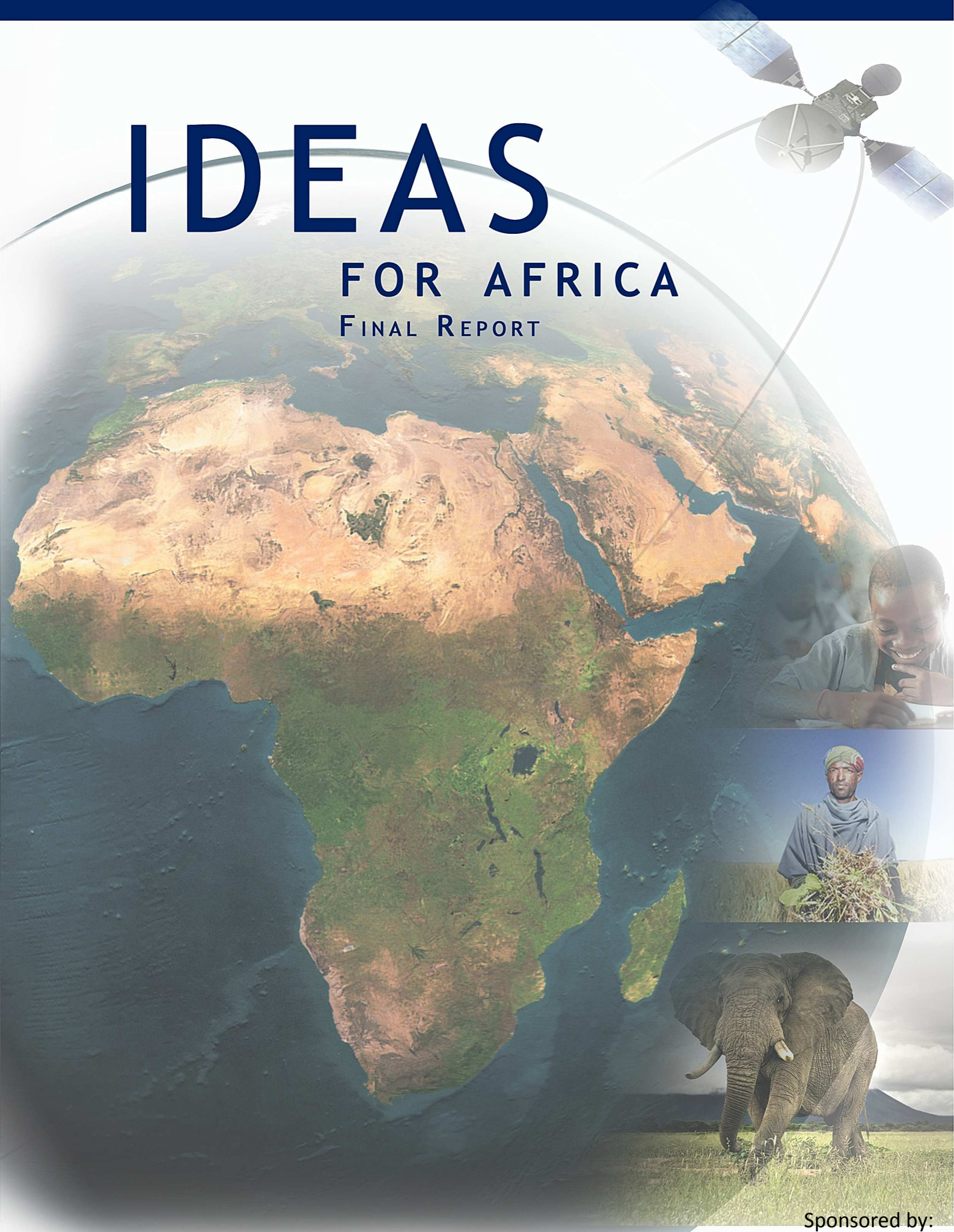
IDEAS

FOR AFRICA

Final Report



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ISU

Identifying and Developing Effective Applications of Space

NASA



IDENTIFYING AND DEVELOPING EFFECTIVE APPLICATIONS OF SPACE

Final Report

International Space University

The 2012 Masters Program

Strasbourg, France

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The 2012 Masters Program of the International Space University was convened at the ISU central campus in Strasbourg, France.

The IDEAS cover depicts the many impacts that space can have on the lives of Africans; Spinoff technologies aiding farming, satellite application for protecting the environment, and space businesses for promoting education.

The front cover was created by Team Project member Shripathi Hadigal. The images used are credited to Broadband Genie, Splendid Wallpaper, Cleanseed Capital, Antony Aseal, and Satenews.

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The Executive Summary and Final Report can be found on the ISU web site at

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Additional information about this Team Project can be found on the IDEAS home page at

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ABSTRACT

This report presents the conclusions of the Space and Africa Team Project at the International Space University's (ISU) 2011-2012 Masters Program, held at Strasbourg, France. The Identifying and Developing Effective Applications of Space for Africa (IDEAS for Africa) team has assessed how space can contribute to sustained social and economic development in Africa. Space can provide many benefits - from spinoff technologies, satellite applications, and even establishing self-sustained commercial industries. But how is space relevant for Africa? How can space be used to save and improve lives, protect the environment, mitigate severe weather conditions, and build industries and economies? In ISU's first African-focused team project, this report begins by selecting three dissimilar countries to serve as examples for the entire continent. Liberia, Morocco, and South Africa are selected not only based on their respective levels of space development, but also because they differ geographically, socially, economically, and politically. In learning about these target countries, the report maintains a focus on six socio-political focus areas (agriculture, education, energy, environment, health, and STEM education – Science, Technology, Engineering and Mathematics).

Next, the report discusses three spinoffs especially relevant to improving these conditions. The team selected three for further investigation: Organically Derived Colloidals, Solid Oxide Fuel Cells, and docosahexaenoic acid (DHA) supplements. Born from space industry research, these spinoffs can be repurposed to improve lives across Africa. The report then finds and analyses four satellite applications especially relevant to African concerns. FarmaBooths (a way of bringing satellite imagery to rural African farmers), Telemedicine Vans, a Desert Movement Predictor, and an Anti-poaching program, are all applications of space technology that can be implemented in Africa.

Two potential space businesses are then analyzed. An African Space Education Center can be used to build domestic capacity in high technology fields, prevent "brain drain", and foster a domestic space industry. The revival of South Africa's Overberg Test Range is then offered as a potential commercial venture. A discussion of the strengths, weaknesses, opportunities, and threats is included in the discussion of each space spinoff, satellite application, and space business proposal, along with any ethical implications. Finally, the creation of two organizations to bring space to Africa is discussed. An African Space Agency and a Space for Africa Non-Governmental Organization are two ways to implement our ideas for Africa.

FACULTY PREFACE

"Broken wall, bicycle wheel
African sun forging steel, singing
Magic machine cannot match
Human being human being
African idea
African idea
Make the future clear
Make the future clear"

The above lyrics belong to "Scatterlings of Africa", Johnny Clegg's poignant homage to his beloved continent. Clegg has an international reputation as a musician, statesman and campaigner for civil rights. As a boy in Apartheid South Africa, he visited deprived townships with his step-father who was a journalist. He saw immense poverty and injustice and as an adult became a significant voice in the international, Anti-Apartheid crusade. Despite the problems in his beloved South Africa, songs like "Scatterlings of Africa" speak volumes about Clegg's optimism and faith in a bright and secure future.

This ISU, M.Sc. 2012 team project (TP) addresses important aspects of Continental Africa's future. Specifically, it assesses the effectiveness of various technologies originating in the space sector. Some of these technologies have the potential to greatly improve the standard of life across Africa. The TP, known as IDEAS (Identifying and Developing Effective Applications of Space) for Africa, is composed of a spirited, international team of 21 men and women from 14 nations. They started their work last Fall with a thorough literature review. This work laid the foundation for IDEAS, which has developed into a timely and original project. Indeed, significant international interest has been shown in their work.

The team are to be congratulated on their commitment, knowledge of the subject and overall pride in their work. They have also adhered to ISU's, noble '3I' credo: Interdisciplinary, International, Intercultural. The doctrine is especially significant this year, which marks the 25th Anniversary of the founding of ISU in 1987.

Finally, IDEAS for Africa owes an immense debt to friends and colleagues who have provided precious support and encouragement.

Bonne lecture!

Angie Buckley, John Farrow, and Hugh Hill

AUTHOR PREFACE

Twenty-one individuals from fourteen countries in six continents undertook the team project on Space and Africa during the 2011-2012 Masters Program at the International Space University (ISU), in Strasbourg, France. The team members, from varied backgrounds and with diverse academic and professional experiences, aspired to fulfill the ISU ethos of an international, intercultural, and interdisciplinary approach to space. We began our work towards understanding both the complexities and subtleties of Africa and the challenges and opportunities born from the first half-century of humankind's exploration of outer space.

Bringing these two topics together in ISU's first African-focused team project sharpened our understanding of Africa, the birthplace of humanity and the home of more than one billion of our fellow citizens of the Earth. Over the next six months, the team project, which was titled IDEAS for Africa (Identifying and Developing Effective Applications of Space for Africa) thought creatively and constructively to imagine ways that the daring innovations from the global space industry could be implemented to better the lives of those least related to the use and exploration of outer space.

Many possibilities were found, and this report presents the best of an impressive set of innovations. The IDEAS for Africa team encourages the reader to imagine a future where our suggestions and those like it can inspire Africans and bring change to Africa. The next step is for you to take.

IDEAS for Africa

20 April 2012

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REPORT STANDARDS

LIST OF ACRONYMS

Acronym	Definition
AICD	Africa Infrastructure Country Diagnostic
AIDS	Acquired Immune Deficiency Syndrome
AfSIS	African Soil Information Service
ASEC	African Space Education Center
AU	African Union
BGAN	Broadband Global Area Network
CELSS	Closed Environmental Life Support System
CFF	Centralized FarmaBooth Facility
CNS	Central Nervous System
DEAT	Department of Environmental Affairs and Tourism
DHA	DocosaHexaenoic Acid
DMPC	Desert Movement Prediction Center
DSP	Digital Signal Processor
EADS	European Aeronautic Defense and Space Company
EAIF	Emerging Africa Infrastructure Fund
ECG	Electrocardiogram
ESA	European Space Agency
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information Service
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
IAU	International Astronomy Union
IDEAS	Identifying and Developing Effective Applications for Space
IFAD	International Fund for Agricultural Development
InSAR	Interferometric Synthetic Aperture Radar
IPO	Intellectual Property Office
IRS	Indian Remote Sensing Satellite
ISRO	Indian Space Research Organization
ISU	International Space University
JAXA	Japan Aerospace Exploration Agency
LEO	Low Earth Orbit
LiDAR	Light Detection And Ranging
NAP	National Action Plan
NASA	National Aeronautics and Space Administration
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organization

NSBRI	National Space Biomedical Research Institute
NTR	New Technology Report
NTTS	NASA Technology Transfer System
O3b	Other 3 billion
ODC	Organically Derived Colloidal
OECD	Organization for Economic Cooperation and Development
OIC	Organization of the Islamic Conference
OTB	*Overberg Toetsbaan* (Overberg Test Range)
PAIDF	Pan African Infrastructure Development Fund
PAN-LCD	*Programme d'Action National de Lutte Contre la Désertification* (National Action Program to Combat Desertification)
RSA	Republic of South Africa
SACSA	South African Council for Space Affairs
SADR	Sahrawi Arab Democratic Republic
SALT	South African Large Telescope
SANSA	South African National Space Agency
SAR	Synthetic Aperture Radar
SMS	Short Message Service
SOFC	Solid Oxide Fuel Cells
SPOT	*Système Pour l'Observation de la Terre* (Earth Observation System)
STEM	Science, Technology, Engineering, and Mathematics
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TMDL	Total Maximum Daily Loads
UN	United Nations
UNCCD	United Nations Convention to Combat Climate Change
UNEP	United Nations Environment Programme
UK	United Kingdom
US	United States
USAID	United States Agency for International Development
USD	United States Dollar
VHF	Very High Frequency
VoIP	Voice over IP
VPN	Virtual Private Network
VRC	Village Resource Center
VSAT	Very Small Aperture Terminal
WWF	World Wildlife Fund
ZAR	South African Rand

LIST OF DEFINITIONS

The following definitions are used by the IDEAS team in this report and are included here to aid the reader as a reference in understanding the report.

Aeroponics: Growing plants in an air or a mist environment without the use of soil

Desertification: The process by which fertile land becomes desert

Electrochemical Reaction: A reaction which converts stored chemical energy in a fuel into electrical energy

FarmaBooths: Satellite-based village information centers to provide agricultural information to farmers

Macro Species: High value, normally large, animals that are large enough to be easily detected through airborne of even satellite platforms

Micro Species: Low individual value animals, too small to be remotely detected, although detection of swarms may be possible

Oxidation Reaction: A chemical reaction in which a reactant is split into a product and free electrons. Oxidation is always accompanied by reduction

Poaching: The hunting or catching of game or fish on another's property, or which is under environmental protections

Reduction Reaction: A chemical reaction in which free electrons combine with an oxidant to produce some product

Satellite Application: A product or service that uses spaceborne technology, whether directly or indirectly

Space Business: A company or association that has for its main product or service a major component that interfaces majorly with a space sector

Space Economy: All public and private actors involved in developing and providing space-enabled products and services

Spinoff: technologies or processes that are used in applications unrelated to their original purpose

Telemedicine: A satellite application which provides healthcare services, and helps distribute medical information to remote areas

Water Harvesting: Capturing run-off rainwater locally, and taking measures to ensure cleanliness of water by not allowing pollutants to gather in the catching devices.

PART I – TOPIC SELECTION



1 INTRODUCTION

With its breathtaking landscapes, untouched environment, and incomparable vistas, Africa is beautiful. But the forests being destroyed by logging and remade into agricultural lands, and the industrial pollution spilling into rivers and streams tell a different story. And while Africa is known for its incredible wilderness and rich biological diversity, irresponsible management and poaching threatens this magnificent heritage. The continent's rich natural environment also means that catastrophic floods wreak havoc on homes, and droughts that threaten both animal and human communities' ability to survive.

Africa is a celebration of world-renowned colors and tremendous festivals. But no African celebrates when regional, national, and international conflicts tear families and countries apart. Africa is a land of ancient tribal customs, and cutting edge research; a land of democracies, monarchies, and dictatorships. Above all else, Africa is a land comprised of many lands - a continent of contrasts. No single viewpoint describes it, as Africa escapes generalizations. In learning about Africa, our understanding and appreciation grew and grew - and we wondered how space fits into this already rich story, bursting with life and overfull with tragedy and wonder and promise and hope.

The IDEAS (Identifying and Developing Effective Applications of Space) for Africa team faced quandaries and uncertainties very early on in our process. Was our project Africa for space, or space for Africa? In other words - was the aim of our project investigating and understanding the ways that Africa can contribute to the global efforts of space exploration, taking a place at the table along with other continents with existing and emerging space capabilities? A project along these lines envisioned African launch sites for European and Asian rockets, and using Africa's vast mineral resources to cheaply fund and assemble space systems.

We firmly rejected this approach.

After learning about the political, economic, health, and security concerns in Africa, the focus of our investigations and the aim of our efforts is to promote space *for Africa* - space first and foremost for the needs, and in the interests, of Africans.

In contemplation of the daunting tasks and ethical implications behind this report's proposals, Jacques Arnould, the philosopher in residence at CNES, on 12 February advised the IDEAS for Africa team that "space is not a solution... space is a way to make real the policy that you introduce". In light of this, the policy of our group is that research and applications from the space sector can be used to improve lives and strengthen communities. We hope that this report has reflected with clarity and fidelity our beliefs, findings, and ideas - that the realization of these goals and the inauguration of these policies are both laudable and practical, both wise and worthwhile, and that Space for Africa is as inspiring as it is achievable. We look forward to working with partners from Africa and from around the world in making these changes real, and bringing our ideas from the pages of this report to the people of Africa.

1.1 Mission Statement

The main objective for this report is to propose spaceborne innovations and solutions to benefit Africa. To that end, three "target countries" will be selected as examples of Africa's diversity.

This report's Mission Statement is:

> *Using three diverse African countries as examples, the IDEAS for Africa team proposes and analyzes innovative space spinoff technologies, satellite applications, and space business potentials applicable in fostering sustained social and economic development across the African continent.*

1.2 Project Scope

To achieve the Mission Statement, this report will begin with a brief overview of the challenges and key issues many African countries face. It will then look into the present space capabilities across the continent, and how these can be effectively leveraged to provide additional benefits.

Following the Mission Statement, the report will discuss the main proposals of the IDEAS for Africa team. The proposals will focus on three main categories: spinoff technologies, satellite applications, and space businesses. The categories will be the topic of the following three chapters. Each of these proposals is specifically selected to address the social and economic challenges in Africa.

Finally, suggestions for how to best implement these proposals are offered. Two possibilities are stressed: a Non-Governmental Organization, and the unification of African resources through an African Space Agency. These two suggestions will be discussed in the *Future Work* chapter in the Appendix.

While the intent of this report is not to provide a fully detailed description of how to design and implement these proposals and an analysis of all of their implications, we believe that the reader will receive an informative overview of what space can do for Africa.

2 IDENTIFYING FOCUS AREAS AND TARGET COUNTRIES

Africa is considered as the birthplace of humanity and a treasure house of cultures and customs. Its social, political, and environmental features are as diverse as its countries are numerous. The IDEAS for Africa team first sought to obtain a fuller understanding of Africa's by studying (amongst other topics), its politics, conflicts, and economies.

When studying Africa, one learns that it is a continent of contrasts. An optimistic view of the continent's future can be adopted after reading reports like McKinsey's "Lions on the Move", which highlight Africa's growing economies - predicted to reach USD 2.6 trillion by 2020. This figure will be only a sixth of the size of the current US economy (Roxburgh, 2010). Alternatively, one is saddened by the numerous ongoing conflicts, which have degraded from post-colonial wars of independence and struggles against apartheid and dictatorships, to civil wars, to today's essentially lawless and interminable battles between amorphous groups lacking justifying ideologies (Gettleman, 2012).

2.1 Introduction

Proposing space-related solutions with the potential to ease problems experienced by African nations is not a clear task. It warrants a better understanding of problems affecting life in Africa: the root causes, and the obstacles preventing the solution. An investigation was undertaken into specific sociopolitical aspects of African life, which we called focus areas. Subsequently, three target countries were selected to serve as examples for all African countries in similar socioeconomic situations. This chapter provides a description of our focus areas, along with the selection methodology used in selecting our target countries.

2.2 Focus Areas

The focus areas that are most concerning for the African continent are agriculture, education, energy, environment, health, and science and engineering. While our analysis is grouped into these specific focus areas that affect life in Africa, the understanding of life in Africa includes the realization that these topics are in fact interlinked. The following section provides a basic overview of these various situations throughout the continent.

2.2.1 Agriculture

Agriculture is the most important sector in Africa's economy, employing approximately 60 percent of its labor force. When compared to a three percent world average, African labor provides almost a quarter of the continent's Gross Domestic Product (GDP) (African Development Bank Group, 2010). However, agricultural development suffers from unpredictable environmental conditions and faces a rapidly increasing population. Despite recent improvements, African food security remains a major issue, as shown in Figure 2-1.

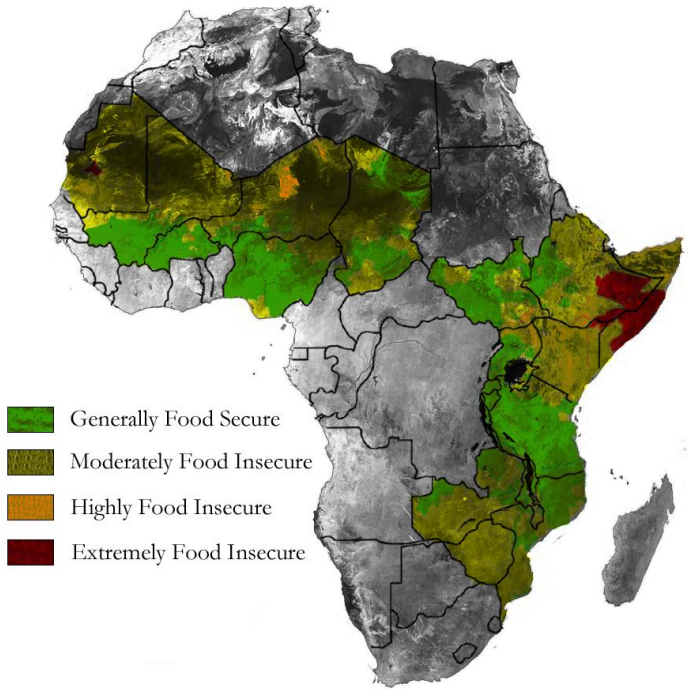


Figure 2-1: Food security in Africa [Fire Earth, 2009] [Osborne, 2012].

2.2.2 Education

Sustained social and economic development to preserve Africa's natural environment requires high levels of education. Unfortunately, schools across the continent often lack basic facilities. Universities suffer from overcrowding, regional conflict, and staff lured abroad by higher pay and improved living conditions. For primary education, the situation is improving with more children being enrolled in schools, especially in Burkina Faso, Madagascar, Niger, and Zambia (Gettleman, 2012). There are disparities in education for different races, and women typically have lower education levels than men. Global literacy rates are shown in Figure 2-2, indicating the contrast between Africa and the rest of the world.

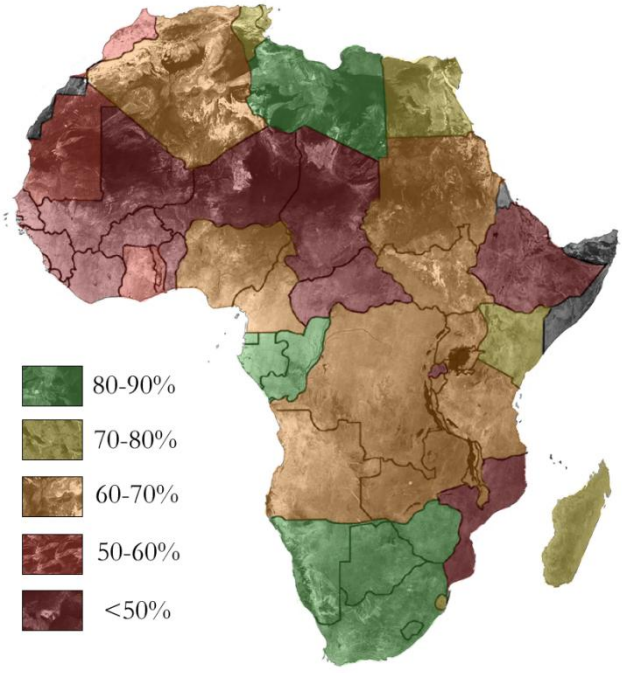


Figure 2-2: World literacy rates [Wikimedia Commons, 2011c] [Osborne, 2012].

2.2.3 Energy

Energy sources in Africa are coal, oil, and hydroelectric power. Coal consumption takes the lead, whereas hydroelectric potential remains vastly under-exploited. This homogeneous generation profile, constrained by financial investments and lacking regional links to facilitate power trade, has resulted in a severe energy crisis in many countries across the continent, as shown in Figure 2-3 (Foster & Pushak, 2011). To improve healthcare and household systems, these energy concerns must also be addressed. Growth in capacity has stagnated across the African continent over the past several years. The total energy generation across the continent remains less than that of Spain. Given current trends, the electrification of most African countries will not be achieved by 2050 (Foster & Pushak, 2010). Consequently, it is difficult to imagine great improvements in healthcare or education while access to energy remains underdeveloped.

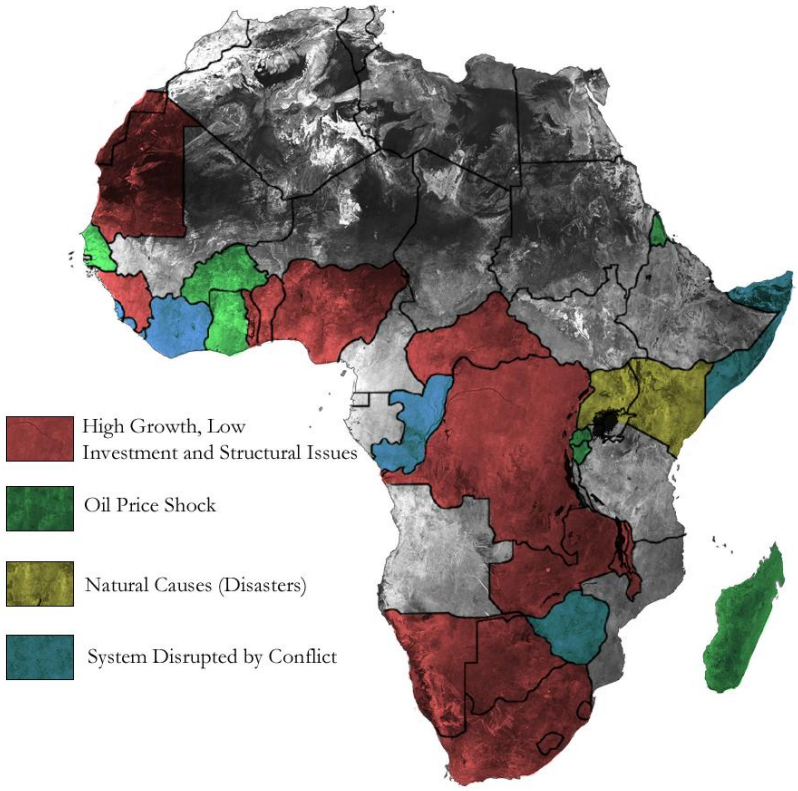


Figure 2-3: Factors having major effects on Africa's energy sector [Foster & Pushak, 2011] [Osborne, 2012].

2.2.4 Environment

Sustained agricultural development depends on the continent's environmental health. The diverse and complex nature of Africa's territory poses great challenges. Deforestation and droughts are two of the major environmental challenges Africa faces. Every year, the continent loses four million hectares of forests due to desertification (University of Pennsylvania, 2008). The main cause of desertification is deforestation, with trees being cut to meet energy needs and expand agricultural land (UN Economic & Social Committee, 2007). Northern Africa is also one of the driest areas of the world, receiving only seven percent of Africa's total precipitation. Eastern Africa has been the most frequent sufferer of the most severe recent droughts (UN Environment Programme, 2002). An overview of the climatic conditions on the continent is presented in Figure 2-4.

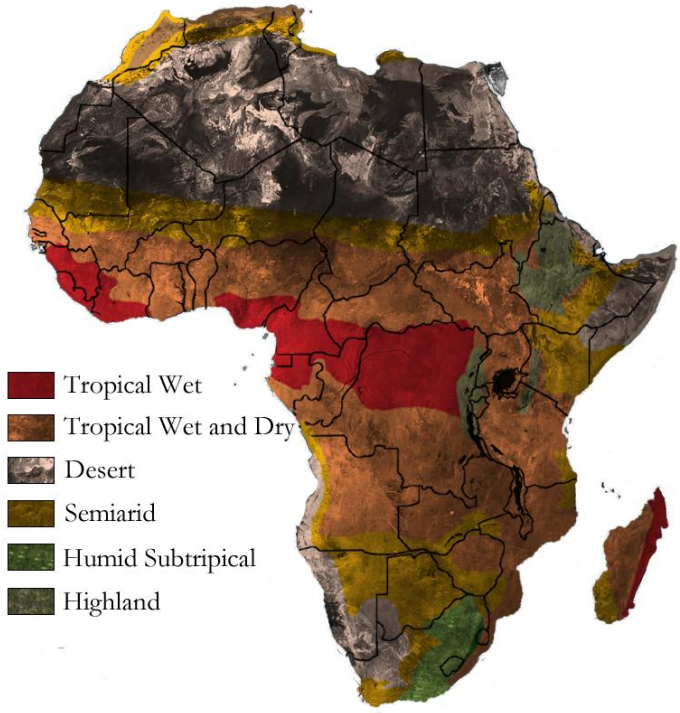


Figure 2-4: African climate overview showing the diversity [Westshore, 2011] [Osborne, 2012].

2.2.5 Health

Due to the lack of trained medical professionals and improper practices, the African healthcare system is incapable of meeting the basic needs of its people. In addition to the human lives lost, the poor healthcare system slows economic development. Resources which could otherwise have been committed to economic growth are instead put towards combating infectious disease, maternal death, and malnutrition. African countries have yet to benefit from the many advances made in medical research, and often rely on traditional medical practices. Every year, several thousands of Africans die of diseases that can be inexpensively prevented and treated. A recurring theme among reports on the continent's progress is that for it to develop economically, it needs to implement public health policies and practices with a proven efficacy (WHO, 2006). Figure 2-5 shows Africa's lamentable mortality rates and life expectancy. The first step in improving life on the African continent is helping its people live longer and healthier lives.

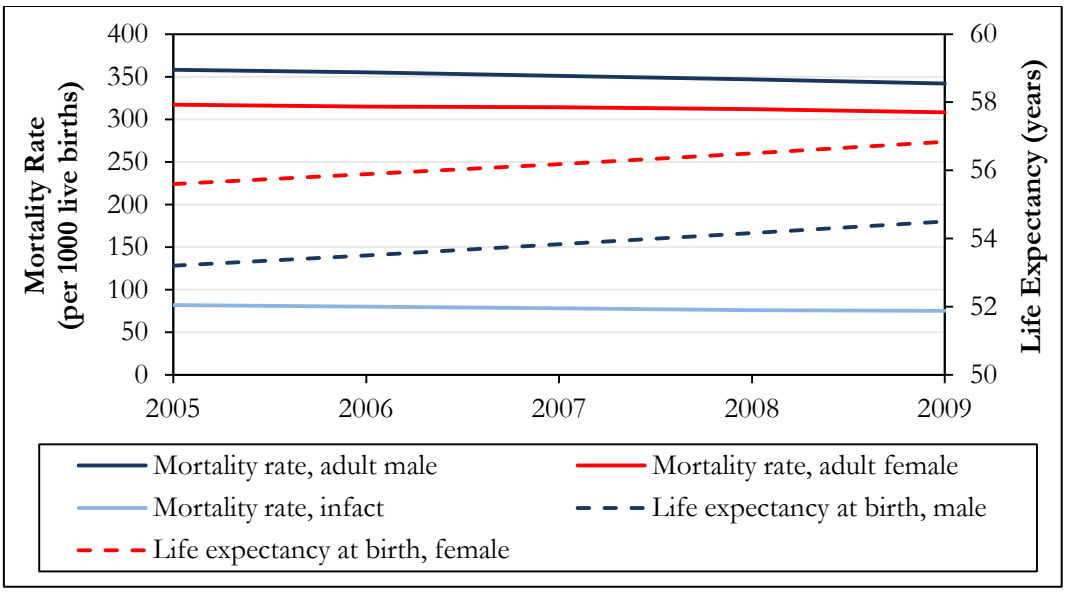


Figure 2-5: African population mortality and life expectancy, 2005-2009 [The World Bank, 2011].

2.2.6 Science, Technology, Engineering, and Mathematics (STEM)

To provide sustainable solutions for Africa, growing energy and agricultural demands will need advancements in the science, technology, engineering, and mathematics (STEM) fields. This technological progress will require skilled professionals in the fields of STEM. Due to the current socioeconomic situation in Africa, highly qualified professionals often leave their home country to seek employment in the developed world. Approximately a third of all African scientists and engineers live and work abroad. Scientific and educational development across the continent is crucial to prevent Africa's "brain drain" (Network of African Science Academies, 2009).

2.2.7 Summary of Focus Areas

It is clear that the African continent faces a myriad of challenges. The African community will have to pay particular attention to these focus areas to improve life on the continent. It is worth noting that there is no single solution to individually overcome each of these challenges. Furthermore, a solution that addresses one of these focus areas in one country may not have any application in another lesser developed country, as there is a great contrast across the African continent. As previously mentioned, these focus areas will be the basis for the investigating and proposing solutions derived from the global space industry.

2.3 Target Countries

No two African countries are the same and certain social constraints that prevent an application from thriving in one country may promote its development in another. One country may not have the economic means to support a specific application, whereas another country's economy may allow it to flourish.

Applying spaceborne solutions to every African country may not seem feasible. Consequently, three target countries were selected and used as examples for implementing the spaceborne solutions. Each country will best represent the diverse African continent. The following section describes the selection methodology used to identify our target countries.

2.3.1 Selection Methodology

When considering the project's goal of introducing space technology to Africa, a logical way to proceed is to base the selection of the target countries on their current space capabilities. As a result, the first stage of the selection process split African countries into three different categories. These are shown in Table 2-1.

Table 2-1: Descriptions of the three target country types.

Country Type	Description
High Space Technology	Countries with space agencies
Medium Space Technology	Countries with space involvement or capabilities, but no space agency
Low Space Technology	Countries with scarce or no space involvement or capabilities

For the High and Medium Space Technology Countries, selection was based on an existing framework for evaluating national space activity. The Technology Country Ladder methodology is designed to capture the activity of countries that traditionally have been less involved in space (Wood & Weigel, 2012).

The Technology Country Ladder measures and ranks the technical and managerial autonomy by considering specific space projects within the countries. The levels of the Mission Ladder are defined based on the types of technology used in the various projects. These are grouped into three types:

Satellite Infrastructure, Satellite Hardware, and Satellite Services. Table 2-2 shows the different levels of the framework.

Table 2-2: Country Technology Ladder.

Country Technology Ladder	
Level	Activity
Satellite Infrastructure	
A	Satellite assembly integration and test facilities
B	Satellite design and development facilities
Satellite Hardware	
C	Design, build, operate satellite
D	Buy and operate satellite; train in satellite design/build
E	Operate others' satellites
F	Contribute to collaborate satellite project
Satellite Services	
G	Lease satellite capacity and distribute service
H	Operate ground segment to send or receive satellite data
I	Process satellite data and create data products
J	Use satellite data products
K	Participate in regulatory action regarding satellites

For countries in our High and Medium Space Technology category, space technology projects are assessed and ranked in one level. While each project is enabled by satellite technology, differences exist. Some projects involve working directly with the satellite (in design and development), while others interact indirectly (through services or data). Projects are ranked on the Mission Ladders according to the country's direct or indirect involvement.

Once all the countries in a category are evaluated, the target country was selected according to the number of projects and their relevance. The Technology Country Ladder also shows that it is more important to have a level A project than a level F project. It is worth noting that selection will be based on a qualitative process. It cannot rely on an accurate mathematical weighting algorithm due to the presumed lack of information and transparency in some countries, which makes us assume that the number of projects in some classes might be higher.

In the Low (or non-existing) Space Technology category, there are no benefits from applying a technology framework to countries which hardly produce spaceborne technology. Consequently, other factors like culture, social development, technology level, infrastructure, and geographic diversity will be taken into account to ensure that all three chosen countries represent the diverse African continent.

High Space Technology Countries

Algeria, Egypt, Nigeria, and South Africa, are already capable of undertaking many space related projects, and are the most advanced African countries in the space field. All these countries have a national space agency and have developed some form of space policy. Apart from the information obtained in the Technology Country Ladder, the geographical location, economic and political characteristics of each country were also taken into account when selecting the High Space Technology Country. The country selected from this group shall have advanced existing space capabilities and the most potential to pursue further development in the space sector. The results obtained after applying the Technology Country Ladder methodology are shown in Table 2-3.

Table 2-3: Country Technology Ladder for High Space Technology countries.

Country Technology Ladder		**Nigeria**	**South Africa**	**Egypt**	**Algeria**
Level	**Activity**				
Satellite Infrastructure					
A	Satellite assembly integration and test facilities	0	1	0	0
B	Satellite design and development facilities	1	3	1	0
Satellite Hardware					
C	Design, build, operate satellite	0	3	4	1
D	Buy and operate satellite; train in satellite design/build	4	0	1	2
E	Operate others' satellites	0	2	0	2
F	Contribute to collaborate satellite project	3	2	4	0
Satellite Services					
G	Lease satellite capacity and distribute service	3	2	2	0
H	Operate ground segment to send or receive satellite data	1	5	2	1
I	Process satellite data and create data products	1	1	5	1
J	Use satellite data products	1	2	1	1
K	Participate in regulatory action regarding satellites	2	2	1	2
Total Projects		16	22	21	11
Total: Satellite infrastructure projects		1	4	1	0
Total: Satellite hardware projects		7	6	9	6
Total: Satellite services projects		8	12	11	5

As seen in Table 2-3, Egypt and South Africa lead the ranking with the highest number of projects. Since the difference between these countries is minimal, emphasis was placed on the relevance of the assessed projects. Regarding satellite infrastructure, South Africa has four A and B level projects. The recently established South African National Space Agency (SANSA) has resuscitated a pre-existing satellite test facility known as SANSA Space Engineering. South Africa also relies on several organizations that are capable of satellite design and technology development (e.g. University of Stellenbosch, the Cape Peninsula University of Technology, and the Sun Space and Information Systems firm) (Wood & Weigel, 2012). These projects, compared to Egypt's one B level project, places South Africa at the top of the Technology Country Ladder assessment methodology. The current political unrest in Egypt was also taken in account. Political instability complicates space asset and infrastructure development, which results in a nation's space program plans being stifled. Long-term space requirements demand consistent and reliable funding and support, so a stable political regime is essential for developing space projects. The High Space Technology country chosen is South Africa.

South Africa presents an attractive balance between its current capabilities and its potential for development. South Africa has the potential to have space capabilities comparable with American, European, and Asian space powers, and details of the country itself are discussed in the next chapter of this report.

Medium Space Technology Countries

The medium space technology country category is intended to represent developing countries that lack a space agency and operational satellites but use space applications extensively and are in the early stages of developing domestic space infrastructure and capabilities. Five African countries fitting this description were identified. These are: Ethiopia, Ghana, Kenya, Libya, Morocco, and Tunisia. Each of these countries already possesses a national remote sensing center and makes use of satellite telecommunications.

In this case, because none of our candidates own facilities for building satellites, is appeared fruitless to use the complete Country Technology Ladder methodology. Satellite infrastructure types were therefore removed from the ladder for our medium space technology country, shown in Table 2-4.

Table 2-4: Country Technology Ladder for Medium Space Technology countries.

Country Technology Ladder		**Kenya**	**Libya**	**Ghana**	**Morocco**	**Ethiopia**	**Tunisia**
Level	**Activity**						
Satellite Hardware							
A	Design, build, operate satellite	0	0	0	1	0	0
B	Buy and operate satellite; train in satellite design/build	0	0	0	1	0	0
C	Operate others' satellites	0	0	1	0	0	0
D	Contribute to collaborate satellite project	2	1	0	0	0	1
Satellite Services							
E	Lease satellite capacity and distribute service	3	0	1	1	1	0
F	Operate ground segment to send or receive satellite data	8	1	1	3	0	1
G	Process satellite data and create data products	3	1	1	2	0	0
H	Use satellite data products	5	1	1	2	0	1
I	Participate in regulatory action regarding satellites	3	0	1	2	1	31
Total Projects		24	3	6	12	2	34
Total: Satellite hardware projects		2	0	1	2	0	0
Total: Satellite services projects		22	2	5	10	2	33

Taking into account the total number of projects requires shortlisting Kenya, Morocco, and Tunisia. Once again, it is not the quantity of projects, but their quality and relevance. Consequently, Morocco is selected as the target country because its activities include the construction of two satellites, which prevails over the operating activities of Kenya and Tunisia. Besides space activities, Morocco offers the best balance of a favorable economic climate (including extensive foreign investment), existing and potential space applications, and longstanding political stability. Morocco is discussed in greater detail in the next chapter of this report.

Low Space Technology Countries

As mentioned previously, the remaining African countries do not have a sufficient number of space technology projects to justify using the Technology Country Ladder methodology. Therefore, other criteria were considered for selecting the third target country.

The IDEAS for Africa team investigated the conditions in the least space-capable African countries, which comprise a large majority of the African continent. These were evaluated with regards to their social characteristics (including political, economics, and health) as well as their physical characteristics (including geographic, agricultural, and infrastructure) which would lend themselves to improvements from a variety of space-related applications and innovations

While many African countries are troubled, Liberia has been selected for further investigation. Located in the Equatorial Africa, the country is largely Anglophone and has plentiful resources including rubber and timber. Most importantly, its people are eager and prepared to make changes to improve. A long and ghastly civil war ended in 2003, and since 2005 Liberia has regained a fragile stability under its current president, Ellen Johnson Sirleaf. Liberia is discussed in greater detail in the next chapter of this report.

Further reasoning for selecting Liberia for space development is that it has vast mineral resources. If properly managed, the iron ore, gold, and palm oil can be brought to market (CIA, 2011c). However, proper management of these resources is required and space applications could be of use to Liberia in this respect. While the previous target countries were selected based on a mathematical framework, the IDEAS for Africa team felt that selecting one with low levels of development would preclude mathematical examination, and needed a more individual approach. Liberia will be analyzed to determine how space can be used in countries which face such monumental challenges.

2.3.2 Summary of Country Selection

The three target countries - South Africa, Morocco, and Liberia - met our requirements for disparate characteristics. With their geographical locations (northern, southern, and central Africa), their climate and environment (desert, semi-arid, and tropical rainforest), their governance (republics and a constitutional monarchy), and in their levels of development and problems, they represent a broad representative range of Africa. As a result, the IDEAS for Africa team believes that South Africa, Morocco, and Liberia emerge as very good representatives of common African realities, and excellent discussion points for this project.

2.4 Conclusions

This chapter examined our report's six focus areas - agriculture, education, energy, environment, health, and STEM. It gave an overview of the current situation in Africa for each of these areas and found that across Africa, opportunities are being wasted and potentials are left underdeveloped.

Agriculture is an important aspect of Africa's economy, but unpredictable environmental dynamics and population pressures threaten Africa's sustainable environment. Likewise, Africa lags behind the rest of the world in healthcare and education. The healthcare industry is both underfunded and losing its most valuable workers to opportunities elsewhere. Africa's energy and educational infrastructure also needs maintenance and improvement. As with healthcare, Africa's STEM capacity and workforce is threatened by government underfunding and workers emigrating abroad.

We omitted lengthy discussions about Africa's governments, or the level and extent of political instability and cross-border and internal violence - all of which threaten Africa's future. Political concerns are largely omitted from this report, as it is unlikely that space technology can impact this area as directly as it can our focus areas.

Following our focus area overview, three target countries were selected to serve as representatives of a broad range of Africa's diverse circumstances. We chose countries based on a range of characteristics and included the Technology Country Ladder methodology to assess space readiness levels across Africa.

Based on its space experience and history, we selected the Republic of South Africa to represent Africa's most space-capable country. The Kingdom of Morocco was chosen as an example of African countries with a medium level of space technology capacity and infrastructure, based on its expertise with remote sensing and aerospace. Lastly, we decided that Liberia can serve as our least space-capable country. It represents African countries with diverse problems, including educational, energy, and health concerns which are common across Africa. Applications and innovations from space which can be used in Liberia could likely have a wide impact elsewhere.

The following chapter examines our three target countries in greater detail. We discuss general aspects of each country, along with their space capabilities (or related technological sophistication) and opportunities for further space endeavors.

3 DESCRIPTION OF TARGET COUNTRIES

3.1 South Africa



The Republic of South Africa is arguably the most developed country in Africa. It is bordered by Namibia, Botswana, Mozambique, and Zimbabwe and encloses Lesotho and Swaziland, as shown in Figure 3-1 (CIA, 2011a). While the predominant languages in South Africa are indigenous, the country has eleven separate official languages, the most common being Afrikaan, Xhosa, and Zulu. The climate varies across the country, with the eastern region being sub-tropical and the west being semi-arid, making for difficult farming conditions (CIA, 2011a).

