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Global Cooperation for Space Development and Knowledge Transfer in Africa

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ABSTRACT

This paper reports findings of the International Academy of Astronautics (IAA) study group, *International Cooperation for Space Life Sciences Knowledge Sharing and Development in Africa*. The Study Group (SG), comprised of space life sciences experts from eight countries, was established in 2010 and charged with developing a collaborative global strategy to generate and share space life sciences knowledge among space-faring and space-aspiring African nations. The SG's findings highlight the need for global cooperation, including engagement of emerging and established African space-faring countries to reflect indigenous societal objectives and to support global space exploration policies. This paper presents the SG's findings and examines the implications and potential of ongoing projects to enable and promote space life sciences research, education and development in Africa—particularly through increased international governmental/non-governmental partnerships. Finally, the SG proposes a roadmap for Africa's space-emerging countries seeking to develop global partnerships to develop indigenous space life sciences programs. The SG made five recommendations: (1) establish international collaborations to promote research collaborations in areas of mutual interests; (2) work with emerging African programs that foster science, technology, engineering and mathematics (STEM) education to develop a robust African space workforce; (3) facilitate international exchange programs to develop undergraduate-graduate-postgraduate level training for Africa's "brightest and best"; (4) establish a synergistic space life sciences research institute/center at the NASRDA, Nigeria, Africa; and (5) encourage the use of multimedia technologies to foster public engagement and education. Finally, the paper calibrates this Report with the IAA's commissioned report, *Global Exploration Strategy: The Framework for Coordination*, which 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].

***Keywords**:* Global, Cooperation, Life-sciences, Education, Africa

1.0 INTRODUCTION

The theme of the *2010 International Academy of Astronautic (IAA) Heads of Space Agencies Summit*, which celebrated the 50th anniversary of space exploration was, "Space for humanity through international cooperation." [2]. This theme, which advances the IAA's mission to expand the frontiers of space by supporting innovation to develop and transfer space-based knowledge, gave impetus to the formation of the IAA Study Group (SG), *International Cooperation for Space Life Sciences Knowledge Sharing and Development in Africa.* The SG, comprised of space life sciences experts from eight countries, was established in 2010 and charged with developing a collaborative global strategy to generate and share space life sciences knowledge among space-faring and space-aspiring African nations.

The genesis of the SG was the Third African Regional Conference, *Space for Africa: Joint Participation, Knowledge Development and Sharing,* held in Abuja, Nigeria in 2009. The conference, hosted by the the IAA and the National Space Research and Development Agency (NASRDA) of Nigeria, included space life scientists and educators who drew up a proposal to develop and advance space life sciences education and research programs for Africa. [3]. Memorandums of Understanding (MOUs) were obtained from the IAA and participating organizations, including NASRDA and the Morehouse School of Medicine, and a proposal was submitted to the IAA by IAA Space Life Sciences- Commission 2.

1.1 SCOPE AND GOALS

The SG 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. In addition, the report makes recommendations for an IAA strategy to engage select African space agencies, beginning with Nigeria's National Research and Development Agency (NASRDA), 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 NASRDA.

The SG took into account each African country's space faring activities to ensure that the strategy that the SG proposed emphasized 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 Nigerian National Space Research and Development Agency'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 astronautics conferences in Nigeria. It has also instituted an IAA-Node Office in Nigeria to advance its support of NASRDA's mission to "pursue and attain … space capabilities that enhance the quality of life … [for Nigerians]." [4].

The goals of the Study Group were 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. It is the expectation that these partnerships will collaboratively develop indigenous African space life sciences research and educational outreach programs that benefit from a rapidly globalizing space exploration world. The following guiding questions were used to frame the review of existing space programs across the African continent:

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.

