AFRICAN PERSPECTIVE ON INTEGRATED SPACE AND AIR TRAFFIC MANAGEMENT

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ABSTRACT

Space Traffic Management (STM) is an emerging area of interest in the space sector because States and private actors are collaborating on ways to manage the growing congestion in orbit and to mitigate the impact of space debris and space weather as part of sustainable use and exploration of outer space. Further, the pace at which commercial space operations is mushrooming and the potential for growth that the suborbital space flight market presents has led to talks about integrating space and air traffic management, through technological interfaces and harmonised regulatory regimes. But, the current global challenge is the lack of a legal framework, either in the existing space-related treaties or the adoption of a new treaty regulating STM similar to the other traffic regimes, namely aviation and maritime, and advancement in technology to seamlessly integrate Space Traffic Management (STM) and Air Traffic Management (ATM). Therefore, the proposed integration of space and air traffic management necessitates an analysis of African perspectives when it comes to consolidating the two traffic regimes, taking into account the fact that ATM in Africa is fragmented. Hence, this study analyses the legal aspects of integrating Space and Air Traffic Management from the African perspective.

DEDICATION

I would like to dedicate this dissertation to my late brother Kasper Gairiseb may his soul rest in eternal peace.

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I would like to extend my gratitude to my beloved wife Mrs. Whitney Gairises and our three beautiful daughters Rona-Lee Gift Ochurus, Precious Naomi Ochurus and Esperanza Glorious Gairises, for the love, support and understanding they displayed during the late nights I spent away from them whilst writing this dissertation, and for cheering me up when the research got tough. I would like also to thank my supervisor Prof. Peter Martinez for his guidance, time and effort he dedicated to me at the time of writing this dissertation despite his busy work schedule. May God bless you in all your endeavours.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFUA	:	Advanced FUA
AfSA	:	African Space Agency
AGAC	:	Autorité Guinéenne de L'Aviation Civile
ALPA	:	Air Line Pilots Association
ANACIM	:	National Agency for Civil Aviation and Meteorology for Senegal
APAC	:	Asia-Pacific
ASAT	:	Anti-Satellite
ASM	:	Airspace Management
ATC	:	Air Traffic Control
ATM	:	Air Traffic Management
ATNS	:	Air Traffic and Navigation Services
AU	:	African Union
CAA	:	Civil Aviation Authority
CANSO	:	Civil Air Navigation Services Organisation
COPUOS	:	Committee on the Peaceful Uses for Outer Space
CSP	:	Cameroon Spaceport
EAC	:	East African Community
EAS	:	East African Spaceport
ENNA	:	Etablissement National de la Navigation Aérienne
FAA	:	Federal Aviation Administration
FOV	:	Field of View
FUA	:	Flexible Use of Airspace
GEO	:	Geo-synchronous Earth Orbit
GNSS	:	Global Navigation Satellite System
HAPS	:	High-altitude Platform System
IAA	:	International Academy of Astronautics
ICAO	:	International Civil Aviation Organisation
INAC	:	Instituto Nacional de Avicão Civil
LEO	:	Low Earth Orbit
Medusa	:	Mechanism for Entrapment of Debris Using-memory Alloys
MSX	:	Midcourse Space Experiment
NAMA	:	Nigerian Airspace Management Agency

NANSC : National Air Navigation Services Company
NCAA : Namibia Civil Aviation Authority
NextGen : Next Generation Air Transportation System
NEOSSat : Near Earth Object Surveillance Satellite
NOTAMs : Notices To Airmen
NSBE : National Society of Black Engineers
ONDA : Office National Des Aeroports
OST : Outer Space Treaty
OTR : Overberg Test Range
RPAS : Remotely Piloted Aircraft Systems
RVA : Regie des Voies Aériennes
RVL : Reusable Launch Vehicle
SAATM : Single African Air Transport market
SANSA : South African National Space Agency
SARPs : Standards and Recommended Practices
SAR : Synthetic Aperture Radar
SBSS : Space-Based Space Surveillance
SATM : Space and Air Traffic Management
SES : Single European Sky
SESAR : Single European Sky Air Traffic Management Research
SSA : Space Situational Awareness
STCs : Space Transition Corridors
STCOs : Space Traffic Control Officers
STM : Space Traffic Management
SUA : Special Use Airspace
SWIM : System Wide Information Management
TBO : Trajectory Based Operations
TFRs : Temporary Flight Restrictions
UNOOSA : United Nations Office of Outer Space Affairs
UN SDGs : United Nations’ Sustainable Development Goals
UAS : Unmanned Aircraft Systems
UAV : Unmanned Aerial Vehicle
USSTRACOM: US Strategic Command

1. INTRODUCTION

To begin with, the 21st century has witnessed the congestion or crowding of the space environment for a number of reasons, *inter alia*, the entry of private actors into the space arena as new entrants, commercialisation of space exploration and use, and the emergence of the small satellite industry that makes use of off-the-shelf components and cheaper than traditional large satellites. Consequently, this has led to the space environment being crowded due to the increased number of spacecraft but not yet regulated like other traffic regimes in order to ensure safety and sustainability in outer space.

Therefore, numerous academics and professionals in the aerospace sector have proposed the establishment of an international regulatory regime for Space Traffic Management (STM). For instance, scholars such as Jakhu, Sgobba and Dempsey (2011:128) have proposed a sort of "ICAO for Space to regulate space traffic, which should be designed as a comprehensive, permanent, and holistic space safety oversight regulatory regime." In the opinion of Jakhu, Sgobba & Dempsey (2011:138) "the ideal solution to accommodate space traffic management and other space safety requirements would be to amend the Chicago Convention, thereby expressly extending ICAO's jurisdiction over space activities. This will, in their view, eventually lead to a corpus of integrated aerospace law."

Others have also opined for the integration of commercial sub-orbital flights into the existing Air Traffic Management regulations. This was the case for the Federal Aviation Administration, which has developed the "Concept of Operations for Commercial Space Transportation in the NAS in anticipation of the evolution of a National Airspace System environment in the 21st century that fully integrates commercial space operations in the existing regulatory framework for aviation" (Federal Aviation Administration, 2001:1). Equally, Europe is also investigating on ways to integrate a European STM system within an evolving global Air Traffic Management system (Tüllmann *et al*. 2017a:2).

Now, it is common knowledge that there is no international legal regime, legal in the sense of binding rules and regulations as opposed to soft laws, addressing space traffic management, whereas, air traffic management is well regulated within the international air law regime under the auspices of the International Civil Aviation Organisation (ICAO). But with all these developments taking place in North America and Europe, the international community forgets to address the impact of such initiatives on Africa, let alone the perceptions of African stakeholders on integrating Space and Air Traffic Management. In particular, there is a huge gap between Africa and the United States and Europe in as far as technological and regulatory development is concerned. For instance, the United States as one of the leading space-faring nations (indeed the dominant space power) in the world has an advanced space programme, both from the regulatory and technical side, compared to that of African nations collectively. Eventually the technical and regulatory requirements which will be imposed by any integrated space and air traffic management scheme require an analysis that looks at it from the perspective of non-space faring nations. Non-space faring because the majority of countries in Africa have a little or no space programme, with the exception of the "big four" space actors in Africa, namely, Algeria, Egypt, Nigeria and South Africa. Both Nigeria and South Africa are currently engaged in a space race in the continent, in particular, Nigeria and South Africa have by far the most advanced space programs on the continent (CNN, May 2018). However, even the leading space actors in Africa are lurking behind with technological and regulatory challenges related to the integration of space and air traffic management.

Therefore, the purpose of this dissertation is to examine the African perspective on integrated space and air traffic management (SATM). The primary focus of this dissertation is on the legal aspects of air and space traffic management. Naturally these two fields rely heavily on technological capacities in the fields of radar, communications, navigation and so on. We will touch on these technological aspects only as they pertain to the legal subject matter of the dissertation; a detailed examination of the technical aspects is outside the scope of this study. In addition, it is already a challenge for the African continent to utilise satellite-based augmentation systems such as Egnos for navigation in the aviation sector. Therefore, the question arises whether integrated SATM presents an opportunity for Africa to flourish in light of the African Union's Agenda 2063 and the African Space Policy and Strategy, or whether it is there to put a regulatory burden on emerging space faring nations such as Algeria, Egypt, Nigeria and South Africa? These are the big four countries in space exploration and utilisation in Africa as alluded to earlier, though from global perspective they are emerging space faring nations.

Hence, this dissertation will include a comparative analysis of jurisdictions where space and air traffic management has been or is anticipated to be integrated in order to examine the historical evolution of space and air traffic management. The rationale for such an approach is premised on the fact that the major space-faring nations have the technological, human, and financial capability to implement the integrated SATM, while on the other hand, Africa as whole is an emerging space faring continent, which might be lacking in technological and regulatory development. Consequently, the continent may be faced with some major challenges that can impact on the integration of space and air traffic management, and in the final analysis this will affect the realisation of the full potential of STM. However, before the objectives and outline of the dissertation is discussed, we begin with a brief analysis of space launch capability in Africa.

1.1 Proposed Spaceports in Africa

As a starting point, there have been talks about establishing or developing spaceports in Africa, maybe because of the opportunities presented by commercial space operations, especially space tourism, and suborbital point-to-point travel. Consequently, feasibility studies were conducted on the possibility of establishing spaceports in Africa. Firstly, in 2005 Takashi Space conducted a detailed feasibility study on the opportunity for a space launch facility and associated infrastructure in Cameroon, also known as Cameroon Spaceport (CSP) (Takashi Space, 2005:3). In that study, it was observed that Cameroon Spaceport would provide some benefits to the space industry in general, namely, “providing more cost effective traditional launch facilities for solid- and liquid-fuelled rockets than other current facilities further north or south of the equator; CSP would provide a substantial opportunity for all African nations to launch satellites from Africa itself, and with a more cost-effective model, enable more research, telecommunications and other satellite functionality for African countries” (Takashi Space, 2005:3). In addition, the study also found that the CSP would bring benefits to Cameroon as a country, therefore, “the benefits of the CSP are said to be not simply revenue and job creation, but also benefits for the local communities surrounding the CSP, benefits in science and technology bargaining, partnership and positioning opportunities for the Cameroon government, enrichment and educational opportunities for the people and educational system in Cameroon, support and input for Cameroonian industry, as well as the creation of potentially dozens to hundreds of new industry opportunities in Cameroon and partner countries” (Takashi Space, 2005:4-9). The study analysed the potential customers and partners for the CSP, and concluded that “the CSP would work for pretty much all space payloads, excluding highly secret ones, which would likely not be a competitive bid outside of tightly controlled facilities or military launch facilities in-country, and specialised missions like the manned space programmes of the United States, China or Russia utilising specialised facilities of Cape Canaveral and Baikonur Cosmodrome for United States’ Space Shuttle and Soyuz manned missions” (Takashi Space, 2005:9). Furthermore, according to Takashi Space (2005:12-16) “the list of possible partners included entities in the launch systems and space technology sector, universities and research institutes, and as well as the African regional community.”

> At the time the SWOT analysis of the CSP showed that Cameroon's "equatorial position provided substantial (approximately 17%) benefits compared to other launch facilities not near the equator – both in launch momentum and in-orbit fuel to correct for launch outcome as one of its strengths, whereas, the cost to enter the space launch market was relatively high – requiring a high-quality facility and surrounding support services, and this presented a weakness for CSP. The CSP had the potential to generate substantial revenue, however, partnerships with launch systems, technology companies and adjacent African nations could be hard to establish and fragile" (Takashi Space, 2005:18).

The technical details of the feasibility study, which includes the facility overview, revealed that "the planning for the location of the CSP should be made with a number of key notions in mind, namely, population density of the urban and rural regions; land ownership and rights of way; availability of transportation systems; landscape / terrain / weather, and easy implementation of energy and other support infrastructure" (Takashi Space, 2005:21). In addition, there were a couple of sites that were proposed for the CSP: firstly, "site idea 1 in the North or Extreme North Provinces because of their sparse population and savannah terrain with light vegetation; secondly, site idea 2 in the Adamawa Province, and which was made up of a huge area of savannah and forest, and was very thinly populated; thirdly, site ideas 3 and 5 in the East Province, the lowest population density was enjoyed by these provinces, which accommodated placement of drop zones; fourthly, site idea 4 in the South Province was an attractive site from the standpoint of proximity to the Atlantic Ocean and the harbour at Kribi, as well as the deepwater harbour in Douala" (Takashi Space, 2005:22).

However, each of these sites had a downside: for instance, "at site idea 1 the temperatures were hotter in this region and the politics and infrastructure was less developed; whereas, at site idea 2 it was harder to get around in this area, and would require some road infrastructure or use of the rail transport, but is rich in water resources. Similarly, site ideas 3 and 5 were said to be largely rainforest as part of the Congo Basin and largely poor road and transportation systems as well. Environmental and natural concerns could force these regions to remain non-options. Consequently, site ideas 4 and 5 seemed to be the most attractive locations from a Cameroon-controlled territory perspective, with direct control of some of the initial drop zone areas" (Takashi Space, 2005:22). According to Takashi Space (2005:22) "the safe drop zone distance for a decent LEO launch vehicle requires…drop zone positions to: span approximately 1500 km along the selected trajectories, site ideas 4 and 5 both had drop zones that fell within the estimated distance along the trajectories, which minimised the amount of agreements that Cameroon had to enter into with neighbouring countries such as Chad, Central African Republic, Congo and/or Democratic Republic of Congo."

Furthermore, Takashi Space (2005:24) suggested that "the composition of the CSP should consist of a technical complex, launch complex and mission control centre. Additional infrastructure potentially required to accommodate a full-featured space launch facility would include energy management or production (as required), accommodation for staff and launch resources and administrative spaces." In as far as transportation was concerned Takashi Space (2005:25) suggested that "a location with access to the Atlantic Ocean and the various Cameroonian harbours is preferable. Additionally, road and most likely train shipping from the harbour were preferable both during construction, and for movement of pre-integrated larger launcher stages and payloads, etc."

Another development related to commercial space operations, was a recent conceptual analysis of an East African Spaceport (EAS) also known as *uhuru* (freedom). In particular, there have been recommendations for the East African community (EAC) to conduct a feasibility study as first step in the development of an East African Spaceport, because Kenya is uniquely positioned on the equator, with all the attendant benefits for satellite launches. Consequently, an East African Spaceport would foster local capabilities and advancement in satellite launch, propulsion, aerospace engineering, provide economic and development benefits. In particular, the benefits for the East African Community include sustainable economic growth, science and technology advancement, infrastructure development, improved global market position (Futron, 2012).

It's more than a decade since the feasibility study on the Cameroon Spaceport was carried out. What has been done so far in order to realise the dream of establishing a spaceport in Africa? Is the East African Community currently implementing the recommendations made by Futron to conduct a feasibility study in order to establish *Uhuru* as the first East African Spaceport? The feasibility study (at least for CSP) asserted that there is a need to establish a spaceport in Africa. To substantiate the need for a spaceport in Africa, Takashi Space contended that "many African nations are taking space seriously as a telecommunications and broadcast television enabler. Traditionally, strong broadcast television countries like South Africa, Egypt and Morocco have taken steps to participate in remote sensing, Earth observation and other scientific missions.

Hence, a critical missing link in the space value chain is modern, cost-effective launch facilities on the African continent. Because launch capability was examined in South Africa and rejected based on the cost vs benefits from such Southern launch latitude, and a German entity also pursued the idea of establishing a launch facility at Shaba North in the Democratic Republic of Congo. Consequently, launch facilities near the equator are a substantial natural asset for equatorial African nations" (2005:8).

Therefore, despite the challenges that the continent may face in order to realise that dream, the presence of a spaceport in Africa will close one gap in the African space industry, namely, launch capability, which will in the long run open the African launch sector as well as the possibility of suborbital point-to-point travel to and from Africa. These sub-orbital point-to-point travel and launch and re-entry operations in the continent will eventually have an impact on space and air traffic management in Africa, which in the writer's view necessitates the need for this dissertation.

To substantiate the argument that the establishment of spaceport in Africa will open up the launch sector in the continent, Dr. Obadia Kegege (2016:48) echoed that "at present, Sub-Saharan Africa does not have a spaceport, which is a major element of the space value chain. Furthermore, the concept of a spaceport being located in Sub-Saharan Africa is not new."

In the case of *Uhuru*, "members of the National Society of Black Engineers (NSBE) Space Special Interest Group (Space SIG) worked to strategize the prospective development of an East African Spaceport (Uhuru) during the Space Technology Session. This working group proposed establishing a permanent spaceport in the East African region close to the Equator, accessible to the mainland and airports. The study recommended that this spaceport be developed in three phases: (1) Uhuru Earth Research and Education Center, (2) Suborbital Infrastructure Development and Suborbital Space Science Center, and (3) Orbital Launch and Planetary Development Center" (Obidiah *et al.*, 2014). Consequently, Obidiah *et al.* (2014) suggested possible sites for future *Uhuru* spaceport, in particular they proposed that:

> *"Having the spaceport on an island helps in terms of testing, safety, and security. An island east of the equatorial African coastline also has the advantage of a flight path that is over water and not residential or commercial communities. Several islands in the East African region offer the best sites for spacecraft launches to LEO, Geostationary Earth Orbit (GEO), or interplanetary trajectories, due to their nearly equatorial locations. GEO is a circular GSO directly above the equator...there are several potential island locations*

> *for the East African Spaceport. The four major ones are: Pate Island (Kenya), Manda Island (Kenya), Pemba Island (Tanzania), and Mafia Island (Tanzania).”*

In the final analysis, the question posed above, i.e whether the EAC is implementing the recommendations made to conduct a feasibility study on East African Spaceport, should be answered in the affirmative. In other words, the Space SIG is currently investigating the feasibility of a near-equatorial spaceport located in East Africa, particularly, the key technical and operational considerations relevant to an equatorial launch facility are studied, in order to determine whether East Africa can once again provide spaceport services to the global launch market (NSBE Space SIG, 2018). However, that is not the case with the Cameroon Spaceport. After the CSP feasibility study was conducted, the CSP died a natural death. As of this writing there is no evidence whatsoever to suggest that the concept of Cameroon Spaceport is being taken or developed further.

1.2 Current Air and Sea Launch Capability in Africa

In addition to the potential or proposed spaceports discussed in Section 1.1 above, currently there are other launch possibilities/capabilities such as air or sea launch, which will raise issues on STM, and proposes the integration of SATM. Firstly, Denel Overberg Test Range (2018) is of the view that the launch facility was built in order:

> *“To provide a strategic capability for launching of Low Earth Orbit satellites during its establishment in 1980s. At the time South Africa has embarked on a space programme to meet the remote sensing needs of the South African Defense Force. This resulted in the establishment of a comprehensive and wide spectrum of measurement capabilities, control systems and infrastructure at the Test Range. Three successful sub-orbital launches were conducted from the Test Range between 1989 and 1991, proving and qualifying the Test Range's ability to manage and conduct complex launch campaigns. However, since the termination of the RSA space program in 1994, the Test Range has been utilized exclusively for the advanced testing of non-space related systems for domestic as well as international customers. Therefore, during her speech on the 9th of December 2010 at the launch of the South African National Space Agency (SANSA) and National Space Strategy, the then Minister of Science and Technology Mrs. Naledi Pandor stated that:*
>
> > *‘In light of the lessons learned with the delays we experienced in the launch of SumbandilaSat, my Department is also looking at redeveloping South Africa’s launch capabilities through defining a 20-year launch plan. We plan to conduct*

> *consultative workshops with relevant stakeholders with the aim of developing this 20-year launch plan'."*

Hence, it is envisaged that the launch facility "could play an important role in this new long-term launch plan. The main focus of the Test Range's current space initiatives is thus to support Department of Science & Technology (DST) and SANSA in developing and executing the launch plan. Relying on the experience gained during the previous space program, the Test Range can provide crucial assistance in aligning South Africa's space priorities, ground launch infrastructure, launch vehicle manufacturing and satellite development program" (Denel Overberg Test Range, 2018).

Currently the Overberg Test Range (OTR) launch facility "provides infrastructure for the testing of aerial weapons systems. The test range markets its services internationally and has a well-established client base in Europe and the Far East. The country conducted two suborbital launches in the late 80s from this range" (Foundation for Space Development South Africa, 2011). However, it has been more than two decades when the last launch took place at the facility, therefore, we cannot with confidence say that OTR currently provides launch capability. Nevertheless, the space launcher programme did leave a heritage of a considerable physical space infrastructure (Gottschalk, 2010:4).

Secondly, the Luigi Broglio Space Centre of Malindi, Kenya, (also known as San Marco Platform) shown in **Figure 1.1** below, which has been managed by the University of Rome "La Sapienza" through the San Marco Project Research Centre (CRSPM) since the 1960s, presents the opportunity for sea launch in Africa. According to Agenzia Spaziale Italiana (2009), the San Marco Platform has an advantage "because of its equatorial location on the Indian Ocean's coast, it is the ideal place for activities of launch and satellite control from Earth." It is worth commenting that, the soil/land on which the San Marco Platform is located, "is property of the Republic of Kenya, but the management was entrusted to CRPSM until December 31st, 2003 and to ASI starting from January 1st, 2004 in accordance with the intergovernmental agreements between Italy and Kenya currently in force" (Agenzia Spaziale Italiana, 2009). According to Agenzia Spaziale Italiana, (2009) "this agreement involves the possibility to carry out launch activities, data acquisition from satellites, remote sensing and training activities, both in Kenya and in Italy. Italy defines the programmes, supplies the necessary equipment, trains and takes on local employees. Kenya grants the land under the payment of a rent by Italy. The local government must be informed about programmes making use of the Centre and asks, for commercial programmes, a royalty depending on the terms of the commercial agreement." But the last launch - Scout vector which lofted the San Marco D/L satellite - was carried out on March 25th, 1988. Since then the platforms have not been used and are generally submitted to the ordinary upkeep (Agenzia Spaziale Italiana, 2009).

Fig. 1.1 San Marco Launch Platform. Image courtesy of NASA/John Ives and John Raymont.

Thirdly, the Pierre Van Ryneveld Airport in Upington is worth mentioning here, because it has the capacity to be transformed into an aerospaceport, mainly substantiated by the length of its runway. According to Gottschalk (2010:5) "this airport has a 4.9 km runway, the longest in Africa, used for only three scheduled flights per day, surrounded by the sparsely-inhabited Kalahari Desert. The runway could accommodate an emergency landing of the Space Shuttle. With spacious aircraft parking facilities, it is also suitable to become a test flight area for a HOTOL RLV."

1.3 Goals/Objectives of the Dissertation

This dissertation is aimed at achieving the following objectives, namely:

- To provide the reader with an overview of launch facilities in Africa;
- To analyse the institutional and regulatory framework governing space activities in Africa;
- To examine the current organisation of air traffic management within Africa.

- To examine the perception of the African continent in relation to the integration of space and air traffic management, in light of the current institutional arrangements, air traffic management in Africa, proposed spaceports in Africa, and the existing launch capability in the Africa continent if any;
- To provide an analysis of strengths, weaknesses, opportunities and threats for integrating space and air traffic management in Africa;
- To contribute to recent efforts aimed at promoting safe and sustainable use of outer-space through efficient air and space traffic management.

1.4 Structure of the Dissertation

The structure of the dissertation is as follows: firstly, the historical development of the integrated space and air traffic management will be discussed in Chapter 2. This will involve a discussion on the concept of space traffic management, i.e what space traffic management entails, as well as a conceptual analysis of air traffic management. Similarly, the dissertation will look at the evolution of integrated space and air traffic management, hence, the United States' approach and Europe's proposed way of integrating STM into global ATM will be discussed for comparative purposes.

Chapter 3 will discuss the current initiatives to adopt an African Space Programme. This is followed by a discussion on the integrated space and air traffic management in Africa in Chapter 4, which mainly focuses on space tourism, launch and re-entry operations from the African perspective. Here, the dissertation will address the challenges facing the continent and the opportunities that exist to embark on this initiative or for Africa to be part of this international trend in space activities. This Chapter forms the basis of the dissertation. Finally, Chapter 5 will provide an analysis of regulatory and legal implications posed by integrated space and air traffic management, because the rules applicable in outer space differ substantially from the rules applicable in air space. Chapter six presents our conclusion and possible recommendations and the way forward.

2. DEVELOPMENT OF THE CONCEPT OF INTEGRATED SPACE AND AIR TRAFFIC MANAGEMENT

In this Chapter we look at the meaning of the concepts of Space Traffic Management and Air Traffic Management. This is necessitated by the fact that we need to understand that these concepts sound similar because both deal with traffic management but differ technically in the areas of operations. By understanding the meaning of these concepts, we can eventually draw inferences on what an integrated Space and Air Traffic Management (SATM) system would entail, because the concept of SATM has not be defined by any academicians so far. Despite the conceptual analysis of the meaning of Space and Air Traffic Management, this Chapter also discusses the historical evolution of STM and ATM, and current or future framework for SATM as proposed in the United States, and efforts by the EU to integrate STM in the global ATM. This will help us to understand where we are going in as far as the integration of space traffic into ATM is concerned.

2.1 Concepts of STM and ATM

According to the study conducted by the International Academy of Astronautics (IAA), Space Traffic Management is defined as "*the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space, and return from outer space to Earth free from physical or radio-frequency interference*" (International Academy of Astronautics, 2006:17). On that note, more than a decade later, the IAA conducted a new study that "draws from the extensive academic work and policy-making activities carried out since the 2006 Cosmic Study. The purpose of the new study is to revisit and adjust the concept of STM to current advancements in space activities as well as to geopolitical developments" (IAA, 2018). However, at the time of writing this dissertation the new study was not available in order to allow this writer to analyse whether the IAA concept of STM has been revised.

Hence, from the definition provided by the IAA in the 2006 Cosmic Study, we can deduce that the definitional elements of space traffic management link back to the fundamental principles enshrined in the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty [OST], 1967). In particular the phrase *safe access into outer space…* is related to the principle of free access contained in Article I paragraph 2 of the OST, whereas, the phrase *free from physical or radio-frequency interference…* is indirectly related to the principle of freedom from harmful interference contained in Article IX of the OST, because any form of interference whether physical or radio-frequency will cause potential harmful interference with space exploration activities which will contradict the principle of freedom of exploration and use of outer space as outlined in Article I paragraph 2 of the OST.

However, the definition provided by the IAA is more than a decade old, therefore, we must ask if there is a need for a contemporary definition of STM. Consequently, according to Jakhu & Pelton (2017:305-306) in their recent study entitled '*Global Space Governance: International Study*', they argued that "*people have differing perceptions when it comes to STM. On the one hand, some view it as representing more structured approach to regulating the use of Earth orbits, space debris, the establishment of debris graveyards, and consists of the improved management and registration of orbits and frequencies associated with especially large-scale satellites constellations and small satellites. On the other hand, others perceive it as the creation of national laws, international regulations, or even international space agencies to enforce safety, non-interfering, and control programs to prevent the creation of further space debris.*" In addition, in terms of Section 2 (b) of the U.S. National Space Traffic Management Policy (Space Policy Diretive-3 issued on 18 June 2018) STM *"means the planning, coordination, and on-orbit synchronization of activities to enhance the safety, stability, and sustainability of operations in the space environment.*"

With all these differing perceptions in place, and in light of the initiative to integrate space and air traffic management, there is a need for a legal and regulatory definition of STM; maybe such a definition can be borrowed from the more familiar traffic management regimes of maritime or aviation.

On that note, Air Traffic Management (ATM) according to the International Civil Aviation Organisation's (ICAO) Doc 9750 "*is the aggregation of the airborne functions and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations*" (International Civil Aviation Organisation [ICAO], 2002: I-4-1). Similarly, Doc 9854 defines ATM as "*the dynamic, integrated management of air traffic and airspace — safely, economically and*

efficiently, through the provision of facilities and seamless services in collaboration with all parties" (ICAO, 2005:1-1). For the purpose of this dissertation, the phrase '*in collaboration with all parties…*' in the second definition of ATM implies that space actors should form part of an integrated management of air traffic and airspace as spacecraft transition through airspace to outer space and from outer space to airspace during re-entry, which qualifies them as airspace users.
Now that we have an idea of what the concepts of STM (at least the non-legal definition) and ATM entail, the next question that lingers on every aerospace enthusiast's mind is what does the concept of space and air traffic management (SATM) entail?

If we can draw inferences from the analyses of the concept of STM and ATM, we can consider that the new concept of SATM could, in the writer's view, be defined as the *integrated provision of space and air traffic services to space vehicles during all phases of operations, using space-borne, air-borne and ground-based platforms to ensure the safety and efficiency of both space vehicle/spacecraft and aircraft.* Consequently, the Concept of SATM should allow for the provision of space and air traffic services to both spacecraft and aircraft, as the users of national or international airspace systems without the need to close the airport/spaceport and surrounding airspace to all other users.

