EXPLORING THE NEED AND VIABILITY OF A SMALL SATELLITE PROGRAMME FOR LESS DEVELOPED COUNTRIES

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ABSTRACT

Small satellites are artificial satellites of unusually low weights and small sizes, usually under 500 kg. Satellites may be miniaturised to reduce costs in both launching and design; Small satellites may be launched using excess capacity on larger launch vehicles and their size may also allow for cheaper designs as well as ease of mass production. Other than the cost issue, another rationale for the use of miniaturised satellites is the opportunity to enable missions that a larger satellite may not accomplish, such as constellations for low data rate communications; using of formations to gather data from multiple points and in-orbit inspection of larger satellites. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) recommended, inter alia, that the joint development, construction and operation of a variety of small satellites offering opportunities to develop indigenous space industry should be undertaken as a suitable project for space research, technology demonstrations and related applications in communications and earth observation. This study reviews the state of the industry, as well as specific data on the viability of introducing such a system in a developing country like Kenya.

Keywords: Small Satellite Systems; Peaceful Use of Space; Earth Observation.

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INTRODUCTION

Satellite technologies have been available for use in various sectors of the world economy for several years. The technology is particularly useful in the areas of remote sensing, communication and navigation. Satellite technologies provide valuable information which may be used in achieving most of the development goals of the less developed countries. Adoption of the technologies is also likely to lead to a greater level of technological uptake. The technology is however not used to its full potential due to lack of funds, expertise, equipment or awareness. This paper is motivated by a desire to increase and improve the use of satellite based technologies. Many of the less developed countries have minimal Space presence, a fact which hampers efficient exploitation of some of the more useful technologies available to man.

This paper is motivated by the extremely low uptake in the use of satellite technologies in regions that would normally be expected to substantially benefit from it. It is informed by the wide availability of satellite data and pervasiveness of the availability of Global Positioning System signals at all corners of the earth on the one hand, while economies in the less developed countries do not appreciate the uses to which it may put all this available data. GPS has been successfully used diverse applications such as in locating villages and dwellings during census, mapping boundaries and national borders and in tracking the movement of elephants and other wildlife (NAS 2002). Other satellite data are readily available for years.

This study considers the availability and possible use of satellite technologies in achieving the millennium development goals. Kenya is used as a typical example of a less developed country which may need to more aggressively exploit satellite technologies for national development. Use is made of available literature in the field.

The paper explores the issues concerned in the development of small satellite programmes and considers the applicability and viability of developing such programmes.

Wood (2005) investigated the correlation between national development in African countries and the uptake of satellite technology. The Human Development Index was used to measure a country’s level of development whereas uptake of satellite-based activities was evaluated from participation in a number of space based activities. A correlation was found between the two; The higher the uptake of satellite technologies, the higher the human development index, which infers a greater level of achievement of Millennium Development Goals. Of course, the converse could also be true, in that countries which are already more developed have more funds to spare in embarking on ambitious satellite projects.

Space technologies are mainly used in Communication, Navigation and Remote Sensing. There exist six main hierarchies in the exploitation of satellite technologies:

Satellite Design and Manufacture

Most satellite builders are based in the large industrial and more developed economies. The major players are agencies like NASA, ESA and CSA. Some companies like SSTL, Greatwall from China and Yuzhnoe from Ukraine are also actively involved in satellite construction.

Two African firms, SunSpace and ESL have also developed satellites for use in remote sensing projects. Communication satellites are more complex, and no local African expertise has been developed for the development of communication satellites.

Satellite Ownership and Operation

There are several instances of African satellite ownership for remotes sensing and communication satellites; Satellite owners and operators include African Space Agencies like in Nigeria and Algeria. They also include African National Remote Sensing Agencies like Egypt's NARSS and South Africa's SAC. Africa is least involved with navigation spacecraft.

Satellite Data Processors

These include African Regional Remote Sensing Centres like RCMRD, OSS, SADC Regional Remote Sensing Unit, AGRHYMET and ACMAD; African Universities like University of Ghana; African Scientific Networks (Muombo and Mara); African National Remote Sensing Agencies (Morocco, Mozambique, Senegal).

Coordinating Organisations

African Regional Associations (SADC, CILSS, Nile Basin Initiative, Lake Victoria Fisheries Organisation) and Multilateral Development Organisations (World Vision, UN, World Bank, World Conservation Union, WHO, USAID)

Data Users

African Government Agencies (Morocco's Watershed Authority, Kenya's Ministry of Health, Burkina Faso's Water Resources Agency, Zambia's Ministry of Agriculture, National Meteorological Services) and African Universities (South Africa's University of Kwazulu-Natal and Egypt's Drainage Research Institute).

