The road construction was already in the pipeline because of this satellite and for the people living around. Jobs will be created for local people and local businesses will receive a boost (Kuntunse local leader).[21]

The development of infrastructure to modernise Africa is viewed as a double sword that feeds into the Africa rising narrative but on the other end perpetuating the extractive nature of European modernity (Beresford, 2016) and 'establish dependency relationships between Europe and Africa' that develops the former and the expense of the later (Rodney, 2012, cited in Beresford, 2016: 1) In this case one can arguably say that infrastructure developed is a gateway for extraction of data and knowledge generated through astronomy.

The encroachment to the telescope is not only in terms of building structures but comes in form of radio frequency interference which has always been a source of conflict between radio astronomy infrastructure and community (Agar, 1994: 12-13). Each time residents use a microwave or mobile cellular phone; they emit a signal which distorts the astronomers' data which may be difficult to mitigate. One way to resolve this has been to declare areas around observatories as astronomy advantage areas and resettling the residents. The process of resettling or buying out the residents is not always a smooth one and opens contestations of international, national, and local imaginations of development. This observation was also noted in the Karoo region in South Africa where tensions have arisen between the SKA, other land users and the local community (Walker, Chinigò and Dubow, 2019). Although tensions in Ghana are not particularly visible compared to resistance in places such as Mauna a Wākea (Mauna Kea) in Hawai'i where the local communities have protested the construction of the telescope (Iokepa Casumbal-Salazar, 2017), the learning point for

[21] The Kuntunse local leader interviewed was a close associate of the municipal executive of the area and ruling party (NPP) apologist.

big science is community engagement to ensure development perspectives match and possibly seek social license to operate. Social licence to operate can be defined as the ongoing acceptance or approval of an operation by those local community stakeholders who are affected by it despite having government approval and legal licence to operate (Moffat *et al.*, 2016: 480)

In South Africa, the telescope is in a remote place near a desert in the Northern Cape, Karoo region. The South African government has enacted the Astronomy Geographic Advantage Act of 2007 which grants the Minister of Science and Technology the power to protect areas, through regulations, which are of strategic national importance for astronomy and related scientific endeavours. All these measures by governments to advance 'development' from an international and national perspective does not coalesce with local development expectations. The tensions expose the unequal power dynamics that underlie big space science infrastructural projects. The relationship between Africa and the Global North has always been unbalanced where the interest of the Global North take precedence over African interests (Mostert, Young and Hassman, 2019). The bargaining positions for countries that receive aid is compromised where local priorities are not illuminated during project negotiations.

Negotiating these tensions and community engagement should remain a priority for big science projects. On the other hand, science is also influencing changes in government policies though it takes time but the appreciation for service provision in the Kuntunse area, and declaration of sites into astronomy advantage areas may open opportunities for smooth implementation of future projects.

5.2.2 Individual capacities versus a systems approach

The dominant paradigm of scientific knowledge and development plotted in a linear path is problematic as it overlooks the systemic nature of an innovation system at national level which brings another tension. Scientific knowledge production is practically a collective process. In as much as individuals may possess scientific knowledge through learning, they alone cannot produce it (Cheon, 2014), but must navigate complex interactions with different boundaries (disciplinary, geographic, economic, and political). A science policy expert who has been watching closely the developments in the SKA project argued

> My fear is the narrow focus of our interventions that may look at individual skills set yet research is an ecosystem that involves interactions at different levels for example interdisciplinary interaction, government, industry, and other non-state actors as well as the society at large who are the ultimate beneficiaries of all research outputs. So, as you can see this goes beyond individual skills and is about a system and we need a systems approach if development is to happen in Africa. (Science Policy Expert, Ghana)[22]

The statement emphasises the importance of a systemic approach to the innovation system if development is to be realised. Translation of knowledge into tangible goods and services from a systemic approach is another layer of non-linear relations marked by multiple interactions, feedback loop, success stories and failures (Lundvall, 2007). Therefore, meaningful, and sustainable contribution of science must be linked to the national development strategies and applied holistically at systemic level (social, economic, and political institutions, practices, and norms) not just a few individuals. A policy maker in the national science, technology and innovation system of Ghana buttressed this point during interviews and she claimed that,

> This is a two-way process, while scientific capacity is bestowed upon individuals in an innovation system it should be understood that the same people also form part of the system and it's up to them to ensure that it is capable of absorbing new knowledge and make use of it in development strategies at the same time the system should be flexible enough to embrace the skills. (Ghana Policy Maker)[23]

Governments and industry in a country on the other side need to be aware of their innovation system, its failures, possible remedies, and evaluation of system performance. The combination of instruments and institutions to support ST&I system are always evolving and the more they become, the more complexity is experienced. The complexity of the systems pauses a challenge of governance frameworks that can keep up with the pace of an ever-evolving system. Hence, the thesis attempts to shed

[22] The science policy expert was involved in the development of the national science and technology innovation policy and was actively involved with the Council for Scientific and Industrial Research (CSIR).

[23] The policy maker interviewed sat on advisory panel that advised the Presidential Council of Advisors on science and technology in Ghana and had both political and scientific insights about the national ST&I system.

light on the implementation challenges inherent in innovation policy making in developing countries. On the design front of science policies, weak capabilities may lead to default positions of isomorphic mimicry (Andrews, Pritchett and Woolcock, 2012; Cirera and Maloney, 2017) which simply means importing organograms and practices that may not address the local issues. During the interviews a key stakeholder of the science policy working in the civil society central in advocating for increased funding by government summarised key issues around Ghana's science policy and its evolution.

> We drafted a science and technology policy around year 2000 and it was not adopted by government and in 2009 the Ministry of Environment, Science, Technology, and Innovation with the help of some UN agencies reviewed the policy and recently in 2017 we reviewed the policy again. My feeling is that the institutions who were assisting us like UNACTAID and World Bank have predetermined templates which are like one size fits all and because our capacity is limited in terms of science policy and resources our government just agrees. (Civil Society Representative, Ghana)[24]

Reflecting on the statement by the civil society representatives in Ghana, frameworks and science policy instruments that are meant to facilitate development should be tailored to local context. Experimentation and evaluation of these frameworks to generate the greatest functionality tend to be an exception rather than the norm (Cirera and Maloney, 2017) where the government just adopts the predetermined templates of science policy. It is therefore imperative that the implementation of science policies needs appropriate tools, management quality, coherence, and consistency of application over time (Ibid). In Ghana, policy is developed by a government ministry and in many cases as noted from some sentiments by key informants, there are weaknesses in the system that needs simultaneous investment with the training being offered. This means that besides the training and infrastructure for science, the governance of the innovation system itself needs capacity building as well. An atmospheric physicist working closely with the DARA project interviewed in Ghana affirmed,

[24] The civil society representative was a leader of non-governmental organisation running a tech hub in Kumasi, Ghana

> The usefulness of the skills gained from astronomy are enormous but that needs people who think outside the box to connect the dots for the benefit of the economy. Everybody works in silos, there is no optimisation of resources and sharing of information to create synergies that will benefit the economy. So, we need institutions that enhance uptake of such good projects like SKA in our economy. (Atmospheric Physicist, Ghana)

Previous studies for example a study contacted in 15 science granting councils (SGCs) who are examples of knowledge facilitators in Sub-Saharan Africa (SSA), it was noted that even in innovation systems where they are well established they face deficiencies in capacity to execute their mandates among them including resource constraints, governance issues, poor coordination, marginalisation of influence and clarity of their roles (Mouton, Gaillard and Van Lill, 2014; Cloete, Maassen and Bailey, 2015). The same conclusion on the lack of capacity to govern and manage the process that brings together scientific expertise, interests and ultimate benefits of science was noted in other studies in SSA (Smith, 2010, Chataway et al, 2006).

Having a general overview of the system alone may be insufficient but require specific skills to engage the society and its needs. This calls for co-option of other disciplines to bridge the gap. A scientist working with GSSTI acknowledged this gap and emphasised the importance of social science disciplines in natural science projects.

> While we may appreciate the parallel social issues of poverty and the role science can play to solve them we rely on our colleagues in the social science fields who are experts in understanding the politics of things and approaches that can speak to powers that be. So, all I am saying is we need an interdisciplinary approach and division of labour in the implementation of these big science projects. (Scientist, Ghana)

The challenges of 'development' that big science intent to solve are interconnected (Kauffman and Arico, 2014: 413) and calls for researchers to adopt a comprehensive, integrated, and participatory approach to science and reality (Sala *et al.*, 2013). The reality on the ground aspect is always not taken as a priority in the conceptualisation of big science projects. The ambition therefore is to build on several foundational disciplines and have the capacity for interdisciplinarity; embrace theoretical and methodological pluralism and have the capacity for reflexivity (Isgren et al., 2017). The idea being not to unify the actual disciplines or their theories and methods into

integrated frameworks, but that pluralism is a better way forward for dealing with development challenges (Olsson and Jerneck, 2018:1). Part of the social science ontologies is understanding the operating environment which ought to be an important element of big science infrastructure projects and associated human capital development. The next section discusses the importance of knowing the operating environment especially weaknesses in institutional arrangements and coordination, agency of institutional leadership, administrative issues and 'challenges' of informal economies.

5.2.3 Institutional arrangements, coordination, and relationships

Ghana is one of the countries with established ST&I institutions that form its innovation system and ST&I is crosscutting in the key sectors of the economy. The Ministry of Environment Science, Technology, and Innovation (MESTI) is mandated to coordinate the ST&I policies and the Ministry of Education oversees the national ST&I education policies (Draft Ghana National STI Policy, 2017). At implementation level there are several institutions which include the Council for Scientific and Industrial Research (CSIR) with 13 specialized Research Institutes and the Ghana Atomic Energy Commission (GAEC) with 6 Atomic and Nuclear Research Institutes in operation. The Ghana Space Science and Technology Institute (GSSTI) coordinating the SKA and DARA projects is also under GAEC, Cocoa Research Institute of Ghana (CRIG), Noguchi Memorial Institute for Medical Research, Centre for Scientific Research in Plants Medicine (CSRPM), GRATIS Foundation, Ghana Standards Authority, and Food and Drugs Board were some of the institutions constituting the ST&I system of Ghana (Quaye *et al.*, 2019a: 6). The institutional arrangement of GSSTI under GAEC was a concern among those interviewed. There was a feeling that GSSTI because of its national importance and coordination of international projects such as SKA and DARA should be autonomous and directly receive its own funding to reduce bureaucracy. One of the leading scientists and astronomer influential in space science in Ghana argued,

> The arrangement of GSSTI under GAEC is a problem. GAEC is a big organisation with more than six institutes, and they all compete for the budget allocation. GSSTI which manages the observatory is among those institutes, so you can imagine the hustle of getting approvals and actual resources flowing to the observatory. In my opinion the GSSTI should stand on its own to reduce

> the red tape if it must achieve its objectives with this SKA international collaboration. (Scientist in Ghana)[25]

The other challenge highlighted apart from the institutional arrangements within the Ghana ST&I system was lack of a robust coordination and governance mechanism for all these established institutions. A science policy expert interviewed expressed issues around weak coordination and poor communication in the following statement.

> Most of the projects do not reach their desired impacts and do not leverage on already existing structures. Projects themselves do not address the real issues in the immediate to medium term but they leave a legacy. Sometimes stakeholders are not even aware of projects such as SKA and there is lack of coordination among researchers and those funding them and sometimes people are not willing to share. We have all the institutions but for some reason they are not well coordinated, they operate as silos. (Science Policy Expert, Ghana)[26]

The relationships, partnerships and communication are important components of any innovation system because institutions on their own do does not translate any knowledge into development as noted in the following quote by a researcher in an interview.

> I can identify three clear communities the research community, operations community, and applications community. SKA and DARA is more of research and operations community but its connection to the applications community is an issue. The people leading development isolate themselves from the science vice versa. Dialogue and sustainable relationships among the communities is always a challenge. (Researcher, Ghana)[27].

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[25] The scientist is one of the senior employees of Ghana Atomic Energy Commission (GAEC) who felt that the GSSTI that manages the telescope was supposed to be autonomous given the scale of the project and its significancy to the nation.

[26] The science policy expert interviewed was the former director of science, technology and innovation in the Ghana Ministry of Environment, Science, Technology, and Innovation (MESTI) and had insights to the goings of science at national level.

[27] The researcher was on a senior fellowship project in the UK but originally from Ghana heavily involved in astronomy projects.

The challenges identified are not different from other studies contacted in Ghana and other parts of Africa. The weak developmental governance capacity and inability to harness different institutional capacities has been noted (Englebert, 2000; Ayee, 2019: 324). Smith postulates that 'where interactions are dynamic and progressive, great innovation strides are often made' but in a 'siloed' and compartmentalised system productivity is limited (Smith, 2005: 651). Therefore, it can be a safe analysis that capability for new competencies depends on how well the parts fit together and strengths of their connections (UNCTAD, 1996 cited in Smith, 2005). Connection of institutions is also tied to the leadership, governance, and quality of their interactive skills which the next section explores.

5.2.4 Agency of institutional leadership

The concept of agency is important in politics and in this thesis it is more relevant especially when dealing with an innovation system. Agency can be described as capacity to act (Braun *et al.*, 2019), the ability of actors to make things happen or power to produce change. In innovation systems leaders of institutions are thought to have some form of agency that they wield to make things happen. Leaders are expected to possess some power to exert influence in terms of decision making and even advocating for certain conditions to prevail within their institutions. This agency can be synonymous to political astuteness where leaders of institutions should be aware and manage how they are perceived. In an interview with one of the pioneers of the SKA project in Africa and engineers who worked on the Ghana telescope they had this to say:

> For projects such as SKA you must be in the right place, right time, and have right narrative. You need people who can drive projects, recognised by political leadership, and can be listened to. Some of us were fortunate that we had both scientific and political credentials within the struggle for independence and that helped to ensure the support needed for astronomy was given and to set off. We didn't struggle to get funding from treasury. (Former Director, SKA South Africa)[28]

[28] The SKA South Africa former director was a scholar and one of the pioneers of the project in Africa from its conception up to the stage it is now and is a respected person in the astronomy community globally.

> You must have champions who drive the projects internally and internationally who knows or are abreast with the political terrain, so I mean we need institutional leaders who can engage with governments. In Ghana we have engaged the Minister who is also a scientist, and it was easy to convince (SKA Engineer South Africa).

An analysis of the sentiments above shows not only the importance of agency but the characteristics of individuals who lead institutions and research networks such as their standing in society, being at the right time and being able to give a narrative that can easily relate with the decision makers. Similarly, the scientists leading international research collaborations need to possess individual knowledge, experience, and reputation to successfully carrying out diverse roles within the collaborations (Bozeman et al, 2016: 233). Senior scientists in the case of space science and astronomy tend to have bigger networks and access to resources.

The narrative of science projects is often not taken seriously in the implementation of science and the belief is that science is factual, and facts can speak for themselves. One of the astronomers said this in an interview.

> The challenge with scientists is that we confine ourselves to doing the science and we think that it's not our job to do narratives. Unfortunately, narratives are needed and forms part of greater work than the science itself especially in situations where huge amounts of resources are required. (SKA Astronomer)

Another critical element to execute agency besides narrative is credibility of institutional leadership. Credibility is the ability to be believed convincingly. In this study it was revealed that political will for projects is not something which is guaranteed but needs some effort on the part of those implementing the project to ensure political leadership in government is aware and kept abreast of the projects. In Ghana there was a feeling that much needed to be done in this front to convince political leadership on the importance of astronomy in terms of its funding. In an interview with a science policy expert, he maintains that,

> There is political will to support and invest in science with the current government, but I want to believe that to galvanise political will and support you need credible management within institutions with agency to convince and sensitise politicians the importance of science so that they can convert their

> political will towards science into real funding support. (Science Policy Expert in Ghana)

While the importance of agency has been acknowledged, there are challenges which have been noted in public institutions where the government is the major shareholder. Emma-Loise Anderson and Amy Paterson in their important work on dependant agency in developing countries where people can simultaneously act and be dependent (Anderson and Patterson, 2016) explained the power dynamics in externally funded projects. Astronomers and their institutional leaders act as agents of the SKA and DARA projects in Ghana. In as much as they act as dependent agents and push for government buy in on space science on behalf of SKA they also activate their ability to influence decisions at national level on science and technology. However, legitimation of those projects rests with ultimate beneficiaries. The efforts of dependent agents are constrained by power imbalances, where their success depends on the funding received from DARA and SKA. Even in the tight space in terms of resources, leadership in these scientific institutions have managed to convince their national governments to support the projects and to project Ghana as a frontier in technology which speaks to the agency they can exert on their systems.

The challenges experienced by the agents place the government in the spotlight as the principal to exercise a proactive role as the major shareholder to ensure institutional leaders do not pursue their own individual agency divorced from their mandate. Government in this case is the mainstay for establishing institutions, leadership, and determination of whether a nation has open and inclusive or extractive institutions (Acemoglu, 2012). On the other hand, institutional leaders and other actors have also placed the blame for failure to achieve as expected on lack of political will and support which is analysed in the next section.

5.2.5 Political will and institutional capacity

The implementation of big science infrastructures comes with complexity in administration. Governmental affairs and political power running the state are factors behind the wheels of big science infrastructural endeavours. They dictate the rules and administrative architectures in their jurisdictions. The management of SKA in Africa acknowledged the misjudgement done in appreciating the administrative landscapes of the eight countries participating in the SKA project. A leading

mechanical engineer in the conversion work of the satellite dishes into working telescopes lamented,

> There are a lot of administrative issues that we overlooked at project inception especially in the upgrading of the Khuntunse Telescope. Bureaucracy in Africa is still an issue. We are donating equipment to Ghana in the spirit of scientific cooperation, but the equipment is taxed there were no exemptions until 2021. Had we known before, this issue should have come during signing of agreements with the government of Ghana (Engineer SKA, South Africa)

The tax exemption was issued in 2020 after a process that involved lobbying by Ministry of Environment, Science, Technology and Innovation and the Ministry of Finance through parliament (Ghana Parliament, 2020). The scientific cooperation agreement between South Africa and Ghana to upgrade the satellite dish was signed in 2013 by the two governments meaning that it took seven years to get the tax exemption. Administrative issues take a big portion of big science infrastructure projects that are transboundary i.e., involving different countries. In a separate interview with another member of the SKA management team he said

> In some countries like Mozambique, we had to shelve the conversion work because there were issues of language barrier that took time in negotiating the agreements. English speaking countries were easier to start with. However, this does not mean there were no interpreters but the targets that we had with funding expectations needed us to show some work on the ground at a faster rate. (SKA South Africa Management Representative)[29]

Local language and culture within the operating environment are often taken for granted at project inception but prove to be important at operations level. The need for tax exemptions of construction material in scientific cooperation by the parliament of Ghana is welcome development for future projects. However, there are other issues referred to as missing social science ontologies such as political will, ability of the

[29] The respondent was working in the SKA Africa project management office responsible for planning and project oversight.

innovation system to absorb new knowledge and nature of the economic set- up that equally weigh in on big science and are considered each in the following paragraphs.

The omitted ingredient in big science often referred to as missing social science ontologies is the understanding of science and associated infrastructure projects with the lens that views it as a social system influenced by culture and beliefs (Saidi and Douglas, 2018). The social system is not easily understood. More so, the incremental reliance of modern states and societies on science and technological systems has redefined relationships between science and technology, government affairs, and political power in a broad range of issues underpinning the development of the modern world (Fisher et al, 2016). Factors such as political will, ability of the innovation system to absorb new knowledge and nature of the economic set- up that equally weigh in on big science are missing in the assumptions.

Political will and support for science has been on agenda for any ST&I policy discourse as a missing gap which affects implementation of projects. What constitutes political will has been a subject of debate among scholars strewed around issues of government inaction, commitment, and extent of policy success. Political will has therefore been defined synthesising different threads in literature as "the extent of committed support and action among key decision makers for a particular policy solution to a particular problem" (Post et al., 2010: 659). Technocrats implementing various projects, in this case big science infrastructure projects and their associate researchers in universities expect support from the political system, not only in form of rhetoric and commitment but in actual funding.

However, the situation in most African countries is an inconsonance of policy makers' expectation of the research fraternity and the current mode of scientific knowledge production. During the Seventh African Higher Education Week and the Regional Universities Forum for Capacity Building in Agriculture Triennial Conference 2021 in Benin, African ministers of education, science and technology had the perception that 'scientists were doing research that seemed to be producing knowledge for the sake of it without clear benefits for the society and its national challenges… and was unlikely to catch attention of bureaucrats' (Waruru, 2020). The ministers were from Benin, Cameroon, Democratic Republic of Congo (DRC), Ghana, Liberia, Malawi, Mozambique, Uganda, and Zimbabwe. Ghana was also among policy makers at this

forum that expected research aligned to addressing national challenges. The higher education sector criticised their governments for their low spending on research and development and lack of political will in support of research.

The political will and support are often affected by policy inconsistencies and lack of continuity with political tenures. Padilla-Pèrez and Gaudin posits that understanding of political upheavals and their impact on government policy is limited(Padilla-Pérez and Gaudin, 2014). In Africa there is frequent change of leadership and development strategies (Chataway et al., 2017). Every new political order and development strategy unsettles the ST&I policy resulting in thinly spread effort and resource affecting the political will and momentum already gathered for certain programmes. However, in the case of the SKA in Ghana, the project has been fortunate to survive political upheavals. From the time of inception around 2003 to present SKA received political support from different government administrations. Ghana has two main political parties that have exchanged power from 1993 to date after coups and these are National Democratic Congress (NDC) and National Patriotic Party (NPP).

During an interview with an academic cum politician she said astronomy in Ghana has been fortunate to get political support from both parties (NDC and NPP) from its inception to date but on the ground the political support is not materialising to real financial support. The main political parties believe in science as a tool for development and the academic who supported NDC argued,

> The SKA has received political buy in and support from the initial discussions in the early 2000s up to its present status. Politicians across the divide have rallied behind the project. You should understand that in Ghana we only have two main parties that have taken turns to get into power after the military rule. Governments have changed, ministers have changed but the support for SKA has remained constant. Both NDC and NPP have shown political will but obviously not action in terms of actual funding which is still low of the project. (Academic in Ghana)[30]

[30] The academic is well respected in the astronomy circles in Ghana and in the African Astronomy Society who doubles as a politician in the opposition party.

The statement from the academic highlights the uneven nature of funding and difficulties in accessing regular funding, a situation in Ghana and most African countries. Those in charge of implementing big science projects like SKA should also ride on the momentum and political will garnered by the project in the African continent to advocate for more resources from governments. While political will and commitment can be garnered in big science infrastructure projects and for research in general, the translation of that into real funding remains far from reach.

5.2.6 Power of data as the new currency and digital capitalism

Data has become more of a 'new currency' in the global market. The world is in a digital revolution that is transforming traditional mechanisms of transactions into institutions of digital capitalism (Marciano, Nicita and Ramello, 2020: 1). Digital capitalism is understood as a dimension of capitalism among others organised around the production of digital commodities and products (Fuchs, 2020a: 71 cited in de Rivera, 2020). The impact of digital capitalism manifested in the renewal of strategies in capital reproduction, changing mobilisation mechanisms of market forces, bringing new habits and a new society altogether (de Rivera, 2020: 726). The SKA is promising to gather vast amounts of cosmological data that amounts to big data capabilities which is one of the biggest spin-offs of the project that will put Africa on the global platform as a force to recon with, in terms of analytics and big data. In this sense the SKA becomes one of the platforms in digital capitalism in as far as cosmological data and related applications, exploring new ways of value extraction and capital accumulation. Ghana is trying to diversify its economy from reliance on natural resources and commodities which are susceptible to price shocks (World Bank, 2019). Data and technological expertise are areas the government of Ghana has noted as having endemic weakness (Baidoo et al, 2012: 412) and rapidly embarked on the Digitisation Agenda enhancing the Information, Communication and Technology (ICT) sector as well as capacity building. The DARA Big Data project easily fit within the digitisation project in Ghana. In their own words Ministry of Environment, Science Technology, and Innovation (MESTI) official claimed this in an interview.

> The projects being implemented at Kuntunse Telescope training students in big data is strategic to our country and coincides with the national digitisation programme. We hope the expertise gained will help different sectors from

agriculture, health, banking, education, and ICT sectors. (MESTI Official, Ghana)[31]

The strategic positioning of the SKA head office in the UK for central processing of all data collected from an array of telescopes has raised concerns among partners in the Global South (Walker and Chinigo, 2018: 1988). The UK was the colonial power for most of the African countries participating in the SKA project in Africa. Given that history, data can still be instrumentalised and used to 'initiate, maintain, routinise, and normalise asymmetrical power relations between the (former) colonisers and their agents and the (former) colonised' (Benyera, 2021: 5). The importance of data in the 4th Industrial Revolution and the impetus for Africans to invest in skills to manipulate data for the benefit of their economies, there is always some sceptics on how the benefits of this data will be shared given the challenges inherent in Africa in terms of funding, infrastructure, technologies, and network.