2.1.1 Definition of aircraft and spacecraft

The term *aircraft* refers to *"any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the Earth's surface"* (Annex 7 to the Convention on International Civil Aviation of 1944). Whereas, there is no clear definition of the term "*spacecraft*" under the international space law regime, however, for the purpose of liability the term *space object* includes the component parts of a space object as well as its launch vehicle and parts thereof under the Convention on International Liability for Damage Caused by Space Objects (Liability Convention, 1972). The definition of the term *space object* in both the Liability Convention and the Registration Convention is unclear, as there is no clarity on what the term denotes; this brings us back to the question on the definition of *spacecraft*. The literal definition of spacecraft refers to a vehicle or device designed for travel or operation outside the Earth's atmosphere (Space Policy Institute, George Washington University and Secure World Foundation, 2012:132). However, the Radio Regulations in Article 1.178 defines *spacecraft* as a "*man-made vehicle which is intended to go beyond the major portion of the Earth's atmosphere."*

2.2 Historical Development of ATM

2.2.1 Prior to 1944

According to Union Sindical de Controladores Aereos (2018) “air traffic control services were born virtually at the same time as commercial aviation, in the first decade of the 20th Century. When aerodromes were first put into operation, it became necessary that someone informed the pilots about the condition of the runway, the wind direction and the presence of other aircraft or vehicles in the area, using flags, flashing lights or radio communications. The quick growth of air traffic and the adverse meteorological conditions in some aerodromes made necessary that ground operators didn’t just inform the pilots, but also gave them instructions when they departed or landed, in order to avoid possible collisions. And this was when the history of air traffic management began.”

Therefore, in as far as the development of air traffic management is concerned, Union Sindical de Controladores Aereos (2018) commented that:

> *‘The first aerodrome to provide an actual air traffic control service was Croydon, south of London. In 1922, after a minor collision between an arriving and a departing aircraft, the aerodrome published a NOTAM in which it was stated that all the pilots had to obtain a sequence number for departure, as well as authorisation from the tower for taking off. This authorisation was given by waving a red flag from the observation tower. Croydon was also a pioneer in establishing an aeronautical radio-navigation system, ground-air communications, the use of the Q code, and also a control zone in which it was required that the pilots had authorisation from the controller before entering it. They also developed the first standard procedures to depart, more oriented to appease the neighbours that complained about the noise than for safety reasons. From the control tower, the controller marked the situation of the aircraft on a map with little flags according to the radio signals that the pilots sent, therefore being able to warn them in case he calculated that they were going to fly too close to each other.’*

Furthermore, the success of commercial aviation became clear at the beginning of 1920s, and governments were urged to “establish a set of rules as soon as possible, in order to regulate the activity” (Union Sindical de Controladores Aereos, 2018). Hence, according to Union Sindical de Controladores Aereos (2018) “in order to achieve this the International Commission for Air Navigation (ICAN) was created in 1919 by virtue of the Treaty of Versailles, and it developed the first air traffic regulatory framework, initially signed by 19 states. Two years later, in particular on the 7th of April 1922, the first mid-air collision took place in France, due to fog, and 7 people died." This resulted in authorities being compelled to "define the first air routes in the English Channel, and to make compulsory the use of on-board radio equipment and the interchange of meteorological information between the aerodromes" (Union Sindical de Controladores Aereos, 2018).

Further development in air traffic management was seen in the United States when a consortium of airlines began to monitor the operation of their own flights after witnessing some mid-air collisions of commercial aircraft (Union Sindical de Controladores Aereos, 2018). Consequently, in 1935 several carriers created the first air control centre in Newark (New Jersey) for the purpose of supervising their air routes, which later also resulted in the addition of two more centres in Cleveland and Chicago in 1936 accordingly (Union Sindical de Controladores Aereos, 2018). However, it was too risky from both safety and security perspectives to vest air traffic control services in the stakeholder or operator. Therefore, according to Union Sindical de Controladores Aereos (2018):

> *'The Department of Commerce assumed the control of the operations and, shortly after, opened eight more units in order to cover the United States airspace. At the time they used blackboards to register the positions that the pilots reported, and maps where they placed aircraft in order to avoid mid-air collisions. Taking into account the speed of the aircraft and the flight time, they were able to foresee the future position of the planes and warn the pilots in case a conflict was detected. Shortly after, pilots were instructed to always follow ATC instructions. This method to order and separate the traffic, based on estimated positions and times reported by the pilots, is what we call "procedural control. Blackboards and maps would later be substituted by the flight strips, but this kind of control is still used in a similar way in oceanic areas where there is no radar coverage, or in low workload aerodromes.'*

2.2.2 Post-1944

The evolution of air traffic management continued to flourish post World War II, and this historical and current developments of air traffic management/air traffic services is contained in the foreword of Annex 11 to the Chicago Convention. In particular, "in October 1945 the Rules of the Air and Air Traffic Control (RAC) Division at its first session made recommendations for Standards, Practices and Procedures for Air Traffic Control. These were reviewed by the then Air Navigation Committee and approved by the Council on 25 February 1946. They were published as Recommendations for Standards, Practices and Procedures — Air Traffic Control in the second part of Doc 2010, published in February 1946" (International Civil Aviation Organisation, 2016).

According to the ICAO (2016) "the RAC Division, at its second session in December 1946 – January 1947, reviewed Doc 2010 and proposed Standards and Recommended Practices for Air Traffic Control. It did not appear possible, however, to finalize those Standards prior to basic principles being established by the RAC Division for the organization of the relevant services."

However, the Standards and Recommended Practices "were established by the RAC Division at its third session in April – May 1948 and a draft Annex was thereafter submitted to States. This was adopted by the Council on 18 May 1950, pursuant to Article 37 of the Convention on International Civil Aviation (Chicago, 1944), and designated as Annex 11 to the Convention with the title International Standards and Recommended Practices — Air Traffic Services. It became effective on 1 October 1950. This new title — Air Traffic Services — was preferred to the title Air Traffic Control, in order to make it clear that the air traffic control service was a part of the services covered by Annex 11, together with the flight information service and alerting service" (ICAO, 2016).

According to Union Sindical de Controladores Aereos (2018) the next step for ATM arrived in "1950 when air control centres were provided with long-distance direct communications between the pilot and the controller. Now there was no need to use flight handlers in order to transmit the messages. The arrival of radar in the mid 50's shook the air traffic control system up. The precision of this tool, the modern air navigation systems and the improvement in the ground-air communications, make it possible that nowadays airplanes flying at over 1000km/h need to be separated by only 5kms, which allows the system to safely assume and integrate the constantly increasing number of air operations worldwide."

2.3 Current status of SATM

Historically, spacecraft integration into the air transportation system was based on the concept of traffic separation through the definition of restricted areas, which corresponds to calculated areas along the operational event or flight track for which the risk threshold accepted in case of a mishap is exceeded (Kaltenhaeuser, 2017: 1). For instance, Murray & Van Suetendael (2006:2) commented that "the Federal Aviation Administration (FAA) has over the years developed separation standards for aircraft. These standards describe minimum altitudes and lateral distances for separating one aircraft from another in flight to avoid collisions and hazardous conditions like wake turbulence. A present lack of experience in spacecraft operations has prevented the development of similar separation standards between spacecraft or between aircraft and spacecraft. In the meantime, the procedures for ensuring that aircraft are safely distanced from spacecraft during a launch or re-entry involves the use of Special Use Airspace (SUA) and Temporary Flight Restrictions (TFRs)." According to Murray & Van Suetendael (2006:2) "this can be achieved by issuing Notices To Airmen (NOTAMs) to alert the air traffic community, including air traffic controllers, airlines, and general aviation pilots, of the times of these operations and boundaries of the required airspace. Flight service stations provide these notices to pilots and they are also made publicly available on the internet. Once NOTAMs are issued, flight plans and paths are adjusted accordingly so that aircraft that would normally fly through this airspace take a longer, alternate route to their destination. Radar and visual surveillance of these areas prior to the launch activity ensures that they are clear."

Therefore, the traditional method of separating space and air traffic is costly to the civil aviation operations, because time is of the essence in air transportation, be it cargo or passenger transportation, in that other users of airspace are required to suspend or divert their operations. In other words, the traditional approach of closing airspace during the launch or re-entry of a spacecraft affects the timely dispatch of cargo and passengers in civil aviation. Hence, Murray (2013:2) echoed the same sentiments that the traditional method of separating spacecraft from aircraft or closing airspace during a launch or re-entry bring conflict "between space operators and other national airspace stakeholders for access to the airspace and to areas on the ground at or near airports." Therefore, this was supported by Jakhu & Pelton (2017:307) who stated that "frequent commercial spacecraft operations in the near future, are not only a safety concern from the perspective of ongoing commercial and military aircraft flight operations but also that the future use of airspace and outer space for commercial operations will have a great economic and operational impact on aviation operations as large flight sectors need to be shut down for significant periods of time. In other words, space traffic management and range safety for launches are today highly inefficient, and this inefficiency has a negative impact on both air traffic and aircraft operations."

Consequently, there is a need to find an approach that will amalgamate space and air traffic safely and efficiently. Eventually this has led to the concept of Space and Air Traffic Management, i.e the integration of commercial space operations into national airspace systems, the concept which was initiated by the Federal Aviation Administration in the United States.

2.4 Proposed/future SATM Frameworks

The United States is at the forefront of the future of the SATM in that extensive research and development is being done to integrate commercial space operations into the national airspace system seamlessly. In this section we will address the United States' future SATM strategies and the initiatives taken by the E.U. to integrate space in global ATM from an E.U. perspective.

2.4.1 United States

The United States is the source of the concept of SATM, in particular, the FAA developed a concept of operations for a future Space and Air Traffic Management System (SATMS). Hence, Murray & Van Suetendael (2006:1) contended that "the proposed framework for seamlessly integrating spacecrafts on their way to and from space with traditional air traffic operations required new space and air traffic management tools and enhanced communications, navigation, and surveillance (CNS) services." The rationale for the development of the concept of SATM was due to the fact that "the increase in space operations, coupled with an expected doubling of air traffic operations, could place unprecedented demands on the National Airspace System (NAS) and the nation's Air Traffic Control (ATC) system" (Murray & Van Suetendael, 2006:6).

This called "for the use of space transition corridors (STCs) to segregate air and space traffic safely. The STCs would be defined by strategically-sized airspace restrictions that would be dynamically issued and withdrawn, as necessary, to maximize safety while minimizing the impact to air traffic" (Murray & Van Suetendael, 2006:3). Therefore, according to Murray & Van Suetendael (2006:3) "the vertical extent of the STC would span all altitudes, while the lateral sizing would be determined using specific characteristics of the space vehicle and the way in which it is to be operated, combined with predicted weather conditions. The proposal called for the establishment of these corridors shortly before a flight or controlled re-entry is to take place and withdrawn once it has been completed. During the flight, air traffic controllers would monitor its progress against actual weather and air traffic conditions, standing at the ready to respond to an accident by quickly identifying the extent of the affected airspace and maintaining its closure until it is determined to be free of hazardous debris. Airspace within the STC that is no longer at risk from the vehicle or its debris could be released."

Consequently, in order to ensure that there is communication with the spacecraft and to track it, as well as the planning and identifying of "potentially affected airspace (in both a planning and an operational mode), and the most efficient air traffic reroutes, the SATM's Decision Support Tool was developed. This is a software and computing system which is designed to assist air traffic controllers in managing airspace restrictions and the risk to aircraft from space operations with improved situational awareness" (Murray & Van Suetendael, 2006:4). However, the technicalities and how this tool operates fall outside the scope of this dissertation.

Hence, how does the United States ensure that there is seamless integration of spacecraft into the airspace? The seamless integration of spacecraft into the airspace will in the opinion of Murray & Mitchell (2010:9) require "high data rate processing, flight planning and real-time data communication. Furthermore, because of the high speed of spacecraft, there is a need for high-rate surveillance and tracking data which must be ingested and processed by the SATM's Decision Support Tool, while being filtered and displayed alongside standard aircraft traffic data. However, the requirement does not stop there, additional requirement will be the flight planning for launch and re-entry vehicles which will be required in advance of missions, and much earlier than traditional aviation flight plans." The rationale behind this requirement is that "these plans will allow air traffic controllers to manage the mission needs and impacts on the NAS, while adapting to the off-nominal events through planning and prediction tools" (Murray & Mitchell, 2010:9).

In addition, the FAA has conducted initial testing of ADS-B technologies as candidate systems for providing communication, navigation, and surveillance capabilities for commercial space operations (Murray, 2013:8), the ADS-B technologies is utilised in civil aviation operations, hence this will be a good way of providing interface between spacecraft and civil aviation operations. Therefore, as part of the initiative to integrate SATM, the "FAA intends to develop and apply flexible planning tools and advanced analysis techniques to safely reduce the amount of airspace that must be blocked in advance of a launch or re-entry operation. At the same time, the FAA is focusing on ways to automate safety calculations and data transfer to allow air traffic control (ATC) to respond effectively to contingencies and maintain safety during launch and re-entry operations. Consequently, this is a move towards automating data consumption and transfer in order to allow ATC to quickly release airspace blocked for a launch or re-entry mission to return it to normal use once it is no longer affected" (Mazzotta, & Murray, 2016:2). Finally, Jakhu & Pelton (2017:308) echoed "the need for an integration of traffic management in airspace, protozone[1] and outer-space, the existence of single international organization such as ICAO" (International Civil Aviation Organisation) in charge of air and space traffic management and coordination," as opposed to multiple actors.

2.4.2 EU

Unlike the United States, the E.U. has member states all with their own national legal systems and in this way, it is analogous to the African Union, which has 55 Member States. The E.U. comparison is relevant on the issue of coordination and harmonisation of legal and regulatory requirements as well as an integrated air traffic management, based on the need for open skies and liberalisation of air transport. In the case of the E.U. the liberalised air transport has been in operation for some years now, whereas Africa is yet to realise its dream of air transport liberalization, taking into account the fact that African Heads of States recently adopted the initiative to liberalise air transport in the continent.

Therefore, the integration of spacecraft operations into the airspace and air traffic management is not only a United States issue but a global challenge. Consequently, in order to address the challenges of spacecraft integration into the Air Transport System and Air Traffic Management system in Germany, the DLR (German Aerospace Centre) has established a case-based approach, which intends to consider various kinds of air traffic related space operations as well as the development of general space traffic integration concepts (Kaltenhaeuser, Morlang, & Schmitt, 2017:1).

In this light, the mission concept of the DLR SpaceLiner, a future high-speed suborbital intercontinental passenger transport-vehicle, has been chosen as the first case study. The SpaceLiner, shown in **Figure 2.1**, is designed as a rocket-propelled, two-stage suborbital Reusable Launch Vehicle (RLV), servicing ultra long-haul distances such as Europe – Australia in 90 minutes. A traffic impact analysis has been prepared and conducted for the SpaceLiner return trajectory towards a European landing site as depicted in **Figure 2.2**, which gave evidence about the challenging sectors regarding air traffic integration during the high- and low-altitude phases of its proposed flight trajectory (Kaltenhaeuser, Morlang & Schmitt, 2017:2).

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[1] According to Jakhu & Pelton (2017:314) protozone is defined as "the portion of sovereign airspace above civil manned aviation (i.e., beyond 21 km), but still within Earth's atmosphere (i.e., below 160 km)". The other name or synonym of protozone is near-space arena, sometimes referred to as sub-space (Jakhu & Pelton, 2017:306).

Fig. 2.1 SpaceLiner. Image courtesy of DLR.

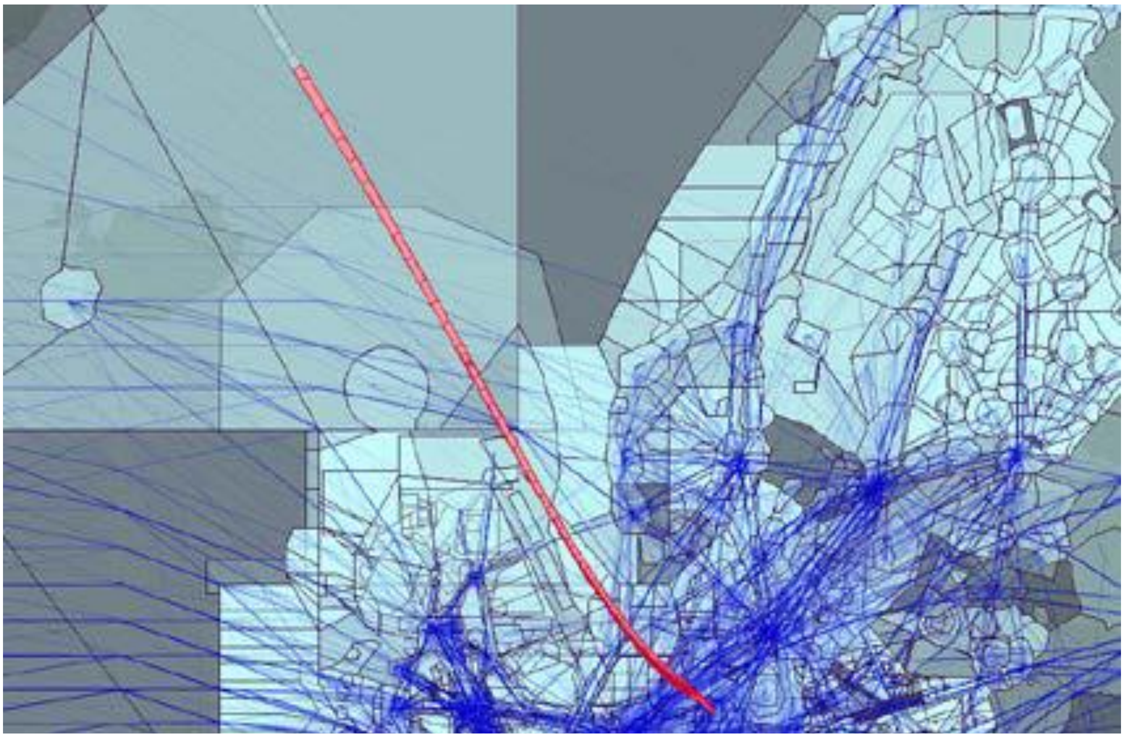

Fig. 2.2: Integration of the SpaceLiner trajectory into a European air traffic scenario**. I**mage courtesy of Luchkova, Kaltenhaeuser & Morlang (2017).

Hence, in order to tackle the challenge of integrating spacecraft operations into the ATM, an important element of improved integration of space operations into ATM is timely and reliable access to essential operational data of the spacecraft by all relevant stakeholders. The System Wide Information Management (SWIM) concept can be used to fulfill this requirement. SWIM is part of the European and United States' ATM development programs, called Single European Sky Air Traffic Management Research (SESAR) and Next Generation Air Transportation System (NextGen) in the United States. It can be seen as an intranet for ATM, aiming at providing all relevant information at the right time and with the right quality to the right stakeholders. SWIM is based on a net-centric approach for connecting multiple stakeholders, each running its own information system, and using SWIM to communicate. It "consists of standards, infrastructure and governance enabling the management of ATM information and its exchange between qualified parties via interoperable services" (Kaltenhaeuser, Morlang & Schmitt, 2017:2). Consequently, by providing all kinds of relevant data, SWIM-based information exchange can foster the planning, coordination, monitoring and common situational awareness through all phases of SVOs for its interfacing with air traffic (Kaltenhaeuser, Morlang & Schmitt, 2017:2).

In addition, in the context of Europe, new ATM concepts have been proposed or are in the verge of development facilitating the integration of spacecraft into the global ATM. Firstly, as important as data availability is, its benefit depends on ATM concepts and supporting technologies which can use such information exchange during planning and execution of space flight for improved efficiency of the overall air- and space transportation system. As such, the transition of ATM towards trajectory-based operations (TBO) under the regimes of the Single European Sky (SES) and the United States' Next Generation (NextGen) is an essential key element for this purpose. The TBO model is based on the use of a 4D-trajectory for each aircraft, which precisely describes the flight of an aircraft in airspace and time. Therefore, Europe has witnessed the modification of the Flexible Use of Airspace (FUA) concept. In particular, the FUA concept has been further evolved to an Advanced FUA (AFUA) and became part of the SESAR concept developments. AFUA addresses the need for faster information exchange and applying the principle of TBO to ensure dynamic airspace management in all phases of the flight, from the initial planning to the execution phase.

The second concept is the Flight-Centric ATC or Sectorless ATM, which is an innovative concept adopted by the SESAR 2020 research program. The idea is to eliminate sector boundaries and change air traffic controller responsibility from managing the entire traffic in one sector towards being in charge of guiding several flights through a large volume of airspace whereas other controllers are responsible for a certain number of different aircraft within the same airspace. Nevertheless, the controller still has to ensure a conflict-free flight of the aircraft he/she is responsible for (Kaltenhaeuser, Morlang & Schmitt, 2017:5). The concept of Flight-Centric ATC or Sectorless ATM is represented in **Figure 2.3** below.

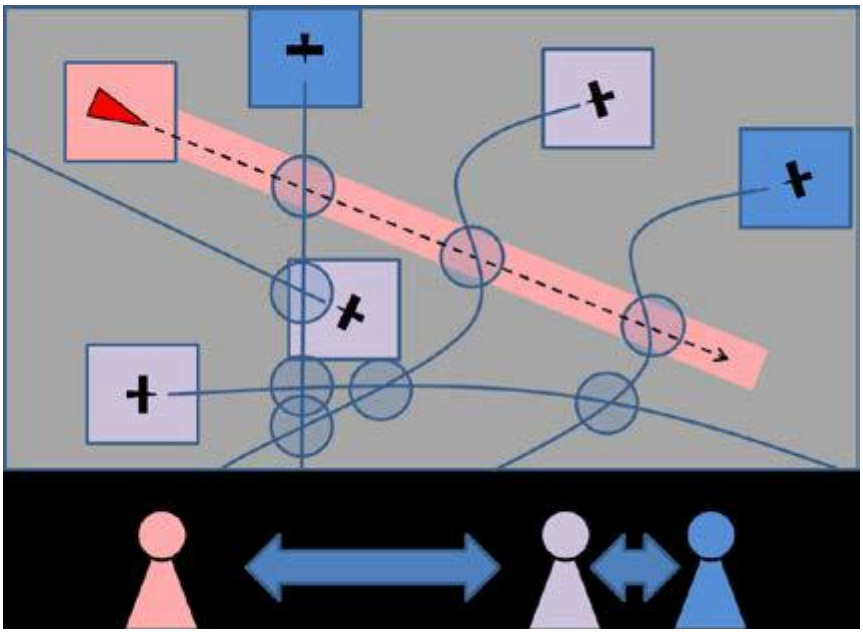

Fig. 2.3: Illustrating the allocation of responsibility for individual flights within a flight-centric ATC concept, assigning the space vehicle to a dedicated controller (Korn, *et.al.*, 2009)

The German Space Agency (DLR) and partners recently conducted an evaluation study on behalf of the European Space Agency (ESA), according to Tüllmann, *et al.* (2017:2) the objective of the evaluation study was "to generate a roadmap for the implementation of a European STM system within the next two decades under consideration of an evolving Air Traffic Management (ATM) system. The European STM concept is developed against the Reference Operations Scenario (ROS), which reflects routine and contingency operations scenarios and relevant safety operations aspects" (Tüllmann, *et al.*, 2017:2). However, in as far as the integration of STM and ATM in the European context is concerned, Tüllmann, *et al.* (2017:19-20) commented that "in order to find integration points for merging STM and ATM systems, the ATM Master Plan from 2015 was broken down into high-level operational and organizational key areas and matched with the corresponding areas of the envisaged STM system."

But, Tüllmann, *et al.* (2017:20) were sceptical about the integration of spacecraft into airspace and stressed that "the concept of space vehicle integration into civil airspace generally calls for new route and separation standards to be laid out by ICAO in order to allow for changes in airspace and procedure design with respect to spacecraft parameters and capabilities." Therefore, one of the challenges for ICAO related to performance, procedure design, routes and spacecraft parameters, "will be the development of generalized spacecraft categories, which reflect design layouts, flight performance as well as operational profiles (e.g., booster usage and jettison, re-entry with burn-off elements or manoeuvrability of the vessels" (Tüllmann, *et al.*, 2017:20). "However, knowing the performance of a spacecraft, such as climb rate, speed and turn radius is crucial for an ATCO to safely manage air traffic." Therefore, ICAO has the challenge of determining whether or not "a true separation standard similar to today's standards for civil aircraft can be found or if the common practice of temporarily reserved airspaces is the only way forward" (Tüllmann, *et al.*, 2017:20).

How is Europe going to realise its dream of a European STM system that will serve the United States' commercial space travel market? According to Tüllmann *et al.* (2017:21), "there are several interfaces that are needed for combined ATM and STM operations, namely, Flight Planning & Scheduling Operations, Air Traffic Control Operations, Space Traffic Control Operations, Ground Operations at Airports and Spaceports, and Spaceplane Operations." Tüllmann *et al.* (2017:21) continue to provide a detailed description for each the interfaces, extrapolating the foreseen interaction during the different flight path phases, from pre-departure operations, to in-flight operations and post-arrival operations. In order to address or to realise this European dream Tüllmann *et al*. provide the Roadmap for a European STM System. Hence, technological development and building of the Skylon spaceplane is the first stage for the Roadmap.

According to Tüllmann, *et al*. (2017:27) "the second development area is infrastructure that needs to be ready in order to support routine and safe spaceplane operations. The infrastructure consists of spaceports, support buildings and communication networks. The last area relates to the development and validation of products and services, such as a STM concept, a concept for 24/7 routine and contingency Space Traffic M&C operations or Space Weather and SST products."

3. AFRICAN SPACE PROGRAMME: LEGAL, REGULATORY, AND POLICY ASPECTS

The African Space Policy is a political commitment from the African countries to set out the objectives and ambitions of the continent, and the rationale behind the participation of the African continent in space exploration and use. These objectives and /or goals are broad statements which need to be supplemented, and this is where the African Space Strategy comes into play, which is an action plan or roadmap for the implementation of the policy goals. Consequently, the African Space Policy and Strategy are the fundamental documents for the eventual realisation of the African Space Programme. However, it should be stressed that the African Space Programme should be understood in the context of legal, regulatory and institutional arrangements, as opposed to technical perspectives, i.e. the African launch program or the launches to be carried out under the African Union. But we must understand that the African Space Programme will need a legal and regulatory framework to be in place, which will provide a stable platform for investors and establish relevant institutions and governing bodies. Because policy formulation, governance and regulatory frameworks are prerequisites or *conditio sine qua non* for any space programme, the African Space Programme has kicked off with the adoption of a policy framework and the establishment of a governing institution in the form of an African Space Agency, which will be discussed later in this section. Hence, in order to examine the African Space Programme there is a need to analyse the current legal and policy framework for space in Africa from a regional perspective. However, this dissertation will not discuss the international legal regime on space because there is already an enormous literature that covers this.

3.1 Space law, regulation and policy at regional level

The African continent does not have a unified law in the form of a multilateral treaty at the regional level that addresses space law issues in the region, rather African space law is scattered in the sense that different space-related activities are governed through bilateral agreements, memoranda of understanding or letters of intent. Secondly, each country (at least emerging space faring nations) promulgate national space legislation at State level to regulate space activities in their territories, and these countries have different legal systems, ranging from common law, to civil law, to a hybrid legal system, which can be linked to the era of colonialism, where the colonial masters imposed or made their legal systems applicable in their colonies.

Technically speaking, each individual bilateral agreement concluded between all Member States on space activities constitutes a source of space law in Africa at regional level. But, as alluded to earlier, there is no multilateral treaty regulating the African space programme. However, the AU's Specialised Technical Committee on Education, Science and Technology considered the fifth version of the Draft Statute Establishing the African Space Agency during its second ordinary session from 21 – 24 October 2017, in Cairo, Egypt (African Union [AU], 2017). The African Union Member States highlighted the need for appropriate institutional arrangements for the effective governance, promotion and coordination of space activities on the continent in order to realize maximum benefits (Draft Statute of the African Space Agency, 2017), which necessitate the adoption of a Statute/Treaty establishing the African Space Agency. Hence, it is worth noting the efforts taken by the African Union to adopt a legal framework aimed at governing, promoting and coordinating space activities in the continent. Therefore, the elements of the Statute of the African Space Agency will be discussed in Section 3.3.

3.2 African Space Policy and Strategy

The first step towards the realisation of an African Space Programme was the development and adoption of the African Space Policy (attached at the end of this dissertation as an appendix), which is the first in a set of instruments that will help in formalising Africa's space programme. The African Space Policy provides the guiding principles for a sustainable and fully effective space programme that will serve the needs of the African continent (African Space Policy, 2017:3). Generally, the rationale behind the African space policy and initiative/strategies is based on sustainable development as key driver. This Policy is tailored to meet the challenges faced by Africa collectively and how its developmental priorities were shaped by these and by the broader United Nations' Sustainable Development Goals. But, this dissertation will not dwell on the issue of challenges faced by Africa because much research has been conducted on this area already.