2.0 REVIEW OF SPACE ACTIVITIES IN AFRICA

Space activity in Africa varies from county to country. In general, Africa-based space programs focus, to varying degrees, on aspects of Remote Sensing (RS) and Geographic Information System (GIS) applications and basic space sciences research. South Africa has an historic role in the area of observation and the study of celestial bodies and more recently has built a unique educational outreach program, *National Youth Development Trust (NYDT) of South Africa*, which is designed to introduce space-based subjects to schools in disadvantaged communities throughout South Africa. Other African countries have used RS/GIS applications to survey and map natural resources such as vegetation, landuse and soil. It is the general consensus of the SG that investment in core space activities, including educational outreach and space life sciences research endeavors are limited by a "knowledge gap" and scarce resources. However, in recent years, the Gross Domestic Product (GPD) spending of the African continent on space science has increased among "emerging space faring nations" and "space aspiring countries" and this portends success for future space activities on the continent. [5]

2.1 Space-faring African Nations.

Emerging Space-faring African Nations countries are defined as nations, which have already established governmental space agencies whose activities are guided by approved space policies and possess significant levels of expertise in satellite technology missions and space science and astronomy. Three African countries (Algeria, Nigeria and South Africa) command significant space capacities. For example, Nigeria has invested in "know-how-technology-transfer" (KHTT) from Surrey Satellite Technology Limited (SSTL), UK; South Africa has astronomy capacities that are globally recognised; and Algeria is developing global partnerships to develop satellites that monitor and manage African resources and the environment. Recently, these three countries led the process for producing a comprehensive policy roadmap, *African Space Policy,* with a goal of developing a mutually reinforcing space agency for the continent of Africa. Brief reviews of these agencies follow. [6].

Algeria: The Algerian Space Agency (ASAL) was established in January, 2002 through a presidential decree. 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, Ukraine and the Russian Federation, and through governmental framework agreements with France and the United Kingdom. Algeria is also cooperating with Kenya, Nigeria and South Africa to develop satellites to monitor and manage African resources and the environment through the African Resource Constellations (ARM) satellites program. Algeria has launched two EO satellites, Alsat-1 and Alsat-2, which has generated and disseminated over 1,000 images to promote telecommunications, agriculture, disaster management and water resources sector development among countries in the region. The five centers under the Algerian Space Agency are: 1) The Center of Space 2) The Satellite Development Centre 3) The Satellite Applications Centre (4) The Telecommunications Satellites Operation Centre 5) The Doctoral School of Space Applications and Technologies. (www.agencespatialealgerienne.com).

Nigeria: The National Space Research and Development Agency (NASRDA) of Nigeria was established in May, 1999 and administered by the National Council on Space Science and Technology. It seeks to "build indigenous competence in developing, designing and building appropriate hardware and software in space technology as an essential tool for the socio-economic development and enhancement of the quality of life of its people. Six NASRDA centers: 1) Center for Basic Space Sciences 2) Center for Space Science and Technology Education 3) Center for Satellite Technology Development 4) Center for Geodesy and Geodynamics 5) Center for Space Transport and Propulsion 6) National Center for Remote Sensing, all have their various responsibilities of accomplishing the Agency's mission. The mandates of these centers are well defined in Nigeria's National Space Policy [7].

South Africa: South Africa's space exploration focus has evolved out of its 50-year collaboration with USA's National Aeronautics 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 unique space satellite infrastructure to include space life sciences educational outreach to schools. 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. South Africa's space astronomy through the Southern Africa Large Telescope (SALT) and the Square Kilometer Array (SKA) has emerged as a model of global space enterprise. [8].