5.2.7 Science funding situation

African countries have committed to funding research to the tune of 1 per cent of GDP through the Abuja Declaration of 2006 (African Union, 2006). Low expenditure on research and development (R & D) is pervasive in Africa with all countries in the continent being among 80 per cent of countries globally who invested under 1% of GDP on research (*UNESCO Science Report, 2021*). South Africa and Egypt are the only countries in Africa that have recorded high R&D expenditures but still below the agreed 1%. On average the R&D expenditure as a percentage of GDP is 0.51% in Sub-Saharan Africa (ibid) and in Ghana it is at 0.38% though the figure has not been updated since the survey of 2010 (World Bank, 2021). Most of this funding is external from donors and other philanthropic organisations. The government funding is catering for salaries and administrative functions of research institutions and universities and meagre resources are targeted towards research. In response to the question on contributions of participating countries, respondents during the fieldwork expressed sentiments worthy noting at this stage pertaining the projects understudy. A respondent from the UK SKA strategy office in charge of partnerships management stated that.

[31] The MESTI official worked in the ministry's directorate of science and technology.

> The match from national governments for funding research and scientific endeavours in astronomy is still lacking. Most African countries participating in SKA look up to South Africa, but Kenya has begun to take some inward funding initiatives. (SKA Strategy Office, UK)

An[32]other academic buttressed the point on low investment and its implications on research in the country and bemoaned the level of dependency on external funding.

> As it stands, we are at the mercy of external funding because our government is not doing enough except to give us salaries to teach, and the research pillar of our education system is suffering. We end up just chasing any form of funding stream that comes by so that we keep abreast in terms of research skills and at times for survival (Academic in Ghana)

The implications of low expenditure on R&D are wide ranging in Ghana's innovation system which unsettles the widely held positive relationship between ST&I and development in developing countries and the risk of relying on external funding for national development is high. On the other hand, low funding for higher education and research can be attributable to imposed neoliberal policies of structural adjustment programs (SAP) by Bretton Woods institutions (World Bank and International Monetary Fund) that required governments in third world countries to cut back on public expenditure and employment (Anyinam, 1994). Ghana implemented the SAP in the early 1980s and had negative effects like any other conditional development project in Africa (ibid).

5.2.8 Astronomy and Informal Economy

The relevance and utility of space science in human life cannot be doubted or questioned but this thesis questions deployment of the science in some settings, especially the Global South. This section discusses the astronomy projects in the context of African economies which are informal in nature especially urban areas. Informality in Africa encompasses economic activities, settlements (Dovey and King, 2011); Obeng-Odoom, 2011) and it has gone beyond being viewed as a phenomenon tied to developing nations and poverty (OECD, 2009; King and Dovey, 2011). The definition of informal economy has been synonymised with being 'hidden,' unplanned,

[32] An academic at one of the main universities in Ghana who was frustrated about the model of funding science at national level.

and illegal (Akuoko, Aggrey and Amoako-Arhen, 2021: 2). In Sub-Saharan Africa, the informal sector constitutes over 80% of employment and small businesses in cities contributing immensely to urban economies (Steele et al, 2014; Ghana Ministry of Trade and Industry, 2019). The continuous proliferation of the sector can be attributable to governments resentment, inability to provide infrastructure and rising poverty levels in Africa (Watson, 2009). Urban dwellers have therefore adopted coping and management strategies to make a living in the city, respond to market failures, and for survival simply put (Dovey and King, 2011). The thriving of the informal sector may also be an indication of a sustained demand for a service from the market which is not well catered for by the formal sector. In an interview with an innovator in Ghana who also received DARA training had this to say

> I am a recipient of the DARA training, and it opened other avenues in my career. Besides teaching physics, I am also an innovator who has invented a disinfectant chamber during this Covid-19 Pandemic. What drives me is to meet the everyday challenges that we have but each time I pass through the busy Accra market I ask myself on how our big science can satisfy the needs of this informal market. I do not see a clear link and again our government is not doing much to see how science supports this sector. (DARA Trainee, Ghana)

The informal context of African economies is where big science projects such as space science and astronomy deemed to prime development through innovations and modern technologies. Ideally through formal channels of the economy. However, survival of people in such environments is innovation itself and may not necessarily rely on the science or wait for the linear processes from basic to applied science which big science are modelled. Technology and innovation from an African perspective is not something which is brought from outside or primed by scientists in an observatory of laboratory. Africa can be viewed as a transient space where inputs such as data and science ‘catches up’ with an already moving population driven by the need to survive. Africa is not just a recipient of outside technologies; rather, African people are “designers” of technology in the innovative ways they chose to use technologies they found valuable (Mavhunga, 2014: 16). This argument leads to another important section of this thesis that explores politics of knowledge production and associated human capital development programs that aim to ‘empower’ African scientists. This

linear view of innovation in informal economies may be magnified in another critical lens and assist in tracing its epistemological origins.

The material challenges and deficiencies in administrative capacities in the national institutions reveal global power asymmetries in defining development, contextual aspects at national levels (institutional capacities, political support, funding levels and informal economies) affect knowledge production. Explanation of the situation in developing countries with regards to knowledge production capacity can be explained by exploring coloniality, decolonial efforts and dependency which the next section discuss.

5.3 Knowledge Production

Power and knowledge production analysis is rooted on the claims made by big science projects to contribute to enhancing African scientific expertise and by insinuation feeding into wider campaigns to 'decolonise' global knowledge enterprise. The SKA presents its project with a 'new' outlook of partnership with the developing world in the following quote.

> For the first time, the developing world is an active and integral contributor to fundamental research on an unprecedented scale. Emerging and developing countries are already active in the production and exchange of knowledge, stimulating their participation in the global knowledge-based economy. (Square Kilometre Array, SKA Prospectus, 30)

Based on the statement from the prospectus the SKA may represent an unprecedented reversal in unequal relationships between the Global North and South in sciences, one which will halt the 'brain drain' of promising 'southern' scientists to institutions in the north (Walker and Chinigò, 2018: 1988). The envisaged world would see top global scientists trooping to African sites of knowledge production instead (ibid). However, evidence on the ground shows that brain drain is still active in Africa especially in Ghana where scientists are looking for opportunities in the Global North due to challenges mentioned earlier in this section. The conditions of knowledge generation appear to maintain this unequal balance. Knowledge production is deeply situated in the geopolitical power structures that privileges certain locations over

others (Ndlovu-Gatsheni, 2018) and big science is no exception in this dynamic given that

> Control of the domain of knowledge generation and knowledge cultivation remain very important for the maintenance of asymmetrical global power structures in place since the dawn of Euro-North American-centric modernity. (Ndlovu-Gatsheni, 2018: 18).

In the case of astronomy and space science, Africa produces less than 1% of the scientific output in planetary and space science despite having 15% of the World's population (Baratoux, 2017). Modern astronomy is still at infancy stage in most countries except a few e.g., South Africa, Egypt, and Nigeria. Modern astronomy has colonial roots in some parts of Africa. Oldest ancient astronomical site believed to be the dawn of observational astronomy is in Egypt.

At face value the statement from SKA gives an impression that there is a turnaround in power relations between Global North and Global South (Walker and Chinigò, 2018a). But the reality of the situation is that governance systems of most developing countries especially those that were former colonies of the empires have done little effort to address the political economy imbalances especially the digital world and knowledge divide between the Global North and Global South. For instance, the Intellectual Property Rights (IPR) have been inscribed in wider geopolitical development which has a knowledge disequilibrium (Tian, 2009). This global imbalance has roots in the colonial history where developing countries, Ghana included have limited contribution on the crafting of international intellectual property rights which they adopt at national levels. IPR is a cornerstone of the flow of knowledge in any innovation system that ensures that technologies have a return on investment. In Ghana academics and innovators interviewed pointed out the challenge of outdated IPR laws, colonially driven and weaknesses in protecting their inventions.

> Our intellectual property regime was designed from a colonial mind to serve the master and when we gained our independence we did not do much to address this and as a result the knowledge we develop continue to enrich the

> North and impoverish us. In this environment the incentive to develop knowledge and innovations is not there. (Academic, Ghana)[33]

Colonial systems of knowledge production and its dissemination is still a persisting feature. National frameworks to assist local knowledge producers are not robust enough to protect the locals. The extractive nature of global knowledge production and dependency disproportionately affect countries in the developing world battling postcolonial systems. The next section explores some of the factors that may maintain or further widen the knowledge gap between the Global North and South.

Knowledge production in the Global South typically follows the Western education system and hardly does the curriculum incorporates the local knowledge inherent in the cultural system in the case of Africa. Coloniality in this context draws on decolonial thinkers such as Ndlovu-Gatsheni (2018,2020), Mignolo (1995, 2017), Torres (2007) and others and it refers to long-standing patterns of power that emerged because of colonialism, but that define culture, labour, intersubjectivity relations, and knowledge production well beyond the strict limits of colonial administrations. Hence, coloniality sustains colonialism. Coloniality is sustained through books, criteria for academic performance, cultural patterns, common sense, self-image of peoples, aspirations of self, and many other aspects of our modern life (Maldonado Torres 2007: 243 cited in Ndhlovu -Gatsheni, 2013). Coloniality is also a tag for the 'darker side' of modernity that needs to be unmasked because it exists as 'an embedded logic that enforces control, domination, and exploitation disguised in the language of salvation, progress, modernization, and being good for everyone' (Mignolo, 1995: 6).

Astronomy has a connection with the people in Africa for a long time in terms of determining the seasons, daily time, and supernatural beliefs in celestial deities (Okwei *et al.*, 2022). Modern astronomy research is still developing in countries such as Ghana with the participation in the SKA project and DARA human capacity building programme (ibid). At the time of the study Ghana had no curriculum in radio astronomy in its universities. In one of the interviews with a lecturer in one of the universities and

[33] The academic was a lecturer in one of the national universities in Ghana with interest in postcolonial studies and intellectual property.

comments from Ghana Planetarium during one of the meetings organised by GlobalLab Network they had this to say about the astronomy curriculum

> In our universities there is no formal curriculum on radio astronomy, or shall I say we don't have our own curriculum, we have relied on isolated courses from the DARA project and experts from UK, other European countries, and South Africa to train our physics graduates. The adoption of a curriculum takes a long time here in Ghana due to a bureaucracy and in this case the situation is worsened by lack of human resources to teach the subject. (University Lecturer, Ghana)[34]

In one of the science café meetings on cosmology in Ghana, the Planetarium representative commented on the same issue of curriculum and argued.

> While the efforts to raise awareness about astronomy through the Ghana Planetarium, Ghana Radio Observatory and All Nations University are proving to generate interest in the subject, the bad news is that there are no undergraduate courses in astronomy, very little astronomy in the school curriculum, no science centres and very little reporting of astronomy news or even science in general. (Ghana Planetarium Representative)[35]

Based on the statements by key stakeholders in Ghana, one can be tempted to conclude that the teaching of radio astronomy is currently relying on Western curriculum, thus coloniality of knowledge production and not much from the local context of Ghana or Africa in general. The argument can be that modern astronomy has to be standard whether being studied in the Global North or South and that good science transcends boundaries. In that effort to standardise astronomy and its big science consciously or unconsciously falls within the topical debates around epistemological racism and decolonisation. Epistemological racism relates to historical, social, political, and economic functions of race on how Eurocentrism, hegemony, and colonialism (re-)produce "legitimate" knowledge and knowers in the

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[34] Physics lecturer at a university in Ghana and part of the technical committee working on the radio astronomy curriculum.

[35] Ghana planetarium educates the public about astronomy and carries out outreach services to schools.

Western world (Almeida, 2015). Scheurich and Young posits that “epistemological racism means our current range of research epistemologies, positivism to postmodernisms/poststructuralisms, arise out of the social history and culture of the dominant race; that these epistemologies logically reflect and reinforce that social history and that racial group (while excluding the epistemologies of other races/cultures)” (Scheurich and Young, 1997: 8).

Since Ghana did not have a formal curriculum on radio astronomy at the time of the study, asymmetric power relations in terms of knowledge production are likely to be perpetrated and racial structures that used to prevail in colonial settings have greater chances of being reproduced. As Stoler (1995) cited in argues, power organizes knowledge in a way that justifies and re-produces historical, social, and racial distinctions and exclusions in the world. The only difference now is that the former colonised nations are willingly participating. Even though there is no formal curriculum on radio astronomy, there is some connection that Ghanaians have with their universe from time immemorial which is not covered in the current courses being delivered. This is not omission of African experiences and knowledge of astronomy but it’s the complexity of the power structures in the global knowledge production industry where most African states find themselves trapped. The decolonisation drive in the astronomy projects is entangled in this complexity and it is easier said than done as Ndhlovu-Gatsheni argues that.

> The ‘westernized university’ is a globalized institution and exists in Africa and the rest of the world as the ‘Tree of Coloniality’ (TC). Those who eat its fruits immediately speak in European colonial tongues. (Ndlovu-Gatsheni, 2020: 10)

Western hegemony in knowledge production replicates the coloniality of knowledge even where there are apparent ‘good intentions’ to decolonise. The influence of the West has been deeply entrenched in the global knowledge production to an extent that those making efforts to correct this imbalance find themselves falling into the enduring trap of coloniality. Linked to knowledge production and coloniality is the generation of data which has become a ‘new currency’ and enabler of digital capitalism.

Under the big science projects and the attached scientific cooperation and collaboration, advanced economies are looking at the use of more sophisticated models of exerting influence in a way that partners involved may not realise how they have been manipulated. A smarter course of action through a multifaceted 'charm campaign' as described by Kurlantzick (2007) is an attempt to dangle all 'goodies' especially to African leaders where agreements and their wide-ranging implications are not usually flagged out. The G7 countries who are the most developed economies are already looking at transitioning from industrial economies to post industrial economies which are enabled by knowledge creation, innovation, and rapid manipulation of data in a digital world (Wilson, 2008). In Africa, the digital penetration is still very low with about 28.6% of the population connected to internet as compared to over 90% in developed world (International Telecommunications Union, 2021). In this case while the idea of capacity development in skills like radio astronomy and big data through SKA and DARA project initiatives is needed, the developed Global North will harvest the greater share of the benefits because they are already visualising a 'post-industrial' economy while the Global South is still battling to industrialise.

The extension of the 'olive branch' to assist in capacity development has been viewed by some interviewees as tokenism and extension of colonial schemes especially the international collaboration agreements which inherently favour the Global North. African researchers and scientists feel they are suffering from the power dynamics that favour the Global North in scientific cooperation. This is more of a top-down liberal approach to multilateral cooperation. Some sentiments to support the top-down approach from the interviews include the following.

> While some of the initiatives like SKA and DARA truly help us to build our own local capacity, our own contributions like infrastructure, sustaining the workforce at those infrastructures and even the geographic advantage of being at the centre of the Equator where we are better positioned to observe the universe, both the northern and southern hemisphere are undervalued in decisions taken at higher levels. (GSSTI Technical Representative, Ghana)

The sentiments echoed reflect some challenges that are often encountered and paused by international scientific cooperation. The local contributions and the geographic advantages in astronomy in the case of Ghana may not be viewed as bargaining positions in agreements on the basis that they are not matching up with the

financial resources. Ghana is strategically positioned geographically that they can make observations of the sky in the northern and southern hemisphere. Another competitive advantage for Ghana, is its location close to the African Undersea Cables covering the east and west coasts of the continent connecting Africa to the rest of the World (Asabere *et al.*, 2014). The weak bargaining power can be explained by coloniality of knowledge and the way out may be decolonisation.

5.3.1 Decolonisation of Knowledge Production

There are many interpretations of decolonisation in the education fraternity, but this thesis adopts typologies of decolonial thinking from Ndhlovu-Gatsheni. This thesis may not exhaust his thinking but picks on three elements. The first one is anchored on epistemic justice which places African knowledges within the historical epoch of dehumanisation of African people that corresponded with misappropriation of their knowledge. Second, that the epistemological and ontological struggle can be achieved by 'provincialising Europe' and 'deprovincialising Africa.' Provincialising Europe in this `case refers to challenging dominance of European ways of thinking in all spheres of knowledge production and education system (Booi, 2020: 89) while deprovincializing Africa is "an intellectual and academic process of centring Africa as a legitimate historical unit of analysis and epistemic site from which to interpret the world while at the same time globalising knowledge from Africa" (Ndhlovu-Gatsheni, 2018: 4). This entails reimagining knowledge production and centre African methods of knowing. Third, is a critique of Western modernity that has given rise to human social relations and racial hierarchy. With influence from Samir's economic extraversion (1963) and Hountondji's intellectual extraversion (1996), Ndhlovu-Gatsheni postulate that the same way Africa has economic dependence, the same way intellectual extraversion led to scientific dependence (Ndlovu-Gatsheni, 2018: 10). He therefore suggests that Africa must delink from this dependence and 'rethink thinking itself' thus moving away from the normalised Eurocentric ways of knowing. The decolonial thinking from Ndlovu-Gatsheni also is in tandem with other meanings of decolonisation of education that 'a nation must become independent with regards to the acquisition of knowledge skills, values, beliefs, and habits' (Wingfield, 2017). Given the operational definitions of decolonisation, this thesis examines the decolonisation claims in human capital development projects of SKA and DARA.

5.3.2 Human Capital Development and claims of decoloniality.

The approach of the human capital development is to target individual capabilities in STEM subjects embedded and operationalised within the confines of the radio astronomy project and adjacent industries. This draws from the human rights framework that justifies capacity building for individual scientists where it lacks especially in Africa. Article 27 of the Universal Declaration of Human Rights (UDHR) and Article 15 of the International Covenant on Economic, Social and Cultural Rights (ICESCR), promote universal access to scientific research and its benefits (Shaver, 2009; Chapman and Wyndham, 2013; Plomer, 2013). The core argument of targeting individual is grounded on the concept of human capabilities which suggests that justice from a human rights perspective demands not only the diffusion of knowledge, possessed, and utilised as any other good, but equitable participation by individuals in the cocreation of knowledge (Timmermann, 2014). Therefore, the capacity building to the African continent is viewed as the exercise of justice given a history of inequality and de privation during colonial periods (Dalgleish, 2021). Projects such as SKA and DARA are therefore viewed as opportunities for decolonisation, advancing diversity and inclusivity. The following extract from the DARA explains how the project is cognisant of inclusivity and diversity in astronomy.

> Championing inclusivity and diversity, the project is an exciting attempt to inspire more people to pursue STEM careers. The fact that Africa is hosting state-of-the-art scientific facilities, such as the SKA, is something to be celebrated – and the hope is that visionary projects such as DARA will tap into the raw talent on the continent, upskilling and mobilising a new generation of researchers, industry professionals and entrepreneurs. (DARA Project website, 2018)

Space science has always battled with diversity and inclusivity issues especially astronomy and physics as much they have existed (Gohd, 2020). The main contributing factors identified include lack of a supportive environment, financial challenges, and systemic issues that persist in most institutions disadvantaging marginal communities. In the African scenario subjects such as physics and astronomy were a preserve of ‘white’ minorities during colonial times and access to places such as observatories or planetarium was restricted to the privileged

(Gottschalk, 2012). In this case astronomy courts with identity politics and issues of race. Race and colour of skin by then determined access to modern space science subjects. With the advent of political independence in Africa, almost all the countries have removed the restrictions, but the structures are still ingrained in the education systems. The difference is that privileges to access space sciences is still cast along the lines of affordability, class in the society and access to information. Astronomy is one of the STEM subjects that has a history of racialisation where is it has been offered along racial lines in Africa (Dubow, 2019). The allocation of resources to certain group of students and deprivation to others is a function of domination and power (Ladson-Billings, 2009; López, 2016; Pulliam, 2017). The engagement of astronomy with race is also going to be extensively dealt with in chapter six that discusses ontological security racialisation of IR discipline.

During fieldwork the researcher had an opportunity to discuss with management about how astronomy was being popularised through outreach activities that were being done by the Ghana Astronomy Observatory at Kuntunse and they explained,

> We are engaged in outreach activities to schools and greater public because radio astronomy is a subject which is not well known among Ghanaians. The teams go to schools, universities, science clubs, contact workshops and conferences. Most of the activities are being funded externally and we cannot do much in terms of coverage. We are exploring other funding avenues including internal funding from the government. As you know outreach needs money. (Kuntunse Satellite Station Management, Ghana)

There are higher chances of reproducing the same structures of privilege and access of information about astronomy and space science limited to a few, falling in the trap of situations that the project is trying to address. The structure of the human capacity development is to train physics graduates who would have excelled in astrophysics, technical aspects of radio telescopes, observational training, and data reduction. The following extract from one of the lead academics in the DARA project gives a sense of the aims in building sustainable African university research groups.

> This project is training astronomers, just as we do in the UK. So, we want to build sustainable university research groups at the beginning. In Ghana and

> Kenya, for example, there are plans to increase the staff at universities through this project, and a university in Botswana has already taken on a PhD graduate from Liverpool John Moores University. But we expect some from the cohort to move from the PhD into work outside universities. (Prof. Melvin Hoare, June cited by Bowler, 2017)

In Ghana the thrust is to build capacity so that the trained radio astronomers can popularise the subject and in turn teach undergraduate and postgraduate courses at university level. However, there is also a plan to diversify that is getting into other professions that are needed by the industry. As noted in the assumptions in the first section of the chapter the academia-industry linkage in Ghana is currently weak and more effort is still required to strengthen the relationships and partnerships. Human capital development is therefore intertwined with the critical issues discussed in the science, technology, and innovation system. A key challenge identified in some studies on research collaborations is that once southern researchers gain significant experience in international research projects, they tend to get attracted working as consultants for multilateral and bilateral agencies rather than the initial aim of strengthening tertiary education and training the next generation of researchers in their home countries (Bradley, 2007; Carbonnier and Kontinen, 2014: 11). Although the recent PhD graduates from the UK universities have gone back to Africa and are working in institutions, a pessimistic speculation based on previous trends is likely to see them trooping back to the developed world. A graduate from the DARA project who was facing prospects of unemployment bemoaned the low absorptive capacity of their skills in Ghana.

> I have completed my master's degree but there are no jobs for my high-end skills. The industry is not expanding and those already existing have their systems and data requirements handled by their foreign head offices. Vacancies in government are indefinitely frozen. The next thing in my mind is look for opportunities for PhD back in the UK or another place because my system cannot absorb me. (Master's Student, Ghana)

The decolonial entry point and claims to bridge knowledge gap between the Global North and South becomes problematic not because they are not genuine in the case of SKA and DARA projects but their entanglement in mainstream debates of

decolonisation. The general calls around decolonisation first collides with the hurdle of defining the concept due to its heterogenous interpretations and applications given different historical and political sites of decolonisation spanning over 500 years of history (Bhambra, Gebriel and Nişancıoğlu, 2018: 2). University curriculum and knowledge produced has remained a structure of the West and they have maintained custodianship (Michael A Peters, 2021). The diversity and inclusion have often been of tokenistic reduced to scholarship levels. Products and outcomes of scientific research in big science is still strategically deployed in the pursuit of imperial projects conducted by Western states and firms in former colonies (Said, 1978; Gurminder and Bhambra, 2007; Ndlovu-Gatsheni and Zondi, 2016; Sithole, 2016) as dependency theorists such as Dos Santos and Houtondji argued. Lack of support for researchers in the Global South as noted in first section on funding situation in Ghana and innovation system that is siloed is likely to prime the brain-drain. Plans to increase staff in African universities may remain as plans instead of materialising into sustainable scientific workforce unless strategic investments are done in the education sector and sustained funding for research and development.

The human capacity building initiatives should not only focus on STEM skills but should extend to understanding the context in which astronomy operates, its social, political, and economic situation so that an astronomer trained can be of value to their local environment. An African astronomer should have that epistemic freedom understood as “cognitive justice where Africans are able to think for themselves, theorise and interpret their own lived realities and existential experiences; to be able to employ their own methods for conducting what they rightfully regard as research; and to write from their own ontological positions” (Ndhlovu-Gatsheni, 2018 cited by Booi, 2020: 89). The attainment of epistemic freedom to a greater extend is the one that can meaningfully remove the knowledge divide between the Global North and the Global South. A situation that can give the much-needed credence to African scholarship. In a way epistemic freedom give rise to real decolonisation of the global knowledge production in the sense that the methods of knowing are not predetermined and validated by the West. Equity in international scientific collaborations is also part of this decolonisation. The next part examines the scientific collaboration in big science as there are claims within human capital development projects to strengthen South-South collaborations and science diplomacy.

