PROSPECTS AND CHALLENGES OF BUILDING CAPACITY FOR SPACE SCIENCE AND TECHNOLOGY DEVELOPMENT IN AFRICA

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ABSTRACT:

The need to build indigenous capacity in Space Science and Technology (SST) in Africa, especially in core areas such as information communication technology (ICT), navigation and Earth observation systems for geo-information production and management, cannot be over-emphasised. ICT and geospatial information remain the bedrock for the development of the various sectors of the economy including petroleum and energy, solid minerals, agriculture, water resources management, weather forecast, aviation, transport, environmental and disaster management/monitoring, defence and security, tourism, population census, telecommunication, education and health. Capacity building to enhance the use of space and geographic information systems (GIS) technologies in planning, project execution, decision-making and good governance has become sine-qua-non in Africa's sustainable development efforts. In recent times, there have been increasing interests by some African countries in SST development and the development of geospatial data infrastructure (GDI). Lately, GI-specific issues and events have brought to the front burner the need for proactive capacity development in the use of geospatial technology in Africa. Accordingly and in responce to these needs, three African countries, Algeria (2002), Nigeria (2003) and South Africa (2008) launched their own Earth observation satellites, thereby joining the league of 'sensing' countries and moving Africa out of the former class of being totally a 'sensed' continent. South Africa has been involved in space technology development, particularly in the area of astronomy for a long time, while the Egyptian Nilesat (a communication satellite) and Morocco's shared experience in Arabsat are also part of the aspirations towards the development of competence within the African continent. These efforts are associated with some forms of capacity building in astronomy and satellite technology development. Do the efforts constitute the bedrock for furure development in the space enterprise? What are the prospects for the requisite knowledge generation, development and sharing through regional and international cooperation? What specific roles should the tertiary institutions and the existing Centres of Excellence play in this endevour. What challenges needs to be overcome? These and other related issues are discussed in this paper.

1.0 INTRODUCTION

Education is a major indicator of human development. It occupies the centre stage of any development effort. An essential element of development in any nation, is its level of literacy and the training opportunities made available to its citizenry. There is no doubt that a well-educated society will be a direct beneficiary of technology development. Empirical evidence has shown that the more educated a society is, the more the rate of technology development, adoption and application to meet the society's needs. The patterns of investment in education in the developed countries, for instance, have also been noticed to be long term in nature and consistently at a reasonable level of the GDP.

With the exception of a few, most African countries are faced with the challenges of accelerated development and improvement of the quality of life of the large population, through the meeting of basic needs such as education, energy, food, potable water supply, efficient healthcare delivery, tackling the problems of desert enchroachment and deforestation and sustainable environmental management. Increased industrial activities (e. g., oil and gas) of the past decades did not take into cognisance the need to takle the associated problems of environmrntal degradation, the growing populations and the economic activities of the host communities. All these point towards the need for a comprehensive sustainable development approach in order to achieve the objectives of the millennium development goals.

Space technology offers a wide range of innovative and cost effective solutions for sustainable development by providing a unique opportunity to balance consumption and production, and therefore ensure sustainability of our resources and environment. Many countries are now well informed of the invaluable benefits, direct and indirect, derivable from the development and applications of space science and technology (SST). An essential pre-requisite to partaking in these opportunities, however, is the building of various indigenous capacities for the development and utilization of SST. In recognition of such a pre-requisite, a consensus has emerged within the international community that if effective assimilation and appropriate application of SST are to succeed in developing countries devoted efforts must be made at the local level for the development of the necessary human and infrastructural capacity in all fields of SST. Capacity building in space science and technology is especially critical to the development of various sectors of the African economy including petroleum, solid minerals, forestry, agriculture, transport and aviation, environment security, defense, tourism, population census, monitoring and control education, health and water resources management, especially its use in planning and decision-making processes. For effective assimilation and appropriate applications of space technology to succeed in Africa, commited efforts must be made at the national and regional levels for the development of necessary high-level knowledge and expertise in all ramifications of space science and technology.