2.2 Space-aspiring African Nations

Seven additional African countries have expressed aspirations to join the global space exploration community and are developing space policies to establish and/or strengthen existing space programs. These countries include Egypt, Ethiopia, Ghana, Kenya, Libya, Morocco and Tunisia. However, recent civil unrest and upheaval in Libya, Tunisia, and Egypt may have consequences for the status of space development in these countries

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. Egypt recently launched its first EO satellite, NileSat-1, dedicated for water resources management in the Magreb region**. [9].**

Ethiopia: Ethiopia's space endevours draws largely from the development of its human resources, particularly in the area of space applications and hosting of many regional and international space-related conferences taking advantage of the infrastructure and facilities provided by the United Nations Economic Commission for Africa. The country has played host to conferences/Seminars such as the European Union Seminar on New Codes of Conduct for Outer Space Activities and *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. [10]

Ghana: In May, 2012, Ghana launched its Space Science and Technology Centre (GSSTC) to plan programs in space science and technology that directly impact on the development of the country. Ghana wants to use its space centre to look at natural-resource management, weather forecasting, agriculture and national security. GSSTC hopes to build its human capacity by partnering with the Space Generation Advisory Council branch in Ghana (SGAC-Ghana), which seeks to engage university students and young professionals in collaborations related to space exploration and its applications. GSSTC has also established collaboration with South Africa in its Square Kilometer Array (SKA) project using an existing VSAT facility for initiating the radio astronomy project. www.ghanaspace

Kenya: In 2009, the National Space Secretariat of Kenya, was established to: conduct/co-ordinate space-based researches, and update Kenya space science policy; initiate training aimed at ensuring adequate transfer of space technology and its applications; promote peaceful uses of space science applications including, but not limited to, satellite earth observations, navigation, telecommunication and disaster management; 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, data acquisition and application in the field of space science. Kenya's launching site in Malindi, built and operated by the Italian Space Agency, is the first of its kind in Africa. (www.kenya+space.com)

Libya: 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. [11].

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. 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. [12].

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. Tunisia also is leading efforts to develop Arabic-language terminology for use in international communications systems. Tunisia's national space program falls under the aegis of the National Commission for Outer Space Affairs (NCOSA) and is hosted by the Regional Center of Remote Sensing. The commission 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. It has also established five strategies to achieve its educational outreach objective: space techniques and technologies; space telecommunications; Earth observation and remote sensing; training; and public engagement. (www.hudsonfla.com/aethiopia.htm).

3.0 FINDINGS

The Study Group's findings highlight the need for global cooperation, including engagement of emerging and established African space-faring countries in programs that reflect indigenous societal objectives and support Global Space Exploration policies. These findings, based on reports of space programs of Algeria, Nigeria, South Africa, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Libya, Morocco, Senegal and Tunisia, suggest that African involvement and investment in core space activities has been limited due to a knowledge gap and challenging social and economic conditions. Some countries have established and developed their own space agencies with clearly defined policies and objectives. Space science efforts among these countries focus on satellite technology and ground station operation, astronomy/space science and investment in other, related activities to advance their specific space exploration/utilization aspirations. These aspirations include communication services, satellite data collection and processing, with applications in areas such as food security, health and education, crime control, environmental and disaster management, and urban sprawl; radio telescope technology; and space science education outreach and awareness. Also, the IAA study examines the

implications and potential of ongoing projects to enable and promote community-based space life sciences research, education and development in Africa—particularly through increased international governmental/non-governmental partnerships. Finally, the study proposes a roadmap for Africa's space-emerging countries seeking to develop global partnerships to develop indigenous space life sciences programs.

Space exploration foci vary among African nations, including Remote Sensing (RS), Geographic Information Systems (GIS) applications, and basic space sciences education. For example, South Africa is recognized globally for excellence in astronomical studies and has participated in space programs for the observation and study of celestial bodies and has served as a ground station for the USA-National Astronautics and Space Administration (NASA) exploratory missions. Other African countries have employed RS/GIS applications to survey and map natural resources, including vegetation, topography and soil, while Algeria and Nigeria have acquired technology transfer capabilities from Surrey Satellite Technology Limited, UK to build significant satellite capacity. These activities are being codified in a collaborative African *Space Policy*, which is designed to serve as a blueprint for meeting the aspirations and furthering the establishment of an African Space Agency.