5.4 Power relations in international collaboration in big science

This section examines the international collaboration as a platform for knowledge production and to narrowing the knowledge gap between the Global North and the Global South. International collaboration comes in two main forms (1) North-South collaboration were developed countries partner developing countries in doing research and this collaboration is an opportunity to bring in funds, expertise, and resources to conduct research in low-income countries (Van Der Veken *et al.*, 2017); (2) South-South collaboration refers to the exchange of resources, technology, and knowledge between developing countries. It is becoming a tool used by the states, international organizations, academics, civil society, and the private sector to share knowledge, skills, and successful initiatives in specific areas (UN DESA, 2019).

Areas of collaboration between Global North and Global South include but are not limited to research, teaching, moderation/examination, member of board, and capacity building. In the context of DARA and SKA collaboration has mainly been in capacity building, teaching, and research. The dominant form of collaboration is vertical in the SKA and DARA projects. Researchers in the Global North universities identify universities and institutions in Africa whom they collaborate with especially among the eight participating countries. A university lecturer in the physics department of one of the partner universities in Ghana described the main collaborations they have in the following statement.

> We mainly collaborate with UK, Netherlands, and other Western countries in research because they come with funding and other opportunities for career mobility. I don't see much of collaborations among our fellow African institutions because we are in the same boat, we sing the same song of no funds and it's rare for a colleague to believe and trust you. We still have this inferior complex among ourselves. (University Lecturer, Ghana)

From this statement and other previous studies there is minimal communication and collaboration among scholars within Africa. The fact is that these scientists are biased towards what Hountonji calls vertical exchange (North-South collaboration) and dialogue with scientists from the North than in any horizontal exchange with their fellow scholars from the South (Hountondji, 1990a). The fate of the South-South collaboration is still wedged on the perception that better outcomes are from the North

and the domination by the North has been reinforced by weak coordination among the South (The South Commission, 1990: 3). Internal space for South-to-South scientific collaboration is limited due to challenges of funding and governance of the science ecosystem. The domination of the North is also manifested in agenda setting for research which the next section discusses in the implementation of the SKA and DARA projects.

5.5 Research agenda setting

At the centre of collaboration in research and capacity building is the key aspect of agenda setting. The form of knowledge created and for whom in collaborations is a function of power, politics, and priorities of those involved in donor–recipient partnerships (Bradley, 2008, p. 38). In most research collaborations 'academia meets the international development habitus and heritage' (Carbonnier and Kontinen, 2014, p.6). Both Northern and Southern research institutions comply to the requirements of the research and development communities (Upreti *et al.*, 2012). Donors set agenda, provides funding with regulations, accountability frameworks and oversight (Carbonnier and Kontinen, 2014: 5). From a post-colonial perspective, such relationships are equivalent to paternalism and patronage (Lewis, Wood and Gregory, 1996; Baaz, 2005) where a weaker partner requires guidance and help from the stronger in a spirit of paternal care. In a colonial trusteeship argument, the donor seems to know what is best for the recipient and acts accordingly (Cowen and Shenton 1996; Kontinen 2003; Gould 2005).

The foregoing is the context in which most big science projects in Africa operate in, where research agenda setting is a constellation. SKA is an intergovernmental organisation with participating governments who already have their own agendas. Similarly, the DARA human capital development project supported by the Newton Fund and Global Challenges Research Fund (GCRF) funding agencies that have an agenda targeting 'Africa, Asia and Latin America to support economic development and social welfare, tackle global challenges and develop talent and careers' (*Newton Fund* | *UK Funding Agency*, 2022). The following extract was taken from the abstract on funded projects on the UKRI website to buttress the point on agenda setting.

> DARA Big Data provides bursaries for students from the partner countries of the African VLBI Network (AVN) - Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia - to study for MSc(R) and PhD degrees at universities in South Africa and the UK. These degrees are in the three data intensive DARA Big Data focus areas of astrophysics. (DARA Big Data, 2019 Extension)

The statement illustrates influence of the big-science that extends beyond shaping the modus operandi of scientific research, but often shape and even dictate research agendas in related branches of science (Autio, 2014: 11). In this case, astrophysics research can have direct implications for health, agriculture, and climate change research (STFC, 2009), and the quest for information processing increases the impetus for investing both information technology infrastructures and related information science (COST, 2010; STFC, 2011). The situation on agenda setting is also fortified by local researchers who have also built their own 'ivory towers' around big science and other research needs which currently do not have international attention receive little attention. In an interview with a researcher in Ghana instrumental in the teaching of astronomy asserts,

> The agenda for research is set by those who put more money like the UK and here in Africa, South Africa also takes lead. It's difficult for us to have a say in the research agenda because we are not putting our own money as a country. Among ourselves we have also built ivory towers as researchers which many of our communities and politicians have questioned applicability in everyday life. (Researcher, Ghana)

The Newton- GCRF funding emphasises equitable research partnerships. But before equal partnerships the capacity building is inherently colonial project with the idea of civilising the South to catchup with the North (Carbonnier and Kontinen, 2014). Fowler argues that true equitable research partnerships should be based on mutual dependency not the assumption that one party needs support from the other (Fowler, 1998: 2000). In the African set up the support is really needed but a voice on setting priorities to maintain equity and equality is the missing aspect in North-South collaborations.

The opportunities and challenges presented by the collaborative efforts of big science and associated capacity building to a greater extent leads to a dependency redux and

how the gap between the North and the South further drifts apart in both knowledge production and development. Although North–South partnerships can boost individual skills and institutional resources and skills, they are not a relief for all the challenges associated with capacity building and creation of knowledge to inform sustainable development policies (Bradley, 2015: 4). The last section of this chapter sums up with a discussion on dependency which forms a crucial unit of analysis for the thesis that in as much as Ghana and by inference Africa does not make efforts to dealign from dependency on the North.

5.6 Dependency Redux

Science in this context is instrumentalised to extend domination and preserve geopolitical hegemony by the developed countries (Dos Santos, 1971, 1973). The preservation of asymmetries of power is linked to the Dependency Theory with regards to the models of human capital development which in a way replicate the core-periphery relationship where Global North researchers are powerful and assume the core status and perennially harvest the fruits of technological advancements and the Global South (periphery) remain supplying the raw materials for these high-end technologies (Dos Santos, 1971, 1973). The thesis further explores how national governments in developing nations become complicit in extending this domination by the Global North when reference is paid to scientific capacity building within the SKA and DARA projects in Ghana. They are complicit in the sense that they are not significantly investing in science from their own scoffers and little attention is given to build robust governance frameworks for science. In the end dependency on the Global North is not only in terms of scientific knowledge but goes beyond to permeate economic, social, and political systems which has been described as the coloniality of knowledge production.

The hypothesis is underpinned on the thinking that scientific dependence and economic dependence are developed simultaneously and spill over to other spheres like political systems and social structures (Hountondji, 1990, pp. 7-9). This last section of the chapter focuses on the scientific dependencies observed by Hountondji. Despite significant improvements the existence of a resilient, uneven intellectual division of labour which engenders epistemic dependence where Europe and North America

have remained the epitome from which what is considered valid and scientific knowledge cascades and circulates to the rest of the world. In this uneven division of labour, Africa, and the Global South in general exist as sites for the hunting and gathering of raw data (Hountondji 1997, 2002). Hountondji identified thirteen scientific dependencies which persist in the Global South, and this sum up most of the attributes that are at stake in the SKA project and other similar big science projects operating in the Global South. Table 5.1 shows the scientific dependencies.

Table 5.1 Forms of scientific dependences.

1. Dependence on sophisticated and simple technical laboratory apparatuses made in the North
2. Dependence on foreign libraries, documentation centres for up-to-date scientific information and reliance on an international scientific information system that includes computer-based devices and is largely controlled by the North
3. Institutional nomadism, a restless going to and from European and North American universities
4. Brain drain
5. Importation of theory from the North to enlighten the data gathered in the South
6. Aversion to basic research and sticking to the colonial ideology of instrumentality of knowledge
7. Choice of research topics that is determined by interests of the North where knowledge is validated
8. Confinement to territorial specializations in which African scholars are often reduced to native informants
9. African scholars are engaged in scientific research that is of direct service to coloniality
10. Research into Indigenous knowledge that eventually is disciplined to fit into the modes of Western science
11. Linguistic dependence on six European languages (English, French, German, Spanish, Italian and Portuguese)
12.Lack of collaboration among African scholars as most prefer 'a vertical exchange with scientists from the North than horizontal exchange with fellow scholars from the South'
13. Reproduction of mediocrity that makes it justifiable to look for competent scholars in the North

Source: Author's table adapted from Hountondji, (1990:9-13)

Dependence on the North for equipment, laboratories, and libraries is a reality on the ground in countries such as Ghana where institutions even struggle basics such as access internet, publications, support in grant making and communication of results (public engagement in general). Most of the students are enrolled at UK universities for masters and PhD studies. Basic training in radio astronomy is the one domiciled in Ghana and other African countries such as Kenya and South Africa. The probability of brain-drain is likely given the low absorption capacity of new knowledge and skills in the innovation system as well as limited job opportunities. The beneficiaries of DARA

training viewed brain drain as career mobility and an important development that will help Africa in the long run since current conditions may not be able to offer opportunities. Continuous knowledge accumulation, institutional nomadism, and getting experience though in different settings can bring in new skills set to Africa. The good part of astronomy with connectivity can be done from anywhere in this world. The aspiration for better prospects in research and career development may not be the only reason for expatriation of scholars from Global South. The reason is beyond individual motivations of scholars, economic, political, and other objective factors but the challenge is tied to the nature of international relations, power dynamics of knowledge production in the field of science and technology (Houtondji, 1990).

The awareness that knowledge produced is consumed more in the North than in the South, African researchers are enticed to focus on issues primarily of interest to a Western audience and mimic knowledge structures of the West. This where agenda setting also creeps in due to that conditioned thinking that local has no audience to consume knowledge. The fact that Global South researchers' scientific production is preoriented and predetermined leads to theoretical and social extraversion (ibid). The tendency to be transposed from own environments, chasing what the perceived audience likes and desire to be around them.

The other indices mentioned by Hountondji which this section may not repeat in terms of explanation have been discussed at length in the preceding sections. The indices though conceived decades ago are still functional in explaining the chronic scientific dependency of the Global South on the North. The discussion on several critical issues around big science infrastructures and capacity building has touched on the key research questions and this leads to the following conclusion.

5.7 Conclusion

This chapter exposed the structural challenges of power imbalances in knowledge of development and incessant domination of Western modernity in knowledge production. Due to this skewed relationship of the Global North and South tensions are common on the international conceptualisation of development, national and at local levels. Expectations at all these levels are varied and making them unison is not easily resolved. Evidence from the research in Ghana and by extension to South Africa as the leading country on the SKA project reveals several hurdles to jump up to a level

when scientific knowledge can make notable impact. These hurdles are within the Ghana innovation system which include weak coordination mechanisms and relationships among institutions; agency of institutional leaderships; political will and support for science; low levels of funding for science; low absorptive capacity of new knowledge and institutional arrangements.

The African continent is escalating ambitions to modernise and transition into knowledge-based economy. However, the assumptions in big science projects influenced by modernisation may need effort to set conditions necessary to stimulate development. Scientific capability is determined by country-specific political and institutional contexts and are thought to simulate countries' different development trajectories and strengths (Bartholomew, 1997). The assumptions about science are simplistic in their connections of different variables that relate to development.

The discourse of development based on the assumptions identified somehow had suspended the structural fissures of power, coloniality and decolonisation of knowledge and issues of dependency which influence Africa levelling up with its developed counterparts in the Global North. The suspension of these structural issues in the assumptions as understood by post development theorists is an attempt to depoliticise science in development discourse yet development template is ingrained in the ideals of modernization, which reflect western hegemony, its economic structure and society as a universal model for others to follow and emulate (Ferguson, 1990, Escobar, 1994). Within this Western hegemony, the developmental discourse manifests the unequal power relations between the west and the rest of the world, whereby the western epistemology of development dictates the course for the rest of the world as witnessed in Ghana on international conceptualisations of development that do not tally with local priorities and visions of development.

Power imbalances in knowledge are expressed in Northern dominance in knowledge construction, reproduction, and dissemination, thus coloniality of knowledge. In systems of domination, knowledge serves the function of justifying hierarchical relations. It is codified as ideology, as economic or social theory, or as religious doctrine; like the "cultural hegemony" in the Gramscian sense. In the Gramscian sense, a class cannot dominate in modern conditions by merely advancing its own

narrow economic interests; neither can it dominate purely through force and coercion (Sassoon, 1991c: 230). Instead, it must propagate intellectual and moral leadership, and make alliances and compromises with a variety of forces. The true sense of decolonisation of knowledge can be brought by reimagining knowledge production that decentres Western thinking as dominant and privilege other sites as bonafide epistemic sites.

Dependency theory in this thesis helps understand why Africa and other countries in the Global South are in their current stage of development by accounting for the role of history and persistent efforts to maintain core-periphery relationships in global knowledge production structure. Dependency theorists argue that, even though colonialism formally came to an end, resources have continued flowing to the North. Therefore, the so-called underdevelopment which science wishes to address of countries in the South can be elucidated by persistent exploitation at the hands of the North, rather than just the usual mantra of internal policy failures and that infrastructure and human capacity building science alone may not be a solution. McKenzie and Ndlovu-Gatsheni (2017) argues that colonial systems and mind-sets are reproduced by local elites after formal independence.

The conditions created by such historical experiences reincarnate in post-colonial Ghana's science, technology, innovation landscape and by inference to the African continent in terms of dependency, allocation of internal resources and investment priorities. However, despite all these structural challenges in the political economy of ST&I and the realisation of the science- development complex relationship, there are unintended consequences or side effects of development (Ferguson, 1990) which the SKA project brings. The next chapter expounds on one of the 'side effects' of big science that looks at ontological security built around SKA and ideational power.

Chapter 6
Building Ontological Security around Big Science

6.1 Introduction

The last two chapters have dealt with big science development assumptions and the structural power asymmetries that exist in the production of knowledge and inherent scientific dependencies. This chapter argues that big science infrastructure projects and associated human capacity building have some unintended consequences on African identity, position in international relations and political hierarchy. While Ferguson (1990) emphasised the consolidation of bureaucratic power as a side effect. This thesis takes this further and interrogates how ontological security is built at individual, state, and transboundary levels. Building ontological security around big science also illuminates the role of science in international relations (IR)

In IR, politics of science and technology deals with a variety of perspectives ranging from classic themes such as nuclear weapons, space science to recent debates about nanotechnology, drones, peak oil, cyberspace, supercomputers, and biomedical technologies (Mayer, Carpes and Knoblich, 2014: 2). It is difficult to imagine an international issue that does not carry with it scientific aspects, yet science and technology has been treated as an external field to the study of mainstream IR (ibid). This thesis rides on Mayer's argument that science and technology is an under researched sub-field of IR due to lack of empirical studies, but it occupies an unrecognised position of centrality in the dealings of states. To make matters even more complex is the lack of diversification and pluralisation of international political perspectives beyond the West in the IR discipline (Sabaratnam, 2020). Such a vacuum 'reinforces lazy and often factually incorrect stereotypes about the continent' (Gallagher *et al.*, 2016: 2). Pertaining to science and technology, particularly astronomy, few studies have investigated big science projects and their effect on IR in the African settings. Studies by Dubow, 2019, Walker and Chinigo, 2018, and Gottschalk, 2012 on the SKA in South Africa were biased towards sociological implications of big science in areas around the telescopes and media perspectives, so there is still a gap for systematic study of big science in the mainstream IR.

This chapter, therefore, amplifies the argument by Mayer through engaging with other IR scholars who have explored the needs of states in terms of security for both physical and the mind but takes this forward to demonstrate how science and technology can build other forms of security such as ontological security at three levels: individual, state, and transboundary. A bottom-up approach to building ontological security as opposed to elite-led strategy, i.e., top-down.

Interaction of states has been traditionally shaped by the need for physical security ahead of other equally important forms of security like ontological security. The concept of security is a contested one with different schools of thought. Realists are leaned to the traditional state centric definition of security which refers to the protection of the country against external aggression plus existential threat (Lasan, 2013) and scholars such as (Mearsheimer, 2001; Waltz, 2008) emphasise the importance of material factors like economy and technology as major determinants that shape the forces of power and interests in international relations. For Liberals security can be achieved through international law, international organisations, political cooperation, and democratisation (Lasan, 2012). The main assumption is that there is cooperation among states through multilateral institutions at international level. Institutions are described by Keohane as “persistent and connected set of rules (formal and informal) that prescribe behavioural roles, constrain activity, and shape expectations” (Keohane, 1989: 3).

Constructivists, view security as being constructed and re-constructed through intersubjective human understandings (Smith, 2002: 7). There is much consideration for socially constructed knowledge as being a factor of power that affects the states’ interests and identities (Lasan, 2012: 43). The Constructivists interpretation is crucial in this chapter and the thesis because of the meaning making and subjective human understanding security derived from big science. Other theories of like Marxism consider security as determined by the structure of global capitalism (Hobden and Jones, 2019), Copenhagen School mainly popularised by Buzan (Buzan, 1983, 1997) emphasises social aspects of security and on the independent identity and the functional integrity of states (Lasan, 2012). Post-modernist security studies underscore the role of identity, discourse, and narration in the analysis of security and to them the main unit of analysis is not the state, but non-state actors, from individuals to cultural and ethnic groups, regional blocs, nongovernmental organizations,

including multinational corporations and the security of individuals is clearly superior to that of the state (Sarcinski, 2005: 11 cited in Lasan 2012). Postmodernism has similar traits to Constructivist approaches and this thesis agrees with both approaches and argues that security starts from the individual, the aggregation of individuals' security builds onto the state and goes beyond the state becoming transboundary security.

Both Realists and Liberals view traditional physical security against invasion and external threats and focuses on the state as the main unit of analysis but fails to acknowledge contemporary developments in the interstate or international relations field as well as within states. Three, the everchanging world has witnessed the rising influence of other actors including individuals and non-state actors on world politics (Menashy, 2016).

This chapter drawing on two emerging interrelated or rather complementary concepts in IR which are Ontological Security and Ideational Power, explains the position of astronomy as a big science in development discourses. The first section of the chapter defines ontological security, the application of the concept in different disciplines (psychology, sociology, and international relations), more of the genealogy of the concept and then contextualise it in astronomy. In the second section I will illustrate the relationship between ideas (ideational power and ontological security) and how the concepts intersect in identity formation or negotiation of a new identity. The explanation shows how people in their discourses and language used, attach meaning to materials, make certain infrastructures in this case, the Square Kilometre Array relevant in African development (Adler, 1997; Pouliot, 2010).

In this chapter, the thesis unveils the desire by Africans to position themselves as a continent with positive influence, a science frontier, and an aspiration to be part of framing the intellectual agenda rather than being narrated to in this 'racialised' IR discipline and how OS is vulnerable to power imbalances. The current IR discipline is pro-West in the sense that the ways of knowing i.e., epistemological, locations, assumptions, and commitments naturalise racialised accounts of world politics based on hierarchies of the human (Lake, 2016; Sabaratnam, 2020: 5). The dominance of astronomy and big science in general as sources of power and in development is explained. This section is also contributing to the theoretical and conceptual framework for answering the main research question of this thesis.

Throughout the chapter I will argue that ontological security can be applied beyond individuals, that states besides physical security needs ontological security and are constantly in search for ideas that create a positive image (identity) in the international political hierarchy. In this case it is about Africa's position in the world. I will conclude that the pursuit of astronomy besides having the physical or tangible outputs of human capital development and technological advances boosts the ontological security and identity of the continent and its member states. Science and technology are a subfield of IR. The conclusion buttresses the utility of ideational power and ontological security as theories useful in the contemporary study of IR and explaining some of the exceptional ideas propagated in policy making.

6.2 Situating Ontological Security in Astronomy

Ontological security is the need to experience oneself, continuous person in time as being rather than constantly changing to realise a sense of agency (Laing, 1969; Giddens, 1991; Mitzen, 2006: 342). The concept as applied to IR, refers to "security not of the body but of the self, the subjective sense of who one is, which enables and motivates action and choice" (Mitzen, 2006: 344). The decision-making power which manifests itself in political action that give a sense of physical security may not be enough. Nations in addition to physical security seek to achieve ontological security by routinising relationships with significant others and actors.

One way of routinising relationships in the global political arena is through scientific collaborations. The need for ontological security can be extrapolated from assemblages of individual identity, national identity and transnational shifting the focus from the state centric approach of Realism in IR.

The increasing role of science in development discourses requires a critical lens more so when regional bodies such as the African Union in the Global South have endorsed a Space Strategy with astronomy as a flagship programme (African Union, 2017). Though, ontological security has grown significantly in the IR scholarship, it is marked by conceptual blurriness in terms of its relation to other key concepts of ontological insecurity (Gustafsson and Krickel-Choi, 2020) and background processes that take place through ideation. The conceptual blurriness may be partially solved by looking at the genealogy of ontological security and how it links to the motives behind its attainment.

The term, ontological security is initially associated with Laing (1990 [1960]), drawing from the psychological explanations of anxiety which is an important theoretical precursor of ontological security. Laing, a psychiatrist, borrowing from existentialists anxiety theorists (Heidegger, 1929; Sartre, 1934 and Kierkegaard) sought to understand his schizoid and schizophrenic patients i.e. individuals who cannot keep up with expectations levelled on them by the society (Gustafsson and Krickel-Choi, 2020: 881). Ontological security in this context is therefore, defined by Laing as experiencing oneself as "real, alive, whole, and in a temporal sense, a continuous person" (Laing, 1990: 39). This gives a firm position for one to interact with surroundings and other people in the world. The recognition and congruence of subjectively felt and externally assigned identity gives a secure feeling of oneself (Laing, 1990: 35-37). While Laing dealt with individuals with pathological conditions of anxiety, he also found out that ontologically secure people experience anxiety when they are misrecognised or when their needs for significance and genuine relationships are not met (Lang 1990). Laing however, implicitly suggested that persons who are ontologically secure and ontologically insecure experience bouts of anxiety at different levels; the former experiencing 'normal' and temporary anxiety, while for the latter anxiety is neurotic and existentially threatening (Gustafsson and Krickel-Choi, 2020: 882).

The concepts by Laing were applied in other disciplines for example Giddens (1991) on his work on the impact of modernity on the human condition gave ontological security a sociological perspective. Ontological security is defined in sociological terms as possessing "on the level unconscious and practical consciousness, "answers" to fundamental existential questions which all human life in some way addresses" (Giddens 1991: 47). Giddens dismisses the Laing dichotomy of anxiety (normal and neurotic) and is more concerned with individual's existence in the society than the individual 's psychological configuration. He however acknowledges that ontological insecurity is something not ordinarily experienced by most people and is related to neurotic conditions. Ontological security has been transfigured from psychology to sociology and now IR. The theory of Ontological Security has been applied in IR, irrespective of the precise denomination, and has proved fruitful for addressing a wide variety of theoretical and empirical concerns (Gustafsson and Krickel-Choi, 2020: 877-878). Ontological Security has been used by scholars in different themes as noted by

(Gustafsson and Krickel-Choi, 2020: 877) and these include the following: status-seeking (Zarakol, 2010; Zarakol, 2011; Pacher, 2019); revisionism (Behravesh, 2018); ideology (Marlow, 2002); nationalism (Kinnvall, 2004; Skey, 2010) has been into a conversation with scholars working on identity practices (Combes, 2017); diasporas (Kinnvall and Nesbitt-Larking, 2010; Abramson, 2017); regionalism (Russo and Stoddard, 2018); foreign policy (Lupovici, 2012; Darwich, 2016; Mitzen and Larson, 2017; Oppermann and Hansel, 2019), and power transitions (Chacko, 2014; Young, 2016).

However, the current application of ontological security in IR has been popularised and made visible by a generation of authors on foreign policy (Mitzen, 2006, 2017; Lupovici, 2012; Darwich, 2016), regionalism (Russo and Stoddard, 2018), power transitions (Chacko, 2014; Young, 2017) and other topical themes mentioned in the paragraph above in international politics but has not been applied in the politics of big science such as astronomy and other space sciences. A gap potentially filled by this thesis. Mitzen and others have argued for the application of ontological security to states though it was originally developed to understand individuals (Mitzen, 2006; Steele, 2008). In her explanations of rationales for some foreign policies Mitzen (2006) argues that states might compromise physical security for ontological security. States become attached to established roles and routines because they sustain self-identity and thus provide ontological security. Hence, routines (as “cognitive and behavioural responses”) are followed even when they are destructive and endanger the actor (Mitzen 2006: 346). Routines provide a sense of continuity and certainty in an international environment of constant change and uncertainty. Besides routines, narratives help state’s self-identity because they justify actions and give meaning to a state’s behaviour. Through narratives, states link behaviour (e.g., humanitarian aid or foreign aggression) to the understanding of the self (Steele 2008a: 10). Moreover, (biographical) narratives are used to sustain the state self-identity (Berenskoetter, 2014: 262). Government representatives of a state employ biographical narratives in political discourse (e.g., narratives of belonging) to provide a sense of stability to the public (Marlow 2002: 248).