Launch Capability

Only a few industrialised countries and developing countries have satellite launch capability. No African country has indigenous launch capability, although satellite launches have previously been carried out from the San Marco platform in Malindi, Kenya.

SATELLITE TECHNOLOGY

Satellites are usually described in terms of a mission system (payload) and a service module or 'bus'. The mission system enables the satellite achieve its mission including communication, broadcast and weather monitoring. The body (bus) of a satellite holds all of the scientific equipment and other necessary components of the satellite. Satellites combine many different materials to make up all of their component parts. Since satellites are essentially pieces of scientific or communications equipment that must go into space a bus that will take the equipment safely into space is designed.

The goals when choosing materials for the satellite's bus are protection from collisions with micrometeorites and particles (outer layer), protection from radiation of the sun (anti-radiation), thermal blanketing to maintain a comfortable temperature for instruments to function, conduction of heat from vital instruments, structural support and connecting materials.

SMALL SATELLITES

Satellites have traditionally been large undertakings costing a lot of money and taking several years from conception to launch. This is however changing. Modern small satellites have appeared on the scene starting from the 1980's. The new breed of low-profile, low-cost space system is built by maximising the use of existing components and off-the-shelf technology and minimising developmental efforts. Such small satellites are sometimes called 'lightsats' (Bearden 2001). Small satellites typically weigh less than 500kg, although sometimes cost is used as the threshold.

One reason for miniaturising satellites is to reduce the cost. Smaller and lighter satellites require smaller and cheaper launch vehicles. They may also be launched using excess capacity on larger launch vehicles. Another rationale for small satellites is to enable special missions, e.g. constellations for low data rate communications, formations to gather data from multiple point or in-orbit inspection of larger satellites.

Small satellites are classified depending on the wet mass (i.e., mass inclusive of fuel). *Minisatellite* refers to a satellite weighing between 100 and 500 kg. They are sometimes simply called ‘small satellites’. *Microsatellites* (microsats) weigh between 10 and 100 kg. *Nanosatellites* (nanosats) weigh between 1 and 10 kg, while *picosatellites* (picosats) weigh between 0.1 and 1 kg.

The table below shows typical performance parameters for some low- and high-end small spacecraft buses derived from information presented in NASA's Rapid Spacecraft Acquisition contract offerings.

Table 1: Characteristics of Small Satellites

Parameter	**Low-End Buses (w/o options)**	**High-End Buses (w/ options)**
Design life (years)	1–3	>>5
Reliability (at design life)	.8–.9	.8–.9
Avionics redundancy	Limited	Extensive to full
Bus mass (kg)	150–300	425–650
Payload mass (kg)	100–300	300–500
Payload power (orbital average, W)	60–125	100–500
Propulsion authority (kg Hydrazine)	0–25	33–75
Pointing accuracy (deg 3-sig)	0.02a–.25	0.01a–0.03a
Pointing knowledge (deg 3-sig)	0.001a–0.2	0.003a–0.008a
Data storage (Gbit)	2–64	12–200
Downlink (Mbps)	2–4 at S-band; 100 at X-band available on SA200S	2 at S-band, 320 at X-band

Source: NAS (2000)

The move toward smaller spacecraft places added emphasis on the costs and availability of appropriate launchers. The aerospace industry has moved to develop a number of "small" launch vehicles tailored specifically to meet this growing market segment.

Small satellites are currently becoming more attractive even to the countries considered traditional leaders in space technology like the US; Large satellites typically carry several sensors so as to make the mission cost effective. A sensor may require an equator crossing time that differs from that of the majority of sensors to be flown. A small satellite may house that sensor, rather than forcing overall performance to be compromised in a suboptimal orbit. Further, multiple small spacecraft in different orbits may provide repeat coverage for data collection, commercial communications and search-and-rescue transceivers (NAS 1994)

Israel is actively developing small satellites, and has maintained indigenous space capability since 1988. The Israeli space programme is mainly geared towards defence by providing satellite surveillance. The programme uses Shavit launch vehicles built by Israel Aerospace Industries (IAI), and can lift satellites of 300-350 kg. to retrograde (western) orbits. Israel has also considered aerial launches, by use of the military transport aircraft, Ilyushin Il-76, a launcher carried by an F-15, or even a civilian jetliner. Aerial launches cost less than a ground launch. Israel also uses space based assets in the deployment of autonomous Unmanned Aerial Vehicles, hence extending navigation, situational awareness and tactical control.