The Study Group concluded that there are many platforms available to promote inter-regional African cooperation on space science programs. African countries have built appreciable capacity in virtually all areas of space science and technology applications, particularly through the establishment of regional training centers of excellence, including the Regional Centre for Mapping of Resources for Development in Nairobi, Kenya; Regional Centre for Training in Aerospace Survey in Ile-Ife, Nigeria; and two Regional Centers for Space Science and Technology Education, in English and French, located in Nigeria and Morocco, respectively. In addition, the African Union recently established a multi-campus Pan African University for Science Technology and Innovation, which includes the Institute of Space Science and Technology in South Africa; Institute for Basic Sciences, Technology and Innovation (Kenya); Institute for Life and Earth Sciences (Nigeria); and Institute for Governance, Humanities and Social Sciences (Cameroon).

These findings are congruent with the consensus arrived at during the International Astronautical Federation's conference, *Space for the African Citizen*, held in Brussels, Belgium, in 2010. That consensus reaffirmed that space exploration has potential to contribute to the general development of Africa and underscored the "imperative for Africans themselves to take the lead and truly develop space for Africa." Also, the IAA study Group, *Future Human Spaceflight: the Need for International Cooperation* (2010), underscores these common global interests for human space exploration to support the outcomes of three African IAA regional conferences focused on "Space for Africa." The collective wisdom generated by these conferences is that Africa's steady emergence as a global space-faring influence has ignited interest in space life sciences research and education that can strengthen African engagement in international space projects and produce spin-off benefits that benefit nations across the continent. Further, a systematic approach, based on African priorities and building on African space-faring strengths, has the capacity to leverage global support for a synergistic consortium of African space dedicated to the development of a space life sciences research and educational workforce in Africa

3.1 Existing Platforms for African Inter-Regional Cooperation

Many African countries have made appreciable progress in capacity building in virtually all areas of space science and technology applications, particularly through the establishment of regional training centers of excellence. The centers include the Regional Centre for Mapping of Resources for Development (RCMRD) located in Nairobi, Kenya; Regional Centre for Training in Aerospace Survey (RECTAS) located in Ile-Ife, Nigeria; and the two Regional Centers for Space Science and Technology Education in English and French affiliated to UNOOSA and located in Nigeria and Morocco respectively. Recently, the African Union established a Pan African University for Science Technology and Innovation with multi-campus training departments/institutions which include the Institute of Space Science and Technology located in South Africa, Institute for Basic Sciences, Technology and Innovation (Kenya), Institute for Life and Earth Sciences (Nigeria) and Institute for Governance, Humanities and Social Sciences (Cameroon).

The African Leadership Conference (ALC) on Space Science and Technology for Sustainable Development is another platform of regional cooperation aimed at achieving rapid sustainable socio-economic development within the African region through the use of Space Science and Technology. The ALC has organized four (4) regional conferences with the running theme, "Space for Africa: Joint Participation, Knowledge Development and Sharing" The ALC has been hosted by four member countries since 2005: Nigeria '05, South Africa '07, Algeria '09, Kenya '11. One of the key collaborative outcomes of the ALC is the establishment of the African Resource and Environmental Management Constellation of satellites (ARMC). It is a partnership of four countries, namely: South Africa, Nigeria, Algeria and Kenya where each country was expected to launch a satellite to be operated in constellation and dedicated to meet some regional challenges which include food

security, climate change research and disaster management and monitoring. Membership of the ALC is open to all African countries. Ghana joined recently and will host the 5th ALC in December, 2013. During the 2009 conference, held in Mombasa, Kenya, for example, the Mombasa declaration on "Space and Africa's Development" was made. The key/focal points include the development of Africa's human capital in space science and technology; protection of Africa's natural environment and the collective management of the continent's resources; the enhancement of human security, development and welfare; strengthening of space activities in the African Union; enhancement of public awareness of the importance of space activities; advancement of scientific knowledge of outer space and to protect the space environment for future generations.