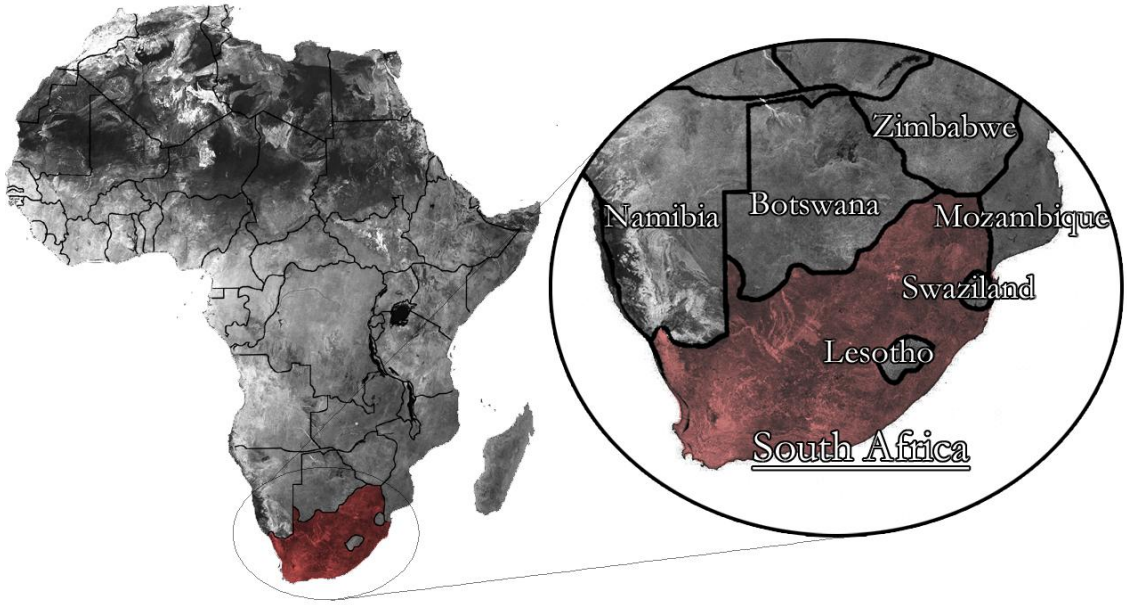


Figure 3-1: Location of South Africa and neighboring countries [Osborne, 2012].

The economy of South Africa is the largest in Africa, relying on natural resources, agriculture, and advanced manufacturing. In particular, it has a well-established aerospace and defense industry, stemming from Apartheid-era sanctions that forced South Africa to develop its own autonomous industry. Education in South African is very well established, as it constitutes the single largest federal budget expense (5.4 percent). However, South Africa is also the country with the highest number of crimes per capita in the world, and with approximately 16,000 murders, 15,000 attempted murders, 66,000 sexual assaults, and 200,000 assaults in 2010-2011. Although the country has developed tremendously in recent years, there are areas for improvement (CIA, 2011a).

Table 3-1: South Africa country facts [CIA, 2011a].

Official name	Republic of South Africa
Government type	Republic
Capital	Pretoria
Official language	Zulu
Currency	South African Rand
Area (km²)	1,200,000
Population (millions, 2012 estimate)	50
GDP (USD billions, 2011 estimate)	400

3.1.1 Space Capabilities

The 1993 Space Affairs Act established the South African Council for Space Affairs (SACSA). SACSA administers all legal aspects of South African space activities. It maintains a registry of all current objects launched into space by South Africa (South African Council for Space Affairs, 2011). However, the establishment of space activities in South Africa did not originate from the development of SACSA. It was a combination of the work completed by academics in constructing satellites, and the necessity to develop autonomous launching capabilities as a direct result of Apartheid-era sanctions against South Africa. The National Party's government developed a series of launchers (RSA-series) as well as the Overberg Test Range (OTB) to handle South Africa's defense needs when the international community was restricting trade with South Africa (Maruping, 2005).

Today, South Africa has a renewed interest in space, and in 2010 reestablished its space agency to coordinate the country's space efforts and implement its National Space Strategy. The major functions of SANSA are to implement the national space program, to advise the Minister for Science and Technology on space issues, and to acquire, assimilate, and distribute space-derived data (Pandor, 2010a).



Figure 3-2: South Africa RSA-series apartheid-era launchers (RSA-series) [Schutte, 2011].

The domestic development of satellites began at the University of Stellenbosch in 1991, with the country's first satellite, SUNSAT-1 for remote sensing, launched on 23 February 1999 (Electronic Systems Laboratory, 2011).

In addition to South Africa's capabilities in both launching and building satellites, they have a wealth of capabilities in ground-based astronomical observations. The Hartbeeshoek Radio Astronomy Observatory, built in 1975, is a 26m parabolic antenna system and remains the only radio telescope in Africa. The main dish is equipped with radio receivers that operate in the microwave bands (Gaylard, 2002). The MeerKAT is a radio telescope that is currently under construction. Upon completion, it will operate 64 parabolic antennas, each with a diameter of 13.5 m. It will be the largest radio telescope in the Southern Hemisphere.

South Africa is also bidding to host the Square Kilometer Array (SKA). South Africa is looking to use the MeerKAT to enhance and demonstrate its technical ability to host the SKA in the future (SKA South Africa, 2011). During the 1980s, South African astronomers realized that the country would fall behind in astronomical research if a major new telescope was not built. In 1998 the decision was made to construct the Southern African Large Telescope (SALT) and the project was completed in 2005. SALT is the largest optical telescope in the Southern Hemisphere, and one of the five largest telescopes worldwide (Southern African Large Telescope, 2011).



Figure 3-3: Artist's impression of a MeerKAT radio telescope [SKA South Africa, 2011].

Although no longer a launch facility, OTB still is in use as an aircraft and weapons testing facility, and there are reports of SANSA looking to use OTB once again to reestablish South African launch capabilities (Pandor, 2010b). Additionally, the nation is well-developed in terms of astronomy and South Africa has numerous observatories and is a potential site for the massive SKA project (shown in Figure 3-4).



Figure 3-4: Artist's impression of the proposed Square Kilometer Array [Square Kilometer Array, 2011].

3.1.2 Space Opportunities

South Africa has the potential to become a major player in the international space community, although this process has only just begun. SANSA was established in 2010, and is still in its developmental phase. South Africa is also unique among African countries in terms of its technical ability in the space sector. Although space activities have lingered in the past decade, the renewed government interest, combined with the infrastructure and industry legacy, places South Africa in a prime position to be a leader in space development in Africa.

The way forward for South Africa's use of space will largely revolve around the development of commercial aspects of the space industry. The country already has an established industrial sector that develops new technologies. Therefore, the introduction of space spinoff technologies, while still having an impact, may not be as effective as other forms of space development. Although satellite production in South Africa is limited, with the country only having two satellites, development of

satellite applications will be met with many challenges. It is difficult to compete with the services already provided by other nations' satellites in areas like communication or remote sensing. To benefit from satellite applications, it will be necessary to identify an area that is currently not being done by any competing satellite, and that can greatly benefit South Africa. The greatest benefit that can be provided to South Africa by space development will likely be in the area of space business. Currently there exists only one commercial space company in South Africa, Sunspace. This lack of competition in the space market provides opportunities for new enterprise to thrive.

Furthermore, thanks to its well-developed defense industry, South Africa has the high-technology knowledge base to branch off to the commercial space industry. As a rising economy, South Africa must identify niche commercial applications. It is likely that these niches will revolve around the development of South Africa launch capabilities. Located on the southern tip of Africa (see Figure 3-5), OTB is well situated for launches to both polar and eastern orbits with an inclination of 38 degrees or more (Overberg Toetsbaan, 2011). This capability gives South Africa a specific advantage over other launching countries. The development of the South African commercial space industry will likely involve the development of OTB as a permanent space launching facility.



Figure 3-5: Maps of southern Africa showing the location of OTB [Osborne, 2012].

3.2 Morocco



The Kingdom of Morocco is an emerging country with a market economy, although specific sectors still remain under strict government control. It is located in the northwest of the continent, between Algeria and Western Sahara. Its economy is the fifth largest in Africa, with an increasingly strong tourism industry (CIA, 2011b). The country gained its independence from France in 1956, and is an active member of the Arab and international community. With its largely Muslim, Arabic-speaking populace, Morocco is often regionally considered more a part of the Middle East than of Africa. It is the only African country that remains as a non-member of the African Union, although it is still deeply involved with African diplomacy (US Department of State, 2011a).

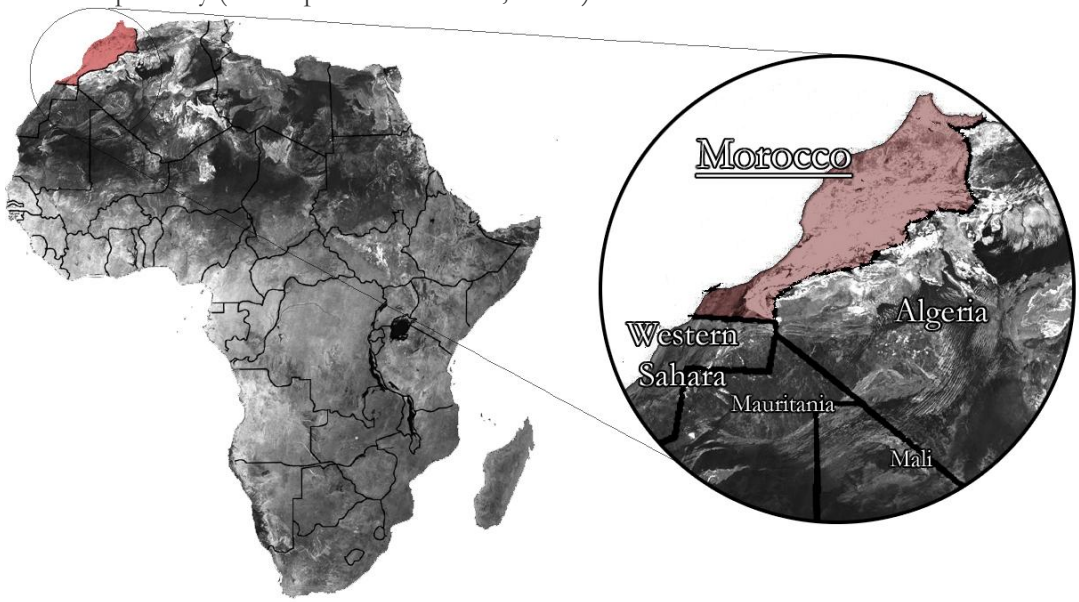


Figure 3-6: Location of Morocco and neighboring countries [Osborne, 2012].

The country is rich in many natural resources, such as phosphates, iron, manganese, lead, zinc, fish, and salt. Morocco faces a number of environmental challenges most importantly land degradation, desertification, water contamination, and oil pollution in coastal areas. General education is provided for youths aged four to fifteen, though patterns exist that favor males and city dwellers. Morocco is steadily developing its educational infrastructure.

Table 3-2: Morocco country facts [CIA, 2011b].

Official name	Kingdom of Morocco
Government type	Republic
Capital	Rabat
Official language	Arabic
Currency	Moroccan dirham
Area (km^2)	110,000
Population (millions, 2012 estimate)	30
GDP (USD billions, 2011 estimate)	150

Morocco also suffers from "Brain Drain", as was described in *the Identifying Focus Areas and Target Countries: STEM* section. In recent decades, Morocco has seen a great deal of outward emigration, typically towards Western European countries and most notably France (see Figure 3-7). Currently, more than ten percent of Moroccans are living abroad (Hein de Haas, 2007). Conversely, the majority of those immigrating into Morocco are unskilled and uneducated.

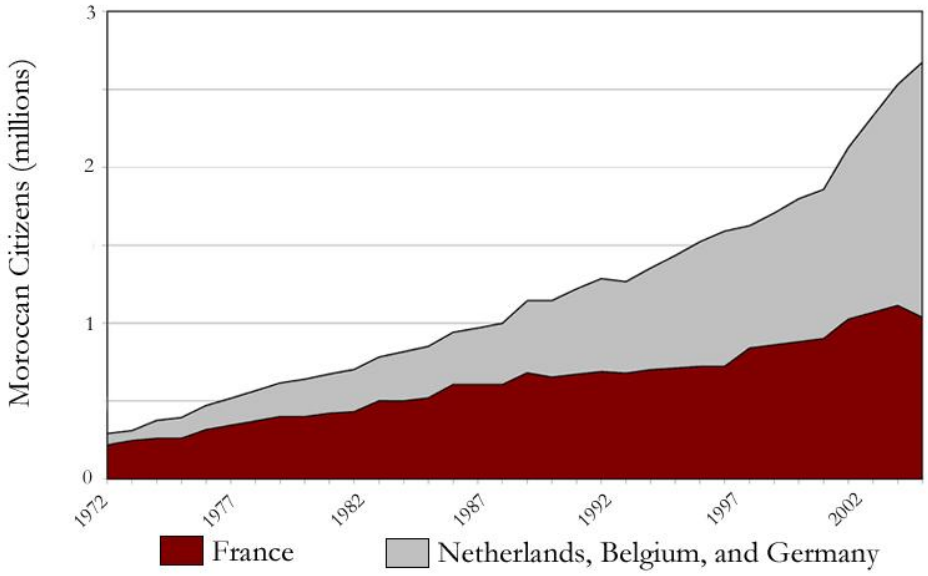


Figure 3-7: Population of Moroccans living in Europe from 1972 to 2005 [Focus Migration, 2009].

3.2.1 Space Capabilities

Due to its relative proximity to Europe, and its position between the US and Asia, Morocco attracts a great deal of foreign investments, including the aerospace industry. There are currently over 100 European and US companies working in Morocco, including European Aeronautic Defense and Space Company, Boeing, The Safran Group, Daher, Souriau, and Zodiac Aerospace. These companies create more than 7,000 jobs in Morocco (*Groupement des Industries Marocains Aéronautiques et Spatiales*, 2010), with GIMAS playing the role of managing and organizing the aerospace sector (BCI Aerospace, 2011). In 2001, Morocco launched its first remote sensing microsatellite. Dubbed the Maroc-Tubsat (see Figure 3-8), it was built by the Technical University of Berlin (Space and Tech, 2001).

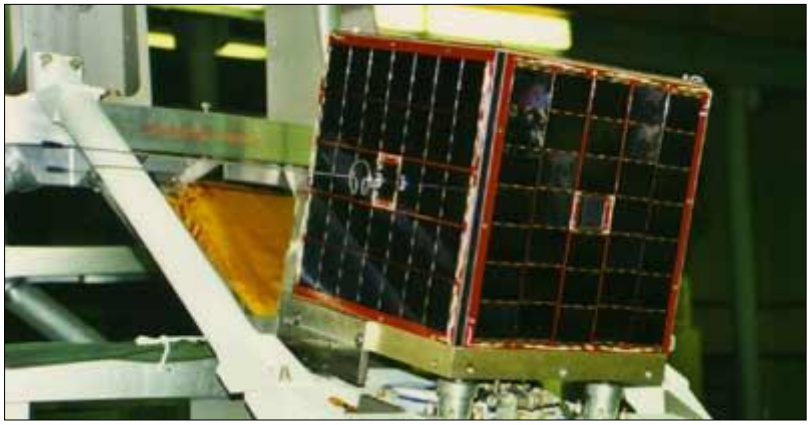


Figure 3-8: Maroc-Tubsat is Morocco's only satellite [Krebs, 2012].

3.2.2 Space Opportunities

Considering Morocco's current social challenges and problems, and its space and space related capabilities and opportunities, there are a number of ways that Morocco can benefit from innovations from space.

Spinoffs from space can be used to improve conditions in a variety of areas, including healthcare and energy independence. Despite the large proportion of the economy based on agriculture, Moroccans still use archaic agricultural techniques.

Satellite applications could also be applied to accelerate Morocco's development. For example, satellites are frequently used today to improve agriculture and farming techniques, and these can be employed in Morocco. Satellites can also be used to monitor and manage desertification. Although communication infrastructure is already fairly prevalent in Morocco, a need still exists to connect rural and urban areas, which could be done by satellite communication and internet. Monitoring the flow of immigrants and emigrants using satellites can aid crime reduction, skill retention, and even illegal trade. Satellite applications can also potentially be used to monitor the ports, as this is an area that is expected to see a surge in growth in the coming years, which means new opportunities but also new challenges.

Aerospace is already a part of the Moroccan economy, and broadening into space is an attractive possibility. As stated previously, Morocco is well situated for high-technology development because of its high amount of foreign investments, cooperation with well-developed countries, and its various international trade agreements. However, Morocco must identify the ways and areas where it can provide unique services and capabilities, and retain and produce more skilled and educated workers.

As an emerging nation, Morocco is well-poised to use new space capabilities to foster socioeconomic growth. It is likely that the greatest benefit from space applications will come in the form of spinoff technologies and satellite applications. As stated before, there are a number of reasons why educated workers leave Morocco to establish businesses in other countries, and this will make it difficult for Morocco to develop domestic space businesses.

One of the unique ways in which Morocco can thrive from space applications is in part due to its tenuous relations with neighboring countries. One area that warrants further investigation is how Morocco can implement satellite applications which to combat desertification, illegal movement of peoples, or for agricultural management, and use these applications to improve relations with its neighbors.

3.3 Liberia

3.3.1 Socioeconomic Description



The Republic of Liberia was established in 1847, and is situated in West Africa. It shares a border with the Ivory Coast, Guinea, and Sierra Leone (see Figure 11). The country has been devastated by two lengthy civil wars, which began in 1989 and finally ended in 2003. In 2005 President Ellen Johnson Sirleaf was democratically elected, in a period when the unemployment rate had reached a record of 85 percent. A relative stability has been achieved under the new government, but the country's severe and ongoing socio-economic and security problems remain unresolved. The presence of the United Nations (UN) is evident throughout the country, with a force of more than 18,000 peacekeepers. (CIA, 2011c).

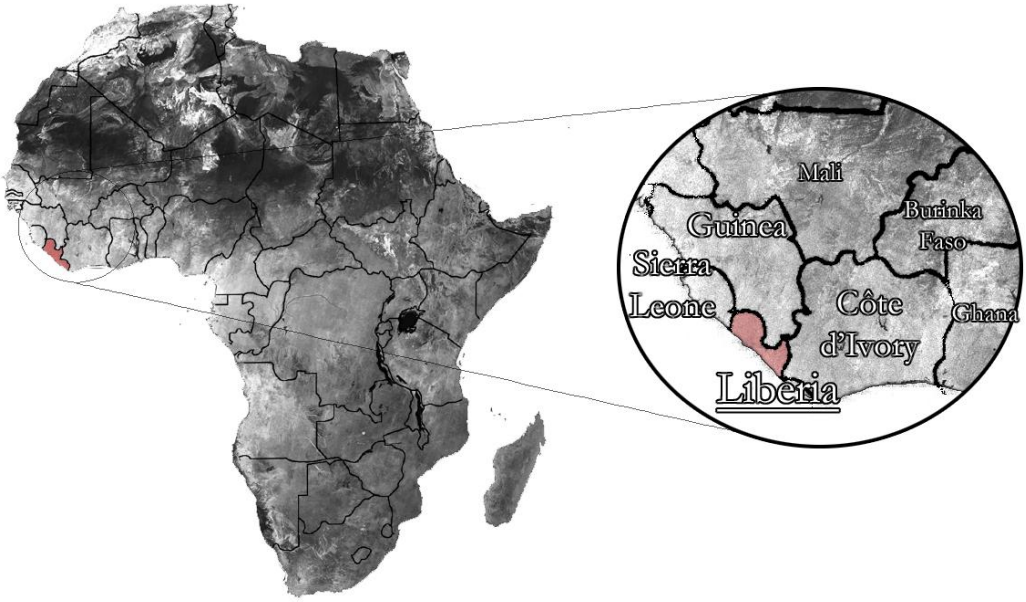


Figure 3-9: Location of Liberia and neighboring countries [Osborne, 2012].

The country has a plethora of natural resources; mainly iron ore, timber, diamonds, gold and hydropower. The terrain is mostly flat and favors agriculture significantly. These resources however, are predominantly used by foreign investors and the Liberian people hardly see any benefits, with mining companies often seeing higher profits than the total revenue of the government (Van der Kraaij, 2010).



Figure 3-10: Liberian President Ellen Johnson Sirleaf (right) after inauguration for her second term in office (16 January, 2012 [Ministry of Information, Cultural Affairs & Tourism, 2012].

Liberia has a focused strategy to collaborate with international players to revive its economy while fighting corruption. The new government's primary goal is to improve the country's credit rating and to issue bonds. Liberia depends heavily on foreign investments for revenue, having the highest ratio of direct foreign investment to GDP in the world. The end of the civil war has boosted the economy due to the return of some businesses and experts that had fled the country during the turmoil. Although it achieved a growth rate of six percent in the past year, Liberia's GDP still remains one of the lowest in the world, estimated at USD 1.2 billion for 2011 (ranking 191st worldwide). The GDP per capita ranks even lower at approximately USD 400 per person (CIA, 2011c). Liberia produces and exports mainly raw timber and rubber but local manufacturing remains underdeveloped. The labor force of the country is more than 1.3 million, with 70 percent employed in agriculture. The new government lifted embargos on timber and diamond exports, to increase government revenue. In 2010 nearly USD 5 billion of international debt was permanently eliminated. Liberia has the second largest number of ships flying under its flag, but this is largely due to tax avoidance as well as to bypass national labor and environmental regulations (UN Conference on Trade and Development, 2009).



Figure 3-11: A cargo ship docking in Hong Kong bears the Liberian flags [Flickr, 2009].

Liberia is attempting to rebuild and reenter the world as a stable and prosperous nation. To meet this goal, it will have to face and overcome numerous challenges. Household problems include a lack of access to electricity, water, and basic sanitation facilities. The country also does not have working public utilities. The current state of the healthcare system is a growing setback in Liberia. HIV is a major problem in the country due mainly to the civil war at which time rape and sexual slavery were rampant. Most of the services in the health sector have been provided by international Non-Government Organizations (NGO) and UN agencies. The civil war also promoted the spread of illiteracy, and now illiteracy has been declared as the second enemy of the state (the first being corruption), with illiteracy rates reaching in excess of 57 percent overall (Daygbor, 2007). Funding for schooling remains so low that only one in three schools have functioning flush toilets, and one in four public schools have access to a functioning watering point (US Department of State, 2011b). During the civil war the country's human resources suffered from a brain drain and crisis-related deaths. Bad governing, embezzlement, smuggling of natural resources, and economic mismanagement are still prominent and continue to hurt vital socio-economic infrastructure (UN, 2006). Among the most important environment challenges facing Liberia today are tropical rain forest deforestation, soil erosion, loss of biodiversity, pollution of coastal waters from oil residue, and raw sewage (CIA, 2011c).

Crimes in the country are mostly crimes of opportunity, with an occasional residential burglary, and armed robbery (use of knife or machete), with current policing capacity unable to properly respond to criminal activities. Moreover, the police are ill-equipped and largely incapable of providing effective protection or investigation. Corruption is endemic mainly due to the low pay and lack of training in the civil service area. Another contributor is the inefficiency of the court system and other governmental bodies directed to look into the various cases of alleged corruption. The issue of refugees in Liberia has become a major problem because many of the people who left Liberia during civil war have returned and at the same time refugees from neighboring countries have entered the country, adding to the current population and hence exacerbating the problems (CIA, 2011c).

Table 3-3: Liberia country facts [CIA, 2011c].

Official name	Republic of Liberia
Government type	Republic
Capital	Monrovia
Official language	English
Currency	Liberian dollar
Area (km^2)	110,000
Population (millions, 2012 estimate)	4
GDP (USD billions, 2011 estimate)	1

3.3.2 Opportunities

The *Liberia: Socioeconomic description* section it clearly shows that there are many challenges that Liberia has to face. However, these challenges bring about opportunities within Liberia, not just for the government but for outside investors and the people of Liberia themselves. Some of these challenges can be resolved and their effects mitigated by applying space-based solutions. These opportunities for Liberia will revolve around the application of space spinoff technologies and satellite applications. The challenge remains for the IDEAS Team to identify the specific tools that can be taken advantage of that will have real-world positive effects for the people of Liberia. Special consideration will need to be paid towards how to make them widespread, that is how to make them a viable solution for the majority of Liberians, and not just the wealthiest or the ones in a role of power. Some of the main challenges facing Liberia, such as deforestation, illegal immigration and emigration, or civil wars can potentially be alleviated by the use of satellite applications. What space can do to help and how these actions can be implemented will be discussed in the following sections.

3.4 Conclusions

This chapter described some of the socioeconomic situations in the three target countries: Liberia, Morocco, and South Africa. Unfortunately, each of them faces several problems related to our six focus areas: agriculture, education, energy, environment, health, and STEM. The intent of this chapter was to illustrate how situations across Africa differ, and how no one solution to the multitude of challenges can be offered. Liberia, Morocco, South Africa, although part of the same continent face dissimilar issues that require innovative and specific approaches to overcome them.

In South Africa, one of the most developed countries of the African continent, there is still room for improvement in the focus areas of education, and STEM. Currently there are significant space capabilities, with a national space agency, articulated space policy, and existing infrastructure like the Overberg Test Range, Haartbeeshoek Radio Astronomy Observatory, and similar projects. These projects can be the starting point for South Africa's greater involvement in the space sector.

Within Morocco, significant large-scale projects and foreign investment can make the country well-suited to undertake more ambitious space activities. These investments in capacity building can help to alleviate Morocco's persistent agricultural, environmental, and health problems, the most important being coastal pollution, desertification, land degradation, and water contamination. The country is developing its educational infrastructure which will improve its STEM foundations. These, in the long-term, will be the core of the country's future space programs and projects.

Liberia is a country devastated by civil wars and instability. The country has issues concerning all our focus areas. After years of turmoil, Liberia is hopeful for change. The country can greatly benefit from easily implementable space-related projects related to the focus areas of agriculture, energy, and health.

In the following chapter, the IDEAS for Africa team will detail a series of proposals related to space spinoffs – inventions and innovations borne from research and development in the space industry, but repurposed to make life better here on Earth.


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PART II - IDEAS FOR AFRICA

Using three diverse African nations as examples, the IDEAS for Africa team proposes and analyzes innovative space spinoff technologies, satellite applications, and space business potentials applicable in fostering sustained social and economic development across the African continent

- IDEAS for Africa Mission Statement

This report investigated six key areas integral to the social and economic development of Africa. These focus areas (agriculture, education, energy, environment, health, and STEM) were shown to be both intrinsically linked with each other, and diverse across the African continent. Challenges to improving one focus area in one African country might be entirely different that the circumstances in another country. Moreover, there is no one simple way to address these challenges for all of Africa - a proposal to solve problems in one country will not produce the same result in another, or may even prove counter-productive.

The broad spectrum of all African countries must be somehow included. To do this, three target countries (South Africa, Morocco, and Liberia) were selected. These target countries were selected based on their social, political, economic, environmental, and geographic diversity. South Africa has a developed economy and burgeoning space industry. As an emerging economy, Morocco showcases a potential for space development. Lastly, Liberia - with an infrastructure hindered by conflicts, enjoys an increasing stability of late and shows a desire to improve. These three target countries will serve as examples for how space can impact African countries in all situations.

The IDEAS for Africa are a series of proposals that, if implemented, can bring social and economic development to Africa. The proposals will focus on three areas of the global space industry - spinoff technologies, satellite applications, and space business potentials. These areas of space activity were chosen because they represent a broad spectrum of possibilities in which countries in all circumstances can benefit. Spinoff technologies have the potential of bringing high-technology knowledge to everyday individuals. Satellite applications have the ability to unify countries to cooperate on common projects with far-reaching benefits. Finally, space businesses have the ability of energizing new industries, building and retain skilled workforces, and allow people to develop their own technologies and keep the economic benefits. Each proposal is designed to address the challenges faced within each focus area, and applicable for the three target countries. Although the proposals were selected for South Africa, Morocco, and Liberia, the intent of this report is to illustrate how these proposals can be applied across Africa.

The Appendix of this report will focus on two future frameworks for implementing these proposals - a space-oriented NGO, and an African Space Agency. It will discuss the benefits of each proposal, and then will investigate which of the IDEAS for Africa proposals are best suited for either an NGO or African Space Agency. The overall intent of the following chapters is to provide the reader with an overview of what applications of space are applicable, and how to implement these applications to foster sustained social and economic development. In the end, it seeks to answer the simple question:

What can space do for Africa?

4 SPINOFF TECHNOLOGIES

Rigorous mission constraints and harsh operating environments encountered during space missions frequently require innovative technologies. In meeting these demands, the global space industry has created a great number of high-technology innovations that are also useful on Earth. For the purposes of this report, the word "spinoffs" refers to technologies or processes that are used in applications unrelated to their original purpose.

In public awareness campaigns around the world, spinoffs are heralded as yet another justification for further investment in space technologies and exploration. NASA, for example produces an annual spinoff report, a list of featured spinoff technologies resulting from the space industry that have begun commercial application. Many of the articles in these reports emphasize how spinoff technologies could be used to improve quality of life, often mentioning the potential for application in developing nations. However, specific details and examples of how these spinoffs could be taken from their existing state and applied for public good in developing nations is rarely emphasized.

As part of the effort to demonstrate how space can be used to improve the quality of life in Africa, the IDEAS for Africa team strove to demonstrate in detail how spinoffs could be taken from their current state to real-world application in Africa. Doing so required an examination of how technologies are first spun off from their use in space to terrestrial application. An example of the NASA spinoff process is the first portion of this chapter. Secondly, the capabilities of a large variety of spinoffs had to be compared against the different needs and capabilities of the three target countries, to select a small number of promising candidates for further study. The selection process and the spinoffs selected are detailed in the second section of this chapter.

Lastly, detailed case studies of the selected spinoffs, and an analysis of the modern African market environment in which they will be applied, was required to make informed judgments as to how useful the spinoffs will actually be in a real-world application. These case studies comprise the final portion of this chapter.

4.1 The Spinoff Process

Understanding how technologies transfer from space agencies to private industries can help policy makers, commercial enterprises, and individuals to discover, distribute, and use space spinoff technologies. While many national space agencies have their own rationale and means of technology transfer, the IDEAS for Africa team found that the American approach to spinoffs had the greatest transparency and legislative documentation. Consequently, NASA's approach to spinoffs will be used as an example to describe the process. The main steps are identifying potential spinoff technologies, transferring this technology to commercial market actors, and their subsequent use by the public.

At NASA, everyone is able to propose a technology that may be a suitable spinoff. Individuals that do identify spinoffs may gain name recognition, monetary awards, and patent rights (Martin, 2012). Spinoffs can be identified from many different sources (Comstock & Lockney, 2011), including:

- Transformation of NASA technology
- Contributions of NASA personnel
- Collaborative developments
- Faculty use agreements
- Commercial endeavors by former NASA employees
- Entrepreneurs who use NASA public data and research findings

Following identification, a NASA employee or contractor files a New Technologies Report (NTR) (Martin, 2012), which then becomes part of the NASA Technology Transfer System (NTTS). The

NTTS is reviewed by NASA's Intellectual Property Office (IPO) and Patent committee. Following deliberation, the technologies can be transferred through the means shown in Figure 4-1. The basic structure of this transfer is to determine if the technology is NASA's intellectual property, if the technology is patentable, and lastly, if the NTR can be publically released.

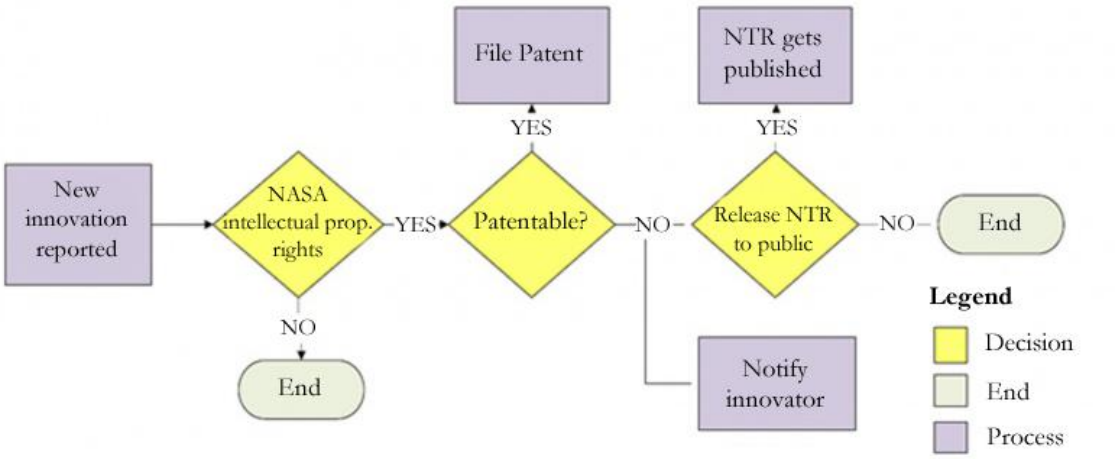


Figure 4-1: NASA's NTR reporting and tracking process [Martin, 2012].

NASA also has a few formal programs designed to promote spinoff transfer (Martin, 2012) (Comstock & Lockney, 2011), including:

- Small Business Innovative Research Program
- Small Business Technology Transfer Program
- Space Technology Development Program
- Exploration Technology Development Program
- Partnership Development and Strategic Integration Program
- Prize challenges (e.g. NASA's Centennial Challenges) (NASA, 2012)

Based on the findings of the IPO and Patent committee, NASA will move towards establishing and implementing partnerships, or in some cases, doing a controlled release of the technology to the general public. If the committee does not act on a NTR the file remains within the NTTS database.

Understanding the process by which a spinoff is adopted and developed will greatly increase one's ability to use spinoffs. NASA often rewards employees and contractors with the patent rights for correctly identifying one. As stated previously, there is the potential for individuals outside NASA to propose spinoffs, creating an opportunity for individuals or organizations to come up with some that would be particularly beneficial for Africa.

4.2 Selection Methodology

The IDEAS for Africa team first investigated databases published by several space agencies, to develop a comprehensive list of possible spinoffs for detailed study. The spinoff and technology transfer offices of NASA, European Space Agency (ESA), Indian Space Research Organization (ISRO), Japan Aerospace Exploration Agency (JAXA), and US National Space Biomedical Research Institute (NSBRI) were all consulted. From the dozens of spinoffs detailed in the respective databases, a shortlist of potential candidates for further study was created, based on low cost and applicability in Africa, as shown in Table 4-1.

Table 4-1: Spinoffs considered for further investigation.

Spinoff Name	Space Agency
Thermal insulation paint	ESA
Car components	ESA
Distress alert transmitter	ISRO
Direct-to-home disaster warning dissemination system	ISRO
Automatic weather station	ISRO
Search and rescue beacon	ISRO
Solar light and heat hybrid power system for educational purposes	JAXA
Organic waste recycling equipment	JAXA
Sterling engine for education use	JAXA
Water purification system	JAXA
Heat insulation and noise absorbing interior material for buildings	JAXA
Fabrics to protect skin from ultraviolet rays	NASA
Docosahexaenoc Acid (DHA) for nutritional supplements	NASA
Regenerative iodinated resin beds for water purification	NASA
Organically-derived Colloidals (ODCs) as a natural pesticide alternative	NASA
Therapeutic ultrasound device for mission-critical medical care	NASA
Inflatable antennas for emergency communication	NASA
Polymer fabrics for firefighters and military protection	NASA
Solid Oxide Fuel Cells (SOFC)	NASA
Lab-on-a-chip blood analysis	NSBRI
Critical care dialysis system	NSBRI
Critical care dialysis system	NSBRI

Based on a rough analysis of the cost f the spinoff, its ease of use, power requirements, simplicity of implementation, technological maturity, ability to aid socioeconomic development, overall quantity of information available, as well as its application for the six focus areas, the IDEAS for Africa team selected three from this list for detailed investigation:

- ODCs to be used as a pesticide replacement in conjunction with Aeroponics
- DHA for nutritional supplements
- SOFCs for inexpensive electrical generation and possible development of a distributed electrical infrastructure

4.3 Organically Derived Colloidals

One of the spinoff technologies developed from NASA's Space Shuttle program are Organically Derived Colloidals (ODCs), with Aeroponics growing systems. ODC are a plant growth promoter sprayed on plants grown in suspension, which provides nutrients and reduces fungal infections. Tests onboard the Mir space station produced significantly higher crop yield rates, with a lower rate of fungal infections (National Technology Transfer, 2006). ODCs were synthesized by NASA sponsored research aboard the Mir space station. It was pioneered by Richard Stoner, who went on to become the founder and president of AgriHouse Inc, which is the company formed to bring the technology developed from the research to consumers as a commercial product. ODCs can be applied to both traditional (i.e. soil-based) and aeroponic (i.e. without soil) growing methods. However, the implementation of ODCs in an Aeroponic growing environment has been shown to produce significant benefits over those grown in soil-based environments. According to a NASA

report on the method of growing "progressive plants", the soil for traditional growing methods provides a possibility for contamination. The article states that aeroponically grown plants have also shown to uptake more minerals and vitamins (National Technology Transfer, 2006). In conjunction with Aeroponics, the use of ODCs can result in lower growing costs, higher nutritional content, and more effective uses of crop land.

The following is a spinoff designed to address the focus areas of agriculture, environment, and health. As will be shown, ODCs and Aeroponics have a great potential for enhancing food security and nutrition, directly affecting the health of Africans. Moreover, a means of crop growth with higher yields and less water usage will promote agricultural development without harming the environment. Lastly, because of the reduced water requirements of extreme low cost of ODCs and Aeroponics, it will be shown that this spinoff is best applied to the target countries of Morocco and Liberia. The following section will provide an overview of the technical aspects, the benefits, the financing, an implementation assessment, and finally an ethical consideration for the ODC and Aeroponics spinoff.

4.3.1 Technical Overview

ODC is an organic disease control product that helps to reduce plant losses by mitigating the effect of invasive species. It simulates a plant's natural defense system in the presence of pathogens, and then switches off when the disease is eliminated. The main element of the ODC is Chitosan, produced from the exoskeleton of crustaceans (like lobster, crab, and shrimp), which acts by inducing a defense response from plants. The ODC molecules will first cling to cells in the tree roots. Once these molecules have attached to the plant cell receptors, a chemical response is activated throughout the plant that stimulates photosynthesis and helps to overcome environment stresses, like invasive species (NASA, 2006).

ODCs can be applied at any time of the plant life cycle - to seedlings before planting, when the seeds began to sprout, or during the entire planting season. ODC are a biologically safe plant supplement that strengthens the plant structure to prevent fungal infections. They contain no enzymes, hormones, petrochemicals, acids, or manure source, and do not harm plant mineral uptake. ODCs have been applied to various crops including yams, potatoes, coffee, corn, carrots, cauliflower, soybeans, spinach, peas, papaya, melon, cucumbers, rice, papaya, tomatoes, and apples (Aeroponics International, 2011). The effects of ODC on tomatoes and spinach are shown in Figure 4-2 and Figure 4-3, respectively.



Figure 4-2: Effect of ODC on tomatoes shows enhanced growth in soil-based growing [AgriHouse, 2011].



Figure 4-3: Effect of ODC on spinach shows enhanced growth in soil-based growing [AgriHouse, 2011].

Aeroponics is the method of growing plants in air. The system ensures that plants are enclosed in an air or mist environment, requires no soil, and uses approximately 98 percent less water than traditional growing methods. Support structures with holes around two and a half centimeters in diameter hold the plants in the air. The roots hang through these holes, putting them in contact with the mist, as shown in Figure 4-4 (Aeroponics International, 2011).



Figure 4-4: An Aeroponics system with its roots exposed to mist and not soil [The Young Agropreneur, 2011].

To grow the plants from seedlings, they are put in a mesh underneath the plant support structure. A control system delivers a nutrient-rich solution to the water jets in the lower portion of the chamber, which create a spray that reaches the stem and root areas, giving adequate moisture and nutrients to the plants. The force of this spray also acts to remove any contamination or pathogens attaching to the plants or root sections. Using the reverse osmosis equipment, all viruses and bacteria are eliminated from the water. Growth hormones can also be separately injected, or in conjunction with the nutrient (Aeroponics International, 2011). Vapor and humidity levels are maintained within the system, and at the end of each pulse, the water and nutrient solution are drained from the system and pumped back into the chamber. Advanced aeroponic systems require specific operational conditions, including adequate ventilation, fresh water, sufficient light, temperature control, and a sterile environment.

4.3.2 Benefits

The main rationale behind ODC in conjunction with Aeroponics, is to address the issue of malnutrition in Africa. One way that ODCs and Aeroponics do address malnutrition is by increasing the total crop yield over a planting season versus traditional soil-based farming, by accelerating the germination process. For example, a tomato plant's growth in soil is dependent on the seasons, and typically only two harvests can occur during the planning season. Using Aeroponics, however, the increased growth rate results can increase the number of harvests to six per growing season (NASA, 2006).

ODC is also a method for promoting immediate plant production for farmers who transport crops between different growing mediums. Typically, tomato farmers will plant their tomatoes in a pot, wait 28 days until the plant sprouts, and then transfer them into another medium. With ODC this 28 day growth period lasts for only approximately 10 days (refer to Figure 4-2 and Figure 4-3) (NASA, 2006).

In addition to the growth benefits, ODC protects plants against harmful pathogens, meaning that pesticides do not need to be used as extensively (AgriHouse, 2011). Plant diseases decrease crop yield and plant quality, particularly during the seedling phase of planting. To reduce plant disease and crop loss, treatments like fungicides, soil fumigates, and chemical seed treatments have been developed. However, the pollution caused by these chemicals pose threats to food safety and public health (NASA, 2006). Minimizing pesticide use via ODCs will mean that crops produced will be healthier for human consumption.

Lastly, the use of Aeroponics for growing is a very promising growth method for Africa because the system is very efficient in low rainfall conditions. In fact, it used 95 percent less water than traditional methods (Aeroponics International, 2011). These radical savings in water consumption will have a particular benefit for regions affected by droughts. Furthermore, Aeroponic systems have the benefit over traditional soil-grown crops because they do not require large fields. They will typically accommodate 200 plants per square meter, where a traditional soil-grown method can grow only approximately 70 in the same area (AgriHouse, 2011) (Government of Saskatchewan, 2008). Aeroponics can also be grown without access to farmland, meaning that individuals without farmland can now grow their own crops independently. This feature is particularly attractive for countries that have a problem with food security. Household or community controlled systems address the issue of food security by increasing food production closer to the location of consumption. This solution also limits transportation and handling costs, while minimizing the effect that a supply chain disruption can invoke.

4.3.3 Financing

Costs

The ODCs developed from NASA research are sold by AgriHouse, a privately held United States (US) company (AgriHouse, 2011). AgriHouse holds the ODC patent and is the only company selling this product (NASA, 2006). Hence, all costing estimates for Africa are based on prices quoted by AgriHouse. The cost of the ODC formula for irrigation purposes is approximately USD 260 per 500 ml. With an estimated need of 10 ml per hectare, and an application rate of once every 30 days, the IDEAS Team for Africa calculates a cost of USD 62 per hectare per annum. Additionally, the cost of an Aeroponics system depends on the needed growing area and the average cost per square meter is approximately USD 5,250. With an estimated plant growth of 200 plants per square meter (compared to approximately 70 for soil-based farming) this means that the Aeroponics system costs approximately USD 26 per plant (Government of Saskatchewan, 2008). Of course, the Aeroponics system is a one-time-only fee. The cost for the ODC and Aeroponics are shown in Table 4-2.

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Table 4-2: Summary of costs associated with the ODC and Aeroponics.

Costing Parameter	Value (USD)
ODC Cost (per year per hectare)	62
Aeroponics Cost (per m^2)	5,000
Aeroponics Cost (per plant)	25

Funding Sources

The Food and Agricultural Organization (FAO) of the UN, and the Peace Corps, are two organizations with interests related to global food security and health, and both organizations are potential sources of funding.

