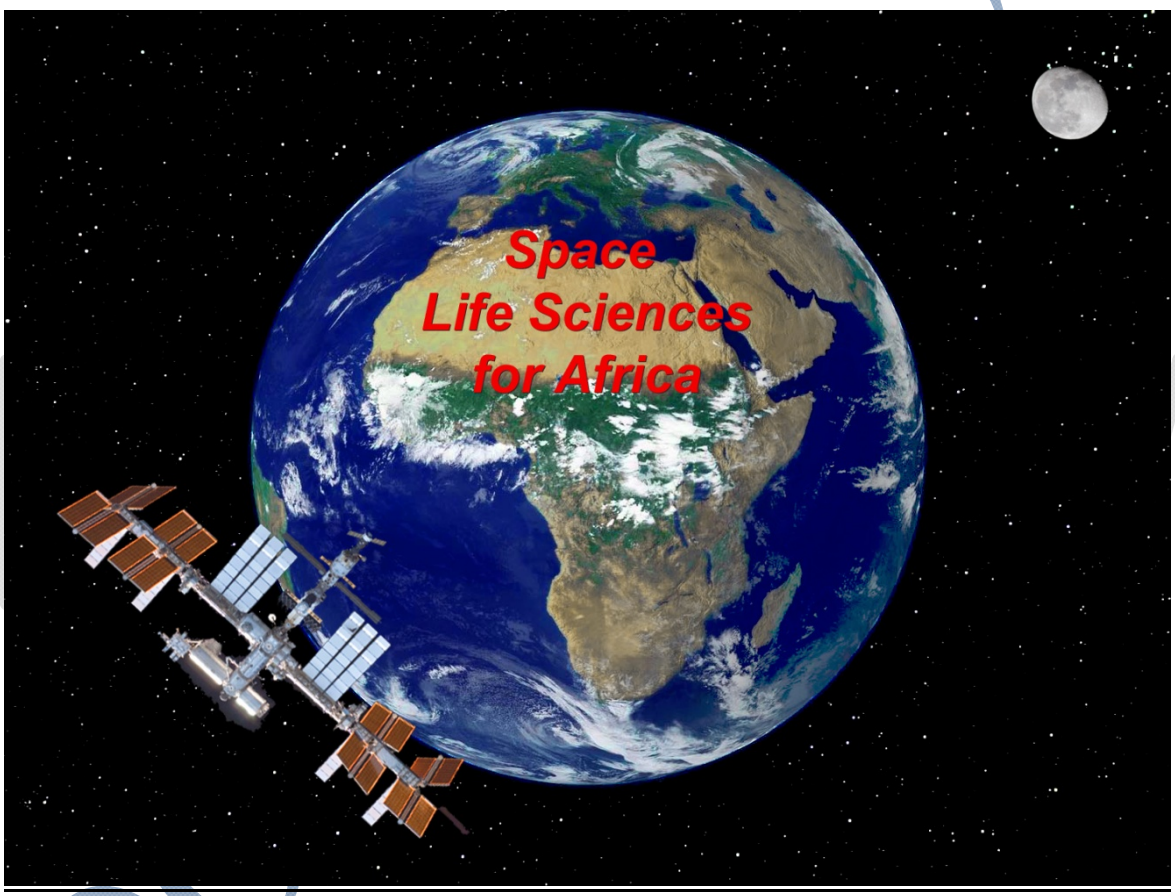
SPACE LIFE SCIENCES FOR AFRICA

INTERNATIONAL COOPERATION FOR SPACE LIFE SCIENCES KNOWLEDGE SHARING AND DEVELOPMENT IN AFRICA



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The International Academy of Astronautics (IAA):
Commission 2 – Space Life Sciences Study Group Report
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EXECUTIVE SUMMARY

Space for humanity through international cooperation was the compelling theme of the *2010 IAA 50th Anniversary Heads of Space Agencies Summit*, Washington, DC, USA. [1] This theme supports the IAA's mission to expand the frontiers of space by developing and promoting new ideas and initiatives for space knowledge development and transfer (www.iaa.org). This Study Group (SG), which is charged to create the IAA's strategy for space life sciences knowledge development and sharing for emerging space faring African nations in general, and for the NASDRA in particular, supports the Summit's theme as well as the IAA's mission.

The SG's review of space activities in Africa reveals that two African countries—Nigeria and South Africa—have fully developed space agencies and programs. Nigeria focuses on ground-based astronomy, satellite development and space geodesy. South Africa's space disciplines are satellite applications, satellite engineering and space sciences. Other African nations, including Algeria, Cameroons, Egypt, Ethiopia, Kenya, Libya, Morocco, and Tunisia are investing, to varying degrees, in infrastructure building activities that advance their space exploration aspirations. These activities include: security protection and global monitoring of the African environment; earth imaging and satellite data collection and processing; radio telescope and astronomy education; governmental space exploration policies development; and various celebratory space exploration education and public engagement projects and activities.

It is noteworthy that in recent months (from late 2010 to present), there have been civil unrest and upheaval in Libya, Tunisia, and Egypt. Therefore, governmental changes might affect the status of space development in these countries.

The Study Group's charge is to assess existing space-related activities among African nations and suggest strategies for enabling and promoting space life sciences research and educational outreach in African countries that wish to expand their role in the space science community through increased international cooperation. The Study group considered key questions codified in the recent *IAA 50th Anniversary Heads of Space Summit Declaration*, which calls for international cooperation and the development of international governmental/non-governmental partnerships that facilitate space life sciences research and education among space-faring African nations.

The IAA Proposal, which established the IAA Commission 2 Space Life Sciences Study Group 2.10, emanated from discussions held in November 2009, during the third African Regional Conference, *Joint Participation, Knowledge Development and Sharing,* hosted by the IAA and the National Space Research and Development Agency (NASRDA) of Nigeria. Discussants included representatives of the IAA, NASRDA, Morehouse School of Medicine (MSM) and the National Space Biomedical Research Institute's Educational Outreach Program. The Committee took two actions after this meeting: 1) a proposal to establish a Space Life Sciences Study Group 2.10 was submitted to IAA Commission, and 2) a Memorandum of Understanding among the IAA, NASRDA and MSM was drafted and later ratified by the principals of these organizations. The MOU supports the IAA's efforts to develop space life sciences education and research activities and programs for Africa. The Memorandum assures initial institutional commitment to

aid in the development of an IAA space life sciences research and educational outreach roadmap that includes recommendations for NASRDA in particular, and Africa in general.[2]

The first face-to-face meeting of the IAA Study Group was held in September 2010, during the International Astronautical Congress (IAC) conference in Prague. The second meeting was held, April 2011, during the *18th IAA Humans in Space Symposium*, in Houston, Texas. The Study Group has convened additional meetings and conferences at various stages of this report's preparation.

Guiding Questions for the Study Group.
Which African countries are most interested in developing space life scenes disciplines?

What is the best overall strategy for effectively transferring existing space life sciences research and educational outreach knowledge from international space faring nations to Africa?

Which African space organizations are most prepared to offer the infrastructure and support needed to conduct space life sciences research and produce space-related educational outreach materials?

Which international organizations have capacity and inclination to collaborate with countries, such as Nigeria, to develop human spaceflight research and education?

Which African space organizations would best provide infrastructure to support space life sciences research and educational outreach materials production?

How could telemedicine capabilities be employed to disseminate space life sciences spin off benefits for communities in rural and urban Africa?

How could the space life sciences research and capacities be better developed in Africa? To date space life sciences research in Africa is almost non-existent.

How could space life sciences research be included in regular space related meetings in Africa? Presently most of the meetings being held on the African continent are covering mainly Satellites, physical aspects.

Goals and Scope

The goals of this Study Group report are to: (1) review existing space exploration activities in Africa; (2) recommend feasible IAA strategies for space life sciences knowledge development and sharing in Africa; and (3) suggest a design for a roadmap showing how Africa's space-faring countries may develop international partnerships. These partnerships will collaboratively develop indigenous space life sciences research and educational outreach programs in a rapidly globalizing space exploration world.

This report briefly reviews existing space programs and activities in Africa. In addition, the report makes recommendations for an IAA strategy to engage African space agencies, beginning with Nigeria's National Research and Development Agency (NASDRA), in the design and implementation of an integrated space life sciences research and educational outreach operation that adds value to existing African space life sciences programs. This strategy should inspire the next generation of African students; educate the public across the African continent about the benefits of space exploration for life in Africa; establish innovative public/private international partnerships; and strengthen existing programs that facilitate indigenous space life sciences research and educational outreach activities for the NASDRA.

This Study Group report represents the collective thinking of a team of international educators and scientists committed to the long-term development of space life sciences research and educational outreach in Africa and the short-term development of space life sciences research and educational outreach in Nigeria. IAA's history of successful engagement with NASDRA, coupled with NASDRA's expressed interested in advancing its space life sciences education and research makes Nigeria a signal focus of the Study Group's recommendations.

The SG took into account each African country's space faring activities to ensure that the strategy that the SG proposes emphasizes the strengths that each nation has at its disposal to launch a space life sciences development agenda. The Report has roots in the IAA's history of successful engagement with space development in Africa and the National Space Research and Development Agency (NASRDA) of Nigeria's expressed interest in collaborating with international organizations to expand its current space activities to included space life sciences education and research. This makes NASRDA a primary focus of the Study's recommendations. The IAA has convened three regional astronautical conferences in Nigeria. It has also instituted an IAA-Node Office in Nigeria to advance its support of NASDRA's mission to "pursue and attain … space capabilities that enhance the quality of life … [for Nigerians]." The NASDRA's current space objectives are to develop space science and technology through research, development, and capacity building in science, and engineering.

A Memorandum of Understanding (MOU) among the IAA, the NASDRA, and Morehouse School of Medicine (MSM), drafted at the conclusion of the 2009 African Regional Conference, recommended that the IAA take action to convene an IAA Study Group to advance an indigenous space life sciences education and research roadmap for NASDRA. This Study report emanates from the recommendation, which established this Study Group. The Report has engaged select international experts to suggest a global space life sciences education and public outreach (EPO) model that: (1) strengthens NASDRA's and Africa's future space exploration workforce; and (2) promotes science, technology, engineering, and mathematics (STEM)

education and public engagement to communicate the benefits of space for health and life in Africa.

Summary of Key Findings and Recommendations
The Study Group (SG) summarizes its principal findings and recommendations below. Additional findings are included in the body of the report.

<u>*Key Findings*</u>: This (SG) acknowledges the international consensus, encoded in *The Global Exploration Strategy* [Footnote], which supports partnership-building and global collaborations for Africa's quest to utilize "space for humanity." Therefore, the deliberations of the Study Group were guided by the *IAA's 50th Anniversary Heads of Space Agencies Summit* reports and declaration, which underscore how globalization is defining the future of space exploration. Also, the SG reviewed current space activities in Africa and recognized that individual African countries are creating roadmaps and investing national resources to expand their existing satellite-based space activities to include research on human adaptation and counter measure to spaceflight research, education, and public engagement.