Small satellites offer new opportunities to address the core observational requirements of both operational and research missions. Small satellites, in particular single-sensor platforms, provide great architectural and programmatic flexibility. They offer attractive features with respect to design (distribution of functions between sensor and bus); observing strategy (tailored orbits, clusters, constellations); faster "time to science" for new sensors; rapid technology infusion; replenishment of individual failed sensors; and robustness with regard to budget and schedule uncertainties (NAS 2000).

DISCUSSION

Needs of Less Developed Countries

Satellites in Communication

Satellites provide many services in the area of communication by providing a platform to transfer data from one point on the globe to another. Satellites play a valuable role in providing phone, internet, and broadcast services in developing countries. These services can improve access to education and medical care.

Satellite communication technology can improve medical care in developing countries by enabling telemedicine. In rural areas of developing countries, it may be difficult or expensive to get access to medical care. Telemedicine is “the delivery of health care and the exchange of healthcare information across distances.”

Thus, health care providers and patients are connected virtually rather than being in the same place. They may communicate via video conferencing email, pictures, or by sending medical data. Doctors may use the system to provide diagnosis, treatment and counselling.

Satellites in Navigation

Satellite navigation involves the use of satellites and ground receivers to determine latitude, longitude and altitude. Satellite navigation technologies are facilitated by operators at three levels: At the highest level is the operator of the GNSS. Currently the most available GNSS is the US Army owned GPS. At the second level are the owners of the satellite navigation augmentation system owners. The third level includes the manufacturers of satellite navigation ground equipment.

At the base are the final users of the satellite navigation technologies. Final users of navigation technologies in Kenya can involve applications like in census bureaus; Hand held receivers may be used to accurately locate dwellings during a populate census. Accurate census enables governments to provide health, social and economic services and facilities and hence move towards meeting the first MDG of eradicating extreme poverty and hunger and the fourth MDG of reducing child mortality rates; It would also go towards meeting the second MDG of achieving universal primary education. Wildlife monitoring and tracking by the Kenya Wildlife Agency and various researchers would go towards meeting the seventh MDG of ensuring environmental sustainability.

Satellites in Remote Sensing

Satellite remote sensing allows visual imaging of the earth's surface as well as the collection of scientific data about the earth, sea and atmosphere.

Satellite remote sensing can address needs in developing countries by supporting such efforts as urban planning and disaster management. Urban planning is an urgent need in many developing countries where so called "mega-cities" of over ten million people, such as Manila and Nairobi, are growing quickly due to urbanisation. High resolution satellite imagery used with Geographic Information Systems can provide city planners with much needed information about the growth of their cities.

A second need of developing countries that can be addressed by satellites is disaster management. Disasters like hurricanes, volcanoes, and fires or long term problems such as famine, drought and disease occur commonly and cause great damage in developing countries. Satellites can sometimes provide early warning about disasters through remote sensing. Satellites can detect hurricanes, volcanic activity and fires. A successful use of remote sensing data is the Africa continent-wide Mapping Malaria Risk in Africa (MARA) project which uses environmental satellite data to understand the spread of disease by animals. Also, satellite data can give warning of famine or drought conditions before they become severe.

Geographic data describe spatial variations across the landscape at a variety of scales (local, national, global) and include such elements as climate, elevation, soil, vegetation, population, land use and economic activity (NAS, 2002). Good governance promotes geospatial capacity and vice versa. Access to integrated geographic information allows civil society to hold government accountable; and government creates policies that determine public access to information and public participation in the decision process. Akinyemi (2008) has shown poverty mapping using GIS. This may be used in achieving the MDG of eliminating absolute poverty.

Barriers to Establishing Space Programmes

Cost

Cost of launching a satellite is quite expensive. The table below shows the costs of launching small satellites using the available launch vehicles.