The FAO is an arm of the UN that supports countries in the area of food security, nutrition, policy and strategy formulation, strengthening of production, and support systems in agriculture, forestry, and fishing. Most importantly, the FAO helps governments remove barriers to food access. It helps mobilize donors and assists in the kick-off and implementation phases of projects. Finally, the FAO reaffirms that political, social, and economically stability support food security and poverty eradication (FAO, 2012). The IDEAS for Africa team believes that the FAO could help bring the benefits of Aeroponics to food security in Africa.

A second potential funder is the Peace Corps, an international non-governmental organization focusing on improving the living conditions of rural populations. The Peace Corps contributes to food security by sending volunteers to developing countries to assist in capacity building. Although they do not provide direct food aid, the Peace Corps assists in other aspects of food security - including nutrition education, gardening, agriculture development, food processing, storage techniques, and marketing. The Peace Corps is already involved in training farmers in efficient farming techniques, and they may help provide Aeroponics training to farmers (Peace Corps, 2009).

4.3.4 Implementation

The IDEAS for Africa team recommends the implementation of ODCs and Aeroponics to enhance growing prospects in Africa. The following section details how these solutions are to be implemented.

Target Countries

There are varying levels at which ODCs can be implemented: either by applying ODCs directly to soil-grown plants to enhance growth and protect against invasive species, or used in conjunction with an Aeroponics system. As such, the implementation of ODCs in the three target countries will vary.

As stated in the *Target Country Selection* section, almost 70 percent of Liberia's employed population works in agriculture. Enhancing agricultural output and increasing food security is therefore extremely important for Liberia's development. However, the combination of terrain that promotes agriculture coupled with extremely low income levels will mean that an Aeroponics system is not likely to be implemented in Liberia. Nevertheless, the low cost of using ODC, as shown in

Table 4-2, is extremely attractive as a means to enhance crop growth in Liberia and in countries like it. Using Aeroponic growing techniques is not recommended for implementation at this stage due to the high initial investment cost of aeroponic infrastructure. The use of organically derived colloidals would provide a beneficial contribution to the agriculture industry in Liberia.



Figure 4-5: Liberian agriculture mostly consists of subsistence farming [Lee, 2008].

The conditions that exist in Morocco, as described in the *Target Country Selection* section, may be prohibitive for the deployment of both ODCs and Aeroponics. Although a major portion of the Moroccan economy relies on agriculture, the population uses many archaic techniques and may be reluctant to embrace new systems. Furthermore, the desert conditions of Morocco invoke the need to implement the Aeroponics system, but the high initial investment required, as shown in

Table 4-2, may be prohibitively high. The most efficient approach is likely a slowly implemented ODC system, with a population gradually adapting from their traditional practices to the Aeroponics system. See the *Organically Derived Colloidals: Ethics* section for a discussion on the ethics of changing traditional farming practices. While implementing ODCs and Aeroponics may not be initially feasible, Morocco will ultimately need to apply sustainable agricultural methods that work with their desert conditions.

Finally, in South Africa, the conditions exist for the implementation of both ODCs and Aeroponics. South Africa has very poor conditions for crop growth, with only approximately 11 percent of the land being arable (CIA, 2011a). Furthermore, the higher GDP in South Africa over other African countries means that the high initial investment for the Aeroponics system is not prohibitively expensive. As such, the implementation of both ODCs and Aeroponics in South Africa is recommended.

Application to Other Countries

As stated in the *Implementation: Target Countries* section, the degree of implementation will depend on the particular needs and conditions that exist in any African country. One of the main advantages of ODCs is the inexpensive nature of the product and the almost immediate effects on plant growth. Any African country that has difficulty in food production and security can implement ODCs, regardless of their economic situation. For example, in Zimbabwe almost 80 percent of arable land is used for agriculture, and yet 30 percent of the population is malnourished. Or similarly in Chad where agriculture accounts for more than 50 percent of GDP, and yet up to 40 percent of the population is malnourished (FAO, 2011). These are just two examples, but the situation is similar across the continent and hence this proposal has many potential applications.

In addition, African countries that have difficulties with invasive species destroying crops can implement ODCs to prevent damage to crops without using harmful pesticides. For example, the 2004 locust outbreak in the west and north of Africa which cost the FAO almost USD 60 million

illustrates the need to develop methods of fighting invasive species (FAO, 2004). Moreover, countries that have difficult growing conditions because of desert conditions (e.g. countries within the Sahara desert including in Algeria, Chad, Egypt, Libya, Mali, Mauritania, Niger, Western Sahara, Sudan, Tunisia, and the target country Morocco), will benefit from the implementation of an Aeroponics growing system in that they will be able to increase crop yield without using water resources that can be used for other applications. There are certain African countries which use Aeroponics currently, including Kenya, Uganda, and Malawi (Lung'aho et al., 2010). These countries would therefore not have an application for Aeroponics.

Technological Availability

The technology for the ODCs and Aeroponics currently exists and is available from vendors such as AgriHouse (AgriHouse, 2011). The readiness of the technology will not be the limiting factor preventing ODCs and Aeroponics from being brought to market. However, logistical issues surrounding the development and deployment of Aeroponics will instead be the limiting factor, as discussed in the next section.

Time to Deployment

There are a few factors to take into account when considering the time estimation of deployment of a complete ODC enriched Aeroponics farm. In places where the soil is sufficient to grow crops, the method of using ODC can be implemented on an order of days from the delivery of the ODCs. The benefits of ODC will be seen in the first harvest. For example, tomato growers take approximately two months to harvest plants with ODC, compared to the traditional six to eight months for traditional growing methods (National Technology Transfer, 2006). In places with insufficient soil or drought that necessitate the Aeroponics system, the time to deployment is significantly longer, weeks for smaller systems, to months or years for larger systems. Entire farms can be replaced with Aeroponics, but this requires the necessary funding and maintenance. The system for larger farms can be built from scratch or bought from companies that sell enclosed greenhouses, like Synergy International Inc. (Synergy International, 2007).

4.3.5 Ethics

As described in the *Implementation: Target Countries* section, one of the ethical concerns over the implementation of ODCs and Aeroponics is the replacement of traditional farming techniques. Of the target countries, these concerns are particularly acute in Morocco, where traditional farming is the most widely practiced (refer to *Target Country Selection* section). Consequently, implementation should not be forced upon the citizens of Africa. The benefits of the product should be showcased, and the individual farmers should be the ones to make the decision regarding its implementation.



Figure 4-6: A Moroccan practices traditional farming [Knots, 2012].

Furthermore, there are ethical considerations when using chemicals to alter food growth. ODCs are organically derived from crustaceans, and they are not as controversial as chemically produced pesticides or genetically engineered food. However, ethical considerations should be addressed whenever considering the implementation of ODCs in countries that historically have not supported chemically enhanced food.

4.3.6 SWOT Analysis

The IDEAS for Africa team has recommended the implementation of ODCs in conjunction with an Aeroponics growing system to increase crop production rates and nutritional value, to protect against invasive species, and to promote food security in Africa. The intent of this spinoff is to address the agriculture, environment, and health concerns which this report is specifically addressing. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the ODC and Aeroponics system was done and is shown in Table 4-3.

Table 4-3: A SWOT analysis for the implementation of ODCs and an Aeroponics growing system.

Strengths	Weaknesses
1. Faster growth cycle 2. Increased yield 3. Plants are more nutritious 4. Plants are resistance to infections 5. Biologically driven rather than chemically driven	1. High investment due to its requirement of cleanliness and sterile conditions 2. Potential policy issues on patents 3. Need to create a new market 4. No documented side effects of ODC known
Opportunities	**Threats**
1. Requirement of new infrastructures for growing crops provides business potential	1. Competing products like fertilizers 2. Public perception of biodegradable product

4.4 DHA Supplement

In the early 1980s, NASA used strains of microalgae as a food source, a supplier of oxygen, and a catalyst for waste disposal under their Controlled (or Closed) Ecological Life Support Systems (CELSS) experiments. During this research, it was realized that this microalgae could not only be used in space, but also had potential applications on Earth. In 1985, the Martek Biosciences Corporation was incorporated to undertake research with these microalgae, during which time it was discovered that a certain strain of algae naturally produced Docosahexaenoic acid (DHA) in large

quantities (Space Foundation, 2009). Martek Biosciences plays a major role in the nutritional industry with its newly marketed products called Life's DHA. This product is found in many developed countries, the implementation of which in African countries can result in significant benefits, as will be discussed in the following sections.

4.4.1 Technical Overview

DHA is a dietary fatty acid that acts as a major structural fat in the brain and retina. DHA accounts for up to 97 percent of the Omega-3 fatty acids in the brain, and up to 93 percent of the Omega-3 fatty acids in the retina (Cornucopia Institute, 2011a).

DHA acts to change specific cells properties, including cell membrane viscosity, elastic compressibility, permeability, and interaction with regulatory proteins. These impact cell modifications to the Central Nervous System (CNS) which acts to support brain functionality, in that it promotes electrical signaling in the CNS. The result of the increased signaling is an increase in learning ability and memory. High levels of DHA are deposited into the CNS during the early stages of life - notably the last trimester of pregnancy, first two months of infancy, and throughout the first few years of life (Glomset, 2006). Within the retina, DHA is found within the photoreceptive outer segments. Enhanced levels of DHA in this photoreceptive layer facilitate a faster response to stimuli, and therefore enhanced vision (Litman, Niu, Polozova & Mitchell, 2001). Without proper supply of DHA during the early stages of development, it can lead to impaired learning abilities and visual acuity (Youdim, Martin & Joseph, 2000).

DSM (*De Nederlandse Staatsmijnen*) oils have been added to infant formula since 1994 and to date an estimated 50 million babies have been fed infant formulas containing DHA (*De Nederlandse Staatsmijnen*, 2011). There have been a few reported side effects of the DHA when added to infant formula. These side effects include nausea, diarrhea and vomiting. However due to scientific uncertainty and lack of medical evidence, these side effects are still inconclusive (Cornucopia Institute, 2008).

As it will be discussed in the *DHA Supplement: Ethics* section, this spin-off has also been a part of a controversy when it was added to infant food formula in the US in the 1990s (Cornucopia Institute, 2008). Therefore, this spin-off is not recommended for application to infant food formula, and an application of only the soft-gel tablets will be discussed in the following sections.

4.4.2 Benefits

The purpose of the DHA spinoff is to promote neurological and retinal development for various stages of life, including infancy, childhood, adulthood, pregnancy, lactation, and aging. The supplement is intended to provide African populations with adequate amounts of DHA that is otherwise lost due to poor diet.

For infants (ages less than 3 years), DHA is necessary for promotion of neurological and visual performance. Studies have shown that infant formula that contains DHA result in an improvement in mental development over those that consume infant formula without DHA. Furthermore, better visual development has been shown in infants fed DHA as compared to a control formula. Both of these are measured using the Baylay PDI (Psychomotor Development Index), which quantifies progression of mental and motor skills, the result of which are shown in Figure 4-7. It should be noted here that while a statistical difference was found at 30 months of age, no statistical difference in Baylay PDI was found at 12 months of age (Jensen et al., 2005).

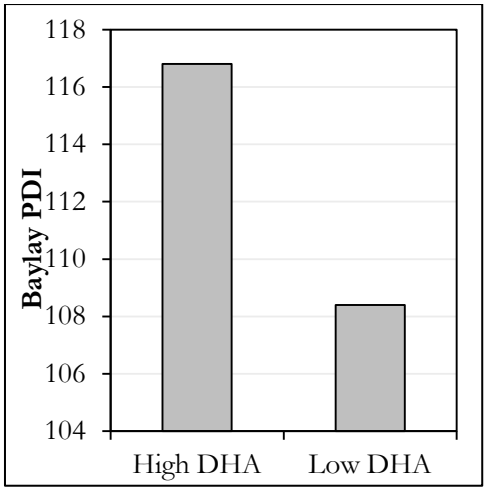


Figure 4-7: Barlay PDI scores for children at 30 months of age with mothers who exhibited high and low levels of DHA in their breast milk [Jensen et al., 2005].

For childhood (ages less than 13), there have been some studies which show a decrease in aggression and hostility for children with attention deficit hyperactivity disorder with an increase in consumption of DHA (Hamazaki & Hirayama, 2004). Furthermore, a recent study showed that for children with developmental coordination disorder, a supplement of 170 mg of DHA (including 558 mg of EPA, another Omega-3 fatty acid), increased reading age by six months, spelling age by six months, and resulted in behavioral improvements (Richardson & Montgomery, 2005).

Studies have shown that the use of DHA during adulthood (ages 20 to 50) results in an increase in perceived mood, as measured by the profile of mood analysis. The study showed an increase in vigor and a decrease in anger, anxiety, fatigue, depression, and confusion, indicating the role DHA plays in continuing neurological support (Fontani et al., 2005).

For aging populations (over 60 years of age), a study over the course of six years reported a slowing down in the degeneration of mental cognition with an increase in DHA intake (Morris et al., 2005). Furthermore, in a 12 year study an increase in DHA for aging populations showed a decrease in the frequency of stroke incidents (Mozaffarian et al., 2005).

Finally, there are benefits of DHA for women during pregnancy or lactation. During both of these phases, the primary reason for DHA intake is to promote the health of the baby. Studies have shown that mothers that consume a higher level of DHA in their diet gave birth to babies with higher cognitive developmental scores, and also had children with higher IQ scores up to the age of 4 (Daniels, Longnecker, Rowland & Golding, 2004).

The above shows that DHA supplement promotes neurological function and visual acuity throughout life. However, DHA is not only found via a supplement - it is part of a healthy diet. The main sources of DHA are fish, fish oils, crustaceans, eggs, and certain plants. DHA is most commonly consumed through intake of fish and crustaceans. Typical values of DHA in fish and crustaceans are approximately 500 mg per 100 g (US Department of Agriculture, 2005). The recommended daily intake of DHA varies, but typical values are in the range of 500 to 1,000 mg per day (DHA/EPA Institute, 2012). As such, a person can acquire their entire daily DHA intake through consumption of 100 to 200 g of fish.

Unfortunately, fish stocks in Africa are extremely limited. The current per capita supply of fish in Africa is 6.6 kg per year, indicating that a person will only intake less than 20 percent of their required DHA (World Fish Center, 2005). This low supply is a result of a decline in fishing compounded with poor infrastructure for transportation and storage. The situation is improving, as Africa remains the only location in the world where the supply of fish per capita is decreasing, as shown in Figure 4-8.

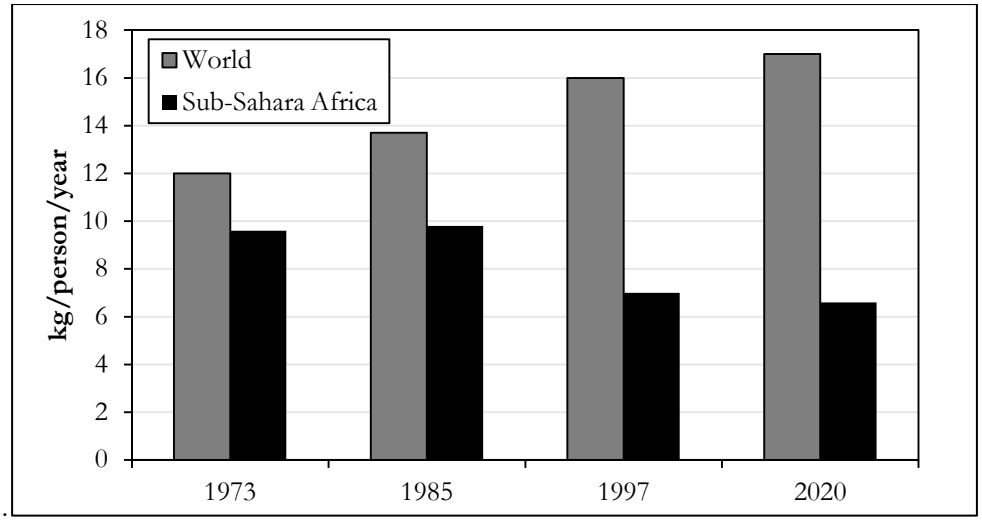


Figure 4-8: Fish availability per capita per year in Africa [World Fish Center, 2005].

4.4.3 Financing

Cost

The average cost of the DHA supplement is approximately USD 25 per 60 tablets, with this quantity lasting an estimated two months (Drugstore, 2012). Therefore, for one year the cost per individual is approximately USD 150.

The above cost estimate does not include the cost of transporting the DHA supplement, which will depend on how the program is implemented and how many people are to receive the supplement. The higher number of people that receive the supplement the lower the costs of transportation on a per tablet basis. In addition, the more rural a population receiving this supplement are, the higher the cost of transportation. It is estimated that initially the DHA supplement will be distributed in urban centers, minimizing the cost of transportation. Because this product will be implemented in large capacity, it is estimated that the transportation costs will be negligible compared to the cost of the individual tablets.

One criticism of providing DHA supplements is that the money spent on these supplements could just as easily go to purchasing food, like fish, with equivalent levels of DHA. An estimate of the cost of acquiring DHA from food sources was therefore performed. As stated in the *DHA: benefits* section, the largest source in food is found in fish and crustaceans, at approximately 500 mg per 100 g of fish. The price of fish varies, but an estimate can be made by the average price in the target country of Liberia in 2008 of USD 0.25 per 100 g piece of fish (Republic of Liberia, 2008). Using this value, the cost of providing all the recommended daily intake through fish would amount to a yearly cost of USD 90, only half the cost compared to direct DHA supplements. While it may seem prohibitively expensive to distribute these supplements, the *DHA: benefits* section discusses how supply of such products, including fish, is declining in Africa. Therefore, it must be stressed that while the supplement is not a replacement for proper diet, it can still be used to augment and support a healthy diet.

Funding Sources

One of the major obstacles in implementing the DHA supplement in Africa is to convince donors that it can be used in addition to traditional food-based aid. There is no doubt that it could never replace food aid. However, the addition of the DHA supplement can most definitively promote African nutrition in that current African diets do not get the required levels, as described in the *Financing: cost* section. In addition, the relatively low cost of the supplement makes its implementation economically feasible.

The funding sources of the DHA supplement will likely be similar to those that provide traditional food aid, including the UN Food and Agriculture Organization, the World Health Organization, the Africa Health Organization, and the UN World Food Program.

As described in the *Organically Derived Colloidals: Funding Sources* section, the UN FAO would be supportive of this supplement as it is an organization that works to promote nutrition and aids with kick-off of projects focused on this area.

This spinoff could also be implemented with the assistance of the WHO through its numerous programs already existing in Africa. These programs include the Health Promotion Cluster which focuses on food safety and nutrition, family and reproductive health, and health financing. These programs are currently active in Africa, and would provide a means of distributing DHA to individuals, particularly those in remote areas (WHO, 2012).

The Africa Health Organization is an NGO constituted to assist the people of Africa in health and social care. The organization has programs for maternal health, child growth, and is looking for new ways to assist in these areas. Because the DHA spinoff is particularly for assisting in early life and maternal health, the Africa Health Organization would be an excellent organization to assist in its deployment (African Health Organization, 2012).

Lastly, the UN World Food Program is involved with providing food care during emergency and disaster situations. One of their programs is providing food for areas affected by HIV/AIDS, as proper nutrition is necessary to protect lives of individuals living with the disease. Because the DHA supplement will augment nutrition, this spinoff is likely to be accepted by the UN World Food Program under its HIV/AIDS program (World Food Programme, 2012).

4.4.4 Implementation

The IDEAS for Africa team has recommended the distribution of the DHA and ARA supplements on the African continent to promote better nutrition. The following section details how this can be implemented.

Target Countries

The DHA supplement is a spinoff technology that has the capabilities to be implemented in any one of the three target countries because of their common need to promote nutrition. However, the main application will be for the target country of Liberia. As described in the *Selection of Target Countries* section, Liberia has one of the lowest life expectancy rates in the world. In addition, despite the large percentage of the population involved in agriculture, food security remains a major challenge. Even more, fish stocks in Liberia are lower than the average in Africa at 4.9 kg per person per year (compared to 6.6 kg per person per year as described in the *DHA: financing* section, indicating the deficiency of DHA in Liberia (World Fish Center, 2005). The low cost of the supplement and the ease to introduce it into a country makes it very applicable for Liberia. Nevertheless, with a per capita GDP of only USD 400, the USD 150 per year is prohibitively expensive for Liberians to self-finance this supplement. Consequently, the implementation of this spinoff will require external support. To supply Monrovia's roughly 1 million inhabitants (Government of the Republic of Liberia, 2008) with a yearly supply of DHA supplements would require approximately USD 150 million. Instead, to implement the economically, an assessment will have to be made regarding the population groups that are in the most need for this supplement. Groups that would be targeted for the supplement include young children and pregnant women, to allow the supplement to promote health for those who need it most while minimizing total costs.

Notwithstanding, the DHA supplement will have an application in both Morocco and South Africa. For Morocco, as was described in the *Selection of Target Countries* section, there are still major challenges in terms of infant and maternal health. South Africa, on the other hand, does not have the same difficulties in terms of nutrition as does Liberia or Morocco. The implementation of a DHA

supplement in a country like South Africa would more be from the perspective of a commercial endeavor and not strictly for the purpose of helping in nutrition. However, such an implementation is beyond the scope of this report.

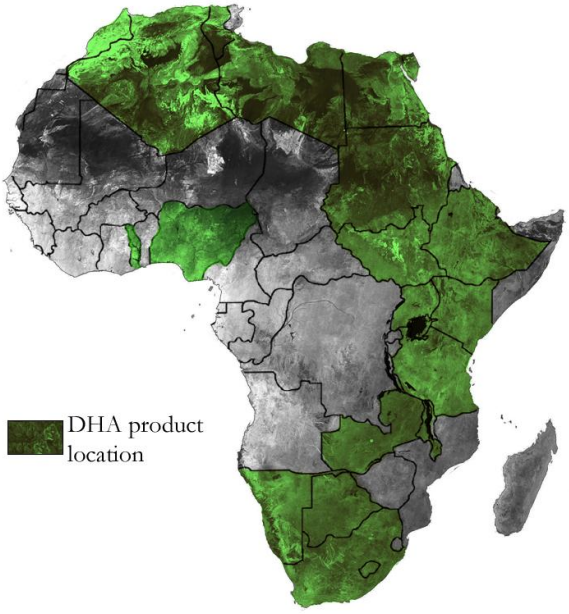


Figure 4-9: Presence of supplements from life's DHA in Africa [Life's DHA, 2012].

Application to Other Countries

Implementation of the DHA supplement will vary depending on the country of application, with the ultimate goal of full implementation across the continent (with consideration to the needs in each country). The IDEAS for Africa team envisions DHA implementation in three distinct phases. The first phase will be an identification of potential countries in Africa that could implement the supplement. These countries will likely be highly developed (like the target country of South Africa) and near regions where there are nutritional concerns. This phase will also incorporate a study of the side-effects of DHA, which will be elaborated upon in the *DHA Supplement: Ethics* section. The second phase of its implementation will be to establish regional distribution centers. These centers will be located away from the highly developed countries so that individuals in underdeveloped regions can have access to the supplements. Finally, local distribution hubs can be established to ensure rapid transport to those in need, as well as minimal costs. These three phases will allow for the supplement to be implemented across the continent to improve the dietary nutrition of Africans.

Technological Availability

DHA is a mature spinoff with a well-defined manufacturing and developing process. The technology is ready to be applied to various African countries after obtaining necessary manufacturing rights. This product can be purchased from many stores, including online stores such as drugstore.com (Drugstore, 2012). These stores have procured the distribution rights from DSM Nutrition, the holder of the exclusive rights for the DHA compounds (*De Nederlandse Staatsmijnen, 2011).*

Time to Deployment

The time estimation to deploy this spinoff is essentially negligible, the only thing needed is the financial investment and then the tablets can be purchased. However, there will be a time associated with noticeable health improvements in the population. As was described in the *DHA Supplement; Benefits* section, benefits are typically shown within the first 30 months of life for infants, with benefits taking much longer to notice for older populations. It can thus be expected that the benefits of DHA supplements will begin to appear with approximately three years of its implementation.

4.4.5 Ethics

Unfortunately there are a plethora of ethical issues surrounding the implementation of DHA tablets in Africa. These relate to the cost of DHA, the distribution of supplements from foreign entities, and lastly regarding a major health controversy that occurred in the US in 2008.

One issue arising from the implementation of the DHA supplement is that it can be argued that investments towards these would be better spent in food. While it is true that food can supply all the necessary DHA, as was described in the *DHA Supplements: Benefits* section, quantities of DHA producing food products (like fish) are expected to diminish in the coming year, invoking the need for them. Furthermore, in Africa the supplement will likely be met with resistance from certain populations who prefer to rely on traditional means of nutrition. This concern can be mitigated by showing to populations the added health benefits of DHA supplement in conjunction with their diet. It is likely that this product will be implemented slowly, and as individuals get more accustomed to the supplements than implementation can gradually expand.

There are also concerns regarding distribution of supplement to Africans from foreign entities. The supplements may be seen by Africans as a new drug that is being tested on the population. This has to be dealt with initially and will likely be done by introduction the supplements via an international body, like the UN, again with a clear demonstration of the health benefits of the supplement.

Lastly, and perhaps most importantly, is a major controversy around the addition of DHA to infant food formula that occurred in 2008 in the US. When this happened, the product was able to bypass the US Food and Drug Administration screening process and was sold on the market without being completely scrutinized. Following its release, there were reported cases of nausea, vomiting, diarrhea, increase liver size, and even Sudden Infant Death Syndrome. In total, there were 98 reports of such incidents. The reason the product was able to go to market was because Martek, the company that sells DHA, paid research institutions to examine the effects of DHA in infant formula. This meant that the effects of the infant formula were biased and not scientifically valid. Concerns still exist about the safety of DHA, particularly for application in infant formula. Therefore, prior to any introduction to African populations the effects of the DHA tablet need to be thoroughly scrutinized to ensure that it is safe for consumption (Cornucopia Institute, 2011b).

4.4.6 SWOT Analysis

The IDEAS for Africa team has recommended the distribution of the DHA and ARA nutritional supplements across the African country, but specifically in countries similar to the target country of Liberia. These supplements have been shown to improve health in all stages of life, but are particularly applicable to infant and maternal health. However, it is worth noting that countries which have access to food that supplies DHA, such as fish, would not have a use for this spinoff. A SWOT analysis was done on these supplements as shown in Table 4-4.

Table 4-4: SWOT analysis for the DHA and ARA supplements.

Strengths	Weaknesses
1. Maturated spinoff technology 2. Partial presence in Africa 3. Worldwide use 4. Safe and affordable 5. High number of health benefits	1. Large import delivery cost 2. Expires quickly 3. High initial investment for production facility 4. Conflicting studies on side effects
Opportunities	**Threats**
1. Manufacturing within African continent 2. Generation of employment and revenue 3. Promote collaboration between African nations 4. Assist ongoing UN health projects in Africa	1. Cheap and inferior quality substitute 2. Geopolitical disagreements between manufacturing countries in Africa and the subsequent countries using DHA 3. Negative public perception

4.5 Solid Oxide Fuel Cells

A fuel cell is a device which converts chemical energy into electrical energy *via* a series of reactions. Depending on the type used, this method of energy production frequently has water as a waste product, which can then be used as potable water for crews on human exploration missions (O'Hayre, Cha, Colella & Prinz, 2009). The typical one used in the space industry is an alkaline fuel cell, which combines gaseous hydrogen as fuel and oxygen as the oxidizer to produce free electrons (the electricity) and H_20 (waste product).

The lead-up for the design of Solid Oxide Fuel Cells (SOFCs) was the innovation that fuel cells could be reversed (which is the conversion of electricity into oxygen and hydrogen). In 2001, a system was designed that would convert Martian water into breathable oxygen and hydrogen gas for fuel. To meet the constraints in terms of mass, durability, and design simplicity, a new design, the SOFC, was used as opposed to conventional fuel cells. This new design prompted the formation of Ion America, now called Bloom Energy, which mass produced SOFCs for terrestrial use (NASA, 2010). Their SOFCS, called Bloom Box SOFCs, are marketed towards commercial companies as a means of generating electricity on-site at low costs using existing natural gas infrastructure as a fuel source. There are also plans to develop SOFCs for home use, which are expected to be integrated into the market in the next 5 to 10 years (NASA, 2010).

Energy and environmental concerns can be addressed with SOFCs, and they can also impact health. The following section will describe the technical characteristics of an SOFC, the benefits of using this spinoff in Africa, the financing aspects of an SOFC system, an examination of how to implement SOFCs in Africa, and the ethical considerations in bringing this technology to Africa.

4.5.1 Technical Overview

SOFCs produce electrical power through electrochemical reactions between fuels and oxidizers which convert the fuel's stored chemical energy into electrical energy. The basic structure is shown in Figure 4-10. There are two basic reactions that occur in a fuel cell; a reduction reaction and an oxidation reaction. A reduction reaction is when free electrons combine with an oxidizer (which is molecule, atom, or material that easily accepts free electrons) to produce a product. Conversely, an oxidation reaction is when a reductant is split into a product and free electron. The combination of these two reactions is called a Redox Reaction, as shown in Figure 4-10.

Oxidation Reaction

$$\text{Reductant} \longrightarrow \text{Product} + e^-$$

(Electrons **lost**, oxidation number **increases)**

Reduction Reaction

$$\text{Oxidant} + e^- \longrightarrow \text{Product}$$

(Electrons **gained**, oxidation number **decreases)**

Figure 4-10: A reduction and oxidation reaction make up a redox reaction.

The reduction reaction for an SOFC occurs on the cathode layer, whereas the oxidation reaction occurs on the anode layer. The electrolyte layer allows for the flow of the reduction reaction product, while not allowing for the passage of electrons. This means that the electrons generated in the oxidation reaction at the cathode size have to pass through a circuit, creating electricity.

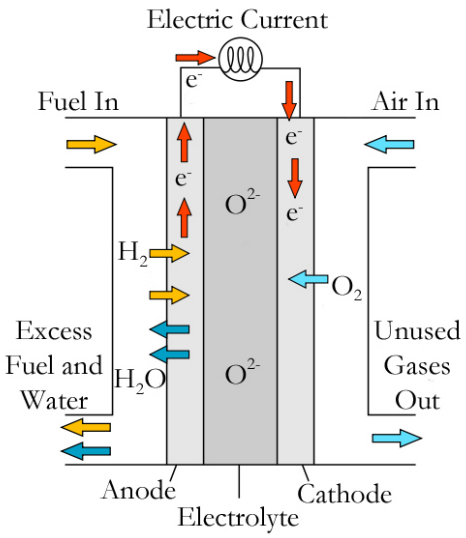


Figure 4-11: Operating principle of an SOFC [Wikimedia Commons, 2007].

Compared to traditional fuel cells such as alkaline or proton exchange membranes, an SOFC lacks an expensive catalyst. For low temperature traditional fuel cells a catalyst is necessary to initiate the redox reaction. This catalyst is made out of platinum, as there are no other materials that can initiate these reactions. However, platinum is a very expensive metal, which drives up the costs of fuel cells. Because SOFCs operate at high temperatures (ranging from 500-1000°C), they can use catalysts with much lower costs (they use a solid, non-porous metal oxide, hence the name solid oxide). Furthermore, SOFCs are capable of being fuel-flexible, meaning able to use many different fuels as their input, including fossil fuels, biogas, or methane. For energy independence, SOFCs could bring enormous benefits to Africa (O'Hayre et al., 2009).

4.5.2 Benefits

The main rationale for the use of SOFCs in African countries is to provide a means of local energy generation. Energy costs in many African countries are extremely high. In Liberia, the government spends USD 770 per MWh to produce electricity, and consumers pay USD 430 per MWh (Africa Infrastructure Country Diagnostic, 2010) This is more than four times as much as it costs for the same energy generation in the US (US Energy Information Administration, 2012a). This high cost of power is restricting the development of African countries, and reducing electricity generation costs to below USD 200 per MWh has been identified as a strategic goal for Liberia by the Africa Infrastructure Country Diagnostic (Africa Infrastructure Country Diagnostic, 2010). One of the reasons identified for the expensive cost of generation of electricity in many developing countries is the small scale of demand for electricity. Many developing countries have a higher percentage of individuals who generate their own electricity than those that are connected to the grid. In Liberia's capital, Monrovia, only 0.1 percent of homes are connected to the grid, while three percent use on-site generators (Africa Infrastructure Country Diagnostic, 2012).

An advantage of SOFCs, in particular, compared to existing generation technologies, is that it can produce electricity at costs comparable to large-scale generation facilities, but on a small scale. For example, in California the cost of generation using an SOFC can range from USD 90 to 100 per MWh (Bloom Energy, 2012), whereas hydroelectric is around USD 85 per MWh, natural gas plants are around USD 90 per MWh, and coal is around USD 110 per MWh (see Figure 4-12).

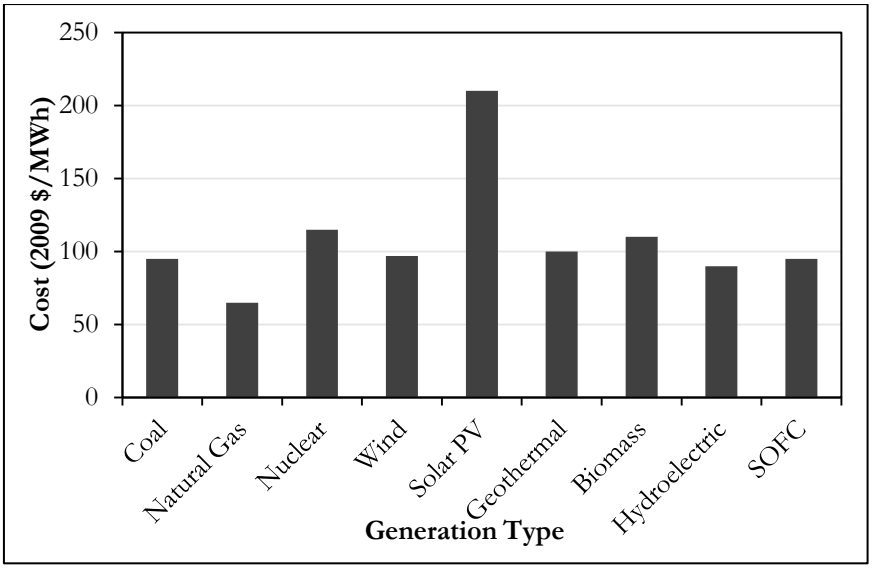


Figure 4-12: Comparative cost of electricity sources in the US [US Energy Information Administration, 2012a].

Along with cheap small-scale generation, SOFCs are fuel-flexible, using fossil fuels, diesel, natural gas, and biogas. Biogas even allows SOFCs to be carbon-neutral (i.e. producing no net increase in carbon emissions). While some modifications are needed to make SOFCs completely fuel-flexible, their adaptability means that local generation will not rely on a continuous supply of one fuel type.

Typically, consideration for local generation sources looks into renewable energy sources - such as wind, or solar - as potentials for meeting the niche application of local distribution. However, one of the main issues with this type of generation is that it is not constant, and requires a means of storing energy to use when generation is not available (e.g., during the night or when there is no wind). SOFCs can run continuously, removing the need for storage infrastructure.

Nevertheless, changing the operating level of SOFCs can be difficult, as electrical output is usually fixed at a given level and SOFCs cannot respond to changing energy demands. Therefore, a means of power generation to respond to peaks and troughs in energy demand will still be needed. The key use of SOFCs is to provide baseload power requirements, where power demands remain stable.

4.5.3 Financing

Costs

As stated in the *SOFC: Benefits* section, one distributor of SOFCs is Bloom Energy, what states generation costs of USD 90 to 100 per MWh (Woody, 2010). This estimate is based on the capital cost of the initial purchase, setup, annual maintenance, and fuel costs. However, these costs are claimed for California, USA, where government subsidies and extensive natural gas infrastructure currently exists (Woody, 2010). Therefore, to obtain a more accurate depiction of the life-cycle costs of and SOFC system, the following cost analysis was performed. Several assumptions were made in the life-cycle cost analysis, including:

- Total lifetime of ten years, after which the SOFC system must be replaced with no cost recovery during the disposal
- Technical specifications are same as for Bloom Energy model ES-5400 (USD 800,000 initial price, 18 m^3/hour natural gas flow rate, power output of 105 kW
- Estimated maintenance cost of USD 10,000 per year, time in operation of 95 percent, and an interest rate of seven percent (for capital cost estimation)
- Fuel cost estimation based on average cost of natural gas in California from 2008 (installation of first Bloom Energy SOFC) until 2011, as shown in Figure 4-13

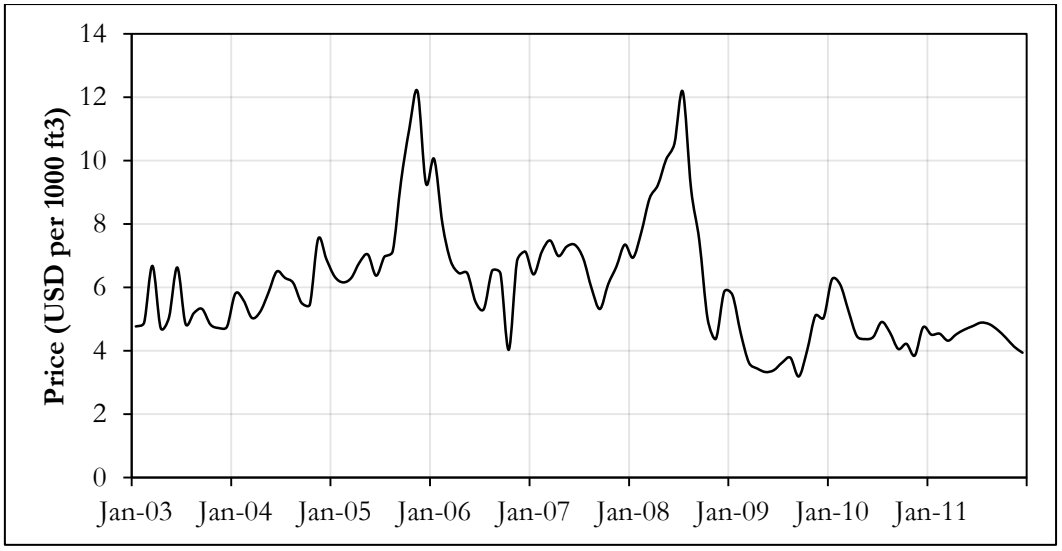


Figure 4-13: California natural gas prices from 2003 to 2011 [US Energy Information Administration, 2012b].

The analysis was first performed using Californian natural gas prices to validate the capital cost model against the actual advertised cost of the SOFC system. The results of the cost analysis are shown in Table 4-5. Based on the above assumptions, the cost of a Bloom Energy SOFC is approximately USD 140 per MWh. If California subsidies are subtracted from this estimate, the value is consistent with the advertised figure of USD 90 to 100 per MWh.

Table 4-5: Results of cost analysis of Bloom Energy SOFC system.

Item	Value	Source
Initial cost (USD '000)	800	(Bloom Energy, 2012)
Annual maintenance costs (USD '000)	40	Estimated
Time in operation	95%	Estimated
Interest rate	7%	Estimated
Capital Cost USD per kWh	**0.11**	**Based on net present value of initial and maintenance costs**
Fuel at nominal power	18 m^3/hr	(Bloom Energy, 2012)
Power output	105 kW	(Bloom Energy, 2012)
Natural gas prices (USD)	190/28,32m^3	(US Energy Information Administration, 2012b)
Fuel cost USD per kWh	**0.033**	**Based on fuel rate and power output**
NET COST (USD)	**140/MWh**	

Following the cost analysis, a sensitivity analysis was performed to evaluate the magnitude with which modifications to the Bloom SOFC could affect the net cost per MWh of electricity generation. The results of the analysis are shown in Figure 4-14. The solid lines represent the sensitivity of generation costs to parameters published by Bloom Energy; variations in these parameters are expected only occur due to modifications to the system while adapting it to African application. Dashed lines represent the sensitivity of the generation cost to estimated parameters.

Variations to published parameters all sensitively affected the cost of generation; therefore, for the cost analysis to be relevant when used in Africa, the minimum amount of modifications to the off-the-shelf SOFC should be performed to reduce the risk of increasing costs. However, of the estimated parameters, only the useful lifetime of the SOFC had a profound effect on the generation cost per MWh. As the lifetime increases, the generation cost decreases, as the user has more opportunity to pay off the fixed initial price of acquiring the system. Variations in interest rate and annual maintenance costs did not have a serious effect on the generation costs.

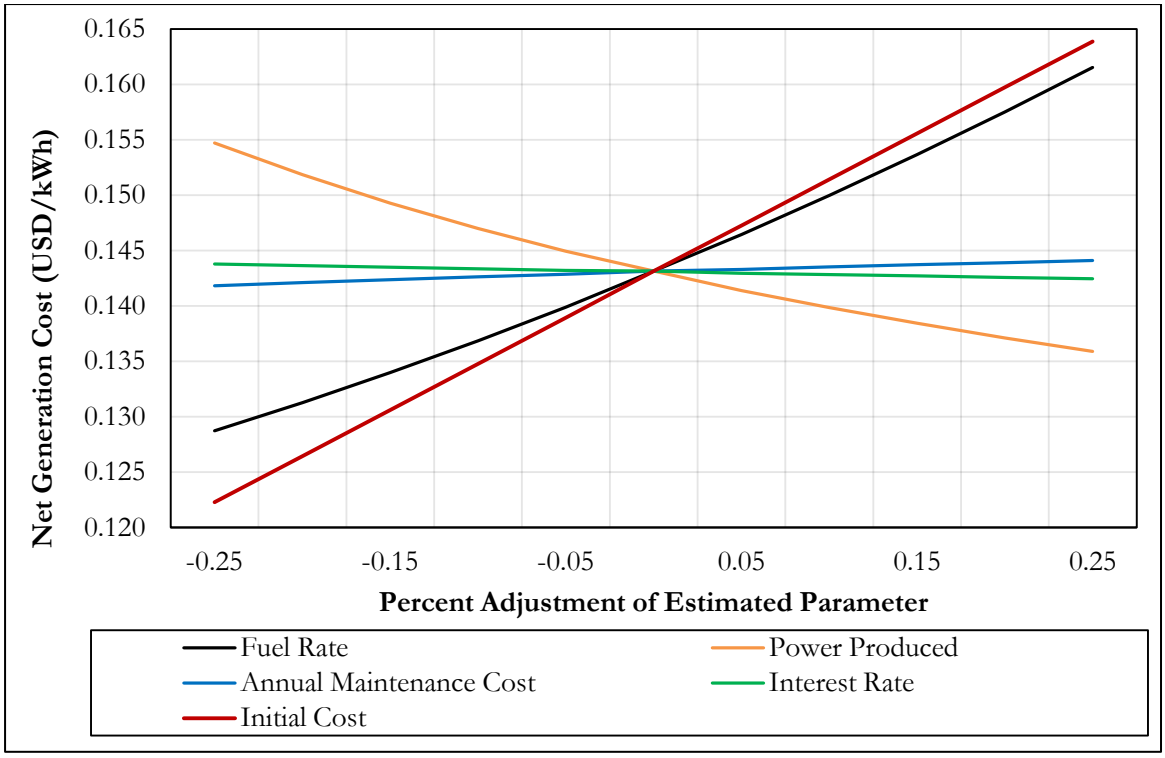


Figure 4-14: Cost sensitivity for the SOFC spinoff.