Lupovici conceptually and empirically tested the ontological security concept by focusing on situations in which states faced with threats to several identities they hold, resulting in ontological dissonance (Lupovici, 2012). Ontological dissonance in the

sense that not only are several identities threatened, but solutions to ease threats are contradictory, forcing the state to choose between different cherished values. The theoretical framework was used to explain Israel's foreign policy towards the Palestinians in recent years. Similarly, to the application of ontological security to foreign policy, Darwich argues against the ontological position that differences in identity can be a source of conflict, whereas convergence and similarity lead to cooperation (Darwich, 2016). However, empirical evidence from the Middle East has long defied this hypothesis. The Kingdom of Saudi Arabia, an Islamic model and claims Islamic leadership, has turned against the rise to power of similar Islamist movements in the Middle East. Darwich's argument therefore explains how similarity can generate anxiety and identity risks adding to the critique of traditional regime security approaches to reveal that security is not only physical but also ontological.

Ontological Security has also been applied in regionalism through the work of Russo and Stoddart. They researched on the Eurasian region and concluded collective ontological security derived from collective identity is an expectation of populations from their leaders (Russo and Stoddard, 2018). In the Eurasian region, Russian and Kazakh presidents have instituted regional cooperation efforts as, among other objectives, an elite-led strategy of ontological security building and reinforcement (ibid). However, national identities were a point of contestation and became weak after the collapse of the Soviet Union. The findings by Russo and Stoddart reinforces the argument from this chapter that ontological security is built from the individual and cascade upwards not a top-down approach.

In power transitions, ontological security has been of utility. Chacko, argues that power transitions do not generate physical security concerns alone for states, but also "ontological" insecurity, since established identities, hierarchies, and relationships are revised and challenged (Chacko, 2014: 329). Therefore, routinising "special relationships" with others is a strategy to deal with uncertainty. Chacko analysed the "rise of India" discourse among policy- makers and commentators in the United States and found that recent US representations of India seek to consolidate a particular US identity. Like the rise of India discourse, Young employs the ontological security framework to demonstrate how New Zealand identity as a 'small trading nation' and 'good international citizen' has shaped its trade and foreign policy decisions and responded to the 'rise of China' by forging ties (Young, 2016: 514). In all these

applications of the concept in IR from Mitzen to Young, there is a gap on the role science in building ontological security which this thesis potentially fills.

In addition to conceptual blurriness, ontological security has been criticised on several points. There are two main points of criticism which are of interest to this thesis. First criticism of ontological security is that, how can a concept originated purely to understand individuals be applied to states and by insinuation treat states as persons with psyches and emotions (Lebow, 2016). This view looks at states as large impersonal political, corporate, or social structure regarded as indivisible (monoliths) and reifying them (Krolikowski, 2008; Delehanty and Steele, 2009; Croft, 2012; Steele, 2017). Secondly, ontological security has been criticised in IR for obsessive concern with continuity and focusing mostly on how states protect their identity, while to a considerable extent ignoring change, or viewing it as a negative force that should be avoided (Browning and Joenniemi, 2017).

This thesis argues that identity is not fixed and intersects with power in international politics. The teaching and epistemologies used to know Africa are often defined and represented by outsiders to an extent that in IR, the continent is viewed as peripheral and uninteresting (Gallagher et al, 2016 and Waltz, 2011). The ascribed identity imbued by stigmatisation of countries in the Global South is that of developing economies, poverty or underdeveloped often framed as a residual problem or lack of 'something' (e.g. markets, technology, globalization) and so are disconnected from the processes and structures that generate wealth and prosperity (Horner, 2020: 418-19). Hence the position of 'Africa' as a (mis)represented object in Western academic discourse and mainstream IR (Mudimbe, 1990) cited by Gallagher et al, (2016: 2) is a cause for concern given the growing number of universities and quality in Africa.

African countries as part of the Global South are not satisfied by that relational perspective and want to change this ascribed identity. States not satisfied by their ranking on the international hierarchy tend to adopt status enhancing policies (Zarakol, 2011), similarly states that view memory narratives to be threatened take action to preserve those narratives (Gustafsson, 2014; Mälksoo, 2015). Several states in the world today still assess themselves based on ideals and ideas of modernity (Meyer and Jepperson, 2000). As noted in chapter two and four, modernisation is associated with progress, development with improvement though these ideals and ideas are hardly questioned (Zarakol, 2011: 5). Therefore, status enhancing policies are

strategies employed by states that rely on recognition from other states for their free existence, implying that there is a common agreement about what constitute a modern state from the ideals of modernity (ibid). Borrowing from this literature on identity formation and status seeking in the international community, this chapter demonstrates that ontological security concept can be of use to understand how individuals, states and across the boundaries try to raise their status in the international system, explain the quest for modernity through space science in development discourses. Croft (2012) contents that ontological security should be of use to investigate collective identities of individuals within and across state boundaries. This thesis combines ontological security and background ideational processes that interact to form or negotiate a better identity of Africa in IR. The following sections explain this combination.

6.2.1 Ideational Power intersection with Ontological Security

The position enjoyed by astronomy can be explained by the theory of ideational power as a complementary to the ontological security. The theory is predicated on the direct use of ideas to influence actors and the background ideational processes constituted of knowledge, discursive practices and institutional setups that ensures some ideas enjoy authority ahead of others. Certain ideas gain influence ahead of others because 'believers' obtain power for unrelated reasons; because the ideas somehow empower actors to achieve power; because they make possible new coalitions of actors; or because they inform the crafting or retooling of institutions that matter (Parsons, 2016). However, in practice the power status of an individual propagating those ideas in the first place is important as that determines whether their ideas are taken seriously.

Carstensen and Schmidt (2016: 5) define ideational power as the capacity of actors (whether individual or collective) to influence other actors' normative and cognitive beliefs using ideational elements. This may occur directly through persuasion or imposition or indirectly by influencing the ideational context that defines the range of possibilities of others. Ideation can also be understood as the distribution of ideas and knowledge (Wendt, 1999:24).

The concept of ideation traces its roots to the Constructivism scholarship in International Relations and is associated with pioneer work of scholars such as (Onuf,

1989; Finnemore, 1996; Ruggie, 1998; Reus-Smit, 2001; Hayward and Lukes, 2008). However, Wendt (1999) is the notable advocate of social constructivism which is more related to the context of ideation in this study. He proposed two increasingly recognised basic positions of Constructivism "that the structures of human association are determined primarily by shared ideas rather than material forces, and that the identities and interests of purposive actors are constructed by these shared ideas rather than given by nature" (Wendt, 1999: 1). The scholarship in ideation power has evolved over the years in public and foreign policies with more insights on how ideas influence action among actors as acknowledged by Peltonen that IR constructivist tree has many roots with intertwined stems (Peltonen, 2017: 3) and its growth continues. A relatively new taxonomy has been proposed by Carstensen and Schimdt.

Carstensen and Schimdt (2016: 7) suggested three types of ideational power which when aggregated help understand certain ideas in the public policy domain and interstate action in scientific collaboration. First, *power through ideas* is perhaps the most analysed within discursive institutionalism. In this context ideational power occurs when actors have a capacity to persuade other actors of the cognitive validity and/or normative value of their worldview using ideational elements. Second is *power over ideas.* Ideational power is illustrated as a capacity of actors to control and dominate the meaning of ideas, either directly by imposing their ideas or indirectly through shaming opponents into conformity or resisting alternative interpretations (power over ideas). This form of ideational power relates more with Lukes' third face of power (Lukes, 1974) which emphasises control over public discussion through the dissemination of an ideology supported by massive propaganda campaigns and relentless repetition of misinformation provided by educational institutions, intellectual and artistic production, as well as all forms of public communication, since here the beliefs of others are directly disregarded. Third, and finally, *power in ideas* manifests itself when certain ideas enjoy authority in structuring thought or institutionalizing certain ideas at the expense of other ideas (power in ideas). In this instance ideational power is closely related to structural and institutional forms of power (Carstensten and Schimdt, 2016)

The scope of this thesis may not exhaust the three constituent parts of this conceptualisation of ideational power but will focus on power through ideas and power in ideas which are more applicable to the analysis of space science. Power in ideas is

also closely linked to Foucault's understanding of power as intimately bound up with knowledge. The generation of knowledge for development in astronomy projects is a central theme which consistently dominates the discourse of its input to various sectors of economies. Foucault suggests that we best 'abandon the whole tradition that allows us to imagine that knowledge can exist only where the power relations are suspended and that knowledge can develop only outside its injunctions, demands, and interests' (Foucault, 1977: 315). This similar analysis by Foucault was later conceptualised by Ferguson on his famous work 'Antipolitics Machine' in which he analysed how the "development discourse" works, that is, how the language and practices used by development specialists and technocrats influence the ways in which development is delivered, and the unintended consequences it fosters. This analysis has been developed in greater detail in chapters four and five.

The ability of ideational power to connect with other forms of power has been a major attraction to its adoption in this thesis. The combination of ontological security and ideational power helps us understand why certain ideas sail through among competing interests, why the narrow focus of knowledge generation end up dominating development discourses, the interaction of actors (individuals, states, significant others, and non-state actors) in international scientific collaborations and rationale of their actions. This contributes to the understanding of the policy sphere, in which policy actors (consisting of experts/scientists and advocacy networks, organized interests, civil servants and public officials) engage in a 'coordinative' discourse of ideational generation and contestation, and the political sphere, in which political actors (engage in a 'communicative' discourse of translation, granulating their ideas to levels digestible to their constituencies and informed publics or opinion makers (Schmidt, Schmidt and A., 2002; Schmidt, 2006, 2008). The interaction and reciprocal input of ideas (ideational power) and ontological security at individual, state and transboundary levels creates an identity positively ranked with enhanced status in the international political hierarchy.

Both Ideational power and ontological security share the common goal of identity formation but literature on identity politics in IR has not really done justice in defining 'identity' and the complexity associated with the term especially when applied to corporate levels such as the state. The term has a double sense where it refers to social categories and to sources of an individual's self-respect and dignity. In the social

sense, an “identity” refers simply to a social category, a set of persons marked by a label and distinguished by rules deciding membership and (alleged) characteristic features or attributes. In the personal sense of personal identity, an identity is some distinguishing characteristic (or characteristics) that a person takes a special pride in or views as socially consequential but more-or-less unchangeable (Fearon, 1999: 2). The main question is whether the identity at state level takes the social form or personal form or both. The fact that identity can have a double sense spiral into ontological security which can be at personal, state, and transboundary levels.

In the conceptualisation of this study, identity is a fluid concept meaning that Africa’s identity in international politics is not fixed and offers little resistance to external pressure. Africa’s identity is analogous to a ‘water balloon’ that at one point is inflated to be bigger, at some point deflated to be smaller. The research note by Rita Abrahamsen invokes a question on Africa’s position in the discipline of IR. Abrahamsen argues that ‘bringing Africa into IR cannot be simply a question of ‘add Africa and stir’, as the continent does not enter the discipline as a neutral object of study’ instead it has to be treated as a place in the world and of the world, capturing the continent’s politics and societies as both unique and global (Abrahamsen, 2016: 1).

Depending on what is at stake the identity of Africa is that of a rising giant, sometimes a dependent, “land of deficit” in need of rescue or just in the middle. Identity intersects with other factors which have played a significant role in African history such as slavery and colonialism positions the continent to oscillate on different points of the political pendulum. In this case it becomes important on the part of Africa to continuously seek for ideas that feed into ontological security and balance the fluid identity. The identity that allows one to change the way they see themselves, the world and actions taken.

The relationship between ideational power and ontological security in identity formation or balancing is explained in the following conceptual framework. The proposed conceptual framework is an illustration how a new identity is built through interaction of ideational power, ontological security and adds capability in this case through big science such as astronomy. The power of space science represents a logical extension of the concept of power in IR (Bowen and Rochberg, 2019) and it is about building capabilities to attain a certain identity.

6.2.2 Ideational Power, Ontological Security, and Capability

The main question underpinning this thesis is to understand why astronomy and space science have become exceptional in the development discourses. At face value the main question is genuinely tied to influence of science in development, but a critical analysis exposes nuances of power in international relations and global development politics. Power is a complex concept to define because it comes in different forms. This section considers the definition of power proposed by Viotti and Kauppi who defined power as "the means by which a state or other actor wields or can assert actual or potential influence or coercion relative to other states and non-state actors because of the political, geographic, economic, and financial, technological, military, social, cultural, or other capabilities it possesses" (Viotti and Kauppi, 2013: 202). The process of attaining a position of influence or power requires introspection where states ask several questions: What capabilities do we have to exert influence? Which ideas are at our disposal to attain power? Do we have the self-esteem and positive image out there to wield influence? All these questions converge into a conceptual framework that identifies the main theoretical and conceptual relationships that can offer a viable explanation of why some ideas become exceptional. The key conceptual relationships will focus on issues of capability, ideas, ontological security, and identity described in the following section.

Capability

There are many definitions of capability Viotti & Kauppi (2013: 191) define capabilities as "material and nonmaterial resources that can serve as the basis for power." Capabilities come in different forms and they play an important role in positioning a state to be influential as it relates with other states and non-state actors. Material capabilities can be in form of economies, natural resources, military strength, and geographic position. Non-material capability may include human resources and expertise, governance systems and reputation. States always search for ideas that increase their capabilities and reputation in international politics. Amartya Sen's capability approach to development is of use here to explain investment in humans in the SKA and DARA projects as a starting point. Capability approach to human well-being is a 'concentration on freedom to achieve in general and the capabilities to

function in particular', and the core concepts of this approach are 'functionings and capabilities' (Sen, 1995: 266 in (Nussbaum and Glover, 1995). In chapter four and five, it has been noted that both individuals and systems need certain capabilities if science is to transform the African fortunes. In the African innovation system training people in science is seen as a process of enhancing people's capabilities by expanding their real freedoms. Capability also underscores the fact that people's abilities are determined by external factors such as interaction with other people, social arrangements, material factors such as access to infrastructure and funding as noted in Chapter 5. Prejudices and discriminations in this instance Africa's position in IR, impacts on the extent of opportunities to participate in this complex international system.

Ideas

Ideas can be defined as 'claims about descriptions of the world, causal relationships, or the normative legitimacy of certain actions' (Parsons, 2002: 48). They play an important role in framing political action be it in terms of raising self-esteem or image of states, choice of capabilities and resultant identities assumed. The ability of ideas to influence action is referred to as ideational power and this may occur directly through persuasion or imposition or indirectly by influencing the ideational context that defines the range of possibilities of others (Carstensen and Schmidt, 2016: 5). Consequently, some ideas become more influential than others and appeal to those in power.

Ontological Security

This thesis supports the claim by academics such as (Mitzen, 2006, Steele, 2008) that states are as much concerned with upholding and enhancing a sense of self-esteem and national dignity (ontological security) as with preserving their territorial sovereignty from physical threats of violence. This claim appears to be relevant, in a context where perceptions of international order are changing, with geopolitical frames of reference increasingly being replaced by frames emphasizing globalisation and neoliberal forms of governance, nation-branding strategies also reflect an upheaval on how self-esteem and national dignity are understood and can be achieved (Browning, 2015). Therefore,

there are significant effects concerning how states negotiate their identities, the types of identities constituted, ideas considered, and capabilities required.

Identity

The term identity has a double sense where it refers to social categories and to sources of an individual's self-respect and dignity. In the social sense, an "identity" refers simply to a social category, a set of persons marked by a label and distinguished by rules deciding membership and (alleged) characteristic features or attributes. In the personal sense of personal identity, an identity is some distinguishing characteristic (or characteristics) that a person takes a special pride in or views as socially consequential but more-or-less unchangeable (Fearon, 1999: 2). The identity of states is fluid and like a 'water balloon' it can be inflated or deflated depending on the ideas generated to give ontological security (self-esteem) and the capabilities at the disposal of individual and corporate/state levels. Figure 6.1 below shows the intersecting circles of the Venn diagram to indicate the interaction of capability, ideational power, and ontological security in shaping identity.

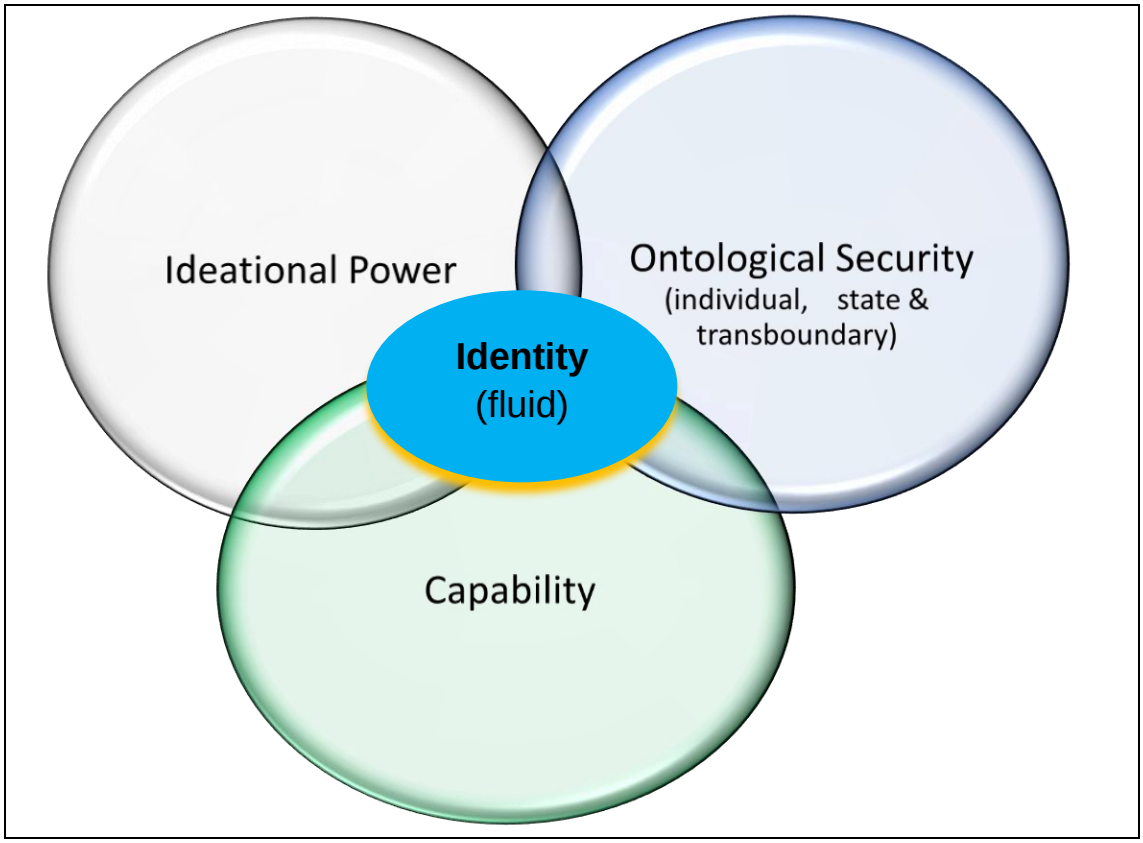

Figure 6.1 Author's diagram on Ideational power, ontological security, and capability relationship

The convergence of ideation power, ontological security, and capability inflates or deflates the identity of individuals and states. Foreign rule influenced Africa's conscience and resulted in somehow a 'loss of identity' (Nkrumah, 1964) or in other words a deflated identity. African states are therefore seeking to position themselves in the political hierarchy giving a coherent story of who they are with an inflated identity full of 'capability.' State actions in international relations and development politics is not just about interaction with other states but also include communicating values and identity narratives to citizens. In that sense ontological security starts at individual level cascading upwards to the state and beyond the state boundaries.

6.2.3 Ontological security and ideational power application

Ontological Security and Ideational Power is supported by evidence gathered over the period of over 8 months of fieldwork on the Square Kilometre Array (SKA) and the Development in Africa with Radio Astronomy (DARA) projects, with both technical and human capital development focus using Ghana as a case study. Data from individuals

who participated in the projects as beneficiary students on the human capital development arm of the project, technical staff who worked on SKA in South Africa and Ghana, academics leading the project and key informants from government gave insights on how ideas propagated from a technical language end up being priority among politicians who make decisions. The understanding of the terrain in which the experts navigate to influence policy makers and the world in which politicians exist is also explained by the key informant interviews. The ontological security which builds from individuals to states, continents to international level is explained. The narratives on why astronomy is regarded as 'crown' of science by the experts and at the same time the underinvestment in the discipline by governments illustrate the fact that state participation in international scientific collaborations in astronomy and related space science is not primarily driven by the physical security (accrued benefits of education, knowledge, and other spin-offs) but is more of the identity and how they are perceived by other significant states, thus, ontological security.

6.2.4 Individual Ontological Security

The initial conceptualisations of ontological security centred on the state as main actors are getting alternative insights which suggest that individuals as actors are the ones who experience ontological insecurity within the state. The students who participated in the SKA and DARA projects had a general feeling of self-identity at three levels; biographical reinforcement, consciousness at individual level that sifts options on how to fit in the world and that feeling of being in control of things in the world to a certain extent. It became apparent from the interviews with beneficiaries of the human capital development programme for both SKA and DARA projects that radio astronomy apart from being an intriguing subject, a great deal also has to do with boosting the level of consciousness and confidence at individual level.

Biographical reinforcement in this context refers to the experience in which structures of daily life and knowledge forms which sustain them are strengthened. The situation in most developing countries may not readily create opportunities for big science due to low absorption capacity of new knowledge in the economies, high unemployment rates, weak industrialisation, and stagnated manufacturing sector contribution to national GDPs. The youthful population in most of these economies, Ghana included

felt their identity has been disrupted and need reconstruction. However, a new future has been ushered in by the prospects of the 4th Industrial Revolution (4IR) which is promising a digital revolution. The transition to a digital world means a lot of capacity is needed that is specialist technical skills to cope with emerging technologies. The opportunities that are likely to be created reconstruct an identity of a youthful African population, hyper-active and entrepreneurial with full of potential.

At individual level, beneficiaries of the human capital development programme for both SKA and DARA felt that acquiring skills that are versatile to fit in the future economy is one of the greatest things that can ever happen to them to reconstruct their identities given the gloom circumstances in their present settings. One of the PhD students under the DARA programme said.

> Aside from all the excitement and intriguing findings about our origins, astronomy has transferable skills and is on the gateway to other technological applications like data analytics applicable to other sectors of the economy like finance. (PhD Student, Ghana)

Another feeling of self-identity is consciousness at individual level that evaluates options on how to fit into the world. The students who attended the basic training in radio astronomy and went on to enrol for master's programs showed strong convictions that they were capable of doing what was only the preserve of advanced nations. Students visualised their input into the national economy and Africa as well as identifying sectors where skills can be utilised.

A masters student enrolled in one of the universities participating in the project mentioned that.

> Data analytics skill is an important skill set required for Ghana's economy and making sense to decision making in sectors such as telecommunications, Wi-Fi for example traces its roots from astronomy. But what we can do as astronomers is to come up with innovative ideas that can be taken by private sectors. (Master's Student, Ghana)

Another, student of the same cohort added his support to the point by saying "Almost every sector of the Ghana's economy will have a good bite of radio astronomy" (master's Student, Ghana July 2020).

As the discussion unfolds, an analysis of possible sectors that could benefit from astronomy was done. Sectors such as education, agriculture, health, meteorology, finance, telecommunications, and defence among others were identified.

The level of consciousness at individual level is linked to the inspirational power that big science such as astronomy gave students. A state of being inspired feeds into individual ontological security and this in turn gives a “yes I can do it mentality.” The mentality has an important contribution in affirming identity and prompts ideation to maintain individual ontological security.

In one of the interviews a student who had just received basic training in radio astronomy stated that

> I am inspired, I now have the ‘I can do mentality’. Astronomy opened my brains to wider and deeper thinking. I now have the confidence to build our own telescope and praying that next time we are constructing a telescope in Ghana; I will be among the engineers contributing immensely not only for my country but even towards the growth of astronomy in Africa. (DARA Basic Trainee in Ghana)

The effect of astronomy at individual level goes beyond skills acquisition but self-consciousness, attachment to one ‘s national identity and a “do it yourself” (DIY) attitude. This attitude has ripple effects which when aggregated leads to state ontological security.