Nonetheless, the African Space Programme involves or has to involve coalitions from science, technology, commerce, security, autonomy, and finance, who each have their particular perceptions about space. In this context, space is seen as an object of scientific exploration, opportunity to improve quality and technological capability, a business opportunity, a source of intelligence, national prestige, and cost-benefit relation.

What the African Space Policy aspires can be derived from policy goals and objectives, in other words, the African Space Policy is aimed at meeting various needs within the continent. Therefore, the African Space Policy consists of policy goals which are found in chapter/section 3 of the ASP attached as Appendix 1 in this dissertation, this policy goals include amongst others, the creation of a well-coordinated and integrated African space programme that is responsive to the social, economic, political and environmental needs of the continent, as well as being globally competitive; and secondly, developing a regulatory framework that supports an African space programme and ensures that Africa is a responsible and peaceful user of outer space (African Space Policy, 2017:8). The latter policy goal is evidenced by the AU's adoption of the Statute of the African Space Agency.

In addition, in chapter/section 4 the African Space Policy outlines six objectives which need to be adhered to or achieved during the implementation of the African space programme, namely, "addressing user needs, accessing space services, developing the regional market, adopting good governance and management, coordinating the African space arena, promoting intra-African and other international cooperation" (African Space Policy, 2017:8-14). Of particular importance, for the purpose of this study, is the objective aimed at developing regional and international markets for space technology and services, because such an objective encompasses the development of commercial space operations in the region, of which space traffic management is an integral part of commercial space operations.

This objective means developing a sustainable and vibrant indigenous space industry that responds to the needs of the African continent, and its underlying principles including amongst others, creating an industrial capability, promoting public-private partnerships, and promoting Research and Development-led industrial development. In the context of this study, industrial capability denotes an African space industry that has the capability to seamlessly integrate space and air traffic management, from both technical and infrastructure perspectives.

The second important objective of the African Space Policy relates to the adoption of good corporate governance and best practices for the coordinated management of continental space activities, which includes: establishing an organisational framework that will coordinate all

African space activities and assets to serve the goals of the policy in an efficient and cost-effective manner; supporting the African space programme financially; etc (African Space Policy, 2017:12). Such an initiative aims at meeting the said objectives, but good corporate governance is also needed in the private space sector in Africa, for the purpose of participating in public-private partnerships with the object of integrating space and air traffic management in commercial space operations.

However, promoting public-private partnerships requires a horizontal approach in Research and Development of integrated space and air traffic management in the African space industry, which will serve the global market.

While the African Space Policy lays down the objectives and goals of the African continent in respect of space, it remains to be seen how such policy objectives can be achieved. This is where the African Space Strategy comes into play, to provide the plan of action for the achievement of the African continent's objectives in space arena. As alluded to earlier, the African Space Strategy was adopted at the same session of the Assembly of African Union that adopted the African Space Policy. The African Space Strategy (2017:5) which is attached as Appendix 2 in this dissertation, in its introductory section states that it "provides a framework for developing and operationalising continental-level space initiatives. It clearly spells out the strategic goals and objectives of a long-term collective space vision for the continent. Hence, the Strategy hinges off the African Space Policy, which provides a guiding framework, for both the African public and private sectors, on the underlying principles to be adopted en-route to a formal African space programme" (African Space Strategy, 2017:5).

The strategic actions that are relevant to this dissertation include institutionalising a corporate governance structure, and building critical infrastructure. The former denotes the need for "contextualisation of a centralised governance framework that must be embedded in current attempts to formalise African space initiatives. The African Space Policy provides for principles to be adopted in a programme for African space initiatives, whereas the strategy articulates the space ambitions of the African continent. These instruments must be used as a frame of reference for all indigenous and developmental assistance programmes to ascertain their relevance and fitness for purpose in relation to the needs of the African continent. If this is not done, the result will be a proliferation of initiatives that will ultimately contradict the developmental focus and initiatives of the African continent, and the key indicator is the establishment of a formal corporate governance structure" (African Space Strategy, 2017:15). This strategic action is on the verge of accomplishment, as is evident from the recent adoption of the Statute of African Space Agency, establishing an organisational framework that will coordinate all African space activities.

The latter strategic objective denotes "leveraging existing facilities and developing strong regional and continental coordination in respect of new facilities" (African Space Agency, 2017:15). Furthermore, a public-private partnership is needed to promote the development of the continent's space infrastructure. This strategic action is relevant for the purpose of this study in order to address infrastructural requirements needed to seamlessly integrate space and air traffic management in an African context. Hence, the African Space Strategy details supporting programmes as part of an implementation guideline that indirectly links to the integration of space and air traffic management in Africa. To that effect, appropriate infrastructure is the cornerstone of an effective African space programme, enabling technology transfer and human capacity development initiatives which have an impact on the integration of spacecraft into the civil airspace.

3.3 Statute of the African Space Agency

3.3.1 Origin of the Statute of the African Space Agency (AfSA)

The origin of the Statute of AfSA can be traced back to the request sent by the Executive Council of the A.U. to the African Union Commission "to coordinate with the science and technology sector to implement the recommendations of a feasibility study on the African Space Agency and develop a space policy for the continent, taking into account remote sensing applications and satellite image processing. The Executive Council of the AU took note of the Draft Statute of the African Space Agency during its 32nd Ordinary Session, and recommended the Draft Statute of the AfSA to the Assembly for consideration and adoption. Consequently, the Statute of the African Space Agency was adopted by the Assembly of the African Union during its 30th Ordinary Session in January 2018" (African Union, 2018).

3.3.2 Establishment of the African Space Agency

The preamble of the AfSA Statute lists the various decisions which paved the way for consensus by the governments of the various African states to establish a continental space agency. Article 2 of the Statute provides for the establishment of the African Space Agency, abbreviated "AfSA", as an Organ of the African Union, dedicated to promoting, advising and coordinating the development and utilization of space science and technology in Africa and associated regulations for the benefit of Africa and the world, and forging intra-African and international cooperation. The primary objectives of AfSA are to promote and coordinate the implementation of the African

Space Policy and Strategy and to conduct activities that exploit space technologies and applications for sustainable development and improvement of the welfare of African citizens (Draft Statute of AfSA, 2017). Article 4 lists 7 actions that the Agency is expected to implement in order to achieve the stated primary objectives. In addition, in terms of Article 3 the Agency is granted legal personality to a) enter into agreements; b) acquire and dispose of moveable and immovable property; c) institute legal proceedings (Draft Statute of AfSA, 2017).

The institutional governance and management of AfSA consists of a) the Assembly, b) Heads of State and Government Chamipioning-Education, Science and Technology, c) the Executive Council, d) the African Union Specialised Technical Committee on Education, Science and Technology; e) The African Space Council; f) Advisory Committee; and g) the Secretariat (Draft Statute of AfSA, 2017) as provided for in article 8. From the above institutional governance and management structure of AfSA, the African Space Council stands out, because it has the authority to oversee the Agency, issue directives, and review and approve strategic plans, work plans, budgets, regulations, policies and guidelines to govern the administrative activities and operations of the Agency for adoption by the relevant policy organs of the AU (Draft Statute of AfSA, 2017). Hence, under Article 8 –A (1) the proposed composition of the African Space Council consists of ten (10) elected persons from Member States, two (2) per economic region; and representatives of the Commission (Draft Statute of AfSA, 2017).

The Draft Statute of the AfSA extends diplomatic immunities and privileges to AfSA and its staff, hence, the Agency has to enjoy within the territory of all AU Member States in particular the Host Country, the status, privileges and immunities provided in the 1965 General Convention on the Privileges and Immunities of the Organization of African Unity and other relevant international agreements (Draft Statute of AfSA, 2017). It is a common practice under general international law to grant immunities and privileges to international organisations and/or their affiliates. Where will the headquarters of the AfSA be located? In terms of the Draft Statute, the Headquarters of the Agency shall be determined by the Assembly of the Union in accordance with the AU criteria adopted in 2005 (Draft Statute of AfSA, 2017). To that effect five countries, namely Egypt, Ethiopia, Ghana, Kenya and Namibia, are bidding to host the space agency (Space in Africa, 2018). However, Ghana's bid to host the African Space Agency suffered a blow after the African Union has rejected it's (Ghana) bid to host the A*f*SA because the bid came in very late leaving the AU with no option but to reject. Accordingly, the deadline for the bid was 30 October 2018, and Ghana submitted its bid in November 2018. This means that only three countries, namely, Egypt, Ethiopia and Nigeria, are contending for hosting the AfSA after Namibia withdrew its bid and following the rejection of Ghana’s bid (Space in Africa, 2019).

3.3.3 Membership and Entry into Force

The membership to the AfSA is open to all Member States of the African Union (Draft Statute of AfSA, 2017), but the Statute will only enter into force upon its adoption by the Assembly (Draft Statute of AfSA, 2017). Therefore, the AfSA Statute will have legal basis by virtue of Article 10 of the Abuja Treaty, which states that the decisions of the Assembly of the African Economic Community shall be binding on member states and organs of the community as well as on RECs according to the Treaty Establishing the African Economic Community (Abuja Treaty, 1991).

The Statute of AfSA was adopted by the Assembly during its 30th ordinary session from 28 – 29 January 2018 in Addis Ababa, Ethiopia. What remains to be seen is the enforceability of the Statute, because pursuant to paragraph 3 under Article 10 of the Abuja Treaty, 30 days have to lapse from the date of signature by the Chairman of the Assembly for the African Union’s Decisions to be enforceable. Whether the Chairman has exercised this administrative or executive function is yet to be determined.

4. AFRICAN PERSPECTIVE ON INTEGRATED SATM

4.1 Commercial space travel and tourism market in Africa

The commercial space travel and tourism market is a *sine qua non* for the integration of space and air traffic management, therefore, this call for an analysis of the commercial space travel and tourism market, in particular an African space tourism market. To begin with, the global space tourism market has evolved into a number of regional markets, each with its own characteristics. Hence, the overall market has been divided into three regional markets, namely: a) Europe, Middle-East and Africa (EMEA), b) the Americas (United States, Canada, Latin America), and c) Asia-Pacific (APAC), which consists of China, India, Japan, Korea, South-East Asia (Space Travel Consultants International Ltd., 2018:2).

However, our focus will be on EMEA, of which Africa forms part. According to Space Travel Consultants International Ltd. (2018:10), the space tourism market, in terms of regional passenger volumes for this region, from 2018 to 2020 is estimated to be 5 – 15% of the global market and to experience less than 20% market growth per annum. In addition, the business outlook by region indicated that EMEA was one of the initial high-growth regions of space tourism. The high status value among the very rich in the region is expected to drive the initial uptake. Once space tourism becomes a bit more commonplace, it will lose some of the status value and therefore become less interesting to customers from the EMEA market as contended by Space Travel Consultants International, Ltd. (2018:11).

However, the forecasting conducted by Space Travel Consultants International doesn’t provide a detailed breakdown of the estimates for the African space tourism market at sub-regional level. Similarly, the figures provided by Space Travel Consultants above are not reliable because there was zero space tourism that took place in 2018 globally or at regional level. Hence, it is worth commenting that the commercial space market in Africa, in the context of space tourism, and for suborbital point-to-point travel, is in its infancy or not in existence at all, with the exception of one African citizen who travelled to space as private paying customer or space tourist in 2002. Therefore, there is a need to forecast the potential space tourism market in Africa, which has an impact or effect on the realisation of an integrated SATM in the continent. Such forecasting should be based on quantitative analysis, which is currently lacking, but it is not the purpose of this study to provide quantitative analysis of the space travel and tourism market in Africa. However, we have observed that there is a link between space travel/tourism and the seamless integration of SATM. Therefore, the establishment of a niche market in Africa is also a precursor to the integration of SATM, due to the fact that suborbital point-to-point travel to and from the African continent, which if it takes place, will have an impact on the other users of air space in the region. But it is worth noting that only a few African billionaires are willing to or have the capability to become space tourists. This is evident from the fact that Mark Shuttleworth, a South African, who was dubbed an Afronaut by the Late Nelson Mandela, was the first African citizen to travel into outer space on a Soyuz TM-34 rocket from the Baikonur launchpad on the 25th April 2002, and it cost him £20 million or £60 000 an hour, which was payable in instalments at the time (Durrell, 2002).

4.2 Integration of space operations into African ATM

4.2.1 ATM in Africa

4.2.1.1 Organisation of ATM

The United Nations' African regional group consists of 55 countries (United Nations [UN], 2018) which all enjoy complete and exclusive sovereignty over the airspace above their territories under the Convention on International Civil Aviation (Chicago Convention, 1944). This implies that the 55 African countries are responsible for the provision of air navigation services in their respective territories regardless of whether such provision of air navigation services is vested in the government/state owned enterprise or a totally privatised entity. However, within national airspace the laws and regulations of a State relating to the admission to or departure from its territory of aircraft engaged in international air navigation, or to the operation and navigation of such aircraft while within its territory, are applied to the aircraft under Article 11 of the Chicago Convention. This implies that air traffic management in the territory of Member States is regulated through a domestic legal regime.

Therefore, in the African context there are 55 different air navigation service providers of various geographical areas. In particular, in countries such as Algeria (Etablissement National de la Navigation Aérienne [ENNA], 2014), Angola (*Instituto Nacional de Avicão Civil* [INAC], 2014), Democratic Republic of Congo (Regie des Voies Aériennes [RVA], 2014), Egypt (National Air Navigation Services Company, 2014), Morocco as stated by CANSO (2018), Mozambique (Aeroportos De mocambique, E.P/Mozambique Airports, 2018), Nigeria (Nigerian Airspace

Management Agenc [(NAMA]), and South Africa (Air Traffic and Navigation Services Soc Limited [ATNS], 2018), air navigation services are provided by state-owned enterprises or government-controlled entities but with autonomy as service providers from the oversight entities/regulators. In countries such as Botswana (CAA Botswana, 2010), Burundi, Cape Verde (Civil Aviation Agency, 2018), Djibouti (National Agency for Civil Aviation and Meteorology [ANACIM], 2015), Ethiopia (Ethiopian Civil Aviation Authority, n.d.), Gambia (Gambia Civil Aviation Authority, 2017), Ghana (Ghana Civil Aviation Authority, 2016), Guinea (Autorité Guinéenne de L'Aviation Civile [AGAC[, n.d.), Kenya (Kenya Civil Aviation Authority, 2018), Lesotho (Department of Civil Aviation-Lesotho, 2013), Liberia (Liberia Civil Aviation Authority, 2018), Libya (Libyan Civil Aviation Authority, n.d.), Mauritius (Civil Aviation Department under the Prime minister's Office, n.d.), Namibia (NCAA, 2017), Rwanda (Rwanda Civil Aviation Authority, 2018), Sudan (Civil Aviation Authority – Republic of Sudan, 2016), Swaziland (Swaziland Civil Aviation Authority, 2018), Tanzania (Tanzania Civil Aviation Authority, 2018), Tunisia (Office de L'Aviation Civile des Aeroports, 2013), and Uganda (CAA – Uganda, 2018), the provision of air navigation services and the regulations of the same is provided for by the same entity (civil aviation authorities), whether autonomous, semi-autonomous or not.

However, air navigation service provision is clustered in some parts of Africa. For instance, 17 African countries, are members of ASECNA, also known as the *Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar* (Agency for Air Navigation Safety in Africa and Madagascar), who mark their commitment to the single African sky initiative that represents a symbol of regional cooperation and integration (ASECNA, 2018). Hence, ASECNA provides air navigation services in Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comoros, Congo Brazaville, Ivory Coast, Gabon, Bissau Guinea, Equatorial Guinea, Madagascar, Mali, Mauritania, Niger, Senegal, and Togo.

Nonetheless, the provision of air navigation services in the remaining 38 African countries, who are not members of ASECNA, is sectored. Hence, the establishment of a Single African Air Transport Market in January 2018 (AU, 2018), is anticipated to reduce the fragmentation of ANS provision in Africa, because the SAATM will bring about enhanced connectivity across the continent, leading to sustainable development of the aviation, including air navigation service provision and tourism (AU, 2018:1). It necessitates the adoption of "measures with the aim of progressively establishing a liberalized intra-African aviation market concerning, among other things, traffic rights, capacity, frequency and pricing" (Yamoussoukro Decision, 1999:2), which also includes air navigation services. But the situation might change with the adoption of Single African Air Transport Market, and there is a possibility for an entity like ASECNA to be in charge of the provision of air navigation services in the region, not to mention the fact that ASECNA is open for membership to any country.

Evidently, we have seen a call for the harmonisation or amalgamation of air traffic management in the region from the airline industry. In particular, “Africa could benefit significantly if its governments were to come together to establish one air traffic control region for the entire continent” (Key Publishing Limited, n.d), something which is currently lacking within the African region. According to June Crawford, chief executive of the Board of Airline Representatives of South Africa, “Africa is divided into 52 air traffic control regions, compared with just two in the Unites States and one in the European Union region. These multiple air traffic control regions protect state-owned national carriers from competition when governments should be actively deregulating their domestic aviation sectors and opening their skies to participation by more airlines, particularly low-cost carriers (LCCs).”

4.2.1.2 Airspace Management (ASM)

“Airspace management is the process by which airspace options are selected and applied to meet the needs of the ATM community” (ICAO, 2005). As alluded to earlier, the ATM system in Africa (with the exception of ASECNA) is fragmented, therefore airspace management is the prerogative of the individual States (Eurocontrol & FAA, 2016:16), derived from Article 1 of the Chicago Convention. However, the adoption of SAATM might result in the consolidated airspace management in the African region, but that does not mean individual countries will lose their sovereignty over the airspace above them. Airspace management is purely an administrative function, hence territorial sovereignty, which includes airspace, will override any form of airspace management in the sense that the national security interest of individual states will prevail as the overlying principle that should be considered for any airspace management arrangements. Therefore, airspace management, which is an integral part of ATM, is also fragmented, because ATM is the function performed by different entities, i.e. private or public, in Africa.

4.2.2 Space Tourism in the ATM of Africa

The aviation industry in Africa is growing at an alarming rate and has huge potential compared to space tourism/space travel; the latter does not exist currently in the region, whereas in the case of the former, there is political commitment by the African leaders to liberalize air transport in Africa through the establishment of Single African Air Transport Market. But we should ask how many people in Africa are willing and able to spend millions of dollars on space tourism or just to experience zero gravity? If we look at the global picture, how often do space tourists go to the space station or take suborbital flights? The answer is minimal, in other words, it takes time to get the chance or spot as a space tourist or to travel to space in private capacity. Therefore, why should an African spend millions just for the sake of experiencing zero gravity? Yes orbital, suborbital, space travel is fast, i.e. you can travel around the world within one hour, but is Africa ready to embrace such a concept? The answer is negative, in the sense that, we are a long way back, before we can even count a dime of a space tourism market in Africa. It could take years or even decades before space tourism or suborbital point-to-point travel can be a reality in Africa. Long before this happens, the United States and the E.U will be at the fore-front should suborbital flights or space tourism become a successful market.

However, there are others who hold the view that space tourism has a place in Africa. According to Gottschalk (2010:9) “the OTB-TFDC complex is ideally suited for the sub-orbital hops of current space tourism entrepreneurs, as it offers an unending panorama of bays and beaches stretching over the horizon, as viewed from 100 kms altitude. Some South Africans have initiated business negotiations to such adventure tourism operators”. But how many African entrepreneurs still hold the business idea of venturing into space tourism? Furthermore, is it worth it to invest millions of dollars in infrastructure, when the demand for launch services currently is low in the continent, and not to mention the maintenance-related expenses. Therefore, before Africa can think about embracing space tourism, we should focus on enhancing the launch capability in the continent by making use of existing infrastructure and technical skills, because we first need to experience how the launch activities in Africa (if that ever happens) will have an impact on civil aviation operations in the continent.

In addition, the accessibility of outer-space to Africa is dependent on the launch capability of other nations, because space actors in Africa both public and private procure launch services from other countries that have the launch capability. Unlike the E.U and the United States, Africa does not have a concept similar to SWIM that can be used for providing timely and reliable access to essential operational data of the spacecraft by all relevant stakeholders as part of SESAR or NexGen, in E.U and United States, respectively. Furthermore, space tourism requires the existence of a spaceport or space hub for the purpose of take-off/launch and landing of spacecraft. Currently, there is no spaceport or space hub in Africa designated for the purpose of space tourism, except an abstract idea of designating Johannesburg as a secondary passenger hub for space flights as depicted in **Fig. 4.1** below.

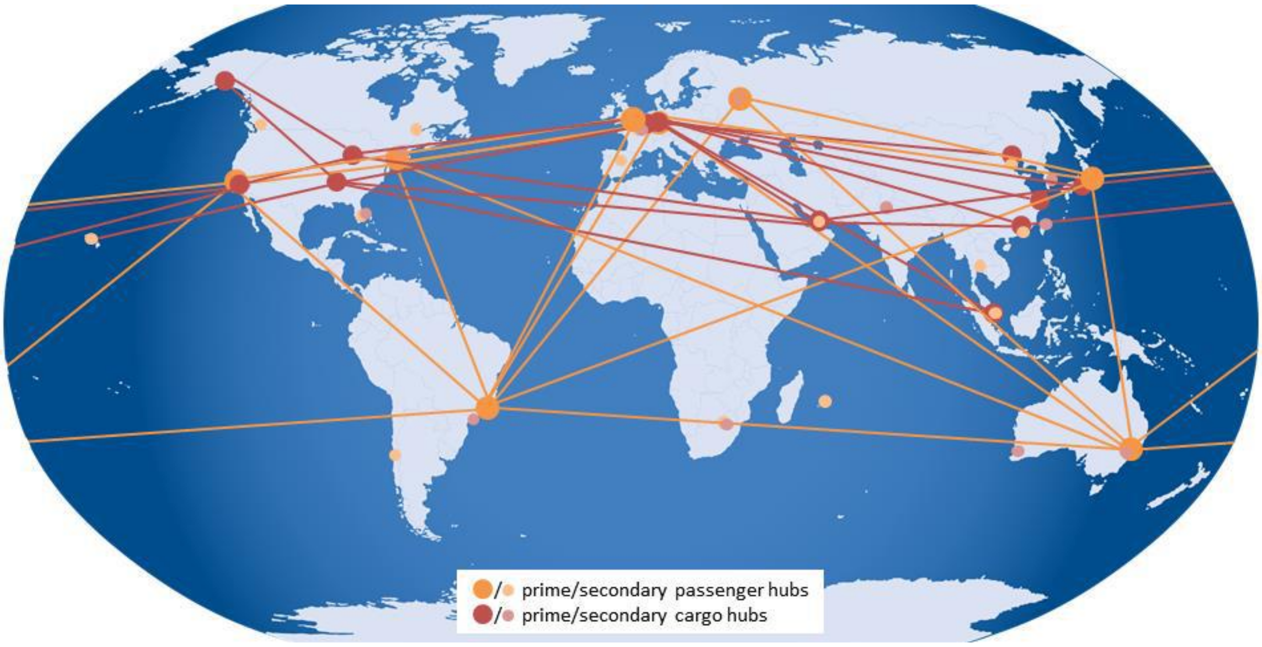

Fig. 4.1: Image depicting future proposed space hubs for both passenger and cargo, including in Johannesburg, Africa. Courtesy of Holger Krag.

Despite Johannesburg being chosen as a secondary passenger hub for suborbital flights, how can we be certain that this will be the case in reality? For that dream to be realised a lot must be done to integrate suborbital flights in the regional ATM, which at the moment is fragmented. In addition, lack of space hubs is not the only issue. Another concern is that there is no African initiated spacecraft to be used for space tourism; the initiatives that we see today are from outside Africa by companies such as Virgin Galactic, Blue Origin, etc.

4.2.3 Integration of Launch, re-entry and sounding rockets in the African ATM

The history of sounding rockets in Africa is closely linked to the French national sounding-rocket program in the 1960s. Hence, the global distribution of sounding-rocket launch ranges was extended to Africa, owing to the French rocket launches from the Sahara. Consequently, there were French sounding-rocket launch sites established in Africa, namely, *Hammaguir* and *Regane* in Algeria, with a total number of launches 33 between 1963 and 1964 (Seibert, G, 2006:23), see **Figure 4.2** showing the then Hammaguir launch site. However, “in 1962, Algeria became independent from France, leading to an agreement to dismantle the Sahara-based Hammaguir launch site by July 1967. In particular, the accords *d'Evian* (Evian agreement) was reached between the French government and the Provisory Government of the Algerian Republic on 18 March 1962, giving independence to Algeria. In the wake of the agreement, French military installations, including the rocket launching site in Hammaguir, were to be evacuated" (Anatoly Zak, 2008).

Fig. 4.2 Launch Site at Hammaguir in Algeria. Image courtesy of Sven Grahn.

To date, neither South Africa nor Nigeria, as "space powers" in the African context, have developed sounding rocket launch services in support of their countries' or the African continent's scientists who must use expensive foreign sounding rocket service providers. To that end, the University of KwaZulu-Natal (UKZN) started the Phoenix Hybrid Sounding rocket program (HSRP) in 2010 within the School of Engineering's Aerospace Systems Research Group (ASReG), which started in the context of South African government's prioritisation of skills and resource development in space-related research (University of KwaZulu-Natal, n.d). Therefore, in the African context, we see the development of amateur sounding rockets or University-initiated programs that aims to address the user needs of the African scientific communities. Despite this, there is a need to analyse how sounding rockets are being or must be integrated in the regional ATM.

In as far as the integration of both current and future sounding rockets in the ATM in Africa is concerned, this has to go through some hurdles or challenges. On the one hand, the ATM in Africa is fragmented, as alluded to earlier; this means that sounding rockets will require permission from each individual State as they transition through the airspace of the said country in whose jurisdiction they operate. On the other hand, sounding rockets will require licensing for launch operations and launch facilities, such as those that were in Algeria, from the competent authorities of each individual State in charge of licensing. Since ATM in Africa is fragmented, the current trend of separating or shutting down commercial airspace during the launch of sounding rockets will continue, unless the ATM is harmonised or integrated within the region, which is something that this writer does not foresee to be done in the near future. Currently, the harmonisation of civil aviation rules, standards and procedures within the region or at sub-regional level (except in the east African region) is yet to be attained, not to mention that the open skies for Africa was launched in early 2018, and we have to witness the implementation of the same. Therefore, integrating sounding rockets within a fragmented ATM in the region is a mountain to climb, because unlike in the US where there is one entity in the form of FAA that is in charge of licensing commercial space operation and the regulation of civil aviation operations which will make it easy to integrate sounding rockets within the ATM or NAS, the picture is totally different in Africa. Almost in every State, at least among the emerging space faring nations in Africa, both the licensing and regulation of space and civil aviation operations are regulated by different institutions. The situation could be different for those countries that form part of ASECNA, but there is no sounding rocket program undertaken in these countries to warrant the integration in their ATM.

In as far as launch and re-entry operations are concerned, during the "launch and recovery phase, spacecraft must transit through airspace that is utilized by civil and military aircraft. To date, these operations have been managed by segregating space operations from aviation by utilizing military or other specially designated airspace on either a permanent or real-time basis" (Jakhu, & Pelton, 2017:308). This scenario is not unique to Africa. As alluded to earlier in Section 1.2 there were a few launch sides that were utilised for launch services in Africa, in Algeria, at the coast of Kenya and in South Africa, therefore, the general assumption is that spacecraft were separated from civil aviation operations through the closure of the airspace before the launch and after the launch. History tells us that, only a few launches took place in the continent in Algeria, Kenya and South Africa, therefore, the traditional approach of restricting the airspace during a launch has been followed for all launches that took place in the continent. On that note, we do not foresee the possibility of integrating launches and re-entry operations in the regional ATM any time soon, because, there are currently no launches or re-entry operations taking place in the continent. If any re-entry takes place, that will be from entities outside the continent. Thus, in that event we can assume that the airspace of an affected State will be closed provided that there is mechanism put in place to track spacecraft upon re-entry as part of space situational awareness. Currently, the normal practice under those circumstances is to issue a NOTAM to the affected region or area. On the other hand, those member states who form part of ASECNA can easily collaborate on efforts aimed at integrating launch and re-entry activities as they transition through the airspace managed by ASECNA. Furthermore, since membership of ASECNA is open to any country, it is possible for more countries to join the entity which will make the organisation of ATM and airspace management to be amalgamated eventually making the integration of launch and re-entries operations in the African ATM easy. Furthermore, there is no launch market in Africa currently. This is attributed to lack of infrastructure or non-operational facilities such as the Overberg Test Range that have been decommissioned, low demand for launch services (i.e the number of satellites launched on annual basis for African space actors is minimal), therefore, we cannot integrate that which does not exist. This may sound pessimistic but unless Africa establishes the launch capability, and the demand for launch services in Africa increases, there is no need to integrate space into ATM, because there are not sufficient spacecraft launched or projected to re-enter African airspace to require integration in ATM. The only scenario that we foresee is the re-entry of spacecraft, whether planned or not, by another State through African airspace, which will raise safety issues on the ground.

