IAC-13-E3.4.1

COMMON HORIZONS: ASSURING SPACE SUSTAINABILITY IN THE SERVICE OF ACHIEVING SUSTAINABILITY ON EARTH

Scott Fisher
International Space University (ISU), Australia, scott.fisher@spacegeneration.org

Scott Dorrington
ISU, Australia, scott__dorrington@hotmail.com
Clementine Fox
ISU, Australia, clementinefox1@gmail.com
Advait Kulkarni
ISU, India, contactadvait@gmail.com
Brian Lim
ISU, Singapore, brian@thinkntinker.com
Alejandro Ortega
ISU, Spain, ao2v07@googlemail.com
Miguel Sampaio
ISU, Brazil, miguelangelo.dss@gmail.com
Ray Williamson
Secure World Foundation, USA, rwilliamson@swfound.org

Many of the nearly one thousand satellites in orbit about Earth currently provide tangible social, scientific, and economic benefits to billions of individuals throughout the globe. From satellite position, navigation and timing to weather forecasting, from treaty verification to the management of Earth's resources, international dependence on the benefits derived from systems in outer space has steadily expanded and will continue to grow.

Yet the continued enjoyment of the benefits of the use of outer space is anything but guaranteed. The space environment is threatened by, among other things, increasing amounts of orbital debris and the effects of space weather.

Even as the sustainability of outer space is threatened, space systems are becoming ever more critical in the effort to ensure long term sustainability for humankind on Earth. A sustainable space environment is therefore crucial to humankind's ability to assure a sustainable Earth environment. As a result, space sustainability has become a major focus of interest among the space-faring nations of the world.

This paper presents the results of a study conducted by a team of 37 students from 11 countries focused on examining the use of space systems to support the sustainability of Earth and the issues surrounding the sustainability of space activities into the future.

The project team considered sustainability and outer space technologies from the perspective of the developing space countries of the 'Global South', defined as the countries south of the Tropic of Cancer. Three recommendations were ultimately formed to address these issues. First, increasing the involvement of Global South nations in international organisations focussed on space sustainability; second, raising public awareness of space sustainability; and third, the establishment of a Global South Space and Earth Sustainability Prize Foundation.

I. INTRODUCTION

Common Horizons presents the results of a study conducted by a team of 37 students from 11 countries during the International Space University's (ISU) Southern Hemisphere Summer Space Program (SHS-SP) in 2013. It examines the use of space systems to support the sustainability of Earth, and the issues surrounding the sustainability of space activities into the future.

This paper seeks to promote awareness of the link between sustainability on Earth and the sustainability of space. Space sustainability is the ability of all humanity to continue to use outer space for peaceful purposes and socioeconomic benefit over the long term[1]. This paper aims to create awareness of the importance of space sustainability through highlighting humanity's ever increasing dependence on space activities, risks to these activities, and the results their loss will have on society.

In modern society we all benefit from access to hundreds of satellites that provide navigation, weather forecasting, land management, telecommunications and other valuable services. Satellite capabilities are a fundamental part of the strategy for addressing the eight Millennium Development Goals (MDGs) as highlighted by the United Nations (UN). Thus, to ensure our Earth is sustainable, a sustainable space environment is crucial. *Common Horizons* emphasises this important link.

A major focus of this paper is the Global South, defined as "all regions and States aligned with the Tropic of Cancer and all those below that latitude"[2]. The Global South is of particular importance because many of the nations of the region are only now developing space capabilities.

Section II of this paper will detail how space systems are currently used for Earth sustainability. Section III will subsequently introduce the link between the sustainability of the Earth and outer space environments. Finally, Section IV will describe the recommendations made by the students of the ISU SHS-SP 2013 to policy makers in an attempt to achieve a sustainable space, for a sustainable Earth.

II. SPACE SYSTEMS FOR EARTH SUSTAINABILITY

A number of problems face humanity and the Earth. Natural disasters, climate change, and access to clean water are just a few of the serious issues that pose a threat to our world and our future. Space technologies such as remote sensing, Position Navigation and Timing (PNT), and communication satellites allow us to monitor these threats, provide awareness of how the sustainability of the world is affected and contribute to improving the chances of achieving sustainability. Industry should be challenged to assist in this process, not only because it has a social responsibility to assist such efforts, but because innovative business models can take economic advantage of carrying out their activities in a sustainable manner. This section will discuss how space-based systems assist in the monitoring and mitigation of sustainability issues that face the world.