6.2.5 Corporate/State Ontological Security

States just like individuals have a constant need to self-identity and consciousness of who they are. As a result, ideas that create this desired self-consciousness at the same time routinising relations with other significant states. Astronomy has won the hearts of politicians in several national governments as a flagship programme to talk about at international fora. The launch of the Kuntunse telescope in Ghana in 2017 was described by national leadership as the beginning of new era for the country in harnessing space science towards socio-economic development of the country. Apart from contributions to the economy participation in such big science is to position the country in a level of frontiers in science which is a positive identity in international political hierarchy. During the launch the President of Ghana, Nana Addo Dankwa Akufo-Addo explained how Ghana joined the SKA in 2007. He claimed that.

> This decision……. was made at the time when Ghana did not have any programme in astronomy and was an example of the bold and visionary leadership of the time, its purpose being to propel the country to the enviable league of countries pursuing space science. (President Akufo- Addo, Communications Bureau, 2017)

The statement by the President of Ghana is to build a national corporate identity of a country that seeks to be a developed country and a science frontier. Liminality concept seems to be an analytical tool to analyse both individual and corporate identities that being pursued by Africans. Liminality is a concept traditionally utilised by anthropologists and sociologists to denote the way societies or individuals can inhabit a "threshold status" and ambiguity, in which they appear to be moving from one distinctive phase of their history to another, yet their transition to a new fixed status is not fully realised. In a liminal stage, participants "stand at the threshold" (Overland, Guribye and Lie, 2014) between their previous identity and the newly bestowed identity.

In their work on stalled democracies in South Africa and Rwanda, Beresford et al introduced the concept of productive liminality, to analyse how regimes reproduce power capitalising on ambiguity and ductility of the liminal space between authoritarianism and democracy (Beresford, Berry and Mann, 2018: 1232-33). They argue that productive liminality is common in countries coming out of periods of crises led by dominant political parties self-proclaiming as liberation movements. Similarly, productive liminality can be applied to analyse ontological security built at individual and corporate levels. Individuals and countries in Africa who carry a label of "underdeveloped" and are in liminal threshold status can easily be preyed upon by their "visionary leaders" that only them have the extraordinary mandate and vision to deliver development and propel the continent into enviable league of advanced economies.

The venture in space science is not only appreciated by national leadership but even the national scientific community concurred that as a nation, Ghana needed to dream big to attain the status of being a developed nation. In a discussion with a thinktank advisor in Ghana he opened his contribution by reciting President J.F. Kennedy's famous Rice University Speech:

> We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too. (JFK, 1962)

He went further to explain that Ghana's space programmes including astronomy can be likened to the USA ambition that clouded development policies Post World- War II which had the sole goal to put the country at the global scientific leader. Therefore, it is incumbent upon Ghana to think in other terms and propel ideas that give a favourable identity. One of the participants in a discussion stated that.

> If Africa continues to think around this way of bread-and-butter issues, and we are not prepared to break the bark and do things that our peers will think are well beyond the scope of comprehension and maybe expose our stupidity our development may be dithering. (Science Activist, Ghana)[36]

South Africa, the country which is leading the SKA initiative in Africa echoes the same sentiments and believes that investment in astronomy projects portrays a favourable image, one of 'modernity, international standing, and validation for African scientific and intellectual capabilities (Gastrow, 2014: 83). The drive on astronomy is also viewed as the African National Congress (ANC) government's idea and rationale to prop up national prestige and dignity of the African continent. The 1996 White Paper on Science and Technology buttress this point.

> Scientific endeavour is not purely utilitarian in its objectives and has important associated cultural and social value. It is important to maintain a basic science competence in 'flagship' sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future - the view that we are second class nation, chained forever to the treadmill of feeding and clothing ourselves. (South Africa White Paper on Science and Technology, 1996)

[36] The respondent chose to call themselves science activist because they were highly critical of the national science policy and institutional arrangements of science in Ghana.

Immediately after the end of apartheid in South Africa in 1994, the leadership had the desire to show something good and putting to beneficial use the infrastructure and innovative skills initially used in defence. At international platforms image is critical and any government will endeavour with all its arsenal to preserve it in an enviable state. A commentator on science issues exhorted.

> When our politicians go on international platforms, they want to brag on what their governments are doing, and astronomy is an attractive science that has been used for this purpose. (Science Writer, Ghana)[37]

While the will to become first class nations, some quarters of the research participants were sceptical on the ideation of African national governments. They are of the view that the identity that the nation is seeking to assume should not stop at having the infrastructure but go beyond to exploitation. One of the policy advisors and activist on science issues commented,

> Anytime I look at Ghana I look at South Korea and Japan we need to begin to understand and remember that Sanyo is now Samsung but today Sanyo Ghana is Graphic Road, dilapidated building that is what thinking, and ambition does it sifts the grain from the chuff. Increasingly because we are not exploiting our science we are becoming chuff by the day and every time the grain is getting sifted away from us and we cannot continue down this road, we need to begin to understand that we have the same mettle with them. (Policy Advisor, Ghana)[38]

The state ontological security involves associating with like-minded states implying that there is a transboundary spill of positive identity seeking behaviour. The search for positive identity does not end at state level, but it goes beyond the country's boundaries. This is what the thesis refers to as transboundary ontological security. States sharing the same ideation form a consortium which in the case of astronomy has even cascaded upwards to the continental apex political body, African Union.

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[37] The commentator contributes to science magazines and writes for the Conversation.

[38] The policy advisor worked as head of the policy institute of Ghana CSIR

6.2.6 Transboundary ontological security and space technology in Africa

The challenges of a negative ranking in politics and development for the African continent has not gone unchallenged. A philosophy which has been adopted to give a promise for a brighter future, self-determination and continental biographical reinforcement is African Renaissance (Achieng', 2014). The African Renaissance philosophy aims to revive the "golden age" of Africa's social economic and political fabric laced with good governance and improved state-citizenry relations. The idea of African Renaissance idea was first formally used by Thabo Mbeki in an address to a US audience in April I997 (Vale and Maseko, 1998: 273). The wider appeal awakened by Mbeki's 'I am an African' speech resonated with the wider idea of an African Renaissance. The emphasis is on the continent being the author and laying seed beds for its political and socio-economic rebirth.

South Africa's former president Thabo Mbeki championed this idea during his tenure between 1999 and 2008. The interpretation of African Renaissance from a modernist tradition firstly links South Africa's economic interest to Africa through the lens of globalization and is often referred to as a globalist interpretation (Vale and Maseko, 1998). African Renaissance puts Africa in a group of economies which, with time, might become equivalent of the Asian Tigers. In this interpretation, African Renaissance puts Africa in the same category alongside economies in Asia, Europe and North America and South African capital assuming central role through development of trade and strategic partnerships (ibid). Secondly, the interpretation uses African Renaissance to decipher complex social constructions build around African identity (Appiah, 1992: 284). Africanists argue that globalisation will not benefit Africa much as they continue to recipients of external ideas.

The reservations from Africanists justify rewriting of history and identity, that has nothing to do with colonial constructs towards strengthening African knowledges which they already possess. Renaissance in this context means rebirth or revival. The implication of rebirth points towards loss of something significant which warrants starting over again. In this case the continent is reviving its identity and want to attain that ontological security against Afro pessimism, a narrative of Africa as inferior and that nothing good can come out from black people. The bid to host the SKA in Africa

is believed to have faced this Afro pessimism. South Africa's then science minister, Naledi Pando had this to say after the results of the bid were announced.

> As much…reckon that the decision had more to do with politics than science. As with all such big projects, questions of national prestige intruded upon technical judgements and that was particularly so in Africa, where the SKA is seen as a good news story for a continent still struggling to overcome its image as a violent and chronically unstable place. (Economist, 2012)

The Africa Union (AU) is a product of the African Renaissance philosophy. Continental rebirth from Organisation of African Unity (OAU) founded in 1963 to AU in 2002 ushered a new era for the continent. The continental body came up with a development blueprint named Agenda 2063 in 2015, the same year at global level, the United Nations General Assembly adopted the Sustainable Development Goals (SDGs). Agenda 2063 identifies Africa Outer Space Strategy as one of its renaissance flagship programs premised on harnessing space technology towards the continent's development. Prior to the Agenda 2063 in 1996 participants attending the UN conference of Space Science and Technology for Development agreed that

> There is now a very urgent need for national and regional leadership in Africa to adopt space technology as a tool for meeting national and continent-wide development needs, particularly in the following areas: resource management and the environment, information and communications, food, health, and capacity-building. (Abiodun, 2012: 285)

The implementation of Agenda 2063 is through various strategies in addition to the Outer Space Strategy. A ten year Science, Technology and Innovation Strategy (STISA 2024) has been formulated and adopted by the African Union to guide ST&I initiatives among member countries (African Union Commission, 2015). STISA-2024 identified six pillars of ST&I focus necessary for Africa's acceleration to an innovation led and knowledge-based economy. The six priorities are: eradicate hunger and achieving food and security; prevention and control of diseases; communication (physical and intellectual mobility); protect our space; live together –build the society and create wealth (STISA 2024: 22-23). The fourth priority on protecting Africa's space is of interest to this study as astronomy is specifically mentioned in the STISA-2024

as one of the strategies to address the continent's socio-economic development issues.

> Space presents a unique opportunity for the continent to collectively address socio-economic development issues through derived services such as Earth Observation, Navigation and Positioning, Satellite Communication Space Science and Astronomy. (STISA 2024, African Union Commission 2015)

There is a strong connection between space science and socio-economic development that the African continent has established as evidenced by astronomy and space science discussed in Chapter 4. This also feeds into ontological security at transboundary level aggregated through the continental body's development blueprints. However, there are lingering threats and some of them have already been mentioned in chapter five on the effects of neoliberal policies to science funding, power asymmetries in knowledge production and dependency which makes ontological security built around big science vulnerable.

6.3 Threats to 'new' identity and ontological security

Material challenges discussed in chapter five and the general lack of funding for R&D in most of the African countries has an impact on ontological security. At the whims of the Conservative, the UK government in 2021 announced funding cut to Overseas Development Assistance (ODA). ODA refers to aid intended to promote economic development and welfare of developing countries. Such assistance must be reported to the Organisation for Economic Cooperation and Development (OECD). In a letter by the UKRI, to universities the executive chair notified the UK research fraternity that the reduced ODA allocations would affect every UKRI Council, including Innovate UK, and had whole-system impacts in the UK and overseas (UKRI, 2021). The DARA project which is also a recipient of these funds was also affected including myself and other students who were working on the projects in Africa. This has long-term impacts on the ontological security at all three levels but mostly at individual level and it only shows how vulnerable the OS built on big science is. The funding cuts for research follows Neoliberal policies and politics of austerity that consider cuts to social policy expenditures for services such as education and health as solutions to crises (Navarro, 2020).

The case of funding cuts on live projects is linked to the dependency syndrome explained not only in terms of funding but in terms of failing to think differently. Dependency already featured in one of the core analytical chapters (chapter 5) of this thesis is echoed as a threat to ontological security. One of the civil society representatives mentioned that.

> There is need for level of consciousness at individual and national levels that we should not be going for every solution out there, every funding, country interests should match the solutions. In so many times it's not about the money but it's all about confidence to do it. (Ghana Civil Society Representative)

Another research participant weighed in by saying "The funding situation of the SKA and DARA projects in our country for now does not give us independence" (Lecturer in Ghana, July 2020).

The SKA is funded through the members states and in Africa the African Renaissance Fund is also contributing. DARA is also funded by the UK government in partnership with the South African government. So, the sentiment from the lecturer in Ghana speaks to the precarious position they find themselves and the limits that this imposes on ontological security at corporate level.

Africa's colonial past was also identified as a threat to ontological security. The 'new' identity for Africa is regarded as coming out of a huge yoke on the neck. The respondents believed that many African national governments still have ties with their colonial masters and a tendency to directly or indirectly seeking approval as well as endorsement to embark on certain projects is still very common. Even if they are not forced to so, but their experience has an indelible mark in ideation. In an interview with a policy analyst, she stated that.

> We always seek approval of our former colonisers in everything that we do in the name of best practices which we did not participate in their calibration. How can a former colonial master look at you as a force to reckon with. It's high time we start breaking away from such a mentality. (Policy Analyst , Ghana)[39]

The sentiments from the policy analyst in Ghana link to wider decolonisation debates. Decolonialists such as Frantz Fanon (1968) featured in Ndlovu-Gatsheni's work

[39] The policy analyst worked for UNECA and participated in the review of the science policy in Ghana

emphasised the necessity of worlding beyond Europe, when he declared, ‘Let us decide not to imitate Europe and let us tense our muscles and our brains in a new direction. Let us endeavour to invent a man in full, something which Europe has been incapable of achieving.’ (Ndlovu-Gatsheni, 2020: 17) Coincidentally, Ghana is resident to early decolonial theorists in Africa such as Kwame Nkrumah who laid a solid foundation which continue to inspire the decolonization efforts of the twenty first century (ibid).

Despite all the inspirational power of astronomy the participants in the DARA and SKA projects were quick to point out that, the challenge with our governments is that they do not believe in local talent to solve internal challenges. While significant effort is spent accumulating skills at times using the same government resources, the worthy of human capital is not recognised internally. The self-consciousness and identity are disturbed and the ontological security at individual level is diminished. One of the master’s graduates in astronomy said.

> The problem of our government is outsourcing skills from outside the country instead of relying on expertise within. We know that people are healed by their own soil. (Master’s Graduate)

The statement has many implications on state and transboundary ontological security. Self-belief is the main ingredient for a ‘new’ identity which is being sought in Africa. Lack of self-belief was attributed to several factors but chief among them were dependency syndrome, colonial past, corruption, and fear of the unknown. There was also a linkage between external outsourcing of skills from developed countries and dependency. One of the former government employees in an interview mentioned that.

> Our systems at times lack merit in recruitment, selecting and awarding of contracts because of the economy of affection, relationships, and recommendations from better off people. (Former Government Employee)[40]

On corruption respondents believed that the reason why there is a lot of outsourcing of skills is premised on lack of meritocracy. It was noted that it’s a deliberate act by those in positions to outsource demeaning their own talent pool in exchange of some

[40] Former employee in the ministry of education in Ghana and was now working the civil society organisation

benefits. Ghana ranked 81 out of 181 countries on the corruption index report by Transparency International with almost every sector permeated by corrupt activities (Rahman, 2018). Lack of transparency in recruitment processes and bureaucratic systems were attributable to this corruption. However, follow up interviews with government officials, they dismissed the issue of corruption raised for instance in recruitment and their defence was that all graduates from universities whether local or from abroad are treated the same and competition for jobs is high because the economy is not expanding.

Fear of the unknown which is the tendency to be afraid of something new to the mind was mentioned as militating against self-belief and states ontological security. A masters student graduate who was on the verge of returning to Ghana facing prospects of unemployment said

> In this part of the world when you acquire skills such as astronomy the industry is myopic, they just see you teaching and nothing else. Even teaching it takes time for them to gain confidence in you. There is fear of the unknown to venture into uncharted waters and afraid of disruptive technology by young people. (Master's student, Ghana)

The industry and wider innovation systems in countries such as Ghana are still limited in terms of their preparedness to absorb new knowledge and skills. These are realities at national and local levels which makes it difficult to build ontological security basing on science. The identified threats to the 'new' identity being negotiated by Africa as a continent call for search of new ideas that constantly feed to ontological security and vice versa to maintain a favourable identity in political hierarchy. The SKA project happens to be a project that has come at the right time coinciding with a continent seeking to restore its biographical narrative and ontological security.

6.4 Conclusion

Space science position in the political and developmental discourses can be theoretically explained using the complementary theories of ideation power and ontological security. Though, they are not mainstream theories in the study of

International Relations they are proving to be useful in explaining the behaviour of states, scientific community and those responsible for bringing the narrative consumed by the society on the rationale of certain actions.

The interaction of ideas feeding into ontological security and capability as shown in figure 6.1 creates desirable image and positive identity. In the African context, big science such as astronomy has become attractive in negotiating a ‘new’ identity of an awakened giant in both knowledge contribution and ideas for its present and future development. The identity about the continent of lack, poverty and backward is being dismissed with the contempt it deserves through a combination ideation and ontological security. Identity is not static. Africa’s identity is fluid it mutates depending on the circumstances. At some point the renaissance mantra carries the day as an awakening giant but morphs into a dependant, colony and modest.

The widely held conceptual position that ontological security can be applied to individuals without ambiguity and theoretical blurriness (Lebow, 2016) is being challenged. Ontological security has been criticised for applying individual status to the state and transboundary levels, but this thesis proves that Mitzen was right to say states needs ontological security in addition to physical security. Evidence from the interviews and political statements from politicians suggest that ontological security can be applied at different levels from individuals, state and transboundary. The case study of the SKA and DARA projects has demonstrated that individual ontological security aggregated extends to states and transboundary. The underlying denominator being search for a better image and positive identity.

Astronomy is highly placed as a flagship programme on negotiating Africa’s identity, reinforcing the continental biography and the centre of renaissance. The merging of all the strategies in science gives Africa ontological security and the much-needed positive image. However, the maintenance of ontological security and a positive identity is constantly under threat at individual, state and transboundary levels and requires constant ideation.

Threats to ontological security serve as prompts to generation of ideas that position a nation at a certain rank widely acceptable by its citizens and allies or states with same thinking. Therefore, their existence in as much as they can cause feeling of discomfort, they keep states on their toes in search of ideas which feed into a virtuous cycle

impacting on ontological security. My suggested conclusion is not blowing a trumpet of sole utility of ideation power and ontological security in the absence of other theoretical explanations of certain ideas in policy making and the field of International Relations. I am simply proposing a possible explanation on politics of big science that can modestly shed light of the sudden attention given to astronomy in the developing world amidst other development challenges faced. The answer to space science privileged position in development discourses may not be exhausted in this chapter but the nuanced relationship of big science, pursuit of power and coproduction of science and politics is dealt with in the next chapter.

Chapter 7
Pursuit of Big Science as a Source of Power in Global Politics

7.1 Introduction

This chapter overlaps with the preceding chapter on ontological security and focuses on how power is constructed and reproduced around the discourse of big science in global politics. The chapter contributes towards an in-depth understanding of the role of power in the pursuit of big science projects and global political economy of science and technology. The main argument advanced in this chapter is that depoliticisation efforts in big science fortify rather than alleviate the power dynamics at play in the implementation of these projects and national level participation. The depoliticised discourse of universalistic ideas of development through science noted in the previous chapters ignore the political differences of states participating in the SKA project in Africa. Africa as a continent and in particular countries like Ghana and South Africa are trying to negotiate unequal geopolitical power relations and in the process asserting their position in international politics. In advancing this argument, the chapter engages with depoliticization arguments already put across for instance by Ferguson (1990), co-production, (Jasanoff, 2004), knowledge and power (Foucault, 1991) and geopolitics (Dolman, 2002; Bowen and Rochberg, 2019)(Dolman, 2001; Bowen, 2020). Jasanoff's coproduction thesis is pertinent for the argument in this chapter in that science and social order are coproduced, and she emphasise the role of politics in influencing science (Jasanoff, 2004).

Despite the growing evidence of correlation between big science and power, political dynamics of big science have received insufficient attention in the developing countries especially in African contexts more so, with the advent of mega science infrastructural projects involving different countries. Little attention has been paid to the political economy issues of who wield power, who wins and how science systems are shaped by politics. The pursuit of big science is not the neutralised realm of mere scientific knowledge production but is motivated by the quest to exert power and influence. Political rationales 'understood as goals, motivations and reasons that are formulated by state actors such as governments and appointed officials, i.e.,

bureaucracies, such as ministries…' to embark on certain projects (Epping, 2020:3) are not fully interrogated in literature.

The rapid transformation of big science from a pro-defense thrust during the Cold War to a multifunction role in national economies has not been fully explored in developing countries (Hallonsten, 2016). Despite this rapid transformation and promotion of a 'new' understanding of big science, Hallonsten argues that the basic structures of *big machines, big organisations and big politics* discussed in chapter one has been maintained but the nature of research is now different from previous historical periods. The point of departure with this thesis builds on Lele' s argument that though the research content of big science has changed, the 21st political processes of globalisation are intertwined, dependent on high-end technology unevenly distributed and the goal remains attainment of power (Lele, 2016). A nation's power is based on its capability to use the various resources available at its command in the pursuit of national objectives and space power, becomes a subset within the entire spectrum of power sources available (Lele, 2016: 3).

Developing states like Ghana in Africa is exploring the power potential of big science projects like astronomy to pursue national strategic goals in global politics. The multifunctional role of science is incrementally gaining so much currency in development and political strategy of nations, especially in the Global South. This chapter makes a case for both given that they all fall within the conceptual framework of capability and there is bidirectional relationship between scientific knowledge and national prestige, by extension power. In certain instances, technological capability even without tangible contribution to economic growth and development can thus be held in high esteem by developing countries (Cirera and Maloney, 2017). There is much controversy which surrounds the question of whether elites of the Global South and 'rising powers' genuinely have the intention to challenge the dominant structures of global capitalist development, or seek to support and reproduce these structures, while altering their global position in the system and enhancing their influence within the existing structures (Gray and Gills, 2016: 559). The attempt by developing countries to sit on the governance committees of the UN on space science is a clear agenda to change the status quo. This chapter shows that in as much as the Global South want to be part of the dominant structures of capitalist development, there are insurmountable challenges to overcome.

The first section of the chapter shows how advancement of science and technology influence international affairs or global politics in several ways using the taxonomy proposed by Weiss. Weiss identified six basic patterns in which science and technology influences international relations: 1) as a juggernaut or escaped genie with rapid and wide-ranging ramifications for the international system; (2) as a game-changer and a conveyer of advantage and disadvantage to different actors in the international system; (3) as a source of risks, issues and problems that must be addressed and managed by the international community; (4) as key dimensions or enablers of international macro phenomena; (5) as instruments of foreign policy or sources of technical information for the management of an ongoing international regime; (6) as the subject of projects and institutions whose planning, design, implementation and management provide grist for the mill of international relations and diplomacy (Weiss, 2015). The patterns of interaction of science and politics identified are then linked to the astronomy project. The thesis proposes to add the seventh pattern based on evidence from chapter six where states are building ontological security around big science.

The second section explores the ‘Space Race’ in its initial form and the current version which is witnessing ‘new entrants’ to the race such as the African continent, countries like Ghana and South Africa being part of it and the section analyse the implications of such democratisation of space.

Thirdly, the chapter proceeds by arguing that beneath international scientific cooperation and collaboration the quest for power is always simmering. The initial focus of space was on competition and now its cooperation given the opportunities presented by globalisation and interdependence. However, interdependence does not always culminate into cooperation instead it comes with its own dynamics among them wielding soft power which will be another unit of analysis in this section. The perspective of cooperation from the African perspective especially in science is explored from the cultural values such as Ubuntu which means humanity to others, appreciation of the value of other people in life. This concept is applicable in astronomy where observation of the sky cannot be done by one country alone but needs cooperation from other states. In the fourth section countries in the Global South also want to influence governance issues of space science and astronomy at international,

regional, levels. The section analyses how political leadership leverage on big science to deepen and consolidate bureaucratic power.

7.2 The concept of power and its relationship with big science

The concept of power comes in different variants and as a result no single explanation captures all the tenets. Therefore, in this section I will consider the main definitions that are closer to the purpose of this thesis. As early as Fourth B.C. the Indian statecraft master, Kautilya described power as a possession of strength derived from three elements: knowledge, military, and valor (Kauṭalya. and Kangle, 1986). The emphasis by Kautilya was on knowledge that fed into military power and great courage, elements that characterised that time even though they are still relevant today. Modern conceptualisations of power are associated with writings of Nicollò Machiavelli and Thomas Hobbes. Machiavelli represents strategic, decentralised thinking about power and organisation. In Machiavelli's thinking power is viewed as a means, not a resource, and seeks strategic advantages, such as military ones, between his prince and others (Sadan, 1997). Power, in Hobbes, is centralized and focused on sovereignty and the basic premise is that there exists a total political community, the embodiment of which is the state, or the community, or the society.

The Hobbesian line of thinking was adopted by Max Weber during the Post Second World War period, and he defined "power as the probability that an actor within a social relationship would be in a position to carry out his will despite resistance to it" (Weber, 1947). Activation of power is therefore depending on a person's will, even if it is in opposition to someone else's. There is an element of force in this definition of power. Weber also explored the domination factor of power as based on economic or authoritarian interests. Power based on economic interests are also of significance to this thesis as big science investment is often linked to boosting economic development as highlighted in the earlier chapters. In his research Weber believed that power comes in three main forms: economic, social, and political illustrating the bureaucratic hierarchy of power in terms of charismatic, traditional, and rational legal (Lebow, 2017).