Furthermore, integration into the African ATM is not only about the launch and re-entry operations. It also has an impact on the future airports that can be used for dual purposes, dual in terms of civil aviation operations and the horizontal take-off and landing of spacecraft. But currently, no such airports are in existence to accommodate both aircraft and spacecraft, even if they are anticipated to exist in the future. This will impose additional burdens on Africa both technically and financially, in order to ensure that infrastructure is in place to integrate space operations at airports. However, some airports in Africa, because of the length of their runways were identified as ideal to accommodate the Space Shuttle program as Trans-Atlantic Landing sites. To that end, Pelton & Jakhu (2017:308) were of the view that “today, a vertical launch from a spaceport has very different impacts on air traffic management as compared to a launch from an aircraft launcher, a towed rocket lifted to high altitude, a balloon or some form of dirigible launch system. Indeed, many operators of commercial space vehicles intend to operate from existing airports. Thus, the issue of integration of these various operations, not only into the existing air traffic management system, but also into airport surface management, presents a challenge that requires attention and addressing". Consequently, as part of integration in ATM issues such as the manoeuvrability of the spacecraft at the apron, airport emergency planning to accommodate spacecrafts, terminal operations and airport designs will come into play, not to mention the training needs for both the operational and inspectorate personnel to handle spacecraft operations.

4.2.4 SWOT Analysis

The perception of Africa on the integration of SATM, requires an analysis of the strengths, weaknesses, opportunities and threats. Therefore, in the next section we will address this.

4.2.4.1 Strengths

There is a political commitment to adopt the Single African Air Transport Market, which will have a direct impact on the seamless amalgamation of ATM in Africa, and eventually impacting the integration of space and air traffic management in the region indirectly. Though, in the last 15 years only one African space tourist travelled into space, there is global interest in space tourism which will extend to Africa once the necessary infrastructure and regulatory framework is put in place. Another indicator of strength for the integration of SATM in Africa are the ongoing feasibility studies on the establishment of spaceports in the region that will serve as necessary infrastructures for integrating SATM, though currently there is no active spaceport in Africa despite the presence of the San Marco platform off the coast of Kenya and the Overberg Test Range in South Africa. Another strong point is the existence of expertise in the integration of civil and military aviation; the same sort of coordination will be needed if Africa is to integrate SATM. The aviation sector in the continent is facing a paradigm shift towards satellite/space-borne communications, navigation and surveillance system, which could also play an important role when integrating space and air traffic management in the region.

4.2.4.2 Weaknesses

The downside for the integration of SATM in Africa is the manner in which air navigation services and airspace management are so fragmented. This presents a weakness because it will be difficult to seamlessly integrate SATM in a fragmented framework. Furthermore, the mere fact that there is no spaceport or space launch site established in Africa poses as a weakness in the sense that there is no technical capability for licensing spaceports which are an integral part of space and air traffic management.

4.2.4.3 Opportunities

Firstly, despite the challenge that air navigation service provision and airspace management in Africa is fragmented, this presents an opportunity to develop strategies aimed at integrating both space and air traffic management at the initial phase of consolidating the airspace management and provision of air navigation services. Further, there is an opportunity for Africa to transform the existing airports into spaceports or aerospace ports so that they can play a dual role for both commercial space operations and aviation as users of airspace in Africa, eventually contributing to the integration of space and air traffic management through the provision of relevant infrastructure required. In addition, Africa has an opportunity to evade the impact faced by commercial aviation globally, such as flight delays, flight plan alterations, increased distance flown, longer flight times, flight cancellations, crew duty cycles, gate slot management, and added fuel burn (Air Line Pilots Association [ALPA], 2018:10), from the segregation or closure of airspace during a launch, by developing technologies that will integrate SATM.

The southern hemisphere of Africa is demarcated as the secondary passenger and cargo hub for suborbital flight routes connecting South America to Australia, hence the international community has already earmarked Africa for point-to-point travels, which justifies the integration of SATM in the region. Therefore, if infrastructure is developed this will present an opportunity to attract investors within the region.

4.2.4.4 Threats for space traffic integration in African airspace

Typical areas where the African aviation sector faces challenges include infrastructure and technology, regulation and governance, and this will similarly be experienced in an effort to integrate space and air traffic management in Africa. Consequently, there is a lack of adequate resources and infrastructure required in order to integrate space and air traffic management. As alluded to earlier, Africa does not have an established spaceport or launch site that comprises the necessary facilities in order to facilitate the seamless amalgamation of space into the African air traffic management framework. The next challenge will include the lack of a regulatory framework and governance required in order to integrate space and air traffic management effectively in Africa. The fact remains that the lack of a regulatory regime for the integration of space and air traffic management is a global phenomenon, i.e is a challenge experienced globally. Furthermore, the over-emphasis on national security or security matters will curtail any effort aimed at amalgamating airspace management, eventually affecting space and air traffic management integration.

Africa also faces an institutional challenge, because unlike in United States where there is one entity in the form of Federal Aviation Administration which provides aircraft and pilot certification, operational approval, air traffic control, and safety oversight of commercial aircraft operations in the NAS, and at the same time also provides the necessary permits and licenses for space operations, for the space vehicles used by space operators, and the licensing of spaceports (ALPA, 2018:7), the licensing and monitoring of both commercial aviation and space operations are vested in various organisations or entities in the individual states in Africa. Hence, this will have an impact on new institutional developments aimed at integrating SATM in Africa.

We can infer from the SWOT analysis above that there are opportunities for Africa to integrate SATM, however, the threats that the region faces outweigh any effort to integrate space into ATM in Africa. Africa as a region has to implement its space programme, backed by the established regulatory framework and institutional arrangements before we can shift the attention to integrating space and air traffic management. Although, both the current spaceports and the feasibility studies suggest the potential for spaceports in Africa, the launch activities per annum in the region currently is zero. Thus, why should Africa be concerned about a traffic regime that has not yet kicked off in the context of space travel and tourism, and which might take decades before its impact is felt in Africa? If there is any need for integrating space into ATM in Africa, it will be as a result of push effect from the United States and E.U. There are those who might argue that Africa should see STM in the context of sustainable utilisation of outer space. But that will be irrelevant for the purpose of this dissertation, because the whole objective is about Africa integrating SATM.

4.3 Technical/Operational Aspects of STM

Despite the legal, regulatory, policy and organisational issues related to the integration of SATM discussed in section 4.2, as well as in preceding and subsequent chapters, it is essential to understand the technical/operational aspects of STM. The technical aspects of STM which will subsequently play a crucial role in the integration of SATM is the use of radar systems, optical sensors and Global Navigation Satellite Services (also referred to as satellite-based positioning, navigation and timing (PNT)) in dealing with Space Situational Awareness, eventually addressing orbital space debris.

4.3.1 Orbital Space Debris

Space debris increasingly threatens the sustainable use of space, as increasing debris build-up is becoming a major threat to functioning satellites. For instance, the first reported collision took place between Cerise on July 1996, a French microsatellite orbiting at an altitude of 700 km, and a fragment of space debris from an exploded third stage of an Ariane launcher. Since then, the low-Earth orbit (LEO) debris population has grown to a significant degree. Another catastrophic event in the context of space debris happened in 2007 when the Chinese anti-satellite missile test created over 2,000 new debris elements of trackable size in LEO, of course the intentional destruction of satellites by means of ASAT weapons is contentious due to the impact it has on international peace and security. Nonetheless, ways are being considered to mitigate intentional destruction of satellites as part of *Space Debris Mitigation Guideline* which is discussed below in the following subsection. However, catastrophic space debris events never stopped, this is because in 2009 there was accidental collision between Iridium 33 and Cosmos 2251, which also created over 2,000 new debris elements. Recently, a 20-year-old U. S. military weather satellite exploded and caused at least 43 new pieces of debris tumbling into different orbits around Earth on the 3rd of February 2015. Hence, it is estimated that, even without additional new launches, there will likely be a collision every five to ten years going forward. Consequently, without any remedial action, a distinctive feature of space debris is that the amount of debris will continue to increase, in LEO generally and in particular in polar orbit (Jakhu & Pelton, 2017:332).

As a result, the rapid growth of space debris poses a real and continuous threat to existing operational satellites in orbit and to the long-term sustainability of all future space activities including the potential hazard to civil aviation operations. The congestion of certain orbits, along with the growing number of pieces of space debris, increases the collision probability among space objects and debris. In case of a collision with space debris, the damage to the space objects is likely to be significant, due to the hypervelocity impact and can result in the creation of new debris. These additional particles, in turn, increase the probability of new collisions, causing an ever-increasing number of impacts. This “cascading” or “chain reaction” effect is known as the Kessler syndrome (Jakhu & Pelton, 2017:332-333). Accordingly, this will in the long-run cause operational challenges to Space Traffic Management and, in particular to integrate space into ATM. Consequently, this calls for measures such as active debris removal to address the increasing space debris challenge. Therefore, there have been many proposals for solutions, either based on active debris removal or for on-orbit capabilities that carry out a variety of tasks, such as on orbit satellite servicing (Jakhu & Pelton, 2017:333). Such initiative will be discussed briefly below to provide a reader with an overview.

4.3.1.1 Active Space Debris Removal and UN Guidelines

From the onset, before we address the initiatives of active space debris removal, we need to understand what the concept of space debris denotes? Space debris can be defined "as all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional" (United Nations Office for Outer Space Affairs, 2010:1).

There have been several proposals for active space debris removal, for example the removal of elements from a defunct satellite, such as a large aperture antenna, and installing those elements on another spacecraft. Other proposals aim for the complete removal of an uncontrolled satellite (Jakhu & Pelton, 2017:334). At this juncture, typical example of active space debris removal initiative was taken by the U. S. DARPA in 2007. The U.S. DARPA undertook the test in order to assess the active interaction between two satellites to simulate on-orbit servicing, as well as the possibility of active de-orbiting. Hence, the ASTRO and NextSat spacecrafts were mainly foreseen as prototype systems to carry on-orbit servicing, retrofitting, and refueling, although de-orbiting capabilities were a significant secondary objective. Both satellites were designed for proximity maneuvering in space. In this respect, NextSat allowed a full simulation of the activities necessary for the capture of a debris element for active debris removal (Jakhu & Pelton, 2017:336).

In addition, according to Jakhu & Pelton (2017:340) "the Clean-Space One project of the *École Polytechnique Fédérale de Lausanne* (EPFL) which aims at the development of technology demonstration for space debris removal using a grabbing mechanism, could be the first family of satellites that would clean up space debris. The Clean-Space One satellite will have the mass of 30 to 50 kg with embedded technologies and hardware to capture and de-orbit the non-functional Swiss small satellite, the Swiss Cube, weighing 1 kg. Both Clean-Space One and its target satellites will move toward Earth and will burn up in the atmosphere."

From the above we can infer that there are technological advancements as part of space debris mitigation measures for commercial purposes. But Africa is way behind in developing the technology that will help in active space debris removal. Nevertheless, there are efforts at academic level i.e postgraduate students and researchers in African Universities who have proposed some concepts for active space debris removal. For example, just to mention but a few, University of Cape Town SpaceLab's masters student Louis Feng developed the concept of MEDUSA (Mechanism for Entrapment of Debris Using Shape-memory Alloys) which is based on the use of the shape-memory alloy Nitinol to create the capturing volume around the target object (UCT, SpaceLab, 2017). However, we need to know what regulatory measures exists at international level to serve as guidance and control mechanisms for space debris? It is important to stress *ab initio* that there is no international legal regime regulating space debris, however, the international community has developed some guidance materials to mitigate space debris in the form of "*The Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*". These are voluntary guidelines for the mitigation of space debris adopted by the Scientific and Technical Subcommittee at its forty-fourth session, in 2007 under the Committee on the Peaceful Uses of Outer Space (COPUOS). In 2007, COPUOS endorsed the space debris mitigation guidelines at its fiftieth session, and the General Assembly endorsed the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space in its resolution 62/217 of 22 December 2007 (UNOOSA, 2010:iv). These mitigation measures are divided into two broad categories: those that restrict the generation of potentially harmful space debris in the near term and those that limit their generation over the longer term. The former involves the curtailment of the production of mission-related space debris and the avoidance of break-ups. The latter concerns end-of-life procedures that remove decommissioned spacecraft and launch vehicle orbital stages from regions populated by operational spacecraft (UNOOSA,2010:1).

Therefore, there are seven guidelines containing mitigation measures, the first guideline for mitigation require the space systems to be designed in such a way that they do not to release debris during normal operations. Alternatively, if this is not feasible, the effect of any release of debris on the outer space environment should be minimized.

The second mitigation measure necessitate spacecraft and launch vehicle orbital stages to be designed in such a way to avoid failure modes which may lead to accidental break-ups. Thirdly, in developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited as a mitigation measure. Fourthly, following the development of anti-satellite weapons to destroy defunct satellites in orbit, the next mitigation measure requires the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris to be avoided. Fifthly, as a mitigation measure all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal in order to limit the risk to other spacecraft and launch vehicle orbital stages from accidental break-ups. Sixthly, spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion. Where this is not probable, they should be disposed of in orbits that avoid their long-term presence in the LEO region. Finally, spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the GEO region should be left in orbits that avoid their long-term interference with the GEO region. However, we should stress that these guidelines are voluntary and not binding on Member States, and therefore can be regarded as part of soft law. However, we should take into account the fact that Space Debris Guidelines endorsed by General Assembly can form part of customary international law provided that the two requirements of state practice and *opinio juris* (sense of legal obligation), for the custom to amount to customary international law.

4.3.2 Existing Space Situational Awareness Techniques

There are few space surveillances and tracking techniques that are used to track space objects which help in promoting space situational awareness and in the long run contribute to space safety and sustainability. Space Situational Awareness (SSA) is the cornerstone of safe exploration in outer space and could play a crucial role in the integration of space and air traffic management. The main requirement for effective SSA is to find and then track space objects, this can be achieved by radar for satellites in LEO and by optical systems for satellites in higher orbits such as GEO. Therefore, this section briefly discusses the existing radar and optical systems for space situational awareness systems for the purpose of contributing to efforts aimed at integrating SATM or continued segregation of spacecraft from civil aviation operations. However, we should mention from the outset that “the ability to detect and track space debris is a different operational concept than simply creating a traffic control for space”, as alluded to by Jakhu & Pelton (2017:318).

4.3.2.1 Using Optical Sensors to Track Space Objects

Optical telescopes form the major type of sensor used to track space objects. They operate in the same fashion as telescopes used for astronomy applications, on that note, electromagnetic radiation emitted by an object is gathered and focused to form an image. On the one hand, refracting telescopes use lenses, while reflecting telescopes use mirrors. On the other hand, catadioptric telescopes used a combination of mirrors and lenses. Although telescopes can be designed for many different parts of the electromagnetic spectrum, the visible portion is most often used for SSA (Weeden, Cefola & Sankaran, 2010). **Fig. 4.3** shows the European Space Agency's (ESA) Space Debris Telescope, located on the island of Tenerife, Spain.

Fig. 4.3 ESA Space Debris Telescope, Tenerife, Spain. Image courtesy Merrill I. Skolnik.

The capabilities of optical telescopes are usually measured by the size of their aperture and field of view (FOV). The size of the aperture determines the amount of light that is collected and the depth of field over which the telescope can focus. The FOV determines how much area can be seen by the telescope any given moment. Traditionally, there is an engineering trade-off between the ability for a telescope to quickly search a wide area and the ability to detect very faint objects.

An increasing number of optical telescopes are being developed with adaptive optics (AO) for SSA applications. AO systems work by measuring distortions in a wavefront and compensating for them in the light detection system. In SSA applications, this typically involves using a laser to create a temporary guide star near the object being imaged. The laser's distortion due to the Earth's atmosphere is measured and used to correct the image of the target object (Weeden, Cefola & Sankaran, 2010).

The main advantage of optical telescopes for SSA is their range. Above 5,000 km altitude, it becomes very time consuming and difficult for radars to search for objects. Optical telescopes can perform this function much faster and easier. The main disadvantage of optical telescopes is that they can only operate under certain conditions. Those that rely on the Sun to illuminate their targets can only work when the target is illuminated, and the telescope is in darkness. Clouds and light pollution from cities and human activities are also an issue. The best locations for telescopes are where the air is thin, dry, and free from contaminants, and these locations are usually only found at high elevations or in remote desert areas (Weeden, Cefola & Sankaran, 2010).

Hence, Ground-based radar systems are traditionally used for detection and tracking of space objects in low earth orbit (LEO), but optical systems are necessary for detection and tracking of satellites in higher orbits such as medium earth orbit, geosynchronous earth orbit and high earth orbit (Ackermann *et al*., 2015:1). Ground-based systems are generally built larger and are therefore more sensitive, but they suffer from weather constraints, they must be distributed around the globe, and they are generally not useful in daylight (Ackermann *et al*., 2015:10).

Space-based optical telescopes provide a number of advantages over ground-based, primarily the absence of weather and an atmosphere, and are increasingly being seen as an important part of an SSA system. The U.S. military launched the Midcourse Space Experiment (MSX) satellite in 1996 which became the first dedicated space-based optical telescope for SSA. Until its end-of-life in 2006, MSX used its optical sensors to contribute to the Space Surveillance Network (SSN), primarily by finding lost objects in the GEO belt. MSX is due to be replaced by a more advanced constellation of dedicated SSA sensors known as the Space-Based Space Surveillance System (SBSS) (Weeden, Cefola & Sankaran, 2010). In addition, space-based systems are expensive, vulnerable to ASATs and generally have smaller apertures, making them less sensitive. Space-based sensors still have problems with solar exclusion, but the restrictions are much less than for ground-based telescopes. Depending upon the architecture, space-based sensors often have quick revisit times. Larger aperture sensors can be flown, but they increase cost and complexity (Ackermann *et al*., 2015:10).

Therefore, because of the merits associated with space-based sensors, Canada is also planning on launching space-based optical satellites to support SSA. It's Near Earth Object Surveillance Satellite (NEOSSat) will have the mission to detect and track both asteroids in orbit around the Sun and objects in high altitude orbits around the Earth. NEOSSat will be followed by Sapphire, an autonomous, dedicated satellite for SSA that will contribute to the U.S. SSN (Weeden, Cefola & Sankaran, 2010). The question remains whether Africa has similar optical sensors in order to improve SSA and play a crucial role in the integration of SATM? Currently, there are no optical sensors in Africa whether ground-based or space-based for the purpose of SSA, however, Africa uses optical sensors for the purpose of remote sensing and earth observation. Therefore, any effort to use optical sensors for improved SSA in Africa will be through international cooperation with countries such as the U.S, Canada and E.U that have or are planning to develop the technology.

4.3.2.2 Using Radar Systems for Tracking of Space Objects

Radars form the backbone of an SSA system. Radar consists of at least one transmitter and receiver; the transmitter emits radio waves at a specific frequency. Some of these waves reflect off the target and are measured by the receiver, which is then able to calculate location of the target in relation to the radar (Weeden, Cefola & Sankaran, 2010). According to Weeden, Cefola &

Sankaran (2010), “the primary advantages of radars are that they can actively measure the range and range rate to a target, and that some types of radars can accurately track many objects at once.” However, the main disadvantages of radars are their cost, in initial construction and operations and maintenance, size, and complexity (Weeden, Cefola & Sankaran, 2010).

At the beginning of the space era, two radar concepts or radar systems were available for space object tracking. The first is an interferometer-based system, also known as a bi-static or multi-static system, where the receiver and transmitter(s) were separated by a specific distance, as shown in **Fig. 4.4** below. Bistatic radar systems are especially well suited to so-called "fence" applications, where a continuous amount of energy is emitted in a certain direction. All objects passing through this "radar fence" will thus be tracked (Weeden, Cefola & Sankaran, 2010).

The second initial radar concept was a monostatic radar shown in **Fig. 4.2**, which had collocated transmitting and receiving antennas, usually mounted on a parabolic dish that could be rotated and elevated. Monostatic radars mounted in this fashion are also known as mechanical trackers and are especially well suited to precision tracking of one or a few objects. With enough power, monostatic radars can also be used to track space objects in the GEO belt at more than 36,000 kilometers away. In regions with inclement weather, mechanical tracking radars are usually mounted inside domes which are made of a material that is transparent to EM radiation at their operating frequency (Weeden, Cefola & Sankaran, 2010). However, the new S-band radar “space fence” might assist in detecting and tracking smaller debris than currently tracked (Jakhu & Pelton, 2017:318). Currently there is no specific radar systems available in Africa for space object tracking. But the continent has the strengths of radar systems available for aviation and maritime, therefore, the continent can learn from existing technologies in other domains in order to develop a radar system for tracking space objects.

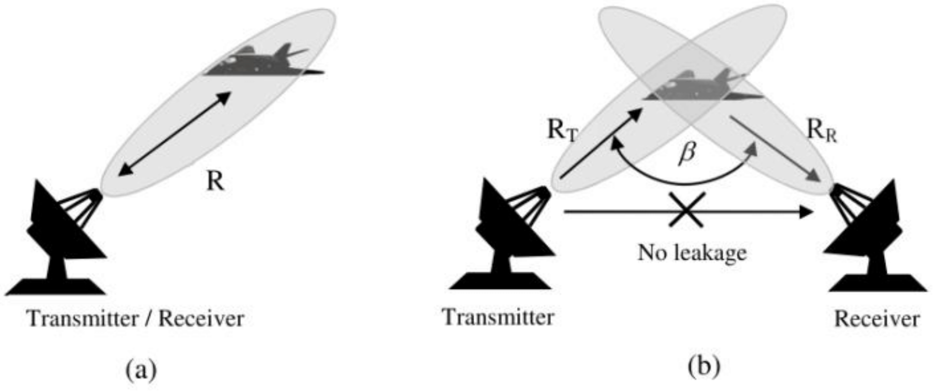

Fig. 4.2 Radar Systems: (a) Monostatic Radar and (b) Bistatic Radar. Image Courtesy of Asem Salah.

4.3.2.3 GNSS/PNT for SSA

GNSS emitters are at MEO, and the space debris of interest are at LEO. Therefore, most of the radio signals collected will be of forward scattered signals, where the angle of incidence and the angle of re-emission form an obtuse angle. Furthermore, most space debris are small, so at GNSS wavelengths is on the boundary between the Mie and Rayleigh scattering regions. This means that the forward scattered signal is equivalent to the diffraction pattern formed by a hole of the same silhouette as the object. The key property here is that the forward scattered signal has a known phase relationship with the incident signal, eliminating the scintillation that generally limits the coherent integration period of a radar. Obtaining long coherent integration periods is difficult, as many parameters must be controlled and there is a high processing cost, but it is possible, as evidenced by the widespread application of Synthetic Aperture Radar (SAR) (Mahmud, Lambert & Benson, 2015).

Given the predictable phase of the scattering from the small orbital object, and the very small dynamic disturbance forces on both the illuminator and the object to be tracked, there is an opportunity for very long periods of coherent integration. However, integration over very long periods is subject to resolving a range of technical difficulties, which include; correction for ionospheric and tropospheric delays, correction for receiver clock instability, availability of sufficient computational capacity and algorithms to search an adequate uncertainty volume, and provision of a collection aperture of sufficient area.

Accordingly, the signal power density at the Earth due to scattering of GNSS signals from small objects is very low. This is because the already low energy density in the GNSS signal arriving at the debris is then made weaker by the small radar cross section (which will be less than unity), and finally experiences a very large spreading loss over the path from the debris to the ground based receiver, which is of the order of 1000km (Mahmud, Lambert & Benson, 2015). Despite the potentially low cost of each receiver element the cost of such an array is likely to exceed $10 m. Investments of this scale should not be made without demonstration of the key behaviors to mitigate risk. In particular these include demonstration that GNSS signals arriving through the ionosphere and troposphere are stable enough in phase to integrate blindly, scattering from space debris is approximated by the Babinet principle – having consistent phase and sufficient radar cross section, signals can be collected and processed in an efficient manner, and that the acquisition and operating costs of such a system are tolerable.

Variations in the signal propagation time through the ionosphere and troposphere are important, because it will be necessary to calibrate for them in a practical system. The key behavior is therefore the stability of the perceived delay over an integration time of the order of tens of seconds to minutes. Furthermore, for engineering a practical system it is also convenient if the illuminator and receiver have excellent timing stability, since this relieves the receiver processing system of an additional adjustment parameter (Mahmud, Lambert & Benson, 2015).

4.3.3 Operational issues related to near-space, sub-space or Protozone

The near-space, sub-space or the protozone, is used for a growing number of new applications, which in turn are faced with the risk of collisions and interference and, as such, safety concerns. Space traffic management is an important element of safety because of the public safety risks, the risk of the loss of important (and sometimes safety-critical) space-based services and infrastructure, and the safety risks for human spaceflight (Jakhu & Pelton, 2017:306). Hence, the interface between airspace regulation and control and the near-space is a matter of increasing concern and interest due to the increase in commercial launch systems to low-Earth orbit associated with large-scale constellations, and ever increasing programs to launch cube satellites (CubeSats) and small satellites (SmallSats) (Jakhu & Pelton, 2017:307). Furthermore, integration of space and air traffic management has been complicated by an increasing number of proposed new uses of the protozone. In particular, there are safety concerns with the increased usage of different systems operating at very different velocities in this in-between area. These new stratospheric systems include high-altitude platform systems (HAPS), unmanned aircraft systems (UAS) (also known as unmanned aerial vehicles, or UAVs, remotely piloted vehicles and drones), high-altitude balloons and dirigibles, dark sky stations, supersonic and hypersonic transport, and systems that might be used for military, security, or law enforcement and border surveillance purposes (Jakhu & Pelton, 2017:307).

4.3.3.1 Supersonic and Hypersonic Transportation Flights

The various transportation systems in the protozone can be used of commercial or military purposes and, thus, subject to different types of licensing, authorization, and safety control mechanisms as well as different taxation and economic control systems (Jakhu & Pelton, 2017:307). Nonetheless, in as far as stratospheric flights by supersonic and hypersonic aircraft with top altitudes above 40 km to 42 km is concerned, there is proposal to grant an acknowledged right of free passage once a clear flight path has been established (Jakhu & Pelton, 2017:315).

The likelihood of increased levels of operation, especially at hypersonic speeds, may give rise to considerations for the separation standards above 60 000 feet (FL600) (Jakhu & Pelton, 2017:315).

Establishing separation standards between aircraft, which sometimes cannot be controlled and may have a trajectory that is difficult to predict, poses a technical challenge. Simultaneously, the priority given to a controlled aircraft to assume the responsibility for an avoidance maneuver gives rise to an equity issue. For separation between two unmanned free balloons, strategic, rather than tactical air traffic control mechanisms must be employed. A very complex situation arises where multiple operators of uncontrollable aircraft seek to operate in the same airspace. In this case, on the one hand, the procedures used for satellite orbit assignment may provide instructive models. On the other hand, space situational awareness of all space objects will become more rigorous in coming years. This is because more and more small, nano, and femto satellites are being launched, and large-scale constellations are being deployed with perhaps thousands of satellites in each network. The advent of the new S-Band radar “space fence,” which the United States is deploying in the Kwajalein region of the Marshall Islands, is designed to track as many as 160,000 space objects in low Earth orbit, some of which are as small as the size of a marble. Presumably, such capabilities could greatly assist with the design and operation of any new space traffic management system, particularly in terms of detecting and warning of possible major collisions (Jakhu & Pelton, 2017:315).

A further technical consideration is that GPS and other space navigation systems were designed to provide precise locations on Earth’s surface rather than at high altitudes or in outer space. It may well be that improved software would become necessary to produce sufficiently accurate tracking and positioning data to facilitate the control, positioning, and maneuvering of objects in the protozone (Jakhu & Pelton, 2017:316). However, as the operational barrier to utilization of this region of airspace is overcome, a rapid development and competition for use of these altitudes above commercial airspace up through the protozone and into outer space are expected. Long endurance operations create distinct challenges for flight plan processing. Existing systems are not able to accommodate flight plans that span several days. Many of the early entrants into the protozone area anticipate flight durations of up to 90 days each for thousands of dirigible or stratospheric balloons, such as the aforementioned Google’s Project Loon aimed at providing global Internet connectivity. This is beyond the processing capacity of even the most advanced air navigation service providers currently functioning (Jakhu & Pelton, 2017:316).

The operators operating with unmanned systems in the protozone must adjust safety models to reflect the fact that the risks are not to HAPS, for instance, but rather to aircraft or to those on ground (Jakhu & Pelton, 2017:317). The modern surveillance systems, including secondary radar and automatic dependent surveillance systems, depend on cooperative onboard systems in order to provide surveillance data. Therefore, it is probable that any surveillance system usable in the protozone would have similar cooperative requirements (Jakhu & Pelton, 2017:317).