II.I Climate Change

According to the Secretary-General of the United Nations, climate change is the "defining challenge of our time"[3]. The Intergovernmental Panel on Climate Change warns[4] that climate change has detrimental effects on long-term global economic growth, as well as posing a serious threat to the survival of coastal communities. Satellites are used to monitor climate change and the effect climate change has on the environment. They are able to provide a unique and critical global perspective that is vital to our understanding of the current climate situation[3].

In order to monitor the Earth's climate and its changes over time, a set of climate variables are measured from various instruments around the world. The Essential Climate Variables are a set of 50 geophysical variable types that are associated with climate change[5]. These variables give a means of quantifying the state of the Atmospheric, Oceanic, and Terrestrial domains. Satellite observations make a significant contribution to 25 of these 50 Essential Climate Variables.

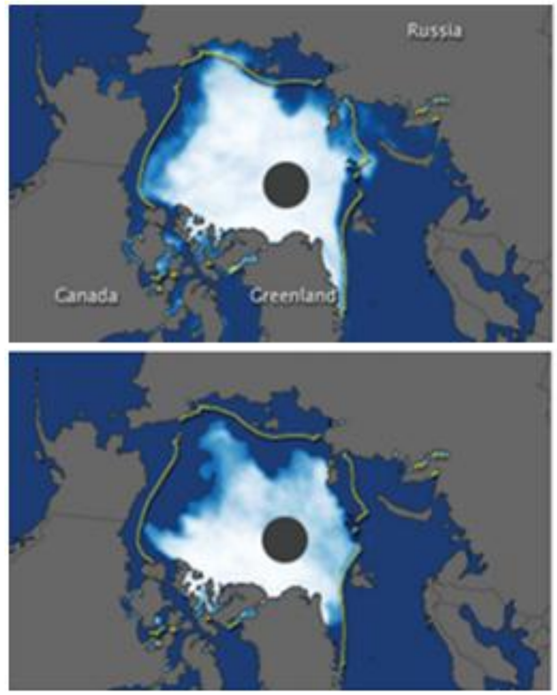

Fig. 1: Satellite monitoring of polar ice caps: Sept. 1999, top, Sept. 2010, bottom[6]

Images depicting the overall decline in Arctic sea ice since monitoring began in 1978, have made a significant contribution to raising public awareness and highlighting the problem of climate change (Figure 1). It is important for governments, scientists, and the general public to be aware of the current issues surrounding climate change, so that mitigation procedures at international, national, and local levels can be implemented. Information collected from satellites in conjunction with terrestrial-based systems observing the Essential Climate Variables have helped raise public awareness.

Two examples of these space applications are the Orbiting Carbon Observatory 2 (OCO-2) and ARGOS. OCO-2, due to launch in 2014, will provide global measurements of atmospheric carbon dioxide. It will combine this data with meteorological data to characterise the sources and sinks of greenhouse gasses[7].Comparatively, ARGOS is a satellite system that relays position and sensor data from a variety of probes all around the world. Thousands of ocean buoys linked into the ARGOS network have previously allowed studies of El Niño and La Niña effects, which define Southern Hemisphere weather, notably drought and flood seasons in Australia[8], and monitored sea level temperature. Such studies have provided evidence that the ocean has been warming over the past 20 years[9].

Case Study: IBUKI Greenhouse Gas Observing Satellite (GOSAT)

The Greenhouse gas Observing SATellite (GOSAT), developed by the Japanese Aerospace Exploration Agency (JAXA), provides scientists with important data regarding current atmospheric conditions. The GOSAT project monitors carbon dioxide density in the atmosphere, using up to 56,000 observation points. This information provides an improved dataset for analysis on the previously limited and poorly distributed number of terrestrial carbon dioxide observation points around the globe. Data from the GOSAT project is available to scientists and plays an important role in developing an improved understanding of carbon dioxide emissions and possible mitigation techniques[10].