Table 2: Launch Capacity to EOS Orbit, Cost and Performance History of Candidate Small Satellite Launch Vehicles

Vehicle/Configuration	Capacity to 700 km Sun-Synchronous Orbit (kg)	Cost ($M)	Performance History (Successes/Flights through Oct. 1988)
U.S. LAUNCH VEHICLES			
Delta II 7920/25	3,275	50	47/49
Delta II 7320	1,750	35	0/0
Pegasus XL	225	14	18[a]/23[b]
Taurus XL/Orion 38	945	24	0/0
Taurus/Orion 38	860	22	3/3
Athena 3	2,200	30	0/0
Athena 2	700	22	1/1
Athena 1	200	16	1/2
Conestoga 1229	220	12	0/0
Conestoga 1620	540	18	0/1
FOREIGN LAUNCH VEHICLES			
CZ-2D (China)	1,200	20	5/5
PSLV Mk2 (India)	1,300	12/15	1/1
Molniya M (Russia)	1,775	30	256/289
Shavit 2[c] (Israel/US)	340	15	0/0
Shtil 1N (Russia)	185	5/6	1/1
Tsyklon 3 (Ukraine)	2,300	25	111/117

Source: NAS (1994)

A total launch cost of $5 million to $7 million is cited by the industry and experts as a threshold considered critical for an expanded market; This cost appears affordable for experimenters, innovators, commercial and university users. However the current launch prices are about twice this desired range (NAS 1994).

Technology

The development and construction of satellites remains a challenge for many less developed countries. Whereas some countries like India have been developing their industrial base, many of the less developed countries like Kenya have a poorly developed cadre of engineering and technical capability in developing satellite technologies.

Capacity is required in systems engineering and operations; spacecraft propulsion technology; spacecraft electrical power; spacecraft structures and materials; small spacecraft communication technology; guidance and control technology; sensors for small spacecraft; robotics, automation and artificial Intelligence; launch vehicle technology

Policy Framework

There is a dearth of expertise on international Space Law in many less developed countries. Many people in the technical fields are not aware of the legal framework in which space research is carried out, and have no information on the applicable regulations. There is need to strengthen mechanisms to improve safety of space operations. There also need to be a concerted effort in offering solutions to the problems related to space debris. This is particularly important with the expected exponential increase in space activity as costs come down. Other issues to be considered are the equitable administration of the electromagnetic spectrum, frequency resources, orbital positions and space operations. In developing the technologies there is also need to consider issues of space security.

User Demand

The most effective application of satellite information is carried out by individuals who understand both the technology and the socioeconomic development context in which it is to be applied (Akinyemi 2001). Learning to apply modern geographic information and tools to address evolving societal needs requires a long learning period and attention to the development of research and analytical abilities as well as technical skills. Universities are the logical source of this kind of education and training since they focus on teaching and research. Unfortunately universities in Africa in general, and in Kenya specifically, tend to operate as discrete entities, focussing on teaching with limited interaction with wider society (NAS 2002). Even in cases where satellite imagery and data is available, there is a low uptake by the potential users of the technology.

Overcoming the Barriers

Universities are currently at the forefront in the development of small satellite programmes, and have overcome the odds in trailblazing small satellite programmes.

South Africa was the first to show the way. Stellenbosch University in South Africa launched the first satellite built and managed by a university in 1999 with cooperation of NASA (NAS 2002). The Stellenbosch University Satellite (SUNSAT) program started in the Computer and Control Systems Group of the Electrical and Electronic Engineering Department. The satellite was designed, constructed and tested entirely by the students and staff. The impact of SUNSAT on capacity building can be measured by the more than 50 masters and PhD degrees that have been awarded to students who participated in the satellite's development.

CubeSats have provided an opportunity to many academic institutions to launch their own space programmes. CubeSats are standardised nanosatellites of a volume of exactly one litre, i.e. 10 cm^2, with a mass of up to 1.33kg. They typically use commercial off the shelf electronic components. The specifications have been developed specifically to allow universities worldwide to perform space science exploration. A typical mission of a CubeSat in Low Earth Orbit is to communicate with a ground station and send back some data. The CubeSat Project began as a collaborative effort between California Polytechnic State University and Stanford University's space Systems Development Laboratory (SSDL). The purpose of the project was to provide a standard for design of nanosatellites so as to reduce cost and development time, increase accessibility to space and to sustain frequent launches.

The University of Surrey and SSTL are developing a nanosatellite, the Surrey Training Research and Nanosatellite Development (STRaND-1) with a smartphone payload. STRaND-1 is being built as a part-time project with advanced off-the-shelf components. The payload is a Google Nexus One mobile phone with 32GB data storage, 1GHz processor and 512MB RAM.

SUMMARY AND RECOMMENDATIONS

The School of Aerospace Sciences of Moi University is well-placed to provide leadership in the development of satellite programmes in Kenya. Kenya is particularly suited for satellite launches, being on the shores of the Indian Ocean. The School should consider starting off with a CubeSat as is the trend for many universities launching their maiden satellite programmes. It is important to establish partnerships between universities and the private sector so as to achieve advances in developing space capacity. The School should establish a goal of launching a nano/picosatellite in the next five years.

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