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Space Research in Africa: Challenges and Opportunities

Ligate, Obed Hugh
University of North America
8618 Westwood Center Drive, Suite 100,
Vienna, VA 22182
United States
Email: Obj_hugh@yahoo.com
Telephone: +1(301) 655 7569

Abstract

Africa has lost its glory as the pioneer of space research as evidenced by the ancient library of Alexandria in Egypt that housed the first space research centre more than two thousand years ago. Cave paintings in Olduvai Gorge in present day Tanzania showed how the first humans communicated millions of years ago. Early Africans used drum beats to alert of an impending danger or of festivities. The discovery of papyrus the material used as writing paper and the invention of words that make the alphabet all originated in Ancient Egypt. All of these examples show that at a certain stage in history, Africa was a leader in science and technology (Shibanda & Isabel, 2000). However in the 21st Century, Africa has lagged behind technologically compared to all the other continents. Space research and deployment of supporting technologies including remote sensing and Geospatial Information Systems (GIS) remain fundamental to bridge the technological gap between Africa and the rest of the world hence solving some of Africa's challenges. This study analyses the challenges and opportunities that African countries face in harnessing space technologies to be used in natural disaster management, disease prevention, land use, agricultural productivity improvements and even in conflict resolution.

Key Words: Space Research, Geospatial Information Systems, Remote sensing, Africa

Space Research

Soviet Union launched the world first satellite – Sputnik I in 1957. The Americans quickly followed by launching the Explorer I satellite in 1958 (Bradford, 1997). These two countries may be considered the World pioneers in Space Research. Space research is subdivided into nine major divisions: namely Remote sensing from earth's observations satellites whereby data is used to predict and interpret rainfall patterns, assisting with agricultural productivity and alleviating effects of natural disasters as some of its applications (Schott, 2007); Geodesy is used to understand the earth's geometrical shape and orientation that resulted in Global Positioning Systems (GPS) that is used to map land boundaries, identify locations and shorelines thence improving transportation and navigation safety (NOAA, 2014). Moreover, Aeronomy is another subdivision that studies the effect of solar radiation on ionization and dissociation that results in the greenhouse effect, aerosols due to volcanic eruptions and magnetic storms that may interrupt telecommunications (BISA, 2014). Space physics is the science of understanding the atmospheres, magnetospheres and plasma environs of the solar system. Applications of space physics are in the areas of how habitable environments may have evolved in the cosmos (CSP, 2013). Planetology centres on the composition, dynamics, formation, interrelations and history of planets (Beichman et al., 2006). Astronomy is the study of the universe using instruments like telescopes and high precision detectors these instruments analyse the forms of light from the universe (Mclean, 2008). Material science research is the study of properties of matter this culminates in the development of new materials and ways to improve existing materials by isolating chemical and thermal properties from the effect of gravity (NASA, 2013). Space life science is the use of microgravity to study life forms and biological processes this may be used to analyse and study diseases that affect humans, animals and plants (NASA, 2012). Finally, the study of Physics in space conditions enhances the understanding of the laws of nature that can result in improved technology, both in space and on earth, intelligence gathering and most importantly inspiring the future generations to study science and technology (CIT, 2010).

Africa Lagging behind in Science and Technology

Africa has lost its glory as the pioneer of space research as evidenced by the ancient library of Alexandria in Egypt that housed the first space research centre more than two thousand years ago. Cave paintings in Olduvai Gorge in present day Tanzania showed how the first humans communicated. Early Africans used drum beats to alert of an impending danger or of festivities. The discovery of papyrus the material used as writing paper and the invention of words that make the alphabet all originated in Ancient Egypt. All of these examples show that at a certain stage in history, Africa was a leader in space research and particularly in science and technology (Shibanda & Isabel, 2000). However, today Africa has lagged behind other continents in space research and its applications towards development. Many reasons can be attributed to this lagging behind some are due to poverty, lack of human skills and lack of infrastructure to embark in such sophisticated research (Timberlake, 1988).

This study will analyse the trends in space research in Africa, Key players in space research and practice in Africa, areas of future expansion of space research in Africa. Furthermore, a SWOT analysis looking at the Strengths, Weaknesses, Opportunities and Threats that can be used a framework to present the way forward for Space research and applications in Africa. Remote sensing and Geospatial Information systems (GIS) as fundamental tools for Africa development challenges were briefly described and finally a conclusion was presented.