There is also an existing network of basic space science research with installation of GPS units and magnetometers in many African countries in order to contribute data to the global ionospheric footprint. These instruments were donated by the United Nations and other collaborating international institutions. Series of basic space science training workshops and public awareness programs were organized through the United Nations Program on Space Applications and by many space agencies and specialized organs of the UN. The GPS are being densified by some countries, through the African spatial data infrastructure initiatives and African Reference Frame (AFREF) project to enhance the quality of geo-information production and also ensure the continuity of geodetic data across the continent.

All of these efforts provide platforms for research, public engagement, knowledge acquisition and education outreach, which can be harnessed and channeled, in parnership with the relevant international organisations, towards the development of space life sciences in Africa. Such efforts will go a long way in planning/advancing the relevant space exploration programmes and researches to tackle the diseases that are endemic or peculiar to the African continent. [13]

4.0 FRAMEWORK FOR RESEARCH AND EDUCATION IN SPACE LIFE SCIENCES.

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. 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 has ignited interest in space life sciences research and education that can strengthen Africa's international engagement in space and produce spin-off benefits for societies across the continent. 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 emerging 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. In order to achieve these future objectives, a systematic approach will be needed to design a strategy for building on existing African space exploration strengths. Suggested strategies identified by the Study Group are discussed below.

4.1 African Priorities: Building on Strengths

Beginning with the 2002 *World Summit on Sustainable Development* held in Johannesburg, South Africa, many African nations identified with the rest of the world the need to ensure that, through collective actions, they live in a society that is free of the indignity and indecency occasioned by poverty, environmental degradation and patterns of unsustainable production, consumption and development. Accordingly, through decisions on targets, timetables and partnerships, there was a reolve to speedily increase access to such basic requirements as clean water, sanitation, adequate shelter, energy, health care, food security and the protection of biodiversity. There was a determination to strengthen space research efforts at national and regional levels and to use space as a springboard for capacity building, skills, knowledge development and technological innovation [14]. These and other various programmes highlighted under the existing platforms for regional cooperation provide viable opportunities for research and knowwledge development in space life sciences.

4.2 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 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 [13].

4.3 Potential Organizational Model for Space Life Sciences in Africa: A synergistic consortium of African space agencies, select international space organizations, universities, and the IAA would have capacity to establish an organizational entity such as, *The Pan-African Space Research Institute*, which is dedicated to the development of space life sciences research and educational programs in Africa. This organization would then 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 and SANSA, will ensure utilization of the ISS research platform. It will also ensure that space life sciences are included in the program at space related meetings in Africa. Indigenous space life sciences research and spin-off ancillary activities that improve health, education and career opportunities for Africans would be promoted. Importantly, dissemination of research findings of African space scientists through national and international symposiums, publications, multimedia technologies should be encouraged including the transfer of research findings through commercial and other partnerships. [14].

4.4 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. It further recommends that models of successful space life sciences research implementation strategies and facilities could be adapted. Prospective laboratories in Africa, for example, 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. New knowledge, based on Africa's indigenous cultural and psychological perspectives could be generated leading to more profound international cooperation [15].

4.5 Integrated Research Team (IRT) Approach

Groups with interacting research programs, established among centers, universities, and space research organizations, have efficacy for maximizing research because discussion and group interaction among diverse and 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 (IRT) 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.

4.6 Space Life Sciences Education

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 centers that are appropriately positioned to leverage and deliver teacher professional development and other education development activities. In the paper, '*Global partnerships: Expanding the frontiers of space exploration education*' by MacLeish et al, an extensive study of how to promote and facilitate space life sciences research and education in Africa was documented. It identified pertinent areas of sustained educational consortium that are required for a holistic approach to establishing space life sciences. These include a mutually reinforcing system of educational outreach programme from kindergarten through postgratuate level such as elementary/secondary education, teacher professional development, curriculum materials development, after school education, undergraduate level college education, effective course design, summer research programs, graduate/postgraduate level research and education. [16].