It is important to note that one of the reasons for the low prices in California is because of the extensive natural gas infrastructure that drives costs down. Therefore, to obtain a better picture of the generation costs in Africa it is necessary to perform a sensitivity analysis for the overall generation costs as a function of fuel prices. Although in the previous cost analysis the portion of the generation cost directly attributable to fuel was only a third of the capital cost (see Figure 4-15), this is likely due to the relatively low cost and easy availability of natural gas in California (US Energy Information Administration, 2012b). Figure 4-15 shows the relationship between the cost of SOFC generated electricity as a function of how many times more expensive the fuel source is relative to Californian natural gas. Even when the cost for fuel rose to five times than the one used in the initial cost analysis, the net generation cost remained approximately USD 250 per MWh, roughly double the initial estimate. This relative inelasticity of generation cost to fuel price would be advantageous for African countries that rely on imported fossil fuels for their domestic energy supply.

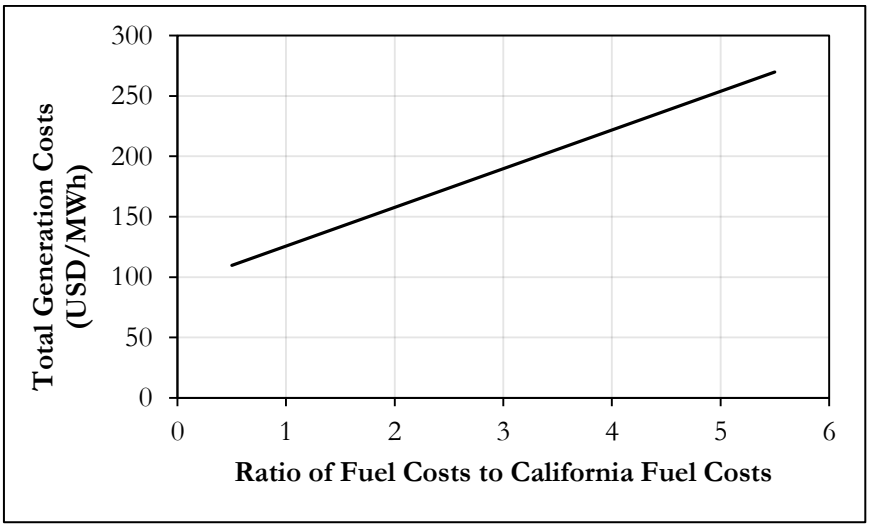


Figure 4-15: SOFC-generated electricity costs as a function of ratio to California fuel prices.

Funding Sources

Public funding remains the dominant source of funding for energy utilities and has traditionally borne the majority of costs for infrastructure development in Africa (Africa Infrastructure Country Diagnostic, 2008). However, as a large number of African nations do not possess sufficient public resources to meet the demand for improved energy infrastructure, alternative funding sources must also be considered for the deployment of SOFCs in Africa. The IDEAS for Africa considered three major forms of financing for SOFCs: public investment, institutional investors, and regional organizations.

In the majority of countries in sub-Saharan Africa, the ability of commercial banks to provide financing for infrastructure projects has been limited. This deficiency is largely due to a variety of factors including poor credit discipline, deficient regulatory frameworks, high transaction costs, and a lack of economic stability over the long investment terms required for infrastructure development (The World Bank, 2009).

Although international aid is another proposed source of funding for energy infrastructure, it has historically played a limited role in financing of energy sector development. While aid to other utilities such as road construction and water infrastructure undoubtedly frees up public funds for other uses, direct investment in electricity generation has been virtually nonexistent (Africa Infrastructure Country Diagnostic, 2008)

Public Funding

Although the majority of nations spend between 6 and 8 percent of their GDP annually on infrastructure development, which is comparable to many developed nations, the actual per-capita expenditure remains quite low due to the relatively small size of their respective economies. For example, between 2001 and 2005, all but three nations in sub-Saharan Africa spent less than 50 USD per capita total on infrastructure (Africa Infrastructure Country Diagnostic, 2008). Furthermore, African nations have on average been able to spend only two-thirds the amount actually budgeted for capital expenditure, the remainder being lost due to poor planning, deficiencies in project preparation, and procurement delays. (Africa Infrastructure Country Diagnostic, 2008). Consequently, public funding alone is, in most countries an insufficient source of funding for SOFC power generation.

In Liberia, for example, it has been estimated that the energy infrastructure will require between 251 million USD and 122 million USD of investment before 2015, depending on the infrastructure standards applied (Africa Infrastructure Country Diagnostic, 2010). This estimate does not include the increasing demand for power in the mining and natural resources industry, which will have to rely on private financing for the development of their own generation infrastructures. The expected available public funds for energy infrastructure development during that period is only expected to be 23 million USD, leaving a gap in funding on the order of at least 100 million USD in even the most pragmatic scenario. Liberia's gross domestic savings of -121.5% of their GDP (The World Bank, 2010) further indicates that the country has "severely little or no potential" of creating domestic funds for infrastructure projects (The World Bank, 2009).

In South Africa, however, the situation is radically different. Although it invests over 500 USD per capita on infrastructure (Africa Infrastructure Country Diagnostic, 2008), South Africa also consumes 40 percent of all electricity generated on the African continent , and is suffering from an energy crisis due to its rapidly expanding domestic demand, resulting in rolling blackouts and restrictions on the sale of electricity to neighboring states (BBC, 2008). Despite the availability of public financing for SOFCs, South Africa is not would not be an ideal location for them to be deployed, for reasons discussed in the Implementation section below.

Institutional Investors

Although investment in infrastructure in theory should be a natural fit for institutional investors, due to the longer terms of liabilities of infrastructure projects, historically they have played a limited role in financing the development of energy infrastructure in Africa. Reasons for this limited role have included overly risk-averse investment policies enforced by many governments that favor portfolio stability over performance. Although there is very little reported data on exactly how much institutional investors invest in local infrastructure, the limited existing data shows it is likely very small; as of mid-2007, infrastructure represented on average only 0.03 percent of the investments of African national pension systems (The World Bank, 2009).

Institutional investors are beginning to hold increasing potential for funding infrastructure in Africa, for a number of reasons. Firstly, a general trend towards increased transparency and proper regulation is increasing the total amount of assets available to institutional investors. Secondly, there are a number of regional initiatives seeking to coordinate the investments of separate institutional investors from different countries such that the funds can be used to finance infrastructure projects, as explained in the next section (The World Bank, 2009).

Regional Initiatives

One such regional investor is the EAIF, a private-public partnership founded in 2002 to provide debt financing to private enterprises for the purpose of infrastructure. Operating in 47 countries in sub-Saharan Africa, the EAIF currently holds roughly 600 million USD, and can provide loans of up to 30 million USD, which is greater than the entire national budget of Liberia for energy infrastructure (Emerging African Infrastructure Fund, 2012). One example of an EAIF funding opportunity would be to cover the capital cost of the deployment of SOFCs in Liberia at commercial mining operations, furthering the development of electrical infrastructure in the country. A similar organization, the PAIDF, had raised over 625 million USD to date using only African investors, and is hoping to grow the fund beyond 1 billion USD in its next round of capital seeking. EAIF and PAIDF are both investors in Aldwych International, an international body established in 2004 to spur development of power infrastructure in developing nations. Since its founding, Aldwych International has financed 11,000 MW worth of power generation facilities worldwide, worth 3.75 billion USD (Aldwych, 2012).

4.5.4 Implementation

The IDEAS for Africa team has recommended implementing SOFC for small-scale, off-grid locations in Africa to provide baseload power generation. The following section details how this can be implemented across the continent.

Target Countries

The degree to which SOFCs can be implemented in the three target countries, and across the rest of Africa, will vary according to a variety of factors, including availability of financing, local electricity demand, local electricity tariffs, fuel availability, and existing infrastructure.

As a consequence of the recent development in South Africa, the country faces an energy supply crisis which has resulted in rolling blackouts, and cuts of electricity to neighboring countries (BBC, 2008). In response to this, the state-owned electricity company Eskom has called for investments of USD 45 billion for new plants and distribution networks to reach the goal of universal electricity access by the end of 2012 (South Africa Info, 2012). Most electricity generation in South Africa is from coal-fired power plants. As such, marketing SOFCs as an alternative to existing coal plants is not recommended, as it fails to benefit from existing infrastructure and expertise, is more costly, less profitable, and ultimately fails to take advantage of the small scale generation capabilities of SOFCs.

To meet the large scale of the demand, South Africa is transitioning from its almost entirely coal-powered energy sector to pursuing conventional nuclear power generation (South Africa Info, 2012).

Due to the lack of any proven natural gas resources and the lack of natural gas distribution infrastructure (Anyanwu et al., 2010), the introduction of SOFCs into South Africa for public electrical generation would likely be met with limited success. There have been proposals to artificially convert some of the South Africa's coal resources into natural gas, which could be used to generate electricity in a more environmentally-friendly way. However, the added cost of converting coal to natural gas would make SOFC-generated electricity even less competitive against coal and nuclear power.

In Morocco, SOFCs would also likely not achieve significant market penetration, due to the lack of domestic natural gas supplies and infrastructure. Furthermore, the country is almost completely dependent on its neighbors for its energy supply, with approximately 96 percent of its electricity needs coming from direct low-cost electricity imports (Mohamed, 2007). The low cost and easy access to foreign electrical generation would make SOFCs for public grid generation unfeasible.

Current electrical infrastructure investment in Morocco is focused on renewable sources of energy such as solar and wind generation (Ferhat, 2012). In particular, Morocco is trying aiming to meet a target of 40 percent of electricity produced from wind and solar energy by 2020 (Ernst & Young, 2012). As such, unless the current trend in funding changes to promote SOFCs, it is unlikely that this technology could be implemented economically in Morocco.

In Liberia, SOFCs would be well suited to meet the demand for inexpensive electric power generation at a small scale. The scalability of the Bloom Box energy servers could provide affordable baseload power for distributed, localized power grids, while a more extensive interconnected grid capable of importing inexpensive power from Cote D'Ivoire is constructed. However, the most significant barrier to such a system is the availability of SOFC fuels and the lack of infrastructure to affordably distribute it to the geographically disparate servers. As Liberia also lacks access to natural gas, an alternate fuel such as octane or diesel could be used, but this would require modifying the SOFCs to tolerate such fuels.

Nevertheless, for this to be implemented in Liberia, it would necessitate external investments. The World Bank alone has invested USD 53 million in Liberia, 63 percent of which are earmarked to energy production (The World Bank, 2010). Based on the costing estimates described in the *SOFC: Costs* section, this investment would allow for approximately 4.6 MW of energy directly from SOFCs, effectively increasing the energy capacity in Liberia by almost 40 percent. Another potential market for SOFCs in Liberia is within its mining industry, which is expected to self-fund the development of its own electrical generation system of up to 840 MW in the coming 30 years (Africa Infrastructure Country Diagnostic, 2010). SOFCs are attractive for this industry particularly because their needs are distributed in remote areas and because the compact nature of SOFCs mean they can be transported to other facilities. In addition, the added benefit of a potentially carbon-neutral SOFC is very attractive from a public relations standpoint as mining companies often face environmental criticisms.

Application to Other Countries

In general, SOFCs will provide the greatest benefit in public electrical generation to nations that have access to natural gas, have sufficient demand for small-scale power generation, and have access to sufficient funding, either from domestic public finances or from alternative means. While these requirements may seem sufficiently restrictive to prevent SOFCs from succeeding at all in Africa, there are certain niche locations in which they could be very advantageous.

One such application is in supplying reliable baseload power to the commercial enterprises in Nigeria in place of less efficient conventional backup generators. Although Nigeria has made great strides in improving access to electrical power, it suffers from chronic power shortages, due to underspending on maintenance and growth in demand (Africa Infrastructure Country Diagnostic, 2011). Consequently, surveyed Nigerian enterprises have reported power losses 320 days per year, forcing over 60 percent of them to rely on backup power generators. The aggregate social cost due to these frequent power losses is estimated at 3.7 of the national GDP, and if the economic productivity lost

is considered, this value can conservatively be doubled (Africa Infrastructure Country Diagnostic, 2011).

Although the cost of electrical generation in Nigeria is estimated to be approximately USD 150 per MWh, residential electrical tariffs in Nigeria are greatly underpriced at only USD 30 per MWh, making SOFCs seemingly uneconomical for commercial enterprises (Africa Infrastructure Country Diagnostic, 2011). However, the economic loss due to power outages is estimated at USD 1,000 per MWh (Africa Infrastructure Country Diagnostic, 2011); consequently, gains in productivity due to reliable power could more than pay for the cost of the systems. Financing for SOFCs in such a manner could be provided by regional organizations, such as the EAIF, as discussed in the *SOFC: Funding Sources* section above.

Africa currently ranks fourth in the world in terms of proven natural gas reserves, with over 90 percent of these reserves contained within Egypt, Libya, Nigeria, and Algeria (Anyanwu et al., 2010). In addition to these countries, many other African countries have access to natural gas, biogas, crude oil, and other SOFC-compatible fuels through international trade. As such, and thanks to its diversity in terms of development and electrical infrastructure needs, there exist other areas on the continent where there is a convergence of sufficient access to funding, access to fuels, and small-scale demand for inexpensive power where SOFCs would be well-suited.

Technological Availability

Existing SOFC systems are currently at the market deployment stage of its development, with the first energy servers having been installed in 2008. These servers are now supplying power to the office buildings of a number of Californian companies, including Google, ebay, Bank of America, Walmart, FedEx, and the Coca-Cola Company (NASA, 2010). Bloom Energy has announced plans for a mass-produced version for home installation (costing USD 1,000 and producing 1 kW of power), but is not expected to be ready for another 5 to 10 years (Woody, 2010). Nevertheless, the technology is available today to produce power at a scale and cost that would be advantageous to the African, including the target countries of South Africa and Liberia.



Figure 4-16: 800 kW SOFC system outside a Walmart [Bloom Energy, 2010].

The main precursor required prior to use in Africa is the infrastructure necessary for fuel distribution. For example, Liberia does not possess any proven domestic natural gas reserves, has no distribution infrastructure and has no natural gas imports (CIA, 2012b). And hence, prior to full SOFC deployment, investments would need to be made into fuel distribution infrastructure. Initially, it is envisioned that locally-produced biogas could be used as an alternative fuel for the SOFCs in such

countries that have no distribution infrastructure. Using biogas would require a local bioreactor to converts manure into usable fuel. Biogas would have the added benefit of eliminate adding extra carbon to the global carbon cycle, allowing the system to be carbon-neutral. However, upon investigation, the use of a biogas-SOFC proved unfeasible as the scale of biogas currently available and the amount required for generation using current technologies. Producing sufficient biogas would require a prohibitively large bioreactor, and would consume large quantities of organic matter (OECD, 2005). Even when highly-efficient bioreactors are used, electrical generation using agricultural biogas was not economically viable (Gebrezgabherm, Meuwissen & Lansink, 2010). As such, technological advancements would need to be made for biogas reactors to become a viable solution in Africa. Consequently, in the near-term it is instead necessary to improve infrastructure to distribute fuels for the SOFCs, or rely on standard octane fuels.

Time to Deployment

As mentioned in the *Technological Availability* section, there is a commercially-available SOFC system on the market in California, sold by Bloom Energy. Barring export controls, this solution is already fit for application using natural gas. Bloom Energy also offers an "extreme weather kit" option (Bloom Energy 2012), which allows the SOFC to be operating in harsher environments, a modification that would be required for use in many African nations.

Bloom Energy also advertises that their SOFC systems are "fuel flexible", insofar as they can operate using either natural gas or directed biogas (Bloom Energy 2012). Theoretically, SOFCs can also operate using octane for fuel (Wilson, 2009), and this may be a required modification for nations that lack natural gas resources and infrastructure. In addition to modifications to the feed system, the internal operating environment may also be different using the different fuel. Nevertheless, because the Bloom Energy SOFCs are designed to tolerate high temperatures, it is unlikely that such modifications would require significant overhaul of the system. As such, a modified octane version could likely be made available following only a few years of directed research.

4.5.5 Ethics

With growing concerns over climate change, any new technology that relies on non-renewable fossil fuels must be carefully considered. An advantage of SOFCs in this respect, in particular the Bloom Box version, is that they are capable of operating using not only natural gas, but also renewable biogas which does not add any excess carbon to the global carbon cycle (Bloom Energy, 2012). Currently, biogas is not a feasible option for SOFC fuel; however, as natural gas resources are depleted and biogas becomes commercially viable, having an existing SOFC-based infrastructure could actually help the transition to a carbon-neutral energy sector that instead uses biogas.

Furthermore, because method with which fuel cells generate electricity is reversible, SOFCs can actually be used in conjunction with renewable sources of energy, including solar and wind power, to provide power during periods when the renewable resources are unavailable or during peak power periods. One proposed architecture, for example, would use a fuel cell to create hydrogen and oxygen through hydrolysis when there was an excess of power available from solar and energy; the oxygen and hydrogen would then be used to fuel the cell and create electricity at night, during calm air, or during peak demand periods.

Another potential concern of the use of SOFCs in natural gas exporting countries is the potential for loss of export revenue due to the use of the gas domestically for energy. These concerns are particularly relevant in nations where much of the national economy relies on resource exports. In 2008, for example, revenues from natural gas exports represented 36.9% of Nigeria's GDP, and 92.2% of their total exports (Anyanwu et al., 2010). The potential gains in productivity resulting from reliable access to power would vastly outstrip any lost export revenues, due to Nigeria's power reliability crisis described in the *Application to Other Countries* section; nevertheless, in each potential application, the lost export opportunities will have to be carefully weighed against the potential gain

by SOFC power. In some cases, it may be preferable to instead invest in better distribution infrastructure and buy power directly from neighboring countries.

4.5.6 SWOT Analysis

The SOFC is designed to provide small scale energy generation to African people that are isolated from the grid, or to supplement discontinuous electrical supply. The SOFC is an application for the target countries of South Africa and Liberia to address their growing needs for small scale generation. The SOFC spinoff is intended to address the energy, environment, and even health concerns across Africa. A SWOT analysis was performed, as shown in Table 4-6.

Table 4-6: SWOT analysis for SOFC applications.

Strengths	Weaknesses
1. Low cost per MWh of generation 2. Flexibility of fuel 3. Modular scaling efficiently generates small to medium quantities of electricity 4. High level of readiness to enter marker 5. Generation in remote areas can save electrical distribution losses 6. Easily converted to carbon-neutral 7. No use of rare noble metals	1. Requires constant sources of fuel, which many African nations lack 2. High up-front cost 3. Requires weather proofing for some nations where temperatures can exceed 45 degrees 4. Immobile platform 5. Requires fuel distribution infrastructure 6. Lack of demonstrated full life
Opportunities	**Threats**
1. Demand for efficient, small-scale energy production in Liberia and others 2. Rapid growth in electrical consumption in certain areas (ex. South Africa) 3. Continued scaling down by Bloom Energy could eventually make Biogas operation feasible for remote communities	1. Increased use of more sustainable in-situ resources (ex. hydroelectric power in Morocco) 2. Uncertain total life-cycle cost due to fuel price fluctuation

4.6 Conclusions

In this chapter, the IDEAS team investigated DHA, Organically Derived Colloidals and Solid Oxide Fuel Cells for application in Africa and their relevance to agriculture, energy, environment, and health concerns. It was demonstrated how a spinoff technologies' success in real-world applications in Africa depended not only on the technology itself, but on a convergence of other factors, including available funding sources, local receptiveness to the technology, available national resources, local environment, competing technologies, and national policy.

ODCs and aeroponic systems have been shown to increase crop yields while simultaneously reducing the amount of pesticide and water required. Although these spinoffs work most efficiently when used together, Aeroponics are currently prohibitively expensive in countries like Liberia. Fortunately, ODCs can be used either to complement existing farming practices, or in conjunction with Aeroponics. If applied correctly, including taking advantage of international funding sources and taking care to integrate with existing agricultural techniques, these two spinoffs hold the potential to enhance the nutritional value of plants, promote growth, reduce fungal infections, and strengthen Africa's agricultural system.

DHA tablets have demonstrated positive effects for pregnant women, infants and during adulthood, covering the complete life cycle of a human being. It serves the brain, eyes, and heart with vital growth supplements, with the potential to alleviate malnutrition and increase life expectancy. Our spinoff can also be applied to nearly all countries in Africa at varying stages of development. However, analysis revealed that the cost of obtaining the recommended dosage of DHA using direct supplements is higher than simply eating foods which naturally contains (e.g. fish). Furthermore, a

previous application in which DHA was added to infant food formula generated widespread criticism, as the product was sold as a substitute to breast milk and had the effect of worsening poverty in some areas. Consequently, for the spinoff to be beneficial, is should be applied only in the form of gel tablets distributed to compliment food aid, or in areas where natural sources of DHA are unavailable.

Solid Oxide Fuel Cells are designed to provide small-scale and economically viable means of energy production. The ability of SOFCs to deliver power on a small scale, with a cost and efficiency comparable to large-scale power plants, makes them an attractive option for many African nations. However, for them to be economically viable, they should be applied where there is a local fuel supply, where there is sufficient demand for their use, and where competing generation options (including direct imports of electricity) are otherwise too expensive. They are also useful in niche applications where the incentive of private industry to finance their own independent power infrastructure is high enough to justify their capital cost. Such applications include mining the industry in Liberia, and commercial enterprises reliant on uninterrupted power in Nigeria.

The IDEAS for Africa team believes that spinoffs are important and worthy technologies derived from space, and if applied correctly, could have direct impacts to Africa - improving lives by making them safer, healthier, and more productive. Some of the widespread and root causes of many of Africa's problems could be alleviated with these space spinoffs, provided they are used in countries and environments where they can be economically successful. Emphasis was placed on the application of spinoffs in countries with little or no domestic space activity, to demonstrate how space can benefit regions of Africa which cannot yet afford to invest in space technology.

To demonstrate the benefits space can provide in regions that can afford to invest in it, the following chapter will discuss satellite applications that are applicable in fostering even more sustainable social and economic development in Africa. The chapter will focus on four satellite applications, which again address agriculture, environment, and health concerns - first in our example countries, and indeed, throughout all of Africa.

5 SATELLITE APPLICATIONS

Arguably the most wide spread use of space, satellite applications have served a vast multitude of purposes since the onset of the space age. Satellite application can be grouped into three broad categories: Earth observation, navigation, and wireless communications. For the purposes of this report, a satellite application is defined as:

A product or service that uses spaceborne technology, whether directly or indirectly.

There are many satellite application projects already taking place in Africa, coordinated by international organizations (e.g. ESA, the EU, and NASA), which have specific programs addressing the benefits of satellite applications for the African continent. The 2010 European-African Partnership in Satellite Applications for Sustainable Development report lists a total of 51 projects related to space applications where European countries are involved (Giannopapa, 2010). These projects are related to several topics, such as crisis monitoring, Earth observation, health, sustainable development, telemedicine, and water management. They also list five additional private sector initiatives: GEO-Africa, Other 3 Billion (O3B), mHealth for Development, Network in Francophone Africa for Telemedicine (*Réseau en Afrique Francophone pour la Télémédecine*), and SALT.

This chapter of the report will focus on satellite applications with relevance to Africa, and the chosen ones will have relevance to all three target countries. The outline follows the building of programs and services for basic human needs – first addressing improvements to the focus areas of Health and Agriculture, and then on to the focus area of the Environment in protecting Africa's unique wildlife.

5.1 Selection Methodology

To investigate how satellite applications can benefit Africa, the IDEAS for Africa team initially identified some potential applications, and conceived others, and then selected those that appeared the most promising. These potential applications and their descriptions are listed in Table 5-1.

Table 5-1: Satellite applications and their descriptions.

Satellite Application	Description
FarmaBooths	Based on the Digital Soil Map (DSM) (Gilbert, 2009)
Telemedicine Vans	A mobile diagnostic unit capable of providing effective and direct medical relief, especially in remote areas
Citizen Services Centers	Rural facilities providing community services like tele-education, pollution monitoring, epidemiology monitoring, and agricultural information
Desert Movement Predictor	The use of Interferometric Synthetic Aperture Radar (InSAR)
Water Quality Satellite	Remote sensing to assess water quality parameters (for example, suspended sediments, chlorophyll, temperature, salinity
Mineral Mapper	Use of satellites for a mineral mapping to identify phosphate lands, a valuable mineral in many African countries, and producing high resolution maps of African minerals
Sea Intrusion and Border Watcher	Use of InSAR for detection of point target movements to aid law enforcement efforts
Freedom of Speech Project	Using space technology to pool information from citizens suffering under oppressive governments and openly broadcasting this information
Combating Poaching	Real-time remote sensing to detect illegal poachers, and reporting to local law enforcement or community groups
Space Experiments for Medicine	Using satellites for medical research, particularly pertaining to tuberculosis and HIV infections

These potential satellite applications were then compared based on their applicability to other countries, their feasibility, their level of innovation, and their relevance to the six focus areas. Based on these criteria the aforementioned FarmaBooths, Telemedicine Van, Desert Movement Predictor, and anti-poaching applications will be analyzed in the following section.

5.2 FarmaBooths

Food security is one of the major issues hampering African development, and stable crop growth in most of the continent suffers persistent threats. These concerns are further exacerbated by natural disasters and ecosystem disruptions. Meanwhile, many African countries depend on agriculture for their economic well-being. While several of them are in the tropical zones, with good annual rainfall and abundant arable land with rich soil, the poor management and inefficient agricultural methods have squandered the continent's plentiful natural resources. It is clear that technological solutions for improving agriculture in Africa are urgently needed. To better use available land, personalized guidance from satellite imagery directly to farmers will help to optimize these resources. Similar projects are already in place in many developed countries, including France (EADS, 2009). To aid African development, the same technology will have to be implemented in rural areas, and be used by individuals without training in advanced technologies. In this section, the IDEAS for Africa team will develop the concept of satellite-based village information centers, called *FarmaBooths*, to provide this service.

The FarmaBooth is a satellite application designed to address the focus areas of agriculture, environment, and health. The intent of this application is to provide rural farmers with up-to-date information from satellite imagery about their agricultural lands. This application is relevant for the target country of Liberia, and setting up FarmaBooths requires the Pan-African e-Network's involvement. However, Morocco and South Africa are not participants, and implementation is therefore constrained in those target countries. The following section provides an overview of the FarmaBooths application, an examination on their cost, potential funding sources, implementation, and finally an examination of their ethical concerns.

5.2.1 Technical Overview

FarmaBooths are small information centers in locations for local farmers from four or five villages can easily access their information. The main objective of these centers is to provide personalized information on critical agricultural characteristics, including variations in soil type, soil nutrient variations, crop health, and crop growth data. The centers will display processed satellite images for a particular location to aid farmers in agricultural planning.

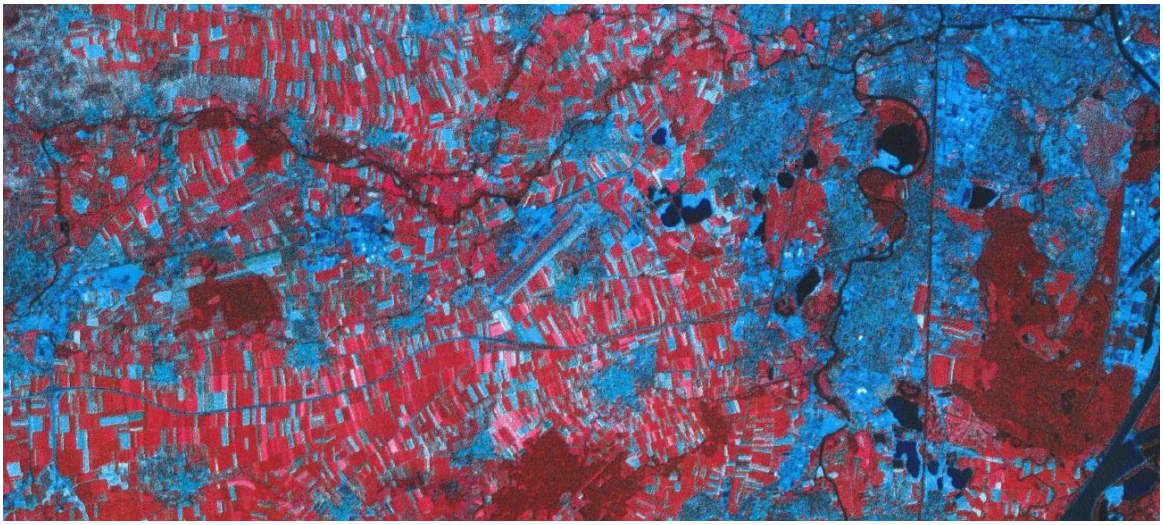


Figure 5-1: SPOT **i**nfrared image of Strasbourg's surroundings [Farrow, 2011].

The FarmaBooth system has four major components: the space-segment providing both remote sensing and communication capabilities, the data interpretation centers, a centralized FarmaBooth facility, and the individual FarmaBooths themselves, as data accessing facilities. In terms of the space-segment, there is already an adequate space-based infrastructure to provide both the remote sensing needs and related communication requirements. The data interpretation centers convert raw satellite data into easily accessible information for farmers. The centralized FarmaBooth facility can be located in a major city center for training sessions and teleconferences, and the individual FarmaBooths are in rural locations, near to farmers. Figure 5-2 shows the FarmaBooth information flow.

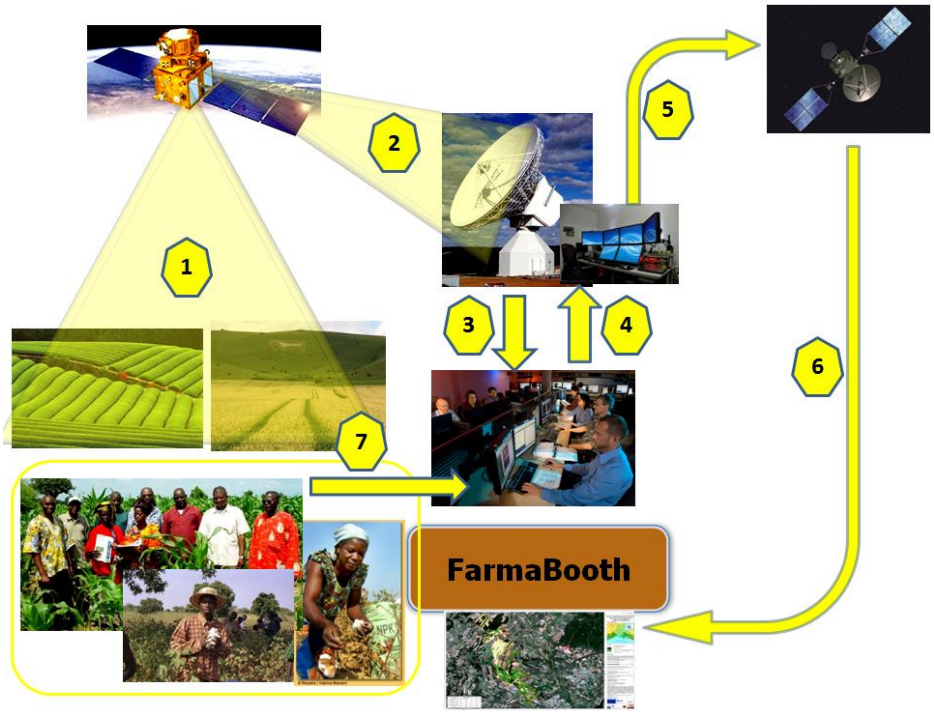


Figure 5-2: FarmaBooth information flow [Hadigal, 2012a].

1. An Earth observation satellite acquires the image
2. Images are sent to ground stations
3. Data is sent to processing and interpretation centers
4. Interpreted data is returned to ground stations
5. Interpreted data is uplinked to a communication satellite
6. Recommendations and map data is sent to the FarmaBooths
7. Occasional feedback from farmers is sent to interpretations centers

Successful implementation of the FarmaBooth project requires bridging the gap between satellite imagery creation and rural farmers. A similar project was undertaken by ISRO's Village Resource Center, which used Indian remote sensing satellites providing data on land, water resources, and interactions between crop growth variation and the climatic behavior, taking information from satellites and distributing it to rural farmers. ISRO piloted this project successfully across a wide area of rural India, with many end-user applications including tele-education, e-health, land and resource management, interactive advisory services for the farmers, weather services, and telefishery (Indian Space Research Organization, 2011).

The FarmaBooth's satellite system enables remote sensing of crops using three wavebands: microwave, visible, and thermal, which is interpreted to provide information about the size and yields of crops, crop damage, water sources, water use, moisture levels, and an estimation of surface temperatures (Niel & McVicar, 2001). Furthermore, the FarmaBooths will use information provided by an ongoing space-based project called the African Soil Mapping Project, carried out by African Soil Information Service, which aims to produce a detailed digital soil map of all the 42 Sub-Saharan

countries. It will collect and catalogue the radiation signature of around 10,000 African soil samples. As of 2011, soil sampling has begun in twenty sites across fifteen African countries (African Soil Information Service, 2009) (Gilbert, 2009). This project will provide a sophisticated database of information that will be used by the FarmaBooth project for soil monitoring. Based on plant crop cycles, remote sensing of crops is done in two phases: the vegetative period (in which the plant grows in size before flowering), and the reproductive stage (in which flower groups and grains start developing). Using tropical rice as an example (and grown in Liberia), these periods last between three to four months (Niel & McVicar, 2001).

Since remote sensing techniques for these insights are well understood, satellite observation can discern the specific spectral reflectance patterns for rice crops because of its water absorption characteristics in the middle infrared (IR) range (Niel & McVicar, 2001). To provide these services, the spatial resolution of the imaged area will be approximately ten meters. It is also expected that each FarmaBooth will cover an area of 400 km^2, meaning that the region of interest will be 20 km by 20 km for each one. The reason for selecting an area that size is so the FarmaBooth will be easily reachable by the local population. Existing satellites that can provide this service are shown in Table 5-2. Temporal resolution will depend on the phase of the plant. The vegetative phase is the most demanding and requires a revisit time of ten days (Niel & McVicar, 2001). However, with a revisit time of five days, the Resourcesat-2 satellite is capable of this frequency and is suitable for this application (National Remote Sensing Agency, 2003). In total, this will amount to approximately seven images of the target region per year.

Table 5-2: Remote sensing instruments and satellites of intest for FarmaBooths.

Instrument (Satellite)	Wavelength (μm)	Application
AVHRR (NOAA)	VIS (0.58-0.68) NIR (0.725-1.1) SWIR (1.58-1.64) MWIR (3.55-3.93)	Soil moisture and vegetation indices
HRG (SPOT 5)	VIS (0.50-0.59, 0.61-0.68) NIR (0.79-0.89) SWIR (1.50-1.75)	Agricultural land management
LISS (IRS)	VIS (0.52-0.59, 0.62-0.68) NIR (0.77-0.86)	Improved crop discrimination and crop yield information
MODIS (Aqua & Terra)	VIS - TIR 36 bands in range 0.4-14.4	Chlorophyll fluorescence
TM (Landsat)	VIS - SWIR 0.45-12.5	Vegetation state and change

One of the main challenges is bridging the connectivity gap between the satellites and the FarmaBooths. The Pan-African e-Network offers a solution. This project is an international partnership between the Indian government and the African Union, which connects satellites to both urban and rural locations and support tele-education, telemedicine, e-commerce, e-governance, resource mapping, and meteorological services (Pan-Africa, 2011). Currently, there are 47 African Union countries which are members of the Pan-African e-Network project, including Liberia. Members of the Pan-African e-Network have existing facilities that are connected to the internet *via* satellite (including universities, hospital, and community centers) and these locations can be used as centralized FarmaBooth facilities.

However, the FarmaBooths themselves require their own satellite link to connect with the centralized facility. These centralized facilities are located where external specialists come to demonstrate how to

use the FarmaBooth information, and how to improve agricultural practices, and can be sent *via* satellite to end-users at the individual FarmaBooths. This step uses the existing Pan-African e-Network, with its dedicated communication infrastructure (RASCOM satellite system), and well-established financial framework and technical and academic support (Pan-Africa, 2011). The overall system architecture for the FarmaBooths is shown in Figure 5-3.

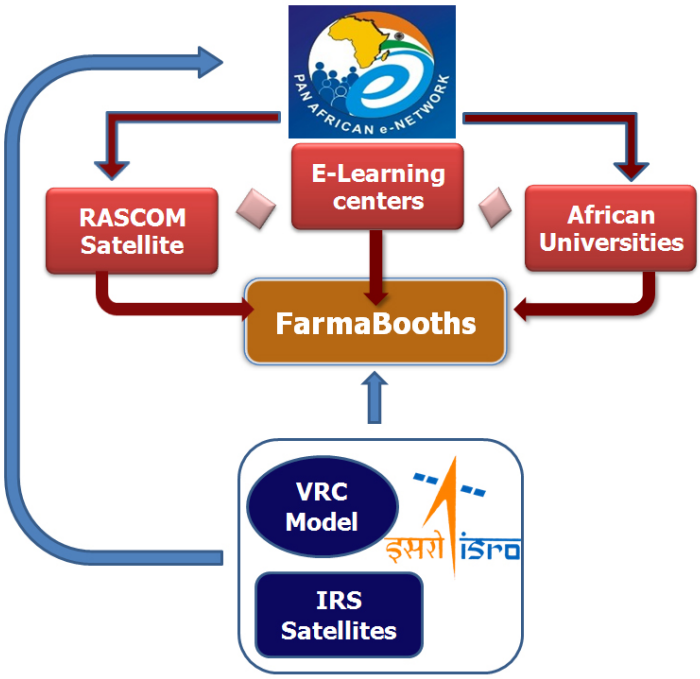


Figure 5-3: FarmaBooths overall system information [Hadigal, 2012a].

After image acquisition, data is sent to data interpretation centers. These centers take the image from the satellite and based on land requirements, maps are generated to provide farmers with agricultural information. One of the biggest challenges for the system will be the interpretation and distribution of the maps from these centers to the individual FarmaBooths. To minimize these risks, the Indian Village Resource Centers can be used. The Indian Village Resource Centers already possesses the essential infrastructure to receive, interpret, and send the data to FarmaBooths. Since the Pan-Africa e-Network project is also a collaboration with the Indian Government, the use of the VRC data processing centers should not pose many political challenges.

5.2.2 Benefits

Africa is a land of tremendous natural resources, which often suffer from mismanagement. The FarmaBooth project encourages agricultural self-reliance in Africa, raising crop yields and farmer incomes, promoting food stability, and the efficient and rational use of natural resources. Besides the evident agricultural benefits, Farmabooths also encourage local and regional cooperation, instilling mutual trust and a sense of community. They offer the hope of increased social stability and elevated living standards. Farmabooths can also be used to combat desertification and deforestation by giving up-to-date information about agricultural lands and their soil qualities.

5.2.3 Financing

Costs

To predict the costing of the FarmaBooth project, it is necessary to distinguish between start-up costs and running costs. Start-up costs include creating internet connectivity for the individual FarmaBooths, and power requirements for the centralized facilities. The running costs of the FarmaBooth project include human resources costs for managing the FarmaBooth centers, costs to

rent space for the centralized facilities, costs associated with using the Indian Village Resource Centers, and any application imagery costs. The following details the cost of setting up one FarmaBooth.

Internet and hardware setup fees at the centralized facilities are free because of the Pan-African e-Network, however each FarmaBooths will still have hardware costs. Internet connection hardware is available from GlobalTT, the satellite service provider for Africa. The start-up hardware cost from GlobalTT for a Ku-band Very Small Aperture Terminal (VSAT) kit is approximately USD 1,000 (GlobalTT, 2012).

While start-up and running costs for the centralized facilities are free, there will likely be a rental fee for the facilities. Estimates depend on the country of application, for example in Liberia costs are approximately USD 600 per year (Nah, 2011). The centralized FarmaBooth facility will also have human resource costs associated with bringing in external experts to provide teletraining services. These costs will include a remote sensing expert and an agricultural expert. Both the remote sensing and agricultural experts will likely be foreigners with salary requirements higher than typical Liberian salaries. They may only need to come to the centralized facilities twice a month, to aid the customers with data interpretation and developing agricultural planning strategies. The yearly cost for these experts is around USD 5,500 each.

The individual FarmaBooths will have their own construction and running costs. The construction costs of such facilities will likely be similar to the costs for the Indian Village Resource Centers, at around USD 2,400 (Indian Space Research Organization, 2011). The running costs will include the human resources and energy needs. Because electricity in Africa is unpredictable and often does not reach rural areas, the FarmaBooths will require their own independent electricity generation source. Furthermore, since shipment of fuels is not completely reliable, a solar power-based electricity generation system is recommended. Based on an estimated yearly need of 25 MWh for the FarmaBooths, at an estimated cost of solar generation of USD 210 per MWh (US Energy Information Administration, 2012a), this amounts to a total start-up cost of USD 5,500 for power supply. In terms of human resources for the individual FarmaBooth, it is estimated that they will require one full-time maintenance person, and one part-time trainer for the users. Both the maintenance personnel and trainer will likely be from Liberia; hence their salaries will be much lower. The maintenance person salary will be similar to the GDP per capita of Liberia (USD 226 per annum (CIA, 2011c)) and is estimated at USD 225 per year. A trainer can be present at the FarmaBooth once a week, and based on Liberia's GDP per capita, will cost USD 30 annually. A summary of human resources costs is shown in Table 5-3.

Table 5-3: Estimated human resources cost for the FarmaBooth project.

Personnel Title	Percentage Employed	Total Cost
Remote sensing expert	10%	5,500
Agricultural expert	10%	5,500
Maintenance personnel	100%	200
Training personnel	20%	30
Total (rounded)		*11,000*

There will also be costs associated with using the services of India's Village Resource Center as an interpretation center. The cost of using this resource, as the facility is already established, will likely be close to the human resources of interpreting the data. Therefore, this cost is estimated at USD 20,000.

Lastly are imagery costs. Imagery costs refer exclusively to *Système Pour l'Observation de la Terre* (SPOT) imagery, as this is the only fee-charging provider. This estimate therefore represents a worst-case scenario estimate, where all images are provided by SPOT. With a spatial resolution of approximately 10m, a scene size of 20km by 20km, and a total number of pictures of twelve per year, the cost of the

SPOT images is approximately USD 15,300 (EADS, 2011). A summary of the start-up and running costs for one FarmaBooth center is shown in Table 5-4.

Table 5-4: Summary of the costs associated with the FarmaBooth project.

Item	Start-up Cost (USD '000)	Annual Cost (USD '000)
Centralized FarmaBooth Centers		
Human Resources	-	11
Building Rental Fees	-	0.6
FarmaBooths		
Satellite Connectivity	1	-
Construction	2	-
Power Requirements	5.5	-
Interpretation Centers		
VRC Services	-	20
Imagery		
SPOT Imagery	-	15
Total	**-**	**47**

Funding Sources

Since FarmaBooths are designed to benefit villages and farmers, who often have limited financial resources, the establishment of the FarmaBooth project will require a great deal of external support. This support will likely come from four major sources: government, international organizations, NGOs, and private enterprises.

FarmaBooths can be integral to Liberia's agricultural development. The Liberian Ministry of Agriculture has projects that support agricultural development, including the Comprehensive Assessment of the Agriculture Sector of Liberia Project (supported by the United Nations Food and Agricultural Organization, the World Bank, and the International Fund for Agricultural Development (Republic of Liberia, 2010). As satellite imagery is useful in many areas, it is possible that the Liberian government would subsidize imagery costs.

International organizations that support sustained development in underdeveloped countries may also be a source of funding for this project. One such organization is the FAO, a UN agency promoting efforts to end world hunger and aids developing and transitioning countries modernize and improve their agricultural practices. Since Liberia is a member, the FAO would likely support the FarmaBooth project. The United States Agency for International Development (USAID) is a similar organization and provides humanitarian and economic assistance worldwide. One sector of USAID provides agricultural assistance (US Agency for International Development, 2010). The European Commission's Humanitarian Aid and Civil Protection program is another international organization that can potentially support FarmaBooths, and has specific policies and programs for food assistance (European Commission, 2011).