Therefore, the proposed translation of many African nations from the present status of space aspiring nations to space fairing nations is in itself a roadmap to the transformation of the African continent and society. The increasing interest of some African countries in Space Science and Technology development and the development of geospatial data infrastructure (GDI) have brought to the front burners the need for proactive capacity development efforts in Africa.

2.0 RELEVANCE AND DIRECTION OF CAPACITY BUILDING

The UNCED (1992) definition for capacity building encompasses a country's human, scientific, technological, organizational, and institutional resources and capabilities. Capacity building can also be defined as "efforts aimed at developing human skills or societal infrastructures within a community or organization to reduce the level of risk. It is the development of facilities, programs or other resources which help develop a community's (organization or group) ability to perform specific tasks. A fundamental goal of capacity building is to enhance the abilities of stakeholders to evaluate and address crucial questions related to policy choices and modes of implementation among different options for development. These could be based on the understanding of the environmental potential and limits and of the needs perceived by the people of the country concerned.

Empirical evidence has shown that there is presently a dearth of space scientists, engineers and technicians relevant to the development of space science and technology components in Africa. There is need for concerted efforts to initiate programmes that will build to a comfortable level, not only space technicians through the ''know-how-technology-transfer (KHTT) but also and in particular the bedrock of human resources of space scientists and engineers in Africa. It implies therefore that the development of space education in the continent is critical to the adoption and diffusion of space technology and its benefits to all Africans. Africa is increasingly reliant on space based services and applications, particularly those in the domain of satellite Earth observations, telecommunications, navigational positioning and timing. A major aspect of this endevour is capacity building to maximize the benefits of the technologies. Lately, geo-information (GI)-specific issues and events, including the increasing need to build and implement geospatial data infrastructure (GDI), have brought to the front burners the need for proactive capacity development efforts in Africa. Working groups on capacity building has already been set up by the national GDI Committees in some countries (e.g. Nigeria, Mali and Namibia).

Responding to these challenges, three African countries, Algeria (2002), Nigeria (2003) and South Africa (2008) launched their own Earth observation (EO) satellites thereby joining the league of 'sensing' countries, moving Africa out of the former class of being totally a 'sensed' continent. By implication, the African user community, for the first time, have un-indered access to geospatial data from regionally-owned EO satellites. These efforts have been associated with KHTT and to some extent a level of indigenous knowledge generation.

South Africa has a rich heritage of involvement in space science and technology. The country's involvement in modern astronomy spanned more than 180 years of history Recently, in 2005 the South African Large Telescope (SALT) was commissioned to contributing to the study of outer space and to stimulate and inspire the youth and the general public to develop interest in science. The proposed hosting and construction of the Square kilometer array (SKA) radio telescope by South Africa and other countries will be another major technological feat in Africa that will contribute to knowledge generation, development and sharing in the global space arena.

Key factors in this process are adequate provision of critical mass of skilled manpower, improved organizational capacity and institutional reforms. Other areas of critical needs to enhance the growth of these efforts in Africa include knowledge sharing among the space aspiring nations. Four countries: South Africa, Algeria, Nigeria and Kenya, have gone far in reaching agreement to launch and operate a constellation of African Resource and Environmental Management (ARM) satellites as part of the strategies to develop the required capacity for the African space enterprise. These strategies include knowledge generation and sharing.

It is therefore essential to match these developments with a proactive manpower development for research and development in space technology and its applications, in addition to necessary institutional reform.

3.0 CAPACITY BUILDING CENTRES OF EXCELLENCE IN AFRICA

The United Nations (UN) Regional Centres for Space Science and Technology Education in Morocco and Nigeria are already contributing towards the building of competencies in SST through their teaching, research and development activities in core areas such as basic space and atmospheric sciences, remote sensing (RS) and geographic information system, satellite communication technology, satellite meteorology and space law and Global Navigation satellite systems (GNSS). The mandates of these centres include the development of skills and knowledge of university educators (in train-the-trainer programme), resources and environmental research scientists, telecommunications professionals, weather forecasters, policy makers/planners and other relevant project implementation personnels in the principles and applications of SST. The mandates are delivered through post graduate diploma and M.Sc certificate courses, (using the curricula produced by the UN Office for Outer Space Affairs), tailor-made short courses, workshops and conferences. Details of the mandates of these centres and the progresses/achievements recorded to date have been well documented (Akinyede, 2009). Other training centres of excellence in Africa include the Regional Centre For Training In Aerospace Surveys (RECTAS), Nigeria and the Regional Centre for Mapping of Resources for Development (RCMRD), Kenya. Similarly, many universities across Africa have established centres and departments charged with the responsibilities of capacity building in space science and technology, especially RS and GIS.