4.3.4 Conclusion

In conclusion, Africa is lacking behind when it comes to development of technology for active debris. However, the continent can use the ongoing research from the academia on concepts of active space debris removal. Furthermore, in the context of space debris removal African members states should integrate the UN Space Debris Mitigation Guidelines in policies and regulations to address the current and impending threat on space exploration. In as far as Space Situational Awareness is concerned , Africa lacks the capability in finding and tracking space objects, as a result of limitations in technology development, in particular, Africa does not have optical sensors, radar systems or GNSS available for identifying and tracking space objects, nor is Space Situational Awareness at the inception stage within the continent. However, African can enter into regional or global collaboration/ partnerships sharing of key tracking, and collision avoidance systems. For instance, the AU through the African Space Agency can enter into a bilateral agreement with the U.S Strategic Command (USSTRATCOM) on space situational awareness data sharing. Hence, space situational awareness data sharing efforts should be coordinated by the African Space Agency at regional level. However, in as far improving space situational awareness is concerned, we suggest that there is no one single system that can operate without shortcomings i.e every technic for tracking space objects will have shortcoming because of physical characteristics or environmental (whether space or ground based) constraints in the context of detecting and tracking space objects. Therefore, optical sensors, radar systems and GNSS must be used in such a way to compliment each other. But this does not mean that we should not develop technology that can improve space situational awareness such as the use of S-band. Finally, in as far as the operational challenges faced in near-space/protozone are concerned, we concur with the sentiments of Jakhu & Pelton that this area face the “risk of collisions and interference”. Hence, any surveillance and tracking system usable in the protozone would depend on cooperative onboard systems in order to provide surveillance data as alluded to by Jakhu & Pelton (2017:317).

5. LEGAL ANALYSIS OF INTEGRATED SATM

The integration of space and air traffic has some legal implications that need to be addressed. Typical legal issues emanating from the integration of SATM include authority for licensing and supervision of operations, applicability of the principle of sovereignty, and issues arising under aviation law, space law and amalgamation of these legal regimes in SATM. Furthermore, from the definition of aircraft and spacecraft in Chapter 2 above, we can deduce that aircraft are meant to function within the Earth's atmosphere, whereas for spacecraft they are mainly destined to operate beyond the Earth's atmosphere. Therefore, there is a difference in terms of technical capabilities and regulatory aspects applicable to both aircraft and spacecraft. Nonetheless, they both have one thing in common, namely they are both airspace users, but the only limitation is the lack of delimitation between airspace and outer space for one to effectively draw the line on the applicability of one legal regime or the other.

5.1 Regulation of integrated SATM

One of the major issues in the seamless integration of SATM is the authorisation, licensing and supervision of space traffic. In other words, which organisation, both at national and international level, should be charged with the authorization of space traffic, taking into account the fact that the former is not yet as developed in terms of legal a framework compared to the latter that has a legal regime in place for its regulation? According to Jakhu, Sgobba, & Dempsey (2011:49), "the international legal regime governing air transport on issues such as liability, security, navigation, and air traffic management are well developed, and set forth in various conventions, treaties, and various soft law standards".

For the purpose of this dissertation, SATM relates to the provision of space and air traffic services to ensure the safety and efficiency of both space/airspace users during all phases of operations without the need to segregate space operations from airspace users, as alluded to earlier. Consequently, this calls for the need to address legal aspects relating to the licensing of space traffic. Legal certainty should be guaranteed to ensure that the integration of space traffic into ATM is regulated, and to avoid any situation where one entity will usurp the powers of another.

Under existing international treaty law, national space activities are the responsibility of States, in particular, in terms of Article VI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty, 1969).

“states bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty.”

And in instances where space activities are carried out by private actors in outer space, such activities must be licensed and supervised continuously by the State, however, the discretion is left with the State to prescribe through national legislation the entity in charge of authorization and continuous supervision.

The integration of SATM raises concerns regarding the licensing and monitoring (not in literal terms, but in the sense of supervision) of space operations as part of a national airspace system, in particular suborbital spaceflights for the purpose of point-to-point travel, launch and re-entry operations. Therefore, Jakhu, Sgobba & Dempsey (2017:128) argue that “ICAO should extend its jurisdiction to space by appropriately amending its existing Annexes and/or adopting a few extra Annexes thereby extending its coverage to issues like licensing of spaceports, human space flight, space traffic management, safety of astronauts, security, etc.” Hence, they argued that “as suborbital flights are poised to become routine in the near future, now is an opportune time to establish regulations and standardization in connection therewith through ICAO” (Jakhu, Sgobba, & Dempsey, 2011:128). The legal basis for the licensing of space traffic through ICAO is implied from Article 37 of the Chicago Convention, which empowers ICAO to adopt and amend international standards and recommended practices and procedures “dealing with... such other matters concerned with the safety, regularity, and efficiency of air navigation as may from time to time appear appropriate”.

In as far as air traffic management is concerned, there are various Annexes, which are all adopted in terms of Article 37 of the Chicago Convention, that regulate the same, and may eventually become applicable to space traffic in the event of extending the jurisdiction of ICAO to space as part of integrating space into ATM. In particular, the ICAO should adopt and amend international standards and recommended practices relating to a whole lot of issues (Chicago Convention, 1944), such as licensing of operating and mechanical personnel; airworthiness of aircraft; registration and identification of aircraft; collection and exchange of meteorological information etc. But for the purpose of this dissertation, Annexes 1, 2 and 11 (Annex 11 is discussed in the section dealing with the provisions of air traffic services in the protozone) will be discussed briefly in as far as their impact on space traffic navigation through the airspace is concerned.

Firstly, Annex 1-Personnel Licensing, provides standards and recommended practices for the licensing of flight crew members, air traffic controllers, etc. Hence, in the context of SATM, do we anticipate ATCOs to be provided with the necessary training and certification/licensing in space operations, or will future Space Traffic Control Officers go through training and certification provided for under Annex 1, subject to the modifications/amendments to be made in order to cater for space traffic? If an ICAO for space as proposed by Jakhu, Sgobba & Dempsey (2017:128) is realised, then we should brace ourselves for the adoption and amendment of SARPs related to personnel licensing in order to accommodate space operations within the realm of airspace.

Secondly, we need to consider the rules of the air in as far as their application to air traffic and space traffic management is concerned. Therefore, Annex 2 - Rules of the Air, consists of general rules, visual flight rules and instrument flight rules adopted pursuant to Articles 12 and 37 (c) of the Chicago Convention. However, the rules of the air provided for in Annex 2 cannot apply equally to space operations during the integration of SATM in order to effectively apply the VFR or IFR for collision avoidance because of lack of interoperability of the subject matter, for example, the manoeuvrability of spacecraft is different from that of an aircraft. For instance, the following rules of the air contained in Chapter 3.2 of Annex 2 apply to collision avoidance; a) “when two aircraft are approaching head-on or approximately so and there is danger of collision, each shall alter its heading to the right; b) when two aircraft are converging at approximately the same level, the aircraft that has the other on its right shall give way, except as follows: i) power-driven heavier-than-air aircraft shall give way to airships, gliders and balloons; ii) airships shall give way to gliders and balloons; iii) gliders shall give way to balloons; iv) power-driven aircraft shall give way to aircraft which are seen to be towing other aircraft or objects; c) when it comes to overtaking, an aircraft that is being overtaken has the right-of-way; d) in case of landing, an aircraft in flight, or operating on the ground or water, shall give way to aircraft landing or in the final stages of an approach to land. But when two or more heavier-than-air aircraft are approaching an aerodrome for the purpose of landing, aircraft at the higher level shall give way to aircraft at the lower level, but the latter shall not take advantage of this rule to cut in front of another which is in the final stages of an approach to land, or to overtake that aircraft.

Nevertheless, power-driven heavier-than-air aircraft shall give way to gliders. In addition, an aircraft that is aware that another is compelled to land shall give way to that aircraft. In case of take-off, an aircraft taxiing on the manoeuvring area of an aerodrome shall give way to aircraft taking off or about to take off" (Annex 2 to the Chicago Convention,1944).

Therefore, can the rules of the air applicable for collision avoidance be equally applied to space traffic? The answer is in the negative. Annex 2 has to be amended extensively in order to apply collision avoidance rules equally to spacecraft, thus, Annex 2 has to be redesigned to accommodate spacecraft as they transition through airspace during launch and re-entry phases, or at aerospace during taxing, take-off, or landing, as part of the integration of SATM.

Another important rule of air navigation is the provision of information relative to an intended flight or portion of a flight, to be provided to air traffic services units, in the form of a flight plan. This implies that the integration of spacecraft into ATM will result in them providing flight plans to the competent authorities. If the above is in the affirmative, then Annex 2 has to be amended to insert provision for the submission of flight plans by space operators to either ATCs or a new Annex has to be adopted providing for the submission of the said flight plan to the so-called space traffic control (STC).

Hence, according to Jakhu, Sgobba, & Dempsey (2011:128), "it would be an easy and suitable job for ICAO to extend the same to space by appropriately amending its existing Annexes and/or adopting a few extra Annexes thereby extending its coverage to issues like licensing of spaceports, human space flight, space traffic management, safety of astronauts, security, etc." Thus, Jakhu, Sgobba & Dempsey stressed that "in order to implement the ICAO for space proposal, three key areas must be addressed. The first is the development of a space safety oversight operating model. The operating model describes the concept of operations and how the regulatory regime would work. The second is the establishment of an organizational framework for the implementation of the operating model. Finally, the safety certification process also needs to be considered, and this concerns the various processes a commercial space entity would have to follow in order to obtain the relevant safety certification(s) and permission(s) to operate." Thus the basis for amending or adopting new Annexes in order to integrate space operations into ATM through a regulatory framework exists under Article 37 of the Chicago Convention, which confers upon ICAO, the authority to address not only the issues of air safety and navigation, but also to address, and such other matters concerned with the safety, regularity, and efficiency of air navigation as may from time to time appear appropriate.

On that note, an Annex dealing with “rules of the space” should be adopted if the jurisdiction of ICAO were to be extended to space. But, the role of ICAO is not only about adopting Annexes relating to the rules of the space domain. A whole lot of other issues need to be addressed in as far as the integration of SATM is concerned, such as space worthiness, classification of outer space/space, classification of spacecraft, spacecraft maintenance organisations, etc.

5.2 Sovereignty principle and integration of space operations into ATM

The seamless amalgamation of space operations into air traffic management raises issues of territorial sovereignty, which is on the one hand applicable in the legal regime regulating the air domain, whereas on the other hand, it is expressly prohibited in the outer space arena. The concept of territorial sovereignty is well recognised under rules of general public international law, however, can the same be extended to a specific area of international law, like air and space law? To begin with, the 1945 Charter of United Nations, is based on the principle of sovereignty, in particular, the United Nations is based on the sovereign equality of all its members (UN Charter, 1945). Therefore, in terms of general international law, territorial sovereignty means the right to exercise therein, to the exclusion of any other state the functions of a sovereign (Island of Palmas Arbitration). Hence, territorial sovereignty has two aspects, namely internal and external (Kaczorowska, 2010:260). In addition to territorial sovereignty there is territory not subject to the sovereignty of any State(s) and which possesses the status of its own (trust territories), *Terra Nullius* (being legally susceptible to acquisition by States but not as yet placed under any territorial sovereignty), *Res Communis* consisting of “high seas and also outer space, which is not capable of being placed under the sovereignty of any State as it belongs to the Community of States” (Kaczorowska, 2010:260).

Under the *lex specialis* (law governing specific subject matter) governing the air and space domains, sovereignty is recognised differently. On the one hand, in terms of the Convention on International Civil Aviation of 1944, “every State has complete and exclusive sovereignty over the airspace above its territory, and the territory of a State includes the land areas and territorial waters adjacent thereto under the sovereignty, suzerainty, protection and mandate of such State” under Article 2 of the Chicago Convention. On the other hand, under the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of 1969, “outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.”

Now one of the challenges faced is delimitation of airspace and outer space, i.e. the boundary between airspace and outer space. In other words, where does airspace end and where does outer space begin? Or more precisely in legal terms, where is the transition from the legal regime of airspace to the legal regime of outer space? Further, for the purpose of integrating space operations into ATM, are spacecraft subject to the principle of territorial sovereignty as they transition through airspace during launch and re-entry? Integrating spacecraft into ATM at least implies that the same should be subjected to the principle of territorial sovereignty recognised by both general international law and specifically under the international air law regime. However, the provisions of the international air law, in particular the Chicago Convention are applicable only to civil aircraft as opposed to spacecraft. Added to the challenge of non-delimitation of airspace and outer space, none of the applicable legal instruments define spacecraft. Therefore, legal reform is needed before we can conclude that spacecraft are subject to the principle of territorial sovereignty as they transition through airspace as part of integrating them into ATM. On the other hand, the limitations imposed on the principle of sovereignty by Article II of the Outer Space Treaty only relate to claiming ownership on outer space through claims of sovereignty. Therefore, we can argue that the OST does not imply that spacecraft as they transition through airspace and beyond are not subject to the principle of sovereignty. Hence, this brings us back to the issue of jurisdiction, and according to Kaczorowska “the term jurisdiction has many meanings but in the present context it refers to the legal competence of a State to make, apply, and enforce rules with regard to persons, property and situations/events outside its territory and to the limits of that competence. Three types of jurisdiction can be distinguished, namely, a) jurisdiction to prescribe, ‘i.e. to make its [a State’s] law applicable to the activities, relations, or status of persons, or the interests of persons in things, whether by legislation, by executive act or order, by administrative rule or regulation, or by determination of a court’; b) jurisdiction to adjudicate under which a State has the authority ‘to subject persons or things to the process of its courts or administrative tribunals, whether in civil or criminal proceedings, whether or not the state is a party to the proceedings’; and c) jurisdiction to enforce under which a State is empowered to ‘induce or compel compliance or to punish noncompliance with its laws or regulations, whether through courts or by use of executive, administrative, police or other non-judicial action” (2010:309). In as far as spacecraft are concerned, the “State on whose registry an object launched into outer space is carried retains jurisdiction and control over such object, and over any personnel thereof, while it is in outer space or on a celestial body. And ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth" by virtue of Article VIII of the OST. Consequently, spacecraft will remain under the jurisdiction of the State of Registry, and eventually this will imply that spacecraft or space vehicles will be subjected to sovereignty even during the integration of the same into ATM.

The exercise of jurisdiction by the State over spacecraft integrated into ATM is based on the five principles of jurisdiction recognised under general international law, namely, the territoriality principle; the nationality principle; the protective principle; the passive personality principle; and the universality principle.

Firstly, the territoriality principle implies "that every State has jurisdiction over persons and events within its territory. In addition, a State is allowed to exercise subjective and objective territorial jurisdiction over acts that occur partly outside its territory. Under subjective territorial jurisdiction a State will have jurisdiction over conduct that commences within the State but is completed abroad. Objective territorial jurisdiction concerns conduct that commences outside the State and is completed within it" (Kaczorowska, 2010:309). Therefore, States will exercise subjective territorial jurisdiction over spacecraft or space vehicles when the launch or suborbital space flight takes place or commences within the territory of the State, which includes the airspace above it, and completes that flight abroad, either in the airspace of another State, on the high seas or into outer space. Whereas, objective territorial jurisdiction will be applied to space operations that commence elsewhere (outside the State) but are completed within its territory.

Secondly, under the nationality principle, a State may exercise its jurisdiction over its nationals when they commit offences abroad. It is universally accepted that nationals are required to comply with the domestic law of their State, even when they are outside the territory of that State. Likewise, the nationality principle also applies to: Corporations when they are incorporated in that State (the common law countries approach) or have their seat there (the civil law countries approach), but based on the judgments of the ICJ in *Barcelona Traction*, not on the ground that the majority of shareholders are nationals of that State; ships registered in accordance with that State's domestic law and sailing under its flag (ships sailing on the high seas under more than one flag are regarded as being without nationality); aircraft registered with that State (Kaczorowska, 2010:310). Commercial space operations require licensing and supervision from the State, therefore, States can exercise jurisdiction and control over spacecraft that bear their nationality as part of the international responsibility of States for national activities as provided in article VI of OST.

Thirdly, under the "protective principle a State may exercise jurisdiction over foreigners for acts committed outside its territory if such acts are directed against the security of the State or threaten the integrity of its governmental functions or its overriding interests" (Kaczorowska, 2010:310). Fourthly, "under the passive personality principle a State may exercise jurisdiction over foreigners for acts committed outside its territory if the victim of the act is a national. Finally, the exercise of State jurisdiction, under the universality principle, is based on the nature of the crime, not on any nexus between the forum State and the matter under consideration. It is normally relied upon in a criminal law context to prosecute international crimes such as piracy, slave trading, genocide, crimes against humanity, war crimes and torture" (Kaczorowska, 2010:310).

5.3 Liability issues arising from the amalgamation of space operations in ATM

The amalgamation of space and air traffic management raises concerns related to liability under air and space law respectively. Which liability regime will regulate damages caused by spacecraft during the integration of space traffic into ATM? In other words, in the event of damage caused by spacecraft to an aircraft, general public and property, or where an aircraft causes damage to a spacecraft, which liability regime will take precedence?

5.3.1 Liability under international air law

Issues of liability in international air law are regulated under the Warsaw and Montreal System of Conventions, the "Convention for the Unification of Certain Rules relating to International Carriage by Air", was signed in Warsaw on 12 October 1929 (Warsaw Convention, 1929) and it entered into force on 13 February 1933 and has been adopted by 152 States (ICAO, 2018). In terms of Article 1 of the Warsaw Convention, it applies to all international carriage of persons, luggage or goods performed by aircraft for reward. The Warsaw Convention 1929 provides a framework of a harmonised liability regime applicable to claims arising out of international air transport as opposed to domestic air transport.

This Convention (Warsaw Convention of 1929) provides limitation on the carrier's liability in respect of the amount that can be claimed for damages to both passengers and their luggage, and goods, the amount limited is as follows; 125 000 francs in case of passengers and 250 francs per kilogram in case of luggage or goods (Article 22 of Warsaw Convention). In terms of Articles 17 & 18 respectively, the liability of the carrier is based on fault i.e the carrier is presumed to be at fault unless the contrary is proved. Hence, the claimant does not need to give evidence to prove that the carrier was at fault. However, the Warsaw Convention was amended by the Hague Protocol of 1955. In Article XI (1) of the Hague Protocol of 1955 the amount of money that can be claimed from the carrier for passenger injury or death was increased from 125,000 to 250,000 gold francs. However, under Article XI (2) (a) the Hague Protocol 1955 no changes were made on the limitation of the carrier's liability in respect of cargo and registered baggage (which remains at 250 gold francs), or in respect of unregistered baggage (which remains at 5,000 gold francs per passenger).

The emergency of charter and other flights brought about the practice of code-share agreements and airline alliance. Therefore, in order to address the liability issues arising from code-share or airline alliance arrangements the Guadalajara Convention of 1961 was adopted which supplements either the Warsaw Convention 1929, or the Warsaw-Hague Convention 1955, depending on which one is applicable in a given case by extending liability issues to a third party or non-contracting carrier.

In 1971, the Guatemala City Protocol was adopted which was aimed at amending the Warsaw-Hague Convention 195, by increasing the monetary liability of a carrier in respect of passengers and their luggage, but the Protocol has never entered into force.

In addition, “the developments at the International Monetary Fund (IMF) led to the demonetisation of gold and prevented the member States from setting official prices to gold in relation to currency,” thus three additional protocols were drawn up in Montreal, known as the Montreal Additional Protocols Numbers 1, 2, and 3 of 1975 which changed the currency or legal tender from gold franc to the Special Drawing Right (SDR) established by the IMF.

Furthermore, the liability regime under the international air law was fragmented, thus this has led to adoption of the "Convention for the Unification of Certain Rules Relating to International Carriage by Air" (Montreal Convention, 1999) in Montreal on 28 May 1999. The Montreal

Convention 1999 entered into force on 4 November 2003 and has, to date, been adopted by 132 States (ICAO, 2018). In terms of Article 55 of The Montreal Convention 1999 it "shall prevail over any rules which apply to international carriage by air". The Montreal Convention has brought changes to the monetary cap imposed, introduced contributory negligence as a ground for exoneration, and most importantly strict liability.

Finally, in the context of liability, we also have the Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface signed at Rome on 7 October 1952 (Rome Convention, 1952), which imposes liability for damage caused by an aircraft to a third party, and the extent of liability is limited to a certain extent, for instance, liability for damage caused by aircraft weighing 1000 kg or less is 500 000 francs, or 500 000 francs plus 400 francs per kilogram over 1000 kgs for aircraft weighing more than 1000 kg but not exceeding 60 000kg, whereas liability for loss of life or personal injury shall not exceed 500 000 francs per person killed or injured. The Convention on Compensation for Damage Caused by Aircraft to Third Parties (Montreal Convention, 2009) replaced the monetary unit of account when referring to the monetary cap from the gold franc to the Special Drawing Right (SDR). However, the General Risk Convention is not yet in force because only 12 States have ratified it, as opposed to 35 required under article 23 (ICAO, 2018)

5.3.2 Liability under Space law

The foundation for liability for damages caused by spacecraft originates from the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), signed on 27 January 1967 and entered into force on 10 October 1967. In particular, the liability principle is fundamentally enshrined in the Outer Space Treaty, which provides that “Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies”.

However, the Outer Space Treaty does not elaborate on the extent and nature of liability, because the OST only laid down the guiding or fundamental principle of liability for damaged caused by space objects during the exploration and use of outer space. Therefore, a specific treaty has been adopted that regulate liability issues in outer space, namely, the Convention on International

Liability for Damage Caused by Space Objects (Liability Convention), signed on 29 March 1972 and entered into force on 1 September 1972. Neither the OST, nor the Liability Convention defined what constitutes outer space. Similarly, the two treaties are silent on the definition of a spacecraft or space vehicle. However, in both the OST and Liability Convention we find the constant use of the word “space object”, which is defined as including the component parts of a space object as well as its launch vehicle and parts thereof.

Under the Liability Convention, the extent of liability is twofold, namely, absolute liability and fault-based liability. In the latter case, “the launching state is absolutely liable to compensate for damage caused by its space objects on the surface of the Earth or to aircraft in flight. Whereas, if damage is caused elsewhere then the surface of Earth, the launching State is liable only if the damage caused is due to its fault or the fault of persons for whom it is responsible, in other words, the State will be vicariously liable for the acts or omissions of its nationals or agents.”

In addition, the Liability Convention recognizes the concept of joint and several liability including cases of joint launching and the right of recourse in joint launching. However, the mere fact that a State is absolutely liable doesn’t imply that there are no grounds of defence. For instance, a launching state can be exonerated from absolute liability if it can prove that the damage has resulted either partially or wholly from gross negligence or from act or omission done with intent to cause damage on the part of aggrieved State or of natural or juridical persons it represents. But the grounds of defence provided above will not be granted or upheld in instances where the damage results from activities conducted by the launching State which are contrary to international law, which includes the Charter of the United Nations and the OST.

5.4 Provision of Air Traffic Services in the Protozone and outer space

To begin with, Pelton & Jakhu (2017:307) argued that “the issue of space traffic management is further complicated by an increasing number of proposed new uses of the protozone, which is the portion of sovereign airspace above civil manned aviation (i.e., beyond 21 km), but still within Earth’s atmosphere (i.e., below 160 km)” as mentioned earlier. Hence, Pelton & Jakhu (2017:16) explained that “the protozone is a space in between airspace and true outer space that may be considered affirmatively to belong to neither of them. Since the delimitation of outer space has not yet taken place, this is the point where the two regimes seem to merge/ coincide. Because the legal regime of the protozone has not been clarified yet, the obligation/right of States to assert/claim sovereign rights (or extend their sovereignty) over this area is not clear, eventually being dubbed as an uncontrolled airspace."

But in this writer's view, the protozone is not literally unregulated, in fact there is a regulatory regime in as far as the protozone is concerned and this is derived from the language of Annex 11-Air Traffic Services, adopted under Article 54 (l) read with Article 37 of the Chicago Convention. In particular, according to Annex 11 "the Standards and Recommended Practices (SARPs) apply in those parts of the airspace under the jurisdiction of a Contracting State wherein air traffic services are provided and also wherever a Contracting State accepts the responsibility of providing air traffic services over the high seas or in airspace of undetermined sovereignty. A Contracting State accepting such responsibility may apply the SARPs in a manner consistent with that adopted for airspace under its jurisdiction." The relevant words are "**the airspace of undetermined sovereignty**", and this implies that the SARPs contained in Annex 11 can be extended to the protozone and even outer space because of the current challenge of delimitation between airspace and outer space. Therefore, a country that takes the responsibility to provide air traffic services into the protozone will equally apply the SARPs in a consistent manner. Consequently, the State that accepts the responsibility for providing air traffic services in the protozone or any other area with undetermined sovereignty can apply its national laws to regulate air traffic service in compliance with the SARPs.

To be precise, in terms of Standard 2.1.2 of Annex 11 "those portions of the airspace over the high seas or in airspace of undetermined sovereignty where air traffic services will be provided shall be determined on the basis of regional air navigation agreements. A Contracting State having accepted the responsibility to provide air traffic services in such portions of airspace shall thereafter arrange for the services to be established and provided in accordance with the provisions of this Annex." Therefore, any provision of air traffic services in the protozone or outer space as part of the integration of SATM should be governed by a regional air navigation agreement firstly. Secondly, the provision of air traffic services in the protozone or outer space during the integration of SATM should be governed by the national laws of the contracting State accepting the responsibility of providing air traffic services. If indeed the integration of SATM is to be realised from both technical or regulatory perspectives, then Annex 11 has laid down the foundation for the provision of air traffic services (alternatively to be called space traffic services in the future) in the protozone or outer space. The provisions of Annex 11 can be extended to the protozone and outer space because the former is uncontrolled, and the latter is not subject to sovereignty, therefore, both fulfil the requirement of undetermined sovereignty. Now, we need to understand that the provisions of Annex 11 are binding on Contracting States by virtue of Article 90 of the Chicago Convention, which provides that "….any such Annex or any amendment of an Annex shall become effective within three months after its submission to the contracting States or at the end of such longer period of time as the Council may prescribe, unless in the meantime a majority of the contracting States register their disapproval with the Council". On that basis, any country can invoke the provisions of Standard 2.1.2 of Annex 11 in order to provide air traffic services into the protozone or outer space. Whether or not the provision of air traffic services in the protozone and outer space is technically or financially feasible will not be discussed in this study. But the fact of the matter is, there is legal provision in place which allows for States to provide air traffic services in the protozone or outer space. In the long run, the assertion that the protozone is unregulated is premature, because it will be regulated once States invoke the provisions of Annex 11.

However, if a State were to provide air traffic services in the protozone or outer space as per the provisions of Annex 11, does that mean the said State is exercising sovereignty in the protozone or outer space? In this writer's view, the acceptance of the responsibility to provide air traffic services in the protozone or outer space, means that the State can exercise jurisdiction and control over the air traffic control units, aircraft in the protozone or spacecraft in outer space, based on the principles of nationality, protection and passive personality. General international law, international air law and international space law recognise the right of States to exercise jurisdiction and control over their nationals.

5.5 Consolidation or separation of legal regimes

In light of the legal issues discussed above, the integration of SATM calls for two options, namely, the consolidation of the two legal regimes, or to apply the legal rules separately to the two domains, in the long run maintaining the status quo. The latter option is more desirable, because of the nature of operations, and because the salient features of spacecraft vis-a-vis aircraft are totally different. Firstly, the two legal regimes deal with the issue of sovereignty differently, one recognises territorial sovereignty, whereas, the other does not recognise it.

Secondly, debates on liability issues whether the aircraft or spacecraft caused damage or injury will not make meaningful contributions for the integration of SATM, because liability issues for both are well regulated and there is legal certainty. Hence, liability issues should be kept separately or each individual liability regime should apply independently, depending on what caused the damage. In addition, the air law regime has imposed a limitation on the liability amount to be claimed by the victims, whereas the space law regime does not prescribe any limitation on the amount to be claimed for damages caused by space objects, and rather leaves the issue of liability limitation to the discretion of States.

However, there are some similarities between Annex 2 of the Chicago Convention and Article VIII of the OST, for example, Standard 2.1.1 of Annex 2 provides that "the rules of the air shall apply to aircraft bearing the nationality and registration marks of a Contracting State, wherever they may be, to the extent that they do not conflict with the rules published by the State having jurisdiction over the territory overflown. Thus, the State can continue to exercise jurisdiction and control over an aircraft registered and bearing its national marks irrespective of where the said aircraft will be found."

Similarly, Article VIII of the OST provides that "a State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth…".

In the final analysis, the legal regime to be applied to the integration of SATM should be hybrid, encompassing both the air and space legal regimes, until the issue of delimitation between airspace and outer space is sorted.

6. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the initiative of integrating space traffic into ATM was investigated with the purpose of reducing financial burdens and delays faced by civil aviation during the launch and re-entry of spacecraft as they transition through airspace. Furthermore, the need to regard space operators as the users of national airspace has called for finding ways to integrate their operations into ATM. Therefore, the U.S. and the EU have developed the concept of SWIM, which is part of the Single European Sky Air Traffic Management Research (SESAR) and the United States' Next Generation Air Transportation System (NextGen) to provide timely and reliable access to essential operational data of the spacecraft by all relevant stakeholders.

From an African perspective, the technology such as SWIM for the integration of space traffic into ATM is not readily available. Currently, Africa lacks the launch capability which is a missing link in space operations, as well as the integration of launch operations into the ATM. One of the reasons for the lack of launch capability in the continent is attributed to the fact that the existing or previous launch facilities where decommissioned. Moreover, Africa has not developed its own launch vehicle to give it competitive advantage over the other regions. However, prior to their decommissioning, the continent had space launch facilities off the coast of Kenya and in South Africa, as well as a launch facility for sounding rockets in Algeria. In addition, the 21st century evinced the development of feasibility studies to revive the launch capability in Africa, for example, the feasibility study on a Cameroonian Spaceport and *Uhuru* in Kenya.

Despite the infrastructural challenges, another aspect that needs to be addressed in order to integrate space operations into African ATM is a legal and regulatory framework to provide legal certainty and address some of the advance issues when integrating SATM. The African space regulatory framework and institutional arrangement is at its infancy, in the sense that the African Space Policy and Strategy, as well as the Statute Establishing the African Space Agency were adopted only recently. The former was adopted in 2017, whereas the latter was adopted in early 2018. On the one hand, the African Space Policy provides the continental goals for the region in space operations, whereas the African Space Strategy provides the course of action to be taken to implement the Policy goals. On the other hand, the Statute Establishing the African Space Agency merely establishes the regional space agency. Therefore, from the African perspective neither the ASPS and AfSA provides the necessary legal and regulatory framework for integrating SATM, hence, there is no legal regime from the continental point of view addressing the integration of SATM.

The way ATM is organised is also critical in the amalgamation of space and air traffic management. The organisation of ATM in Africa is fragmented (with the exception of ASECNA), in other words, there is no single entity which is in charge of airspace management in Africa. Consequently, the integration of SATM will face this main hurdle because each country will apply its rules differently from the others. Hence, the adoption of the Single African Air Transport Market will provide an opportunity for African Member States to liberalise or harmonise the rules applicable to the provision of air navigation services, which might have a positive impact on the integration of SATM in Africa if this were to be realised.

Furthermore, the space tourism market in Africa is either at its embryonic stage or non-existent due to the fact that the number of space tourists in the African continent to date is insignificant. Therefore, despite the designation of Johannesburg as a secondary passenger space hub in Africa, by the western countries, this will impose huge a financial and infrastructural burden on the continent. Therefore, from an African point of view, integrating suborbital flights into the regional ATM should be out of the question, because space tourism is not happening in the region at the moment. Rather, we should focus our efforts on strengthening the regional space program. In addition, as alluded to earlier, Africa lacks launch capability, however launch, re-entry and sounding rocket operations should also be considered during the amalgamation of SATM. Hence, sounding rocket programs in the region are still in their infancy because none of the main space actors have advanced sounding rocket programs in the region. Rather what we see are initiatives from the universities such as the University of Kwa-Zulu Natal in South Africa, which are aimed at addressing the needs of the African scientific community. But from the African perspective any form of launch, re-entry and sounding rocket operations will go through the traditional process of separating or restricting airspace during a launch or re-entry as opposed to allowing both aircraft and spacecraft to operate simultaneously in the airspace.

Furthermore, the integration of space and air traffic management has raised some legal issues. In particular, should the regulation of space traffic be left to the International Civil Aviation Organisation by way of extending its jurisdiction? If so, this implies that spacecraft will be required to file a flight plans. Moreover, International Standard and Recommended Practices dealing with the rules of the space, spacecraft worthiness and spacecraft maintenance organisations just to mention a few will need to be adopted in the form of new Annexes. In addition, sovereignty is dealt with differently under the aviation law regime and the space law regime, the former recognises territorial sovereignty, whereas the latter does not recognise sovereignty because outer space is not suspect to claims of sovereignty. Consequently, this will be a challenge unless the delimitation between airspace and outer space is defined and agreed internationally in order to determine instances in which the principle of sovereignty will apply or not. In as far as liability is concerned, both regimes address the issue of damages and limitation on liability differently. Another bone of contention is the provision of air traffic services in the protozone. There is a general perception that the protozone is unregulated, however if we invoke the provisions of Annex 11 of the Chicago Convention, a Contracting State can accept the responsibility for providing air traffic services over the high seas or in airspace of undetermined sovereignty and in doing so may apply the SARPs in a manner consistent with that adopted for airspace under its jurisdiction. Consequently, the protozone is not literally unregulated; Annex 11 has laid down the foundation for regulation. Therefore, since both aviation law and space law deal with liability and sovereignty concerns differently, and not to mention the lack of delineation of airspace and outer space, a hybrid form of law should be formulated so that these regimes can compliment each other. Thus, aerospace law should be flexible and not static in order to address the legal issues arising from the amalgamation of SATM.

In the final analysis, the following recommendations are made:

- The international community conduct further research before extending the jurisdiction of ICAO to space traffic management in order to address issues such as the rules of the space, spacecraft worthiness, spacecraft maintenance organisation, flight plans for spacecraft;
- The Contracting States to the Chicago Convention should invoke the provisions of Annex 11 – Standard 2.1.2 in order to provide air traffic services in the protozone;
- African States should revive the defunct launch facilities on the continent in order to establish launch capability in the region before we can talk about integrating space traffic into ATM;
- The fragmented organisation of ATM in the region should be harmonised; alternatively African countries could join the ASECNA;
- Africa should implement the Single African Air Market, which will harmonise the provisions of air navigation services in the region and eventually contribute to the integration of SATM in the region;
- More forecasting is required in order to analyse the viability of space tourism in Africa;

- The international community should clearly demarcate where the airspace ends and where outer space begins;
- Aviation law and space law should be kept flexible in order to complement each other during the integration of SATM.

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5. Convention for the Unification of Certain Rules Relating to International Carriage by Air" (hereinafter referred to as "Montreal Convention 1999")

6. Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface signed at Rome on 7 October 1952

7. Convention on International Liability for Damage Caused by Space Objects [Liability Convention, 1972).

8. Convention on International Civil Aviation of 1944

9. Decision on the Establishment of a Single African Air Transport Market, 30th Ordinary Session of the Assembly, 28- 29 January 2018, Addis Ababa, Ethiopia, Assembly/AU/Dec.665(XXX).

10. Radio Regulations.

11. Treaty Establishing the African Economic Community (Abuja Treaty, 1991).

12. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty [OST], 1967.

APPENDICES

APPENDIX 1- AFRICAN SPACE POLICY

AFRICAN UNION
الاتحاد الأفريقي

UNION AFRICAINE

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SECOND ORDINARY SESSION FOR THE SPECIALIZED TECHNICAL COMMITTEE MEETING ON EDUCATION, SCIENCE AND TECHNOLOGY (STC-EST)
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AFRICAN SPACE POLICY

TOWARDS SOCIAL, POLITICAL AND ECONOMIC INTEGRATION

TABLE OF CONTENTS

FOREWORD

Inadequate mechanisms for resource mobilisation, integrated ownership and leadership, and the lack of a significant industrial sector on the African continent, are a critical impediment to inclusive economic growth and social development. We need a paradigm shift in the way we think, plan and execute programmes. However, reform must be contextualised. A good starting point is the African Union vision of an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena.

The realisation of the AU Vision must be premised on self-reliance, regional integration, industrialisation and enhanced partnerships. A useful framework for this purpose is Agenda 2063, which has the following key drivers:

- Promoting science, technology and innovation.
- Investing in human capital development.
- Managing natural resources in a sustainable manner.
- Effective private and public sector development and the promotion of public/private partnerships.
- Innovative resource mobilisation.

In driving the AU Vision, in the context of the above drivers, it is imperative that any plans of action be undertaken in a sustainable manner, addressing the challenges of transforming Africa's outputs and trade, broadening and strengthening its weak infrastructural and human resource base, and significantly strengthening and modernising its science and technology capability. In this regard, the recently approved Science, Technology and Innovation Strategy for Africa (STISA 2024) is an important intervention for using science, technology and innovation to respond to the continent's priorities. It is recognised that space science and technology constitute an important enabler for the implementation of STISA 2024 and Agenda 2063.

It is clear that space science and technology is an important tool for ensuring the sustainable use of natural resources and the creation of high-technology industrial sectors. Furthermore, it makes a considerable contribution to the creation of enabling environments for addressing a wide range of pressing challenges, including the need to create jobs, reduce poverty, manage resources sustainably, and develop rural areas. A formal space sector will assist Africa to realise the vision of a peaceful, united, and prosperous continent.

It therefore gives me great pleasure to introduce the African Space Policy, which is the first in a set of instruments that will help us to formalise Africa's space programme. This policy provides the guiding principles for a sustainable and fully effective space programme that will serve the needs of the African continent.

Chair of the African Union
[Name and designation to be provided by the AU]

GLOSSARY

Data democracy	Provision of wider and easier access to geospatial data, software tools for manipulating data and capacity building, education and training
Data integrity	Maintaining and assuring the accuracy and consistency of data over its entire life cycle
Earth observations	Gathering of data and information about Earth's physical, chemical, meteorological and biological systems using in situ, aerial and space-borne platforms to monitor and assess the status of, and changes in, the natural and built environment
Global navigation satellite system	Constellations of Earth-orbiting satellites that broadcast their locations in space and time, of networks of ground control stations, and of receivers that calculate ground positions by triangulation
Navigation and positioning	The determination of position and direction
Remote sensing	Acquisition of information about an object or phenomenon without making physical contact with the object
Satellite communications	Artificial satellites placed in space for the purpose of telecommunications
Satellite systems	Artificial objects comprising computer-controlled systems that attend to many tasks, such as power generation, telemetry, altitude control and orbit control
Space exploration	Exploration and discovery of outer space using a variety of technologies

1. INTRODUCTION

As a developing continent, Africa has a significant socio-economic growth potential compared to developed regions of the world. However, this growth potential needs to be realised in a sustainable manner when drawing on the people and the abundant resources of the continent. The prime intention of realising this potential on the African continent should always be directed toward the improvement of the quality of life and the creation of wealth for all its citizens through knowledge generation and exploitation, and the development of congruent economic activities. Experiences in other parts of the world show that space science and technology provide an ideal platform to support the development of a knowledge-based economy. For example, in the United Kingdom, space services contribute to a number of societal benefits, and currently generate £7 billion annually, supporting over 70 000 jobs[2].

Space science and technology, and the many practical benefits that can be derived from their application, have played a significant role in international, regional and national economic and social development efforts. Space presents a unique opportunity for cooperation in using and sharing enabling infrastructure and data towards the proactive management of disease outbreaks, natural resources and the environment, responses to natural hazards and disasters, weather forecasting, climatechange mitigation and adaptation, agriculture and food security, peacekeeping missions and conflict resolution.

Used as tools for peace, satellites have been instrumental in resolving major differences among nations in the last century, and continue to contribute to the reduction of tensions that might lead to wars. Satellite-derived information also forms the backbone of the United Nations Security Council decisions on several conflicts around the world.

Space-derived products and services in Earth observation, satellite communication, and navigation and positioning are crucial for the economic development of the continent. While some of these products and services have helped to meet the social and economic needs of the continent, Africa does not have the full technical know-how to participate independently in these space-related activities. If Africa is to leapfrog into the technological advancements of the 21st century, the continent needs to develop an adequate number of indigenous space scientists, engineers and related professionals who will actively contribute to finding solutions to continental problems.

New applications for space science and technology are constantly being discovered, and spin-offs from space technologies have led to advancements in such diverse fields as medicine, materials science and computers. Exploiting these applications and technological advancements for Africa's social and economic development would bring many benefits. However, the high cost of participating in space activities has hindered many countries, particularly those on the African continent, from taking full advantage of the practical benefits that space science and technology offer.

Space is benefiting Africa and its people in a number of ways. Space applications are effective tools for monitoring and conducting assessments of the environment, managing the use of natural resources, providing early warnings of and managing natural disasters, providing education and health services in rural and remote areas, and connecting Africa with people around the world and

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[2] Extracted from Satellite and Space Services – Intellect Technology Association, UK, Intellect Publication, 2013

is also heavily employed in transportation services, which is another essential component of sustainable development in Africa. Access to transportation allows mobility, promotes commerce, and fosters education and health. In many African countries, transport access rates and network quality are low[3]. Space-related applications are widely used in agriculture, which remains an important economic sector in much of Africa. Space-based information systems play a significant role in risk reduction and disaster management on the African continent, which is heavily affected by natural and man-made disasters.

It is imperative that the benefits accruing from Africa's participation in continental-level space activities should promote the empowerment of women and the youth. If these two groups are healthy, educated and confident, they will contribute to the health and well-being of whole families, communities and nations. The promotion of the political, economic and social status of women and youth is a critical precursor for advancing the development of the African continent. Accordingly, priority attention will be given to ensuring gender equity and the involvement of young people in space-related activities. This imperative cuts across all policy principles and objectives advocated in this policy.

Africa has to build its capabilities in the following constellation programmes: Earth observation systems, navigation and positioning applications, and communications systems. In developing a continental space programme, Africa will not reinvent the wheel. There are some African countries that are in the process of developing their own space-related capabilities and programmes, and are building institutions to manage these programmes. These national efforts could be nurtured to contribute towards a continental programme, without diluting the focus of the national space programmes.

Currently, there are a number of fragmented initiatives that have a regional dimension. The pragmatic challenge is to bring all of these pockets of excellence together to create synergised, complementary programmes to foster collective actions towards Africa's development, and eventually enable the continent to be a global space player. There are only a few countries on the African continent that have established national space programmes. In many other African countries there is limited appreciation of the potential role and benefits of space in socio-economic development. There is thus a clear and urgent need to build awareness among the political, scientific and industrial leadership of African countries on the importance of introducing space education, which, in turn, will assist in the development of space programmes and related industries.

The use of space for development presents many opportunities that Africa cannot afford to ignore. The benefits of space science and technology need to be made available to all African countries, and there is a growing need for Africa to adopt a policy framework that guides the implementation of a continental space programme to enable the continent to develop and exploit its space resources in a more coordinated and systematic manner, with the overarching objective of contributing to Africa's socioeconomic development.

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[3] Extracted from Space Benefits for Africa, draft report of the United Nations Inter-Agency Meeting on Outer Space Activities, 2009

2. BENEFITS OF SPACE SCIENCE AND TECHNOLOGY

Humanity is facing major challenges in ensuring the adequate provision of basic necessities, such as food, shelter, a clean and healthy environment and proper education for the growing population. Africa can only hope to address these challenges through sustainable development – or yet further challenges will arise. Political, social and economic commitments will be effective only if there is a regional partnership for sustainable development and if the available resources are equitably allocated.

Earth observation/remote-sensing satellites use state-of-the-art instruments to gather information about the natural resources and the condition of Earth's interrelated land, sea, and atmospheric systems. Located in various orbits, these satellites use sensors that can "see" a broad area and report very fine details about these systems and their interactions to provide information on, among other things, weather, the terrain and the environment. Satellite sensors receive signals in various spectral bands to provide vital information that is invisible to the naked eye. For example, these instruments can detect an object's temperature and composition, the wind direction and speed, and environmental conditions, such as erosion, fires and pollution.

Satellite navigation uses satellites as reference points to calculate positions that are accurate to within a metre. With advanced techniques and augmentations, satellite navigation can provide measurements that are accurate to a centimetre. Navigation and positioning receivers have been miniaturised and are becoming economical, making the technology accessible to everyone. For example, Global Navigation Satellite System (GNSS) receivers are currently built into cars, boats, planes, construction equipment and even laptops. Navigation and positioning, such as provided by the COSPAS-SARSAT System[4], is the main element for search and rescue. With appropriate augmentation systems, navigation and positioning satellites will enable gate-to-gate navigation and all weather capabilities for suitably equipped aircraft. GNSS is also being used, together with Earth observation applications, for the surveillance and monitoring of illegal shipping activities, such as unlawful fishing, oil spills and the ensuing environmental damage.

Satellite communication is a key technology that could enable developing countries to participate in the build-up of global information infrastructure. Research indicates that satellite-based wireless systems are the most cost-effective way to develop or upgrade telecommunications networks in areas where user density is lower than 200 subscribers per square kilometre. Such wireless systems can be installed five to 10 times faster and at a 50% lower cost than landline networks. Technologies for education and training, in particular distance learning and multimedia technologies, may be instrumental in meeting the needs of African countries that have to train and integrate a large number of workers in widely dispersed and underserviced areas. Many African countries have to cope with large-scale disease outbreaks, and telemedicine may help to meet these challenges by improving the organisation and management of remote health care delivery. Satellite television broadcasting is another important application of space technology, and will help in improving access to information and to make the African voice heard worldwide. The Regional African Satellite Communications Organization (RASCOM) and other satellite systems with global or sub-regional coverage are currently providing a small proportion of these data services.

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[4] COSPAS-SARSAT is an international satellite-based search-and-rescue, distress-alert-detection, and information-distribution system, established by Canada, France, the United States, and the former Soviet Union in 1979. Five African Member States (Algeria, Madagascar, Nigeria, South Africa and Tunisia) currently provide location-related space-based search-and-rescue services, particularly for people and transportation systems in danger, e.g. air crashes, shipwrecks and automobile accidents.

3. POLICY GOALS

The policy drivers for an African space programme are expressed through high-level policy goals, which are as follows:

1. To create a well-coordinated and integrated African space programme that is responsive to the social, economic, political and environmental needs of the continent, as well as being globally competitive.

2. To develop a regulatory framework that supports an African space programme and ensures that Africa is a responsible and peaceful user of outer space.

4. POLICY OBJECTIVES AND PRINCIPLES

During the implementation of the African space programme, the objectives below will need to be adhered to and achieved.

4.1 Objective 1: Addressing user needs

To harness the potential benefits of space science and technology in addressing Africa's socio-economic opportunities and challenges. This will include the following:

(a) **To improve Africa's economy and the quality of life of its people.** Although Africa is one of the wealthiest continents in terms of natural resources and has a relatively high economic growth, it is, however, one of the poorest in terms of per capita income, with a relatively low level of gross domestic product. Space applications will be used to address the socio-economic developmental needs of Africa by providing critical information for evidence-based management of human habitats, ecosystems and natural resources.

(b) **To address the essential needs of the African market.** Space-derived services and products will be applied to address the essential information needs of the African market. The space resources of the few African nations with space programmes should be used to provide technological know-how, data access and information dissemination, as well as operational services and products to nations in Africa that do not have space science activities to address the essential needs.

(c) **To develop the requisite human resources for addressing user needs.** Africa has the challenge of sustaining its space efforts and promoting the use of space technology services among all African nations. Meeting these challenges requires significant human capital development. Accordingly, Africa should develop and adopt essential space education programmes and tools needed to build its capacity and thus maintain the widespread use of space technologies for its development.

(d) **To develop products and services using African capacities.** Spacederived services and products have to be developed primarily through African capacity and managed by Africans, so as to ensure sustained ownership of the space resources. This will ensure timely responses to our essential needs to improve sustainable development in Africa and thereby promote its economy, alleviate poverty and reduce risk hazards.

(e) **To establish communities of practice.** For each of the space application areas, it will be necessary to establish communities of practice for the sharing of experiences and best practices. These communities of practice will also assist in articulating the user needs and technical requirements for each of these areas. Such communities of practice will ensure the facilitation of space applications at grass-roots level, where it is most needed.

(f) **To develop and enhance early warning systems on the continent.** Africa is subjected to various extreme weather, climate, ecosystem and geological events such as tropical cyclones, heavy or lack of precipitation, heat waves, dust storms, red tides and tsunamis, which can lead to loss of life and property and hamper essential services. A combination of space applications will be used to improve, among other things, weather forecasts to develop a range of early warning systems (such as for monitoring flood, drought and health risks).

4.2 Objective 2: Accessing space services

To strengthen space mission technology on the continent in order to ensure optimal access to space-derived data, information services and products. This will include the following:

(a) **To use existing space infrastructure.** Existing infrastructure will be used as a foundation for the development of new capabilities to support the delivery of products and services, research and development (R&D) and human capacity building. Such capabilities will be established in a complementary manner to reduce unnecessary duplication, provide a full range of space-related services, and, at the same time, ensure equitable access to services across the continent. This will enhance Africa's technical development, technology transfer, management of intellectual property rights, and international and intra-continental cooperation.

(b) **To coherently develop, upgrade and operate cutting-edge African space infrastructure.** As Africa develops its indigenous space industrial capability, it needs to ensure the coherent development, upgrade and operation of cutting-edge African space infrastructure that ensures optimal coordination, utilisation and cost-effectiveness. A technology roadmap therefore needs to be produced for the development and strengthening of Africa's industrial capability, underpinned by an appropriate governance structure that draws on both national and regional capabilities in a seamless manner.

(c) **To promote capacity-building for the development of space services.** The development of capabilities and capacities in space science and technology through existing related institutions should be supported to create an enabling environment for knowledge generation and exploitation, which will ensure optimal access to space services on the continent. The Pan African University Space Science Institute should be strengthened to cater for the space-related human resource requirements on the continent.

(d) **To develop and increase our space asset base.** The current space asset base on the continent is limited and it is therefore necessary to develop and increase this asset base to ensure optimal accessibility and interoperability. Any extension of the current space asset base should be premised on ensuring complementarities and minimising duplication. This core capability can only be optimally achieved if a culture of collaboration rather than competition is nurtured, and, where possible, Africa needs to draw on the competencies of existing national space programmes on the continent.

(e) **To establish regional and sub-regional centres of space competencies.** In order to ensure that the continent is appropriately capacitated and serviced in space science and technology, it is important that the varied interests and challenges of all regions of the continent are catered for. This will be accomplished through the establishment of regional and sub-regional centres of space competencies that have a localised span of control and links up with the continental space agenda. Priority should be given to the revitalisation and rationalisation of existing institutions and the optimal shared use of these assets should be promoted.

(f) **To adopt data-sharing protocols.** In line with spatial data infrastructure frameworks, data-sharing protocols need to be developed, adopted and implemented to ensure equitable access and data democracy that is costeffective and acceptable to all Member States. The protocols will encourage Member States that have space assets to share data services and products with Member States that do not presently have such capacity, and ensure that data services and products are interoperable. This will encourage the commitment of all Member States to data gathering and sharing that facilitates the reuse of data in multiple applications.

4.3 Objective 3: Developing the regional market

To develop a sustainable and vibrant indigenous space industry that responds to the needs of the African continent. This will include the following:

(a) **To develop a globally competitive African space programme.** Appropriate interventions should be put in place to ensure the global competitiveness of African space technologies, products and services. In order to achieve this, a continental space programme that meets globally accepted space industry standards will be established. The African space industry should demonstrate its ability and successes by ensuring a space heritage that will serve to attract a share of the global space market.

(b) **To create an industrial capability.** As African countries embark on the development of an indigenous space capability, supported by robust R&D initiatives, it is imperative that the core focus remains a people-centred, market-based industrial capability. Rightsizing the market-based industrial capability with the relevant human expertise and skills will ensure a costeffective continental space programme. Free-market transactions should be encouraged on the African continent to effectively use the core industrial and human capability that is developed.

(c) **To promote public-private partnerships.** Public-private partnerships should be pursued in developing an innovative indigenous and sustainable space industry. These partnerships should draw on complementary capabilities and expertise through effective technology transfer and intellectual property management arrangements, at an intracontinental level. These partnerships should also be bolstered in collaborative R&D efforts that focus on the development of space services and products in response to market needs. In this regard, appropriate commercialisation frameworks and agreements should be put in place to service the regional and foreign export markets.

(d) **To promote R&D-led industrial development.** The technical capability and infrastructure should be used to support R&D and, in so doing, promote an innovative indigenous space industry. The space asset base is a precondition for a fully sustainable, efficient and effective industry, which also forms the basis for cutting-edge R&D that further promotes industrial development. Knowledge generated through R&D should also be translated, through support of an innovation value chain, into services and products for either commercial use or the public good.

(e) **To use indigenous space technologies, products and services.** Development of an African space market will take place both through the development of products and services for the public good and through the commercialisation of indigenous space technologies, products and services. In order to achieve this, it is imperative that we become intelligent users of space-acquired data, where such a use reflects and responds to the user needs of the continent. Hence, the development of technologies, products and services should respond to the African space market and be largely market-driven.

4.4 Objective 4: Adopting good governance and management

To adopt good corporate governance and best practices for the coordinated management of continental space activities. This will include the following:

(a) **To establish an organisational framework.** African Member States will have to establish an organisational framework that will coordinate all African space activities and assets to serve the goals of this policy in an efficient and cost-effective manner. African countries with space science and technology experience will help less experienced African countries to access space services and applications, develop their space capabilities and promote human resources in space science, space engineering and space applications. The organisational framework should follow a bottomup approach when working and providing appropriate levels of transparency and accountability that allow for equal opportunities among African Member States in accessing space products and services.

(b) **To support the African space programme financially.** Funding schemes for space activities should preserve the independence of the African space programme and thus guarantee the alignment of space activities with user needs. In order to develop and enhance its space capabilities, Africa should welcome collaboration and cooperation at an international level according to established rules and procedures. However, Africa should not rely on external donor funding to subsidise its space ambitions, since, the continent will be able to compete internationally (including in the African space market) only through its own committed space efforts. Financial support from African governments should therefore be the main funding source for space activities.

(c) **To maintain an efficient and sustainable African space programme.** Efficient monitoring and evaluation will be needed when the African space programme is implemented. Africa should therefore adopt key performance indicators for regular reviews to ensure best-fit capabilitybuilding initiatives, as well as up-to-date services and products to address user needs.

(d) **To promote knowledge sharing.** Knowledge sharing is one of the main strategic tools that will ensure the sustainability of an indigenous space sector. Knowledge should be disseminated over the African continent under a framework that promotes the development of an African space market. The same framework will have to control space-based intellectual property exchanges to ensure proper usage and avoid improper dissemination.

(e) **To conduct and maintain an awareness campaign.** Space science and technology and the associated applications that provide socio-economic benefits are not generally appreciated by all African Member States. Hence, there is a need for a significant awareness campaign that will educate and inform African decision makers, politicians and the public of the benefits of space science and technology. It is vitally important that
the awareness campaign promotes collective buy-in and ownership of an African space programme.

(f) **To monitor and evaluate space activities.** The organisational framework adopted should clearly state the monitoring and evaluation procedures that will ensure compliance and achievement of the broad objectives set for an African space agenda. The procedures should set and monitor proper return on investment, significant investment in people, best resource utilisation, proper funding approaches, and an efficient risk management and mitigation strategy.

4.5 Objective 5: Coordinating the African space arena

To maximise the benefit of, current and planned, space activities, and avoid or minimise the duplication of resources and efforts. This will include the following:

(a) **To commit funds to optimise and improve effectiveness.** Space technology has many benefits, but the high capital cost is a significant barrier to entry. Therefore, Africa's developed space nations should make their assets and space resources available and African Member States should commit funds to optimise and improve the required space operations and associated services and products.

(b) **To harmonise and standardise all infrastructure.** African Member States will need to harmonise and standardise all infrastructure to ensure the interoperability and seamless integration of space-based and groundbased segments. It is only through such harmonisation and standardisation that all African Member States will benefit optimally from space applications, as it provides a platform for the sharing of experiences, knowledge, and technology transfer.

(c) **To regulate space activities.** The African space programme will need to be regulated in order to guarantee that strategic objectives are attained. Conflicts of interest will need to be managed to best serve African interests. A regulatory environment will have to be established to allow industrial entities to access space technologies and to promote African commercial private sector participation in the space arena. This regulatory framework will need to be developed and implemented to ensure effective compliance with international treaties and conventions, with the necessary levels of transparency. The African space programme should be compliant with national, continental and broader international laws and regulations.

(d) **To secure the space environment for Africa's use.** A prime responsibility in relation to continental space activities is to ensure that wavelength spectrums, orbital locations, quiet areas for radio astronomy and other assets and rights, are secured for current and future continental and national space activities in Africa. Representation on international bodies such as the International Telecommunication Union will be important.

(e) **To preserve and maintain the long-term sustainability of outer space.** During the implementation phase of the continental-level space programme, it is prudent that we exercise commitment and act responsibly in preserving and maintaining the long-term sustainability of outer space. Transparency and confidence-building measures should be enforced to minimise the effects of space debris, thus preserving the space environment for future generations.

4.6 Objective 6: Promoting intra-Africa and other international cooperation

To promote the African-led space agenda through mutually beneficial partnerships. This will include the following:

(a) **To promote intra-continental partnerships.** Intra-continental partnerships should be promoted to leverage national strengths, activities and programmes. Such partnerships remain central to endeavours relating to human capital development, infrastructure development and the development of an indigenous space industry sector. These partnerships would also need to foster African regional collaboration, where the regional needs are primarily addressed.