Figure 5-4: USAID helped to improve agricultural production for small farmers in South Africa, like this papaya grower [Zurba, 2008].

Looking at NGOs, there are currently over 100 national and 40 international NGOs working in Liberia. The Liberian Ministry of Agriculture has detailed information regarding the registered NGOs working within its borders. For example, the Liberian Innovation Foundation for Empowerment intends to improve the lives of Liberians and has projects aimed at sustainable agricultural programs (Idealist, 2011).

Lastly, private enterprise may invest in FarmaBooths. The brand of FarmaBooth would be a powerful advertising tool to showcase the quality of crops grown. Food distributors would likely want to show that their crops were grown with the best practices in mind, and this could be accomplished through the brand of FarmaBooth.

5.2.4 Implementation

The IDEAS for Africa team recommends the establishment of the FarmaBooth project, and the following sections details how this project could be implemented.

Target Countries

FarmaBooths are especially relevant to Liberia, where rice and cassava are the main staple crops and rubber, palm oil, and cocoa are the dominant export crops. Liberia's agricultural sector constitutes almost 80 percent of real GDP, and almost 70 percent of the Liberian population is involved in agriculture (FAO, 2007). Nevertheless, in many Liberian counties, there is only enough self-produced food to feed half of the population. External support for agriculture is extremely small, indicating need for FarmaBooths (FAO, 2007). Figure 5-5 shows the percentage of Liberians involved in food production, the percentage of Liberians self-reliant on their own food production, and the percentage of external aid into Liberia's agricultural sector.

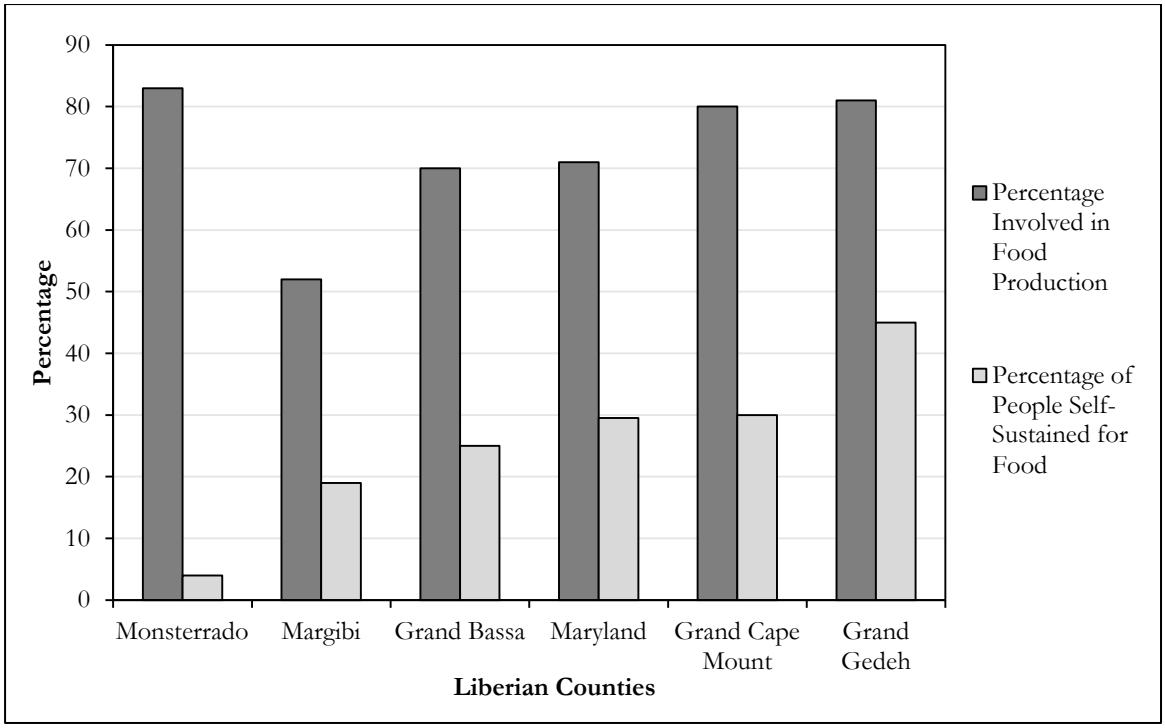


Figure 5-5: Despite the high number of Liberians involved in agriculture, only a small percentage of Liberians have enough food to survive [Owadi, 2012].

Increasing crop yields through technology can raise farmer incomes, promote food stability, and facilitate the efficient use of resources like water and arable land. As a country rebounding from a generation of bloodshed and disorder, Liberia requires a means of encouraging development and stability, and aiding the largest sector of its economy can drive this stability and development. Implementing the FarmaBooth project in Liberia possible as, it is a member of the Pan-African e-Network - which has centers at the University of Liberia, the John F. Kennedy Memorial Hospital, and at the Liberia Telecommunications Corporation, all in Monrovia. Each could serve as a centralized FarmaBooth facility (The Liberian Connection, 2011).

For Morocco and South Africa, FarmaBooths are also possible. However, since neither of these countries is part of the Pan-Africa e-Network, implementation there would likely involve additional start-up costs. Consequently, application for these countries was not considered feasible at this time.

Application to Other Countries

Agriculture is the backbone of many African countries. The continent has an enormous variety of growing conditions. The fertile soils of Sub-Saharan Africa provide many opportunities, while the deserts in the north and south of the continent present many challenges. The application of FarmaBooths throughout the continent is a real possibility to enable farmers to use their available resources to their maximum efficiency.

FarmaBooth information centers can be tuned depending on geographic location, variety of crops, and environmental characteristics of the surrounding area. For example, information provided to croplands in more arid regions would provide advanced details about water reservoirs, whereas crowded agricultural zones would have access to mapping information to ensure farmers were respective property rights. One of the major benefits of the FarmaBooths is the ability to connect it to the information provided by the *Desert Movement Prediction Center* and the *Telemedicine Van*, as will be discussed in the following sections. The information from these satellite applications could be sent to FarmaBooths enabling individuals in rural areas access to this information. The method of information distribution will be discussed in more detail in the *Desert Movement Prediction Center* and the *Telemedicine Van* sections.

Technological Availability

One of the most appealing features of the FarmaBooths project is that the technology to implement these services already exists. The main challenge will be to interpret the data provided by the satellites. This will entail restoring the raw image from the satellite with geometric and radiometric corrections. Geometric restoration corrects the distortion due to the relative motion of the satellite with respect to the Earth, the curvature of Earth, and the panoramic distortion arising due to tilt angles. Radiometric corrections normalize the different detector responses with a laboratory calibration (Aranha, 2008). The images are then enhanced and transformed using processes such as normalized difference vegetation index to obtain strong contrast between pixels. Finally, the images are classified for different requirements. Image classification regarding the yield, soil properties, and nutrient requirements would be used to create an easily interpreted digital map for the FarmaBooths. Farmland images with clearly distinguishable characteristics depicted in different colors would aid farms in understanding and ultimately using the information effectively. This whole process is estimated to take three to four weeks depending on the services provided (National Remote Sensing Center, 2012).

Since the Pan-Africa project is being established in many countries across Africa, connecting FarmaBooths with it should not pose a problem. For an individual FarmaBooth in Liberia, where the Pan-Africa e-Network is already established with academic institutions and communication infrastructure, it would require 2 to 3 months to build this new system in a village. This time includes customized training from the experts to the institutions, and thereby the locals could be educated by them. If VRC processing architecture is used for image processing and interpretation, the large amount of time required in establishing the processing centers would be avoided. As soon as a FarmaBooth is built and connected to the Pan-African communication satellite provider, the image acquisition and interpretation can be started at the centers in India.

Time to Deployment

The estimated time for the FarmaBooth project will be the time from the project onset until the information is able to be used by farmers. This will require the setup of the individual FarmaBooth centers, integration into the Pan-Africa e-Network, the setup of the interpretation centers, the image acquisition, and the information transfer. Because the usefulness of this project requires historical data to be gathered, the limiting factor will be the amount of time required to create a database of information accessible by farmers. It is likely that data acquisition will require a full growing season, and interpretation before farmers can begin using the information. All other setups can be done in parallel to the data acquisition. It is therefore estimated that a full year is required from the project onset until the farmers can begin using the information provided by the FarmaBooth project.

5.2.5 Ethics

The ease of access of information regarding crop production is one of the major ethical concerns which needs to be considered. In this regard, information about the future production of a crop could enable investors and financial speculators to make their investments based on this information, and thus preemptively inflate or deflate the prices of a commodity, further exacerbating the effect of reduced or improved crop production. This way information given to farmers in the same general region could create local conflicts, so a process for managing and avoiding conflicts must be determined.

5.2.6 SWOT Analysis

According to 2011 Mombassa Declaration on Space and Africa's Development, Africa is committed to harnessing space science and technology to drive resource management for sustainable development. The IDEAS for Africa team feels that the FarmaBooth project clearly aids the furtherance of these goals. The proposed system will provide time-accurate information to rural farmers on how to effectively use resources to maximize crop production, allowing more stable,

predicable, and productive harvests. The technology and infrastructures are available, and the project can be implemented in a reasonable time with reasonable costs. An analysis of the strengths, weaknesses, opportunities and threats to implementing the Farmabooth project was performed, and is summarized in Table 5-5.

Table 5-5: SWOT analysis for the FarmaBooth project.

Strengths	Weaknesses
1. Most data is freely available 2. Revisit time (2 days for MODIS and 16 days for Landsat) makes regular monitoring possible 3. High spatial resolution (30m and 250m) enables high detail monitoring	1. End-users need training in information interpretation
Opportunities	**Threats**
1. New methods for preventing property conflicts, optimizing land usage, and increasing crop yield 2. Utilization of the Pan African e-Network	1. Free access to information may create local conflicts 2. Lack of training resources for interpretation personnel in Liberia

5.3 Telemedicine Van

The Mombasa Declaration on Space and Africa's Development encourages the improvement of public health services by expanding and coordinating space-based services for e-health and telemedicine (UNESCO, 2011b). Telemedicine is a satellite application which provides healthcare services, and helps distribute medical information to remote areas. Telemedicine vans can perform diagnosis, apply therapies, aid preventative strategies, perform research and appraisal services, and improve individual health education (WHO, 2006).

The vast majority of the qualified medical staff practices in urban centers, creating problems for Africa's large rural populations. For example, in South Africa, 43% of the population is served by less than 8% of doctors, and the doctor-to-patient ratio is five times lower in rural areas than in urban areas (US Agency for International Development, 2012). By combining satellite communications, information technology, and modern medical sciences, it will enable rural African populations to have access to a higher quality of healthcare services than presently possible. Telemedicine vans are not a new concept, they have been previously implemented in Bosnia, Italy, and India. A program is currently underway to implement telemedicine vans in Zambia (Mupela, Mustard & Huw, 2010).



Figure 5-6: Eye examination in the Telemedicine Van in Chunampet [World Diabetes Foundation, 2008].

The following section will describe the implementation of a Telemedicine Van project in Africa. This application is to address the focus area of health, with a minor application for education. This proposal is relevant for all three target countries, but would most likely see the highest degree of implementation in South Africa because of its relatively high costs. In addition, it will provide an overview on the technical aspects and benefits of the project, an investigation into the costs and potential funding sources, a description of how to implement this project, as well as an ethical consideration for the project.

5.3.1 Technical Overview

The main components that are needed for the satellite Telemedicine Van are shown in Table 5-6.

Table 5-6: Main components for the Telemedicine Van.

Telemedicine Van Components	Comments
Satellite communication terminal	-
Videoconferencing equipment	Includes webcam, video monitor, audio system, and capabilities for information transmission and data sharing
Portable medical equipment	Includes pressure gauges, pulse oximeter, stethoscope, Electrocardiogram (ECG), and disinfection equipment
Global Navigation Satellite System (GNSS) capabilities	-

To be functional, the Telemedicine Van will also need to include a portable power supply, temperature regulation, and a satellite antenna. Email and Voice over IP (VoIP) calls can use the Broadband Global Area Network (BGAN) (global Satellite Internet Network using portable terminals) and Thuraya satellite networks. BGAN covers all areas of the globe, apart from polar regions, and Thuraya has also a very wide coverage, including African countries. The geostationary location of the satellites, as well as the use of the BGAN-Link service (with Inmarsat's L-band network) allows the service not to be adversely affected by connectivity problems during extreme weather conditions.

This project could use the services of O3b. O3b is a satellite telecommunications project whose goal is to provide internet access to the "other 3 billion" people of Earth, using a constellation of eight satellites in a medium Earth orbit. In 2013, the network is expected to have the capacity to deliver speeds of up to 1.2 Gbps (O3B, 2012).

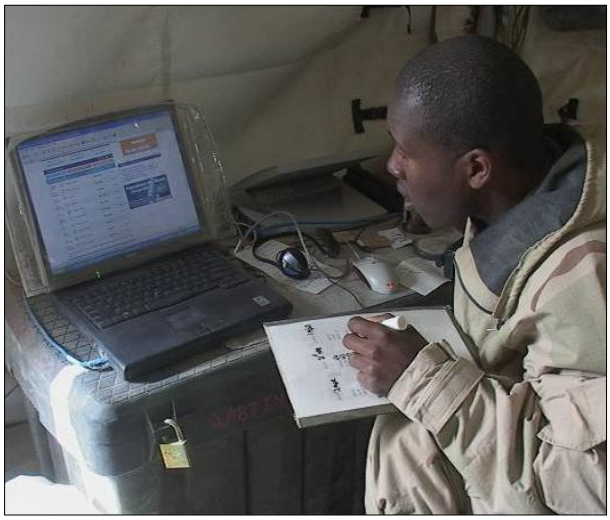


Figure 5-7: A soldier in Iraq uses a BGAN terminal in 2003 [Martin, 2003].

The mobile terminals are very simple to use and it is only a matter of few minutes to establish voice and data connections. Their size is small enough to fit in a backpack, while there are also vehicular terminals to be mounted, offering high performance, extensive functionality, and multi-user capability. The weight of the terminals is negligible, while the potential data rate varies from 256 kbps (streaming IP) to 492 kbps (standard IP, send & receive). There is also an option up to 450 kbps exclusively for high quality video. The applications offered are, among others:

- Email
- Internet access
- Intranet access
- Secure Virtual Private Network (VPN)
- Telephony/VoIP
- Videoconferencing and live video streaming
- File transfer
- Time critical data transfer
- Remote surveillance

These services are well-fitted for the objectives of the Telemedicine Van project (Inmarsat, 2012).

A streaming service with a guaranteed bit rate and high-quality audio are essential for enabling the remotely connected physician to produce an effective diagnosis. The applications platforms should be able to store-and-forward (which acquire and re-transmit data to the medical specialist for offline assessment). However, since the medical information will all be transferred to a medical center in the urban areas of the country (which will have their own means of data storage), the storage needs in the Telemedicine Van will be negligible. Furthermore, the medical equipment in the Telemedicine Van must be able to support and ensure the safety of the medical personnel, particularly in emergency situations (e.g. during natural disasters) (according to a personal conversation with Dr. Veronica La Regina in 2012).

5.3.2 Benefits

The Telemedicine Van will enable patients in remote areas access to national and international medical specialists in medical centers located in urban areas and abroad, while also providing the capabilities for storing and management of clinical data. The basic processes of the Telemedicine Van are:

- Synchronous teleconsulting (e.g., via telephone)
- Asynchronous teleconsulting (e.g., via email)
- Video conference
- Clinical data acquisition and transmission
- Medical data exchange with physicians and specialists

The main benefit of the Telemedicine Van (depending on how well it is equipped) include the ability for remote consultation, diagnosis, treatment, radiology, dermatology, ophthalmology, cardiology, monitoring, disaster management support, as well as the creation of a medical database for patients. Besides the clear benefits of providing remote medical support, the Telemedicine Van can lead to the establishment of a pilot program for establishing a country-wide medical database for individuals who have never had this in the past. By enabling all individuals to have their own personal medical file, it will allow for a significantly reduced time for future prognosis and diagnosis, and eases the work of African physicians.

Another potential use of the Telemedicine Van could be to provide data for epidemiology and disease monitoring, for projects like the ISU proposed SHINE platform (ISU, 2011a). According to the project's mission statement:

The SHINE database allows users to link diseases and their environmental indicators to satellite instrumentation and data providers able to provide the necessary remote sensing data and analysis.

(ISU, 2011a, pp. v)

The main advantage of using a Telemedicine Van over a more traditional telemedicine center is the mobility and the ease of moving services for those in rural areas. One of the major issues with telemedicine for rural areas is that it still necessitates the transfer of individuals from isolated areas to a more central location where they can receive these services. The Telemedicine Van will mean that those in isolated areas will have the medical services brought to them, greatly enhancing their access to this necessary service.

5.3.3 Financing

Costs

VoIP calls and emails are available using BGAN or Thuraya. For internet, data, and phone connectivity, the price for the service is approximately USD 5,000 per year plus USD 4 for every Megabyte (MB) after the first 1,200 MB. For streaming services (such as streaming video) the cost varies from approximately USD 3 to 30 per minute (depending on the quality). The price of the terminal itself varies from USD 2,000 to 5,000 depending on the manufacturer. The setup cost and activation fee is approximately USD 50 to 100. All of these prices are on a per-unit basis and a summary is shown in Table 5-7 (Inmarsat, 2012) (Satwest, 2012).

Table 5-7: Estimated connection costs for the Telemedicine Van.

Service	Estimated (USD)
Internet, phone, data connectivity	5,000
Data transfer (per MB over 1200)	4
Streaming services (per minute)	15
Terminal	3,500
Activation Costs	75
Totals (rounded)	*8,500*

For a more comparative cost estimation, parallels can be drawn from similar maritime technology applications utilizing similar systems. For example, Telespazio offers Internet access, VoIP, and a satellite router for USD 2,000 (128-512 kbps), USD 2,600 (256-1,024 kbps), and USD 3,400 (256-2,048 kbps) to ships travelling off the African waters en route to India (according to a personal conversation with Dr. Veronica La Regina in March 2012).

The costs associated with individual medical equipment components vary depending on vendor and model. For example, a portable ultrasound device can be purchased in a price range from USD 4,500 to 99,000 (Absolute Medical Equipment, 2012). The cost of the medical equipment that will likely be implemented in the Telemedicine Van, however, can be reasonably estimated by examining the cost of a fully equipped ambulance. Ambulances are typically equipped with a wide variety of medical devices, including blood pressure meters, pulse oximeters, stethoscopes, and portable ECG machines. The cost of an ambulance, depending on the extensiveness of the medical equipment, ranges from USD 60,000 to 400,000 (BBC, 2004). The Telemedicine Van will require many different medical tools, the cost of which will likely be at the high end of this scale. As such, a cost for a fully kitted Telemedicine Van is estimated at approximately USD 400,000. However, it is worth noting that there have been numerous cases of decommissioned ambulances being donated to African countries, e.g. from Israel to Uganda in February 2012 (Kenyi, 2012). In that case, the initial cost will be reduced significantly. In some countries, the urban medical centers and hospitals where the remote physicians will be located, may need to be equipped with terminals for establishing the connection with the Telemedicine Van for the medical data exchange. The additional cost would be in the same price range mentioned above (USD 2,000 to 5,000).



Figure 5-8: Mobile telemedicine vehicle used by Loma Linda University in California, US [Fike, 2007].

For the additional power requirements, the Telemedicine Van can be equipped with portable power generators. The price for a 4 kW generator varies from USD 700 to 1,800 (Yamaha Motor, 2012). In terms of personnel required, a three-person team will be needed. This team will consist of a Telemedicine Van driver, a Telemedicine Care Assistant (or paramedic), and a Telemedicine Van Technician, all working full-time. The salary for such a worker (in South Africa) is approximately USD 23,000 to 29,000 per annum (Emergency Medical Paramedic, 2012). In other target countries, such as Liberia, the salary will be much lower in relation to the GDP per capita and is estimated at around USD 640 to 800 (CIA, 2011a) (CIA, 2011c).

Funding Sources

The manufacturers and vendors of modern telemedicine systems are the primary stakeholders in this case. There has been a growing interest by venture capitalists in this area in the recent years, but one cannot make safe assumptions and predictions on their willingness to be involved, given the economic instability of the African continent and the minimal commercial integration. However, one source of funding that would be important for the Telemedicine Van is private insurance providers. This is because they have an economic incentive to promote the health of their customers. Since the Telemedicine Van would provide health services to populations that are generally high-risk for insurance providers, these companies would likely be interested in promoting the Telemedicine Van.

Funding providers could of course also be sought from government agencies involved in healthcare, though the available resources may be limited in many African countries. This is because both the government and the vast majority of the public face economic difficulties, thus preventing the sustainability of the Telemedicine Van long before it is deployed. Therefore, other funding sources have to be addressed. These include NGOs and partnerships like AU- New Partnership for Africa's Development (NEPAD), which aims to mobilize sufficient resources to establish partnerships with underdeveloped countries (African Union, 2008). Finally, humanitarian organizations such as Doctors Without Borders, or the Red Cross, can be expected to support this project as their goals are to assist in projects aiming to provide medical care to underprivileged communities in developing and underdeveloped countries. These organizations provide volunteer doctors and nurses to deliver urgent medical care in countries which have been harmed by war and disaster. As such, Doctors Without Borders and the Red Cross could be sought after for support of the Telemedicine Van, particularly to provide the staffing personnel.



Figure 5-9: Doctors Without Borders provided medical assistance when violence broke out in Johannesburg, and then in Cape Town, South Africa in 2008 [Doctors Without Borders, 2008].

5.3.4 Implementation

The IDEAS for Africa team recommends the establishment of a Telemedicine Van project, and the following section details how this could be implemented.

Target Countries

When considering healthcare innovations and improvements in Africa, discussions must be focused around the effectiveness of government decisions. The lack of political will to provide funding for enhancing the healthcare system is identified as the major obstacle that has to be overcome. At the same time, any effective healthcare application needs to be responsive and dynamic to meet evolving and often unpredictable healthcare needs. The benefits of any healthcare solution cannot be realized without sufficient and consistent governmental support. Regional techno-economic cooperation platforms have an important part to play in attracting and engaging governmental authorities in the use of projects such as the Telemedicine Van. All of the stakeholders involved have to persist in promoting their agenda, to finally achieve sustainable solutions for the African healthcare (Adebola & Adesina, 2010). It must also be mentioned that the Telemedicine Van can have a unique application being deployed during times of armed conflict. Thanks to its mobility it can assist in situations where the medical infrastructure has been destroyed and help those in very serious emergency situations. This is particularly true for instances of genocide, or for refugee support as the people affected by these will not stay close to major cities like Cape Town, Marrakech or Monrovia, where fully operating hospitals exist.

As mentioned in the *Target Country Selection* section, almost 40 percent of Liberia's population lives in rural areas, and the country's total life expectancy is among the lowest in the world at 57 years, indicating the need for a service such as the Telemedicine Van (The World Bank, 2011). With a GDP of USD 1.76 billion and a GDP per capita of USD 500 (CIA, 2011c), the implementation of the Telemedicine Van project would require external funding sources. The recent stability in Liberia is encouraging in terms of political will for a project like this, but the immense lack of infrastructure – along with regulatory gaps, combined with the terrible economic situation of the country - indicate the many obstacles that the project would have to overcome.

Furthermore, as was also mentioned in the *Target Country Selection* section, in the last decade Morocco has initiated large-scale projects to achieve high-quality infrastructure. This infrastructure will mean that the Telemedicine Van is more suitable for moving from location to location and can potentially

reach many more individuals. In addition, Morocco is an emerging nation with a growing economy (with an anticipated average growth rate of 5.5 percent for 2009-2013 (The Economist, 2012)). In Morocco there continues to be a significant rural and desert population (44 percent of population is rural and growing at 0.2 percent per annum (CIA, 2011b)) that suffers from isolation and the Telemedicine Van has the potential to offer great benefits.

South Africa, with its high rural population of about 40 percent (CIA, 2011a), and with a better infrastructure than most African countries is well poised to take advantage of the Telemedicine Van. South Africa's increasing space activities and the development of South African satellites will likely lead to a reduction in the cost necessary to deploy it. On a policy level, the founding SANSA and the renewed governmental interest in space-based activities to improve the country's standard of living indicates that there is a political will for such a project. However, South Africa has excellent mobile phone networks. Almost the entire country is covered by at least GPRS (General Packet Radio Service) and EDGE, and all towns by 3G (Vodacom, 2012). The areas not covered are scarcely populated. Therefore, one could argue that it would be cheaper to use the mobile phone networks instead of satellite, and that the Telemedicine Van would find more efficient use in Morocco, Liberia, and other African countries with a lower level of network infrastructures.

Application to Other Countries

The proposed Telemedicine Van would be equally applicable to many other African countries that face problems of insufficient medical healthcare for remote and rural areas. Modifications to the van could be made to better support incidences of HIV infection (e.g. equipping the vans with HIV medication or the ability to perform HIV testing). For example there are 22.5 million HIV cases in Sub-Saharan Africa alone, and Africa is home to 68 percent of all infections, and approximately 72 percent of all AIDS deaths worldwide, even though it only amounts to about 12 percent of the world population (UN, 2010). However, such as in the aforementioned cases, many implementation problems in these countries relate to limited funding, less-than-ideal regulations, and national and regional incompetence – all of which would adversely affect the deployment and success of the Telemedicine Van. Generally, the concept of the Telemedicine Van can find useful applications in nearly every African country due to its humanitarian-based focus and its simplicity of implementation, but will always meet with problems in terms of financial support.



Figure 5-10: Antiretroviral drugs for treatment of HIV [Kahler, 2011].

Some of the main challenges of implementing the Telemedicine Van are technological. It is not that the technologies needed do not already exist; the difficulty is that often Africa acts as a graveyard for western technologies. These technologies remain underutilized due to the lack of funding, infrastructure, trained personnel, and poor regulatory environment. User-driven (rather than

technology-driven) solutions have the best chances of becoming sustainable in the peculiar African socioeconomic landscape. Designing systems where one needs to change the legal or regulatory framework in Africa is not the best solution, rather making sure the system can operate within the constraints that currently exist. Regarding this program's sustainability, developing strong African ownership into the system with a good knowledge transfer program is advised, and involving as many relevant African stakeholders as possible. According to a personal conversation with Y. Brodsky in March 2012, it is hard to imagine anything surviving a long time in Africa if it is lacking these elements.

Problematic telecommunications regulations exist in Africa, characterized by limited policy liberalization. For example, in 2003 there were monopolies for local, long-distance, and international call services in over 60 percent of African countries, with 10 percent of them allowing monopolies for mobile, VSAT, and Internet Service Providers (ISP). The high cost of internet access prevents telemedicine from being cost effective and affordable. According to Wootton, Nivritti, Scott & Ho, "the average cost of a 30-minute videoconference at 128 kbps, from Africa to the USA, is [USD 48.30]" (2009, p.232). The situation for satellite connectivity however also remains largely unaffordable. Legislation limitations have led to high prices, even though VSAT access is available to all African countries, thereby preventing effective use of the connectivity for telemedicine applications. For example, the average annual VSAT license fee in 83 African universities is USD 13,553, compared with USD 426 for European Union (EU) universities (Wootton, Nivritti, Scott & Ho, 2009).

Approximately 25 percent of all world diseases occur in Sub-Saharan Africa, whereas the percentage of medical professionals is only 1.3 percent (the vast majority of which are based in urban locations) (Wootton, Nivritti, Scott & Ho, 2009). Furthermore, there is a tendency for African physicians to work in Europe or the US, draining the already scarce human resources in the African healthcare system. Adding further complications, these remaining doctors are often unwilling to undergo the extra training necessary for telemedicine. This problem could be alleviated by engaging doctors from Europe or North America, but their remuneration is not able to be sustained by the low-budget African healthcare systems. Other difficulties that would be presented include incompatibilities in diagnostic, treatment protocols, pharmaceutical protocols, and legal gaps regarding liability. These problems can be bypassed by intensifying education and training throughout the African continent.

Technological Availability

All of the technology to set up the Telemedicine Van project is currently available; the difficulty will likely lie in integrating all technologies. The BGAN mobile satellite terminals are immediately available; usually shipping takes 24 to 72 hours, while the installation is done within hours (Satwest, 2012). The collection and installation of all the portable equipment of the Telemedicine Van can be done in the country of operation.

Time to Deployment

The main driver behind the time to deploy the Telemedicine Van project will be intrinsically linked to the political will and available funding. Following a decision to initiate the program, it is expected to require less than half a year before the first Telemedicine Vans are in operation. As we mentioned previously, the terminals are already available and can be shipped to any country within one to three working days after the order. The installation in the van is really simple and can be completed in hours. The medical equipment and the GNSS device can also be sent almost immediately upon purchase. Given the ease of use of the equipment, there is no lengthy training needed for the personnel, and they can be familiarized with the technology in a space of one to two weeks. In conclusion, apart from the expected bureaucracy and any given political reluctance, the satellite Telemedicine Van has by far the shortest time for deployment of all the proposed satellite applications.

5.3.5 Ethics

The ethical implications for a project like the Telemedicine Van would not be complicated, since it is providing a basic need like medical healthcare. Nevertheless, there will be concerns in the acceptance of this new medical practice, particularly for the rural areas that still practice traditional medicine. Traditional medicine is a phenomenon that is more evident in countries like Eritrea, Kenya, Malawi, Mozambique, Swaziland, Uganda, and Zimbabwe. The Traditional Healers Organization is the main organization of tradition healers in the southern region of Africa. As of 2003, its members had reached 69,000, with 25,000 of them in South Africa (Richter, 2003). There will also likely be concerns with the transfer of medical data via satellite, since this information can be relatively easily intercepted. Care will have to be taken to ensure that medical data from patients remains confidential.

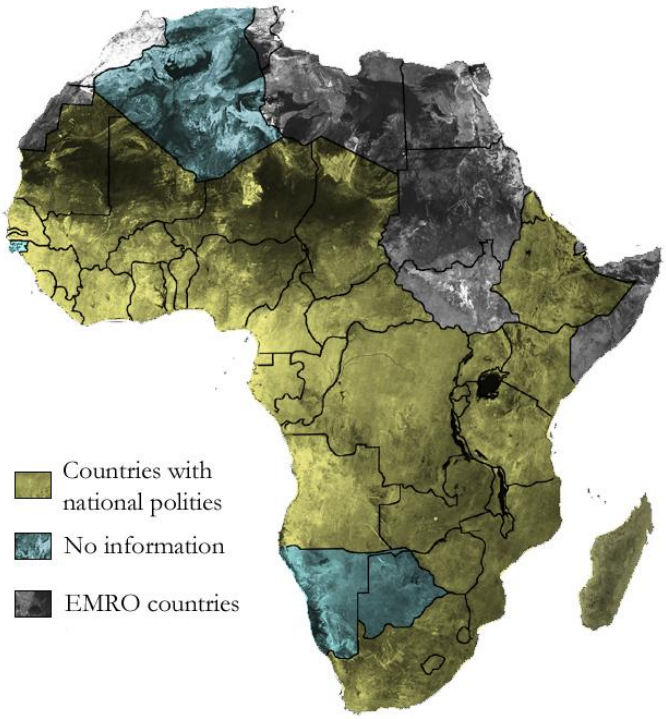


Figure 5-11: African countries with national policies regarding traditional medicine, countries with an Eastern Mediterranean Regional Office, and countries without data [WHO, 2010] [Osborne, 2012].

Another possible ethical concern is that if this project is government funded, the public may not perceive its implementation as an effective use of resources. This was particularly highlighted in 2009, when controversy arose over Namibia purchasing nine mobile clinics from China at a cost of USD 53 million (Mupela, Mustard & Huw, 2010). In this situation the public perceived this as a waste of resources. This indicates the need for intense public awareness of the social benefits from similar projects. This will lead to better reception of the Telemedicine Van project and a more successful implementation.

5.3.6 SWOT Analysis

The IDEAS for Africa team has recommended the establishment of a Telemedicine Van project in Africa to enable access to medical professionals in hospitals in urban areas or abroad and equipment for individuals in remote areas, and also to provide a means of medical data storage, facilitating easy access to this information for future medical purposes. This application is to address the focus areas of health, and is particularly relevant for application in South Africa, although with external support it could see implementation in Liberia or Morocco. A SWOT analysis was performed on the Telemedicine Van and is shown in Table 5-8.

Table 5-8: SWOT analysis for the Telemedicine Van project.

Strengths	Weaknesses
1. Mobility enables accessibility to remote areas 2. Can provide services for a wide range of medical needs	1. High funding requirements for countries with limited resources 2. Weak regulatory environment to enable sustained success
Opportunities	**Threats**
1. Mitigates effect of lack of trained medical professionals 2. Creation of medical database for individual patient files 3. Miniaturization of technologies will expand functions of the van 4. Support of epidemiology and disaster management	1. Patient data security needs to be ensured 2. Disruptive wireless technology limits audio and video capabilities 3. Necessity of political will

5.4 Desert Movement Predictor

In the arid regions of Africa, water resources are scarce and access to them is often unpredictable. This constraint leads to uncertainty to access the resource, which in turn can increase human pressure on the environment, resulting in further water depletion. Desertification is a process by which fertile land becomes desert. Population growth, increased food consumption, and short-term economic interests all contribute to desertification. Other contributing factors include over-grazing, excessive firewood gathering, wasteland cultivation, inefficient use of water resources, excessive agricultural harvesting, and lack of environmental protections related to factories, mines, and transportation infrastructure. Human activities are not the only source of desertification, as natural climate effects from wind, water, salination, and freeze-thawing erosion also contribute (Shili, 2006).

This section will investigate the application of a Desert Movement Prediction Center (DMPC) to provide prediction, modeling, and recommendation services to countries that are affected by desertification. This application will address the focus areas of agriculture and the environment. Moreover, the DMPC is an application for the target countries of Morocco and South Africa as they are the ones affected by desertification of the three target countries. This section will begin with a background investigation on desertification, a technical overview of how to monitor moving or growing deserts, an examination of how much such a center would cost and the funding sources for it, a strategy for implementing this facility, and finally a consideration of the ethical concerns of establishing the DMPC.



Figure 5-12: Shepherd guides his sheep through the desert outside of Marrakech, Morocco [Tarantino, 2010].

Desertification restricts socio-economic development and contributes to poverty in affected regions. Desertification influences everything a local population needs - access to water, crops and livestock maintenance, and even the wood needed for fuel and construction. Desertification leads to weakened opportunities for climate regulation, soil conservation, and recreation. Desertification not only affects the dried region itself, but also makes an environmental impact thousands of kilometers away, as dust clouds formed from vegetation loss cause health problems in densely populated areas. Desertification also leads to human migration to cities, leading to an exacerbated urban sprawl and related socio-political problems (Green Facts, 2006). There are ways to prevent, reduce, and even reverse desertification, as shown in Table 5-9.

Table 5-9: Desertification prevention, reduction, and reversal strategies [Green Facts, 2006].

Prevention, Reduction, and Reversal Strategies	Description
Land restoration	Through reforestation, soil erosion control, water harvesting
Halting cultivation	Done in areas with severe soil erosion and water loss
Mitigating damage	Mitigating wind and sand storm damage through advanced warning systems
Crop conversion	Converting cropland to forest through water saving irrigation projects
Stabilizing sand	Process by which sand is stabilized from moving via various biological, chemical, and engineering techniques
Shelterbelts	Plantations made up of multiple rows of trees planted to provide shelter from wind
Fallow band system (see Figure 5-3)	A land management practice for controlling desertification and improving crop production. Fallow bands are placed at right angles to erosive winds in a cultivated field during rainy seasons and catch windblown nutrients. During the following rainy season vegetation on the previous year's fallow bands are cleared and crops are cultivated on them

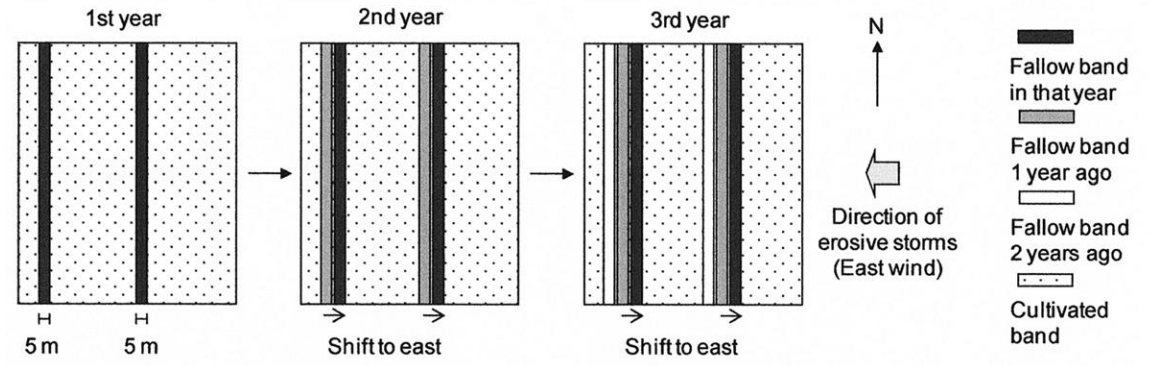


Figure 5-13: Depiction of how a fallow band system works [Ikazaki et al., 2010].

Rehabilitation measures are often difficult and expensive, while prevention measures are cheaper but require management and policy approaches that promote the sustainable use of arid regions. If no countermeasures are taken, the desertification of drylands will threaten future improvements in human well-being (Green Facts, 2006).

In the last 35 years several studies have attempted to understand wind dynamics (which pertain to the activity of winds to reshape Earth's surface) in the Sahara desert. Since the early 1970s, Landsat satellite images have facilitated the observation of inaccessible landforms in arid regions. These images have been used to recognize sand accumulations, identify different types of dunes, and observe sand dune movement. The near-infrared (NIR) band best discriminates sand dunes from

other surface landforms. These Landsat studies however were focused on specific locations in the desert and were always complemented by ground-truthing (Hereher, 2010).

Landsat images have also been used to analyze large sand dunes. By using images taken in 1973, 1991, and 2000, Chinese scientists measured the rates of dune migration in the Gobi desert, and the evolution of dune areas and volumes (Yao, 2007).

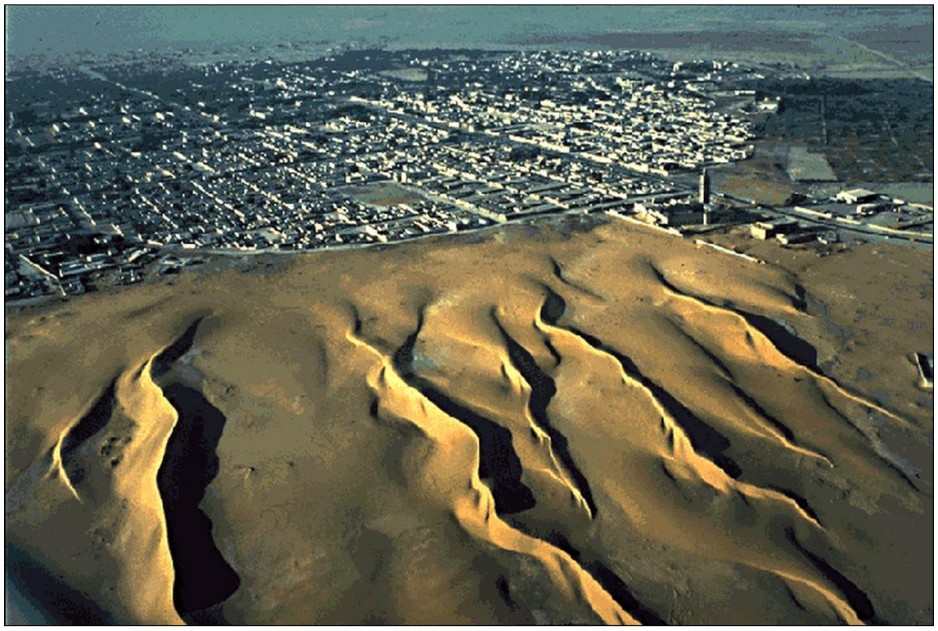


Figure 5-14: Landsat image of the dunes encroaching Nouakchott, capital of Mauritania [NASA, 1974].

In 2006, the Fight Against Desertification in West Africa project showed how InSAR can be used for studying aeolian transport processes and the detection of active sand dunes. This study was performed in three areas of Western Sahara (*Gouré* in Niger, Draa Valley in Morrocco, and Mauritania) by analyzing high resolution interferometric products, like DEM, coherence images (which measure local phase correlations between two SAR images, providing a SAR noise measurement), and intensity images (showing intensity of backscatter of a SAR image), complemented by field observations. Tandem pairs of images of one day interval from satellites ERS-1 and ERS-2 were employed. The results illustrate the potential of InSAR as a useful source of information for the detection of light sand dune movements in semi-arid zones (Bodart, Gassani, Salmon & Ozer, 2009).

In 2011, a two frequency InSAR system for mapping the subsurface topography in deserts and arid regions was demonstrated (Elsherbini & Sarabandi, 2011). Ka-band InSAR systems can be used for mapping the top interface topography and Very High Frequency (VHF)-InSAR can be used for subsurface topography mapping. This is used to map sand layer thickness, which has multiple applications in environmental and archaeological studies, oil field and ground water explorations, as well as mine field detection.

Extensive research has been done in monitoring dust storms with remote sensing imagery. This research has largely focused on identifying individual pixels that were part of a dust cloud. In 2008, Chinese researchers at the Shan Dong University of Science and Technology were able to determine the areal extent of a dust storm, measure its intensity (amount of dust in the air), and track its movement. They used transient data from the MOderate-Resolution Imaging Spectroradiometer (MODIS) sensor on the Aqua and Terra satellites, and applied multi-channel threshold methods. This measurement technique involves taking the difference between intensities at various wavelengths, and comparing these values to a known threshold that is the value for a specific substance, like sand (Di, Lu, Sun & Wang, 2008).

In late 2013, ESA expects to launch the first satellite to study the Earth's wind patterns from space, ADM-Aeolus. It will measure wind profiles globally, using its Atmospheric LAser Doppler Instrument (ALADIN) payload. This instrument will be the first spaceborne Doppler Wind LiDAR, and will create a vertical wind profile showing the relative strength and direction of winds at different altitudes.

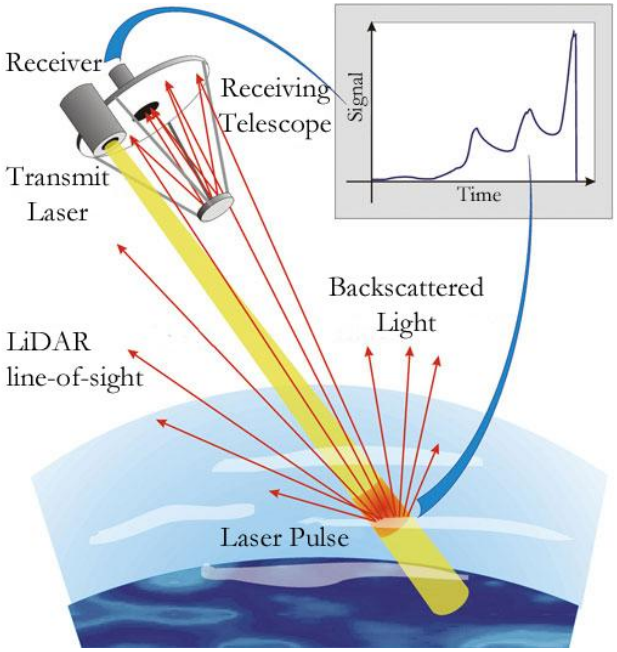


Figure 5-15: LiDAR emits laser pulses towards the atmosphere and retrieves frequency of backscatter from clouds, aerosols, and molecules in the atmosphere [ESA, 2008b].