To complement the capacity building efforts of these centres and institutions, the national space agencies have included in their space policies the development of critical mass of trained space scientists and engineers. The capacity building programmes of the agencies are being pursued as an integral part of the agencies' satellite technology development. For example, Nigeria through NASRDA has trained over 80 scientists and engineers in the design and building of satellites, as well as satellite telemetry, tracking and control and data aquisition as part of its first and second EO satellites (NigeriaSat-1 and NigeriaSat-2) and Nigeria's first communication satellite (NigcomSat-1) projects. Nigeria's EO satellites and the first Algerian EO satellite (AlSat-1) were built with KHTT from the technical partner, Surrey Satellite Technology Limited (SSTL), of U. K.

The existing infrastructure and skilled workforce, both inside these institutions and in wider industries supporting them, could be used to strengthen the ties with the industries towards the achievement of the African space enterprise. Developing links with the existing and any other emerging national space agency and initiative, such as the proposed ARM satellites, could position Africa as a future hub of space science and technology development and application. According to Abiodun (2002) however, mastery over new sciences and technologies requires an unwavering commitment to the development of enabling technologies, through the revitalization of the existing capacity building institutions as well as the establishment of new ones that can participate in world class science. More emphasis should be placed on building capacity in such areas as microwave and antenna systems, space application technology including satellite system, radar and digital electronics including computers, microprocessors and information technology.

4.0 CHALLENGES OF CAPACITY BUILDING IN AFRICA

In African countries, capacity building in this context has been generally difficult to due to a lot of constraints some of which have been addressed by various authors in different forums e.g., Ruther, 2001; UNECA, 2001; Kufoniyi et al, 2002. These include:

(i) Obsolete curricula and facilities: Many of the institutions of higher learning are running obsolete programs with analogue-dominated, or completely analogue equipment.

(ii) Rigid curricula: Apart from being obsolete, the curricula are based on semester system which does not give room for intake of serving personnel to undergo short-term courses as part of the long duration courses.

(iv) Difficulty of releasing many officers for long-term training even when majority require retraining to update their knowledge in the emerging new technologies. Serving career officers that require retraining are many whereas it is not feasible to allow more than a few to go for a long-term training (within or outside the country), making short-term training a very important component of the education programs. This further gives credence to the need for modular curricula that will enable interested persons to join short module(s) of interest and then go back to their jobs. This would have been more efficient than running the regular programs in the usual semester structure and running separate short-term courses, which could create a lot of pressure on the staff and equipment. A modularized education program will limit the need to run separate short courses to only customized training. This is however difficult in our institutions, some of which are still teaching subjects that span a whole session.

(v) Lack of cooperation and networking among relevant departments even in the same institution: This leads to duplication of effort and uncoordinated programs and courses.

(vi) Lack of financial resources for overseas training: Many organizations in African countries can no longer afford to send many members of staff to more developed countries for training due to financial constraints, especially considering the number of persons to be trained before achieving capacity utilization. Consequently, with the small ratio of lecturers that are trained in the modern technology to those that are yet to be trained, developing new curricula may end up being a mere paper exercise that will not produce graduates who are genuinely trained in the new technology.

(vii) Absence of uniform academic standard and lack of networking: Uniform academic standard and proper networking would have facilitated sharing of human and other training facilities, which would have addressed the problem of inadequate number of trained lecturers.

(viii) Lack of provision for continuing education and training: This makes African lecturers to be out of date quickly and therefore unable to sustain a dynamic curriculum. Moreover, there is a lack of coordinated program in Africa on applied research and development in space technology.