(b) **To forge international partnerships.** Space science and technology is a global endeavour and therefore Africa should strive to be involved in international projects from which new knowledge can be acquired and exploited. In addition, where capability gaps exist, these should be accessed through international partnerships, either through technology know-how and transfer or the use of international facilities. Joint research, development and innovation initiatives should be a core focus of international partnerships.

(c) **To foster partnerships across all sectors.** Joint collaboration and synergy among academia, industry and government in all fields of space science and technology in Africa should be fostered in order to ensure comprehensive involvement by all sectors. All sectors will need to work in concert to deliver an efficient and effective African space programme. An enabling environment should be created to ensure a transfer of scarce skills and knowledge between different economic sectors.

(d) **To facilitate equitable partnerships.** A key driver to ensuring the development of an indigenous space capability and capacity will be the level of equity maintained by the African space programme. The principle of equal partnerships should be pursued in developing the African market, and also taken into account when leveraging strategic international partnerships to address technological gaps.

(e) **To ensure a reasonable and significant financial and/or social return.** All international partnerships should be based on mutually beneficial outcomes and should also ensure acceptable socio-economic returns for the African continent. Such strategic partnerships should also be premised on the notion of technical excellence that will help to further strengthen Africa's space asset base and capabilities.

(f) **To influence international agreements.** In our pursuit of an indigenous space capability, it is important that we observe all appropriate international treaties, conventions and agreements. Where such international agreements are considered for implementation, it is crucial that a consolidated African position be heard that best serves an indigenous African space programme.

5. CONCLUSION

This policy identifies the key policy goals that will drive the agenda for any formal space initiatives on the continent. The policy goals are supported by a set of objectives and principles that articulate important aspects that need to be addressed in developing and maintaining a viable and sustainable space programme. These policy objectives and principles form the core building blocks and the basis for all decisions and action of the African space programme.

This Policy is a guiding framework for the formalisation of an African space programme, and is complemented by the African Space Strategy and associated implementation plans, and governance structure.

APPENDIX 2 – AFRICAN SPACE STRATEGY

AFRICAN UNION
الاتحاد الأفريقي

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African Space Strategy

TOWARDS SOCIAL, POLITICAL AND ECONOMIC INTEGRATION

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Foreword

Africa is facing serious challenges in ensuring the adequate provision of basic necessities, such as food, shelter, a clean and healthy environment, and proper education, for its growing population. Howbeit, Africa is slowly awakening to the impact that space science and technology can have in addressing these challenges. If Africa is to aspire towards "An integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena", then bold steps must be taken towards building the indigenous capability and skills required for self-sufficiency and sustained progress. Many of the technological developments needed to address the multitude of socio-economic challenges holding this continent back cannot be outsourced. Africa has significant potential for growth compared to the developed world, and this potential should be used to create a prosperous future for all. The commitments and investments we make now will set future generations free if we show real political, economic and social ambition.

The convenient lifestyle and high standard of living in the developed world are supported by the instant access to information and space-based applications, such as instantaneous television coverage and navigation services. Even the provision of basic commodities such as food and energy resources is facilitated by spacebased technology. In addition, space-based solutions are necessary for the effective management of resources such as water, forests, marine ecosystems and the use of agriculture. Given this reality, it is inconceivable that so many of Africa's space-derived services and products are imported from abroad. This strategy has been developed to advance an indigenous space sector and provides direction for a formal African space programme. The strategy is aligned to Africa's aspirations and is premised upon the following core principles:

- Development of the services and products required to respond effectively to the socio-economic needs of the continent.
- Development of indigenous capacity to operate and maintain core space capabilities.
- Development of an industrial capability that is able to translate innovative ideas from research and development into the public and commercial sectors.
- Coordination of space activities across member states and regions to minimise duplication, but maintaining sufficient critical mass.
- Fostering international cooperation within Africa and with the rest of the world as a means of realising the full value proposition of the space sector.

The implementation of this strategy is important if we are to transform Africa's resource-based economies into the knowledge-based economies to which we aspire. The space sector is not only a high-end technology sector, but also provides the tools required for effective decision making in the management of our natural resources and providing essential communications links, especially to our rural communities. We are therefore at an important juncture, where decisions pertaining to formalising an African space programme will have long-term sustainable benefits, which will help this great continent realise its social and economic potential.

Chair of the African Union
[Name and designation to be provided by the AU]

1 Introduction

Africa has an opportunity to exploit its geographic position and natural resources to promote economic growth, improve the quality of life of its people, and contribute to scientific knowledge. At the same time, Africa is facing major challenges in food security, rapid urbanisation, the sustainable use of the environment, and the need to educate a growing population. Economic, political, environmental and social reforms can make an impact only if there is concerted effort to build indigenous skills and technological capabilities that provide effective solutions to these challenges. Active participation in the development of spacerelated applications and services will enable the continent to address these challenges, meet the objectives of the African Union (AU) Agenda 2063, make a significant contribution to the implementation of the Science, Technology and Innovation Strategy for Africa (STISA), take advantage of new opportunities offered by our geographic advantages, and become a global space player.

Societal needs	**Policy framework**	**Information and products**
Food security	Comprehensive Africa Agriculture Development Programme (CAADP)	Rainfall, yield, production, crops distribution, soil and land suitability
Water resources	African Water Vision 2025	Hydrography, aquifers, water bodies, quality, waste water
Marine and coastal zones	2050 Africa's Integrated Maritime Strategy (AIMS)	Coastal zone degradation and fishing potential
Environment	NEPAD Environment Action Plan	Ecosystems, biodiversity, vegetation and land cover
Weather and climate	Climate for Development in Africa (ClimDev Africa) and the Integrated African Strategy on Meteorology	Rainfall, temperature, wind, aerosol and climate trends and extremes
Security and disaster response	Africa Regional Strategy on Disaster Risk Reduction and the Convention on Cyber Security and Personal Data Protection	Risk and vulnerability data
Health planning	Africa Health Strategy	Disease vectors, environmental factors, population distribution
Governance and commerce	E-Government Strategy	Location-based mobile services, mapping of government information and communication technology (ICT) infrastructure
Infrastructure	Programme for Infrastructure Development in Africa (PIDA)	Spatial information on key infrastructure, such as transport infrastructure, energy sources and power systems, and distribution networks

Information and Communications	Reference Framework for Harmonization of Telecom/ICT Polices and Regulations in Africa	Telecommunications, Internet, television broadcasting, mobile communications, e-commerce, egovernment and e-learning
Innovation	Science, Technology and Innovation Strategy for Africa (STISA)	Food security, disease prevention, communications and security

Table 1: Policy frameworks that respond to key challenges on the African continent.

These challenges have long been recognised and many policy frameworks (see Table 1) have been developed to respond to them. However, the successful implementation of these frameworks is highly dependent on space technologies and applications. Access to sound, secure spatial data for decision-making will require an indigenous space programme and local capabilities. Africa cannot afford to remain a net importer of space technologies, as in the long term this will limit socio-economic development and negate the African Union vision of "An integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena".

Developing an adequate regional space capability has been hampered by the capital-intensive nature of the space sector and the lack of a formal governance structure to advance a collective effort. These difficulties must be overcome given the strategic value of a regional space sector in advancing the economic, political, environmental and social agenda of the continent. Space applications are needed to achieve over 90% of the strategic objectives across the eight departments of the African Union Commission (AUC). The use of space-based products and services to provide critical spatial information for decision-making purposes would have assisted progress in achieving the Millennium Development Goals, and will be valuable in our efforts to achieving the Sustainable Development Goals.

Africa represents 20% of the Earth's land surface area, more than the USA, India, China and Europe put together, yet these countries/region spent more than $50 billion on space activities in 2013, while Africa spent under $100 million (translating to less than 0.2% of the global space budget) in the same period. In terms of performance in the space sector, only one country on the African continent, namely South Africa, ranked in the top thirty countries globally in 2013 – ranking 23rd in terms of its space budget ($41 million) and 30th in terms of scientific production in satellite technology (accounting for 0.87% of global publications in the domain). These comparisons highlight significant underinvestment and suboptimal activities in the space sector, which limit Africa's potential in a fast-growing sector that can make a vital contribution to addressing the continent's challenges.

Hence, overcoming Africa's economic, political, environmental and social challenges is contingent upon a collective effort to formalise and sustain an indigenous space sector that is responsive to these challenges. Such efforts will promote commercial activities, ensure productivity and efficiency gains in diverse sectors, and facilitate cost avoidance measures that support the broader public good. This Strategy provides a strategic framework for developing and operationalising continental-level space initiatives. It clearly spells out the strategic goals and objectives of a long-term collective space vision for the continent. The Strategy hinges off the African Space Policy, which provides a guiding framework, for both the African public and private sectors, on the underlying principles to be adopted en route to a formal African space programme.

2 How space can address Africa's challenges

Space science and technology has contributed to sustainable development efforts and many other societal benefits, and will continue to do so. Depending on their mission, satellites have different orbits. Weather and communication satellites are placed in geostationary orbits (at an altitude of 36,000 km) above the equator, from which they have a constant view of the same hemisphere of the Earth by completing one orbit around the Earth every 24 hours. Other satellites are placed in low earth orbits, which complete one orbit around the Earth every 100 minutes on average. Because the Earth rotates in the plane of the orbit, such a satellite eventually covers the whole of Earth's surface. Such orbits are used for remote sensing, and navigation and positioning applications. Space technology contributes to meeting society's challenges by making it possible to:

- Communicate anywhere in the world;
- Observe any spot on Earth very accurately; and
- Locate a fixed or moving object anywhere on the surface of the globe.

Below is an overview of the socio-economic value and benefits of four key areas of space science and technology, namely, (i) Earth observation, (ii) navigation and positioning, (iii) satellite communications, and (iv) space science and astronomy.

2.1 *Earth observations*

In countries where the failure of a harvest may mean the difference between bounty and starvation, satellites have helped planners manage scarce resources and head off potential disasters before insects could wipe out an entire crop. For example, in agricultural regions near the fringes of the Sahara desert, scientists used satellite images to predict where locust swarms were breeding and were able to prevent the locusts from swarming, thus saving large areas of cropland.

Remote sensing data helps with the management of scarce resources by showing the best places to drill for water or oil. From space, one can easily see fires burning in the rain forests as trees are cleared for farms and roads. Remote sensing satellites have become a formidable tool against the destruction of the environment because they can systematically monitor large areas to assess the spread of pollution and other damage. Such monitoring capabilities are critical for the long-term sustainable use of the continent's scarce resources.

Remote sensing technology has helped map makers. With satellite imagery, they can produce maps in a fraction of the time it would take using laborious ground surveys. The use of synthetic aperture radar (SAR) or stereoscopic imaging provides topographic maps of the landscape. This capability enables city planners to keep up with urban sprawl and gives deployed troops the latest maps of unfamiliar terrain. The latter is vitally important for peacekeeping missions in Africa.

Because remote-sensing satellites cover the entire globe, they are important for the study of large-scale phenomena like ocean circulations, climate change, desertification and deforestation. Satellites make it possible to monitor environmental change caused by human activity and natural processes. Because data is collected in a consistent manner, satellites can reveal subtle changes that might otherwise remain undetected. For example, the well known Ozone Hole over Antarctica and the phenomena of atmospheric ozone depletion were discovered using satellites.

2.2 *Navigation and positioning applications*

The benefits from space infrastructure are becoming more evident in the management of long-term challenges faced by modern society. A case in point is the management of natural disasters like floods, for which navigation and positioning applications from space can provide data for the cycle of information for flood prevention and mitigation, pre-flood assessment, response (during the flood), recovery (after the flood) and accurate localised weather newscasts. In addition, timely satellite imagery and communication links in hard-to-reach places can help stem catastrophic economic and human losses.

Navigation and positioning is the main element of the international air traffic management system, providing worldwide navigation coverage to support all phases of flight. With appropriate augmentation systems, navigation and positioning satellites will enable gate-to-gate navigation and all-weather capabilities for suitably equipped aircraft. With more precise navigation tools and accurate landing systems, flying not only becomes safer, but also more efficient by reducing the delay, diversion and cancellation of flights. These interventions also assist in reducing carbon dioxide emissions in the aviation sector.

In general, mariners use the Global Positioning System (GPS) for navigation and positioning. GPS has also recently been applied to the surveillance of illegal shipping activities, and the monitoring of oil spills and the ensuing environmental damage. Used together with remote sensing imagery, accurate maps of the ocean colour, temperature, currents, salinity and wind direction have been produced. Such rich information is vital for protecting and extracting economic value from Africa's economic exclusion zones and providing a better understanding of climate change models.

Many automotive navigation and positioning applications fit in the category of intelligent transportation systems. Such systems are intended to improve traveller safety, improve travel efficiency by reducing congestion, save energy through the reduction of fuel requirements, and lessen the environmental impact of travel. Automobile navigation applications also help drivers make the most efficient routing decisions. This technology is also useful for fleet vehicle management and the tracking of valuable assets, especially across national borders.

2.3 *Satellite communication applications*

Telecommunication satellites offer telecommunication services at national, regional and international levels. Satellite communications in Africa cover a wide range of applications, from traditional telecommunication services to the use of satellite communications to address social issues on the continent. These services include the provision of telephony and data transmission for remote areas using small dishes and advanced very small aperture terminal (VSAT) techniques, thus providing for specific services to a target group. Satellite television services are widely used for point-to-point television transmissions, as well as for direct-tohome television reception and community television.

The Internet has a lower penetration rate in Africa than anywhere else in the world, and overall available bandwidth coverage indicates that Africa is significantly behind in bridging the "digital divide". According to 2011 estimates, only about 13.5% of the African population has Internet access. Consequently, while Africa holds 15.0% of the world's population, Africa only accounts for 6.2% of the world's Internet subscribers. Moreover, the proportion of Africans who have access to broadband connections are estimated to be 1% or lower of the global broadband subscribers. Satellite communication can help fill this gap and increase broadband access, particularly in landlocked countries and rural areas where cable penetration is non-existent or hard to reach.

Integrating information and communication technologies (ICTs) into governance processes can greatly enhance the delivery of public services to all African citizens. ICT integration will not only improve the performance of governance systems, it will also transform relationships among stakeholders, thereby influencing policymaking processes and regulatory frameworks. In the developing world, however, the potential of ICTs for effective governance remains largely unexplored and unexploited. Such services can be delivered through connectivity via satellite links in areas with minimal access to the Internet. Satellite connectivity through post offices could provide Internet access to communities that currently have no access.

Technologies for education and training, in particular distance education and multimedia, may be instrumental in meeting the needs of countries that have to train and integrate a large number of workers in widely dispersed and underequipped areas. This allows for a constant renewal of skills without being limited by information technology infrastructure. The use of VSAT terminals coupled with communication satellites makes education more accessible, especially in rural areas.

Many countries have to cope with large-scale disease outbreaks, and telemedicine may help to meet these challenges by improving the organisation and management of health care. Databases may be linked through networks to monitor the development of diseases, provide access to medical expertise through tele-consultation, and support remote medical assistance. In this regard, satellite communications can contribute to preparing and implementing health policies. Telemedicine is a cost-effective solution for providing affordable health care in rural areas.

National weather forecasts are based on a current satellite view of Earth. At a glance one can tell which parts of the country are clear or cloudy. When satellite maps are studied, it is easy to see the directional movement of clouds and storms. An untold number of lives are saved every year by tracking the paths of hurricanes and other deadly storms in this way. By providing farmers valuable climatic data and agricultural planners with information, this technology has improved food production and crop management. Weather satellites are integrated into the Global Telecommunications System, as an essential element of global, regional and national meteorological coverage.

2.4 *Space science and astronomy*

The runaway greenhouse effect on Venus, caused by an excess of carbon dioxide in its atmosphere, has led to an understanding of the dangers of carbon dioxide build-up on Earth and the resulting global climate change. In addition, finding aerosols in the atmosphere of Venus and observing how they interact with molecules has led to knowledge about what happens when aerosols are introduced into the Earth's atmosphere. By observing and analysing the dust storms on Mars, scientists have been able to develop models of what happens to a planet's climate if massive amounts of dust are blown into the atmosphere, as would happen on Earth from a volcano or from the impact of a large extraterrestrial object.

Astronomy is a science that reaches from planets to stars, and the universe as a whole, from the first light up to the present, 14 billion years later. It embraces all of physics in an endeavour to understand the origin and evolution of the universe and its constituents. Astronomy is a way of advancing science that, until recently, has been the preserve of the industrialised world.

Increasing public interest in astronomy and improving scientific education help to develop a more skilled workforce. These skills, both conceptual and practical, are easily transferred to applied fields such as meteorology, computer science and information technology.

Space geodesy uses astronomical techniques to determine the International Celestial Reference Frame, which is used to define the International Terrestrial Reference Frame. This terrestrial reference frame is used to provide precise geographic coordinates that are used in many practical applications, such as ocean and ice level measurements, continental drift, and the orbits of artificial satellites. These reference frames, for example the African Reference Frame currently being developed, are also used for modern map making and locationbased applications, such as the mapping of vegetation growth and the demarcation of borders. Space science and astronomy therefore provide basic knowledge that has practical use in daily location-based applications.

The Earth's magnetic field protects us from charged particles and electromagnetic radiation. However, variations in the Earth's magnetic field, due mainly to space weather-related perturbations, may have adverse effects on technical systems in space and on Earth. For example, electrical discharges inside satellites render these satellites inoperable, induced currents in long power and telecommunication lines result in power outages and communication blackouts, and disruptions in geomagnetic surveys negatively affect the commercial exploration of minerals and oil. Space weather monitoring provides an effective tool for mitigation against these disruptions to both space and ground-based operational systems.

3 Situational analysis

3.1 *SWOT analysis*

Strengths	**Weaknesses**
• Political support for the growth and development of high-technology sectors, including the space sector. • Significant government support for the establishment of national and regional space programmes. • A significant number of space professionals committed to leveraging space for socioeconomic development. • Intra-continental partnerships fostering space science collaboration. • Africa's strategic and geographic locations that are suitable for astronomical and space physics facilities. • Existing nodes of space expertise and insitu capabilities. • Established satellite assembly, integration and testing facilities. • Existing knowledge base and expertise in space engineering. • Experience in the manufacture and/or operation of small satellites. • Space physics capability that leverages its proximity to the Southern Ocean islands, the South Atlantic Anomaly, and the study of the Equatorial Electrojets. • Existing and established centres focused on the exploitation of geospatial data.	• Disparities in space expertise and capabilities across the continent. • Wide range of African challenges and societal needs. • African user needs are not well quantified and documented. • No governance structure to coordinate and manage continental-level space activities. • Inadequate core skills in several areas of space science. • Limited number of space initiatives, so skills are lost. • Duplication of efforts and suboptimal coordination. • Suboptimal investments in the space sector. • Disjointed continental efforts because there are no data management or data sharing policies. • Limited access to libraries, journals, and scientific and technical databases. • Uncoordinated regulatory environments on matters such as immigration, and crossborder taxes and tariffs. • Fragmented space activities, not aligned with continental goals. • Limited funding on a continental scale that is allocated for space science and technology.
Opportunities	**Threats**
• Large rural communities whose needs can be supported by space products and services. • A young population that could be trained to serve the requirements of an indigenous space sector. • Maturing public awareness and knowledge of the societal benefits of space applications. • Servicing the sustainable development needs of a population of 900 million people spread over 30.3 million km^2. • Natural resources that provide a significant socio-economic growth potential. • Contribution of space products and services to the challenges of global change. • Leveraging the skills and expertise of the African Diaspora. • International partnerships for the codevelopment of space platforms, products and services. • Potential to share infrastructure and other capacities among various African countries. • Learning from existing satellite programmes to strengthen continental capacity.	• Lack of a coordinated approach to international treaties and conventions. • Political will for continental-level space initiatives not universally shared, amid other pressing national socio-economic priorities. • Over-reliance on financial and technical support from outside the continent. • Political instability. • A weak financial base. • Brain drain of core skills. • Competition for radio frequencies allocated to Africa that could limit the future usage of such resources. • National space programmes not able to assimilate and adopt rapid technological advancements. • Lack of a focus on user needs and innovation in delivering relevant space services and products. • Limited collaboration and coordination owing to an exclusive focus on national priorities. • Lack of a coordinated continental approach to multilateral space agreements and guidelines.

3.2 *Developing the strengths and addressing the weaknesses*

- Establish a continental space programme that is able to promote programmes and projects that foster intra-continental partnerships by strengthening the existing nodes of space and in-situ capabilities; harmonising and standardising the suite of critical facilities and infrastructure; adopting appropriate data management and sharing policies to promote data access; and sharing the space experience to bolster the capacity of member states that wish to pursue national space programmes.
- Leverage Africa's strategic location to attract mega-science projects in astronomy and space physics studies that will enhance the scientific profile of the continent and support the building of critical scientific infrastructure, which will also be used to develop the cohort of skills and expertise required to service the various scientific disciplines.
- Establish human capacity development programmes that attract the young student population into a postgraduate pipeline that primarily serves the requirements of an indigenous space sector and the broader requirements for high-end skills in the changing socio-economic landscape.
- Develop an appropriate governance structure in the context of an African space agenda that is adequately resourced, both financially and in terms of human capacity, to ensure the effective implementation of the African space programme, from continental to sub-regional levels.
- Ensure a regulatory environment that is conducive to the promotion of the African space agenda, but yet is cognisant of the international obligations and responsibilities for ensuring the long-term sustainable use of outer space resources.
- Use the extensive roll-out of optical fibre networks across Africa to secure broadband capacity that will be needed to operate scientific equipment and infrastructure and to ensure seamless connection for data management and sharing of geospatial information.

3.3 *Responding to the opportunities and managing the threats*

- Establish communities of practice for the sharing of experience and best practices, as well as the definition of user needs.
- Develop a robust public awareness campaign that targets and solicits the support of all sectors of society for the manifold benefits of space science and technology and its potential to foster economic growth and address societal challenges, especially the needs of large rural communities.
- Link spatial market needs and the management of natural resources in a manner that takes into account global change and responses to climate change, and ensures the sustainable long-term socio-economic development and growth of the African continent.
- Use international partnerships and the African Diaspora to build local skills and expertise, and to support the co-development of space platforms, products and services, providing employment opportunities that will minimise the loss of skills and over-reliance on foreign support.
- Leverage existing space initiatives, experience, national programmes and the collective capacity of African countries to build and expand indigenous space capabilities and state-of-the-art infrastructure, and to minimise the duplication of effort.
- Pursue a common regulatory framework on the continent that will counter any limitations imposed on the African space agenda and ensure the long-term sustainable use of outer space resources.

- Adopt a collaborative plan for the allocation and use of wavelength frequencies so as to protect and maximise the use of the frequencies allocated for Africa, which will also maximise the opportunities for hosting and operating key space equipment and facilities.

4 Strategic focus

4.1 *Vision*

An African space programme that is user-focused, competitive, efficient and innovative.

4.2 *Goals*

1. Space-derived products and services used for decision-making and addressing economic, political, social and environmental challenges.
2. An indigenous space capability, in both the private and the public sectors, for a coordinated, effective and innovative African-led space programme.

4.3 *Strategic actions*

Strategic actions are intended to give direct effect to the strategic objectives and underlying principles identified in the African Space Policy. The strategic objectives are listed here for ease of reference.

1. **Addressing user needs** – harnessing the potential of space science and technology to address Africa's socio-economic opportunities and challenges.
2. **Accessing space services** – strengthening space mission technology on the continent to ensure optimal access to space-derived data, information services and products.
3. **Developing the regional and international market** – developing a sustainable and vibrant indigenous space industry that promotes and responds to the needs of the African continent.
4. **Adopting good governance and management** – adopting good corporate governance and best practices for the coordinated management of continental space activities.
5. **Coordinating the African space arena** – maximising the benefit of current and planned space activities, and avoiding or minimising the duplication of resources and efforts**.**
6. **Promoting international cooperation** – promoting an African-led space agenda through mutually beneficial partnerships.

4.3.1 Leveraging space-derived benefits

The primary marker of success in an African space programme would be how effectively it responds to user needs, its positive impact on the quality of life of people on the continent, and the improvement of Africa's global economic standing. The initiatives must resonate with and respond to Africa's needs in a relevant way that ensures a reasonable financial and/or social return. The initiatives must also be globally competitive in order to be positioned in the global space market, as there is a significant need in many developing countries outside of Africa for such initiatives.

Space-derived-benefits must transcend all spheres of government, from continental level right down to municipal level. In addition, benefits for women and the youth must be factored into the outcomes of these initiatives.

Indicators

- Number of communities of practice.
- Returns on investment.

4.3.2 Strengthening research, development and innovation

The development of indigenous capacity and capabilities will enable research, development and innovation in the African space sector. Given that space science and technology is still a fledgling sector on the continent, research, development and innovation should play a key part in industrial development. Hence, knowledge production (research and development) and the exploitation of this knowledge (innovation) will be central in ensuring a financial and/or social return. Knowledge production and transfer should, therefore, be a strategic focus for the diffusion of innovation.

Research, development and innovation initiatives should provide opportunities for the scientific and engineering space workforce to internalise the current intellectual capital and excel in the development of next-generation technology platforms, products and services.

Indicators

- Number of services and products using African capacities.
- Number of publications.
- Number of patents.
- Number of industrial designs.
- Number of space-related research centres.

4.3.3 Developing and using human capital

Human capital development is the bedrock of a viable and sustainable African space programme. The requisite skills and expertise will be harnessed through robust training and human capital development programmes. Africa should develop its human capital for space science, draw on the intellectual capital of its strategic partners, and make effective use of the African Diaspora. Optimal use should be made of the Pan African University Space Science Institute.

Investment in human capital development should ensure that higher education and training institutions, including the special purpose Pan African University Space Science Institute, are capacitated to produce the next cohort of scientists and engineers.

Indicators

- Number of graduates in space-related fields.
- Number of space-related experts employed in space-related professions.

4.3.4 Institutionalising a corporate governance structure

The contextualisation of a centralised governance framework must be embedded in current attempts to formalise African space initiatives. The current African Space Policy provides for principles to be adopted in a programme for African space initiatives, whereas this strategy articulates the space ambitions of the African continent. These instruments must be used as a frame of reference for all indigenous and developmental assistance programmes to ascertain their relevance and fitness for purpose in relation to the needs of the African continent. If this is not done, the result will be a proliferation of initiatives that will ultimately contradict the developmental focus and initiatives of the African continent.

A corporate governance structure, including rules and procedures should be adopted for the management of Africa's space programme and activities.

Indicators

- A formal corporate governance structure established.
- Achievement of strategic goals.

4.3.5 Adhering to regulatory requirements

To ensure Africa's commitment and response in preserving and maintaining the long-term sustainability of the outer space environment, African representatives should actively participate in and commit to relevant multilateral forums, especially where such participation is critical for securing outer space resources for Africa's use. A regulatory framework should be institutionalised to ensure that the outer space resources are used in a sustainable manner.

A regulatory framework should be institutionalised to support Africa's space activities so that the continent can compete effectively in the global space market, in line with international treaties, conventions and principles. It is also important to ensure effective African participation in international multilateral forums to secure Africa's access to space, including the assignment and use of orbital slots and the frequency spectrum, for both space infrastructure and ground-based infrastructure.

Indicators

- A regulatory framework that is supportive of space activities.
- Number of contributions made in multilateral forums crucial for the peaceful uses of outer space.
- Coordination of mechanisms instituted by AU member states.
- Number of orbital slots obtained for Africa.

4.3.6 Building critical infrastructure

Leveraging existing facilities and developing strong regional and continental coordination in respect of new facilities is crucial for success. Despite the strong public-sector-driven approach in Africa, public-private partnerships will be needed to promote the development of the continent's space infrastructure, particularly through the integration of space technology into other sectors of the economy.

An integrated network linking regional and continental institutions should be established to build appropriate infrastructure. It is also necessary to develop an integrated network and complementary data processing facilities dedicated to the provision of data to users for applications at continental, regional and local levels. African governments should be encouraged to create an enabling environment for the development of an indigenous space-related industry. The African Resource Management Constellation initiative should be leveraged, and the participation of other African countries encouraged.

Indicators

- Number of early warning systems on the continent.
- Number of space missions.
- Number of space receiving/transmitting/processing facilities.
- Number of networks created and percentage of coverage.

4.3.7 Fostering regional coordination and collaboration

Strong regional coordination is vital for the success of space activities on the continent, given resource constraints and the need to minimise duplication and maximise complementarity. Regional collaboration should be underpinned by the sharing of experiences and knowledge, both tangible and intangible, in order to strengthen the space base on the continent. Such collaboration will be in the form of bilateral and polylateral engagements.

Joint technology development, knowledge sharing, technology transfer and the management of intellectual property should be promoted and strengthened.