5.4.1 Technical Overview

There are currently a large number of satellites in orbit available to provide the required imagery and data products for combating desertification. To assess sand dune displacement and predict future sand dune movements, both wind patterns and medium-resolution optical images are necessary. Furthermore, to see how sand dunes move over time, a large historical database would be advantageous to enhance the predictability of sand dune movements. To understand the entire process, the main parameters to combine include levels of aerosol, humidity, precipitation, topography, vegetation, and wind. The following instruments can provide these parameters:

- Aerosols - Cloud-Aerosol LiDAR with Orthogonal Polarisation (CALIOP), MEdium Resolution Imaging Spectrometer (MERIS), Moderate Resolution Imaging Spectroradiometer (MODIS), and Sea-viewing Wide Field-of-View Sensor (SeaWiFS)
- Humidity - Microwave Imaging Radiometer using Aperture Synthesis (MIRAS)
- Precipitation - Tropical Rainfall Measuring Mission (TRMM)
- Topography - SAR
- Vegetation - MERIS, MODIS, Thematic Mapper (TM)
- Wind - ALADIN, Spinning Enhanced Visible Infra-Red Imager (SEVIRI)

In addition, several weather stations can provide the much-needed ground-truthing for calibrating satellite data. Table 5-10 lsts various capabilities of these instruments.

Table 5-10: Remote sensing instruments and satellites of interest for the DMPC [Topham, 2010].

Measured Entity	Satellite - Instrument	Spatial Resolution	Scene Size	Revisit Time	Date Available
Aerosols	MODIS - Aqua	1,000m	1,200 x 1,200km	1-2 days	Jul. 2002 - present
	MODIS - Terra	1,000m	1,200 x 1,200km	1-2 days	Mar. 2000 - present
	SeaWiFS - SeaStar	1,100m	2,800km (swath)	1 day	Sept.1997 - Dec.2010
Humidity	MIRAS - SMOS	35km	1,050km (swath)	1-3 days	Feb. 2010 - present
Land Cover	MODIS - Aqua & Terra	500m	1,200 x 1,200km	1-2 days	Mar. 2000 - present
Precipitation	TMI - TRMM	5-40km	750km (swath)	0.5 days	Jan. 1998 - present
	PR - TRMM	4.3-5km	220-250km (swath)	0.5 days	Jan. 1998 - present
Vegetation	TM - Landsat	15-120m	170 x 185km	16-18 days	Fall 1972 - present
	MODIS - Aqua	250m	1,200 x 1,200km	1-2 days	Jul. 2002 - present
	MODIS - Terra	250m	1,200 x 1,200km	1-2 days	Mar. 2000 - present
Wind	SEVIRI - Meteosat	80km	Visible Earth disc	Continuous	Early 1978 - present
	ALADIN - ADM-Aeolus	N/A	N/A	7 days	Late 2013

Since imagery is presented in different and varying resolutions, sizes, and physically mapped areas, a number of pre- and post-processing steps are required to ensure data consistency. The envisioned steps are shown in Table 5-11.

Table 5-11: Imagery processing steps.

Step	Stage	Name
1	Pre-start	Data acquisition
2	Pre-processing	Geo-referencing
3		Geometrical correction
4	Post-processing	Registration
5		Projection
6		Visualization

5.4.2 Benefits

Predicting desert movements requires a large amount of data, including historical data on the desert and other desertification indicators (including changes in flora, fauna, and humidity), using both ground-based and space-based instruments. Space-based technologies have a wide number of benefits over other technologies, including:

- Ability to rapidly and remotely measure large areas
- Abundance of data obtained via multiple remote sensing instruments, including optical and infrared data from passive sensors or SAR and InSAR data from active radar
- Ease of distribution of data
- Ability to predict and provide services with respect to disaster management
- Raising awareness of space-based technologies

5.4.3 Financing

Costs

Estimating the cost of developing the DMPC entails analyzing the cost of imagery, staff, hardware, and software. Satellite imagery, except for InSAR images, incurs no expense. InSAR image costs can be obtained from SAR images costs by doubling it (two passes) and adding a 25% more in terms of processing (according to a personal conversation with Dr. John Farrow on 16 March, 2012) The cost of SAR images for areas larger than 100,000 km² range from USD 0.25 to USD 0.45 per square kilometer (Zhdanovich, 2012). Using a mean value of USD 0.35 per square kilometer, the cost of InSAR images amounts to USD 0.87. Since the target monitoring area of the three African deserts is estimated 3,300,000 km² (target area is exterior 200km, or the crown, which is a reasonable portion of land to analyze desert movement with high resolution) as shown in Table 5-12, an estimation of the costs of the DMPC was performed and the results are shown in Table 5-13. From this, it is shown that, assuming four pictures per year, a total imagery cost of approximately USD 11.5 million, and hence a 5-year total project cost of almost USD 57.5 million.

Table 5-12: Size of targeted area estimation.

Desert	Surface ('000 km²)	Perimeter ('000 km)	Crown Surface ('000 km²)	Total Monitoring Surface ('000 km²)
Sahara	9,000	13	2,600	3,300
Kalahari	900	3	560	
Namib	90	N/A	80	

In a personal conversation on 29th February 2012, according to Dr. Singhroy a staff of twenty is assumed for this project. To obtain an overestimation of the human resources cost, and because data regarding African worker compensation is difficult to obtain, US hourly worker compensation rates were used (at USD 30.18 in 2010) and the annual yearly expense for workers was therefore estimated to be USD 1.3 million (US Department of Labor, 2011). Hardware for the DMPC will include five computer servers (estimated at USD 13,000 per unit) and twenty workstations (USD 2,500 per unit). Total hardware costs are USD 100,000 for the whole project. Software licenses for the center are estimated at USD 25,000. Cost estimation is summarized in Table 5-13, with costs less than USD 13 million per year.

Table 5-13: Desert Movement Predictor cost estimation.

Concept	Annual Cost (USD million)	Project Cost (USD million)
Satellite Imagery	4.9	25
Human Resources	1.3	6.5
Hardware	0.02	0.1
Software	0.01	0.03
Total	*6.2*	*31*

Funding Sources

African countries affected by desertification will likely be most interested in this project and hence will be the immediate source of funding. Additional sources outside of Africa include bilateral development assistance, which are typically given as grants (UN Convention to Combat Desertification, 2012a). The Global Environment Facility (GEF) focuses on land degradation and therefore is a potential source of funding. The GEF is an independent financial organization that provides grants to developing countries, countries with economies in transition, supports projects related to environmental challenges, and promotes sustainable livelihoods. The GEF serves as financial mechanism of the United Nations Convention to Combat Climate Change (UNCCD) and its partnership agencies including the World Bank, the African Development Bank, and the IFAD. All these may be interested investors and funders (Global Environment Facility, 2012).

Another major source of funding is the AU's NEPAD. NEPAD aims to mobilize sufficient resources for the implementation of priority programs and projects that address Africa's sustainable development. It looks to achieve this by establishing a platform for global partnerships and collaboration with advanced industrialized countries of the G8 (The Group of Eight) and the Organization for Economic Cooperation and Development (OECD). In addition it seeks to establish partnerships with regional organizations like *Comité permanent Inter Etats de Lutte contre la Sécheresse dans le Sahel* (Inter State permanent Committee for the Fight against Drought in Sahel) and with multilateral development institutions such as the *Union Économique et Monétaire Ouest-Africaine* (West African Economic and Monetary Union) (African Union, 2008).

5.4.4 Implementation

The IDEAS for Africa team recommends the establishment of a DMPC, and the following section shows how the work of the center can be implemented.

Target Countries

Almost fully covered by tropical rainforest, the effects of drought and desertification in Liberia are minimal. Less than seven percent of Liberia's territory is in a moderate risk of desertification. The causes of land degradation in Liberia are not related to desert advancement, but to agriculture and logging (UNCCD & Liberian National Coordinating Committee to Combat Desertification, 2002). Consequently, a DMPC is not directly applicable to Liberia.

Located adjoining the Atlantic Ocean, the Mediterranean Sea, and the Sahara Desert, Morocco has an arid climate and high vulnerability to soil erosion which is caused by both salination and deforestation. The country has desertification concerns in more than 90 percent of its territory. Many Moroccan farmlands are non-irrigated, promoting the conditions for desertification (Ghanam, 2003). Cognizant of the inverse relationship between desertification and development, in 2001 Morocco drafted an National Action Plan (NAP) for combating desertification, the *Programme d'Action National de Lutte Contre la Désertification* (PAN-LCD), which was included in the national strategy for reducing poverty and creating sustainable development.

New governmental departments were created in 2003 and 2004, including the Commission for Water, Forests and Desertification. The PAN-LCD also promotes partnerships with other countries and institutions, including the UN, the EU, Germany, and the Observatory of Sahel and Sahara (UNCCD & Royaume du Maroc, 2004). Within this context, the DMPC meets all the interests of Morocco, and would be a powerful tool for its scientists and environmentalists to forecast the evolution of agricultural lands, to design and apply desertification countermeasures, and to alert populations about dust clouds. These functions will lead to reducing migration to urban areas (via preservation of rural and agricultural areas), consolidate Morocco's sustainable agriculture, and an improvement in urban health.

With the vast Kalahari Desert in the north, and the Namib Desert in the west, South Africa's territory is 10 percent desert, as shown in Figure 5-16. More than 90 percent of South Africa is classified as either arid, semi-arid, or sub-humid (UN Environment Programme, 2002). Furthermore, 25 percent of the magisterial districts in South Africa have lands in a severe state of degradation (UN Environment Programme, 2002). Consequently, desertification and land degradation is a huge problem in South Africa. The edges of the southern Kalahari Desert are the zones of highest deterioration in the country. The introduction of artificial waterpoints and veterinary fences has led to the rapid desertification of large drylands and adjacent areas. The other causes for land degradation include over-grazing, over-cropping, and incorrect irrigation practices.

The South African government is committed to the fight against desertification and land degradation, having ratified the UNCCD in 1997. As a result of this convention, the Department of Environmental Affairs and Tourism (DEAT) prepared an NAP outlining the national policy on desertification (UNCCD & DEAT of South Africa, 2002). Consequently, the IDEAS for Africa team

believes the DMPC will be of interest in South Africa as well, helping to understand the evolution of both Namib and Kalahari Deserts, and assisting the national government to implement efficient environmental policies. The DMPC fits perfectly within this regulatory framework, meeting all the requirements and needs specified by the government for sustainable environmental development.

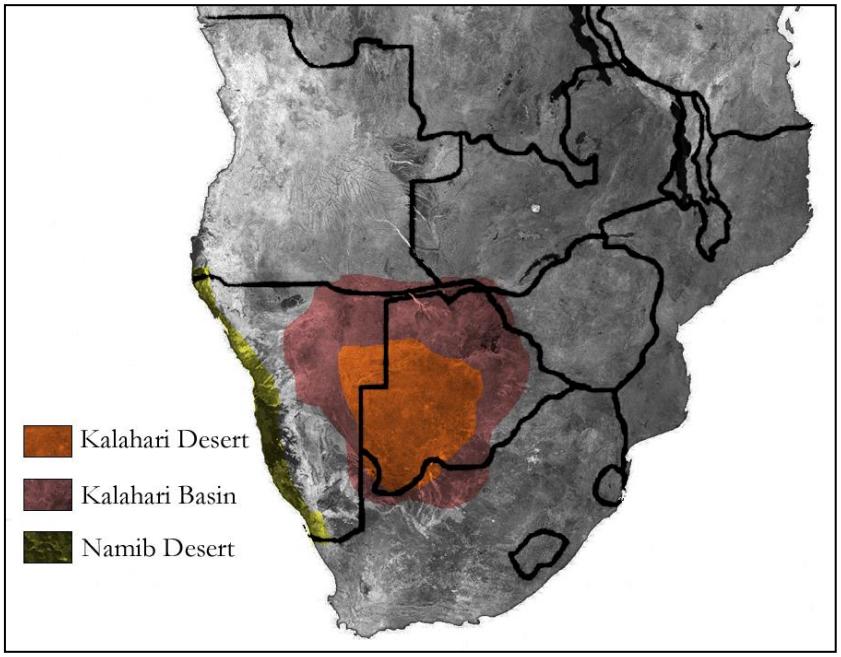


Figure 5-16: Location and extent of the Kalahari and Namib deserts [Tebyan, 2008] [Osborne, 2012].

Application to Other Countries

Two thirds of the African continent is desert or drylands (UN Convention to Combat Desertification, 2012b). More specifically, the Sahara Desert covers large areas of eleven countries - Algeria, Chad, Egypt, Libya, Mali, Mauritania, Morocco, Niger, Western Sahara, Sudan, and Tunisia -, the Kalahari Desert spreads over Botswana, Namibia and South Africa, and Namib Desert runs along the coasts of Angola, Namibia and South Africa. This means that 17 countries in Africa –one third of the total number of countries- are affected by the environmental and economic challenge that desertification entails, as has been explained in target countries sections.

The DMPC is conceived as a cooperative project that involves all the affected countries. Dividing the project into territories, or isolating a country from the project minimizes its scope and efficiency (e.g. imagery costs per km^2 decrease with a larger covered area). All African countries are party to the UNCCD and have developed their NAPs with the review of local authorities, community leaders and NGOs (UN Convention to Combat Desertification, 2012b).

In addition to the NAPs, African countries have created regional and sub-regional plans to facilitate cooperation and to better align their programs to the UNCCD 10 Year Strategy, gaining effectiveness in addressing desertification, land degradation and drought (UN Convention to Combat Desertification, 2012b). The DMPC arises as a perfect project which fits into these regional and sub-regional cooperative plans because it fulfils with Strategic Objective 3, which is to generate global benefits through effective implementation of the UNCCD, and Strategic Objective 4, which is to mobilize resources to support implementation of the Convention through building effective partnerships between national and international actors (UN Convention to Combat Desertification, 2007).

Technological Availability

The IDEAS team believes that desertification across Africa can be combated and alleviated with an international DMPC dedicated to desert movement prediction. Looking to real-world institutions, it was determined that China has successfully combated desertification for over 60 years (via tree planting, decreased grazing activity, and moving farmlands to forest and grasslands) further promoting the idea that desertification mitigation is possible (Tao & Zhenda, 2001). The activities of the DMPC would include:

- Data acquisition from satellite operators
- Remote sensing data-processing and analysis
- Research on the physics of dune movement
- Desert movement prediction and recommendations



Figure 5-17: Aerial view of China's "Great Green Wall" to prevent the encroaching Gobi Desert [Buczynski, 2010].

As discussed in the *Technical Overview* section, data acquisition sources are abundant and include free commercially available sources. For data processing and analysis, software (such as Oracle) would be used for storing and managing raw and processed data. Radiometric and geometric image processing would be performed by software such as ERDAS. Other processing tasks, such as desert movement prediction models, would need to be internally developed.

Desert sand movement occurs in two ways – the movement of the sand dunes across the desert, and the movement of the desert's edge. Typically desert edge movement is more easily monitored than sand dune movement. Desert edge movement can be easily monitored using optical or multi-spectrum remote sensing devices, as well as radar. However, sand dunes are composed mainly of sand, which is difficult to monitor using the same techniques. The IDEAS team has classified sand dune movement in three ways:

- Violent desert movement - Includes sand storms and has sand movements greater than 1km/hr
- Moderate desert movement - Movement of sand mountains on the order of 1m/day
- Passive desert movement - Slow sand drift less than 1m/day

Desert sand movement and prediction can be done in two ways: directly by monitoring and predicting according to historical trends; and indirectly by observing and studying related factors (such as wind, humidity, vegetation, aerosols, and precipitation of the region) and using these factors to predict future movement (Brandt, Geeson & Imeson, 2003). Monitoring this phenomenon entails using suitable sensors for each kind of movement, as detailed in Table 5-14.

Table 5-14: Various desert sand movement monitoring techniques.

Movement Types	Direct Monitoring Methods
Desert edge movement	Optical imaging, SAR, InSAR, multi-spectral imaging
Mild/Moderate desert movement	Optical imaging, SAR, InSAR, radar altimeter
Violent desert movement	Optical imagining equipped to a GEO satellite

In terms of available remote sensing technologies, optical imaging sensors, while used extensively, have poor resolution for this application. This is because the drift of the desert's edge, which will be the location tracked, moves only a few meters per year, and with optical resolutions greater than 1m, this measurement technique will not be applicable. Likewise multi-spectral imaging makes desert movement prediction difficult, as this technique performs poorly when the targeted area is homogenous (Zhao, 2003). It was determined that InSAR, with its high spatial resolution and ability for 3-dimensional mapping, is the most suitable method for directly measuring mild desert movements (Skolnik, 2010).

For data processing and analyzing, Geographic Information Systems (GIS) and desert movement prediction technology has existed for many years and there are many mature methods and algorithms for both enhancing different kinds of images and interpreting images and data. Data analysis methods, such as decision tree analysis, are also applicable (Scull, Franklinb & Chadwick, 2004). Weather forecasting techniques are also applicable but predicting desert movement trends via direct monitor will prove difficult. In addition, violent movement prediction using the available data sources will remain a difficulty. These two constraints could be overcome with a geostationary satellite with SAR capabilities, but this solution remains a technical challenge due to the size of the antenna and the power required.

Time to Deployment

The IDEAS team has estimated that establishing a DMPC will be broken down into four development phases, namely:

- Phase A - Clarifying and defining the DMPC concept and objectives (9 months)
- Phase B - Designing the DMPC organization and structure, and securing financing (12 months)
- Phase C - Acquiring personnel, hardware, software, and other necessary resources (9 months)
- Phase D - Operations (as long as needed)

5.4.5 Ethics

The DMPC is a supplier of information, and does not interfere with how various countries or authorities apply actions to combat desertification. The users of the DMPC are expected to follow their own NAP, which will have been designed in accordance to local authorities and community leaders. Therefore, no ethical constraints are expected regarding environmental policy, social, or religious aspects.

Having said that, since the DMPC is a remote sensing application, security or defense related constraints are expected to arise. This is because there are many African countries which have, as part of their territory, a desert. An example of this is the target countries Morocco and South Africa, but there are many others. As such, these countries may have issues regarding the observation of their territory, despite the altruistic intent of the DMPC. Therefore, care must be taken to ensure that all countries with deserts can be remotely sensed.

5.4.6 SWOT Analysis

The IDEAS for Africa team has recommendation the establishment of a DMPC in Africa to aid in the measurement and prediction of desert movement. The DMPC will also provide information that can be used to mitigate or reverse the effects of desert movement. The DMPC is to address the focus areas of agriculture and the environment, and is applicable for the target countries of Morocco and

South Africa as these countries have challenges with encroaching deserts. A SWOT analysis was performed on the concept of a DMPC and is described in Table 5-15.

Table 5-15: SWOT analysis for the DMPC.

Strengths	Weaknesses
1. Most data freely available 2. Provides information in regards to health issues, urban planning, and water management 3. Shared costs among affected countries 4. Aligned with UN strategy for combating desertification, which assures funding sources 5. It is a source of highly qualified job positions for local professionals	1. Difficulty in integrating data from various types of imagery (ex. Aerosols, humidity, topography, vegetation, and winds) 2. Ground-truthing necessary to calibrate and validate data 3. Wind data services lag in spatial resolution 4. Wind information from Meteosat is estimated by monitoring cloud movements, so surface winds may not match 5. Expensive SAR data
Opportunities	**Threats**
1. Foster research and development in the regions of interest 2. Set the basis for technology transfer from more developed countries to Africa	1. Affected countries may prefer individual studies rather than a continental one 2. Requires cooperation of diverse groups of African peoples

5.5 Anti-Poaching

Poaching is the hunting or catching of game or fish that is either on another's property or is subject to environmental protection. Illegal poaching is a major environmental problem in Africa. Not only does poaching threaten the survival of endangered species, but it also has a significant negative economic impact, due to reduction in wildlife diversity and therefore also tourism numbers. It is widely understood that poaching is a major problem in Africa and threatens the survival of numerous endangered species. Several species are currently under significant pressure from poaching in Africa. In South Africa, the Rhinoceros is hunted for its horns and the perlemoen is harvested as a delicacy. In Kenya, the wild African Elephant is hunted for its tusks.

The following section will describe the implementation of a satellite-based anti-poaching system. This system addresses the environment focus area, and is presented for the target country of South Africa. However, this proposal will have an application in any country that is affected by poaching. This section will include a background of poaching in Africa, an overview of the technical aspects of this system, an analysis of the costs and funding associated with such a system, a implementation strategy, as well as ethical considerations.



Figure 5-18: A perlemoen in a display tank at California [Wikimedia Commons, 2011a].

Many African countries have anti-poaching programs in which national park and law enforcement officers participate. However, the wide geographical distribution of macro species and their low population density makes poaching enforcement very difficult. To stem the tide of poaching, methods are required to patrol large areas or survey large populations for signs of poaching activity. Satellite systems are well-suited for poaching control due to their potentially wide coverage capabilities. For example, Iridium and GPS cover the entire global, allowing animal tracking all over the planet (Iridium, 2012)

Until now most efforts have been directed to making it more difficult for poachers to commit their acts. Nevertheless, often increasing local law enforcement presence will only instigate an arms race between poachers and law enforcement officers. It should be noted that gun battles regularly erupt in South Africa between armed poachers and rangers or soldiers (News 24, 2012). To reduce the number of poaching incidents, a system needs to be established in which those who hire poachers, and those who buy poached products, are found. To stop these poaching syndicates, a real-time system to poaching events need to be implemented, so information can be gathered and perpetrators can be caught.

Due to the wide biological diversity of species being poached, there is no single method for detecting poaching in all species. For example, the methods used to detect illegal fishing may be significantly different than for elephants. To aid discussion on the different poaching detection methods, it is convenient to classify species either as macro or micro. Nevertheless, it will be shown that the technology proposed for the micro and macro species have much in common.

Macro species are high-value, normally large, animals for example elephants and rhinos. These animals are large enough to be easily detected through airborne or even high resolution satellite platforms, and are sufficiently valuable to make individual animal tracking feasible.

Micro species are too small to be remotely detected, although detection of swarms may be possible. Due to their small size and low individual worth, it is not feasible to track individuals. A further problem is that some species, as in the case of perlemoen, live underwater and never surface, making remote detection impossible.

5.5.1 Technical Overview

For the macro species of interest (ie. the rhinoceros and the elephant) it is feasible to equip individual animals with satellite tracking collars. Although tracking collars are not new, until now they have been used mostly for periodic updates of animal movement for research purposes (Lotek Wireless, 2012). Two types of tracking collars exist, those based on terrestrial radio transmission, and those based on satellite communication. The terrestrial transmission models are not considered a viable method of

continuous animal monitoring as radio signals can easily be detected with inexpensive scanners. This would enable poachers to use the collars to easily find the animals. Thus, only satellite systems, whose frequencies typically lie far outside the range of them and do not propagate well on the ground, are the only viable option.



Figure 5-19: Person examines horns cut from endangered black rhinoceros in Zululand in 1996 [Wilderness Conservancy, 1996].

Present satellite tracking collars that monitor animal movements are equipped with a means of position location (typically through a GNSS), and a two-way communication interface (typically a Low Earth Orbit (LEO) communication constellation such as Iridium). Sometimes collars are also equipped with a heartbeat sensor, to sense when the animal has been killed. To enable collars to make real-time detection of poaching events, the following modifications to modern collars are required:

- The unit cost needs to be significantly reduced as the present price of several thousand dollars per device enables only a small percentage of the population to be collared (see *Anti-Poaching: Costs* section)
- Sensors need to be added to detect when the animal is subject to poaching
- Poaching event information needs to be transmitted to law enforcement officials in real time
- Notification of the poaching event must be transmitted to impartial observers to combat corruption

A block diagram of the proposed collar is shown in Figure 5-20. Several sensors will be required to sense when the animal is subject to a poaching event, as described below.

Most poachers use firearms to kill or injure the animal before removing its horns or tusks. This suggests the use of an audio sensor and a Digital Signal Processor (DSP) to detect the sharp noise from a rifle shot. From a signal detection viewpoint it should be relatively easy to detect the muzzle sound as it is both loud and different to any noise that regularly occurs in nature. The acoustic sensor will detect the pressure waves, and the DSP will analyze the signal to confirm a shot. Once a shot has been authenticated, the animal's present position and velocity can be relayed at regular intervals to a response team. The acoustic signal can however be defeated by relatively noiseless weapons (including poison tipped bow and arrows, crossbows, and air-powered tranquilizer guns). A method around this is to program the DSP to also recognize other human sounds (including voices, land vehicles, helicopters, axes, and chainsaws). But, since these may also be defeated by advanced tactics, the acoustic sensor alone will not suffice to detect a poaching event.

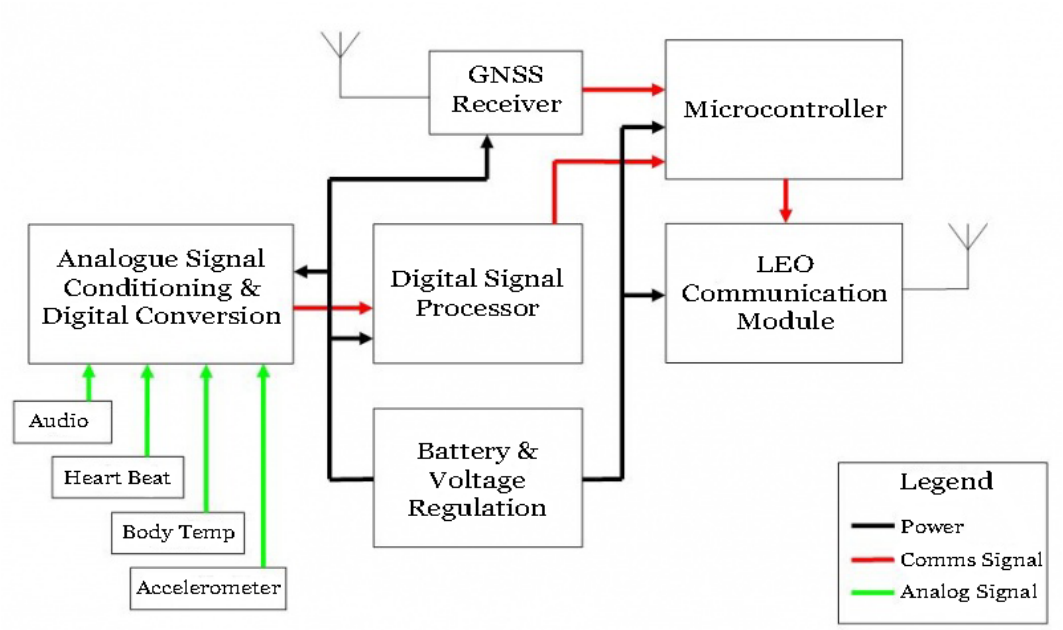


Figure 5-20: Block diagram depicting how information from the macro species poaching event will be gathered and transmitted.

In addition to the acoustic sensor, an accelerometer is also proposed. This will be able to measure the movements of the animal in real-time. The DSP will be able to detect when the animal is walking, running, or resting. Large mammals rarely run as they have few natural predators. An animal running for an extended period of time may indicate that it is being chased by humans, and can be used to trigger an alarm. Also, if no movement is detected for a certain period it may indicate that an animal has died. If an unnatural inclination is detected, it may further indicate that the animal is lying on its side, which rarely occurs naturally.

A heart sensor is also proposed, although this may prove difficult on thick-skinned animals. This will not only instantly alarm when the animal is dead (i.e. no heartbeat), but it may also be used to detect when the animal is under stress (high heartbeat) due to a poaching event. A further biological measurement may be that of body temperature. A low temperature may indicate the animal has died, but this may only occur after a significant time delay. A more sensible measurement would be to detect a rise in body temperature, which may indicate physical exertion by the animal. As large animals rarely exert themselves, except for territorial fighting and perhaps mating, this may be used as a poaching indicator.

The most practical way of detecting a poaching event will probably be by a combination of sensors and movements. If the outputs of the above sensors can be combined, the system can get a relatively complete picture of the animal's situation. Based on this information, an alarm can be generated and transmitted to the ground station (either a dedicated terminal or a simple handset), via the satellite communication system.



Figure 5-21: A cut tracking collar in South Sudan [Langfitt, 2011].

For the micro species of interest, the situation is significantly different. It is impossible to attach a device to individuals and to detect them by means of remote sensing. It may be possible to detect swarms or schools of certain species, but in the case of most ocean-going species, including perlemoen, this is not possible. It is therefore more effective to detect the persons and equipment involved in the poaching acts. There are certain features of perlemoen poaching however that make the previously designed anti-poaching system difficult to use, namely:

- Perlemoen are caught close to the shore, often within two nautical miles from the shoreline (Steinberg, 2005)
- Illegal perlemoen divers use small land-based boats (often semi-rigid inflatables), or simply enter the water from the shore. Using boats is much more efficient than a shore entry, due to the higher payload that can be retrieved by a boat
- Within two nautical miles from the coast small boats need only basic communication and safety equipment, and many boats don't have electrical systems
- There are a large number of recreational boats that are capable of operating within this limit



Figure 5-22: South African police examine poached abalone found in two local homes [Smit, 2009].

A recent report suggests the mandate of a position reporting transmitter on boats (ISU, 2010), but it is believed that this solution would not be practically feasible for perlemoen. Remote sensing satellite imagery can be used to detect small boats operating in an area that is known to have perlemoen reserves, but this normally cannot be done on a continuous basis. Although satellite imagery can be used to identify poaching trends, it is possible that by the time a poaching trend has been determined, the poachers have already moved on to a new location. This is further compounded by the fact that perlemoen grow slowly, with individuals taking eight years to reach the legal minimum size of 115mm and can live for 30 years (Steinberg, 2005). By the time a poaching trend has been identified, the local population may already be wiped out and poachers will not return for years while waiting for the perlemoen to reach maturity again. There are also significant socio-economic factors aiding the poachers. These include the high level of corruption amongst local police, the involvement of coastal communities in the poaching activities, and the (short-term) economic benefits of poaching to the communities. In many cases poaching is easily spotted from the shoreline, but the low reporting rate of such observations illustrates the involvement of local police and citizens. A method is therefore needed to detect perlemoen poaching, and report this to un-biased officials, without the involvement of locals.

One characteristic of perlemoen can be exploited to protect colonies, their habit of attaching to rocks and remaining motionless for extended periods of time (Gill, Appleyard, Elliott & Williams, 2011). To protect the perlemoen, a device similar to the macro species' collar can be anchored to a rock near a known colony location that can detect poachers. An effective method of detecting boat activity is by means of an underwater microphone, called a hydrophone, which detects the sound of propellers through the water. Water is an excellent conductor of sound, and boat propellers can be recognized at a significant range. The propellers also emit a characteristic sound that is different to naturally emitted sounds, which make detection by digital signal processing means relatively simple. A block diagram of the proposed device is shown in Figure 5-23.

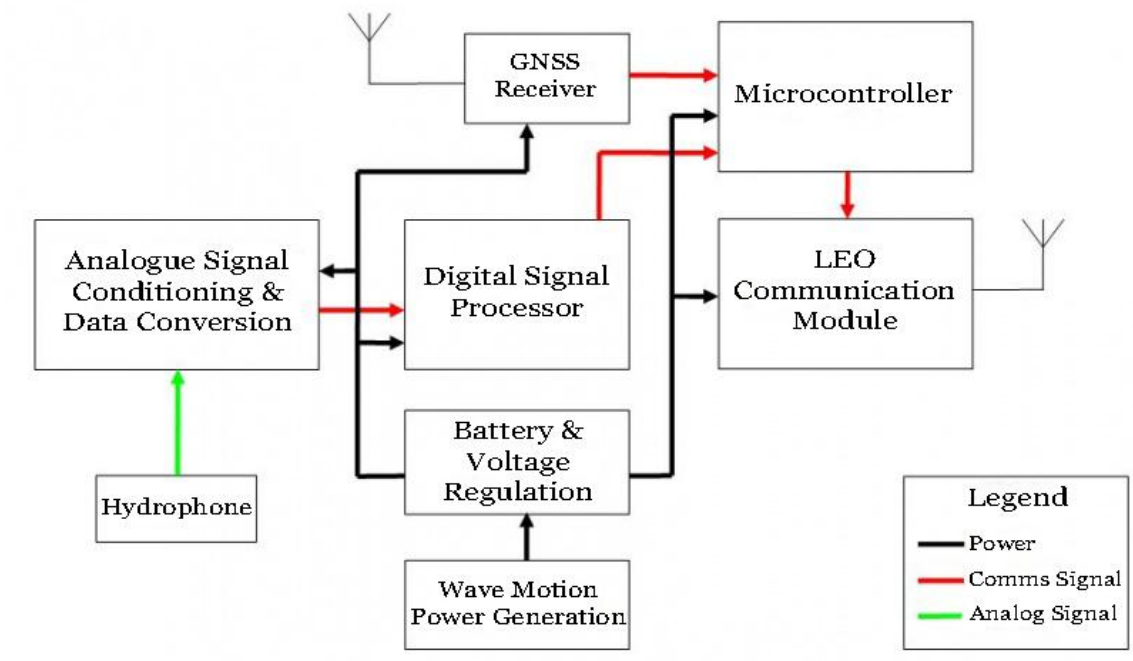


Figure 5-23: Block diagram depicting how information from the micro species poaching event will be delivered to un-biased officials.

The primary sensor of the device is a hydrophone that is located near the seabed to minimize interference from surface water noise. The device contains a DSP that analyzes sound to detect boat activity, and uses a LEO satellite communications service to report suspicious activity. The upper part of the device consists of a buoy which houses both LEO communication and a Global Positioning

System (GPS) antenna. The device can either be battery powered, or use wave motion to generate electricity. Wave motion generation is particularly attractive, since this will extend the lifetime of the device significantly.

A major concern with such a device is that poachers may move it or destroy it. For this purpose a GPS receiver is used to monitor its location, which is reported at regular intervals. If the reported location is outside the nominal position limits, there is a strong possibility that interference with the device is underway. Since the GPS system has high integrity, and satellite communications are easily made secure, there is little chance that poachers will be able to meaningfully interfere with the data. Any attempts by the poachers to destroy, jam, or force the device to cease transmission can also easily be detected, since no regular position reports will be received.

The on-board signal processing capabilities can be expanded to include methods to discriminate between boats that are simply transiting the area and boats that are acting suspiciously. In an even more advanced system, arrays of hydrophones can be used to calculate boat speed and velocity based on acoustic signal phase comparison. From this a map of boat activity can be created. If sufficiently sensitive, the system can also be programmed to detect the sound made by poachers' tools as they remove the perlemoen off rocks, or even diver activity based on their exhalation noise.

The above devices will be most effective when combined with a restriction of boat traffic in the area of interest, although advanced signal processing may be able to overcome this constraint. Response to an alarm will be similar to the response of a macro-species poaching event alarm.

5.5.2 Benefits

The overall benefit of the proposed collar and hydrophone buoy designs are the provision of real-time poaching activity information to law enforcement officials. This will allow personnel to respond immediately by:

- Proceeding to the location of the poaching event and confronting the poachers
- Setting up roadblocks and ambushes near the location
- Deploying aircrafts to track the poachers

These responses will greatly increase the chances of poachers being caught, which in turn increase the chances that the syndicates behind the poaching can be identified and dismantled.

One of the main benefits of the anti-poaching system will be to prevent further damage to the African environment. Aside from the obvious moral obligations, Africa has a significant economic necessity to protect the environment, as its degradation will lead to reduced income from activities such as tourism.

5.5.3 Financing

Costs

The cost of this system is directly proportional to both the number of animals that are tagged or buoys deployed. For the rhinoceros in South Africa, there are an estimated 4,000 remaining in total (Rouse, 2010) (iAfrica, 2012). For full coverage of the rhinoceros (i.e. tagging each individual) and distributing 50 monitoring terminals the total system cost is estimated to be approximately USD 4.5 million (ZAR (South African Rand) 34 million) (this includes the cost of installing the monitoring devices, and all of the hardware needed). For the perlemeon anti-poaching system, simplicity is achieved because one monitoring device can monitor schools of perlemoen instead of by individuals. To monitor the entire coast of South Africa's Western Cape (approximately 1,000km (Google Maps, 2011)), the total cost of the system installation is estimated to be approximately USD 3 million (ZAR 23 million).

It is understood that these estimates are very rough, but they are merely meant to illustrate that the amount to spend on this anti-poaching system is by no means unaffordable. This is particularly true when considering that the above estimates were for complete coverage of the affected area, and in practice this would not have to be done to reduce poaching incidents. The cost of the system can be reduced, and one particular method is to reduce the cost of the collars. There are several means to achieve this, including:

- Locally manufacturing the collars in South Africa, which has both first-world electronics engineering and production capabilities, while at the same time has much lower labor rates when compared to Europe and the Americas
- Substitute locally available, low cost materials where possible. Tests have shown that strips of discarded conveyor belts are ideal for fixing the electronics to the animal's neck (Hackney, 1993)
- Mass production of the devices can significantly decrease costs

Funding Sources

It is likely that such a system would require the support of African governments that are victims of poaching. This includes the target country of South Africa (for rhinoceros and perlemoen), but more broadly will apply to countries such as Kenya and Cameroon (where elephant poaching is a problem). As was described previously, the tackling of poaching problems will need un-biased individuals to enforce such an operation. As such, African governments cannot be the only supported of this program. It would also need the support of international wildlife conservation organizations, including such agencies as the World Wildlife Fund (WWF). The WWF has programs to prevent poaching, for example for the rhinoceros (World Wildlife Fund, 2011), and would likely be extremely supportive of this system. In addition, financial support could come from private game farm owners as well as coastal communities whose legal commercial activities have been diminished by poachers.



Figure 5-24: Seized ivory that was poached from elephants in Kenya [Wildlife Extra News, 2009].

5.5.4 Implementation

The IDEAS for Africa team recommends the establishment of an anti-poaching system, and the following section shows how such a system can be implemented.

Target Countries

In terms of the implementation of this system in South Africa, Morocco, or Liberia, only the former would likely see the use of it. This is because the prevalence of poaching in South Africa is quite high and is well known that this act is extremely detrimental to the country. However, that is not to say that this problem does not exist in either Morocco or Liberia. In Morocco, illegal fishing is a major issue with swordfish commonly being poached for food (Environmental Justice Foundation, 2007). Within Liberia, the issue of illegal poaching of elephants is a major problem. Since the 1980s, approximately 95 percent of elephants have been poached, with only approximately 1,000 currently remaining (Hance, 2011).

Thus, the anti-poaching system, both for macro and micro species, would have a beneficial function in Morocco and Liberia. Nevertheless, as with most law enforcement activities, the success of the proposed anti-poaching systems depends heavily on the political will and resolve to tackle the issue. Even if the systems are technically successful, the success of the operation will largely be dependent on the effectiveness of the response to the alarms raised. The IDEAS team believes that for both Morocco and Liberia, social issues will take priority over this system. Although this solution is considered feasible for South Africa, it should be noted that the country is not free from socio-political issues of its own. Crime has reached epidemic proportions, with violent crimes occurring at an alarming rate. South Africa has some of the highest levels of these crimes in the world, with several tens of thousands of instances like homicides, assaults and sexual assaults (South African Police Service, 2011). Thus, even though combating poaching is an important activity, the common thought is that there are many other more serious problems that require urgent attention. In addition, corruption in the ANC government (South Africa's governing political party) has become commonplace at all levels. It is estimated that up to 20 percent of the country's GDP is lost through corruption (Times Live, 2011). Given the high prices that poached commodities like rhino horn and perlemoen fetch, it is expected that South African anti-poaching enforcement officials would readily participate in corruption.

To effectively combat poaching, the proposed technical solutions need to be considered as part of a wider anti-poaching initiative. Since African government officials are regularly involved in poaching, and often also the local population, methods are needed to ensure that there is timely and effective reaction to poaching events that are detected. The most practical way to accomplish this is to involve reputed international wildlife organizations and private game park owners. It would be trivial to send poaching event alarms to multiple satellite terminals. The alarms can therefore be sent to both law enforcement officers and international or private monitoring groups. The groups can then monitor the reaction of the officers in real time through the following methods:

- Equipping the law enforcement officials' vehicles with similar tracking equipment, to enable their real-time positions to be monitored
- Installing cameras in vehicles that feed video and audio live to the monitoring groups via satellite

In addition to real-time monitoring of the officials' response to the alarms, the monitoring groups can also regularly get updates on the location of the collars and buoys, as well as their operational status. These measures will make it significantly more difficult for corrupt officials to ignore or participate in poaching.

Technological Availability

All the technology required for a real-time poaching detection collars and hydrophone buoys exist. GPS modules are available from several vendors, and Iridium modules are purchased directly from Iridium (Iridium, 2012). These can be integrated with the sensor and a low-power microcontroller or DSP. The major development effort would be the DSP software to detect when a poaching event or suspicious boat activity occurs. For this commonly available voice and pattern recognition algorithms may be employed. Such algorithms would include comparing the signal to noise ratio in multiple

bands, calculating zero-crossing rates, and Hidden Markov Models (although this is outside the scope of the report).



Figure 5-25: Iridium 9602 data transmit modem which could be integrated into collars [Flickr, 2010].

Time to Deployment

Considering all the technology needed for a system currently exists, the time to deployment will largely be dependent on how quickly the tracking devices can be attached to animals and buoys. The IDEAS team has estimated a total development time of less than one year.

5.5.5 Ethics

Poaching at its core is an immoral act. But even more than the moral considerations for the animals is that it robs from those whose subsistence relies upon these animals. However, for many people poaching is a minor problem in Africa. Poaching is seen as a lesser of evils compared with other crimes on the continent, and that it should only be addressed after human suffering has been eased. This approach may result in most of Africa's natural resources being plundered before action is taken. This depletion of resources will further destabilize the region, leading to much larger societal problems. It is not only a moral obligation for governments or other agencies to strive to reduce the incidences of poaching, but it is imperative that such action is taken to ensure long-term development and socio-economic prosperity.

5.5.6 SWOT Analysis

The IDEAS for Africa team has recommended the establishment of an anti-poaching system in Africa to prevent illegal poaching of rhinoceros, elephants, and perlemoen. The anti-poaching system will relay real-time information to proper authorities and third-party unbiased organizations to capture poachers in the act and to gather information on poaching syndicates. The intent of this system is to address the focus area of the environment, and is an application for the target country of South Africa. A SWOT analysis was performed on the anti-poaching system and is shown in Table 5-16.

Table 5-16: SWOT analysis for the anti-poaching system.

Strengths	Weaknesses
1. Enables monitoring endangered species and preventing illegal activities 2. Provides real-time information to stop activities in progress	1. Installing the devices and be dangerous and will take some time 2. Project cost and effectiveness is directly proportional to devices installed
Opportunities	**Threats**
1. Project concept easy to understand and required minimal operational training 2. Technology used is available and integration is simple 3. Economies of scale apply, reducing considerably prices of devices	1. In addition to the tracking devices, an unbiased team would need to be alerted to arrest the poachers 2. Response times to arrest poachers would have to be relatively short

5.6 Conclusions

This chapter examined four satellite applications that were considered in economic, educational, and social growth in Africa. These applications, FarmaBooths, Telemedicine Van, DMPC, and a satellite-based anti-poaching system, addressed four of our focus areas: agriculture, education, environment, and health.

The first application, FarmaBooths, is a multipurpose facility in which farmers would be able to gather information pertaining to agricultural growing conditions to better their practices. Africa has a very harsh environment climate and conditions are heavy burdens for agriculture. These village information centers would greatly benefit local communities, optimizing land use and harvesting methods, with a low priced satellite-based project.

The next proposal examined was the Telemedicine Van. Healthcare is a major concern in Africa and this project would allow individuals in rural areas access to medical services that they otherwise would not have received, considerably improving key health indicators in those regions. Similar systems have already been used in other countries, so implementation in the continent would benefit from the existing know-how of these projects.

The third application is the DMPC, which would provide information to governments regarding desert movement. The information extracted from satellite imagery would enable better urban planning, enhance healthcare, help to mitigate desertification, and improve water management.