(ix) Inadequate enabling technologies: Many of the enabling technologies for modern geoinformatics curricula are in various stages of development in Africa. For example, even though internet is commonplace in some countries, the bandwidth is often too narrow while there are still countries where it is still very difficult to come by, consequently developing a curriculum in some web-based courses in such countries will not make sense.

5.0 AREAS OF SPACE TECHNOLOGY AND CAPACITY BUILDING WHERE AFRICA NEEDS TO BUILD COMPETENCY

Capacity building in space science and technology depends on the quality of higher education in science and technology. There is need for capacity building in Hi-Tech principles and equipments such as telescopes and accessories for astronomical studies, solar terrestrial physics, cosmology and origin of life, meteorology and climatology, ionosphere physics, geomagnetism, communication physics, remote sensing, rocketry and balloons, satellite science and technology. Other areas include capacity building in the operation of ground stations for tracking and telemetry and command, satellite data applications, acquisition and processing of satellite data from various satellites, Operation of multi-choice satellite archiving station, geodetic surveying and mapping, monitoring of coastal deformation and subsidence, monitoring of sea level rise, monitoring of seismic and geodynamic phenomena, application of Satellite Laser Ranging (SLR), Very Long Interferometery (VLBI) and GPS network.

The education and training needs can in principle be undertaken in a University, polytechnic, or specialized institution. While the Universities and Polytechnics concentrate mainly on regular education courses mostly leading to the production of new graduates, the specialized institutions need to focus more on manpower development through the education, training and retraining of serving officers. Furthermore, flexibility should be possible in the specialized institutions, to facilitate the running of their programmes in short modules to permit continuing education of serving officers through short courses that are part and parcel of the regular programmes.

Various experts in the field of space technology can be trained in different categories as follows:

(a) High-level policy-makers: This can be achieved through short-term intensive training in the benefits and spin-offs from space technologies particularly as it relates to sustainable development.

(b) Management and Professional staff: New employees in this category should be already educated in the modern technology while opportunity must also be provided for mid-career (re)training of those already in employment for the purpose of broadening their outlook and keeping up to date on modern developments in space technology.

(c) Technical Support Staff: Education and (re)training of technicians and technologists for efficient production, management and use of space technology.

(d) General Public: through mass media and public lectures, to sensitise the public on the benefits derivable from space technology.

5.1. Capacity Building through Distance Learning

A seemingly effective way of rapidly building a critical mass of the necessary human capacity is through a distance learning scheme. It offers the best opportunity for African countries to take their rightful place in the global economy. It is now recognized that distance education is an additional method to provide quality education to a large number of students spread over wide geographical areas in a short period of time. However, there are many obstacles limiting effective deployment of this method. These include: low human capacity in ICT, low density of ICT-enhanced facilities, narrow internet bandwidth and slow net work (usually dial-up).

Communications technology, particularly space-based communications networks is a very important component in distance education. A communication satellite can readily provide a backbone for the ICT services particularly in the areas of e-learning, e-commerce, e-government, tele-medicine, tele-education, rural telephony, *etc*. In this respect, a super-hybrid communication satellite, such as the NigcomSat-1 which was launched in 2007 by Nigeria, has the capacity to provide a critical and innovative collaboration for capacity-building and the development of satellite technology for a quantum transformation in the telecommunication, broadcasting and broadband industry in Africa. NigcomSat-1 was also designed to provide new opportunities and challenging platforms for business in rural and remote regions through access to strategic information in the new world economic order. Although, Nigcomsat-1 experienced a power subsystem anomaly and was deorbited, but within the period of 18 months for which it operated, NigcomSat-1 offered services to major ISPs, banks and other operators (Ahmed Rufai, 2009). Pilot projects on tele-medicine and tele-education were also demonstrated using bandwidth from NigcomSat-1. Although, the technical partner in NigcomSat-1 project, China Great Wall Industrial Corporation, is working hard to produce another satellite (NigcomSat-1R) as a replacement within the next two years, yet Nigcomsat-1 still offers its services on third party satellites which will eventually be transferred to Nigcomsat-1R. In future, the launch of NigComsat-2 and NigComsat-3 is intended to provide in orbit sparing for Nigcomsat-1r and cater for new markets.