This review is tempered by recent civil unrest and upheaval in Libya, Tunisia, and Egypt, which might have consequences for the status of space development in these countries.

<u>*Key Recommendations*</u>: The SG identified five major recommendations, which have specific applicability to space exploration activities in Nigeria and South Africa. These recommendations support a synergistic space research and education strategy that includes: basic research on human health and performance risks associated with space explorations missions; a comprehensive─elementary to doctoral level─STEM education approach that reaches students, teachers, and families; and the development of culturally competent public engagement programs that build on existing UN-COPUOS initiatives and expand outreach to communities that are currently excluded. Some of the recommendations have specific reference to the NASRDA, which has expressed special interest in collaborating with international partners to develop space life sciences research and educational outreach for NASRDA, in particular, and to support space for Africa in general.

Recommendation 1: Promote and Encourage A Broad Range of Space Related Collaborations among African and other Space Faring Nations
The mission of these partnerships would be to establish international collaborations to: promote research collaborations in areas of mutual interests; share experiences that develop innovative educational public outreach programs; exchange scientific materials, publications, and multimedia information; support conferences, seminars, workshops, including regularly scheduled IAA Federation and Congress international meetings; and expand membership in the IAA's astronautical community.

Recommendation 2: Work With Emerging African Programs That Foster STEM Education for African Space Workforce Development
The IAA, in collaboration with individual countries, would identify a roster of effective African STEM programs, including NASRDA's Centre for Space Science and Technology Education program, currently supported by the UN-OOSA-affiliated African Regional Centre for Space

Science and Technology Education in English Language. These programs would serve as planning centres for designing comprehensive strategies to: 1) transfer space knowledge to educators who teach at elementary and secondary levels; produce indigenous, space-based elementary/secondary level STEM curriculum modules; and 3) develop STEM teacher institutes/academies for the professional development of teachers from across the continent of Africa.

Recommendation 3: Facilitate International Exchange Programs to Develop Undergraduate-Graduate-Postgraduate Level Training for Africa's "Brightest and Best"

Work with select international organizations and space faring African countries interested in designing innovative graduate level space life sciences education, multidisciplinary programs that provide didactic and laboratory training to prepare research scientists for independent research and teaching in the most critical issues limiting long-duration space flight. These areas should include physiological stress, bone loss, muscle wasting; cardiovascular regulation and sensory-motor control; effects of cosmic radiation, and metabolic changes. Nutrition, exercise physiology countermeasures and bioastronatuics─the interface among biology, medicine and engineering─are also areas of critical concern.

Recommendation 4: Establish a Synergistic Space Life Sciences Research Institute/Center at the NASRDA, Nigeria, Africa

Establish a synergistic, multidisciplinary space life sciences research institute, supported by the IAA and other select international partners, at the NASRDA, Nigeria, Africa. The mission of the organization would be to build a space life sciences research operation that: conducts ground/ISS-based research on human health and performance risks of space exploration missions; develops Africa's STEM workforce; and educates the African public. Such a laboratory should be well equipped for doing ground based research into spaceflight related issues. Such equipment includes head up tilt table, lower body negative pressure device, short arm centrifuge, bed rest facitilities, etc. Regular visits to Africa from researchers based in established space faring nations along with reciprocal visits from African counterparts should be encouraged.

Recommendation 5: Use Multimedia Technologies to Foster Public Engagement and Education

Facilitate multimedia consortia arrangements to undertake feasibility studies to promote telemedicine, radio-television, and museum/science centre programs that contribute to the scientific literacy of communities across Africa, including information on how space exploration can spin-off benefits for humanity in Africa. It is recommended that the IAA's and other global E-Learning and social media expertise be leveraged to create new Afrocentric space educational materials; facilitate differentiated learning for students from different parts of Africa, including electronic classrooms, homework hotlines, digital journalism, and civic engagement . This effort should include the re-establishment of the NASRDA planetarium as a model of public engagement for other space faring African nations.

1. INTRODUCTION

Background. Globalization is creating an interdependent space-faring world and fostering opportunities for international partnerships that strengthen individual nations' aspirations for space exploration and facilitate innovative knowledge development and transfer. In 2007, the *Global Exploration Strategy: The Framework for Coordination*, outlined a roadmap to guide the development of global partnerships that promote the "inspirational and educational value of space exploration activities (www.globalspaceexploration.org)" [1]. Similarly, the International Academy of Astronautics' (IAA) *2010 Heads of Space Agencies Summit Declaration* codified global consensus that "many global challenges to come can best be solved by countries working together …, [that] the world is flattening as many newcomers are joining the club of emerging space country, [and that there is] a need to enlarge the circle of current partners [2]." In keeping with this spirit of international cooperation, the central focus of this Study Group is to identify appropriate international partners with the capacity to advance space life sciences research and educational outreach for Africa, in general, and for NASDRA in particular.

The IAA has sponsored four regional conferences, focusing on space science knowledge development and sharing in Africa, in Abuja, Nigeria. [3]. Other IAA events based in Africa include the 62nd *International Astronautical Congress: African Astronaissance*; *Space for the African Citizen* (Belgium, September 2010) [4] and *The 3rd Africa–EU Summit of Heads of States* (Tripoli, Libya, 2010)" [5]. In 2011, two prominent African meetings include *The 4th African Leadership Conference on Space Science and Technology for Sustainable Development* (Nairobi, Kenya, (26th -29th September 2011, [6] and *The 62nd International Astronautical Conference*, Cape Town (3rd -7th October 2011). [7] These meetings are benchmarks that focus our collective attention on Africa's emerging space exploration capacities and aspirations.

The Proposal, which established the IAA Commission 2 Space Life Sciences Study Group 2.10, emanated from discussions held in November 2009, during the 3rd African Regional Conference, *Joint Participation, Knowledge Development and Sharing,* hosted by the IAA and the National Space Research and Development Agency (NASRDA) of Nigeria. Discussants included representatives of the IAA, NASRDA, Morehouse School of Medicine (MSM) and the National Space Biomedical Research Institute's Educational Outreach Program. Following this meeting, two actions were taken: 1) a proposal was prepared to establish a Space Life Sciences Study Group 2.10, which was submitted to, and approved by, the IAA; and 2) a Memorandum of Understanding among the IAA, NASRDA and MSM was drafted and later ratified by the principals of these organizations to support the IAA's efforts to develop space life sciences education and research activities and programs for Africa. [8] The Memorandum assures initial institutional commitment to aid in the development of an IAA space life sciences research and educational outreach roadmap that includes recommendations for NASRDA in particular, and Africa in general.

Also, the MOU recommends the establishment of a Study Group, under the aegis of IAA Commission 2, to engage select international experts to help design a global space life sciences education and public outreach model that (1) strengthens NASDRA and Africa's future space exploration workforce; (2) promotes science, technology, engineering and mathematics (STEM)

education and careers and public engagement that increases space science literacy and the sharing of information about the benefits of space exploration for health and life in Africa; and (3) suggests steps to build select NASRDA space life sciences programs.

The IAA Space Life Sciences Commission 2 proposal to create a space life sciences research and educational outreach strategy for Africa builds on the considerable accomplishments of the United Nations Committee on the Peaceful Uses of Space (COPUOS), which has a long history of successful space development activities Africa. Their involvement is codified in the COPUOS declaration negotiated during the *African Leadership Conference on Space Science and Technology for Sustainable Development,* 38th session of UN-COPUOS, in Abuja, Nigeria. [9] Seventeen African countries (Algeria, South Africa, Kenya, Egypt, Ghana, Republic of Benin, Nigeria, Chad Republic, Niger, D.R. Congo, Uganda, Angola, Gambia, Eritrea, Sierra Leone, Ethiopia, Morocco and Libya), along with other countries such as USA and the UK, participated in the 2006 UN-COPUOS conference. Recommendations resulting from this conference stressed the following: (1) the importance of developing "African Indigenous Technology," with special reference to satellite development in Nigeria, Algeria, Morocco, Egypt and South Africa; (2) the need to strengthen regional training centers with the capacity to expand and sustain training of African space science experts in a variety of specialties; and (3) the importance of investing in the development of space enterprises and human resources for all Africa. [10].

These perspectives are aligned with current "Space for Africa" themes guiding collaborations among various international space exploration organizations, and they frame this report's guiding principle: that space life sciences research and educational outreach knowledge transfer for Africa must proceed through "joint participation in mutually beneficial projects and bilateral and international cooperation [11]." During the IAA's Third Regional Conference, *Space for Africa: Joint Participation, Knowledge Development and Sharing,* Dr. Adigun Ade Abiodun, Past Chairman, United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), made a strong case for knowledge generation and skill development in space sciences and technology in Africa. He proposed the establishment of a global entity, "charged with the responsibility of management of international space traffic," and noted the need for a global mechanism for sharing space information among all UN member states. In addition, he proposed the "development of an indigenous broad-based scientific and technological infrastructure" and issued a call for international cooperation "among [African] countries…that share mutual borders and face common challenges [12]."
These positions are aligned with the IAA's 50th Anniversary Heads of Space Agencies Summit declaration, which calls for the IAA to "explore and discuss cutting-edge issues in space research and technology", has included provisions for its members to "contribute to international endeavours and cooperation in the advancement of aerospace science." [13] Similarly, the International Astronautical Federation (IAF), which is partnering with its South Africa (SA) - Cape Town Local Organizing Committee (LOC), has identified the upcoming 2011 International Astronautical Congress (IAC) as one of "the most important milestone...for the development of space on the continent of Africa." The focus of the IAF-SA partnership was bolstered by consensus arrived at during the conference, *Space for the African Citizen*, Brussels, Belgium, 2010. Conference participants reaffirmed space exploration's potential to contribute to the general development of Africa. Also they underscored the IAF's pronouncement that it is

"imperative for Africans themselves to take the lead and truly develop space for Africa (www.iaa/adrianmeyer/interview.org).

Goals and Scope: The goals of this Study Group Report are to: (1) review existing space exploration activities in Africa; (2) recommend feasible IAA strategies for space life sciences knowledge development and sharing in Africa; and (3) suggest a design for a roadmap showing how Africa space faring countries may develop international partnerships and indigenous space life sciences research and educational outreach programs in a rapidly globalizing space exploration world.