Trends in Space Research in Africa

Key players in Space research and who have actually launched their own satellites in the earth's orbit are South Africa, Egypt, Algeria and Nigeria. Other countries like Angola, Kenya, Uganda, Ethiopia, Zambia and Ghana have nascent space programs and have not launched satellites.

Table 1

Space Research in Africa Key Players

Countries	Space Programs with Satellites	Space Programs (No Satellites)- Nascent
Egypt	X	
Nigeria	X	
Algeria	X	
South Africa	X	
Ethiopia		X
Zambia		X
Angola		X
Uganda		X
Ghana		X
Kenya		X

Source: SANSA

Key Players in Space Research in Africa

South Africa

South Africa can be considered the pioneer of space research in Africa. According to Dr. Peter Martinez, of the South African Council for Space Affairs, South African Astronomical Observatory was established in 1820 it used astro-photography to capture the first measurement to the nearest star. Other projects that emerged from South Africa space inquisitions were project Moonwatch which resulted in observations of satellite transits. South Africa collaborated with National Aeronautics Space Administration (NASA) in 1961 to establish the deep space station 51 that provided ground support to Mariner IV (fly by to Venus), Pioneer 8 (interplanetary weather satellite) and analysis of soil samples returned by the Apollo satellite. Moreover, South Africa serves as the African continent premier space geodetic facility using Very Long Baseline Interferometry (VLBI), satellite laser ranging, Global Positioning System (GPS), Tracking, Telemetry and Command (TT&C). Moreover, South Africa hosts the national earth observation archive and disaster management centers that support the country and its neighbors. South Africa launched its first satellite in 1999 named Sunsat, followed by another Satellite Sumbanila in 2009; the latter project was fully managed by South Africans and created a large awareness of space technology throughout the nation (Ghadaki, 2010).

It is implied that South Africa started space observation in the 19th century and incrementally developed the country's space capabilities by launching its own satellites in earth's lower orbit. Furthermore, the country has been a key partner with world class institutions like NASA during the latter's space activities.

Algeria

Algeria launched its first satellite in 2002 known as Alsat 1. It launched another satellite Alsat 2A that had a capability of high resolution for urban applications. The major mission was to provide medium resolution multispectral imagery for disaster management and remote sensing. The data collected by, these satellites were applied in areas of management and inventory of natural resources, land mapping, forestry, agricultural statistics, desertification, locating infrastructure points, including ports, railways, airports and monitoring of evolutionary phenomena (ASAL, 2014).

Nigeria

Nigeria has launched five (5) satellites in outer space. The first satellite was launched in 2003 in collaboration with a British company. The satellites were intended for early warning signals for environmental disasters, desertification, urban planning, and disease fighting, especially identifying breeding grounds for Malaria and preventing Meningitis. Moreover other applications were in the areas of facilitating distant learning techniques and finally of conflict resolution in areas of border disputes by mapping out state and international boundaries (NASRDA, 2014).

Egypt

Egypt launched its first satellite in 2007, EgyptSat1 which failed due to faulty communication system. It then launched another satellite EgyptSat2 which was successfully launched in 2014. The Satellites used remote sensing to monitor natural disaster, geological resources, better agricultural productivity, Archaeological and monitoring aquatic life along River Nile as it is an important source of livelihood for Egypt and neighbouring countries (NARSS, 2015).

Ethiopia

Ethiopia hosts the East Africa node of Astronomy for Development an organ of the International Astronomical Union (IAU), the major professional organization that governs Astronomy. Ethiopia had formed the Entoto Observatory and Space Research centre a home grown observatory equipped with the state of art two (2) 1-meter class telescopes to be used in studying space. The state of the art equipment is expected to accelerate the use of space science in tackling development challenges in Africa. The regional node will benefit other East African countries including Rwanda, Tanzania, Burundi, Ethiopia, Sudan, Uganda and Kenya. The Entoto Research Center will also provide Masters and PhD training in Observational and theoretical Astronomy, Space Science and Earth observation. This is expected to increase the number of professionals in the East African region (IAU, 2014).