Finally, this chapter examined a satellite-based anti-poaching system, which would provide real-time information to law enforcement officials and international animal rights groups to these illegal activities. Illegal poaching affects endangered species, such as elephants, rhinoceros, and perlemoen, and the project would contribute towards their protection.

These proposals were designed to address the IDEAS four of the six focus areas: agriculture, education, environment, and health, as well as having applications in all three target countries. The following chapter will examine space businesses that can be beneficial in advancing economic, educational, and social growth in Africa.

6 SPACE BUSINESS

When poised with questions regarding where investments are to be made, an individual, organization, or a policymaker will rarely think of space as a viable commercial undertaking. Space is traditionally thought to be exclusively for highly developed countries, extremely ambitious organizations, or incredibly bold individuals. How can one possibly justify the tremendous costs of space? Particularly when there are so many pressing challenges that the Earth faces, which demand time and resources.

What most fail to realize, and what space advocates often fail to articulate, is that all investments made towards space are made on Earth. Furthermore these investments are typically completed within the country advancing its space frontier, or with its close trading partners. Investments towards new technologies needed for the difficult and unforgiving space environment are investments spent towards advancing technology, seeking newer and improved solutions to modern challenges.

Money and time applied to difficult challenges reaps unforeseeable rewards, and nothing brings out the innate ingenuity of humankind such as striving for the impossible. Challenging engineers by informing them that a task is difficult to achieve will drive technological capabilities and innovation. Investing in science and technology brings not only direct technological developments toward mission objectives, but also unforeseen (indeed, unforeseeable) spinoffs, such as those of Chapter 3. In fact, the rewards secured by investment in space are high. Studies conducted by the Midwest Research Institute and Chase Econometrics Associates on the economic benefits to the general economy of the US which were a result of the US government's long and dedicated investment in the Apollo program, illustrate the national return on investment. One widely cited study held that every dollar invested in research and development for the Apollo program, resulted in seven back into the US economy. However, a precise ratio of the return on investment in space research and development towards the general economy has proven elusive and will perhaps never be concretely determined. Over the years, estimates have ranged from nine to one, seven to one, and down to three to one (Logsdon, 1998).

A nation invests in its space program to bring prestige and enhance its current status. The space fairing countries of Africa can be proud of their accomplishments in this demanding, costly, and difficult sector. Their accomplishments show the world that they have the dedication and expertise to achieve technologically advanced projects. This capability brings confidence to investors looking to establish companies within these countries. It gives reasons for citizens to be proud and to believe that the future will be brighter.

Advancing technologies ultimately furthers a country's technological capabilities. Investments in space development result in two important questions. What is the current size of the global space economy, and what kind of revenues does investment in the space sector bring? From 1996 to 2005, there was an estimated USD 175 to 200 billion invested worldwide in space programs. This resulted in USD 150 to 165 billion in revenues from space products and services (e.g. manufacturing), and USD 440 to 645 billion in revenues across the entire space sector "value chain" (OECD, 2011).

The potential for space businesses in Africa is enormous due to the current situation within space fairing African countries. Africa has a chance to enter a market that will be a viable economy in the next few decades. The continent can become a major player by having the courage and forethought to provide funding for development within the space sector. It may be the spark that catapults Africa from a continent with countries continually seeking help from other countries and NGOs to a continent in which the countries prosper from African based technologies.

This chapter explains why African countries should start developing their space infrastructure, and invest in space development and business. Even if this is completed gradually, the long-term technological development may be greatly improved by taking on bold ambitions and accepting difficult challenges. The space businesses chosen will have application for the target countries of

Morocco and South Africa, and will cover the focus areas of education, and STEM. The outline of this chapter will first look at current space businesses in Africa. It will then look at space business proposals which deal with promoting education in Africa and re-establishing Africa's autonomous launching capabilities.

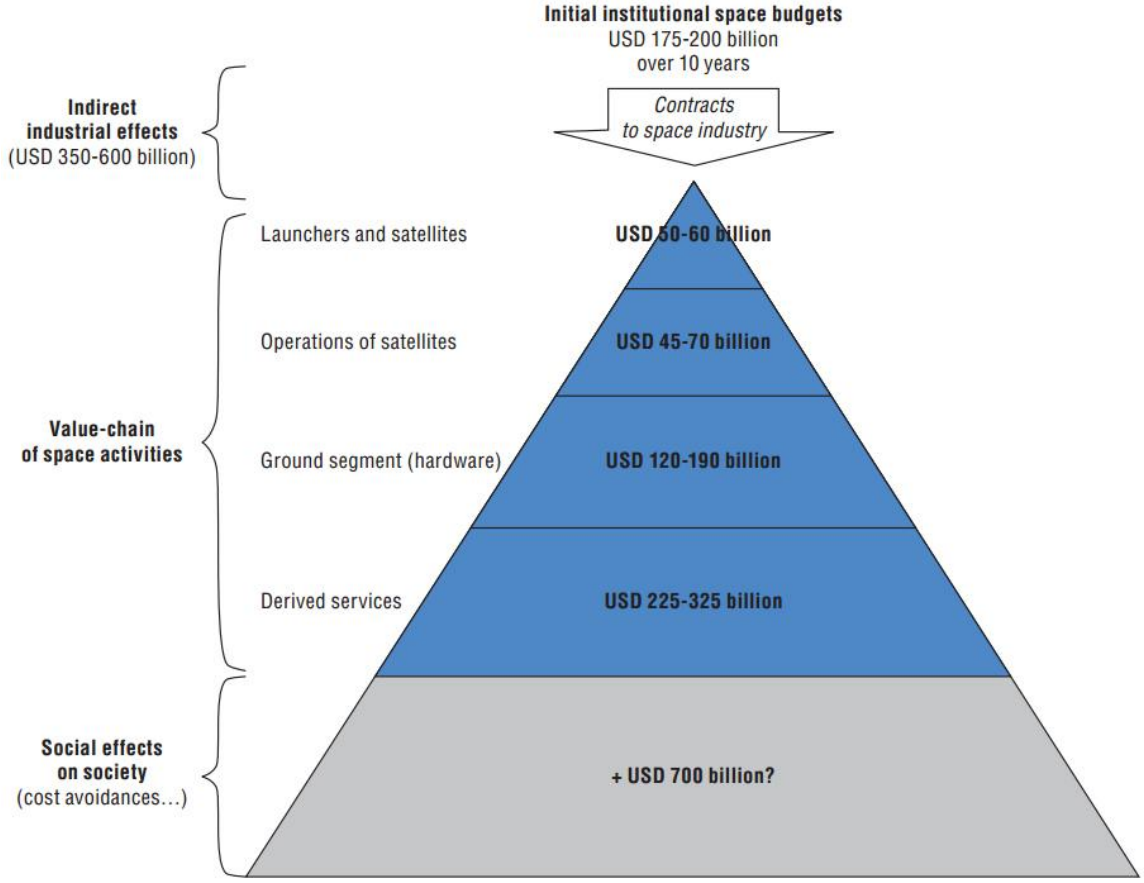


Figure 6-1: Direct and indirect global economic benefits of space activities for 1996-2005 [OECD, 2011].

6.1 Space Business in Africa

The global prospects for space businesses are currently in a state of flux. The recent world economic situation has made investors cautious with respect to investing capital in space activities. As could be seen in the previous chapters on spinoff technologies and satellite applications, there are many different possibilities for ways in which space can be utilized for commercial activities. To propose innovative space businesses, a basic knowledge of what constitutes a space business is required. The pre-condition to identify space businesses that may be implemented in Africa is to define specifically what a space business is. The OECD defines the space economy, which includes aspects of space business as:

All public and private actors involved in developing and providing space-enabled products and services.

(OECD, 2007, pp.1)

This comprises of a value chain of research and development actors, manufacturers of space hardware, and ends with the providers of space-enabled products and services (OECD**,** 2007). Due to the fact that not all countries are ready for space business according to the definition above, a further definition that broadens the scope of what constitutes a space business is required. For the purposes of this report, a space business is defined as:

A company or association that has for its main product or service a major component that interacts with the space sector.

When making the comparison between space businesses in Africa and the developed world, the amount of activity in Africa remains minimal. The most prominent space business among African countries is satellite communication. This form of communication remains a fast and efficient way to create communication links throughout the continent, particularly to remote areas. The satellite communication business began in 1996 with the establishment of the Egyptian Satellite Company (Nilesat, 2011). There are currently three local satellite communication providers in the African region. These include Nilesat, RascomStar-QAF, and Nigcomsat. Due to the high market potential for satellite communication business in Africa and limited local supply, international actors (including Intelsat, SES, and Arabsat) have been attracted to provide services in Africa. Industry experts are confident that the demand for satellite capacity in Africa will not fall in the near future, even with the upcoming competition from the submarine cable system, the West Africa Cable System, as well as the operational Eastern Africa Submarine Cable System (Holmes, 2012). The three aforementioned satellite communication providers established in Africa will be briefly discussed below. An overview of the respective satellite fleet is shown in Table 6-1.

Table 6-1: Overview of African satellite fleet [Nilesat, 2011] [Barbosa, 2011].

Satellite	Manufacturer	Launch Year	Expected End-of-Life	Payload
Nilesat Satellite Fleet				
NileSat-101	Matra Marconi Space (Astrium)	1998	2013	12 Ku
NileSat-102	Matra Marconi Space (Astrium)	2000	2015	12 Ku
NileSat-103	Thales Alenia Space	2010	2025	24 Ku 4 Ka
RascomStar: QAF Satellite Fleet				
Rascom-WAF1R	Thales Alenia Space	2010	2025	8 C 12 Ku
Nigcomsat Satellite Fleet				
Nigcomsat-1R	China Great Wall Industry Corporation	2011	2026	4 C 14 Ku 8 Ka 2L

Nilesat is an Egyptian satellite company, established in 1996. Nilesat provides services mainly in the areas of broadcasting, direct to home broadcasting, and telecommunication. The company is currently operating three communication satellites from control facilities near Cairo (primary facility) and Alexandria (secondary facility) with satellite footprints covering the Middle East and North African regions. Company revenues in 2009 were more than

USD 120 million (Nilesat, 2011). According to a statement by the company's chief engineer, Nilesat is looking towards launching a fourth satellite, Nilesat-202, to serve as on-orbit backup to the Nilesat-201. However, no formal plans for this have yet been formulated (Forrester, 2012).

RascomStar-QAF was incorporated in 2002 by the Regional African Satellite Communication Organization (Rascom). It was created in 1992 to implement a telecommunications infrastructure capable of ensuring the sustainable development of telecommunications over the entire African continent, with special emphasis on providing rural telecommunication services. The Rascom-QAF1 satellite was launched in 2007 with coverage over the pan-African region. An identical satellite Rascom-QAF1R was launched in 2010 to replace Rascom-QAF1 (RascomStar, 2012).

Nigcomsat is a Nigerian communication satellite company initiated by the National Space Research and Development Agency (NASRDA). It was incorporated in 2006 in the form of a public-private partnership. Its first satellite, Nigcomsat-1, was launched in 2007, and failed in 2008 due to power exhaustion associated with its solar array. The replacement satellite NigComSat-1R was launched successfully in 2011. The company has expressed its interest to expand its satellite fleet with Nigcomsat-2 and Nigcomsat-3 (Nweke, 2008).

Satellite communication thus remains the most prominent space business opportunity in Africa. However, this does not imply that new innovative space business opportunities should be overlooked.

6.2 Selection Methodology

The selection of space business ideas differed from that of the previous chapters on spinoffs and satellite applications in that the target country for application had to be examined first to determine if these countries could sustain a space-oriented business. This was followed by the selection of specific space businesses that were most suitable, based on their perceived readiness and potential market opportunity. The space businesses were not only selected to benefit the target countries but to also have a significant long-term benefit on the African continent.

South Africa was considered as the country that has the most potential for growth in Africa and is an ideal country to explore space business opportunities. With the establishment of several private space companies (ex. Sunspace) in South Africa, it is already shown that commercial space organizations can thrive in South Africa. Morocco on the other hand is currently in the process of developing its space assets. The Royal Center for Remote Sensing in Morocco is focused on training, education and raising public awareness (*Centre Royal de Télédétection Spatiale*, 2012). As described in the *Target Country Selection* chapter, strong international relations have also increased foreign investments. The establishment of a space business in Morocco will enhance its space development and status as a space faring nation in Africa. The third target country of Liberia is currently focusing on developing the basic social amenities to fulfill the needs of its people. Developing a sustainable space business in Liberia will not likely be possible in the near future. Liberia will likely benefit more from utilizing spinoff technologies and satellite applications that were described in the previous chapters.

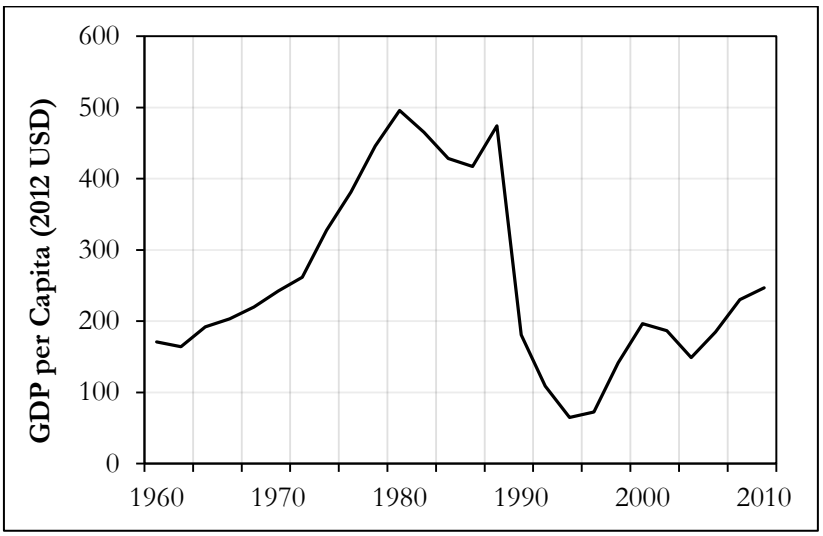


Figure 6-2: Historic GDP per capita in Liberia [Google Public Data, 2012].

Although the concept of designing a space business around a spinoff technology or satellite application is very possible, to provide more innovative space businesses the IDEAS for Africa team opted to exclude these potentials from its selection process.

Implementing a space business in Africa could be carried out in one of two ways. The first is to develop a new innovative space business opportunity. The second is to utilize the target countries' current capabilities and expand them into a space business opportunity. Both these options were considered when selecting the space business ideas to be employed in Africa. After careful consideration the following two space business ideas were selected and will be described in the following chapter:

Table 6-2: Businesses proposal selected for further investigation.

Space Business	Description
African Space Education Center	An educational institute that caters to the growing demand for space professionals
Overberg Sounding Rocket Research Facility	The development of South Africa's Overberg Test Range into a facility capable of launching sounding rockets for experimental purposes

It is worth noting that the aforementioned ideas are not presented in the form of complete business proposals. It consists of the business idea description, a preliminary analysis that includes benefits and challenges, cost, funding sources, policy and ethical considerations, as well as a SWOT analysis.

6.3 African Space Education Center

Space related education is essential in developing a country's competence in this sector, as space technology is highly complex and demanding. Many countries already implement space related curricula into their university degrees. The benefits of implementing space education into the classroom are evident. Space has a positive effect on education, career decisions, and on a student's participation and achievement in the physical sciences (Spencer & Hulbert, 2006). The global space industry has grown and evolved into new areas. Educational curricula and programs on space have reflected this growth by incorporating new topics relating to industry sectors. These include remote sensing, global satellite navigation, and private spaceflight (Space Foundation, 2010). These topics provide inspiration to students who have a long-term goal of being involved in the space industry.

This section will discuss the establishment of a space-oriented educational institution in Africa called the African Space Education Center (ASEC). This proposal is geared towards the focus areas of education, and STEM. It will be also shown that this proposal is for the target country of Morocco because its government considers education a priority, the large number of foreign space and aerospace companies in the country, and its geographic situation relative to Europe, Asia, North America, and Africa.

In October 2011, the IAC was held for the first time on the African continent. More than 5,000 people from widely different educational and professional backgrounds (including space agency officials, senior executives, space industry professionals, and academics) gathered in Cape Town, South Africa (UNESCO, 2011c). Conference papers were presented on space for Africa, and the participants were hopeful towards the improvement of space capabilities across the African continent. To capitalize on this excitement and the topic of space and Africa, it is crucial to recognize the potential and importance of building a domestic African workforce that will benefit from space education.

Space activities are large multi-year programs involving many industrial fields. While Africa has little existing space expertise and a relatively weak industrial base for space activities, the ambition and potential is strong. Space related infrastructure is almost non-existent throughout the continent. To develop sustainable space technologies, African countries should promote education in space and foster domestic space professionals. The question that arises is whether Africa or African countries have the potential to provide such an education? More importantly, are there resources available for African countries to invest in space education? The development of the African Space Education Center (ASEC) will provide a link between the African community and space education. The extended definition of a space business as mentioned in the previous section broadens our scope to allow commercial education regarding space to be considered as a space business.

6.3.1 Business Overview

The development of the ASEC will fill the current gap that exists in space education on the African continent. The ASEC that has the potential to provide space education as well as partnerships with other universities and industries, will greatly enhance the space capabilities of the African space workforce. The two main features of the ASEC will be provision of space education, as well as outreach and awareness.

The ASEC will provide education on engineering, sciences, management, policy, economics, law, and satellite applications. This will allow the students to be able to gain a complete background in space to ensure they are fully capable of participating in the space profession. To provide this, the ASEC will promote a "hands-on" approach to education. "Hands-on" training is a crucial aspect that enables space professionals to be industrially competent. The vision and mission of the ASEC will be:

Vision

- To become a premier space education center focused on value creation through "hands-on" learning and international collaboration

Mission

- To provide high quality space education, learning, and research to African regions' global partners
- To serve as a hub for international dialogue and collaboration
- To drive synergy between educational institutes and its shareholders (i.e. industry needing qualified professionals) towards value creation

6.3.2 Benefits

As stated in the *ASEC: Business overview* section, the intent of the ASEC will be to provide "hands-on" education services. Those who will benefit from this center include the local community, students, educators, industry, and governmental partners.

The local community where the ASEC is established would benefit by being regarded as a hub for international space education. This means that local community members would be able to interact with industry professionals, attend events put on by the ASEC, or simply benefit from the improved reputation of their community for supporting such an institute. There are also the economic benefits of the institute in that space professionals, typically from developed countries, will now be coming to the ASEC and investing in the local economy.

Of course one of the main benefits of the ASEC is to provide space education for students, training them to participate in this high-tech industry. Because the center will be located in Africa, it will greatly promote the prestige of African students, prompting them to take part in this emerging industry.

Educators, particularly African educators, will benefit from an additional location that allows them to teach and work in their field of expertise. Typically African educators in high-tech industries have to leave their home country and pursue opportunities in other areas of the world. This "brain drain" effect will be reduced as a direct result of the ASEC as professionals will have a reason to stay in Africa.

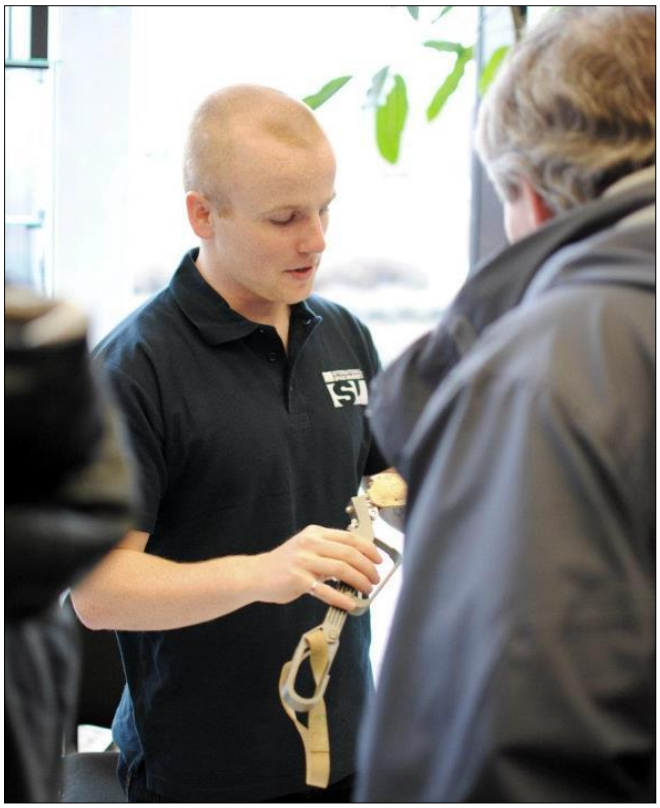


Figure 6-3: A student demonstrating space memorabilia at an ISU Open Day [Hadigal, 2012b].

Lastly, industry and governmental partners, again particularly those in Africa, will greatly benefit from having a new generation of highly skilled individuals. This will mean projects that in the past suffered from a lack of expertise will be able to look to the ASEC and find students who can fulfill their needs. Because one of the missions of the ASEC is to drive synergy between the center and its stakeholders, the needs of industry and governments in terms of education curriculum can influence what programs are being taught. This means that students will be better prepared to enter a workforce that has been tailoring the education that the students have received.

6.3.3 Financing

Costs

The cost associated with developing the ASEC will depend on the type of facility that is to be constructed, as well as the number of students that will be enrolled. Two possibilities exist for the development of the ASEC facility. These possibilities are establishing a new facility, or to use existing infrastructure and facilities. The costs associated with the former would be a much larger initial fee because of development, construction, and operation costs, whereas the latter would limit both the student enrollment and level of autonomy.

In the long-term, the preferred scenario would be to establish the ASEC as its own facility. Therefore, cost estimates are based on the establishment of ASEC with its own independent facility. The cost of recently built Asheshi University was USD 6.4 million and it supports around 550 students (Ashesi University, 2009). This provides an estimate on the facility cost of USD 12,000 per student enrolled. Extrapolating this out to a increased range of enrollment rates gives the cost as a function of student enrollment as shown in Figure 6-4. While in reality the cost of the ASEC will not be linear with respect to number of students enrolled, this provides an approximation for the range of costs associated with establishing such a university. Based on Figure 6-4, and an enrollment rate of approximately 150 students per year, this gives a total cost for establishing the ASEC of approximately USD 1.75 million.

There will also of course be yearly fees including, among others, educator salaries, research facilities, and general upkeep and maintenance. This cost can be estimated by again looking at Ashesi University yearly fees, as this is also a private university. The cost of tuition is approximately USD 5,000 per student per year (Ashesi University, 2012). Therefore, for an estimated enrollment of 150 students per year, this amounts to running costs of USD 750,000 per year. The yearly cost as a function of enrollment rate is shown in Figure 6-4.

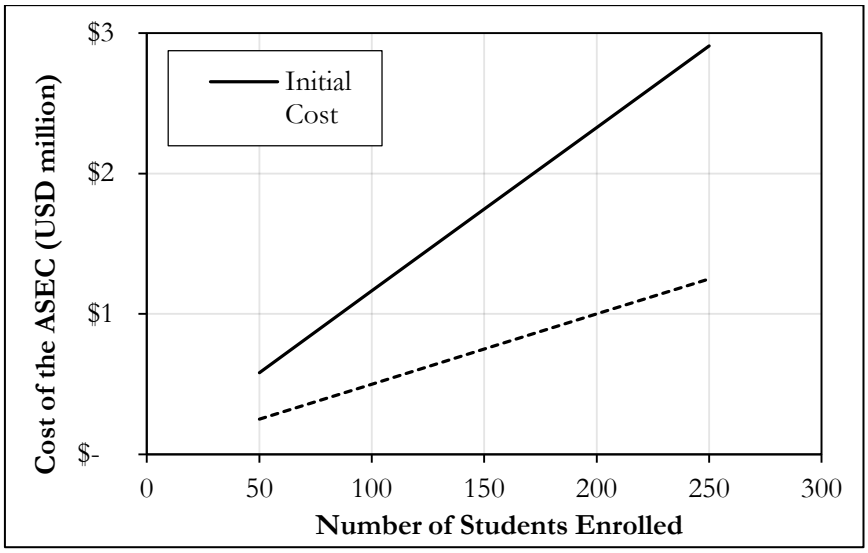


Figure 6-4: Cost as a function of enrollment for the ASEC.

Funding Sources

Since the ASEC is a proposal for a business, it is likely that those interested in establishing it would have their own capital necessary to do so. However, it is also likely that the relatively high costs of such a facility would require outside assistance. Fortunately education is an area in which governments and international organizations understand the benefits of investing in education to promote future social and economic development. As will be discussed in the *Implementation* section, the ASEC is a proposal for the target country of Morocco. As such, the IDEAS for Africa team believes that assistance for the ASEC will come from the following sources:

- Moroccan government
- Royal Centre for Remote Sensing (CRTS)
- Regional African Satellite Communication Organization (RASCOM)

The Moroccan government attaches great importance to education, with a total allocation of more than one fourth of its yearly budget towards education (Visual Economics, 2011).

CRTS is the remote sensing center in Morocco that is responsible for the promotion, development, and implementation of remote sensing applications. CRTS also provides training and education opportunities in space technologies, and maintains partnerships for research actions and programs with universities and research institutes (*Centre Royal de Télédétection Spatiale*, 2006). Because of the center's promotion of space education in Morocco, it is likely that CRTS will be a supporter of the ASEC.

RASCOM is an intergovernmental treaty-based organization with the aim of implementing a telecommunications infrastructure that is capable of ensuring sustainable development of telecommunications across the African continent. RASCOM has a membership of 45 African countries, with one of its main objectives being to provide tele-education. While not directly related to education, RASCOM could be sought after to provide support to tele-education services. This would include allowing lectures from outside the ASEC, or even delivering lectures to remote areas

of Africa from ASEC. Unfortunately Morocco is not a member of RASCOM, and hence to use RASCOM as a funding provider Morocco would likely need to join the organization (RASCOM, 2012). Although this may be a hurdle, the IDEAS for Africa team sees this as an opportunity to extend Morocco's international cooperation with the rest of Africa.



Figure 6-5: Launch of RASCOM-QAF1R [RASCOM, 2010].

6.3.4 Implementation

Target Countries

The ASEC has the potential to be developed in one or multiple African countries. The following factors are believed to be influential in establishing a space education center:

- Strategic location
- Current space capabilities
- Established aerospace industry
- Free trade zones
- Available infrastructure
- Economic and political stability

Because of these factors, the target country of Morocco is selected to host the ASEC. Morocco is strategically located between mainland Africa and Europe, and between the America's and Asia. There are currently more than 100 American and European space and aerospace companies with a presence in Morocco (including Boeing, Bombardier, Safran, and United Technologies) (World Tribune, 2012). These companies use Morocco as a base for their international logistics (*Groupement des Industries Marocains Aéronautiques et Spatiales*, 2010). Additionally, Morocco has a remote sensing education center offering courses to domestic and regional users. The center offers short Geographic Information Systems (GIS) and remote sensing courses throughout the year. The courses cover all aspects of remote sensing and its various applications (*Centre Royal de Télédétection Spatiale*, 2012). The proposed ASEC located in Morocco would leverage this strategic location and the space and aerospace firms already present in Morocco. It could eventually expand its focus from remote sensing into other space applications such as satellite telecommunications, navigation and tracking, ground stations, space systems, planetary sciences, and other topics of education and research. Morocco has six free trade zones in different regions within the country, where companies are exempted from tax, which offer tremendous opportunities to space related industries (Ali Kara & Deshields, 2005). Morocco's developed infrastructure of highways and airports will also help the country excel in

business. Recently, the government created the Tanger Free Zone, in the north of Morocco, a 3.5 km² area where companies are exempt from customs (Tanger Free Zone, 2010).



Figure 6-6: Tanger Free Zone [Tanger Free Zone, 2010].

This center could open the door to greater space education in Africa, and serve as a beacon of learning to Africans interested and inspired by space. It would allow Morocco and its neighbors to create the space infrastructure and workforce for more advanced space endeavors. As a business case, it could be duplicated in many other countries and showcase the demand for space education, and drive international cooperation with space agencies and centers from around the world.

The success of any business is tied to many external factors. Monitoring and understanding political effects is crucial when establishing any business. It must also have a sustainable competitive advantage for the customers (Narver & Slatter, 1990). In democratic countries and stable monarchies which implement business-friendly laws and policies, stakeholders and potential investors are keen to do business and expand, both domestically and abroad. However, in counties with unstable or corrupt governments, or with regimes adverse to business, markets, and foreign investment, these instabilities and adverse conditions lead to poor economic chances, and deleteriously affect growth opportunities for businesses. Morocco has a stable monarchist government and its laws actually attract investment from abroad (Arieff, 2011). King Mohammed VI has ruled since King Hassan's death in 1990. He is seen as a modernizer for the country as he introduced many economic and social reforms (BBC, 2012). Morocco spends 5.6 percent of its total annual GDP on education (CIA, 2011b). Education until age fifteen is both compulsory and free in Morocco (US Department of State, 2011a), and there are fourteen higher education universities in Morocco. Consequently, Morocco is well situated to host a space education center.

6.3.5 Application to Other Countries

The main application of the ASEC is to promote space education not only in the target country of Morocco, but across Africa as a whole. With its geographic location central to North America, Europe, and Africa it will allow for people from all over the world to come to the center. Once the concept has been proven, it will lead to numerous locations or competitors starting similar centers in many other countries. The ASEC can also be involved in promoting base space sciences across Africa. This would entail visiting secondary or primary schools to introduce students to space concepts, and enable them to see how space can make a difference in their lives. Such a program would both promote space education in Africa and showcase the work done by the ASEC. This would encourage students to not only attend ASEC, but to strive for further developments in space that can provide tangible benefits to Africa.

Time to Deployment

As described in the *African Space Education Center: Costs* section, the ultimate goal would be to develop an autonomous facility for the ASEC. The time estimation will be the time needed to select a specific location, acquire necessary licenses, recruit academic faculty, construct the building, and ultimately plan the programs. A estimate on the time needed can be acquired by looking at the time necessary to set up the main campus of the International Space University. From the time that Strasbourg was selected as the ISU's central facility to the opening of the campus was approximately nine years. Hence, it can be expected that that ASEC will similarly require nine years to initiate. During this time host facilities can be used to provide educational services, but this is outside the scope of this report.

6.3.6 Ethics

Access to primary education is a basic human right and the international community has long been interested in expanding it. Nevertheless, the delivery of education through a for-profit enterprise is sure to raise ethical concerns. Many have claimed that the main purpose of education is to educate, not generate profits. This is well encapsulated when in 2000, in response to the growth of for-profit educational institutions in the US, president of the National Education Association Bob Chase stated "educating children is very different from producing a product" (Symonds, 2000, pp. 1). There are concerns that for-profit educational institutions, to make maximum profit, will reduce or eliminate other valuable services (e.g. extracurricular activities). Moreover, to showcase the quality of the school, there may be instances of artificial grade inflation. This would lead to students not gaining a quality education because of the lack of need to work hard. There may also be issues regarding the ASEC pandering to students, industry, or government to ensure sufficient funding, and that students are satisfied with their education. This would lead to a less than superior education. The main causes of these ethical problems revolve around the ASEC's need for external funding, and hence these concerns must be monitored closely to ensure that the ASEC is still living up to its core mission.

6.3.7 SWOT Analysis

This section investigated the concept of establishing a space education center in the target country of Morocco. The ASEC is designed to address the focus areas of education, and STEM, allowing setting the base for further space activities in Africa. The IDEAS for Africa team recommends the establishment of the ASEC to provide "hands-on" education to students and young professionals in the emerging space fields. A SWOT analysis was performed on the ASEC and is shown in Table 6-3.

Table 6-3: SWOT analysis for the ASEC.

Strengths	**Weaknesses**
1. Morocco's strategic location between Africa and Europe, and between the Americas and Asia 2. The space and aerospace firms already present in Morocco 3. The free-trade zones 4. The available resources 5. The country's political stability 6. The Moroccan government strongly supports the use of space	1. Recognition of other African countries 2. Potentially low revenue
Opportunities	**Threats**
1. To set the base for further space activities in Africa 2. Easy to implement business for other countries in Africa 3. International recognition 4. Good possibility to exchange students with the well-known universities and institutes	1. Morocco is not a member of AU 2. Financial sustainability

6.4 Overberg Sounding Rocket Research Facility

During apartheid-era sanctions in the mid 1980s, South Africa developed its own autonomous launching facilities at the Overberg Test Range (*Overberg Toetsbaan* in Afrikaans, or OTB). The facility was built to handle up to ten Low Earth Orbit (LEO) launches per year, but was cancelled in 1994 along with the entire Republic of South Africa space program (Overberg Toetsbaan, 2011). This section investigates establishing the OTB as a commercial launching facility. Without significant governmental assistance, no commercial entity could establish the OTB into a full launching facility. As such, this section will discuss establishing OTB into a sounding rocket research facility. This proposal will address education, and STEM focus areas, and while the OTB is located in South Africa, it may bring benefits to the whole of the African continent. The current facilities that are located at OTB are described in Table 6-4, and are shown via satellite image in Figure 6-7.

Table 6-4: Current facilities location at OTB and their operational status [Overberg Test Range, 1997].

Facility	Status	Comments
Runways	Operational	3km and 2km
Satellite ground station	Operational	10m tracking antenna operating in S & X band
Control Center	Operational	including a control center, mobile control center, and central computer system
Launching site	Non-Operational	
Launch vehicle and payload assembly facilities	Non-Operational	
Testing and launch vehicle assembly facilities	Non-Operational	
Thermal vacuum chambers	Non-Operational	
Rocket firing test chambers	Non-Operational	

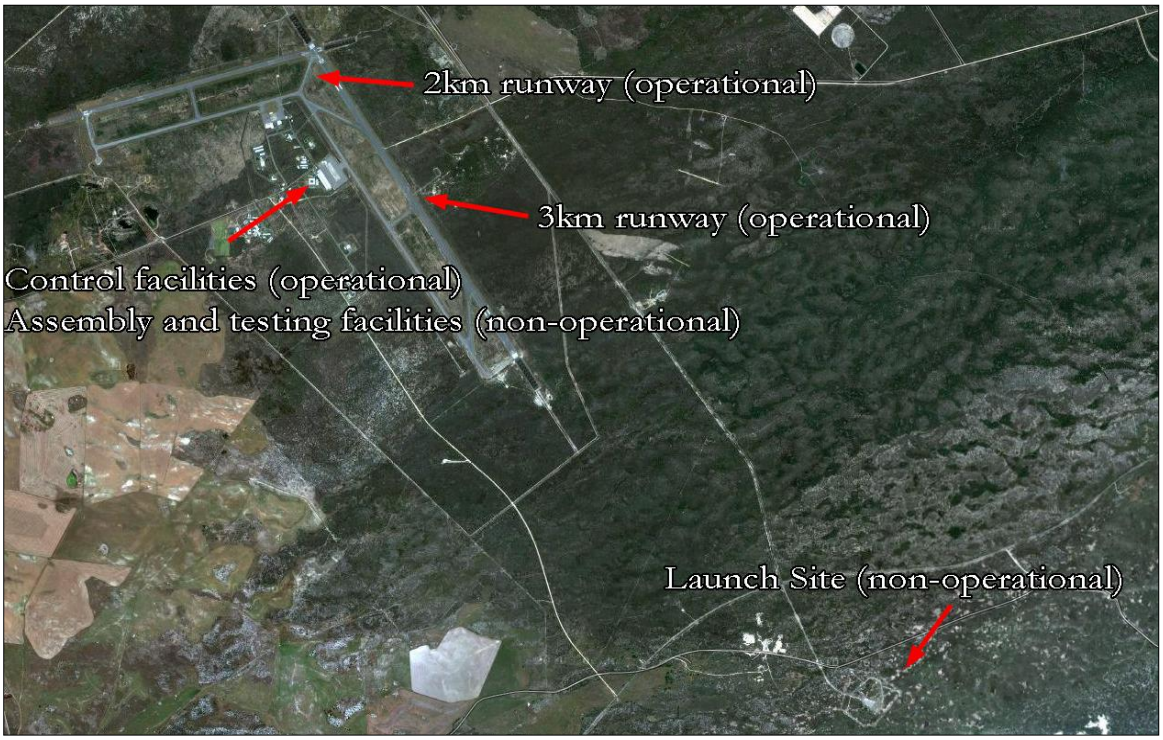


Figure 6-7: Satellite image of the OTB and testing facilities [Google Maps, 2011].

There has been recent interest in re-establishing OTB to perform launches from South Africa, which will ultimately make it the only facility in Africa capable of launches. Naledi Pandor, Minister of Science and Technology, said recently 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. As early as January 2011, we plan to conduct consultative workshops with relevant stakeholders with the aim of developing this 20 year launch plan.
>
> (Pandor, 2010b, pp.1).

Developing the OTB will not be without difficulties. The facilities needed to enable launching are inoperative, and would require major modifications or even reconstruction to bring them online (ISU, 2011b). The costs and schedule of completing such a project would rival the costs of the Kourou space launch facility, which was upgraded to launch the Soyuz vehicle. For Kourou's upgrade, total costs were around USD 500 million over an eight year period (ESA, 2005) (Zak & Chabot, 2011).

Additionally, as all major launching countries have their own respective launching facilities, access to existing launch markets would be less than desirable. The number of African launches per year will remain relatively small in the near future. Without a major political driver to provide the financial support and customer base, private enterprises will find it difficult to justify developing the OTB into a full launch facility. Consequently, launching sounding rockets is a promising commercial option.

6.4.1 Business Overview

A sounding rocket is a general classification for a rocket capable of lifting payloads (up to 500 kg) to an altitude between 50 and 1,500 km in a suborbital trajectory (NASA, 2005). The commercialization of OTB as a sounding rocket research facility should be for educational and experimental purposes. The services provided by the Overberg Sounding Rocket Research Facility (OSRRF) will be for experiments that include:

- Atmospheric studies
- Astronomy (Ultraviolet and X-ray)
- Microgravity research

Research and educational institutions across Africa will provide the market for the OSRRF. It remains difficult to assess the number of launches that will be performed each year by private researchers. As such, in the initial phase, the OSRRF will likely not be supported by experimental testing alone. Because of this, the OSRRF will initially be for educational purposes. The OSRRF will, via public and private sponsorship, support students to design, construct, and launch various scientific payloads. The public and private organizations that will likely provide the support to such an initiative will be discussed in the *Funding Sources* section. The OSRRF will be open to students and researchers from across Africa, encouraging cooperation between South Africa and the rest of the continent. Because the needed upgrades to OTB would be minimal, it would mean relatively minimal risk for the company involved. The initial development of OTB as a sounding rocket research facility will provide a stepping stone for the future development of OTB as a fully operational launch facility.

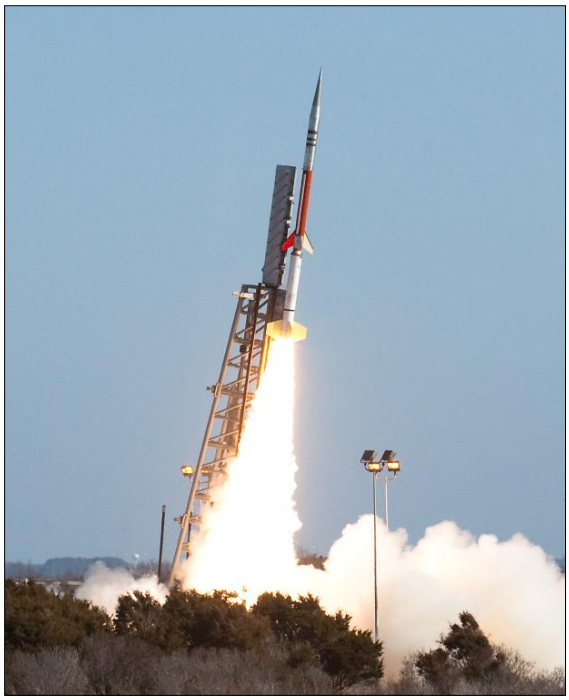


Figure 6-8: Terrier-Malemute sounding rocket launched from Wallops Flight Facility in 2010 [Owen, 2010].

6.4.2 Benefits

Developing the OSRRF will provide a boost to the prestige of the South African space industry, laying the foundation for the nation to become a full space fairing nation. It will establish it as a hub of science and technology advancements in Africa, and will help to further reinforce South Africa as a leader in space development on the African continent. The establishment of a commercial sounding rocket research facility will allow engineers, scientists, and technicians to gain experience in rocket design, testing, and construction. These skills will be necessary in the future to fully use the OTB without incurring the large risks associated with the full development. It will also enable skilled workers to remain in South Africa and reduce the detrimental economic effects of the national brain drain. There are many positive political effects that will result from such a project within the African continent. By allowing individuals from other countries to participate on a project of this magnitude, stronger international relations between South Africa and the rest of the participating African countries can be established. South Africa has established itself as a strong leader in Africa and is committed to ensuring African cooperation. However, in the refurbishment of the OTB, local industries and professionals should be given priority. Finally, the OSRRF could also create educational and outreach links with the local community, for example by organizing field trips and open days for students from the aforementioned ASEC.

6.4.3 Financing

Costs

The major costs associated with the project will be the development of the launching facilities as well as the sounding rockets required for research and experimentation. The development of the launching facility will have to take into account the following components:

- Launching tower
- Launch site
- Payload integration facility
- Rocket fire testing chambers

To provide an estimate on the cost of the sounding rocket development, the size and type of sounding rocket that will be launched need to be determined. An initial cost estimate was therefore done by using NASA's Terrier-Malemute sounding rocket as a benchmark. This choice was made as the Terrier-Malemute rocket had the highest number of successful launches (100 percent) in the period 2000 to 2011 (NASA, 2011). This sounding rocket has a launching height as a function of payload mass as shown in Figure 6-9.

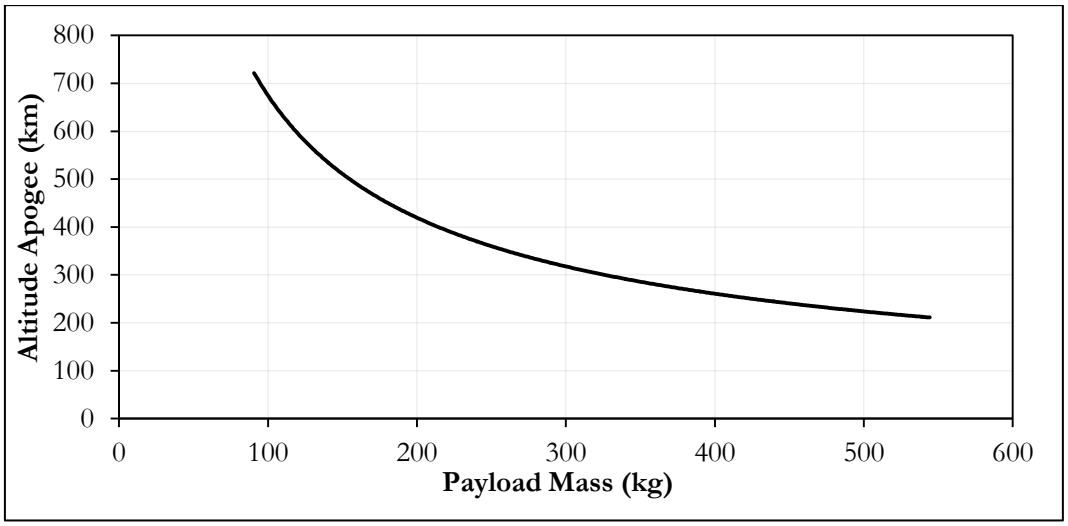


Figure 6-9: Launching characteristics of the Terrier-Malemute sounding rocket [NASA, 2011].