This report reviews existing space programs and activities that conducted by select African nations and makes recommendations for an IAA strategy to engage African space agencies, beginning with the NASDRA, in the design and implementation of a comprehensive, mutually reinforcing space life sciences research and educational outreach operation. This design of this strategy focuses on inspiring the next generation of African students; educating the public across the African continent about the benefits of space exploration for life in Africa; establishing innovative international partnerships; and strengthening existing programs that facilitate indigenous space life sciences research and educational outreach activities for NASDRA. This Study Group report represents the collective thinking of a team of international educators and scientists committed to the long-term development of space life sciences research and educational outreach in Africa and the short-term development of space life sciences research and educational outreach in Nigeria.

2. BACKGROUND: BRIEF REVIEW OF SPACE ACTIVITIES IN AFRICA

A number of African countries, including Nigeria and South Africa, are currently engaged in science, technology, engineering, and mathematics research and educational outreach. Expansion into space life sciences disciplines would offer unique opportunities for African countries to initiate and/or develop additional collaborations with international partners specializing in space life sciences research, and to become active participants in the emerging global efforts to expand knowledge about human adaptation to microgravity, radiation dangers associated with deep space exploration, and countermeasure research space physiology, space biology, space medical sciences and life support systems. In addition, space life sciences research and educational outreach in Africa have the potential to produce health knowledge with embedded indigenous cultural references that allow the public to benefit from Africa-based research endeavors. Below is a non-exhaustive compilation of Web-based information on select African countries with space sciences infrastructure that would benefit from the addition of space life sciences research and educational outreach activities.

Nigeria. The National Space Research and Development Agency (NASRDA) of Nigeria was established in May 1999. NASRDA is a research institution of the Nigerian Federal Ministry of Science and Technology, administered by the National Council on Space Science Technology. It seeks to "build indigenous competence in developing, designing and building appropriate hard and software in space technology as an essential tool for [the] socio-economic development and enhancement of the quality of life of its people. (www.nasrda.gov)." NASRDA's mission is to

achieve technological competence in the manufacture and launch of satellites by the year 2025. Six NASRDA centers, described below, have responsibility for accomplishing this mission.

Center for Basic Space Sciences. The Center for Basic Space Sciences (CBSS), headed by physics professor, Pius N. Okeke, was established in 2001 on the campus of the University of Nigeria, Nsukka. The CBSS conducts fundamental space sciences research and coordinates space-based research activities in universities and institutes across Nigeria. The Center's primary goal is "to initiate and foster the growth of basic space research in Nigeria... and to facilitate international cooperation." The Center has ongoing collaborations with educational and research institutions across Nigeria, including the Nigeria Telecommunication, Radio and Television Broadcasting Organization, meteorological stations, and centers for remote sensing, satellite technology development, space science and technology education, the Nigerian Agricultural Sector, and select industrial organizations.

Center for Space Science and Technology Education (CSSTE). The CSSTE, headed by IAA Study Group 2.10 co-chair, Dr. Joseph Akinyede, serves as NASRDA's skills acquisition and development unit. The CSSTE is located on the campus of the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria, and is run by the United Nations Office for Outer Space Affairs (UNOOSA)-affiliated African Regional Centre for Space Science and Technology Education in English Language (ARCSSTE-E). ARCSSTE-E has a ten-year history of successful space educational outreach activities. Its mission is to train university educators, research scientists, and other personnel in four principal fields of space science and technology: 1) remote sensing and geographic information systems, 2) satellite communication, 3) satellite meteorology and global climate, and 4) basic space and atmospheric sciences. The Center runs a nine-month postgraduate certification course in all four-course options in all four fields. The curricula, developed by UNOOSA, emphasize air, land, water and satellite-management, communication technology, meteorology, global climate, basic space and atmospheric sciences and other elective topics. Curricula offerings on Global Navigation Satellite Systems and Space Law are progress being developed. To date, the Center has trained more than 200 participants from 17 African countries and offered 17 postgraduate courses. The Center also collaborates with the UN-COPUOS to plan and implement the annual *UN-World Space Week* celebrations and other educational outreach programs for elementary-secondary school students, teachers and parents.

Center for Satellite Technology Development (CSTD). The CSTD focuses on the development of geostationary and non-geostationary satellite payloads. Its main projects include collaborations with Surrey Satellite Technology Limited (SSTL) in the United Kingdom to develop Nigeria's first satellite, *NigeriaSat,* which was built by Nigerians as a component of the Nigerian Disaster Monitoring Constellation (DMC). *NigeriaSat-2* and *NigeriaSat-X* also were designed and built in collaboration with SSTL. *Nigerian Satellite X*, based on the SSTL-100 platform, was built by Nigerian engineers as part of their training and development assignment with SSTL.

Center for Geodesy and Geodynamics. The goal of the Center for Geodesy and Geodynamics (CGG) is to maximize Nigeria's workforce and hardware capacities to survey, map and monitor Earth's movement and related geodynamic activities, including Nigerian coastal deformation and subsidence, floods and sea level changes along coastal regions. CGG activities include research in space geodesy, satellite laser ranging, and very long baseline interferrometry. The CGG is

located at Toro, Bauchi State, Nigeria. The CGG selected Toro because the solid geological bedrock upon which the town is located serves as part of a stable craton on which sensitive tracking systems and other equipment are constructed. The CHH also established the *Global Mean Sea Level Coordination Centre* in Bori, Rivers State, Nigeria, with monitoring sites in Bonny, Brass, and Forcados.

Center for Space Transport and Propulsion (CSTP). The CSTP leads all aspects of rocketry and related technology for the Nigerian space program. The Center's mission is to develop and acquire the technology required to manufacture rocket components; develop various types of fuel for rocket propulsion; and develop technological capabilities and platforms to launch rockets for both military and civil applications.

National Center for Remote Sensing, JOS (NCRS). The NCRS is located in Jos, Jos Plateau, Nigeria. It administers training programs, seminars and periodic conferences in all areas of remote sensing (RS) and geographic information system (GIS) applications. The Center aims to build technical capacity and technological expertise that will enable Nigeria to design, build, and maintain its own Earth observation satellites and ground receiving station. This will provide easy access to Nigeria's remote sensing programs and carry out research, application and development of RS and GIS programs. The Center has a mandate from the Nigerian government to carry out special functions. These include applied and action-oriented research, development and applications of remote sensing, GIS and related technologies; acquisition, storage, and information dissemination on the availability of remote sensing data in Nigeria. The Center also undertakes educational and promotional activities to inform the public about practical applications of remote sensing. These activities include dedicated conferences, seminars, workshops and newsletters; and joint/collaborative programs with local or international organization whose objectives are aligned with national interests. The Center operates Nigeria's *Remote Sensing Ground Receiving Station*, which receives data from diverse remote sensing satellites; and generates income through consultations and services and sale of products developed by the NCRS.

South Africa. South Africa's space exploration focus has evolved out of its 50-year collaboration with USA's National Astronautics and Space Administration (NASA) to support lunar and interplanetary mission activities. The *Educational Outreach-National Youth Development Trust (NYDT) of South Africa* is building on the nation's is unique space satellite infrastructure to include space life sciences educational outreach to schools. NYDT's mission is to introduce space-based subjects to schools in disadvantaged communities throughout South Africa, such as the Stanza Bopape Secondary School, north of Johannesburg. The NYDT Internet-based curriculum includes space medicine, covering topics like the effects of extreme environments on the human body, countermeasures to health problems that astronauts encounter in space, and the financial costs associated with human habitation of space. The NYDT also supports the Research Foundation for Emerging Space Scientists, which regulates science competitions, such as *Lost in Space,* and a "survival field trip" to South Africa's Moon Valley, which is collaboration with Namibia (www.iaa/adrianmeyer/interview.org, and www.iac2011.com/space-south-africa).

Beginning with the first close-up images of Mars in July 1965, lunar and interplanetary mission activities have been the core emphases of South Africa's space program. The Hartebeesthoek Radio Astronomy Observatory, administered by South Africa's National Research Foundation (NRF), is one of the main facilities for space geodesy in Africa. The NRF launched South Africa's first space program, *Greensat,* in the 1980s. The mission of this program was to develop an Earth observation satellite facility. *Greensat* was discontinued. The University of Stellenbosch's academic microsatellite engineering program, established in 1999, has a successful international information systems spinoff operation. The program is recognized as a regional center for space science and technology in Africa. Currently, South Africa's space activity hub is located in the Western Cape, home to a number of universities, government research laboratories, and high-tech companies with significant expertise in satellite engineering, satellite operations, optical instrumentation design and testing, synthetic aperture radar systems, and data processing, as well as space policy and space law.

Fig.1 *Deep Space Station 51, CSIR Center*

Fig.2 Earth observation satellite*, Sumbandila*

The South African Council for Space Affairs is the governmental regulatory body that oversees the nation's space-related activities. The Council's mission is to "promote the peaceful use of outer space; foster research in astronomy, earth observation, communications, navigation and space physics; foster international cooperation in space-related activities; and advance scientific, engineering and technological competencies through human capital development and outreach programs." The Department of Science and Technology established the *South African National Space Agency (SANSA),* to implement South Africa's national space strategy. This policy enhances the South African government's strategy to employ space science and technology to enhance economic growth and sustainable development. SANSA's major priorities are innovation and economic growth; safety and security; and environmental and resource management.

South African Aerospace Industry. There are some 74 aerospace and defense sector companies in South Africa, ranging from an R3-billion state-owned enterprise (Denel), to R1-billion multinationals, to small/medium and micro enterprises and broad-based Black Economic Empowerment businesses. A recent audit shows that the annual turnover for industry and public sector institutions involved in space activities is approximately $20M.

French South African Institute of Technology. The French South African Institute of Technology (F'SATI) at the Cape Peninsula University of Technology participates actively in developing the national space technology workforce. F'SATI offers a two-year dual Master's Program in

Satellite Systems Engineering and uses the *CubeSat* platform to give students hands- on experience in satellite technology.

Algeria. A presidential decree established The Algerian Space Agency (ASAL) in January 2002. A board of directors representing 15 ministerial departments and a scientific board of space science and technology experts govern ASAL. ASAL's mission is to (1) develop and ensure implementation of a national strategy for space, (2) develop infrastructures needed to reinforce Algeria's space exploration capacity, and (3) synergize national research institutions engaged in space activities. ASAL is pursuing bilateral cooperation with other space agencies through memoranda of understanding with Argentina, France, Ukraine and the Russian Federation, and through governmental framework agreements with France, the United Kingdom and Argentina. Algeria also is cooperating with Kenya, Nigeria and South Africa to develop satellites to monitor and manage African space resources and the environment. During the last meeting, held in Algiers in July 2006, these countries agreed to develop a constellation of three or more satellites with a high-resolution payload (3m pan, 12m Multi), to a draft data access policy, and to prepare a cooperative agreement to guide future space collaborations. Algeria is a permanent member of the UN-COPUOS, ASAL participated on the COPUOS scientific, technical and judicial committees to organize and conduct the 2005 international conference on space techniques for disaster management in Algeria, space objects damage, and registration of space objects launched into outer space (www.agencespatialealgerienne.com).