It is observed that all the major players South Africa, Algeria, Egypt and Nigeria use the data from their satellites which is transmitted to data centres which role is to store, process and transmit data to the end user. The data is then manipulated by the end user using Geospatial Information Systems (GIS) which in turn assists to manage the adverse effects of natural disasters, land use, especially in urban planning, improvement in agricultural productivity, telemedicine, distance learning, resolving conflicts related to country boundaries and hence increasing economic development. Moreover, regional nodes like the East Africa node based in Ethiopia are fundamental in facilitating knowledge transfer in countries that have nascent space programs.

The next part shows how a satellite receives electromagnetic waves from a Lake using remote sensing and amplifies and transmits the waves to a satellite dish located in a data centre which is stored and finally sent to an end-user computer who can process and analyse the water composition using Geospatial Information System (GIS). Similarly, GIS is used to manage the adverse effects of climate change, agricultural yields, telemedicine and other applications.

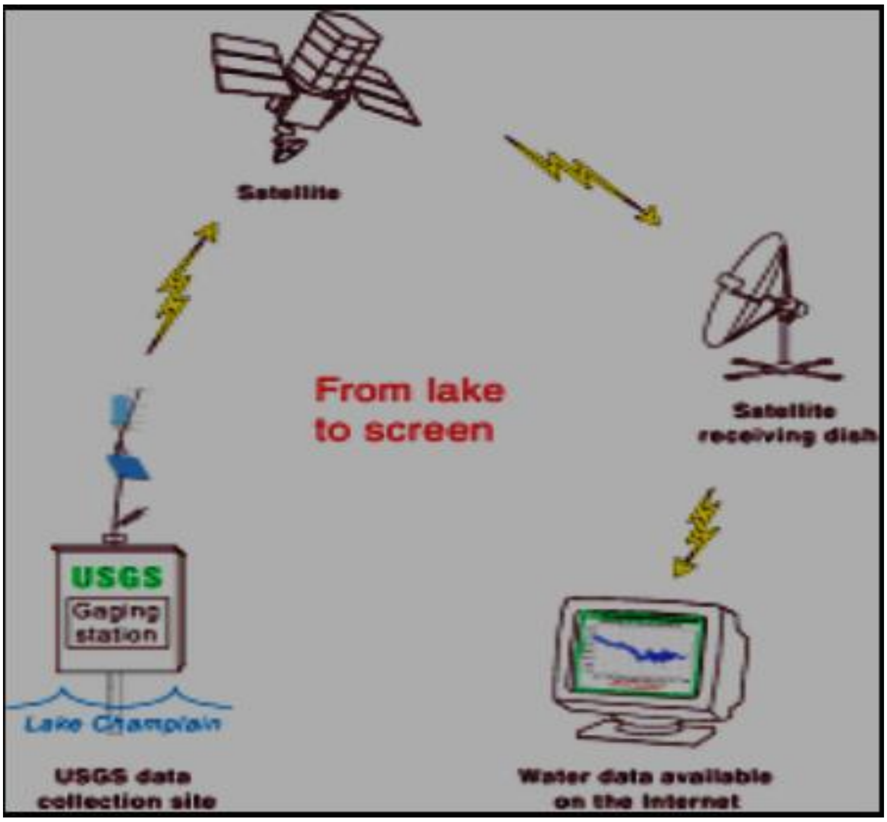

Figure 1: Information flow from Satellite to end user source: vt.water.usgs.gov

Step1: Signal is sent from a gaging station at the Lake to a Satellite using Remote Sensing

Step2: The Satellite amplifies the signal and beams back to Satellite receiving dish at a data center.

Step 3: The Signal is then sent via Internet to the end user

Step 4: Using GIS the end user can analyze and interpret the water composition from the lake and can transmit the data via email to any intended party.

Remote Sensing

Remote sensing is a key technology for quantifying landscape pattern and processes, without being in physical contact of that landscape using electromagnetic radiation either from an aircraft or satellite (active) or passive from sunlight (Newton et al., 2009; Tuner, 2005; Frohn, 1998). When more African countries acquire the ability of launching their own satellites they will be able to customize maps to the unique needs of the countries phenomena like wetlands, land use, deforestation and climate change over time. In so doing, scientists in these countries will be able to advise policy makers more accurately with better land use and how to combat the adverse effects of climate change. Moreover, Geospatial Information System usage allows the data obtained from the satellite maps to be analysed and easily interpreted using computer software. For instance, data from remote sensing is used to predict habitat types for Wetlands biodiversity assessment and necessary action plans can be put in place to mitigate any adverse effects that have occurred over time (see figure 2 below).