In order to achieve rapid capacity building in space technology in Africa, The Nigerian government through the African Regional Centre for Space Science and Technology education in English (ARCSSTE-E) has plans to make use of the NigComsat-1r for its distance education programme in Africa. The proposed ARCSSTE-E's distance learning programme will cover mostly higher education at the graduate and post-graduate levels. It is proposed that in addition to its regular courses on campus, ARCSSTE-E will also make use of this satellite to conduct short courses in open education mode. The lectures will be delivered via satellites in an interactive mode. Here the lectures from ARCSSTE-E in Nigeria can be uplinked to the satellite, and then it can be received over other regions in Africa where the transponder 'foot print' is covered. The communication system for the satellite based distant education will consist of three major elements which include the teaching end, satellite link, including satellite transponder, and the classroom end. The signal will be received in the classroom through Vsat in participating countries. Teacher-student interaction which is important for proper education is expected to take place at the end of each lecture session where students can ask questions from the teacher via the satellite or through other means like fax, e-mail etc. A typical example is the tele-education pilot projecct as demonstrated in Nigeria and implemented in collaboration with the National Open University of Nigeria (NOUN) is shown diagramatically in Figure 1. It has a pilot scheme comprising 12 study centres located across the nation with a teaching administrative HUB at the NOUN headquarters in Lagos, Nigeria (Odimayomi, 2007 and Akinyede and Boroffice, 2008)).

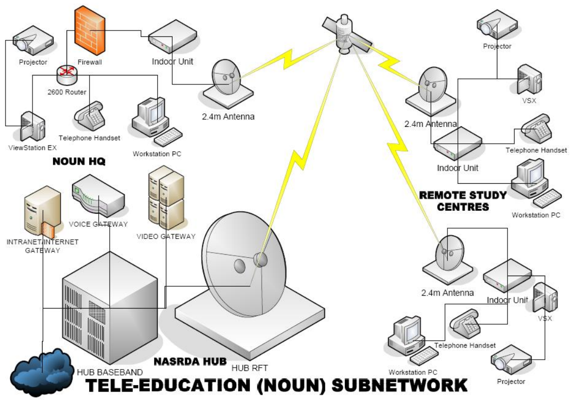

Figure 1: Tele-education pilot project of the National Open University of Nigeria (NOUN) sub-network

The tele-eduaction programme provides a flexible environment and interactive learning between teachers and learners regardless of distance bridging the gap in education unevenness among populace using digital opportunity created by the satellite infrastructure with new equipment. To ensure that the tele-education system meets our goal of capacity building for regional development, the lecture materials will be specially tuned to have liberal practical modules giving step by step approach which the students should be able to perform. It is also essential that the teacher is physically present at the teaching end and every tele-classroom will be equipped with adequate laboratory facility (essential computers with relevant software and satellite data, wherever required).

5.2 Educational Networking

Educational networking has been identified as one of the most efficient and cost effective way of achieving rapid capacity building on continual basis that moves in tandem with advances in technology. It can promote sharing of experts and facilities among institutions participating in the network and training of scientists in these institutions.

The educational network in this case can be a south-south or north-south education network. The south-south network can be collaboration among two or more institutions of learning in the south which may be located in the same country (intra-national) or in different countries (international) but only in African countries, carrying out joint research and training programmes thereby sharing facilities. On the other hand, the north-south collaboration can also be among institutions in Africa and one or more institution(s) in the developed countries. This type of network has the advantage of regular update of curriculum including north-south staff and student exchange programmes.

5.3. Know - How - Technology – Transfer (KHTT)

According to Abiodun (2002), the notion that total technology could be transfered from developed countries to developing countries is mistaken, not even in a competitve technology such as space technology. Therefore, the approaches to technology transfer should be re-examined to ensure transparency in the delivery of technology to Africa. The focus of technology transfer should be to develop a core of competent indigenous staff that will not rely on foreign experts or consultants who can hardly consolidate all their efforts and potentials to deliver advanced space technology and the spin-of benefits to the continent. Hence know-how-technology-transfer should involve sharing of technology and resources between foreign partners and African government institutions such as space agencies, federal laboratories and private industries, including personnel, facilities, methods, expertise, and technical information in general.