ASAL has developed a 15-year satellite program, including ALSAT-1, which was built in partnership with the Surrey Space Centre of Britain. ALSAT-1 has generated and disseminated more than 1,000 photos to promote telecommunications, agriculture, and water resources sector development among countries in the region; tracked earthquakes that affected Algiers and surrounding areas in 2003; and monitored forest fires and the tsunami that recently ravaged Southeast Asia. Algeria's second satellite, ALSAT-2, has built on the successes of ALSAT-1 to enhance Algeria's telecommunications capacities. Recently, ASAL has expanded its satellite collaborations to include South Africa, Argentina, Russia, France and the United States. ASAL's national space program projects that it will develop an alert system for natural disasters and a disaster prevention system to manage floods, desertification, forest fires and locust invasion. Five space centers, described below, oversee ASLA's space operations.

The Center of Space (TCS). TCS, ASAL's premier space technologies and applications entity, is mandated to implement Algeria's space technologies applications program, in concert with other national departments, including water resources, agriculture, telecommunications, transport, and environment. TCS is organized into the following four divisions and research groups.

- *The Satellite Development Centre (SDC.* The SDC provides the technological infrastructure to effect future development of the Algerian satellite systems. The SDC infrastructure includes including CDS will includes: a clean room dedicated to satellite and sub-systems assembly and integration; and rooms for antenna and radio frequency tests, thermal tests; mechanical, electrical, electronics and optics laboratories. An environmental test building is planned for future development.

- *The Satellite Applications Centre (SAC.:* The SAC is charged with responsibility to develop decision-making models, on GIS and space technology through which to develop ASAL's remote sensing and GIS capacities and to train Algerians in space exploration research and activities.

- *The Telecommunications Satellites Operation Centre (CEST)* CEST has major responsibility for: the Algerian satellite, Alcomsat; promoting general usership and utilization of telecommunication satellites services.

- *The Doctoral School of Space Applications and Technologies (DSSTA).* DSSTA's mission is to enroll 50 doctoral-level students among five Algerian national universities. It is expected that these students will major in: space optics and precision mechanics; space computer science; space instrumentation; space imagery processing; and space telecommunication.

Fig. 3: Algerian Satellite Development Centre

Libya. In November 2010, Libya hosted the *3rd Africa–EU Summit of Heads of States* in Tripoli. This conference recognized Libya's specialization in global monitoring for security and the African environment. Libya also organized *The International Conference on the Application of Remote Sensing and Geographic Information Systems* with the theme, "Partners in Development and Space." In 1998, Libya established the Libyan Space Center to administer the Direct Reception Station, which has the capacity to generate data from Earth imaging satellites for the region. Libya also has invested in the Libyan Space Camp, designed to introduce and attract young Libyan students to space exploration. [14]

Egypt. Egypt's space research and education activities are housed at the National Research Institute of Astronomy and Geophysics. The Institute's *Kottami Observatory*, built in 1963, operates a 2-Meter optical telescope, which is the largest optical/infrared telescope in North Africa. The Institute has plans to build a radio telescope as part of the European Very Long Baseline Interferometry (VLBI) Network, to bridge the gap between the radio telescope in Western Europe and the radio telescope at Hartebeesthoek in South Africa. In addition, Cairo University Department of Astronomy provides training for astronomers and solar physicists. [15]

Kenya In 2009, the National Space Secretariat of Kenya, reporting to the Minister of Space for Defence, was established to: conduct research, co-ordinate research-based services, and update

Kenya space science policy to: reflect the current trends in the use of space science and technology; initiate training aimed at ensuring adequate transfer of space technology and its application; provide leadership in the implementation of all capacity building programs on space science and technology; promote peaceful uses of space science applications including, but not limited to, satellite earth observations, navigation, telecommunication and disaster management; provide leadership in the implementation of the space science and technology strategic plan; oversee the transition of the Secretariat into a fully fledged Kenya Space Agency; and enter into association with other agencies within and outside Kenya for purposes of research, date acquisition and application in the field of space science(www.kenya+space.com)[16].

Morocco. Morocco is building its educational infrastructure to inspire and train the next generation of Moroccan students interested in space exploration and focusing on participatory engagement with organizations such as the IAA, IAC, and IAF to promote its international engagement in space exploration activities. A space camp for Moroccan teachers and student, conducted in collaboration with NASA, Huntsville, Alabama, USA, provides multidisciplinary educational experiences, including simulated pilot and mission specialist training aboard NASA's Space Shuttle. In 2010, NASA Mission Specialist, Dr. Robert L. Satcher, visited Morocco to share his Space Shuttle and ISS experiences and to educate teachers, students, and communities about the marvels of space travel. Representatives from the Morocco space community are active participants in international meetings that promote space for Africa. They regularly attend meetings of the IAA, IAF, and COPUOS where training of various categories of experts from different African countries currently takes place. Also, Morocco's *Ben Guerion,* one of NASA's trans-Atlantic abort landing sites, provides a focus for developing indigenous capability for space-based research and applications in Morocco. (www.moroccanspaceadventure.org).

Ethiopia. Ethiopia hosted the *8th Conference of the African Association of Remote Sensing of the Environment* in 2001. The conference's goal was to increase policymakers' understanding of the benefits of geo-information and space technology for life in Ethiopia. The conference was supported by the Science & Technology Division of the United Nations Economic Commission for Africa, the African Association of Remote Sensing of the Environment, the Ethiopian Mapping Agency, the Network for the Cooperative Management of Environmental Information in Africa, the Institute of Electrical and Electronics Engineers-Geoscience and Remote Sensing Society, the Environmental Systems Research Institute, Inc., Astrium, GIS Development, and the European Space Agency (ESA) (www.hudsonfla.com/aethiopia.htm).

Tunisia. Tunisia has pledged a significant portion of its annual federal budget to scientific research over the next ten years and has taken a leadership stance in promoting space exploration activities in the Maghreb countries, which include the Arab States of Morocco, Algeria, Tunisia, Libya, and Mauritania. Representatives from the Tunisian space community have been active participants of IAA's International Programme Committee for the 2007 *Space for Africa: Path to Knowledge and Development* conference; the 2009 *Joint Participation, Knowledge Development and Sharing* conference in Nigeria, Africa; and the 2009 IAC Daejeon, Korea meeting. Tunisian leadership has declared the use of space to be essential for the development of Tunisia's industry, agriculture, environment, and healthcare. In 2010, Tunisia hosted the *2nd Aerospace Meeting* to

encourage commercial and aerospace development in the country. Tunisia also is leading efforts to develop Arabic-language terminology for use in international communications systems.

The main office of the Regional Center of Remote Sensing for North African States is located in Tunis, the capital of Tunisia. This Center is home to Tunisia's national space program and falls under the aegis of the National Commission for Outer Space Affairs, which is responsible for coordinating space-related activities and programs, including media outreach to inform the public about the benefits of space technologies for Tunisian society. The Commission has established five groups to achieve this educational outreach objective: space techniques and technologies; space telecommunications; Earth observation and remote sensing; training; and public engagement. The findings of these groups will provide foundations for a national space policy, which will guide future Tunisian governmental and educational space exploration priorities. [17]

In recent months (from late 2010 to present), there have been civil unrest and upheaval in Libya, Tunisia, and Egypt. Therefore, the status of space development in these countries might be affected by governmental changes.

3. STRATEGIES TO SUPPORT SPACE LIFE SCIENCES RESEARCH AND EDUCATION DEVELOPMENT IN AFRICA

Space for humanity and international cooperation were central themes of the 2010 IAA 50th Anniversary Heads of Space Agencies Summit in Washington, DC. USA. The IAA's commissioned Study Group report, *Future Human Spaceflight: The Need for International Cooperation*, outlines common global interests for human space exploration and recognizes the fundamental contributions of the ISS to space exploration and life sciences research. The Report explores questions that underpin future human spaceflight, provides concrete proposals to guide research beyond the ISS, and recommends an approach to ensure that future human spaceflight strategies become part of the broader international agenda for the "benefit of all mankind [18]." This report is aligned with the Global Exploration Strategy guiding space-faring nations toward more cohesive, interdependent collaboration. It also supports the outcomes of three recent African IAA regional conferences, which have highlighted "Space for Africa." Further, the Report recommends knowledge acquisition and transfer, systems development, and the applications of space science and technology for public good. The collective wisdom reported at these conferences is that Africa's steady emergence as a global space-faring influence and has ignited interest in space life sciences research and education that strengthen Africa's international engagement in space and produce spin-off benefits for societies across the continent.

This Study Group (SG) report recognizes the importance of these objectives. The Group's deliberations follow the basic premise that recommendations for the development of space life sciences in Africa must look beyond the constraints of current political and economic limitations. However, the SG recommends that for the foreseeable future, the primary exploration objectives for the African space-faring countries will be (1) Low Earth Orbit, the Moon, Mars and near-Earth asteroids; and (2) cross-disciplinary research on human body phenomena, health and

performance risks associated with space exploration. These risks run the gamut of radiation carcinogenesis and poor performance due to inadequate nutrition/exercise, behavioral and psychiatric disorders, poor team cohesion, sleep/circadian dysfunction, and fatigue.

3.1 African Priorities: Building on Strengths

The IAA has recommended that countries and organizations taking first steps in space activities learn relevant techniques from more experienced space users to acquire a cadre of appropriately trained personnel. Some Africa countries, including Nigeria, and South Africa have demonstrated success in employing space technology, specifically satellite space-based disaster management, climate change and green systems to tackle workforce development issues and launch new space activities. Other African countries are emerging at rates that are in concert with their respective national interests. Beginning with the 2002 World Summit on Sustainable Development held in Johannesburg, South Africa emerging space faring nations identified the development and management of natural resources─air, water, agriculture, soil, forestry, minerals─as areas of major concern and suggested partnership development within and among African countries to strengthen of space research efforts at national and regional levels and to use space as a springboard for capacity building, skill and knowledge development and technological innovation [19].

3.2 Leveraging Support for Space Life Sciences in Africa: The IAA and COPUOS are premier institutions with capacity to leverage international support for establishing public–private space life sciences partnerships within Africa. The IAA Studies Centre in China, established in May 2010 to celebrate the IAA's 50th Anniversary, provides a model. The Centre is dedicated to academic research on remote sensing, management of academic conferences, and publication and dissemination of IAA reports, studies and position papers. The IAA also is able to facilitate new African partnerships through its roster of corresponding/full members in Algeria, Burkina Faso, Cameroon, Egypt, Ethiopia, Ivory Coast, Libya, Morocco, Nigeria, Senegal, South Africa and Tunisia. Establishing IAA node offices in African countries offers the potential to leverage international space life sciences resources and processes that will greatly advance Africa's emergence as a vital partner in programs to develop space life sciences knowledge and technologies [20].