Indicators

- Number of collaborative intracontinental programmes.

4.3.8 Promoting strategic partnerships

Strategic partnerships will be pursued to address inherent gaps in skills and capabilities. Where possible such gaps should be addressed through continental partnerships, public-private partnerships and partnering across different economic sectors. International partnerships should be encouraged to address any remaining gaps and pursue new learning opportunities through active participation in global space initiatives.

All partnerships should be underpinned by complementary contributions and mutual benefits.

Indicators

- Number of public-private partnerships.
- Number of intra-Africa institutional partnerships.
- Number of international partnerships.

4.3.9 Funding and sustainability

It is crucial that adequate funding is committed to ensure the optimal development and long-term sustainability of space initiatives on the continent. It is critical that such funding be sourced from within the continent to allow for an African-led space programme under a consolidated space agenda. Space technology is costly and it is, therefore, essential to exploit existing space resources on the continent and to build on and optimise such resources. Monitoring and evaluation will be vital to ensure relevance and the long-term sustainability of space activities in Africa.

Funding should be secured from African governments, the private sector and philanthropists. A financial mechanism/instrument should be developed to generate the funds needed for the African space programme.

Indicators

- Level of long-term funding secured from the continent.
- Financial mechanism for the raising of funds developed.

5 Implementation guidelines

5.1 *Thematic focus areas*

The thematic focus areas, namely Earth observation, navigation and positioning, satellite communications, and space science and astronomy, provide the broad framework within which the appropriate technology platforms and programmes, both new and current, should evolve to address user needs. The use of space applications to facilitate responses to Africa's most pressing socio-economic challenges is shown in Table 2, which identifies the primary user requirements mapped against the thematic focus areas. The various deliverables for each of the thematic focus areas are set out in the table below.

User Needs	Earth Observation											Navigation and Positioning	Satellite Communications	Space Science and Astronomy
	Spatial Resolution								Temporal Resolution					
	< 50cm	50cm-1m	1m-2.5m	2.5m-5m	5m-10m	10m-20m	20m-30m	>30m	Daily	Seasonal	Annual			
Disasters	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Health					✓	✓				✓		✓	✓	
Energy				✓	✓	✓					✓	✓	✓	✓
Climate					✓	✓			✓			✓		✓
Water		✓	✓	✓	✓	✓	✓	✓		✓		✓		
Weather		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Ecosystems				✓	✓	✓	✓	✓		✓		✓		
Agriculture				✓	✓	✓	✓	✓	✓			✓	✓	
Biodiversity				✓	✓	✓	✓	✓			✓	✓		
Peace, Safety and Security	✓	✓	✓		✓			✓	✓			✓	✓	✓
Human Migration and Settlements		✓	✓	✓							✓	✓	✓	
Education and Human Resources				✓	✓	✓	✓	✓			✓	✓	✓	✓
Communications												✓	✓	✓
Trade and Industry			✓	✓	✓	✓	✓	✓		✓		✓	✓	
Transport		✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	
Infrastructure			✓	✓	✓	✓			✓			✓	✓	

Table 2: User needs mapped against the various space thematic areas

5.1.1 Earth observation

Specific interventions relating to Earth observation should include the following:

- Developing adequate skills and expertise in Earth observation applications and usage.
- Developing and improving Earth observation institutions in Africa.
- Fostering knowledge sharing among African experts, users and stakeholders.
- Developing space-based and in-situ infrastructure to help in responding to user needs and ensuring societal benefits.
- Developing Earth observation services and products using web-based and other appropriate technologies in order to meet user needs.
- Fostering stakeholder engagement to ensure the generation of the relevant services and products that maximise the benefits of Earth observation applications.
- Raising awareness among the public, users, and policy and decision makers.

5.1.2 Navigation and positioning

Specific interventions relating to navigation and positioning should include the following:

- Developing adequate skills and expertise in navigation and positioning applications and usage.
- Ensuring seamless integration into existing global navigation satellite services.
- Building on existing infrastructure such as the Agency for Aerial Navigation Safety in Africa and Madagascar, TRIGNET (a network of continuously operating global navigation satellite system base stations) and the African Geodetic Reference Frame.
- Promoting an African array study for seismic applications using seismic reference receivers.
- Developing an indigenous continental-level navigation augmentation system.
- Developing navigation and positioning application products and value added services to support user requirements.

5.1.3 Satellite communications

Specific interventions relating to satellite communications should include the following:

- Developing technologies for communication applications in rural and remote areas.
- Developing technologies for e-applications.
- Providing flexible extensions for the terrestrial network expansion and backup.
- Developing platforms to support disaster management.

5.1.4 Space science and astronomy

Specific interventions relating to space science and astronomy should include the following:

- Developing robust and coordinated programmes in the various disciplines of space science and astronomy, such as space physics, space geodesy, aeronomy, and optical, gamma and radio astronomy.
- Instituting capability-building programmes to ensure sustainable space science and astronomy initiatives.
- Developing and maintaining the appropriate infrastructure and facilities for a vibrant space science and astronomy programme.
- Ensuring value addition to Africa's economy through the spin-off development of human capital and technologies in space science and astronomy.

5.2 *Functional programmes*

Functional programmes are the means for achieving the key deliverables and are primarily embedded in the underlying technology platforms. They cover the key elements for a space mission (the collection of satellites, orbits, launch vehicles, operations networks, and all other elements that make a space mission possible). Functional programmes support each of the thematic areas. Scientific and engineering capacities are organised into four clusters, each of which carries out specific functions, as summarised below.

5.2.1 Space missions

The space missions include the following:

- Develop low Earth-orbiting satellites with multispectral and hyperspectral optical payloads and navigation augmentation payload systems.
- Develop low Earth-orbiting SAR satellites to complement optical satellite missions.
- Develop a geostationary orbiting communications satellite with multiple communication transponders and a navigation augmentation payload system.

- Develop independent space launch capabilities.
- Develop space science missions.

5.2.2 Enabling technologies

The requirements for the future satellite missions, as per the payload and subsystem technology options, are as follows:

- Develop a fully indigenous capability for the medium to high-resolution payloads and subsystems.
- Develop the SAR payload and subsystem requirements.
- Develop a geostationary communications satellite with indigenous African participation on the technology and engineering front.

5.2.3 Space mission operations

The requirements for the space mission operations are as follows:

- Develop assembly, integration and testing facilities and design centres to support the satellite manufacturing facilities.
- Develop ground segments for telemetry, tracking and command to support the satellite operations and the retrieval of data.
- Develop space segments, such as mission control centres for the effective housekeeping and health of the satellite.
- Secure appropriate orbital slots for use by indigenous satellites.

5.2.4 Space applications

In order to ensure that the services and products developed in response to user needs are relevant, the following should be achieved:

- Develop a data-sharing policy that ensures affordable and equitable access to spatial data and information.
- Develop timely access to the right data sets in accordance with user needs.
- Develop the provision of appropriate services and products that respond to all user needs.
- Develop robust processing capabilities to ensure that timely access to the requisite services and products are available to end users.
- Ensure that all levels of governments are able to access space and groundbased data through a centralised portal.
- Provide geospatial and scientific data for education, and research and development.
- Provide geospatial data for commercial exploitation at a minimal cost.

5.3 *Supporting programmes*

Supporting programmes are cross-cutting elements that are critical for the realisation of the thematic focus areas and the functional platforms. The supporting programmes comprise of the following:

- **Human capital** – The appropriate expertise and skills necessary for an African space programme will be an area that will receive priority attention, as without this all existing and envisaged programmes and infrastructure will be of limited value.
- **Space awareness** – For the African space programme to appear meaningful to the broader public it is necessary to create public awareness of the benefits of space technology and its manifold applications (products and services).

- **Infrastructure** – Appropriate infrastructure is the cornerstone of an effective space programme, enabling technology transfer and human capacity development initiatives.
- **International partnerships** – Strategic, mutually beneficial partnerships with foreign partners are necessary for tangible and intangible technology transfer and a viable and sustainable space programme.
- **Industrial participation and development** – Development of the continental space industry to participate in the various functional platforms is a key requirement for the sustainability of a space programme.

5.3.1 Human capital development and space awareness

The following are strategic interventions for human capital development and increasing space awareness:

- Developing coordinated, sustained and targeted public awareness and outreach programmes that:
  - Use classical and contemporary communication platforms; o Demystify space science through popularising space science with high-quality outreach material for all audiences;
  - Create opportunities to engage and attract the best minds towards careers in space science;
  - Promote gender parity in space science.
- Supporting space science teaching and research at universities through:
  - The Pan African University Space Science Institute, and linking existing training, research and innovation initiatives;
  - Enabling bi-directional linkages between continental research efforts and national programmes, and between continental research efforts and global research programmes; and
  - Establishing continental researcher and student exchange programmes;
  - Creating an enabling research and technical environment for graduates to be employed;
  - Enabling the development of networks and the dissemination of information using modern media platforms for drawing on the expertise of African Diaspora scientists and engineers;
  - Enabling easy access to open data and processing tools to facilitate capacity development in the use and dissemination of geospatial data and information; and
  - Introducing space science and astrophysics at undergraduate level with a focus on technical and academic requirements on the continent.
- Supporting space science and astronomy teaching and outreach at primary and secondary school level through: o Developing and introducing basic space science and astrophysics courses aimed at science students;
  - Developing in-service training programmes in space science and technology for teachers to promote the discipline at school level;
  - Developing specialised curricula, material and teaching aids to create awareness of space science and technology;
  - Enabling the development of a student portal for the development of virtual space science clubs, access to information, open data, processing tools and advice;
  - Drawing on the deep roots of Africa's indigenous civilisations to explore synergies with space science and astrophysics; and
  - Developing space museums, planetariums and observatories.

5.3.2 Infrastructure

The following are strategic interventions for infrastructure:

- Building centres of excellence and competence in the five regions in Africa, while expanding and upgrading existing facilities.
- Building new and expanding existing national assembly, integration and testing centres on the continent to service continental and regional needs.
- Building national and regional vicarious calibration facilities to support continental and global Earth observation efforts.
- Building national and regional data banks and high performance computing centres, and/or using existing ones.
- Leveraging continental and global partnerships to build a space-based industry for manufacturing space hardware and software, which could serve as a centre for hands-on training.
- Developing and expanding existing mission control systems to service continental and regional needs.
- Developing and strengthening research and development centres so that they are accessible to researchers across the entire continent.
- Expanding existing observing infrastructure and ensuring data accessibility for research (for example, GNSS receivers, magnetometers and ionosondes).
- Developing complementarities between space-based and in-situ infrastructure.

5.3.3 International partnerships

Specific strategic interventions relating to international partnerships include the following:

- Establishing a pan-African cooperation and partnership framework to enable coordination and networking for the effective implementation of continental-level activities.
- Establishing cooperation agreements with governmental, intergovernmental and regional organisations and agencies that focus on the exchange of experience with the objective of reducing the space divide and technological gaps.
- Encouraging African academia to establish a partnership arrangement with international academic networks concerned with space activities.
- Establishing a framework for the development of an African space industry operating in close cooperation with outside space industries with the purpose of establishing synergies between them.
- Integrating African space infrastructure and programmes as a part of the global space infrastructure with a clear recognition of African rights and access.

5.3.4 Industrial participation and development

The strategic interventions for industrial participation and development include the following:

- Developing an industrial framework to unlock industrial opportunities and to enhance industrial development, strengthen manufacturing capabilities and provide support for industry and related services.
- Building an industrial base to support Africa's requirements for space technologies by ensuring maximum participation of the private sector in public sector space projects.
- Establishing a supportive continental regulatory framework to ensure compliance with the United Nations regulatory provisions and applicable international obligations when competing in international space markets.
- Maximising the benefits of innovation and technology transfer into and out of the space sector, thus promoting the broader industrial development on the African continent.

- Creating an enabling environment for small and medium enterprises by supporting their effective participation in the development of the space industry and market.

5.4 *Projected outcomes*

The projected outcomes over the next decade should ensure a long-term sustainable and viable continental space programme that remains aligned with user needs. To meet user needs, a concerted effort should be made to obtain adequate human and financial resources, establish strategic partnerships in Africa and beyond, and set up appropriate technology platforms. While this is being done, the global relevance and positioning of the continental space programme should be kept in mind. The response within the implementation framework being developed for this strategy can be divided into immediate outcomes (within a year), intermediate outcomes (within five years) and long-term outcomes over (10 years) that provide for rolling milestones, which are expressed below.

Projected one-year outcomes

- Establishment of the governance elements needed for a sustainable space programme, including regional centres of excellence.
- Approval and implementation of an intercontinental and international partnership plan.
- Approval and implementation of a human capital and infrastructure development plan.
- On-going research, development and technology transfer programmes that will contribute to building the foundations for a continental space programme.

Projected five-year outcomes

- An established continental space programme.
- Appropriate technology platforms in place to support the various components of a continental space programme.
- Advances in human capital development that support the continental space programme.
- Strategic partnerships, both intercontinental and international, through projects that promote research and technology development.
- Operational and on-going developments of space application services and products for the broader public good.
- Well-defined funding mechanisms for sustainability.

Projected 10-year outcomes

- A continental space programme that is globally positioned and ranked in the world's top 10.
- Independent Earth observation high-resolution satellite data available for all of Africa from a constellation of satellites designed and manufactured in Africa.
- Appropriate services and products relating to space applications.
- Indigenous space capacity, in terms of both technology platforms and human capital.
- Spin-off enterprises emanating from space activities and programmes.
- Strategic partnerships, both within and outside Africa, that are translated into viable space missions, applications, products and services.

6 Conclusion

The African Space Strategy hinges on the African Space Policy, which provides the main tenets and guiding principles for the establishment of a formal African space programme. This strategy is an expression of the key intent and programmes of action that are needed to give effect to the identified goals and strategic objectives, so that maximum impact can be made in leveraging the benefits of space science and technology as a tool for informing solutions to our political, economic, social and environmental challenges. Appropriate governance structures will be mandated to ensure that this strategy is implemented to ensure the effective development and coordination of an African space programme, which will draw on the capacities of member states and regional programmes.

Furthermore, this strategy is intended to support the Science, Technology Innovation Strategy for Africa 2024 and other relevant continental Strategies, and thus contribute to the achievement of Agenda 2063.

APPENDIX 3 – DRAFT STATUTE OF THE AFRICAN SPACE AGENCY

AFRICAN UNION
الاتحاد الأفريقي

UNION AFRICAINE

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SECOND ORDINARY SESSION FOR
THE SPECIALIZED TECHNICAL COMMITTEE ON
EDUCATION, SCIENCE AND TECHNOLOGY (STC-EST)
21th - 24th OCTOBER 2017, CAIRO, EGYPT

HRST/STC-EST/Exp/14(II)
Original: English

DRAFT STATUTE OF THE AFRICAN SPACE AGENCY

(Draft Version 05)

11 OCTOBER 2017

PREAMBLE

WE, MEMBER STATES OF THE AFRICAN UNION:

GUIDED by the objectives and principles enshrined in the Constitutive Act of the African Union that underscores the importance of science, technology and innovation as tools and enablers for socio-economic transformation of the continent;

RECALLING Decisions EX.CL/Dec.744(XXII), EX.CL/Dec.746(XXII) and EX.CL/Dec.739(XXII) and recommendations from sectorial Ministerial Conferences on the growing need for Africa to develop a well-structured Space Policy and Strategy that could guide the continent to implement a globally competitive Outer-Space Programme that would enable Member States to harness space resources in a more coordinated and systematic manner, address the continent's challenges, and develop an African space market and industry;

FURTHER RECALLING Decision Assembly/AU/Dec.589(XXVI) adopting the Africa Space Policy and Strategy with the view to formalizing an AU Agenda 2063 Outer-Space Flagship Programme for developing local capacities in Earth Observation, Satellite Communication, Navigation and Positioning, Space Science and Astronomy;

RECOGNISING the potential of space science, technology and innovation in Africa's development and the realization of the aspirations of our long term vision, AU Agenda 2063 through jointly addressing common development challenges such as natural hazards and disasters, climate-change mitigation and adaptation, agriculture and food insecurity, conflicts, disease outbreaks, provision of education and health services in rural and remote areas and connecting our citizens; and proactively managing, natural resources and the environment among others as outlined in the African Space Policy and Strategy.

UNDERSCORING the need for appropriate institutional arrangements for the effective governance, promotion and coordination of space activities on the continent in order to realize maximum benefits;

HEREBY AGREE AS FOLLOWS:

Article 1

Definitions

In this Statute:

“Agency” means the African Space Agency hereby established;

“Assembly” means Assembly of Heads of States and Government of the African Union**;**

“AU” means the African Union established by the Constitutive Act of the African Union adopted by the Heads of States and Government of the Organization of African Unity (OAU) in Lomé, Togo, in July 2000;

“Council” refers to the African Space Council established by this Statute

“Executive Council” means the Executive Council of the African Union;

“Host Country” means the country that hosts the headquarters or an activity centre of the Agency;

“HSGC-EST” refers to the Committee of 10 Heads of State and Government Championing the cause of Education, Science and Technology.

“**Member States**” means Member States of the African Union;

“RECs” means Regional Economic Communities;

“Statute” means this Statute of the African Space Agency;

“STC” means Specialized Technical Committee of the African Union;

“STC-EST” means the African Union Specialized Technical Committee on Education, Science and Technology.

“Policy” means the African Space Policy

Article 2

Establishment of the African Space Agency

The African Space Agency (AfSA) is hereby established as an Organ of the African Union, dedicated to promoting, advising and coordinating the development and utilization of space science and technology in Africa and associated regulations for the benefit of Africa and the world and forging intra-African and international cooperation.

Article 3

Legal Personality

1. For the fulfillment of its Objectives, the Agency shall possess legal personality and capacity to:

   a. Enter into agreements;
   b. Acquire and dispose of moveable and immovable property
   c. Institute legal proceedings.

Article 4

Objectives

The main objectives of the African Space Agency are to promote and coordinate the implementation the African Space Policy and Strategy and to conduct activities that exploit space technologies and applications for sustainable development and improvement of the welfare of African citizens. In particular, the Agency shall:

a. Harness the potential benefits of space science, technology, innovation and applications in addressing Africa's socio-economic opportunities and challenges;
b. Strengthen space missions on the continent in order to ensure optimal access to space-derived data, information, services and products;
c. Develop a sustainable and vibrant indigenous space market and industry that promotes and responds to the needs of the African continent;
d. Adopt good corporate governance and best practices for the coordinated management of continental space activities;

e. Maximize the benefits of current and planned space activities, and avoid or minimize duplication of resources and efforts;

f. Engage with its users through the establishment of Communities of Practice for each of the identified user requirements; and

g. Promote an African-led space agenda through mutually beneficial partnerships.

Article 5

Functions of the Agency

1. The primary function of the Agency is to Implement the African Space Policy and Strategy adopted by the AU Assembly vide the Decision Assembly/AU/Dec.589(XXVI)

In particular, the Agency shall:

a. Promote and coordinate the implementation of programmes and activities approved by the African Space Council.

b. Address user needs to ensure that space programmes will play a critical role in improving Africa's economy and the quality of life of its peoples

c. Support Member States and RECs in building their space programs and coordinate space efforts across the continent

d. Enhance and facilitate access to space resources and services in an effort to leverage space-derived benefits to the whole continent

e. Support Member States and RECs in building critical infrastructure and coherently develop, upgrade and operate cutting-edge African space infrastructure

f. Coordinate development of a critical mass of African capacities in space science, technology and innovation through appropriate education and training programmes

g. Foster regional coordination and collaboration

h. Promote strategic intra-continental and international partnerships

i. Strengthen research, development and innovation in space science and technology.

j. Coordinate and promote Africa participation in international efforts for the peaceful use of space science and technology for the welfare of humanity.

k. Raise awareness of the benefits of space programmes for Africa;

l. Engage Member States in space-related activities and research in Africa with the aim of fostering cooperation and avoiding duplication of efforts;

m. Take maximum advantage of national activities conducted by Member States and facilitate coordination of the activities of Member States;

n. Operate on the basis of international cooperation.

2. The African Space Agency with other national and international institutions will coordinate a continent wide regulatory framework for space activities on the continent.

3. The African Space Agency will work directly with the national space agencies when interfacing with the Member States and in the co-management of space activities for the continent.

4. A common African position for multilateral engagements should be driven by the African Space Agency.

Article 6

Membership

Membership in the Agency shall be open to all Member States of the African Union.

Article 7

Governance and Management of the African Space Agency

1. The governance and management structure of the Agency shall comprise of:
   a. The Assembly
   b. HGSC-EST
   c. The Executive Council
   d. The African Union Specialised Technical Committee on Education, Science and Technology.
   e. The African Space Council
   f. Advisory committee; and
   g. The Secretariat;
2. HSGC-EST shall provide political guidance and shall serve as champions for space science and technology at the continental level.

3. The STC-EST shall provide overall strategic guidance and orientation to the Agency through the Space Council and

4. The Agency shall submit reports on its annual work to the STC-EST for consideration.

Article 8

Composition of the African Space Council

Qualifications and Election of Council Members

1- The African Space Council shall be composed of high level of Experts elected by the Assembly from among persons of high moral character, who possess the qualifications required in their respective countries for appointment to the highest institution of Space and Astronomy, Earth Observation, Satellite Communication and Navigation or related areas, The Candidates should be citizens of the AU Member States .

2- The Assembly shall elect the President and Vice President of the African Space Agency Council from the ten (10) elected Members referred in Article 8-biss-A sub-paragraph 1-a bellow.

3- The Assembly shall ensure merit and competence in the election of the Council members.

4- The Chairperson of the Commission, shall communicate the list of candidates to Member States, at least thirty (60) days before the Ordinary Session of the Assembly or of the Executive Council during which the elections shall take place.

Article 8-A
Composition of the Council

1- The Council shall be constituted as follows: a- Ten (10) elected persons from Member States, two (2) per each region

b- . The following Representatives of the Commission:

i. Commissioner for Human Resources, Science and Technology (HRST) or his/her representative; ii. Commissioner of Infrastructure and Energy or his/her representative iii. Commissioner of Peace and Security or his/her representative iv Commissioner of Rural

Economy and Agriculture or his/her representative v. two (2) Representatives of the Bureau of the Chairperson (Director of Communications and the Legal Counsel of the African Union).

2- The Chairpersons of the following STCs shall be invited to attend the sessions of the STC on Education, since and Technology where the Council report will be considered :

   i. Communication and ICT
   ii. Defense, Safety and Security
   iii. Agriculture Rural Development ,Water and Environment
   iv. Transport,Transnational and Interregional Infrastructures , Energy and Tourism

3- The representatives of the Commission shall be Members of the Council with no voting rights.

4- The Chairperson of the Advisory Committee shall be invited to attend the African Space Council meetings.

5- The Director General of AfSA shall serve as the Secretary of the Council.

Article 8-B Term of Office

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1. The Ten (10) Members of the Council representing the five (5) African Union regions shall be elected for the period four (4) years term renewable once.
2. A new Member elected to replace another whose term of office has not expired shall complete the term of office of his or her predecessor and shall be from the same region.
3. All the Council Members, except the President and the Vice President, shall perform their functions on a part-time basis.
4. The Term of the president and Vice president of the Council shall be determined in the Rules of procedures of the Council, which shall be adopted by the Executive council.

Article 9

Functions of the African Space Council

1. The African Space Council shall, through the Advisory Committee of the African Space Council, have authority to oversight the Agency, issue directives, and review and approve strategic plans, work plans, budgets, regulations, policies and guidelines to govern the administrative activities and operations of the Agency for adoption by the relevant policy organs of the AU.
2. The African Space Council shall report to the Assembly through the Heads of State and Government Orientation Committee (HSGOC)
3. The African Space Council shall meet once every year, after the meeting of the Advisory Committee of the African Space Council and prior to the annual meeting of the Heads of State and Government Orientation Committee (HSGOC)

Article 10

Meetings of the African Space Council

1. The Council shall elaborate its own Rules of Procedure and shall be adopted by the Executive Council in accordance of the AU Rules..
2. The Council shall meet once every year in ordinary session. It may meet in extraordinary session at the request of Chairperson in consultation with the Agency. The extraordinary session shall be held at the request of:
    a. AU Policy Organs
    b. The Chairperson of the STS-EST, its Bureau or as decided by the STC-EST
    c. The President of the council
    d. Two-thirds majority of the total membership of the African Space Council
3. The quorum for the meeting shall be a simple majority of the total membership of the Council.
4. Decisions of the Council shall be adopted by a two thirds majority of the members present and voting.
5. Except as otherwise determined by the Council, all meetings of the Council shall be held at the headquarters of the Agency.
6. The Council may invite, as Observer, any person or Institution to attend its sessions .

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Article 11

Composition of the Advisory Committee

1. The Advisory Committee shall comprise the following:
    a. Five (5) Director Generals of the National Space Agencies of Member States, one (1) from each of the five (5) geographic regions of the African Union based on the

principle of rotation and geographic representation, the selection shall be done at each region and the nominees shall be communicated to the Commission.

- b. One representative of the eight (8) RECs recognized by the African Union, for a tern of two years on a rotational basis. The Commission shall lead that process for the selection of RECs. .
- c. Two (2) experts from the academia admitted through the African Academy of Sciences and whose membership shall be drawn form the five (5) regions of the African Union, based on the principle of rotation and geographic representation.
- d. Four (4) Chief Executive Officers of four (4) African private sector entities, each representing one of the four space sectors, namely Earth Observation, Satellite Communication, Navigation, and Space & Astronomy

2. The Director General of AfSA shall serve as a secretary of the Advisory Committee.

3. The Chairperson of the Advisory committee shall be elected among the five(5) Directors Generals of the National Space Agencies of Member states, on rotational bases and geographical distribution for a two (2) years term .

4. The term of office of the Members of the advisory Committee shall be three (3) years term renewable once.

Article 12

Functions of the Advisory Committee

1. The Advisory Committee shall review and recommend for approval by the African Space Council strategic plans, annual work plans, budgets, external audit reports, regulations, policies and guidelines to govern the administrative activities and operations of the Agency.
2. The Advisory Committee shall report to the African Space Council
3. The Advisory Committee shall meet once every year, prior to the annual meeting of the African Space Council

Article 13

Meetings of the Advisory Committee

1. The Advisory Committee shall elaborate its Rules of Procedure and submit the same to the African Space Council for adoption .
2. The Advisory Committee shall meet once every year in ordinary session and as may be called upon to advise extraordinary sessions of the African Space Council

3. The quorum for the meeting shall be a simple majority of the total membership of the Committee .
4. Except as otherwise determined by the African Space Council, all meetings of the Advisory Committee shall be held at the headquarters of the Agency.
5. The Director General of the African Space Agency shall present the report of the Advisory Committee to the African Space Council

Article 14

The Chief Executive Officer of the Agency

1. The Director General shall be The Chief Executive Officer and legal representative of the Agency .
2. The Director General shall be assisted by the necessary staff for the smooth running of the Agency
3. The Director General shall be appointed by the African Space Council for a term of four (4) years renewable once.
4. The powers and duties of the Director General shall be as set out in the Rules of Procedures and Regulation.

Article 15

Privileges and Immunities

The African Space Agency and its staff shall enjoy within the territory of all AU Member States in particular the Host Country, the status, privileges and immunities provided in the 1965 General Convention on the Privileges and Immunities of the Organization of African Unity and other relevant international agreements.

Article 16

Financing of the African Space Agency

1. The budget of the Agency shall be borne by the African Union and shall be within the budget of the Union.
2. The budget calendar of the Agency shall be that of the African Union.

3. The Agency shall prepare and submit its budget to the Policy Organs of the Union for approval and inclusion in the Union's budget.

Article 17

Seat

1. The Headquarters of the Agency shall be determined by the Assembly of the Union in accordance with the AU criteria adopted in 2005.

2. The AUC shall enter into a host agreement with the government of the host country in which the Agency Headquarters will be situated for the purposes of the efficient operation.

3. The Council shall hold its meetings at the Headquarters of the Agency.
4. Any Member State may offer to host the Council meeting in lieu of the headquarter country. In the event that a Member State offers to host the meeting, the Member State shall be responsible for all extra expenses as resulting from holding the meeting outside the Agency Headquarters.

5. A Member State offering to host the Council meeting shall not be under sanctions and shall be required to meet pre-determined criteria for hosting of such session.

6. Where two (2) or more Member States offer to host the meeting, the Council shall decide on the venue in consultation with the Secretariat.

Article 18

Working Languages

The working languages of the Agency shall be those of the African Union.

Article 19

Amendments

1. The Statute may be amended by the Assembly upon the recommendation of:
   i. The Executive Council;
   ii. The STC-EST ; or
   iii. The African Space Council.

2. The amendments shall come into effect upon adoption by the Assembly.

Article 20

Entry into Force

This Statute shall enter into force upon its adoption by the Assembly.

ADOPTED BY THE … SESSION OF THE ASSEMBLY, HELD IN …

DATE