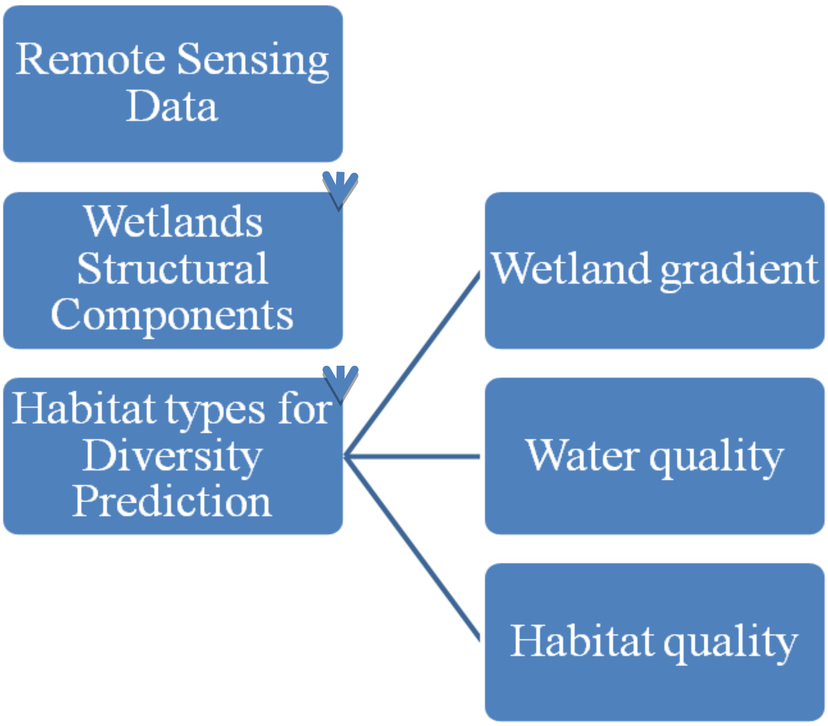

Figure 2: Wetlands Biodiversity Assessment source: (IGNOU, 2010)

Geospatial Information Systems

Geophysicists have used spatial data to characterize geographic distribution, spatial pattern of field data (Ripley, 1981; Meyers, 1988; Cressie, 1991 & 1993).

More recently, spatial statistics has evolved from descriptive, to predictive and now optimization models this is critical in making better choices and accurately making decisions. For example, Precision farming uses GIS modelling to investigate the spatial relationship between crop yield and soil nutrients (Berry, 1996). Soil samples are analysed for nutrient levels, for example, Phosphorus and Potassium spatially interpolated on maps, tracking the variation of these nutrients so that fertilizers can be added based on nutrient levels, resulting in better yields. Predictive techniques like regression to knowledge based modelling are used to relate the dependent (yield) and the independent variable (nutrient levels) (Burgess and Webster 1980; Lam, 1983). According to Stanford University, GIS is a computer system designed to capture, store, manipulate, analyze, manage and present all types of spatial or geographical data as shown in the image below.