3.3 Potential Organizational Model for Space Life Sciences in Africa

This Study Group envisions that a synergistic consortium of African space agencies, select international space organizations, universities, and the IAA would have capacity to establish an organizational entity (e.g., the Pan-African Space Research Institute), dedicated to the development of space life sciences research (or even more generally, space research) and educational programs in Africa. Select international space organizations, including UN-COPUOS and representatives from African agencies involved in space research, could collaborate with the IAA to establish an organizational entity dedicated to space educational outreach in Africa, beginning with space life sciences..

The mission of the organization would be to facilitate opportunities for African nations to collaborate with successful international space life sciences organizations and others to launch programs that expand African space-related endeavors, particularly space life sciences. Initial objectives to achieve this mission would include, but not be limited to, the following:

- Establish and administer a synergistic roadmap for space life sciences research focusing on select biomedical issues associated with long-duration human space flight.
- Advance multidisciplinary life sciences research capacities among African space based-institutions, such as NASDRA to ensure utilization of the ISS research platform. NASDRA should be encouraged to have co-operations with European or American partners to develop space life sciences. Research areas to be included are microgravity or ground based analogs of microgravity such as bed rest; this would be crucial for development of space life sciences research and capacity building in Nigeria. This model could then be extended to other African space agencies or secretariats (such as in Kenya). Research into space life sciences could produce a cohort of African scientists with credentials to participate eventually in research on the ISS.
- Ensure that space life sciences are included in the program at space related meetings in Africa. The participation of both African and international space life sciences researchers would be crucial for exchange of ideas, future co-operations, publications, etc.
- Support 21st century science, technology, engineering and mathematics (STEM) skills development among Africa students, teachers, and communities.
- Harness multimedia capacities, including broadband capability, to educate the general African public about the benefits of space exploration for life on Earth.
- Promote indigenous space life sciences research and spin-off ancillary activities that improve health, education and career opportunities for Africans.
- Disseminate the research findings of African space scientists through national and international symposiums, publications, multimedia technologies.
- Encourage the transfer of research findings through commercial and other partnerships.
- Design new paradigms for successful international partnerships among African nations and other space faring countries.

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- Harness multimedia capacities, including broadband capability, to educate the general African public about the benefits of space exploration for life on Earth.
- Promote indigenous space life sciences research and spin-off ancillary activities that improve health, education and career opportunities for Africans.
- Disseminate the research findings of African space scientists through national and international symposiums, publications, multimedia technologies.
- Encourage the transfer of research findings through commercial and other partnerships.
- Design new paradigms for successful international partnerships among African nations and other space faring countries.

4. AFRICA: CHALLENGES AND OPPORTUNITIES

The *Global Exploration Strategy* has outlined guidelines that promote consensus building and protect independent national space agency prerogatives, while encouraging the development of "space exploration architectures and roadmaps that "guide international cooperation in low earth orbit (LEO) space activities." These principles has gained additional traction from the recently study, *Future Human Space Flight: The Need for International Cooperation,* recently commissioned by the IAA, 50th Anniversary Heads of Space Agencies Summit, calls for international cooperation and recommends human factors research as the bedrock of future human space flight. Therefore, it would be prudent to suggest that future Africa-based space life sciences research architectures align research priorities with these emerging global space life sciences research objectives. Accordingly, this SG offers the following guidelines for space research capacity building in Africa.

4.1 Space Life Sciences Research Capacity and Priorities Development

Given Africa's limited current engagement in space life sciences research, the Study Group recommends that an external advisory committee, including scientists drawn from the IAA and select international partners, be convened to work with participating space faring African

countries to draw up topics/protocols that promote existing indigenous African space life sciences research priorities. Such an advisory committee could formulate linkages between the continent's future research initiatives to multidisciplinary life sciences research conducted by more developed space research organizations. Models of successful space life sciences research implementation strategies. Prospective laboratories in Africa could benefit from application of the most advanced technologies in radiation research, molecular genetics, and quantitative modeling to explain and fully understand the human body's complex physiological interactions with the microgravity environment of space. Additionally, African space life sciences institutions could co-operate with partners in US, Europe, and Russia [21] and do experiments with ground based models of microgravity such as bed rest [22], water immersion [23], as well as gain hands-on-experiences with tools for orthostatic capacity testing such as head up tilt (HUT) and lower body negative pressure (LBNP) [24].

Low Earth orbit space flight produces observable physiological changes in humans, including eye movements [25], temporal-spatial orientation [26], motor function (27), cognitive function [28], sympathetic nerve activity changes bone demineralization [29], cardiovascular de-conditioning [30], post-flight orthostatic intolerance [31], muscle atrophy [32], psychological shifts [33] and alteration of endocrine system and circadian rhythms [34]. Therefore, important aspects of space life sciences including physiological [35], psychological and medical dimensions should be included in research studies. Integrative aspects such as gender [36], metabolism changes, and body core and skin temperature [37] should also be studied. Research into these impacts could produce a cohort of African scientists with credentials to participate in research on the ISS. It is e The IAA Studies Centre in China, established in May 2010 to celebrate the IAA's 50th Anniversary envisioned that individual nations would select research topics that are (1) congruent with their respective space development strategies, (2) compatible with international consensus on the kinds of research required for long-duration spaceflight, and (3) suitable for the ISS before its impending decommissioning. For example, the recent IAA Study Group report, *Psychology and Culture During Long-duration Space Missions,* recommends that greater attention be paid to the cultural and psychological imperatives governing selection and training of future space explorers [38]. An emerging cadre of African space explorers could contribute additional cultural and psychological paradigms that lead to more profound international collaboration and generate new knowledge, based on Africa's indigenous perspectives and resources.

4.2 Integrated Research Team (IRT) Approach

Groups of interacting research programs, established among centres, universities, and space research organizations have efficacy for maximizing research because discussion and group interaction among diverse, synergistic programs reinforce each other in important ways. This approach can facilitate collaborations among newly established space projects in Africa while building international partnerships with established scientists who are working to solve the biological problems associated with human space flight. Integrated research teams have the potential to maximize emergent globalization and to facilitate public–private partnerships to expand training opportunities for future African scientists and students interested in research and transference of biomedical advances achieved through space life sciences research.

4.3. Space Life Sciences Education

Classrooms of the Future: A Global Space Education Context. Deep science knowledge and highly skilled science professionals are key strategic resources of the global space enterprise. To build an African science workforce that is able to contribute to the emerging vision of international cooperation for space exploration, it is critical to recruit and train Africa's "brightest and best" science, technology, engineering and mathematics (STEM) students. The recent *IAA Heads of Space Agencies Summit Declaration* identifies "public engagement" as being central to the future of the international human exploration. The Declaration further encourages partnerships to "engage new and emerging space faring nations" in collaborations that bring the benefits of space exploration to societies around the world [39]. "

Implementation of strategies to develop space life sciences education across Africa will require national will and reliance on 21st century information technologies to link rural and other underserved communities to educational centres that are appropriately positioned to leverage and deliver teacher professional development and other education development activities. Because school systems are complex bureaucracies that resist change, models that bring together national teacher professional organizations, museums, science centres, and educational leaders to: develop educational materials, improve teachers' space life sciences knowledgebase, and to encourage systemic inclusion of space-based knowledge as an educational standard, requires mastery as evidenced by success on national/local examinations.

These tenets could/should guide arrangements seeking to establish a vibrant STEM workforce among African space faring counties and/or to propel African international commercialization opportunities. The United Nations Committee on the Peaceful Uses of Outer Space (UN-COPUOS) has establishes a network of educational outreach activities in Africa. These programs could serve as baselines to expand existing elementary/secondary, undergraduate/graduate/post graduate level programs to educate the next generation of African space biomedical scientists and to engage students, teachers, families, and other stakeholders across Africa in space exploration activities.

African countries, for example Nigeria and South African, may be able to respond to these challenges in the short term, while other countries are likely to require longer periods of time. For example, in Nigeria, the university-based African Regional Centre for Space Science and Technology (ARCSSTE-E), which focuses on remote sensing/GIS, satellite communications, basic space science and atmospheric science, has sustained ten-year collaboration with UN-COPUOS and the NASRDA has unique organizational capacity to establish a space life sciences research and educational outreach operation. International models, such as the NASA-funded National Space Biomedical Research Institute, offer examples provide models that could be transformed by African organizations to pursue their individual visions of success. The primary goals of NSBRI's Education and Public Outreach Team, listed below, could serve as a basis for consideration by African entities seeking to offer space life sciences activities for schools and the lay population.

- Design and conduct a variety of teacher professional development programs to help teachers understand space life sciences.

- Develop curricular materials that span the educational continuum; are aligned with various African/global science education standards; and expand students' understanding of, and interest in, space life sciences research.
- Promote educational access and career awareness in astronautics research among high school and undergraduate students.
- Increase scientific literacy and public awareness of the real-life impacts of NSBRI research through media, informal science activities, direct mailings and journal publications.

International partnerships with commitment to developing space life sciences in Africa must embrace the challenges and opportunities inherent in building an Africa-based workforce. A comprehensive elementary to post-secondary education roadmap is a logical starting point for such an endeavor. Such a roadmap should include: (1) teacher professional development; (2) opportunities for universities and teacher training colleges to include space content and pedagogy in their STEM curricular offerings; (3) international partnerships to support student space-based investigations; and (5) improve access to 21st Century multimedia and information technologies.

The *sine qua non* for success in any segment of the educational continuum is continuous program evaluation, refinement of implementation strategies, and establishment of new educational collaborations among industries, academia and governments that will grow Africa's space exploration knowledge base.

*Elementary/Secondary Education***.** Academic preparation for success in STEM subjects begins at primary-elementary/secondary levels. Because public education systems serve a disproportionate number of students across the globe, it is implausible to omit them from the equation. Additionally, innovative program designs should include teacher professional development; space-based curriculum materials development; public–private partnerships among scientists, educators, and multimedia experts to employ information technologies to advance scientific literacy and generate public appreciation for the benefits of space exploration.

Teacher Professional Development. Teacher professional development and recruitment of the best students into a highly qualified teacher corps will be a necessary precursor for developing a robust African space life sciences workforce. Successful models of teacher professional development exist across the African continent. One example is Nigeria's African Regional Center for Space Science and Technology Education in English (ARCSST-E) program. This program has sustained ten-year collaboration with UN-COPUOS and has demonstrated capacity to work with teacher education institutions to bolster existing efforts to nurture general space sciences education.