The TRANSCOST model for solid rocket development and production (Koelle, 2010) was used to estimate the cost for the development of the sounding rockets and launch facilities. The TRANSCOST model for space transportation systems is a mathematical model which compares the historical mass of launch vehicles (typically the mass of the vehicle without propellant) to the total WYr (worker-years) required to complete the project. It separates the total cost into development and production costs. The development estimation includes factors which account for costs associated with new projects, and it was from this factor that the estimate for facility refurbishment was acquired. The production cost is also separated into first-unit costs (costs of producing the first launcher) and mass-production costs (which includes reduction factors to account for factors of scale). For simplicity only the first-unit cost was determined for the OSRRF. The reader is encouraged to read Handbook of Cost Engineering for Space Transportation Systems with TRANSCOST 8.1 for further information on how this costing estimate was acquired (Koelle, 2010).

The cost to develop and produce a rocket of similar capabilities of the Terrier-Malemute is approximately USD 16 million. This includes an approximate value of USD 1 million for production, USD 10 million for technology development, and approximately USD 5 million to develop the above mentioned facilities. These costs are summarized in Table 6-5.

Table 6-5: Costs for the OSRRF based on the TRANSCOST model.

Cost of Development (Million USD)	Cost of Facilities (Million USD)	Cost of First-Unit Production (million USD)	Total (million USD)
10	5	1	16

Assuming 50 people working on the project, a 4.5 year total project duration is estimated. This number was calculated considering a cost/Wyr value of USD 67,000 for an aerospace employee in South Africa (which was calculated based on the cost/Wyr for an aerospace employee in the US multiplied by the GDP per capita ratio between South Africa and the US (Koelle, 2010)(CIA, 2011a)(CIA, 2012e)). The costs per year was calculated based on NASA's cost spreading model (NASA, 2007), with the assumption of a five year project time. The annual and cumulative costs are shown in Figure 6-10. While not meant to be taken as exact figures, the purpose of this is to illustrate that significant financial commitments will be needed to ensure that the OSRRF can be developed.

The costs associated with such a project, while high, are orders of magnitude lower than that needed for the development of OTB into an orbital rocket launching facility.

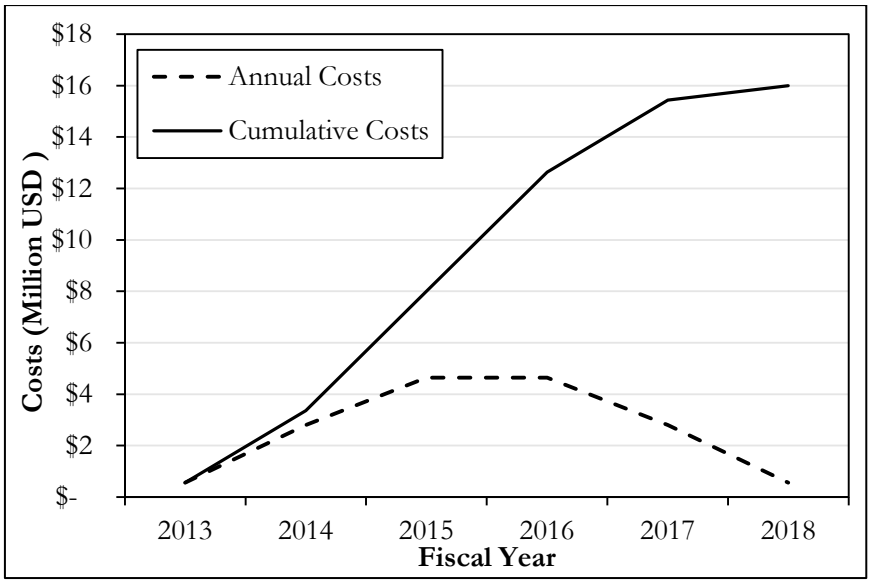


Figure 6-10: Cost spreading estimation for the development of the OSRRF.

Funding Sources

The Overberg Sounding Rocket Research Facility will be designed to provide sounding rocket launch capabilities for researchers. However it is expected that there will not initially be an adequate number of launches per year to sustain development and maintenance costs. To compensate for this, the OSRRF can start with launching student self-designed payloads in open competitions, and subsidies might come from external sources. Examples of potential funding sources include:

- African Union
- South African National Space Agency
- African Ministerial Council on Science & Technology
- African University of Science and Technology

SANSA is committed to promoting youth participation in the sciences, as stated clearly by their Science Advancement & Public Engagement objectives, which are to:

- Promote science advancement and public engagement
- Participate in national science awareness events, and
- Encourage studies in science, engineering and technology (South African National Space Agency, 2011).

Within the African Ministerial Council on Science & Technology, there are discussions regarding the efficiency of establishing an African Institute of Space Science. The main goals of such an agency would be to enable policy makers to become aware of the benefits of space sciences, determine global trends, identify technology opportunities, and to determine institutional arrangements for space sciences in Africa (New Partnership for African Development - Office of Science and Technology, 2006). It is clear that this organization understands the need to develop cooperative space exploration strategies across Africa, and may support the promotion of space for African students.

The African University of Science and Technology (AUST), which is the first pan-African co-educational research university, is dedicated to advancing knowledge and educating students in areas of science and technology that will benefit the African continent in the 21st century. With space rapidly becoming an emerging field of exploitation, it will be in AUST's best interest to promote

education in space activities and therefore it will likely be a supporter of the OSRRF (African University of Science and Technology, 2012).

6.4.4 Implementation

To provide a platform for future launching capabilities, and to promote education in Africa in the space sciences, the IDEAS for Africa team as recommended the establishment of an OSRRF. This section will discuss how to implement this proposal.

Target Countries

Because this proposal is by necessity located in the target country of South Africa, the most immediate impacts of it will be within South Africa. Having said this, there are also indirect benefits to the rest of the continent. The educational nature of the OSRRF will have profound impacts across the continent in terms of promoting youth involvement in the space industry. Furthermore, establishing the OSRRF as a location where researchers from across the continent can come and use the resources will promote cooperation between South Africa and the rest of the continent.

Time to Deployment

As stated in the *Costs* section, the time to development will depend on the number of persons involved on the project. An estimated number of 50 were assumed previously, and this resulted in a time estimation to deployment of approximately 4.5 years. The time estimation as a function of people employed is shown in Figure 6-11.

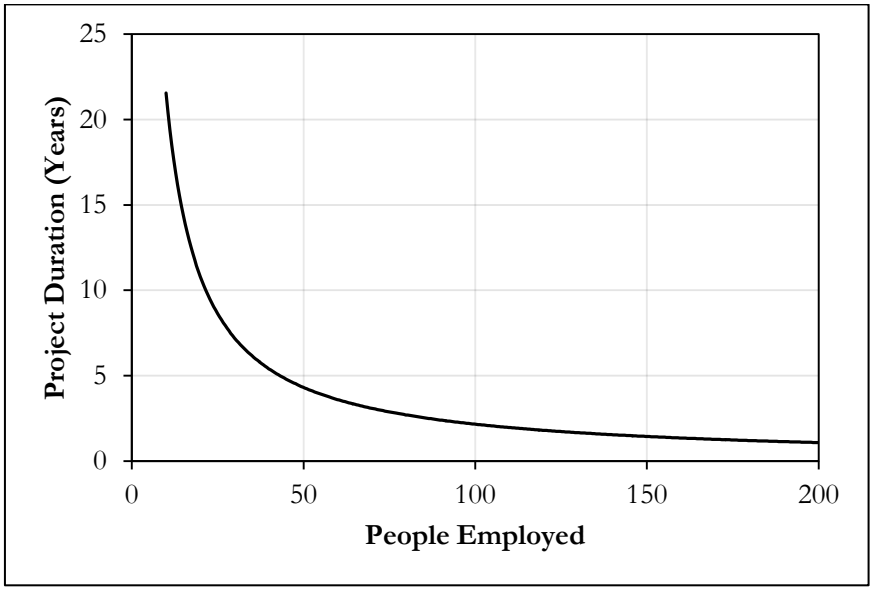


Figure 6-11: Time to deployment estimation for the OSRRF as a function of people employed.

Policy

A commercial sounding rocket research facility at Overberg raises some interesting policy and law considerations which are discussed below, including South Africa's obligations under the public international law related to outer space.

International Space Law

Launching implicates South Africa's international treaty obligations related to the use of outer space, which may be found in the 1967 Outer Space Treaty and subsequent related treaties, including the 1972 Liability Convention and the 1975 Registration Convention.

While states are not normally implicated by the activities of their private entities, the Outer Space Treaty involves the direct attribution of non-governmental actors to the States obligated to authorize and supervise those activities. Under the Outer Space Treaty, states are responsible for national space activities, including those conducted by commercial entities, and are internationally liable for damages resulting from those activities. As a state party to the Outer Space Treaty, the Republic of South Africa has an incentive under its treaty obligations to supervise, license, and otherwise monitor the Overberg facility. Fortuitously, South Africa has national space legislation pertaining to national space activities, and has the correct legislative environment to license and supervise these activities (Republic of South Africa, 1993).

While South Africa is a not a state party to the Registration Convention, both Article VIII of the Outer Space Treaty and the 1963 United Nations General Assembly Principles Declaration Governing the Activities of States in the Exploration and Use of Outer Space gives South Africa the incentive to register space objects launched from the Overberg if it wants to retain jurisdiction and control over those space objects. South Africa can establish its own registry of space objects or use the United Nations Registry of Space Objects, maintained by the United Nations Office of Outer Space Affairs in Vienna.

Political Considerations

The activities of the OSRRF will require the transfer of individuals between African countries. This could lead to potential political problems. South Africa has strong international relations within the continent. For the purpose of this report international relations are divided into five geographical areas. These are relationships with the Western, Central, Northern, Eastern, and Southern parts of Africa.

South Africa has plans to intensify its diplomatic relations with Western Africa. South Africa has supported the efforts of the ECOWAS, the AU, and the UNSC to resolve the impasse of Côte d'Ivoire in 2011. The country is monitoring developments in Niger to ensure a return to democracy following the 2010 Nigerian coup d'état. Bilateral Commissions have been held with the Republic of Senegal, Mali, Nigeria, Ghana, and Burkina Faso. It is envisioned that the politics of allowing West African researchers into South Africa will, for the large part, not pose many political problems. However, tensions may rise if stability is not maintained in the Côte d'Ivoire region. This may prevent individuals from this area from utilizing the OSRRF (Republic of South Africa, 2011).

The most important issue with regards to Central Africa is the formation of bilateral agreements and high level engagements with countries in that region. In 2011 the first Joint Commission for Cooperation Session was held with Equatorial Guinea and Cameroon, and actions have been taken to strengthen economic engagement with other Central African countries. Capacity building projects have been undertaken in Sae Tome and Principe and the Central Africa Republic. This includes agriculture, energy, and infrastructure developments projects in Equatorial Guinea. Although the region is still recovering from conflicts, such as the effects from the civil war in neighboring Rwanda, South Africa seems poised to engage in agreements with the region and thus will likely not hinder scientific cooperation.

Apart from South Africa and Nigeria, the largest economies in Africa are in Northern Africa. This could potentially lead to a large majority of both researchers and educators from the North African region utilizing the OSRRF. Therefore relations between South Africa and this region will need to remain strong to allow individuals to perform research in South Africa. South Africa is dedicated to continuing to interact through Joint Bilateral Commissions and mid-term review meetings. Nevertheless, recent conflicts in Tunisia, Egypt, and Libya have raised concerns for continued international cooperation. Furthermore, continued disputes in Western Sahara between Morocco and the Sahrawi Arab Democratic Republic (SADR), which is strongly supported by Algeria, may pose political problems as South Africa has stated that it will continue its humanitarian assistance program to the SADR. This indicates that there may be potential concerns over allowing individuals from

Morocco into South Africa for this research, and that these concerns must be properly resolved to enable all African countries to participate in this program.



Figure 6-12: Conflicts may pose problems for foreign researchers to attend the OSRRF [Wikimedia Commons, 2011b].

Ongoing conflicts in Eastern Africa pose challenges for the foreign relations with South Africa towards this region. South Africa supported the Comprehensive Peace Agreement, ultimately ending the Second Sudanese Civil War and also allowing the succession of South Sudan (The Government of the Republic of the Sudan & The Sudan People's Liberation Movement/Sudan People's Liberation Army, 2011). South Africa has stated that it will continue to support Sudan through this process, as well as supporting efforts to facilitate post-referendum negotiations. Following the Darfur Peace Agreement in 2011, South Africa is looking to support efforts towards peaceful dialogue to reach a long-term solution in that region. One of the biggest challenges of this region however remains the situation in Somalia. Although there are efforts to have an election 2012, the country still has no central government, meaning that under current conditions it would be practically impossible for individuals from this country to participant in the OSRRF (CIA, 2011d). Furthermore, questions arise over the relations with Madagascar because of political unrest, the most recent being in 2010 with the overthrowing of the government (Bearak, 2010). As such, particular care must be taken to ensure that participation in this program will be open to individuals from Eastern Africa.

Being very closely tied with the growth of South Africa, it is unsurprising very strong ties exist between South Africa and the SADC region. High level engagements, such as memoranda of understanding, have been signed with Angola, Botswana, Lesotho, and Zambia. Efforts are being made to prioritize Bi-National Commissions with Botswana, Mozambique, Namibia, and Tanzania. There is also a special focus, from the NEPAD point of view, to promote special development initiatives within the SADC region. It appears that South Africa is well positioned, from a political standpoint, to allow for external researchers and students to participate in the OTB sounding rocket research facility (Republic of South Africa, 2011).

Overall, despite difficulties in a few regions in Africa, there seems to be no major policy barriers to prevent South Africa from allowing foreign researchers to come into the country. South Africa overall maintains very strong relations with its international partners, and does allow for foreign scientists from other countries, most notably from Europe, to participant in exchange programs (European Molecular Biology Organization, 2011).

6.4.5 Ethics

The main ethical concerns regarding the OSRRF will revolve around the distribution of scientific information that is gathered from the research facility. While South Africa will be the country that is responsible for the launches, it is the purpose of the OSRRF to be accessible to all scientists, particularly African ones. As such, care must be taken to ensure that all data acquired from the OSRRF is published in such a way to benefit both South Africa, the researcher, and the country that the researcher has come from. There are also of course ethical concerns regarding potential malicious use of this new launching capability, and therefore regulatory policies need to be established by South Africa to ensure that the new technology is not used for militaristic purposes. Furthermore, because the purpose of this facility is to provide benefits to the whole of African students and scientists, political tensions between South Africa and other countries may prevent the facility from being used to its full purpose. In other words, if a situation arose where individuals from one nation was barred from entering South Africa to use these facilities, then this would be tantamount to preferential treatment to certain countries. Hence, care must be taken to ensure that all individuals can access the facility. Of course, pragmatically it would be impossible for a private enterprise to influence the international relations between South Africa and other countries, but it must be understood that there are certain uncontrollable factors which may prevent the OSRRF from reaching its full potential in the near-future.

6.4.6 SWOT Analysis

It should be noted here that the development of sounding rocket capabilities as a business model is a long-term project. At the onset, it will be difficult to sustain this business with the current demand from scientists and researchers that exist in Africa alone. As such, the starting platform of this business development will be to use it as a tool to promote education, and over time as capabilities and needs for space experimentation increases it can evolve into a self-sustaining business that is marketed for suborbital research.

Developing the OTB into a commercial sounding rocket research facility is not only practically feasible but an important stepping stone to the establishment of South Africa as an African leader in the space industry. It will work to promote African education in the STEM fields, and provide a uniquely African platform for researchers across the continent to use. The economic and political challenges of such a facility are, while difficult, by no means impossible to overcome. This section, while not intended to provide an complete depiction of how the OSRRF is to be implemented, provided a general overview of the benefits, challenges, and key points to consider for such a development project. The OSRRF is a proposal to address the focus areas of education, and STEM. The IDEAS team believes that a full development plan for the OSRRF should be done by the appropriate entity, and that development of the OSRRF should commence in the very near future. A SWOT analysis was done for the OSRRF and is shown in Table 6-6

Table 6-6: SWOT analysis for the OSRRF.

Strengths	Weaknesses
1. Inexpensive relative to cost of full rocket launching facility 2. Lays the framework for full development of OTB 3. Developed as first African launching facility	1. Limited market
Opportunities	**Threats**
1. Used as a tool for education across Africa 2. Reduce brain drain effect for South Africa's high technology workers 3. Will promote space research in Africa	1. Potential political issues with some African countries 2. Competition with nations with developed space capability

6.5 Conclusions

This chapter investigated the space business proposals applicable for Africa. While the global space economy runs into the hundreds of billions of dollars across the entire value chain, commercial space activity in Africa is minimal. The largest component of commercial space activity in Africa is tied to the global telecommunications industry, and the Nilesat, RascomSat, and Nigcomsat satellite fleets are building capacity across the continent.

Using a space business selection methodology that focused on the specific target countries, we found that Africa has significant potentials in a Space Education Center and in reviving and commercializing the Overberg Test Range. Lastly, the country of Liberia was not considered in this section because it was decided that either a space application or spinoff was more appropriate.

We saw that an African Space Education Center could be considered a business even though it is an educational institution. The ASEC would address both the educational, and STEM focus areas. It would become a high-profile African educational facility driving value creation through hands-on learning and international collaboration. The country of Morocco was chosen since there are already dozens of space and aerospace companies with a presence in the country. This allows the center to benefit from the expertise and experience of the various companies. For example, the local employees could lend their knowledge to the center as adjunct faculty. In addition, the companies and Morocco benefit because they will obtain more highly skilled workers without having to send them to other continents.

Next, reviving and developing the launching facility at Overberg was discussed. The existing infrastructure includes runways, a satellite ground station, and an operational control center. With investment, the launch site and launch vehicle and payload assembly facilities might be revived, but this would necessitate large up-front investments. As a commercial endeavor, the OTB functioning as a sounding rocket research facility would enhance South Africa's space capabilities and boost its domestic engineering and logistics strength. The background, market assessment, cost estimation, funding sources, policy issues, as well as the benefits and challenges of these proposals were discussed. Developing the OTB as a research center would create the educational and technical experience needed if the facility is to someday develop into a major launch facility for the southern hemisphere.

This chapter concludes this report's investigation into specific space spinoff, satellite applications, and space business proposals. However, the IDEAS for Africa team does not stop here. The Appendix to this report will discuss the ways to bring these proposals and ideas to Africa. The first path examined is a Non-Governmental Organization dedicated to space and its application to Africa's endemic problems. The second is a continent-wide African Space Agency to leverage Africa's existing high-tech and industrial infrastructure, and bring prestige to Africa and pride to Africans.

7 CONCLUSIONS

The 21st century can be the century of African space development, driven by space technologies, and driving further space innovation. The ideas we propose for Africa are ripe to become realities.

Realizing the complexity and diversity of life in Africa, The IDEAS for Africa team first grouped our concerns in six focus areas of research – agriculture, education, energy, environment, health, and the STEM fields (Science, Technology, Engineering, and Mathematics). We then chose three African countries to represent the wide range of African nations and their individual characteristics. South Africa, Morocco, and Liberia represent the high, medium, and low space technology countries across the continent, along with a wide range of sociopolitical situations informing our focus areas. We then divided our research into three categories: space-derived and repurposed technologies (called spinoffs); applications of satellite technology; and space business potentials.

Spinoff technologies, as described in Chapter 4, hold great potential to improve the quality of life in developing countries. In particular, they are advantageous in countries that cannot afford to directly invest in developing their own domestic space assets. Organically Derived Colloidals and Aeroponics have been shown to increase crop yields and reduce water requirements. Taking advantage of international funding efforts, these two spinoffs have the potential to strengthen the African agricultural industry and increase food security. DHA tablets have been demonstrated to alleviate malnutrition and increase life expectancy. Solid Oxide Fuel Cells offer low-cost and efficient electricity generation for developing nations.

In Chapter 5 we found that satellite applications have the ability to increase quality of life in the countries that can afford to deploy them. For example, a multipurpose facility for gathering and distributing space-based agricultural information (named FarmaBooths) could allow localized communities to take advantage of modern farming practices and optimize land use. The proposed Telemedicine Van, currently in operation in India, allows isolated communities to access advanced medical care. A Desert Movement Prediction Center could enable governments to make informed decisions in response to desert movements and could eventually aid urban planning, enhance healthcare, manage desertification, and improve water management. Satellite-based anti-poaching systems could provide real-time information to local law enforcement agencies and animal rights groups, and help protect endangered species such as elephants, rhinos, and perlemoen.

African space business proposals were addressed in Chapter 6. We found that Africa has significant potentials in establishing a space education center and reviving and commercializing the Overberg Test Range. An African Space Education Center could provide education services and hands-on learning, raising African capacity in high-tech fields. The Overberg Test Range could provide sounding rocket research capabilities, further driving Africa's high-tech development.

With the completion of the chapter on space business proposals, our investigations into spinoffs, satellite applications and space business potentials ended. However, the ideas for Africa do not stop here. Taking into account potential difficulties and recognizing that material resources are finite, the Report's appendix details the ways to bring our proposals and ideas to Africa. We discuss two paths: A non-governmental organization dedicated to space and its applications to Africa's endemic problems, and a continent-wide African space agency to leverage Africa's existing high-tech and industrial infrastructure, in hopes of bringing prestige to Africa and pride to Africans.

An Africa which vigorously implements space-related innovations and solutions could be better off. In one generation's time, millions of lives could be improved. Benefits include Africans living longer and healthier lives because FarmaBooths increase crop yields and bring prices down, while Organically Derived Collodials and DHA supplements ensure safer food and satisfy dietary requirements. Living conditions improve for Africans attending schools and living in homes with electricity provided by Solid Oxide Fuel Cells, and with access to up-to-date medical techniques via Telemedicine Vans and FarmaBooth technology. This is a society where life is healthier and safer. All

of these benefits would be enabled by space technology. Desertification and other effects of climate change are mitigated and managed through Desert Movement Predictors, and Africa's precious biological diversity of large animals is protected with anti-poaching programs. Space for Africa NGOs could initially drive this change, on a community level and across national borders, facilitating change where African governments are unable or unwilling to do so.

With these innovations, African nations would be better prepared to take more ambitious steps into space. An African Space Education Center would drive capacity building and raise educational ambitions in the STEM fields. Meanwhile, the African Space Agency, pooling African resources and focusing African space ambitions, would drive change with increasing speed and success. A source of pride across Africa, the ASA could develop the Overberg Test Range into a fully functional facility to design, build, and launch African satellites - built by Africans and serving African needs.

Our recommendations all have three critical elements in common. They address problems in Africa that hinder growth and development, they use space technologies that have a significant advantage over existing terrestrial technology, and they are practically implementable. It is our hope that these recommendations will stimulate both African leaders and space professionals to fully exploit the promise that space holds for Africa.

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8 APPENDIX - FUTURE WORK

The benefits from space are abundant and have changed our world. They have help start new industries, saved lives, and driven technological innovation. But the changes they bring are possible because wealthy governments and private multinational companies have the power and capital to bring these changes to life. This report looked at how space can bring change to Africa - from new technologies to promote health, satellite applications for and resource management and wildlife conservation, to commercial facilities to promote scientific research. But how?

What happens when there is no one willing to invest in bringing spinoffs to Africa? When no African government takes the initiative to bring change to its people by investing in large scientific projects? What happens if no company takes the chance and invests in selling spinoffs, or building companies based on satellite applications? The opportunities for change should not be wasted. A Non-Governmental Organization, serving the public good, and focused on people rather than profits, can bring these improvements to Africa.

What happens when no single African country has the infrastructure or can amass the resources to undertake large projects? To truly reap the benefits that space innovation brings, a country or a host of countries needs to develop its own space industry, complete with domestic space and high-tech companies. The IDEAS for Africa team believes that an ASA, uniting the best minds and most forward-thinking African governments and industries, can bring synergies and innovations to Africa. Fifty years ago, a European space agency seemed improbable. Today, ESA unites European space efforts by promoting cooperation and making costly and complex projects a reality. An ASA could provide tremendous benefits to Africa.

This Appendix discusses two ways in which space can be brought to Africa. It begins with a look at establishing a space-oriented NGO dedicated to using space innovations to improve African lives. It then investigates how an ASA could be used to synergize the best of African space capabilities. A better future is not inevitable, but the moral obligation to work towards building a better future makes establishing an NGO and African Space Agency the clear choice.

8.1 Non-Governmental Organization – Bringing Space to Africa

The previous chapters have focused on how different space applications - spinoffs, satellite applications, and space businesses - can bring positive social and economic development to Africa. It has highlighted that the problems Africa faces are linked, and how no one solution can work on the whole of the continent. Across the continent, malnutrition lowers health, malnutrition is spurred by poverty, poverty results in crime, crime brings social instability, social instability leads to warfare, warfare prompts oppressive regimes, oppressive regimes mismanage resources, and mismanagement of resources cycles back to poverty. This vicious cycle of social problems creates the environment for other problems to spread. But if incremental progress can be made to address key areas of development, these inter-linked problems will begin to unravel themselves. The future of Africa will brighten. But how can these challenges be addressed by space application when governments are unable to unwilling to help? How can the proposals of the previous chapters ever be utilized to provide their promised benefits? One means of implementing these changes is through the framework of an NGO, which for the purposes of this report is defined as:

A private organization that pursues activities to relieve suffering, promote the interests of the poor, protect the environment, provide basic social services, or undertake community development (Duke NGO Research Guide, 2012, pp. 1).

A question invariably arises when considering an NGO: what is the business case? This enquiry is flawed in that it makes the assumption that NGOs have the intent of capitalizing on their efforts. In today's globalized world, where major corporations have assets and access to capital greater than

some sovereign countries, it is important to consider the major players that shape the lives of billions of people. Governments enforce their rules and solidify their power, while private industry pursues profit, amassing wealth on behalf of their shareholders. Where is the voice of the common person, and the mass of humanity, in this framework?

There are a multitude of examples of NGOs making life better for people all over the world - they constitute an important part of what the philosopher Karl Popper called the "Open Society", where free organizations of people who believe in the betterment of society work collectively, outside of direct governmental control, and unaffected by corporate goals (Popper, 1971). They are the breathing space for societies which want to make progress, and for people to act altruistically and compassionately.

What would a Space and Africa NGO do? The previous chapters illustrated that there are many areas where space applications and resources can be used. From the SOFCs derived from the Space Shuttle and spun-off to provide energy to rural populations, to the anti-poaching system to provide real-time information to prevent poaching incidents. But will these proposals ever be fully utilized, and implemented with maximum effort? The following section will describe the establishment of a space-oriented NGO to bring the proposals of the previous chapters to fruition. It will address which proposals described previously are best suited for an NGO, how such an organization can be implemented, and will provide an ethical consideration for its establishment.



Figure 8-1: Red Cross workers in Liberia build household latrines (Robinson, 2011).

8.1.1 Background

The intent of a space-oriented NGO is to bring awareness of the marvels that space can deliver, and to improve African lives in ways that neither governments, nor private companies, are willing or able to do. There are a multitude of NGOs working in Africa, including a few which are already pursuing synergies between space and development. In South Africa, there are two NGOs which focus on space and development - the South African Space Association and Foundation for Space and Development.

The South African Space Association is a professional organization linking space professionals together, and engages in general networking, capacity building, and public awareness of space in the South African professional and academic communities (South Africa Space Association, 2012).

The Foundation for Space and Development is similarly focused on education and awareness related to space education. Their mission statement highlights space education, awareness, and research related to space, and bringing it to benefit South Africa (Foundation for Space Development South Africa, 2012). As such, the Foundation for Space and Development might be the organization which most closely aligns with the IDEAS for Africa team's concept of what a space-oriented NGO for Africa might be.

Across the rest of Africa, other NGOs related to space also exist, though many of them pursue the same lines focused on education related to space. The African Regional Centre for Space and Science Technology Education, which is affiliated to the UN, has offices in Morocco and Nigeria. This organization provides standardized educational curricula for African educational institutions to use. Additionally, there are NGOs focused on issues where space is indirectly affected. In Algeria, the National Committee of Algerian NGOs to Fight Against Desertification (*Comité national des ong algériennes pour la lutte contre la désertification*) is an NGO for which space can be of support (see the *Satellite Applications: Desert Movement Predictor* section). A space and Africa NGO can and should seek out other NGOs to work cooperatively towards a brighter future of Africa (UN, 2012).

8.1.2 IDEAS for NGO

In deciding how to focus this report, the IDEAS for Africa team saw that there are many areas where space and Africa meet. Although initially thought of as a major challenge, this abundance of intersections between space and Africa is a strength as it shows the numerous focal points that can be pursued by an NGO. The previous chapters detailed the different spinoffs, satellite applications, and space businesses that could be implemented in Africa, and provided a high-level assessment of how to apply these proposals. An NGO can play a role in implementing many of these proposals, with particular attention to the spinoffs and satellite application geared towards the target countries of Morocco and Liberia.

The spinoff proposals of the previous chapters were the ODCs and Aeroponics, as well as the SOFC. It was shown that for the ODC and Aeroponics, there is an incredible potential to aid health, agriculture, and the environment, and the cost of implementation is not prohibitively expensive. A space-oriented NGO, with its often limited capital backing, would be ideal for implementing this proposal in the target countries of Morocco and Liberia, whose governments may be unwilling to support this proposal. The SOFC, on the other hand, was a proposal for the target countries of Liberia and South Africa. Since it is likely that South Africa will have the financial capital to support implementation of SOFCs, an NGO framework for this proposal may be unnecessary. However, for the target country of Liberia, a space-oriented NGO that can provide the SOFCs to rural individuals would be incredibly beneficial.

The satellite technologies, as described in the *Background* section, have the advantage of being far-reaching, and for the most part, economically viable for implementation by a space-oriented NGO. This is particularly true for the FarmaBooths, and anti-poaching applications. Both of them have the benefit of minimal start-up costs, which are proportional to their potential impact (i.e. an NGO can set up any number of FarmaBooths, depending on their available funding and it will still make a noticeable impact), and have the potential of far-reaching effects.

In terms of a space business, an NGO is not overly applicable because the intent of a business is to make a profit, whereas an NGO does not focus on this aspect. There is the potential for a space-oriented NGO to play a role in the development of the ASEC. As stated in the previous sections, there are many NGOs which act to promote space education. While it is not likely that an NGO will be the sole supporter of the ASEC, it is likely that it will play a major part in supporting it.

8.1.3 Implementation

The first step towards establishing an NGO is to clearly define the purpose, visions, and goals of the Space and Africa NGO. The IDEAS for Africa vision for an NGO is:

To bring improvements to Africa using the innovations and applications of space, and to raise awareness space aspects amongst the African peoples.

The former focus is self-evident, and the latter on raising awareness is aligned to general capacity-building, and increasing Africa's competency in the technologically advanced aspects of space. A concise and clear statement of the space and Africa NGO will allow a target audience of stakeholders, participants, and funders to know exactly what this NGO is all about. This mission statement should be further refined with both a short-term or annual plan, and its longer-term plan.

The NGO's mission statement and plans can be brought to the attention of people who might serve on the initial Board of Directors. The Board is a smaller group of individuals committed to the goals of the NGO and able to help contribute their time and efforts towards seeing the NGO progress from an idea to an actual institution. They should have skill and aptitudes in the legal, financial, and technological aspects of the NGOs work, and should be well aware of the fact that the NGO will be working in the best interests of the people of Africa (Moshman, 2008). It is important to seek legal advice early in the process, to get a better idea of where the NGO should be registered, and with whom to file the articles of incorporation, as well as what legal form the NGO should take - for example as a charitable institution, or as an education nonprofit. Legal advice will also be needed on tax issues, securing licenses, and related administrative and regulatory matters. The headquarters of the NGO will also need to be determined, the location of which will depend on which aspects of space applications the NGO wishes to undertake. For instance, should an NGO seek to focus on satellite applications for Africa, it is likely that the headquarters will be located in a foreign country close to donors, because there is not an urgent need to be located in the country of implementation. Conversely, an NGO focused on distributing spinoff technologies will likely need to be headquartered in the country of implementation.

A wealth of information is freely available for those interested in setting up an NGO. The reader is encouraged to investigate the NGO Handbook (NGO Handbook, 2012) to get an overview on how to establish an NGO. The intent of the IDEAS for NGO section, which not being exhaustive, is to provide the reader with a high-level assessment of the considerations required to be made prior to forming an NGO.

8.1.4 Ethics

The very concept of an NGO in Africa brings along with it great ethical complexities. There are numerous examples where NGOs have become corrupt, or have been mismanaged, and have had negative consequences. NGOs like the International Crisis Group have openly interfered with parliamentary elections in Macedonia. While the intent of this may have been altruistic, it shows how an NGO can act in a manner than may be considered unethical. Furthermore, many international NGOs have lied about their projects to gain recognition. The instances of this were so prominent during the 1994 Rwanda crisis that the Red Cross had to develop 10 ethical codes of conduct for NGOs (Vaknin, 2011). These 10 codes of conduct are (Red Cross, 1994):

1. Humanitarian imperative comes first
2. Aid given is nondiscriminatory and on the basis of need
3. Aid is not used for a political or religious purpose
4. Will not act as an instrument of government policy
5. Respect to culture and customs
6. Attempt to build disaster response mechanisms on local capacities
7. Involve program beneficiaries in relief aid management
8. Relief must act to reduce future vulnerabilities as well as meeting basic needs
9. Hold ourselves accountable to those we seek to assist and those providing resources
10. Recognition disaster victims as dignified human beings, not hopeless objects

A space-oriented NGO in Africa should abide by the above ethical guidelines, or produce its own guidelines that match the vision described in the implementation section.

8.1.5 Summary

The IDEAS for Africa team took note of the tremendous ethical implications behind establishing an NGO in Africa, and all the possible moral quandaries such an endeavor might entail. The intention of this space-oriented NGO will be to bring improvements to Africa using the innovations and applications of space, and to raise awareness of space aspects amongst the African peoples. The NGO will be suited to implement the spinoff and satellite applications proposals of the IDEAS for Africa team, as described in the previous chapters.

The NGO would have the strengths of its connection to grassroots, and would act without political or financial motivations, remaining independent from external factors. This lack of government involvement would enable it to adapt rapidly, allowing the use of new space technologies as soon as they become available. However, at the same time, the NGO might have to deal with limited finances and human resources, which, in the long term, might prove unsustainable. Last but not least, corruption and a lack of vision still are major threats in the African continent; both of them would still be a major concern for the NGO.

The IDEAS for Africa team firmly believes that an African space-oriented NGO would be a great way to bring the benefits provided by space to the continent. The decency and altruism which motivates the enlightened individual to ease suffering wherever they can - the utilitarian ethos to decrease the misery of all of humankind - they all require that when actions can be done, they should be done. We invite and dare readers of this report to take the next step.

8.2 African Space Agency

The establishment of an NGO to provide the proposals of the previous chapters, while with good intention, will likely fall short when projects become too expensive, or require too much international cooperation. When this is the case, space activities will require government involvement to see a project through to completion. Unfortunately, the socioeconomic situation in Africa precludes any one nation from undertaking projects akin to those of space agencies from developed countries. It is undoubted that to reap the benefits of all facets of space activities, the cooperation of African countries will be necessary.

The establishment of the ASA is not a new concept. The 2010 Abuja Declaration - a meeting of African ministers in charge of communication and information technologies - made a formal request for the AU to:

> Conduct a feasibility study for the establishment of the African Space Agency taking into account existing initiatives, and develop an African Space Policy in cooperation with the RECs, United Nations Economic Commission for Africa (UNECA) and ITU.
>
> (African Union, 2010)

The IDEAS for Africa team fully understands that providing a critical analysis of the merits and challenges faced by establishing the ASA would not only be impossible, but also would be a disservice to the establishment of the agency itself. As such, the following section will focus on the envisioned benefits of establishing an ASA, and will look at which proposals of the IDEAS for Africa team, as described in the previous chapters, could be best implemented by it. The intent of this is to provide the reader with a sense of what a future project by the ASA could do to achieve social and economic development across the African continent.

8.2.1 Benefits

To understand why the establishment of an ASA would bring social and economic benefits to Africa, it first must be understood why space agencies cooperate in space. National space agencies orchestrate and organize national space activities, and coordinate their activities with regional and

global partners. Countries cooperate in space when it is in their interest, and conforms to both their national space policy and national priorities. From merely sharing data on their space projects, to sharing personnel and resources on collaborative projects, international cooperation in space can be scaled all the way up to international projects.

Africa is a "capital scarce" continent, and therefore needs an efficient and effective means of managing scant resources. There is an urgent need for Africa to pool these resources in a continent-wide agency. When other countries are using space assets and technology to foster their own development, Africa cannot continue to be onlookers and bystanders. Space technology will continue to be a major asset for all countries. Africa should no longer be a borrower and consumer, but should provide a good ground for scientific excellence (Alkinyede, 2008).

Countries like Algeria, Egypt, Nigeria, and South Africa, are launching micro-satellites in constellations, but download data from them from less than one percent of each orbit. International prosperity and cooperation will be enhanced by a central coordinating entity. For example, the African Resource Management Constellation - a satellite constellation providing high resolution remote sensing imagery over Africa - would be better coordinated within an ASA, as it would allow for data processing, data storage, financial, human resource, and infrastructure sharing capabilities (Gottschalk, 2008).

Table 8-1: Applications addressed by the core technical requirements of the African Resource Management Constellation [Mostert, 2008].

African Resource Management 1 Requirement	
1	Agriculture, climate, environ
2	Disaster monitoring
3	Land use/cover mapping
4	Managed agriculture
5	Water resources management
6	Mineral, oil & gas exploration
African Resource Management 2 Requirement	
1	Disaster monitoring
2	Water management, land use & land care
3	Map food vulnerability
4	Drought status, disaster, global
5	Land use & land care, Water Management, Food Security
6	Mineral, oil & gas exploration
7	Fishing
African Resource Management 2 Requirement	
1	Environmental impact, assessment, farmer settlement, housing, planning & urban planning, border monitoring
2	Disaster monitoring
3	Land use/cover mapping
4	Water resources assessment
5	Mineral, oil and gas exploration
6	Peace-keeping missions

An ASA would provide African countries with a space policy that would help to develop its space sector, provide supportive funding, and commit Africa and its people to changes that enhance future prosperity. It would create synergies between agencies and enabled them to embark on projects that any one country going alone would be unable to execute. The working together of different agencies, organizations, or commercial entities under ASA will promote international cooperation, fostering international good would and strengthen Africa soft power international (OECD, 2005).

8.2.2 IDEAS for ASA

The establishment of an ASA, while perhaps not in the immediate future, is inevitable. One of the early questions for such an organization will be what projects can be best implemented by the agency. The first projects will likely be small scale (a human space program is likely not the first objective of an ASA), and will provide the maximum benefits to all Africa. Some of the proposals of the IDEAS for Africa team, as described in the previous chapters, are well suited for implementation or support by an ASA. This includes some of the satellite applications, and space business proposals. The satellite application proposals of the previous chapters, particularly the ones with large initial investments, are ideal for the initial projects of an ASA. This is particularly true for the Telemedicine Van and DMPC proposals. Both of these projects invoke relatively high initial investments, but more importantly the positive impacts of these proposals can be far reaching. In addition, the ASEC and OSRRF of the previous chapter are well suited to the framework of an ASA, as these will promote future space developments in Africa.

The need to address healthcare concerns in Africa is of great importance, and the sponsorship of the Telemedicine Van project by an ASA, akin to ESA's Telemedicine Van, would be an impactful project for the agency to undertake. The Telemedicine Van proposal requires centralized medical professionals and data storage facility. Without an overarching coordination body this would likely mean that a centralized facility would be needed for each country, greatly increasing the costs to implement this proposal Africa-wide. Similarly, using one coordinating agency to manage data storage would greatly simplify the sharing and distribution of medical data. Perhaps most importantly though, is that a central coordinating entity for the Telemedicine Van project would mean that an individual from one country who uses it could travel to another country, and still have access to the same level of medical care. This includes everything from the same doctors, to the same degree of expertise, to a complete transfer of all medical data.

The central idea behind the DMPC proposal was the establishment of a DMPC. This facility could be one of the initial agencies of an ASA. Similar to the Telemedicine Van project, a single governing entity and centralized location would only act to simplify the actions taken by the DMPC, enhancing its effectiveness. Based on ESA's framework of mandatory and optional programs, the DMPC could be an optional program for member countries, encouraging those affected by desertification to join an ASA. This could be an enormous incentive for African countries to work together and enhance cooperation. While desertification is a major issue for Africa, the IDEAS for Africa team sees the opportunity in using the DMPC to enhance cooperation within African countries under the framework of an ASA.

In addition, the ASEC would benefit greatly from being supported or at even implemented under the framework of an ASA. While space agencies do take a leading role in promoting education, they do not engage in establishing educational centers. It may be possible that Africa would benefit from an ASA fully establishing their own university, with programs oriented towards the goals of the agency. By providing this direct link between space agency and university, it would mean that students are educated in fields that are most applicable to enhancing space activity in Africa.

Finally, an ASA in the future will likely need to develop its own launching capabilities. Although this may not be immediate, autonomous launching capabilities will be a necessity should Africa wish to compete in space with the developed world. While the proposal regarding the OSRRF did not consider the establishment of a full launching facility to be feasible, this was only under the context of a commercial entity. Should an ASA be established then the potential for developing OTB into a

launching facility is revitalized. It is likely that this process with be piecewise, and the development of the OSRRF with the support of an ASA is one step towards its establishment as a launching facility. As was mentioned in the *Space Business: Overberg Sounding Rocket Research Facility* section, the high cost of developing a launching facility is, for the time being, prohibitive to any one country. However, by pooling the resources of all of Africa together, such a facility could be seen through to fruition.

8.2.3 Summary

The IDEAS for Africa team feels that the establishment of an ASA to promote space in Africa is not only necessary, but inevitable. And while it is near-impossible to critically analyze how to establish such an agency, it is possible to make suggestions regarding which projects such an agency could undertake when formed. The IDEAS for Africa team believes that the Telemedicine Van, the DMPC, the ASEC, and the OSRRF, are projects that would promote international cooperation, enhance social and economic development, and better enable to benefits of space to impact Africa.

8.3 Conclusions

This Appendix investigated implementing the IDEAS for Africa proposals with an NGO and an African space agency. After considering our space-related solutions from the report, we wondered how they could be brought to Africa to improve lives - especially when no government or private industry would be willing or able to pay for them.

Some proposals are best suited for a small group of focused individuals with a single goal, while others lend themselves to an international, continent-wide space agency. The proposals best suited to the NGO framework were ones with minimal initial investments. Conversely, a new African space agency would have the resources and reach to implement ideas requiring larger initial investments, or those with international cooperation.

NGOs are committed to bringing social change, and their focus is people, not profits. They can work with other NGOs and civil society partners and can work internationally, drawing support and resources from abroad. A Space and Africa NGO could help to bring ODCs, DHA Supplements, and SOFCs to Africa. It can even help get satellite-related projects started, such as the FarmaBooth or Anti-Poaching proposals.

The new African space agency would be suited to develop different, larger projects, like the DMPC. Currently, various Africa countries work on their own in building satellites or procuring them, and in conducting remote sensing. This is very expensive and a central coordinating entity would allow partner countries to contribute and benefit from the resulting synergies and economies of scale. This agency would also be able to revive the Overberg Test range, and do other large scale and costly projects. We believe that an African Space Agency is inevitable.

The IDEAS for Africa team believes that a space-oriented NGO and an African Space Agency can be extremely powerful vehicles to bring positive social, economic, and technological development to Africa. The next chapter summarizes and synthesizes our project and offers perspectives on the space and Africa theme.

Space can provide many benefits from spinoff technologies, remote sensing applications, and even establishing self-sustained commercial industries.But how is space relevant for Africa? How can space be used to save and improve lives, protect the environment,mitigate severe weather conditions, and build industries and economies?

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