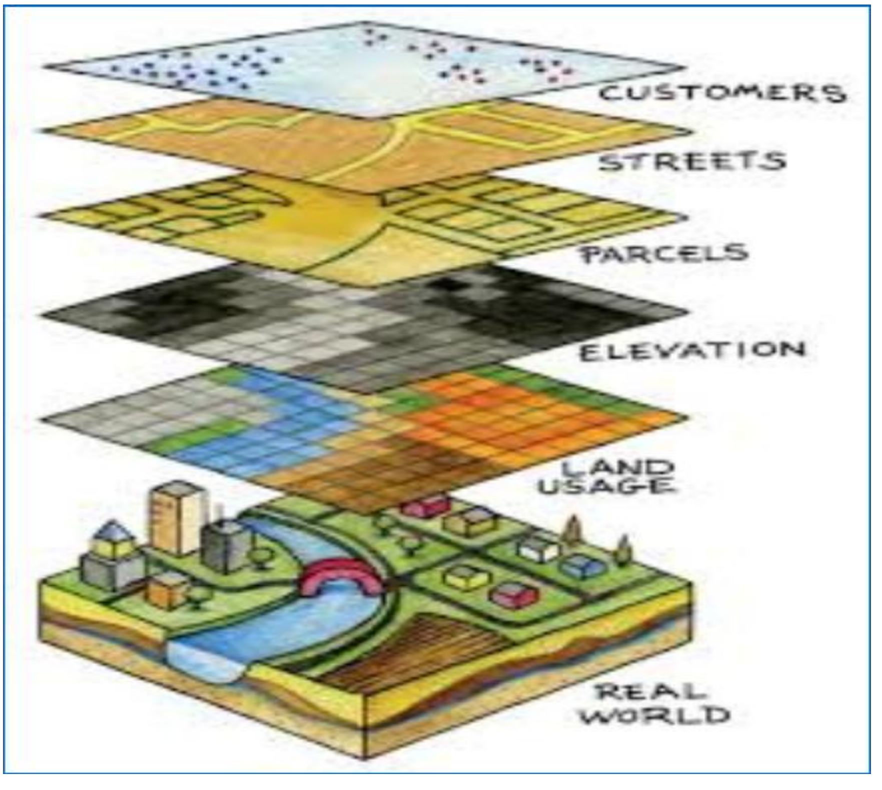

Figure 3: Geospatial Information System Processing. Source: Stanford University

Joint Initiatives by African Countries in Space Research

African Resource Management Satellite Constellation or ARMC was a collaboration involving Nigeria, Algeria, Kenya and South Africa that jointly develops a constellation of satellites to provide real time data to support environmental and resource management in Africa. The constellation design had each satellite equipped with a 2.5m resolution panchromatic imager and a 5m resolution multispectral imager in 6 multispectral bands. Data from the satellite was received by an integrated ground station. From the ground station the data may be transmitted to end users throughout the African continent (Adebola, 2009).

The data may be used to manage and monitor disaster management, food security, public health, infrastructure, land use and water resource management. Moreover, the joint initiative included installation of low cost multi-source ground receiving stations to aid countries less privileged to gain access through these stations for meteorological use (Adebola, 2009).

Other Bilateral projects in space research were Plasmon FP7 whereby South Africa, New Zealand and United States of America (USA) collaborated to explore ways to estimate and prevent damage to space assets due to space events. Moreover, South Africa and Kenya worked on modelling space weather effects using GPS and scintillation; South Africa and Nigeria collaborated in modelling the global peak ionosphere electron density; South Africa and Zambia worked together to investigate and model space weather studies over Africa (McKinnell, 2012).

This outlines South Africa has formed many bilateral partnerships and cooperates extensively with other African countries. These bilateral projects involving different countries have been the basis of transfer of skills and technology between African countries and should be encouraged.

Areas of Future Expansion of Space Research in Africa

Capacity buildings, especially at the undergraduate and graduate levels of education are essential. For example, University of Cape Town has Undergraduate and Graduate programs in Astrophysics and Space science. Scholarships and fellowships for Space studies should be awarded and the cost of education subsidized so that African students can afford the cost.

Formation of research networks, for example, The International Heliophysical year (2007-09) and the International Space weather initiative (2010-12) launched by United Nations Basic Space Science Initiative Program equipped laboratories in Africa with dual GPS receivers that facilitated exchange of data through the internet. These research networks increased the transfer of skills in disaster and resource management areas that are pertinent to economic growth in Africa.

Introducing African youth at an early age during pre-school and primary school in the science of space this could trigger a keen interest in later years and resulting in more researchers and space scientists in Africa.

Another area that can increase Africa involvement in space is holding more workshops and conferences in Africa in collaboration with internationally renowned space institutions of excellence like NASA, South Africa National Space Agency (SANSA), and Indian Space Research Organization. Exchanging of knowledge and expertise in project teams can boost Space research capacity in Africa and the use of its applications to solve African challenges.

Sub-Saharan Africa is the second largest mobile technology market after Asia and the fastest growing one which is expected to reach 346 Million users in 2017. For instance, in 2013, 80% and 55% of the urban population and rural population had mobile phones respectively (Tortora, 2014).

The high mobile phone availability and internet access from the fiber optic backbone around the African continent can be used as a platform to enhance such technologies for example, MPESA money transfer and cloud computing that may give the African user better Information Technology services access at a much lower cost. Moreover, once Africans are educated they can take advantage of available technologies including GIS that can assist them in making informed and accurate decisions in areas of agriculture (yield improvements), health care (telemedicine) and even in education (distance learning).