Teacher professional development programs that enroll elementary-secondary science teachers should engage scientists, teachers and administrators as colleagues; focus on the needs of science classrooms; create opportunities for continued professional growth; incorporates ongoing evaluation and team-building skills, and construct useful information about teaching and learning from teachers' own practices. Successful teacher development programs are designed around:

- Problem-based curriculum workshops to prepare and test science curriculum supplements and design resource material that enrich classrooms

- Field trips to observe and envision how to effectively incorporate technology into classrooms
- Science lectures that focus on content to improve teachers' knowledge
- Leadership modules on principles of change at the level of the school house, including how best to respond to the challenges and opportunities of education reform at local, state and nation levels, and
- Strategies to balance the requirements of standardized test scored against deep understanding and higher-order thinking.

Curriculum Materials Development. Space life sciences curriculum modules that are age-appropriate, based on sound content, and have cultural resonance with students can inspire and motivate students. African educators will have opportunities to develop space life sciences educational modules that capture the cultural imperatives of their respective African cultures to inspire students and support their understanding of science concepts. Also, advanced information technology, including advanced Web-based delivery systems that build electronic visions of teacher guides, video clips of select aspects of space life sciences, background materials, links to other relevant materials, and complete online lessons can be harnessed to promote the development of curriculum materials for African schools. Field testing of materials is essential to ensure that materials are effectiveness.

After-school Education. After-school education can improve student performance by helping students builds skills, improve aspirations to pursue higher education, and improve attitudes toward learning. After-school education can also provide opportunities for student to complete and improve homework assignments, concentrate on science fairs, and prepare for international competitions that bring them into the global community of space sciences. Because these programs are usually not constrained by governmental regulations and processes they have flexibility to engage students from diverse cultures in settings that are less formal than school classrooms and can expose youth to experiences outside of their normal everyday lives. These programs are effectively delivered through museums, science centers, planetariums, and other space programs that concentrate on space exploration topics that expand students' interest in space science and research.

Undergraduate Level College Education. Strong undergraduate space life sciences education programs that prepare African students to participate fully in a global space society will require deliberate curricular intervention by African colleges and universities. Individual African countries should/could leverage established undergraduate level training programs in their respective countries to create research opportunities for the "brightest and best" African students who have demonstrated interest and aptitude for STEM subjects. Because collegiate level education usually falls within the purview of governmental and other accrediting academic bodies, it may require new organizational arrangements that facilitate partnership among academic centres, international and national space agencies to exert leadership that will garner resources and establish new space life sciences courses, majors, and degrees in select universities across the continent.

Effective Course Design. Successful, undergraduate space life science courses include hands-on experiences that build students' interest in STEM challenges of space flight. They also include

content that expands student knowledge of the space environment and of how the human body adapts to microgravity. Eager and bright students could be sent for a few weeks to European laboratories such as the Medical University of Graz, Austria where they could learn about spaceflight deconditioning and have hands- on - experience using tools for spaceflight related research such as had up tilt (HUT) and lower body negative pressure (LBNP).

Some courses should offer opportunities for students to debate the cultural implications of space commercialization and research on the ISS. Successful long-term implementation of new curricula at African colleges and universities will require focused interventions with select educational institutions to create demonstration projects that introduce space life science courses to a significant number of who will progress to more advanced majors.

Summer Research Programs. Summer research programs (SRP) that provide bright students with opportunities to interact with similar cohorts, benefit from close mentoring, do hypothesis driven experiments and become comfortable with the scientific method. These principles have guided the core design and conduct of successful programs that advance the education of student with special aptitude and interest in pursuing science careers. Teaching and learning methodologies─didactic, hands-on, experiential and content-mastery─that teach students how to: plan and complete a hypothesis-driven biomedical research project; make coherent oral and poster presentations on their research findings ; strengthen students' ability to write a science report and assess data presented in journal articles are key standards to guide SRP design.

Effective program evaluations that use effective data collection methods to measure each program objective are invaluable for building measurable outcomes databases. External evaluators with appropriate educational program evaluation credentials, are essential for constructing appropriate evaluation instruments; conducting formative/summative evaluations that provide useful information to improve program outcomes. For example, sound databases can follow students' longitudinal progress towards space-related careers.

Graduate-Postgraduate Level Education and Research. Successful models of multidisciplinary space life sciences training connect biomedical, physical, and engineering sciences to address human spaceflight health issues, advance exploration of life beyond Earth, and spin-off medical care benefits for people on Earth exist at universities across the globe. Some programs target the development of modules to strengthen existing, or introduce new, space life sciences certification and majors.

Students in space life sciences graduate and postgraduate programs work at the interface among biology, medicine and engineering to help establish countermeasures against the physiological and psychological impacts experienced by humans during extended periods in microgravity. Others concentrate on advanced life support systems and still others concern themselves with the threats from space radiation. Graduate/postgraduate course and/or program components may include theses, seminars, advanced lectures, laboratory research on students' areas of research, journal clubs, peer review requirements, and scientific writing. Some programs also offer special summer rotations and clerkships in facilities that conduct space-based research (e.g., bed rest facilities, head down tilt and lower body negative pressure to assess syncope/ maximal cardiovascular stress/orthostatic capacity [40]. Others provide research opportunities on short

arm centrifuge for artificial gravity research and laboratories to assess the harmful effects of radiation, [41]; specialized seminars that run concurrently with coursework during the academic year; and opportunities to participate in hands-on, hypothesis-driven laboratory-based research.

Visiting Scholars programs and symposia, such as the James A. Baker III Institute for Public Policy, at Rice University, USA, and the IAA's Regional African Symposia provide additional mechanisms for bringing together graduate level scholars and other leading minds in space life sciences research from among space-faring nations. These opportunities provide forums for high-level discussions that foster increased communication, cooperation, and collaboration among Africa's top space life sciences experts.

The following three international graduate-post graduate level programs: 1) *The Helmholtz Space Life Sciences Research School (SpaceLife)* in Germany; 2) The *National Space Biomedical Research Institute-funded training programs: Massachusetts Institute of Technology and Texas A&M University;* and 3) The Medical University-Graz Institute of Physiology- Centre of Physiological Medicine, University of Graz, Graz, Austria offer unique models from among several international graduate level programs that have potential for transferring products and processes to emerging African space–based institutions that are interested in establishing research infrastructure and programs. These programs have successfully designed curricula that could encourage space-based research and information dissemination across Africa.

The Helmholtz Space Life Sciences Research School. The Helmholtz Space Life Sciences Research School (*SpaceLife)* offers interdisciplinary training for German doctoral students majoring in biology, biochemistry, biotechnology, physics, psychology, nutrition or sports sciences. The School offers a *SpaceLife* degree program, coordinated by the Institute of Aerospace Medicine at the German Aerospace Center (DLR) in Cologne. The School enrolls approximately 25 students in each class for a three-year program. Other German universities in Kiel, Bonn, Aachen, Regensburg, Magdeburg and Berlin, as well as the German Sports University in Cologne, collaborate with the DLR to make this consortium arrangement unique. Universities of Erlangen-Nürnberg, Frankfurt, and Hohenheim, and the Beihang University in Beijing, China, are associate partners of this consortium. The *SpaceLife* curriculum is structured around multidisciplinary integration of concepts that advance understanding of life in extreme environments, Earth's ecosystem, and the search for life on other planets. Students are required to master basic principles of space life sciences, including gravitational biology, astrobiology and space physiology.

National Space Biomedical Research Institute (NSBRI) Programs. Two NSBRI-funded doctoral programs, described below, provide interdisciplinary training that combines academic work with experiences in clinical medical sciences to facilitate understanding of, and solutions to the problems humans face during spaceflight and exploration. These programs have developed rigorous modules to strengthen the existing graduate curricula at Texas A&M and MIT, and to allow students to take advanced courses in biomedical science and engineering, specifically as these fields relate to the space program. Participating students from both institutions attend a seven-week summer program in Houston, featuring a week of space life science lectures followed by a six-week research internship in a Johnson Space Center laboratory (www.nsbri.org).

Texas A&M University's *Training in Space Life Sciences* program offers a certificate in Space Life Sciences for doctoral students majoring in health, physics, biomedical sciences, nuclear engineering, kinesiology or nutrition. By the end of their training, graduates are able to integrate global perspective into their studies. They select courses from a roster of topics critical to long-duration spaceflight, including muscle and bone loss, radiation-enhanced cancer, and nutrition and/or exercise physiology countermeasures. Students master content through didactic, research, and experiential learning. They also are required to develop deep understanding of the principles of service and teaching to promote scientific literacy for the society at-large. Program faculty members include space life sciences experts at select institutions, such as NASA's Johnson Space Center and Brookhaven National Laboratory.

The Massachusetts Institute of Technology (MIT)/Harvard University Graduate Education Program in Bioastronautics, developed in 2006, is a multidisciplinary initiative that integrates biology, medicine, engineering and space research. The unifying curriculum theme is astronaut protection in space and provision of air, water, food, and telemedicine for space travel. Students must satisfy requirements of the regular Harvard-MIT Ph. D program in Medical Engineering and Medical Physics (MEMP), which entails substantial course work in pre-clinical medicine as well as an introduction to clinical practice conducted in the Harvard hospitals. Beyond that, they take courses in aerospace biomedical and life support systems, human factors engineering, space system engineering and a journal seminar in bioengineering. In addition, they are required to choose one restricted elective from a roster including, sensory-neural systems, spatial orientation, radiation biophysics, technology in health care and life sciences, strategic decision-making, and a detailed space systems analysis (a historical-engineering course on the US Apollo mission that flew humans to the moon). In addition, students must complete a summer course at Baylor College of Medicine, followed by an internship at NASA's Johnson Space Center, or in a commercial space-based laboratory. A thesis, under the tutelage of a Harvard-MIT faculty member, is required for completion of the Ph.D. degree requirements. (www.hst.mit.edu/bioastro.edu)

The Medical University-Graz Institute of Physiology-Centre of Physiological Medicine, University of Graz, Austria:

At the Medical University of Graz, researchers and students can implement ground-based models of spaceflight research using the Automatized multi stimulation test device (AMSTD), which is a combined head up tilt and lower body negative pressure device (#4 – 9, 26). This sophisticated, fully computerized device uses state of the art technology and software to assess orthostatic capacity by driving subjects to presycope. This device can also be used to study head up tilt or varying levels of LBNP induced responses.

Figure 4: *The AMSTD (Automated Multistimulation Testing Device*)

Some of the measurements done at the Medical University of Graz include: a) Beat to beat heart rate, stroke volume, cardiac output, autonomic activity using heart rate variability and total peripheal resistance (using the Task Force Monitor, CNsystems); b) Volume regulating hormones concentrations in plasma, using serial blood samplings [42]; c) cerebral autoregulation and splanchnic blood flow, using Transcranial doppler and portal vein ultrasound, respectively; d) assessment of blood flow in the lower limbs using near infrared spectroscopy (NIRS) [54], etc. It has recently been reported that the cause of presyncope in returning astronauts after 6 -15 days flights may be related to a mismatch of cerebral blood flow with blood pressure [43]. It is, therefore, important to assess cerebral autoregulation in subjects reaching presyncope, using the combined head up tilt + graded lower body negative pressure device (AMSTD) [44].