Subsequent theoretical explanations of power have questioned Weber's bureaucratic model of power located within the organisation and its structures. The understanding

of ruling elites in their exercise of power in a country and relations beyond is a dimension which Dahl and other theorists brought and in this case helps explain some motivations in big science. Within this dimension of ruling elites, power is exercised to make those who are subject to it follow the private preferences of those in power (Elisheva, 1997: 36). This section has gone at lengths to give different understandings of power because the concept is contested, and it is an acknowledgement that there is no agreed position about the definition of power. However, this thesis as flagged out in the chapter one and three, adopts Lukes' definition of power. Lukes claim that power is exercised in three main ways: decision-making power, non-decision-making power, and ideological power (Lukes, 1974; Heywood, 2004).

Decision-making power is the most overt of the three dimensions. The first 'face' of power relates to Thomas Hobbes's suggestion that power is the ability of an 'agent' to affect the behaviour of a 'patient' or that *A* in some way affects B (Heywood, 2004). This notion is like the idea of physical or mechanical power, where power involves pulling or pushing against one's will. So, in decision making power, *A* must affect *B* in a significant way (White, 1972). Power therefore produces obedience to preferences of others. Applying this concept to the study there is evidence from chapter three to six in this thesis that the decision by the eight national governments under the leadership to participate in SKA project had competing interests and priorities. The states and continental level strategies with their decision-making power chose space science despite other developmental priorities and local expectations as noted by studies done in the deprived Carnarvon region of South Africa (Walker and Chinigò, 2018b).

The second face of power is non-decision-making power and has to do with agenda setting. It is the power which sets the agenda in debates and makes certain issues unacceptable for discussion in "legitimate" public forums. The agenda setting gives a two-dimensional view of power permitting the expansion of focus on observable conflict to those types that might be observed overtly or covertly (Lukes, 1974, p. 20). The discourse of development in big science in chapter two and four as noted suppress the structural issues of power for example in defining development, power imbalances in material resources and knowledge production which should equally dominate the discourse of development through science. The political agenda of extending capacity building to African countries and other developing places in the

Global South can be viewed as an inherent maintain the power imbalances and dependency on the Global North.

The third face is ideological power that authorise one or a group to influence people's wishes and thoughts, to an extent of even making them want things ordinarily not in their own circle of interests. Lukes argues that the second face of power incorporates both subjective interests and those "real" interests held by those excluded by the political process. But in this third face, Lukes asserts that the two faces of power emphasise much on overt or actual behaviour exhibited in policy and decision making (Lukes, 2004: 25) and ignores how the structural components of power are maintained through recapitulated compliance and reinforced by systemic level factors. In the context of big science, the global structures manifest in all the three faces of power as buttressed by evidence gathered in this thesis. The following sections illustrate the utility of Lukes' views with examples from the field where pursuit of science as a sign of power is central in decision making and policy formulation in Africa.

During fieldwork, discussions with some of the participants from the African countries who are part of the SKA and DARA projects revealed that, the radio astronomy agenda was brought to them and driven to the front of the political agenda by South Africa, and it's not something which was ordinarily in their development plans. One of the senior policy makers argued.

> I was there from the start when the partner agreement for SKA was signed with South Africa in 2005 and the push for us to join the project was the existence of a redundant satellite dish and initial conversations where feeding into the bigger picture of South Africa hosting this large infrastructure in the continent and it's not something which was within Ghana's development planning due to high costs associated with astronomy. The whole idea of AVN has always been about South Africa's leadership in astronomy research who were already building 64 telescopes in the Karoo while we only had one unused satellite dish. (Senior Policy Maker)

This revelation from some partner countries portrays a much complex power relationship behind the SKA project where South Africa is regarded as an entry point to influence other African countries to have a buy-in to the project. Although the project view is that of integrating the developing world into the global science economy as evidenced by the statement that follows, the feeling on the ground is different.

> For the first time, the developing world is an active and integral contributor to fundamental research on an unprecedented scale. Emerging and developing countries are already active in the production and exchange of knowledge, stimulating their participation in the global knowledge-based economy. (SKA, 2018)

As an illustration of Dahl's conceptualisation of the ruling elites and Luke's agenda setting, uneven power dynamics between the north-south collaborations and within south-south relationships in global science are depoliticised and dehistoricised against a backdrop of a push towards decolonising knowledge and postcolonial debates. This argument was also noted by in the analysis of the impact of SKA in South Africa (Walker and Chinigò, 2018b). Significant resources and even the headquarters of the SKA Organisation are still located in the North despite the South co-hosting the infrastructure. In the African context, South Africa is extending its hegemony as noted by Bell that South Africa's 'dual role of being, by historic and geographic consequence, a big brother and would-be equal partner' (Bell, 2017). This can be paralleled to production of obedience to preferences of others including an expansion of preferences of those subject to it practically applies in this instance. In an interview with SKA representatives, they were very clear that all communication and administration pertaining to the project with other African partner countries was through South Africa. This speaks to South Africa's foreign policy that portrays post-apartheid South Africa as country that has repositioned itself from pariah status to one exercising leadership regionally and globally (Hendricks and Majozi, 2021,p.64). Even though this stature and legitimacy have arguably waned recently, due to, among other things, perceived change of its foreign policy, ideological standing, domestic politics, and of late incidences of xenophobic attacks to fellow Africans (ibid). The interview with SKA representatives revealed how they are currently dealing with other African countries participating in the project.

> At the moment we are very cautious in terms of how we deal with all the 8 AVN partner countries in Africa. The communication and resource channelling are through South Africa for now. (SKA Representatives in the UK)

The interests of those behind the SKA are served and spread to other parts of the world in a well-orchestrated style where even the ruling elites in Africa see opportunities to expand their preferences within their territories. The great Western

powers are exercising their influence, South Africa is also asserting its footprint on the continent as a leader in big science and the partner countries ruling elites including Ghana are advancing their interests at national levels. South Africa for example is the only African country invited as a guest to attend the June 2021 G7 Summit hosted by the United Kingdom and participation on such a platform of great powers may be linked to the view that South Africa is regarded as strategic for furtherance of Western interests in Africa. The G7 is primarily a meeting of seven advanced industrial democracies (Canada, France, Germany, Italy, Japan, United Kingdom, and United States of America) that meets annually to discuss issues such as global economic governance, international security, and energy policy (Council on Foreign Relations, 2021).

Western powers such as United States of America are not just seeking influence in the space science sector but have ambitions to dominate the entire world. In 1959, the then Vice President of USA, Lyndon B Johnson appearing before a Senate hearing on science attested that "Control of space means control of the world" (Vice President Lyndon B Johnson, 1959). Fast forward in 2018 another Vice President of USA, Mike Pence said Trump charged "It is not enough to have an American presence in space; we must have American dominance in space" (Trump, 2018).

These statements support the point that the pursuit of big science is not only utilitarian in terms of development and advancement but rather a quest for dominance and power. The shaping of preferences is also related to Lukes' three dimensions of power: decision making power, non-decision making power and ideological power (Lukes, 1974: 15). Decision making power is the observable overt power which is shown through political action and officially announced policies. Non-decision-making power is the one which sets the agenda and tone of discussions and on several occasions may not be all that overt, it normally works under cover of certain ideas. The agenda set for space science and astronomy in Africa is that of development through big science. The SKA Organisation described big science benefits to society as follows.

> Mega-science projects such as the SKA have the potential to seed or boost significant technological development, enhance capabilities and efficiencies across myriad industrial and educational sectors, as well as generate economic and social benefits to society. (SKA, 2017)

In addition to the benefits enumerated in the SKA description, tools for development have evolved over time (Bhogal, 2018). Land resources used to be key during the agrarian era, came technology during the industrial revolutions and now information, communication technology (ICT), data and knowledge are the current drivers of development. Globally, the agenda is now set for knowledge-based economies (KBE). In a KBE, knowledge creation and its communication are levers for wealth generation and employment creation (Shie, Meer and Shin, 2011). Africa as a continent has taken hid of the call to adopt KBE but at the same time being assertive to be integrated into this global economy on its terms. Ahead of the 2021 celebrations of the Africa Day held annually on 25 May various African Union (AU) agencies were interviewed. I had the opportunity to listen through to NEPAD, the AU development agency and knowledge management unit had this to say.

> Over the last decade Africa is becoming very assertive in terms of picking its own agenda, realizing Africa's own priorities and actually be able to sit on the global platform and say this is us and this is what we need and here is how we can collaborate. That is important because many of these things it is not that they do not mean good or well for you, but you must get it for yourself they will not give it to you... (Martin Bwayla, Director Knowledge Management and Programme Evaluation, NEPAD-AUDA)

The undertones of the knowledge management unit of the African Union Development Agency reflects Lukes' argument that while power is deployed through undermining and concealing certain debates to preserve a safe political agenda and discourse, it also presents itself in subtle ways influencing and shaping the concerns and desires of the suppressed group. The tone on the AU agency here is that of being assertive, agenda setting but cognisant of the power of the norms of acceptance in the global political system where knowledge is a requirement.

7.2.1 Knowledge/Power connection in big science

Knowledge generation in STEM and adjacent subjects is at the heart of big science projects like SKA. In politics knowledge is power. Foucault assumes a connection between power and knowledge which is difficult to separate even semantically (Foucault, 1979). Big science projects with a wider scale of reach such as the SKA can be analysed through Foucault's disciplinary power which operates in three levels

(i) where those in charge are able to observe the entire surveillance range of subjects in a single gaze, (ii)judgement of normality and conformity in the global village and (iii) examining people and judging them according to norms. The knowledge derived through scientific methods of examination are fed back into society to impose standards of normality in various facets of life including legislating laws to govern citizens. The contemporary norm or standard set in the world is modernity through knowledge and every nation thrives to conform.

This entanglement of modernity and knowledge thus brings power/knowledge connection where a state to be acceptable needs to abide by the norms. Typically, the knowledge generated through SKA and DARA projects will be fed back into different sectors of the economy in Ghana and other participating countries and used to promulgate laws that govern the citizenry. Policies and laws at government level are usually shaped by evidence and recommendations from knowledge generated by science. Although Foucault's argument in modern power is that individuals are constituted as objects within a system of thought which, of necessity, implies a form of subjectification to a particular way of being (Haugaard 1997: 43). In South Africa for instance, having realised potential of astronomy to development pieces of legislation have been put in place such as the Astronomy Geographic Advantage Act (AGAA) of 2007 and the extract of the Act shows how knowledge of astronomy is used to regulate land use in these advantage areas.

> To provide for the preservation and protection of areas within the Republic that are uniquely suited for optical and radio astronomy; to provide for intergovernmental co-operation and public consultation on matters concerning nationally significant astronomy advantage areas; and to provide for matters connected therewith. (AGAA, 2007)

The AGAA has caused tension among farmers in Karoo Region around Carnarvon area of South Africa where the main activity is sheep farming but due to the requirement for non-interference nature of radio waves, their farms were bought by the state (Walker and Chinigò, 2018b). At the time of the study Ghana was still in the process of working through its national laws around these protected areas but one of the employees for the Kuntunse Telescope site noted the same tension between an astronomy advantage area and people around the area and had this to say

> I had to do a lot of brainwashing for people around Kuntunse for them to understand the benefits of astronomy because many of them were encroaching into the site since it is built near a residential area and people were already settled. The Municipality authorities of Ga West are aware of the problem but there is little traction. We have gone to court and a demolition order was issued but some of the people are still building their structures at night and it takes bold leadership who are not afraid to be voted out of power to act. (Kuntunse Site Employee)

The assumption that knowledge generated will be fed back into society and used equally in the SKA project partner countries is problematic. As evidenced by the differences in the use of knowledge in South Africa and Ghana to legislate astronomy advantage areas. Power asymmetries among partner countries and within countries manifests. Firstly, South Africa is strategically positioned in this intergovernmental cooperation to exploit proceeds of the SKA project as compared to its partners who are relatively at formative stages to put legislative institutions and structures. Secondly, the relationship between the state and its citizens again brings unequal power relations where the state uses the banner of science to control the type of activities that can be done in these astronomy advantage areas.

7.2.2 Ideological power and science

Ideological power in the third dimension of power proposed by Lukes which allows one to influence the wishes of people and thoughts, can used to analyse how African Renaissance ideology informs participation in the SKA project by African states. Although in this case the SKA is not diametrically opposed to people's interests but the colonial association of astronomy for example in South Africa raises scepticism on its benefits (Dubow, 2019). But Lukes' third dimension is applicable in the context of SKA where it has been used as an example of a rising Africa in the same league of knowledge frontiers. The power of ideology has worked especially in South Africa where most people live in poverty and have a difficult apartheid history but have never significantly opposed the rationale behind huge investments in astronomy at the expense of other social amenities like housing except the Karoo region where farmers where displaced (Govender, Barnes and Pieper, 2011).

Thabo Mbeki, the then President of South Africa in 2002 when he endorsed the SKA project reflected in a broader sense two important issues central to this thesis that is

(i) regional ambitions to promote a continent-wide 'African Renaissance' that would set a new, postcolonial development agenda for Africa 'as a contributor to, as well as a beneficiary of, the achievements of human civilisation' (ii) notion of 'renaissance' that extends far beyond political liberation but also about restoring the centrality of Africa in the history of humankind, through affirming its deep cultural heritage and positioning the continent (under South African leadership) in the global knowledge economy (Walker and Chinigò, 2018b).

The notion raised here point towards the Pan- African ambition to be part of and contribute towards global human civilisation albeit creating a position on the global knowledge economy. Such ambitions do not usually sail without opposition but to date astronomy has even been endorsed at continental level as an instrument for development. In an interview with continental space experts driving the space science projects, the endorsement of astronomy was made clear through the following statements.

> Astronomy is one of the mainstays of the African Space Policy and Strategy – an indication of appreciation of the field, of the political will and determination to develop the science and exploit it for the benefit of Africans. (AU, Global Monitoring for Environment and Security (GMES) Coordinator)[41]

> There is a definite relation, because Africa's renaissance is based on technology, access to information and infrastructural connectivity. Space science and technology has played a key role in the generation and mobility of information as well as communications infrastructure. Satellite communication and Navigation and Positioning are good examples of how space services have contributed to a better-connected Africa. (African Union Space Expert)

The Pan African ambition advanced by people like Thabo Mbeki which has seen its acceptance by other statemen and technocrats in the continent can also be analysed in terms of ideational power discussed in the previous chapter. As highlighted in chapter six, ideational power similar to Lukes' third dimension of power is the ability of actors in positions to influence other actors' normative and cognitive beliefs using ideational elements (Carstensen and Schmidt, 2015a). Ideational elements can be in

[41] The African Union GMES coordinator oversees the earth observation activities in Africa and provide expertise in this area.

form of discourse, practices, symbols, myths, narratives, collective memories, stories, frames, norms, grammars, models, and identities (Parsons, 2007: 96). The narrative that it is time for Africa to renew itself and occupy its position in global politics also known as the African renaissance mantra has been widely accepted in the continent as evidenced by the support received by South Africa to host international events like the 2010 FIFA World Cup and now the current biggest astronomy project, Square Kilometre Array. Although this narrative has carried the day, critiques have put South Africa on the spotlight. The question that has been paused is, are all the initiatives truly an African endeavour or its South Africa's effort to appropriate Africa's image for its own purposes (Vale and Maseko, 1998).

The African renaissance mantra as an ideology has two main interpretations, the globalist and Africanist. The globalist interpretation of African renaissance is that of globalisation, modernisation, creation of wealth, enhancing trade and global competitiveness (Strauss, 1995). However, since the ambition was being driven by South Africa as a way of integrating with wider continent, the idea that what was good for them is also good for Africa had some uncomfortable echoes within Africa's political psyche (Vale and Maseko, 1998). Some analysts influential to the presidency in South Africa even warned about such leadership role assumed by the country to drive the continental agenda. Molesti Mbeki a brother to then deputy president, Thabo Mbeki flagged the uneasiness by suggesting 'that an increasing number of African countries would prefer us not to play a... [leadership]... role' (ibid).

The reservations by other countries were that the linkage of the idea to the market solutions would widen the gap between the rich and the poor instead of narrowing it.

The Africanist interpretation of Renaissance is tilted towards post-structuralism which argues that globalist outcomes will 'amount to nothing more than an externally driven consumerist movement' that will leave Africans continuing to be 'valued' only for an ability to 'absorb and popularize foreign ideas, trinkets and junk' (Mail&Guardian, 1997). This dynamic reinforces existing asymmetries in capacity and influence against a background of crisis in Africa's higher education sector where knowledge generated is normally ignored in international policy making processes (Olukoshi, 2010). The reason why many scholars are calling for a decolonised discipline of IR (Croft, Fredericks and Bronwyn, 2009; Gallagher *et al.*, 2016; Chipaike and Knowledge,

2018). Views about African Renaissance discussed in chapter six can still be relevant in analysing the pursuit of science as a sign of power. The Africanist argument might help in the current big science projects which have a thrust on aiding the 4th Industrial Revolution. Africanists argue that global power in form of institutions, ideologies and the "knowledge" that is taught in pre-schools, school, and universities are meant to keep Africa in a stunted state of growth, so that those that are benefiting will continue to benefit (Benyera, 2021).

One issue that highlights the conflict between 'globalist' views and 'Africanist' understandings of African Renaissance has application to space science and astronomy. For example, the SKA project is going to generate huge quantities of data and equally there is need for storage and processing of big data. The volumes of data to be generated through the SKA are enormous as indicated on the organisation's website.

> Processing the vast quantities of data produced by the SKA will require two (one in South Africa, one in Australia) very high-performance central supercomputers capable of in excess of 100 petaflops (one hundred thousand million floating point operations per second of raw processing power), which is equivalent to the fastest supercomputer on Earth at the present time. (SKAO, 2021)

Africanist interpretation of African Renaissance would question whether African actors will have the capacity to benefit from investments in big data collection, or whether this might benefit external actors more than those on the continent. For example, the analysis of this big data will require not only the supercomputers but also the development of state-of-the-art artificial intelligence (AI) (in terms of ontology, cognitive thinking, imagination, and creativity). This has already presented an opportunity for tech oligarchies to control big data, artificial intelligence, online communities, and the online economy who harvest data, process it, commodify it, and hence make data capital (Benyera, 2021: 10). With the already existing unequal power relations between the Global North and South, there is doubt on whether the SKA and associated projects like DARA will give the same opportunities to African countries as noted in the preceding sections. Data is power and can be used to deploy influence by those better positioned to set ideation context and pre-empts decisions in the political spaces. This may result in the perpetuation of coloniality in Africa where some

jurisdictions have inherent weak accountability institutions and poor governance systems (Ibid).

On the other hand, from a Globalist perspective, combining the Pan-African ambition, renaissance mantra, interest in modern astronomy as an entry point to other sciences and prospects of the 4IR, gives an image of a renewed continent. Gottschalk describes the synergy and merger of the African Renaissance, the resurgence of African astronomy, and the rise of cognate space science and astronautics as Astronaissance, a term coined by the organisers of the first International Astronautical Congress held in Africa in 2011 in Cape Town, South Africa (Gottschalk, 2013).

This section has argued that ideological power has a relationship with the pursuit and implementation of big science in Africa. The discourse analysed in chapter two and chapter six show that countries like Ghana and South Africa who are actively participating in the SKA project are driven by ideology of African Renaissance. Ideology is reinforcing the need to have capability in science as a show cause of power that indeed Africa is rising and is a force to reckon with in global geopolitics. Again, this is a test of the applicability of Lukes dimensions of power.

7.2.3 Soft power in big science

This section discusses another type of power which is being derived through big science. The participation of Ghana and other African countries in SKA has been interpreted as a source of soft power. Sources of power are generally changing from the military and conquest thrust of yesteryears and factors such as technology, education and economic growth are becoming important (Nye, 2004). Soft power according to Nye is the ability to influence others to get the outcomes you want by co-opting them rather than coercing them (Nye, 1990). It is regarded as a “second face of power” that indirectly allows one to get their desirable outcomes. The following description of soft power briefly summarises a contested concept:

> A country may obtain the outcomes it wants in world politics because other countries – admiring its values, emulating its example, aspiring to its level of prosperity and openness – want to follow it. In this sense, it is also important to set the agenda and attract others in world politics, and not only to force them to change by threatening military force or economic sanctions. This soft power

> – getting others to want the outcomes that you want – co-opts people rather than coerces them. (Nye, 2004)

Science has been traditionally used in the production of hard power resources such as military technologies but in this era there is a growing attraction for its utility as a source of soft power. The idea that scientists tend to speak the same language sets the ground for international collaborations, also with countries with whom diplomatic relationships have not always been easy (Koch *et al.*, 2021). This point was also flagged by the Royal Society that "the scientific values of rationality, transparency and universality can enable science to be used to build constructive international relations and should be an important part of soft power." (Royal Society, 2013). Soft power is therefore often linked with science diplomacy, a fluid concept used to describe the role of science, technology, and innovation in three different ways: a) using science cooperation to improve international relations between countries and regions (science for diplomacy) b) facilitating international science cooperation (diplomacy for science); c) informing foreign policy objectives with scientific advice (science in diplomacy) (ibid).

South Africa as the leading country of SKA Africa and other countries such as Ghana, are seeking to attract investment, have a positive image projected out there. Ghana as the first to gain political independence and South Africa as relatively the last, a point mentioned in chapter one shows how both countries are seeking recognition given their misrecognition particularly Ghana in its early years of independence (Gallagher, 2016, 2018).

A quick scan into the countries involved in the SKA project such as China, Germany, United Kingdom, and South Africa shows a great deal of how they have used soft power through scientific collaborations and funding. In the UK for instance, soft power has been the policy objective of most Conservative-led governments for the past few years (Gürsoy, 2020). Soft power is flagged out in official national security documents (HM Government 2015; 2018), parliamentary reports (House of Commons 2011; House of Lords 2014), and the speeches of high-ranking officials (Hague 2012; Howell 2012; Hunt 2019). Science is one of the tools for this soft power which the Conservative government has even put upfront as a strategy for a Global Britain post Brexit (Michael A. Peters, 2021) The attraction for scientists is even reflected in the fast-track immigration scheme for critical skills. China on the other hand has spent

years of efforts to extend its soft power including this pandemic period (Doyle, 2020). South Africa has also used soft power in the African continent and has been reasserting its leadership in the region even though it is contested due to its erratic xenophobic attacks to other African nationals (Ogunnubi and Okeke-Uzodike, 2015).

Astronomy qualifies in this realm of soft power as science fostering cooperation and international relations. The science ministers of eight participating African countries and South Africa meet annually as a high-level forum to provide political and strategic leadership on SKA and related projects (Space Africa, 2018). This can be viewed as a high-level South to South science diplomacy. One of the academics working on the SKA and DARA acknowledged the role being played by the projects in fostering South to South cooperation and science diplomacy among participating countries and had this to say.

> The SKA and DARA projects are uniquely positioned in that they are encouraging networking of astronomers and scientists in Africa thereby promoting South to South cooperation and collaboration. We try as much as possible that every year students who are enrolled for their masters and PhD programmes meet and network with the hope that this continues when the go back to their countries. (Academic Representative, UK)[42]

While networking and science diplomacy are being promoted among the students, it is an area that requires strengthening as a bottom-up approach to science diplomacy and entrenching soft power skills in the young generation of scientists. The current top-down approach of science diplomacy during discussions with students was believed to be not effective at national levels where communication among stakeholders is hampered by 'silos' as highlighted in chapter five.

The attractiveness of countries through soft power is always under threats from both domestic and foreign policies pursued by a country. The recent approach to cut on foreign aid and science funding by the Conservative-led government in the UK noted in chapter six has implications on science as a soft power tool. UK is a major contributor to the SKA and DARA projects through the UKRI for Global Challenges Research Funding (GCRF). This is likely to hit hard on the African partner countries

[42] The academic representative is from one of the UK universities participating the DARA Big Data project and acts as a co-investigator.

like Ghana who are participating in the projects where national government funding is low. The prospects of South-South collaboration are also undermined due to acute dependencies on the Global North of institutions in the Global South (Hountondji, 1990). Actual impact for African students on these projects still needs to be interrogated. Universities in the UK reacted to these funding cuts implying a threat to the Global Britain ambition. Representatives of two major renowned universities (Cambridge and Oxford Universities) in the UK said,

> ..the scale, immediacy, and impact of the announced and potential cuts to UK research budgets, amounting to over £1 billion, will undermine years of investment in our universities and put our research base at risk, not to mention our international reputation. Indeed, there is a real likelihood of the Government's claims of 'Global Britain' ringing hollow. (Toope and Richardson, 19 March 2021)

The threat to soft power is when some of the expectations are not met and when incumbent governments change policy directions. Years spent of investment and nurturing soft power can be diminished by changes in policy in the case of UK with its approach on cutting overseas development assistance. This brings another dimension on how soft power relies on cooperation and interdependency and supporting pillars. Despite these funding cuts developing nations still cooperate because of the nature of global interdependency.