In the next section a SWOT analysis depicting the Strength, Weakness, Opportunities and Threats for the growth of space research in Africa.

Strengths

(1) Youthful population

Africa has the highest youthful population in the world. It is estimated that by 2050 according to a UNICEF report 2 out of 5 children will be African in the world this is due to high fertility rates and high number of women of reproductive age. If Africa invests in the health, education and protection of these children the continent may harvest the advanced skills and technology that accrues from an educated population. Space research is a catalyst that can trigger an interest in the youth in studying Science, Technology, Engineering & Mathematics (STEM) developing scientists and researchers in Africa that can solve Africa's challenges.

(2) Established Players in Space Research

Established players South Africa, Algeria, Nigeria and Egypt can form centers of excellence and transfer technology to the other African countries. An example is the International Astronomical Union (IAU) that had established the Office of Astronomy for Development (OAD) that raises funds for space research development projects in Africa and the developing world. The OAD has been formed with partnership of IAU with the South Africa National Space Foundation.

(3) Social networks

Africans practice a collective culture bound with strong bonds of social networks. The strong bonds can be a platform of collective learning at households, community and at a national level. Taking advantage of the social networks through the media, leaders and even clergy encourage youths to pursue STEM (Science, Technology, Engineering & Math) in so doing increasing the overall interest in Space research and its applications.

Table 2: *SWOT Analysis for the Growth of Space Research in Africa*

Strength	**Opportunities**
➢ Youthful population ➢ Strong social networks in African tradition ➢ Established players- South Africa, Egypt, Nigeria and Algeria transfer skills to Other Countries	➢ Leverage existing technologies e.g. GIS ➢ Collaborations and Partnerships (Academia/Business/Government)- PPP ➢ Use of expert knowledge of Africans in the Diaspora who have Space knowledge and Skills(Interest of Africa at heart) ➢ Build up Supporting Industries for Space Research ➢ More international conferences to be held in Africa
Weaknesses	**Threats**
➢ Lack of human skills ➢ Poverty ➢ Lack of funding ➢ Road Map for Space Program for the African Continent is absent ➢ Lack of a Robust Legal and Regulatory framework that governs Information technology in Africa	➢ Short term policy decisions Versus Long term planning and policy decisions ➢ Perceived not a priority area by politicians ➢ Girl child is denied ample education in favor of a boy child in case of limited family resources.

Weaknesses

(1) Lack of human skills

Lack of human skills due to very few experts trained in space research disciplines and also few training institutions in the continent

(2) Poverty

Poverty results in lack of basic facilities that includes running water, electricity, books, internet connectivity and poor housing all of this do not favor development of space technology in Africa

(3) Lack of funding to invest in space technology

The cost of launching a satellite ranges from USD 50-100 Million; this money can be used to provide for desks in schools, build classrooms, laboratories and books that are of an immediate need.

(4) Lack of a Roadmap for African Continent for Space Research

African continent may not have in place a Roadmap for Space research for all 54 countries whereby they can share and learn from each other synergistically rather than in a fragmented manner. Currently there are a few key players- South Africa, Algeria, Nigeria and Egypt. Countries including Tanzania, Malawi, and Mozambique are not in the forefront of space research. A comprehensive roadmap supposedly by the African Union could facilitate all the 54 African countries to grow in space research.

Opportunities

(a) Deploy existing technologies

Deployment of existing technologies especially GIS and learning how to apply the techniques and methods to solve problems, for example, being able to interpret a digital soil composition map or use of CrowdMap to report on a natural disaster or Open source mapping to trace affected areas in a typhoon so that relief efforts can be put in place. Sub-Saharan Africa has a high mobile phone penetration coupled with broad band internet that can empower people to access telemedicine, obtain distance education, and access interactive maps and images in conflict resolution as evidence in court hearings. The African citizen has to be educated on the available technologies and how to interpret the information gathered from such technologies.

(b) Partnerships

There should be collaborations and partnerships between academia/business/government to form Private Public Partnerships (PPP) and thus leveraging the core competencies of each entity to establish a vibrant space industry.

(c) Tap Diaspora knowledge

Tap the expert knowledge of the Africans in the Diaspora who have knowledge and skills in space research.