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, 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.

4.7 Public Engagement/Awareness

The success of space life sciences research and education 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" [17].

4.8 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 visions and 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. Other avenues of utilization include Technology-enabling Space Life Sciences Research, Public Engagement, E-Learning, Museums and Science Centers.

4.9 International Space Station (ISS) Utilization

Africa has myriad of challenges and issues that can be delved into using the ISS platform and opportunities. Researchers from Africa can also perform long duration studies on the ISS. The SG's report makes the case for a global, cost-effective strategy that advances human space flight-related research and utilizes the International Space Station (ISS) 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." Similar long term studies on the ISS, in collaboration with researchers from Africa, would propel African life sciences research and knowledge development to the forefront.

5.0 RECOMMENDATIONS

The SG's recommendations, which are 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 Nigeria, in particular, and to support similar space programme for Africa in general.

5.1 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 research and educational outreach programs, including African countries interested in establishing platform for space life sciences research and development. The mission of these partnerships would be to establish international collaborations to: promote medical 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.

5.2 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 centers for designing comprehensive strategies to: train African educators in focus areas of space education; produce indigenous, space-based elementary/secondary school level STEM curriculum modules; and develop STEM teacher institutes/academies for the professional development of teachers from across the continent of Africa. Details of the strategies to use have been well documented.

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

Work with select international organizations and space emerging African countries interested in designing innovative graduate level space life sciences research and 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. Such 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: The Helmholtz Space Life Sciences Research School (*SpaceLife*), DLR, Germany; Massachusetts Institute of Technology, Massachusetts, USA.

5.4 Establish a Synergistic Space Life Sciences Research Organization /Institute in Africa

Establish a synergistic and multidisciplinary space life sciences research institute, supported by the IAA, emerging space faring nations and other select international partners. The mission of the organization would be to build a platform for space life sciences research that: conducts ground/ISS-based research on human health, particularly in areas of the endemic diseases ravaging the African continent 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 facilities etc. It is envisioned that such an organization would work with the proposed IAA Node office in Nigeria, for example, and other select international space organizations, such as, ESA, JAXA, ROSCOMOS, CNES, NASA, UK-BNSC and France – The 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 Africa that would be interested in doing research – and offering undergraduate or masters' degrees in Space life sciences-be identified.

5.5 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. A typical example is the NASRDA's tele-medicine and tele-education pilot projects which were used to demonstrate the capacity of the communication satellite (NigComSat-1). The project was developed on mobile outfits and directed towards the provision of healthcare delivery to the teeming population in the rural areas; similarly the tele-education pilot project was carried out in collaboration with the National Open University of Nigeria (NOUN), provided a study link between the NOUN headquarters in Lagos and twelve (12) study centers located across the country. It is recommended that the IAA's and other global E-Learning and social media expertise be leveraged to create new Afro centric space educational materials; facilitate differentiated learning for students from different parts of Africa, including electronic classrooms, homework hotlines, digital journalism, and civic engagement. The three leading space Agencies, ASAL, NASRDA and SANSA are encouraged to establish planetariums to serve as models for public engagement.

6.0 CONCLUSION

The SG's review of on-going space activities in Africa revealed that African space exploration activities do not include space life sciences to any measurable extent, despite the challenges of eradicating deadly diseases ravaging the continent and inproving the quality of life on the countinent. 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. A synergistic, comprehensive approach for introducing space life sciences research and educational outreach in Africa has been presented. 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 study highlights successful models, drawn from IAA-affiliated organizations from across the globe and suggests some potential international partners who could provide expertise to design and support the development of space life sciences research and educational outreach in Africa.

The study also 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 collective recommendations of the IAA-African regional conferences were reviewed, 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 knowledge development. The study 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.

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