7.3 Cooperation and interdependency from an African perspective

One of the driving forces for Africa to cooperate in big science can be explained using Ubuntu philosophy. The concept is not the only one that explains Africa's motivations and views of the international but is among concepts that are slowly gaining traction in IR literature and applied to outer space (Froehlich and Siebrits, 2019: 69). Ubuntu originates from Southern Africa from an isiXhosa proverb "*Ubuntu ungamntu ngabanye abantu*," which means "people are people through other people" (Smith, 2013). The concept contributes to IR and space literature through an alternative collectivist understanding of community in contrast to the Western individualist ontology (Smith, 2018: 87). Smith further explains that Ubuntu goes beyond the predominantly IR dichotomy of friend or enemy and gives the "metaphor of the African family and community structure. In this structure neighbouring countries are seen as

‘part of the clan’ and other African countries are viewed broadly as ‘part of tribe.’ Contextualising this to the case study of the SKA project, parallels can be drawn where the nature of science in astronomy requires cooperation of states to have better resolutions of both northern and southern hemispheres. Therefore, it’s not a surprise that developed nations would want to see Africa building capacity in astronomy to get the southern hemispheric view, likewise South Africa will also be contented if its neighbours and other African states being successful in this SKA project. The challenges of other African countries are challenges of South Africa when Ubuntu concept is applied. The then Minister of International Relations and Cooperation of South Africa, Nkoana-Mashabane, in 2009 said that.

> Our [aim] is to export Ubuntu and partnership amongst our people, people of the continent and the world. Let their problem(s) be our problem. (Smith, 2013: 312).

South Africa would want to see all the eight SKA participating countries that helped its bid succeed and the whole continent. The level of cooperation is also influenced by such ideological positions such as African Renaissance and its foreign policy already discussed in earlier chapters.

The nature of astronomy is also based on ‘commonality and interdependence’ (Murphy *et al.*, 2009). The practice of astronomy is designed in such a way that those who practice it on earth rely on others who are doing the same in distant parts of the globe for their complementary views of the sky. The concept of interdependence in IR is often associated with vulnerability. In this view, states loose more by dissolving their relationships with one another. Thus, vulnerability interdependence emphasise the gains of cooperation and the potential losses of destabilizing relationship (Wooten, 2007).

Astronomy may be interdependent to astronomers practicing in different parts of the world, but the sharing of benefits will not be equal. The Covid 19 pandemic is a classic example where ordinarily interdependence on epidemiological data and vaccination was expected to bring cooperation, but on the contrary developed nations were accused of hoarding vaccines (Basrur and Kliem, 2021). In as much as the African philosophies of cooperation and interdependency which motivates participation in big science the Realism argument that interdependency does not

guarantee cooperation is already becoming a subject of discussion on SKA data proceeds and shall be seen in the section that discusses the commercialisation of space later in this chapter.

The first section of this chapter has looked at concept of power, its different variants and it can be constructed around big science. The motivation for science is to attain power. In Africa, participation of countries like Ghana in the SKA has roots in the values of cooperation and interdependence which have cultural significance, but the reality of cooperation and interdependence is always driven by interests in this case power over the 'superficial' views of the shared sky propagated by astronomy. To further amplify this argument, the next section explores the different ways in which science interacts with politics.

7.4 Patterns of science and political interaction

The above section has gone to length in illustrating how power is built around the discourse of big science right from the early understanding of power to current trends. This section strengthens the argument that science is not neutral by showing how it interacts with politics using six patterns proposed by Weiss as highlighted in the introduction of this chapter. The contribution of this thesis to that interaction has been to contextualise to the SKA, where the project is influencing regional science diplomacy, adding momentum to establishment of continental space agency, and becoming a game changer in terms of how the continent is viewed in global geopolitics. The thesis proposes to add the seventh pattern based on evidence presented in chapter six that explored the role of science in building ontological security, national prestige, and identity formation. The following are the patterns .and their explanations and will classify these interactions in the context of international relations.

Pattern 1: Science and technology as a juggernaut or escaped genie with rapid and wide-ranging ramifications for the international system.

The pace in advancement of science and technology normally outdo international governance capacity to deal with consequences (Weiss, 2015). As shall discussed under the governance of space in the next section, proliferation of satellites and commercialisation of space is posing a huge challenge on multilevel governance systems from international to national levels. While there is an agreement that outer

space is a common heritage that belongs to everyone, non-SKA participating countries would want access to the data generated from project. The new website for the newly formed SKAO, intergovernmental organisation is inundated with questions from non-participating countries about access and benefits. Already this gives an indication of how complex data sharing is likely to and calls for new policies and governance frameworks that the SKA project must deal with. Another live example of advances in science and technology advances that have changed international politics is nuclear proliferation which revolutionised geopolitics conferring disproportionate advantages to two main superpowers and becoming a marker of national power (Krige and Barth, 2006). The emergence of the information, communication, and technology (ICT) is another example where considerable advances in technology is now posing challenge and now requires innovation in its governance (Obar and Wildman, 2015)

Pattern 2: Science and technology as a game-changer: a changer of the ''operations'' of the international system, a conferrer of advantage and disadvantage to different actors in the international system and a blurrer of previously clear conceptual distinctions in the theory of international relations

Technological advancement creates new capabilities that unsettles world order and the international system, wars are now fought using sophisticated technology for example drone war fare, diplomacy now uses science as a tool, and almost every sector of an economy uses science. The accumulation of precision technology in warfare has conferred a superpower status to countries like USA but also posed challenges on democracy and rule of law in their use (Brooks, 2013). Space science capability is giving the African continent and countries like Ghana international competitiveness, building self-esteem, and favourable outlook in the geopolitical order as discussed in chapter six. Clear established boundaries in IR are slowly becoming blurred with technology. In the space sector new forms of bottom-up, and commercially driven space innovations are emerging that are reshaping traditional definitions of space power (Moltz, 2019).

Pattern 3: Science and technology as a source or key dimension of issues, risks and problems that must be addressed by the international community.

New technologies and capabilities can also bring relatively new risks and those driving them give the public assurances that the investment is worth and outweighs the

disadvantages for example the adoption of genetically modified food (Paarlberg, 2013). In some circumstances the risks are frankly acknowledged for instance nuclear capability. Space science has dual role in civilian life and military. The increasing space capability and beehive of activity in space cannot be confined to the purview of national boundaries but can affect other jurisdictions of states without space capability (Aglietti, 2020). While it can be argued that radio astronomy is just limited to ground observations but the data can be used for military operations Jodrell Bank Observatory, the headquarters of the SKA got prominence during Cold War when it was used for military operations to track Russian satellites (Spinardi, 2006). The current data that will collect when the SKA is fully operational will have the international community deliberating through their council on how it is shared and accessed.

Pattern 4: Technology and science as key dimensions of international macro issues or as sources of understanding or enablers that make possible new international macro phenomena.

Science and technology gives a technical basis for a macro processes such as globalisation (Weiss, 2015). Weiss further argues that, although the role of science is enmeshed in other factors such as economic, political, legal, and cultural, its contributions to globalisation are considerable given enablers such as transportation, information, communication, and technology that depend on scientific advancements. Exploration of space has enabled the operations of modern military warfare and civilian domains through technological advances in astronomy and space science. International hierarchies for countries and their competitiveness are strongly influenced by advances in technology and by the relative capacity in different countries to manage technology. Global pandemics and the science behind vaccine technology interacts with political, economic, and cultural variables (Garrett, 2015). Hence, science and technology play a crucial role in furtherance of macro international issues.

Pattern 5: Science and technology as an instrument of foreign policy or as a provider of technical information as an input to the management of an ongoing international regime or problem.

Science is increasingly being used to advance countries' foreign policy goals and 'interaction between science and diplomacy is becoming more and more necessary for governments to tackle global challenges' (Echeverría King, González

and Andrade-Sastoque, 2021: 2). The application of science and technology to international affairs is often referred to as ‘‘science diplomacy’’ (Weiss, 2015). At the height of the space race between the U.S. and the U.S.S.R. communication among scientists played a significant role as a source of political intelligence for the U.S. security establishment during the Cold War (Krige 2006 cited in Weiss, 2015). Science and technology can be useful in bilateral relations (Dolan and Metcalfe, 2012), in addressing global challenges (Miller, 2006), and for creation and maintenance of contacts for the country to a hostile state (Raven, 2013). Emerging market economies seeking to be integrated into regional and global markets are using science as a weapon for public and international diplomacy (Karacan, 2021). As indicated in chapter six, this may also be the case with African countries which are also seeking recognition and favourable standing in the global political hierarchy using science and technology projects such as the SKA as a footprint of modernity (Adam, 2020).

Pattern 6: Science and technology as the direct subject of cooperative projects and institutions whose planning, design, implementation, and management provide grist for the mill of international relations and diplomacy.

The scale of the SKA project qualifies to be a big science project and ‘raises international issues of location, cost, procurement, intellectual property, personnel, management or technical direction that must be resolved by international negotiation’ (Weiss, 2015). It is in the league of international scientific infrastructure that include the International Space Station, the European Center for Nuclear Research (CERN: Krige, 1996) and International Nuclear Fusion Experiment (ITER: McCray, 2010). The location of the SKA and subsequent co-hosting between South Africa and Australia came about as a political process than the science as noted in chapter one and chapter six. The newly transformed SKAO intergovernmental organisation in charge of the SKA project is currently dealing with cost, procurement, and potential intellectual property issues that may arise from the data generated by the telescope (SKAO, 2022).

Pattern 7. Science and technology in building ontological security, national prestige, and identity formation.

The thesis is adding this seventh pattern where science is being used to build a nation’s self-esteem thus ontological security, national prestige and negotiate identity

at international levels. The thesis argues that the acceptance to participate in the SKA project by Ghana and other African countries is motivated by the desire to building ontological security. Majority of developing countries particularly those that experienced colonialism have lost their self-esteem and identity which are key pillars of ontological security because of the categories of underdevelopment the global political hierarchy places them. Threats to self-esteem and identity primarily gives ontological insecurity, so any country in that position seeks to negotiate or re-establish its identity. The motives of state behaviour is to secure self-identity over time (Steele, 2007). Big science infrastructure projects such as SKA brings notions of modernity which are important identity markers in the global economic and political rankings. The thesis in chapter six demonstrated that this ontological security can be built at three levels from individual, state, and transboundary level. The transboundary level is beyond national borders of the countries participating in the SKA project but, influences the whole African continent as an entity to build its ontological security around science.

The following table summarises the contributions of Weiss in the first column from patterns one to six and then added the seventh pattern. The middle column explains the patterns is a condensed form and the third column is the major contribution of this thesis in contextualizing these patterns to the SKA project. The seventh pattern has academic *implications* to the discipline of IR, where ontological security needed not only at state level but at individual level as well. This generates insights into the behaviour of individuals, states and regional levels in international politics (Gustafsson and Krickel-Choi, 2020). The contribution of this pattern adds to the growing literature on ontological security in IR and science and technology as an important sub-field worthy to explored in the discipline. Table 7.1. provides the patterns of science and political interaction.

Table 7.1 Patterns of science and political interaction based on Weiss.

Pattern	Explanation	Relevancy to Space Science and Astronomy
1. "Science and technology as a juggernaut or escaped genie with rapid and wide-ranging ramifications for the international system."	A broad advance of science and technology outpaces the management capacity of the international community and leaves it struggling to catch up and deal with its consequences across a broad range	The level and scope at which astronomy is growing through SKA and amounts of data to be collected pose a challenge of governance in a multi-layered international system
2. "Science and technology as a game changer: a changer of the "operations" of the international system, a conferrer of advantage and disadvantage to different actors in the international system and a blurrier of previously clear conceptual distinctions in the theory of international relations."	The spread of new capabilities through technology transfer and absorption affects the international competitiveness of countries and hence the relative position of nation states in the geopolitical or economic pecking order.	Space science and astronomy capabilities have multiple uses to different sectors of the economy. Those space faring countries in the North with advanced ground-based observatories are at an advantage point to benefit more from SKA than those in the South
3. "Science and technology as a source or key dimensions of issues, risks and problems that must be addressed by the international community."	Advances in science and technology often brings in new issues for reflection on the agenda for the international community	Space science and astronomy have dual use (military and civil). More and more private players are getting involved in space which opens issues around governance
4. "Technology and science as key dimensions of international macro issues or as sources of understanding or enablers that make possible new international macro phenomenon."	Science and technology broods the technical basis for a larger ''macro'' phenomenon, such as globalization	The ambition of the SKA project is to observe the entire universe meaning all the countries participating are easily connected in real time and space. The interconnectedness rides on a globalised world
5. "Science and technology as an instrument of foreign policy or as a provider of technical information as an input to the management of an ongoing international regime or problem."	Science as an instrument to be employed for a clearly defined objective as a tool of foreign policy in a bilateral relationship or in an established international regime	The number of countries involved in SKA warrants a well-established system of science diplomacy that has impact on the foreign policies of parties involved
6. "Science and technology as the direct subject of cooperative projects and institutions whose planning, design, implementation, and management provide grist for the mill of international relations and diplomacy."	Major science- or technology-intensive projects frequently raise international issues of location, cost, procurement, intellectual property, personnel, management, or technical direction that must be resolved by international negotiation	The SKA hosting initially raised issues of location and was contested between South Africa and Australia and now management of IP as well as technical direction is always through negotiation on an unequal footing
7. "Science and technology in building ontological security, national prestige, and identity formation."	Hosting big science projects boost self-esteem and branding of a nation as well as conferring a new status (identity) in international politics	Countries that are building space science capability through the SKA and DARA projects feel proud of their achievements and are often given as examples of advancement at international fora

Source: Author's table with ideas adapted from Weiss's six patterns, 2015, p.413

The second section of this chapter explores how astronomy has been embroiled in the space race in the past and contemporary developments. Again, the main argument is that science is pursued for the attainment of power.

7.4.1 Space race in the past and contemporary

The legacy of the early years of the Cold War is that of heightened rivalry between the two superpowers, United States of America and the then Soviet Union as well as a space race, a competition to outdo each other in science. During the period innovative space technology was developed including being able to send human beings into the orbit. Analysing all these efforts by the great powers, the enduring question even up to now is that, was it for the sake advancement in scientific knowledge, strengthening of military capabilities or mere national prestige? This thesis argues that national prestige comes because of capability be it in science or military if there is breakthrough exclusive to that country. The era was also characterised by a clash of ideologies, Western countries led by USA were spreading capitalism and the socialism in the East being pushed by the Soviet Union (Powaski, 1998: 95-96). The linkages of capability, ideology controlled by ideation power, ontological security, and national prestige by extension an identity of a ‘superpower’ neatly coalesce to show practicality of the conceptual framework proposed by this thesis in the previous chapter.

Notions of national prestige and identity were more pronounced on either side of the great powers. The famous ‘Space Challenge’ speech by President John F Kennedy in 1962 was all about USA superiority enumerating achievements such as modern inventions, nuclear power, completed industrial revolutions and general advancement in science and that they could dominate space too (Kennedy, 1962). USA believed that more could be done on the space technologies for public knowledge only if they are ahead of the Soviet Union (ibid). Fortunately, at the peak of this space race Jodrell Bank Observatory which is the head office of the SKA project played an instrumental role using radio astronomy to track the Russian satellites. Although the prominence of Jodrell Bank and radio astronomy was disputed as an opportunity of Sir Bernard Lovell to demonstrate utility of the telescope amid public scrutiny for overspending on his budget to build the telescope (Spinardi, 2006).

The Space Race is evidence that pursuit of science is not only to advance knowledge, but the main goal is to attain power. On the other side the Soviet Union also believed in being the first to fly higher, to successfully send the first man to space and first to make artificial satellite. Siddiqi argues that the ideas for being 'firsts' in everything forged a linkage between science and national identity and that technology was equated with progress and the survival of one's nation (Siddiqi, 2010). In today's version of the space race, space science and technology are associated with progress and pillar of nations survival as evidenced by claims from projects such as SKA and DARA.

Africa may not have been so prominent during the Cold War era but that does not imply there were no efforts to explore the space. There is evidence which suggest that astronomy began in Africa more than 35 000 years ago (Gottschalk, 2010). As colonialism spread in the continent, European astronomers introduced modern astronomy in South Africa at the Cape of Good Hope and later established the Southern African Radio Astronomy Observatory (SARAO) in 1820 through the British Royal Navy (Heeralall-Issur, 2012). In other countries like Algeria, Kenya, and Libya, Europeans led by France, Italy and Germany established observatories. The only challenge was the exclusion of Africans from taking up subjects like astronomy and very little was done on the curriculum for 'blacks' due to a segregated education system which had a multi-tier curriculum that privileged whites (Anguma, Jurua and Asiimwe, 2012). It is this colonial history which casts doubt on current efforts to introduce astronomy in the school curriculum. At the time of this study in Ghana for instance, there was no curriculum for the subject in schools and universities.

In Zambia during the 1960s at the height of the Cold War, a science teacher, member of the Resistance Movement and self-appointed Zambia National Academy of Science, Space Research and Philosophy, Edward Makuka Nkoloso sought to challenge the USA and the Soviet Union in the Space Race. Makuka had ambitions to launch a rocket with a girl and two cats to the Moon and had plans to travel to Mars (Serpell, 2017). He would use rudimentary equipment like drums made of aluminium and copper to train his 'Afronauts,' a term he invented. There were efforts to source funding from UNESCO and private foreign investors, but his government disowned his efforts (ibid), and some regarded him as Zambia's village 'idiot' (Serpell, 2017). However, some have described Nkoloso as an inspirational figure and to have

something like space exploration crossing an African mind during that time was highly improbable. The story of Nkoloso together with the exclusionary curriculum during colonial times raises several issues around modern-day interventions in astronomy in the continent.

The Zambian government took Nkoloso as a clown and a lack of self-belief as Africans. On the other hand, the ambition for space today by Africa can again be taken by the world as a joke given little investment in such big science projects. The sincerity of funders of the projects may be questionable against a history of exclusion. Is it now their chance to show compassion and perhaps to correct the wrongs of colonialism and other forms of dehumanisation experienced by Africans or it is another endeavour to capture the continent epistemologically? Although astronomy has colonial roots in Africa, but today, astronomy projects in Africa are typically celebrated as decolonisation endeavours, an opportunity to rectify wrongdoings through capacity building (Dalgleish, 2021: 8)

The world today is embroiled in a new space race characterised by trends such as democratization, commercialisation, and militarisation (Pekkanen, 2019). Militarisation was always there and may not be a new trend.

The first trend on democratisation means that space activities are expanding to a growing number of states and nonstate actors, making the new space race distinct from first space age where United States and the Soviet Union dominated (MacDougall, 1985 and Siddiqi, 2000). United States of America, Russia, and Europe remain powerhouses of space technology. The only difference with the current space race is rise of lesser-known states and aggression to harness industrial benefits, ranging from independent space powers like Japan, China, and India, to entrants such as Australia, Luxembourg, the United Arab Emirates (UAE), Israel, Pakistan, Turkey, and South Africa, to name a few (Saadia *et al.*, 2012; Paikowsky, 2017; Moltz, 2019). One important aspect of this development is the entrance of Africa in this space race. Many African countries are now investing in space capabilities of which SKA and DARA projects are working on infrastructure and human capital development though specialising astronomy. Democratisation of space is also occurring at professional levels so it’s not just an addition of other countries but opening opportunities for professions such as lawyers to deal with legal issues, policy makers science

diplomats, communication experts and social scientists in a field predominantly of physics in nature. During the 2021 4th African Space Generation Workshop held in Ghana which I attended virtually, speaker after speaker emphasised the importance of other professions in astronomy projects. One speaker from the international space agency summarised it as follows.

> Democratisation of space means professions from other fields apart from astronomy and space science can come on board and occupy their positions that are equally important for the successful functioning of space programs. (International Panellist, Africa Space Generation Workshop, Ghana 2021)

Democratisation of space has dimensions of equity and access where lesser powerful states are now engaged but another important aspect is recognising the importance of other disciplines in the study of the universe. There is link that can be established with the earlier argument in chapter five about the missing social science ontologies in big science. This realisation of the value of other disciplines is the current democratising effect which can potentially benefit in strategising for impact in big science projects such as SKA.

The second trend on commercialisation brings enormous challenges of governance. Space industry is becoming lucrative, and more entrepreneurs especially private players are getting attracted to venture into the business. The attraction for entrepreneurs is profit all the way as projections estimate that space industry will grow from US$350 billion today to between US$1–3 trillion by the 2040s (Foust, 2018). Private companies especially in the USA like Bleu Origin and SpaceX are leading in space exploration promising faster, cheaper, and dependable access to space. Other new entrants include Chinese companies such as OneSpace and LandSpace which are likely to further unsettle USA and Europe given the current anxiety caused by the rise of China as an alternative to the world order. Space Race in the Cold War Era was marked by competition, but the ‘New Space Race’ has been upholding cooperation. However, with the advent of commercialisation undermines prospects for cooperation but instead competition. The principle of space as a “common heritage” where benefits of space should be shared equally as enshrined in the Outer Space Treaty (OTS) is threatened. The main goal of private players is profit. Capabilities of countries in space can be divided into space faring and non-space faring nations. Space faring nations are those with the ability to access or travel to space and are

concerned with upstream applications of astronomy as opposed to downstream applications where the thrust of SKA and DARA projects are focused as shown in Fig. Space faring great powers like USA, Russia and China opposed the Moon Agreement based on its common heritage principle and sharing equitably the benefits which was against dominance and commercial purposes of space by private players.

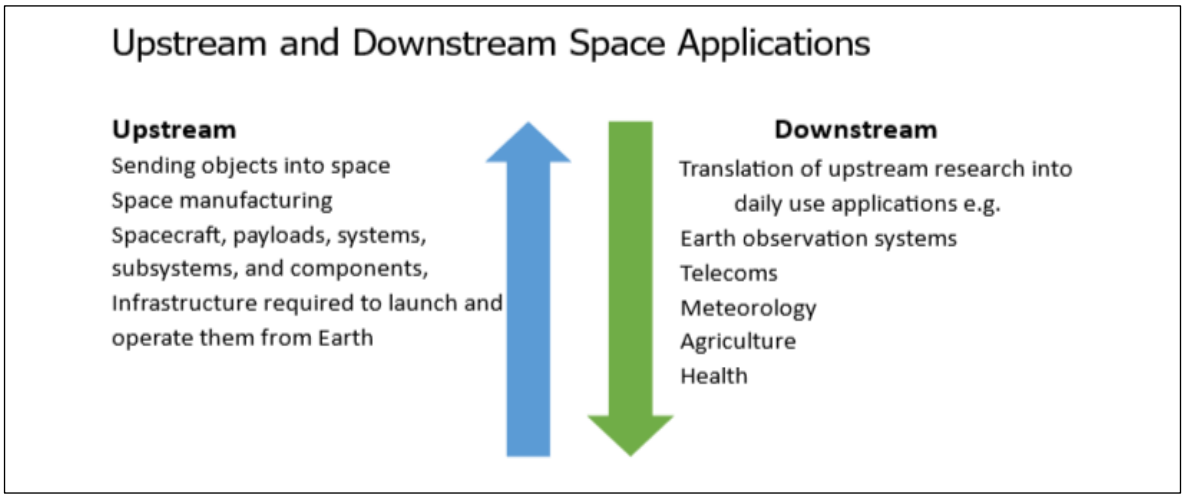

Figure 7.1: Author's diagram showing upstream and downstream space applications.

The current Space Race is emphasising investment in downstream applications of space science which are applicable to other sectors of the economies and touch on livelihoods. Africa is behind in terms of sending sophisticated objects into space and even the downstream applications of space, most of the member countries are still at initial phases either setting up a space agency or the existing agency is not well funded by government.

Militarisation

Lastly, there is a growing militarisation of space. The inherent nature of space science is that 95% of the technologies have dual uses in commercial and military sectors and this has implications for private companies that are worried about business viability and profitability. Government interests in security and military intelligence means satellite business still has demand. Another challenge is shifting world order, marked by great power competition (Rodrik and Walt 2021). Geopolitical rivalries are intensifying on Earth today, with states taking their rivalries to shift the balances of

space power in their favour (Johnson-Freese, 2017). The voices of relatively smaller nations that have or do possess potential to use space capabilities are not often considered during security platforms especially through the United Nations (Johnson-Freese and Burbach, 2019). Therefore, emerging economies need to demand for a 'fair level field of play' with the goal of assuring that there are rules and that they have some say in making them (ibid). This leads to a discussion on the governance framework of space activities in the following section.