(d) Development of supporting Industries

Development of space technologies may support the advancement of other industries by creating new employment for example, suppliers of space research equipment, new partnerships may be formed with local manufacturers, banks and other entities hence developing the local capacity.

(e) Conferences

International conferences that bring together experts, business leaders, academia and all stakeholders in space research can be held in various African countries. This may afford the countries with nascent space capabilities to learn and deploy best practices that have succeeded elsewhere.

Threats

(a) Long term Vision

Space research and exploration needs a long term vision and its will require a long period for a return. Critics may easily proclaim that Africa needs to fix its basic problems of water supply, reliable electricity before embarking on grandiose and ambitious space programs. This argument is a fallacy as Space capabilities allow countries to have more accuracy in decision-making and in the long run be competitive. Deployment of space technologies may afford African countries to leapfrog older technologies and rapidly bridge the technology gap with industrialized nations, achieving higher standard of living for its population.

(b) Lack of political will

Politicians may not view space research as a priority and popular in order to win an election. Therefore, they may not include it in their election campaign agenda. This is because poor people in Africa are more interested in getting other basic necessities solved like reliable power supply and running water. Even if a space research budget is allocated in parliament, the actual allocations for space research may decrease in favour of other priorities weakening the implementation of existing space projects.

(c) Lack of opportunity for the Girl-Child

In African culture the Girl-child is considered inferior to a boy-child. Especially whenever a family has limited resources it will favour paying for a boy's education rather than a girl's education. The main assumption is that a girl will be married off and will bear some other family off springs and will not continue the family name.

This negative culture aspect has denied many girls and women who form more than 50% of the African population good education in STEM and a strong voice in society. Due to the large women and girl population in Africa as girls are denied an education almost half of the overall population remain uneducated this will continue to be a burden on African development efforts.

(d) Lack of a legal and Regulatory framework for Information Technology

Space research and the use of its application involve a large amount of data storage, processing and transfer. Most of African countries do not have an adequate level of data protection both at the legal and regulatory levels. At the legal level most African countries have just introduced laws that govern intellectual property rights and do not have the enough expertise to thwart cyber-attacks and guarantee sufficient data protection. Moreover, the regulatory framework is less established and varies from country to country this is a disadvantage as data may need to move through countries from say a data centre in one country to an international investor or end user in another country.

The lack of a robust legal and regulatory framework may be an impediment for investors in space research to invest in African countries because they are not sure that their trade secrets will be safe and whether heavy penalties will be levied to the defrauders of data. African countries should align the legal and regulatory frameworks governing the use of this data will make countries attract more investment due to higher economies of scale.

Conclusion

This study analysed the trends in space research in Africa, key players and what initiatives within the Africa continent have been adopted thus far. Furthermore, the study has attempted to look at the way forward by drawing a SWOT analysis of the possibility of Space research and science to be used as a tool for economic development in the African context.

Collaboration between business, government and academia and the synergies that may form are critical in growing space and scientific research in the Africa.

Growth of Space research has a multi-pronged benefit in use of data collected from outer space and interpreting it to solve Africa challenges, be it disaster and climate change management and tropical diseases using remote sensing and GIS among other technologies.

Moreover, access to telemedicine and even conflicts may be resolved by using interactive maps that show clear demarcation of land boundaries.

However, it is important to state that political will is important to kick start space research in Africa due to conflicting needs for resources to fund immediate needs like electricity, running water, housing and education for a poor population.

Moreover, African countries should build strong legal and regulatory frameworks, especially in data protection because any meaningful space research program involves storage, processing and data transfer, whereby potential investors want guaranteed protection of data in order to invest fully in Africa.

The benefits of Space research are not short term but rather long term and sustainable. South Africa the leader in space research in Africa and also arguably Africa's most developed nation have harnessed the space research applications to build a robust economy. However, South Africa started space research activities as early as in 1820; as a result, they are reaping the fruits of their investment now. This should serve as a rallying cry for other African countries to invest now and expect to reap the benefits decades later.

Areas for Future Research

More research can be done in determining the rate of return of investment on space research for African countries by attempting to perform a cost- benefit analysis of implementing a space research programme in Africa. Additionally, it will be interesting to determine a particular model for a space program that could be used as a prototype for other countries that are interested in pursuing a space program. As a word of caution, Africa is made up of 54 countries with different culture, languages and locations all these factors should be considered when analysing different space program models.

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