In addition to regular research co-operations between the Medical University of Graz and African counterparts (both at research institutions and individual researcher levels), possibilities of student exchange and higher education exist. For example, the Medical University of Graz could play an important role in educating at the undergraduate or post graduate level students from Africa. Prof Helmut Hinghofer-Szalkay, http://user.meduni-graz.at/helmut.hinghofer-szalkay/, member and former trustee of IAA, has over thirty years experience in spaceflight related research [45]. In addition to being the head of the Institute of Physiology at the Medical University of Graz, he is an active investigator and has been a consultant to ESA. http://user.meduni-graz.at/nandu.goswami). He is Senior Research Scientist, grew up, and studied, in Nigeria and has expressed keen interest in "giving something back to the continent that has given him so much" and to the development of space life sciences in Africa.

5. PUBLIC ENGAGEMENT

There is emerging international consensus that "if space agencies are to retain the support of the public, effective measures must be found to involve the public in the process and outcomes of space exploration." [45] To nurture public support, professionals in space industries also must be willing to work with and influence the decision makers who are stewards of space exploration resources. Indeed, recent public information surveys in the US indicate that the public will not

"automatically" approve expenditure of scarce national resources on space exploration activities. Innovative multimedia projects are being used to respond to these challenges by providing test-beds for the development of culturally competent narratives that delineate the practical, "real-life" benefits and applications of complex space life sciences topics such as forces, gravity and changes undergone by the human body while in space. These narratives are using social networking and other technologies to develop local education networks and create new venues through which to promote civic engagement in "conversations about the benefits of space exploration for society [46]. The success of space life sciences research in Africa will depend upon a scientifically literate populace that is informed about the medical and technological benefits of space exploration for Africa, and supports space exploration activities. To achieve this kind of support, the IAA has suggested "strong effort in public outreach and education... [using] media and education to achieve participatory exploration that allows for active involvement of individuals as contributors in space research, science, and exploration activities" [47]. UN-COPUOS and the IAA have a history of successful engagement with various publics in Africa. This SG recommends that these organizations develop nation-specific roadmaps that reflect each country's priorities for establishing international and local partnerships.

Space agencies in Africa, Canada, Europe, India, Japan, Russia, the US and other countries have significant education and public outreach infrastructures that could contribute to the establishment of long-term cooperative plans, including memoranda of understanding, to foster public interest and support among African cultures and communities. Goals to be considered in this endeavor include, but are not limited to, the following.

- Create individual, short- and long-term, national action plans with full African participation and select international partners, to ensure sustainable, culturally competent, public engagement programs that communicate "space for humanity" themes.
- Establish IAA Node Offices across Africa to facilitate the flow of space exploration educational outreach information and processes to African organizations interested in establishing public engagement plans.
- Create public-private partnerships among governmental and non-governmental entities interested in space exploration development in Africa, including COPUOS, NSBRI and NASRDA.
- Create international partnerships with interested nations to promote access to and use of IAA's E-Learning databases, and to develop to model Afro-centric platforms that disseminate existing space exploration knowledge throughout Africa.
- Convene strategy groups to determine how best to utilize broadband and other technologies, including telemedicine, social media, and Internet as well as television, radio, museum and science center programs to generate public engagement
- Facilitate and support expansion of Africa's role in outreach activities of the IAA, IAC, and IAF, including publication of scholarly works in the journal, *Acta Astronautica,* and other space exploration journals.
- Promote African students' participation in international and national STEM competitions, educational forums, and other activities that focus attention on the benefits of space exploration in targeted communities.

6. INFORMATION-RESEARCH TECHNOLOGIES UTILIZATION

Global Technology Context. The number of space-faring countries has expanded steadily over the past two decades. This growth is accompanied by persistent calls for international cooperation and the use of 21st Century information technologies to generate and share knowledge; develop national workforces with the capacity to compete effectively in emerging global economies; and link developing communities to more developed urban centers. Accordingly, emerging space-faring countries, including those in Africa, are investing in broadband capabilities and seeking international partnerships to design sustainable roadmaps for effective utilization of information technologies that advance their respective space exploration missions. These new stakeholders, which represent academia, industry, governmental, nongovernmental and other organizations, are creating cost-effective, innovative public-private telecommunications partnerships that promote research; capture space life sciences knowledge; foster community engagement by reframing complex science into language suitable for the lay public; and spin-off medical and technological benefits resulting from space research

Technology-enabling Space Life Sciences Research. The technologies required to perform comprehensive, synergistic, cross-disciplinary space life sciences research in Africa will require well-planned, integrated research programs that capitalize upon the strength and expertise available among Africa's space-faring nations, complemented by established international space life sciences researchers. These researchers should endeavor to create partnerships that fill knowledge gaps and promote research and discovery, monitoring technologies and computer-based abilities to maximize space crew health and performance [48], and to produce (1) self-assessment tools to monitor cognitive function in space, and (2) light therapies to combat sleep loss and circadian desynchronization. Technologies that drive ground/analog-based and ISS-based research includes computer software to manage astronaut scheduling and degenerative radiation risks; generate bio-mathematical models that illustrate the biological principles of sleep and circadian rhythms, as well as basic cell, tissue and animal models; facilitate laboratory research that illuminates current understanding of cancer induction; and advance exercise research that defines skeletal-mass performance benchmarks for astronaut health.

Technology-enabling Public Engagement. Multimedia partnerships are generating space exploration films, radio programs and innovative museum-science center products that engage students, teachers and the general public in the excitement of space exploration, and educate them about the changes that the human body undergoes when it leaves Earth's orbit. These innovative media-driven collaborations are transferring new research knowledge to diverse audiences, creating electronic forums to educate the public about science (particularly space life science), providing engaging, current curricula and textbooks on space life sciences; and motivating students at all levels to pursue STEM careers.

Telemedicine technologies have special potential for utilization across Africa, and could lead to the development and launch of African models that feature culturally competent consultation, diagnosis, and delivery of high quality medical care by physicians and other health care professionals who may be a great distance from the patient. These models can demonstrate the potential role of African space agencies in facilitating treatment of patients in isolated locations. One challenge in keeping a multimedia consortium up-to-date is the need to keep abreast of, and

to implement new Internet capabilities driving the "almost instantaneous" nature of global communication. Scholars have described how social networks serve to connect people on many levels, from individuals to nations. Indeed, social networks (e.g., MyFace and Facebook in the United States and Hi5 in Europe and South America) are building new online communities of people with shared interests; enabling users to communicate via e-mail and various forms of instant messaging; and changing the ways people across the globe communicate.

E-Learning: Many information technologies could be indigenized through international partnerships to create electronic classrooms that focus on space science education, global connectivity and electronic learning strategies for African countries. Existing electronic platforms include homework hotlines that provide homework assistance; social media platforms for digital journalism and civic engagement; and e-learning platforms dedicated to the conservation and dissemination of space life sciences knowledge. These electronic innovations could be employed to incorporate archived space education content materials from around the globe into new Afro-centric educational materials, facilitate differentiated learning for students from different parts of Africa, and contribute to a more flexible classroom that allows teachers to weave space topics into lessons.

The IAA's E-Learning Study Group is promoting cross-disciplinary collaboration in space medicine; report on electronic space-based educational activities occurring around the globe; facilitate utilization of contemporary e-learning platforms and environments; share experiences on educational standards; encourage the exchange of digital educational materials among educators; and experiment with the use and application of digital copyright. The proposed IAA site has potential to provide the technical conditions required to develop web-based courses and facilitate interchange among a wide variety of users. The site proposes to employ the Sharable Content Object Reference Model, currently in use by many governmental and nongovernmental organizations, to review and store aerospace space life sciences literature. This unique IAA capacity holds promise for extending "space science to students, teachers, universities and medical colleges, medical associations and medical doctors, as well as researchers in space medicine and space life sciences" throughout participating African countries.

Museums and Science Centers. Museums and science centers engage communities in science, technology and other key disciplines in ways that can communicate the importance and benefits of space exploration to Africa and the world. For example, the National Space Biomedical Research Institute (NSBRI) has developed exhibits, including an interactive knowledge station and the Barany Chair, which have been used to convey space science information in interactive, interesting ways to students and educators in many settings. *The Knowledge Station* and *The Barany Chair*, developed with sponsorship from NSBRI, are accompanied by an interactive collection of biomedical engineering and life support educational materials for elementary-secondary level teachers and students [51]. Many other existing space education international platforms could be indigenized through international partnerships to produce electronic classrooms, focusing on space science education and global connectivity electronic learning capacity for participating African countries. Existing electronic platforms include homework hotlines that provide assistance with homework; social media platforms for digital journalism and civic engagement; and electronic learning platforms dedicated to space life sciences knowledge conservation and dissemination. These electronic innovations have potential to utilize

archived space education content materials from around the globe to create new Afrocentric educational materials, facilitate differentiated learning for students from different parts of Africa, and contribute to a more flexible classroom that allows teachers to weave space topics into lessons.

Museums and Science Centers: Museums and science centers engage communities in science, technology and other areas of scholarship in ways that will serve the nation and the world in the 21st century. For example, the NSBRI has developed exhibits, including an *interactive Knowledge Station* and the *Barany Chair*, which have been used to convey space science information in interactive, interesting ways. The *Knowledge Station* was developed by the NSBRI at the Massachusetts Institute of Technology (MIT). (http://dorfman.mit.edu/spacerciser/). The Station includes an interactive collection of biomedical engineering and life support educational materials for elementary-secondary level teachers and students. (http://dorfman.mit.edu/spacerciser/

Fig. 5: NSBRI-Barany Chair

Fig. 6: MIT Interactive Knowledge Station

Other unique museum-science center models exist across the globe. African countries will undoubtedly expand their repertories to include models that have particular resonance with their individual needs and aspirations.

7. INTERNATIONAL SPACE STATION (ISS) UTILIZATION

The IAA's 50th Anniversary Heads of Agencies commissioned a study, *Future Human Spaceflight Study Group* that recommended this "coordinated approach" to human factors research, with emphasis on radiation dangers, psychological and interpersonal issues, and strong coordinating mechanisms for "calibrating, disseminating and exploiting data [to] fill gaps in research and enhance synergistic research protocols [51]." The Report also makes the case for a global, cost-effective strategy that advances human space flight-related research and utilizes the International Space Station as a common research facility. It further notes that global involvement for spaceflight will require extending "opportunities for as many countries as possible to participate in space activities... in view of its strategic and societal importance for humanity." NASA's endorse these perspectives in its *Life and Physical Science Space Research* survey, which is refining the research objectives that "align space life and physical sciences research to meet exploration needs." Similarly, the European Space Agency (ESA), one of the largest users of the ISS, has identified life sciences research areas - radiation biology and

physiology, food, nutrition and life support systems as key research areas for future cooperation among space-faring nations.