7.4.2 Governance architecture of space activities

The governance of space activities at international, regional, and national levels is worthy exploring in this section as it brings in asymmetrical power dimensions that are of interest and partially explains why Africa as a continent is getting more involved now. Governance architecture of space refers to the 'rules of the game,' interactions of players at various levels ranging from inter-governmental to inter-organisational networks often marked by interdependence. I will first describe the network of this governance system starting with the international, regional, and then to national levels with a focus on Ghana and South Africa. An analysis of power asymmetries is done through evidence from the interviews and discourse from already published material.

At international level, the United Nations (UN) takes a centre stage in the governance of space activities, negotiating international treaties and overseeing their adoption. There are several organisations that assist the UN in its role. Within the UN, the United Nations General Assembly (UNGA) manages most of the global issues including space matters. Six permanent committees help the UNGA in its discharge of duties and two committees directly deal with space activity (UNOOSA, 2021). The First Committee deals with disarmament and security matters and the Fourth Committee, on special political matters including outer space. The Committee on the Peaceful Uses of Outer Space (COPUOS) is the UN body responsible for developing policies related to outer space including astronomy on behalf of the UN Member States and the Office of the Outer Space Affairs (OOSA) is the secretariat (UNOOSA, 2021). It does not deal with military space issues. COPUOS is composed of 74 Member States and 29 permanent observers and is the premier international forum for working out issues of space governance. The work of the Committee is divided into two

subcommittees: the Scientific and Technical and the Legal Subcommittee. Matters that come before COPUOS are deliberated first in working groups within one of the subcommittees and when agreement is reached, the matter is presented to the full committee as a report of the Subcommittee. The COPUOS was responsible for crafting the main treaties that govern space. There is conspicuous absence of the African Space Agency in the COPUOS, and the general participation of the continent historically has been lacklustre (Froehlich and Siebrits, 2019: 72).

The main foundation treaty is the 1967 Outer Space Treaty (OTS) which spelled the broad tenets of outer space law upon which subsequent treaties were based on (UNOOSA, 2013). The key principles that are embodied in the OTS among other things include exploration and use of outer space for peaceful purposes by all States for the benefit of mankind, barring of national appropriation or claims of sovereignty of outer space or celestial objects, ban on placement of weapons of mass destruction in orbit or on celestial bodies, and that States are required to supervise the activities of their national entities (Secure World Foundation, 2013). The other important treaties are Rescue Agreement (1968), Liability Convention (1972), Registration Convention (1976), and Moon Treaty (1984)

The treaties described culminate into two main types of space governance that is binding and non-binding. Binding or normative instruments include treaties, standards and national regulations, and non-binding agreements used to convey voluntary, non-normative and/or aspirational content that may be too difficult to achieve international consensus on (Oltrogge and Christensen, 2020). The OTS and its core treaties are binding to the states that have ratified them and some spacefaring states are yet to ratify.

Ratification of treaties which are binding has brought into being multilateralism and bilateral agreements as well as voluntary consensus principles and guidelines for space operations which unfortunately are non-binding. Multilateralism is a form of membership in international institutions that serves to bind powerful nations, discourage unilateralism, and gives small powers a voice and influence that they could not otherwise exercise. In IR, multilateralism is understood by some scholars in terms of quantity i.e., three or more states involved (Keohane, 1990, Corbetta and Dixon, 2004), however this scholarly position constitute a minority instead others are of a

quality-based definition. Scholars like Ruggie (1992, 1993) and Weber (1991) suggests that multilateralism needs the following key attributes: indivisibility, generalised organising principles, and diffuse reciprocity. Indivisibility demands that multilateralism must be based on socially constructed public good (Ruggie, 1993: 11). Generalised organising principles and diffuse reciprocity require multilateralism to shun discrimination and preferential bilateralism. Multilateralism therefore denies "differentiation on a case-by-case basis according to power or individual preferences and demands for precise quid-pro-quo (something for something) type of agreements (Weber, 1991: viii).

While the ideals of multilateral cooperation are upheld, the status of treaties in terms of their voluntary consensus and dependence on national ratifications by member states brings to fore the Realism argument in IR that states in an anarchic system are preoccupied with power and to defend and retain their sovereignty. The treaties appear to have a strong bias on addressing space exploration with resemblance of Space Race era which had a militaristic agenda at the expense of equally important ground-based astronomical observations which feed into space capabilities in a synergistic manner. The failure of many states to ratify the Moon Treaty of 1984 and its predecessor Moon Agreement of 1979 which espouses the principle of space not just as the province of humanity but as the common heritage of humanity, where the benefits of commercial activity "must in principle be shared equitably by all humankind" (Storr, 2020:2).

Multilateralism has stagnated since the Moon Agreement and efforts to revive came around 1985 with the Conference on Disarmament (CD). The CD was an ad hoc committee to deliberate on the Proposed Prevention of Arms Race (PAROS) Treaty (Abramson, 2009). The treaty sought to preserving "space for peaceful uses by prohibiting the use of space weapons, the development of space-weapon technology, and technology related to missile defence." (Nuclear Threat Initiative, 2020). Little success was registered until 2008 when China and Russia presented a draft Prevention of Weapons and Threat of Force Treaty (Abramson, 2009). The USA rejected this draft on the basis that the nature of space activities has dual use i.e., military, and commercial as well as their interoperability. As a result, the international governance of space has been left to unilateralism, bi-lateral agreements and norm setting voluntary principles. The initiatives of NASA returning to the moon under the

Artemis Accords which is a set of common principles for civil space activities, drafted by the United States and grounded in the OST (Storr, 2020: 1).

The African continent lacked space governance structures for a long time, and this has affected participation with vitality in major international committees such as the UN COPUOS. Africa established its continental space agency in January 2018 (African Union, 2021) through the African Space Agency Act. An associate Space Strategy was also developed. The Act established the African Space Agency, a body set to "promote and coordinate the implementation of the African space policy and strategy and conduct activities that exploit space technologies and applications for sustainable development and improvement of the welfare of African citizens" (African Union, 2021). Governance of space at continental level is still at an infancy stage and the relationship with other international bodies is still at formative stages. The African Union expert on space indicated this status during interviews and mentioned that.

> Both entities (UNOOSA and COPUOS) are important and central to international collaborative space. We have official communication with them which we expect, and hope will elevate our engagement to a higher level. Recently we exchanged letters of collaboration between the two organizations. In some few occasions, African Union has participated in the COPUOS sessions as unofficial observer. Efforts are being made to ensure that the African Union Commission and the African Space Agency both become official observers at COPUOS. (African Union Space Science Expert)[43]

The status gives African states a weak position of bargaining and lack a voice on the rules of the game at international level and this cascades downwards to member states whom the majority are yet to ratify international statutes, build their national governance regime of space activities. South Africa and Nigeria seem to be a step ahead in terms of having formulated national pieces of legislation to govern their space activities (Von Der Dunk, 2017). Ghana was still in the process of formulating its national policy and laws although they are a signatory of the Outer Space Treaty. The African Space Agency Act does not reference much about private actors in space and assumes state centric approach to space exploration yet non-state actors like private

[43] The African Union expert on space science provides technical advice to member countries and played a big role in the establishment of the African Space Agency

companies are actively participating and in some circumstances taking the lead in space (Gabriel and Koven, 2018). There is also an assumption that all states possess the same interest and enthusiasm for space that may affect the developmental pattern of space capability in Africa (ibid). International and regional space governance has been characterised by geopolitical strategies and pursuit of hegemony. Great powers have capitalised the stagnation of multilateralism and unilaterally dictated norms and principles governing space activities. Africa still needs to step up its efforts and occupy a chair on the international stage where rules and agenda is set to exploit the proceeds of space exploration.

7.5 Conclusion

Big science is not apolitical as scientists might portray. Science and politics coproduce each other in diverse ways enumerated in the first section of this chapter. While efforts to depoliticise science and suspend political machinations in the implementation of big science projects such as the SKA, their magnitude and involvement of both state and non-state actors attracts attention of politicians and influence even implementors to act in a 'political' manner. The evidence suggests that there is a correlation between power and big science.

This chapter presented an early opportunity to evaluate the conceptual framework proposed in the previous chapter that there is a relationship that exists on interaction of ideational power, ontological security, and capability to form an identity. States pursue big science projects as a way of building ontological security, national prestige and extend hegemony in a non-coercive manner. Processes in the background suggest that sustenance of ideas that bring national prestige and raise self-esteem requires that interaction of ideational power, capability, and ontological security discussed in chapter six. The Space Race still exists but in a new and sophisticated version. The new Space Race is different from the old in that it ushers contemporary trends such as pronounced entrance of continents like Africa pointing towards democratisation of space. Proliferation of private companies in the space arena and commercialisation has brought implications on governance and challenges. This thesis has examined how these new actors are engaged through global networks, to individual scientist and students and politics at national and gives this exceptional window into how this new space race is evolving in Africa.

The emphasis on principles of cooperation and interdependence which ideally should guide big science projects like astronomy are at odds. Private companies are driven by desire to make profits on a ‘common heritage’ which invokes competition on a science endeavour that requires cooperation. Therefore, it can be concluded that interdependence does not guarantee cooperation. Regional or South to South cooperation is also undermined in the Global South due to the acute dependencies of both expertise and resources on the Global North. Competition in space exploration supports the view that in conditions of anarchy states are concerned with their own security, act in pursuit of their own national interests, and struggle for power. Another trend is the dual use space technology for both military and civil use leaves a delicate situation for unilateralism and nationalisation of space.

The international governance of space has binding and non-binding treaties. The implementation of these treaties at national levels depends on ratification and enactment of laws and policies. While several countries are signatories of international treaties such as the Outer Space Treaty but very few have managed to formulate national policies and laws. Absence of Africa in the decision-making bodies of the UN such as COPOUS present a top-down multilateralism that may not take the contexts of certain regions into consideration. Big science projects require bi-directional exchange of ideas for their ‘smooth’ implementation. The composition of the COPOUS in terms of membership creates unequal power dynamics that perpetuate inequalities of access to outer space benefits and attendant economic development. However, Africa is driven to continue with efforts to get integrated into the international system because of its view of the ‘international’ guided by traditional concepts such at Ubuntu that underscore the importance of collectivism as opposed to individualism.

In conclusion, this chapter has provided a clear understanding of the complex relationship between power, science, and big science projects in the Global South. The chapter has revealed that science is not neutral and that it is intricately intertwined with power dynamics. The concept of coproduction between science and power has been shown to be particularly relevant in the context of large science infrastructure projects in the Global South. These projects often involve multiple stakeholders, including governments, funding agencies, and international organizations, who all have their own interests and priorities. As a result, the power dynamics involved in the planning and implementation of these projects can have a significant impact on their

outcomes. This chapter has also demonstrated the need for a more critical and reflexive approach to big science projects in the Global South. It is essential to recognise the power dynamics at play and the potential implications for the African continent, national governments, and local communities as synthesised in the concluding chapter.

Chapter 8
Conclusion: Advancing In-depth Knowledge Imbedded in Big Science

This chapter presents a synthesis of all chapters and highlights key contributions of the thesis in the process of answering the main and sub-questions. The chapter derives general theoretical conclusions about the role of big science in the development discourse and in the discipline of international relations. The Square Kilometre Array (SKA) project in Africa is a prime example of how big science politics can have a significant impact on global development. The SKA project is one of the most ambitious and complex scientific projects ever undertaken, and its successful implementation in Africa has the potential to transform the continent's economies, knowledge base, and international standing. The legitimation of astronomy as useful science for development begins with depoliticization i.e., taking out or suspending politics from the discourse which Ferguson refers to as the antipolitics machine (Ferguson and Lohmann, 1994). The thesis has argued throughout the chapters that the suspension of political issues in the discourse of development through antipolitics are the ones that matter in the big science-development nexus. I have demonstrated that the big science such as radio astronomy and space science in the African development trajectory is more to do with the assumptions that underpin the science-development nexus which are divorced to the context in these developing states.

The ontological position that building capacity in science, technology and innovation naturally lead to development has been carefully analysed and an extrapolation of its epistemological foundations point towards modernisation perspectives and neoliberalism. The language deployed in big science is that of utilitarian nature where science is the fulcrum for development and modernisation in places such as Africa. Behind this simplified and fixated view of ST&I for development is an undying assumption that science and innovation represent development, but questions around who is doing that science and for who in the global innovation system are not put in the matrix (Zheng and Yu, 2016).

Modernisation and neoliberal theories of development fall short in their knowledge base and assumptions of the Global South were a technocratic framing of the

challenges posed by underdevelopment such as poverty are prescribed a technical intervention mainly from the Global North Development. The ‘underdevelopment’ challenge in the Global South is presented as a technical problem that needs technical solutions such as investment in big science like radio astronomy. While such frontier science is needed by developing nations to maintain basic competence and demonstrate that they are not forever chained to the basics of feeding and clothing themselves (White Paper on Science and Technology, 1996: 16 cited in Gottschalk , 2012). The self-declared moral obligation by the Global North to intervene and modernise the Global South have some basis on post- world war II strategies such as Truman Point Four Program highlighted in chapter one. However, these social and technical tools for development sits on conflicted ideas of civilizing the territories and exploiting human and material resources, while conserving immanent uneven colonial relations, racial connotations and dependency (Mateos and Suárez-Díaz, 2020: 301). Instead of bridging the knowledge gap between the Global North and the Global South big science projects and accompanying human capital development play a background role in maintaining dependency and extractive type of relations.

Power Structures of Knowledge Production

Colonial traits embedded with racially transformed language of ‘underdevelopment’ with a promise of social and economic justice are perpetuated in discourses of development (Adas, 2016). Knowledge generation in the Global South is still deployed in a colonial fashion as argued by Ndlovu-Gatsheni (Ndlovu-Gatsheni and Zondi, 2016; Ndlovu-Gatsheni, 2018). Ndlovu-Gatsheni argues that colonialism has created a binary distinction between the Western world and the rest of the world, which has resulted in the marginalization and exclusion of non-Western knowledge systems. This thesis takes this argument in the SKA implementation where global "coloniality of knowledge" plays that background role in reinforcing the dominance of Western knowledge systems and discredits non-Western forms of knowledge. Coloniality of knowledge production continues to shape contemporary global knowledge production, perpetuating the exclusion of non-Western perspectives and reinforcing existing power structures. Decolonization of knowledge production therefore requires a re-evaluation and integration of non-Western knowledge systems, as well as the

dismantling of the colonial structures that perpetuate the exclusion of non-Western perspectives in knowledge production.

The concept of development and economic progress is becoming established in major scientific infrastructures, skills, techniques, and instruments. This trend has been identified by Mateos and Diaz, who note that interventions and capitalist projects using technoscientific solutions aim to improve societies that are perceived as lacking development (Mateos and Suárez-Díaz, 2020: 299). This thesis contributes to the existing knowledge by presenting current observations on the discourses of development through large-scale scientific projects. The argument made by Lewis is that development policies focused on science, technology, and innovation cannot simply be copied as technical operations to improve efficiency or productivity in the long run (Lewis, Wood and Gregory, 1996) . If the cultural and political contexts are not prepared to absorb and incorporate them, big science infrastructures and associated human capital development programs may not bring socially beneficial effects. This implies that investing in building individuals' capacity should be done simultaneously with significant investment in the entire innovation system, considering the local context. This study's findings show that material challenges of funding, administrative incapacity, informal economies, and weak governance structures persist in Africa. To develop suitable approaches to address challenges in areas such as science, technology, and innovation and development, a new understanding and conceptualization of the term 'development' should move away from Western eulogies and incorporate contextual knowledge.

Development Discourse in Science

Despite the position of science in development discourses its potential to contribute to Africa’s development is dependent on how it is conceptualised and deployed. The thesis has given a snapshot of the African experience in terms of who controls the narrative of development. The meaning of both science and development from an African perspective decentred from the West still needs more research efforts. Material challenges which are being experienced in the implementation of the SKA and DARA projects in Ghana are not only an isolated case but mirrors several countries in the continent. Technical assistance is confronted with innumerable local needs, contrasting interests, to the extent that economic and social outcomes attributable to

technological and scientific solutions are redirected and rejuvenated in a hope generating fashion (Nuijten, 2004). The impending challenge of science to transform lives in Africa is explained through simulations done by development institutions for individual countries 'to fit into the models and into the possible packages and taxonomies in the available areas of technical assistance' (Ferguson, 1990 cited in Mateos and Dias, 2020: 298). However, the realities on the ground and experiences of individual countries defies the projected impact of science on development. Space science in development discourses is not proportional to its funding in the Global South and the context of development at national and local levels.

Although it's too early to fully grasp the development impacts of the projects in Ghana and in the African continent in general because most of the work is still underway in terms of functionality of the upgraded infrastructure and capacity building, there is some remarkable evidence of unintended potentially positive effects. While there is an attempt to take away politics from the discourse of development in a similar fashion noted by Ferguson in Lesotho where "development" agencies presented the country's economy and society as held by a neutral, unitary and effective national government, and thus almost perfectly responsive to the blueprints of planners (Ferguson and Lohmann, 1994: 3).

Ontological security and big science

Governments in Africa have welcomed the SKA project in their countries as a potential instrument to show what they can do for their people locally and externally projecting a different identity to the world. The SKA and DARA projects have succeeded in building ontological security at individual, corporate (national) and transboundary levels as sketching out biographical continuity (Kinnvall and Mitzen, 2017) of the African continent. The thesis has provided a deeper insight on how Africa is asserting its position and negotiating a new identity in international politics and the discipline of IR itself which is currently skewed towards the West (Gallagher et al., 2016).

The thesis innovatively applied the concept of ideational power (Carstensen and Schmidt, 2015b), ontological security (Mitzen, 2006) and capability (Sen, 2001) in identity formation or negotiation of new identity. The empirical findings provide a new understanding of space science and how it is being used in Africa to position itself in

the international political hierarchy. However, the thesis also gives caution in terms of building ontological security and new identity around big science given the vulnerability posed by dependency and power dynamics in knowledge production. Although, Africa is asserting its position in global political hierarchy and negotiating a new identity of a continent that “can do things” using science, it is still in liminal status.

According to Gartner, the technocratic perspective of big science, their infrastructure and human capacity building is ushered as projects with material value (Gartner, 2016: 379). However, scientific technical interventions and development ideas are not neutral conceptualisations. The interaction of the two co-produces power (Jasanoff, 2004; Swedlow, 2012; Montana, 2019; Turnhout, Metze and Klenk, 2019). Jasanoff’s work explores how science is incorporated into state-making, or of governance more broadly, and inversely how governance influence science and utility of knowledge. The thesis concludes that production of power and identity is the main incentive for policy makers and politicians to pursue big science. Space science and astronomy has been incorporated in governance. To politicians, even if the desired outcome is not met, the presence of such big science infrastructures is a symbol of power and justification of the extraordinary mandate that they must modernise their economies. In the developing world and marginalized groups science infrastructure may be viewed as symbols of power and mechanisms to acquire it (Gartner, 2016). Ontological security is therefore built around big science and projects positive African identity. From this perspective, SKA in Africa and development claims are not apolitical but can represent existing power struggles and can be magnified as outcomes of socio-political relationships that subsist in this inequitable global society.

The concept of the "antipolitics machine" as introduced by Ferguson (Ferguson, 1990) has been a useful framework for analysing the political dynamics of big science initiatives in Africa, as demonstrated in this thesis. Analysing the SKA and DARA projects, it became apparent that assumptions, power dynamics, and theoretical frameworks play a significant role in shaping these initiatives, often to the detriment of locally driven development in Africa.

However, this thesis has also highlighted the potential for big science initiatives to contribute positively to the ontological security of African societies. Building on existing social and cultural structures, these projects can foster a sense of community and

identity, thereby boosting confidence, national and regional image in international politics. The contribution of this thesis lies in its nuanced exploration of these complex dynamics, and its identification of the ways in which big science initiatives can be leveraged to build ontological security in Africa. By examining the SKA and DARA projects through a critical lens, this thesis has provided a valuable contribution to our understanding of the political implications of big science initiatives in Africa.

It is imperative for policymakers and researchers to remain mindful of the political dynamics that underlie large-scale scientific initiatives in Africa. Ghana, like many other countries in Africa, faces significant challenges in its scientific endeavours. These challenges are rooted in historical, political, and economic factors, such as inadequate funding for research and development, limited access to state-of-the-art scientific equipment, and a lack of trained personnel. Furthermore, scientific knowledge produced in the North is often not applicable to the local context of Ghana, and research is often conducted without regard for the needs and perspectives of local communities. This results in a dependency on foreign scientific knowledge and resources, which undermines the development of local scientific capabilities and perpetuates economic and political inequalities.

Scientific and material dependency

The thesis takes forward Hountonji's argument that scientific dependencies in the Global South are rooted in historical, political, and economic factors, rather than a lack of scientific expertise or resources (Hountondji, 1990a). As evidenced by the findings of this thesis that scientific knowledge produced in the North is not neutral but is embedded in a specific cultural context that consciously or unconsciously disregards the cultural practices and beliefs of the South. As a result, scientific knowledge and technology are often imposed on the South without consideration of local needs or existing knowledge systems. This creates a dependency on Northern scientific knowledge and resources, which undermines the development of local scientific capabilities and contributes to ongoing economic and political inequalities. To address these issues, Hountonji suggests that scientific research in the Global South should prioritize local knowledge and practices and should be developed in collaboration with local communities to ensure relevance and sustainability. These stakeholders must

take proactive measures to ensure that such projects are geared towards promoting sustainable and inclusive development. This approach would not only enhance the ontological security of African societies, but also foster the overall wellbeing of the communities in the region.

Although the SKA project in Ghana was the case study for this research, the insights gained from this study have implications for understanding the broader context of development in Global South countries. This research has shed light on why certain ideas become powerful in development discourse and has identified areas for future exploration. Specifically, future research could focus on ethnographic contributions from local communities in the vicinity of the Ghana Observatory in Kuntunse to gain a deeper understanding of their perceptions of development. Furthermore, this research has highlighted the importance of addressing global power structures in knowledge production and access to material resources as well as aligning international, national, and local development expectations. These findings suggest that future research should focus on the role of power dynamics in the implementation of big science projects such as the SKA in Africa. Overall, this study provides valuable insights that can inform future research and policy interventions aimed at promoting sustainable development in Global South countries.

In conclusion, this thesis has demonstrated that big science initiatives in Africa are complex and politically fraught, but also that they have the potential to contribute positively to the ontological security of African societies. This thesis provides a valuable contribution to our understanding of the political dynamics of big science initiatives in Africa. By examining the SKA and DARA projects through a critical lens, I have shed light on the ways in which power shapes these initiatives and have highlighted the potential implications for African societies. By building on existing social and cultural structures and promoting inclusive and sustainable development, these projects can foster a sense of community and identity promoting social stability. However, to achieve these positive outcomes, it is essential that policymakers and researchers take a critical approach to big science initiatives, acknowledging the complex political dynamics at play and working to ensure that these projects do not perpetuate existing power structures or exacerbate inequalities.

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Appendix A

Ethical Approval Letter

The Secretariat
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Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Jekoniya Chitereka
School of Politics and International Studies
University of Leeds
Leeds, LS2 9JT

Business, Environment and Social Sciences joint Faculty Research Ethics Committee (AREA FREC)

Dear Jekoniya

Title of study:	**Politics of Science, Technology, and Innovation in Africa: The Case of the Square Kilometre Array in Ghana**
Ethics reference:	**AREA 19-003**

I am pleased to inform you that the above research application has been reviewed by the Business, Environment and Social Sciences joint Faculty Research Ethics Committee and following receipt of your response to the Committee's comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date
AREA 19-003 Summary Response JCv3.docx	1	25/10/19
AREA 19-003 Summary Response.JC.docx	1	08/10/19
AREA 19-003 Ethics _Review_ JC_v3.doc	3	25/10/19

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, the Secretariat
On behalf of Dr Matthew Davis, Chair, AREA Faculty Research Ethics Committee
CC: Student's supervisor(s)

Appendix B

Interview Guide

1. Can you briefly describe your national Science, Technology, and Innovation (ST&I) System and what role do you occupy?
2. In your opinion how is the ST&I policy linked to your National Development Plan?
3. How is the ST&I System funded in Ghana (i.e., government, private sector, and philanthropic organisations' contributions)
4. Why is astronomy important to Africa and specifically Ghana?
5. How do actors in S&T policymaking see international and bilateral processes entering and shaping national S&T governance?
6. How do they conceive national S&T policymaking as a response to global politics?
7. What are the potential benefits of astronomy to Ghana's economic sectors? (economic impact)
8. How are Square Kilometre Array (SKA) and Development in Africa with Radio Astronomy (DARA) projects contributing to develop skills and expertise in Africa and Ghana? (Educational impact of the project).
9. What does the concept of development mean to you?
10. In your opinion how is SKA and DARA addressing race and inequality issues in science?
11. What are the main challenges of implementing big science projects like the SKA and DARA in Africa with specific reference to Ghana?