The transfer of technologies to Africa must be structured into an intentional system of adaptation and application of African space technology to a broad spectrum of industrial, educational, medical, and social needs among others. This can be majorly achieved by the use of Africa’s talents that are based abroad who have excelled in areas of SST to work in an enabling environment side by side with their compatriots in Africa .

5.4. Relevance of Basic Space Education

The governments of many space-fairing nations place great importance on developing and maintaining the skills base needed for the economy of tomorrow. According to BNSC (2008), space is a key hub for training highly skilled scientists and engineers. Space also inspires young people and society at large. It can, therefore, be a useful tool in achieving the government’s wider priority of increasing the take-up by young people of science, technology, engineering and mathematicsrelated subjects and careers. The priority is to enable a coordinated programme of outreach and space-related education activities aimed at improving general awareness and with links to the curriculum and teachers. In recognition of this need, the African Regional Centre for Space Science and Technology Education in Nigeria has been promoting space education awareness and outreach activities in order to stimulate the interest of students at both elementary and secondary school levels in the core sciences and more especially in space science education. The space benefits awareness programme has been extended to the general public. ARCSSTE-E has also been working in collaboration with the relevant stakeholders to develop space science education curricula for the primary and secondary schools in Africa.

5.5. International Cooperation

Scientific and technological development is a learning process that is largely achieved by countries through cooperative or collaborative efforts of sharing experiences, information, infrastructure and such other resources as human and financial. Today no country can secure higher levels of scientific advances and technological progress without interacting with its peers and neighbours. The ability of countries and firms to innovate, both in technical and managerial ways, is largely determined by strategic alliances they forge both within their industrial landscape and across sectors. International cooperation and coordination have occurred extensively in Earth and space science research, Earth applications from space, human spaceflight and microgravity science, satellite communications, satellite navigation, and launchers.

The ARMS initiative is indeed a very encouraging development which the African Union, through the New Partnership for African Development (NEPAD), should capitalize on and strengthen within the framework of its SST agenda. The regional space programme would be better realised if a coordinating agency in form of an African Institute of Space Science (AISS) is put in place. (AISS) which is currently under discussion by a variety of stakeholders on the continent. This would help to promote and coordinate cross-cutting multidisciplinary research and applications in space science and technology to address the development needs of the region.

ARMS is also being proposed to be one of the key flagship projects in the NEPAD Science and Technology Programme. ARMS will require the involvement of African countries involved to collaborate in building capacity to support space programmes in Africa. Specifically the collaborating countries are expected to have identical satellites which are to be built together by participating African scientists/engineers through knowledge development, generation and sharing. The resulting satellites are to be operated in constellation to allow for daily revisit, and accessed through the integration of the individual ground station. This initiative will provide Africa with rapid, unrestricted and affordable access to satellite data thereby ensuring effective indigenous resource management in Africa by Africans.

In addition, many objectives of NEPAD rely on sound and reliable geospatial information in order to eradicate poverty and put Africa on a path of sustainable development. The Africa reference Frame (AFREF) project is expected to serve as a fundamental point of reference to ensure the production of a uniform, reliable and co-ordinated geo-spatial information. This project will also require a continuous international cooperation in Africa. The AFREF project is also expected to provide a geodetic framework for GNSS in Africa. Training, education, access to resources, retention of quality personnel and stability are issues that are critical to the success and sustainability of AFREF.

6.0 CONCLUSIONS

For our future development, it is pertinent to commit ourselves to the development and growth of information economy, which is presently been driven by space technology. Greater priority should be accorded to development and transfer of knowledge and skills through capacity building, joint participation, knowledge sharing, and bilateral and international cooperation.

In conclusion, African member states of the United Nations Committee on the Peaceful Uses of Outer Space should endeavour to participate more actively in the activities of the committee and its subsidiary bodies. It is through our active participation that our regional interest can be guaranteed in the global pursuit of international cooperation in the peaceful use of outer space.

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