In microgravity, humans perform tasks more slowly due to degradation of perceptual motor performance. This may arise either due to direct effects of microgravity on the central nervous system or via multiple stressors. More research is essential to understand fully the adaptation of humans to the stresses of microgravity. An important aspect to be examined: what the similarities and differences are when comparing ground-based (e.g., bed rest immobilization, orthostatic intolerance) with spaceflight-derived datasets? Some of the answers to these questions can be provided by the ISS data. Important data were also obtained by analyses of cardiovascular and hormonal data of Valerie Polyakov, who holds the record for longest stay in microgravity: 438 days. Similar long term studies on the ISS, in collaboration with researchers from Africa, would propel African life sciences research to the forefront [52].

8. RECOMMENDATIONS

This Study Group acknowledges the international consensus, encoded in *The Global Exploration Strategy*, which supports partnership-building and global collaborations for Africa's quest to utilize "space for humanity." Therefore, the deliberations of the Study Group were guided by the *IAA's 50th Anniversary Heads of Space Agencies Summit* reports and declaration, which underscore how globalization is defining the future of space exploration; a review of current space activities in Africa; and recognition that individual African countries are creating roadmaps and investing national resources to expand their existing satellite-based space activities to include research on human adaptation and counter measure to spaceflight research, education and public engagement.

The recommendations outlined below support a synergistic space life sciences research and education strategy that includes: basic research on human health and performance risks associated with space explorations missions; a comprehensive─elementary to doctoral level─STEM education approach that reaches students, teachers, and families; and the development of culturally competent public engagement programs that build on existing UN-COPUOS initiatives.

Some of the recommendations listed below have specific reference to the NASRDA, which has expressed special interest in collaborating with international partners to develop space life sciences research and educational outreach for NASRDA, in particular, and to support space for Africa in general.

Recommendation 1: Promote and Encourage A Broad Range of Space Related Collaborations among African and other Space Faring Nations

Establish an IAA committee charged with responsibility to facilitate partnerships among international organization with histories of successful space life sciences educational outreach programs, including African countries interested in establishing space life sciences research and educational outreach organizations. The mission of these partnerships would be to establish international collaborations to: promote research collaborations in areas of mutual interests; share experiences that develop innovative educational public outreach programs; exchange

scientific materials, publications, and multimedia information; support conferences, seminars, workshops, including regularly scheduled IAA Federation and Congress international meetings; and expand membership in the IAA's astronautical community.

It is important to ensure that space life sciences are included in the program at space related meetings in Africa. Having space life sciences sections in these meetings would allow participation of both African and international researchers. Specific themes could be proposed and young/experienced African researchers could be encouraged to present their research. In this way, international scientists from the world over would travel to Africa to attend these meetings and open the doorways to excellent collaborations and exchange of ideas. During these meetings, potential PhD or post docs that would be interested in collaborations could be identified. International researchers could also spend some time in African research institutes. This could have dual benefits: international researchers could transfer technology/science to Africa (hands-on-approach) but at the same time conduct some experiments in space life sciences.

Recommendation 2: Work With Emerging African Programs That Foster STEM Education for African Space Workforce Development

Support and identify African STEM programs, including NASRDA's Centre for Space Science and Technology Education program, which is supported by the UN-OOSA-affiliated African Regional Centre for Space Science and Technology Education in English Language, to serve as planning centres for designing comprehensive strategies to: 1) train African educators, in focus areas of space elementary/secondary STEM education; produce indigenous, space-based elementary/secondary level STEM curriculum modules; and 3) develop STEM teacher institutes/academies for the professional development of teachers from across the continent of Africa.

Recommendation 3: Facilitate International Exchange Programs to Develop Undergraduate-Graduate-Postgraduate Level Training for Africa's "Brightest and Best"

Work with select international organizations and space faring African countries interested in designing innovative graduate level space life sciences education, multidisciplinary programs that provide didactic and laboratory training to prepare research scientists for independent research and teaching in the most critical issues limiting long-duration space flight. These areas should include physiological stress, bone loss, muscle wasting; cardiovascular regulation and sensory-motor control; effects of cosmic radiation, and metabolic changes. Nutrition, exercise physiology countermeasures and bioastronatuics—the interface among biology, medicine and engineering—are also areas of critical concern.

Programs could include special summer rotations and clerkships in facilities that have space-based research infrastructure, including access to analogy environment research, artificial gravity research laboratories, bed rest facilities, radiation, and chronobiology laboratories. Examples of successful space education programs may be found at: 1) The Helmholtz Space Life Sciences Research School (*SpaceLife*), DLR, Germany; 2) Massachusetts Institute of Technology, Massachusetts, USA; 3) The Medical University-Graz Institute of Physiology - Centre of Physiological Medicine, University of Graz, Graz, Austria;.4) USA-NASA and the NSBRI; 5) China; 4) India; 5) JAXA; 6) Greece; and (7) others.

Recommendation 4: Establish a Synergistic Space Life Sciences Research Organization /Institute at the NASRDA, Nigeria, Africa

Establish a synergistic, multidisciplinary space life sciences research institute, supported by the IAA and other select international partners, at the NASRDA, Nigeria, Africa. The mission of the organization would be to build a space life sciences research operation that: conducts ground/ISS-based research on human health and performance risks of space exploration missions; develops Africa's STEM workforce; and educates the African public. Such a laboratory should be well equipped for doing ground based research into spaceflight related issues. Such equipment includes head up tilt table, lower body negative pressure device, short arm centrifuge, bed rest facitilities, etc. Regular visits to Africa from researchers based in established space faring nations along with reciprocal visits from African counterparts should be encouraged.

It is envisioned that such an organization would work with the proposed IAA Node Office in Nigeria, and other select international space organizations (ESA, JAXA, Russia, UK, France – International Space University) to develop a strategic plan that utilizes the best collective thinking of the global community.

Finally, it is also imperative that specific universities in Nigeria that would be interested in doing research – and offering undergraduate or masters' degrees in Space life sciences- be identified. For example, The Center for Basic Space Sciences (CBSS) at University of Nigeria, Nsukka, could also work closely with the Department of Physiology at the Enugu Campus of the same university to do human spaceflight related research. In addition, co-operations could also be established with the medicine department of the University of Nigeria, Enugu Campus to do research in pathophysiological models of orthostatic intolerance (i.e. patients with Postural Orthostatic Tachycardia Syndrome) mimicking the upright pre-syncopal signs and symptoms following return from microgravity. These could be considered with respect to potential common underlying neural autonomic alterations.

Recommendation 5: Use Multimedia Technologies to Foster Public Engagement and Education

Facilitate multimedia consortia arrangements to undertake feasibility studies to promote telemedicine, radio-television, and museum/science centre programs that contribute to the scientific literacy of communities across Africa, including information on how space exploration can spin-off benefits for humanity in Africa.

It is recommended that the IAA's and other global E-Learning and social media expertise be leveraged to create new Afrocentric space educational materials; facilitate differentiated learning for students from different parts of Africa, including electronic classrooms, homework hotlines, digital journalism, and civic engagement .

This effort should include the re-establishment of the NASRDA planetarium as a model of public engagement for other space faring African nations.

9. CONCLUSION

Space for humanity through international cooperation was the compelling theme of the *2010 IAA 50th Anniversary Heads of Space Agencies Summit*, Washington, DC, USA. This theme supports the IAA's mission to expand the frontiers of space by developing and promoting new ideas and initiatives for space knowledge development and transfer (www.iaa.org). This Study Group (SG), which is charged to create the IAA's strategy for space life sciences knowledge development and sharing for emerging space faring African nations in general, and for the NASDRA in particular, supports the Summit's theme as well as the IAA's mission.

The deliberations of this SG are framed by three major perspectives, that; 1) space life sciences educational outreach knowledge generation and transfer can serve African humanity; 2) the IAA has consensus, gained at the 3rd African Regional Conference, *Joint Participation, Knowledge Development and Sharing,* hosted by the IAA and the NASRDA of Nigeria, to leverage appropriate global partnerships in support of Africa's efforts to develop indigenous space life sciences education and research activities; and 3) space life sciences research strategies should be guided by the *Global Exploration Strategy's* recommendation that "for the foreseeable future:...primary exploration destinations will be Low Earth Orbit (LEO). Therefore, cross-disciplinary research on the human body in microgravity, as well as the health-performance risks associated with LEO exploration, should include physiological deconditioning during prolonged weightlessness in LEO; radiation carcinogenesis; and nutrition, exercise, and behavioral issues that militate against team cohesion in confined spaces.

The SG completed a review of ongoing space activities in Africa. The review reveals that African space exploration activities do not include space life sciences to any measurable extent. Therefore, innovative space life sciences research and education outreach programs in Africa have potential to spin off significant medical and societal benefits for the African people and to launch new space exploration activities for space faring countries in Africa. The SG report presents a synergistic, comprehensive approach for introducing space life sciences research and educational outreach in Africa. The approach focuses on workforce development spanning the full continuum from elementary/secondary to undergraduate/graduate/postgraduate education, professional development opportunities for laboratory-based research scientists, and public engagement. The Report highlights successful models, drawn from IAA-affiliated organizations from across the globe and suggests some, not all, potential international partnerships who could provide expertise to design and support the development of space life sciences research and educational outreach in Africa.

The Report asserts that the design of successful models for respective nationals in Africa will require full participation by space agencies in each country. In addition, the Report heeds the collective recommendations of the IAA-African regional conferences, which underscores that African educational outreach efforts will require "indigenous" African products and processes to inspire the next generation of African students, educate African communities about the societal

benefits of human space flight, and engage political support for space life sciences research and development. The Report further endorses the recommendation of the IAA's commissioned report, *Future Human Spaceflight: the Need for International Cooperation* to discuss "human spaceflight at the highest political levels (e.g. during a meeting of the G-20) following preparatory discussions by the respective Heads of Agencies.

The SG's recommendations acknowledges that while international collaborations can speed up the introduction of space life sciences research and educational outreach activities across Africa, the main strategies to accomplish recommended tasks will require African imprimaturs.

Appendix 1: Contributors

Contributors to the Study Group included the following persons:
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The first face-to-face meeting of the Study Group was held during the International Astronautical Congress (IAC) meeting in Prague, The Czech Republic, September, 2010. The second meeting was held during the 18th IAA Humans in Space Symposium, April, 2011, Houston, Texas, USA. Individual group meetings were held, with the NSBRI EPOP team, October 2010, Houston, Texas, USA.

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