GOSAT has confirmed that satellite data can reduce uncertainties in current carbon dioxide flux estimates by up to 40 percent when used in conjunction with data collected by ground-based monitoring systems. More reliable climate change predictions and more effective mitigation techniques are an expected outcome of these improved measurements. It can now be determined whether regions that are not covered by the ground-based monitoring network are net sinks or sources of carbon dioxide[11].

II.II Natural Disasters

In the last decade, natural disasters have increased in frequency and severity with over 4,130 disasters causing over one million deaths and US$1.2 trillion worth of damage[12]. Disaster impacts are magnified by the rapid growth of both world population and population densities near coastal areas, which are prone to flooding and cyclones[13].

Space applications play a vital role in mitigating the impact of disasters. Estimates suggest that, in Australia alone, between A$100 million and A$200 million per annum is saved by utilising remote sensing data[14].

Space-based communications systems are extremely useful in disaster response. While ground infrastructure is often damaged, satellite systems remain unaffected and are still available for use, enabling reliable communication links between relief workers[15]. PNT satellite systems can provide accurate and fast positioning services for emergency response teams to coordinate volunteers, materials and financial aid. Remote sensing applications may also be helpful in identifying areas at risk of natural disasters, and enabling advanced planning to reduce the harm those disasters may cause.

Case Study: Queensland Floods (Australia)

Following years of drought and restrictions on water usage, December 2010 was the wettest month in Queensland's recorded history. Almost 80 percent of Queensland experienced heavy rains, which caused extensive flooding. Thirty-six people perished, A$5 billion of public and private infrastructure was damaged, and 2.5 million people were affected[16]. Queensland's management of the 2010-11 floods received worldwide acclaim. Satellite services significantly aided the recovery action carried out by the people of Queensland in managing this disaster[17].

More than 600 satellite images acquired by Geoscience Australia were used to show the location of flood affected land[18]. This satellite data assisted in the production of maps that showed the inundated land. These were used for emergency response deployment, early impact assessment, redeployment of government services, and guiding natural disaster relief. The effectiveness of the response demonstrated how vital remote sensing applications are to emergency management[19].

Many of the satellite images used in the flood response came through the International Charter for Space and Major Disasters (Disaster Charter), which was activated to assist recovery. The Disaster Charter is an international agreement used to enable the sharing of satellite data following a major disaster. Queensland has not been alone in seeking the Charter's help. The Charter has been activated more than 366 times by over 100 countries[20]. "Each member agency has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property"[21].

II.III Urbanization

Increasing population displacement from rural to urban areas has led to an ever more urbanised globe. The five million people, on average, who move to urban regions every month have created informal settlements that lack proper planning and infrastructure[22]. These settlements often have poor sanitation and little access to health and education facilities[23]. The contrast between these informal settlements and planned residential areas can be clearly seen in Figure 2.

The Sangli and Pune regions of India are home to highly populated, informal settlements that are without basic infrastructure and services. The lack of up to date information about the people and physical conditions of such informal settlements is a major obstacle to making improvements in the quality of life[24]. Informal settlements benefit from remote sensing, where spatial correlations between areas of land cover and land use patterns are used to estimate the vulnerability to natural disasters in order to improve quality of life[25].

Fig. 2: Slums in Caracas, Venezuela[26]

The Non-Governmental Organizations (NGOs) Baandhani and Shelter Associates, for example, have used remote sensing technology available from Google Earth to demonstrate to local governments that informal settlements are an urgent problem[27]. As a consequence the Indian government established the Rajiv AwasYojana (RAY) policy, which aims to promote an informal settlement-free India. This policy now ensures that future urban developments will consider the equity of informal settlements and help to mitigate the shortages of housing across India. The policy has been instrumental in the relocation of twenty-seven informal settlements to residential areas of Sangli where living conditions have improved tremendously[28].

II.IV Agriculture and Water Usage

A growing world population will place stress on existing social support systems, such as food supplies, water, and power. Estimates show that by the year 2030 the global population will reach 8.3 billion people, with a 35 percent increased food demand[29].

Satellite applications contribute to effective and efficient farming practices through remote sensing data. Such data provides information about crop status and health. For example, remote sensing data can improve productivity by identifying the density of vegetation in crops, where water is lacking or abundant, and where crops are under stress as shown in Figure 3[30].

Satellites, such as NASA's GRACE mission, provide analysis of the replenishment and depletion of ground water aquifers. This data can be used to assist the management of water resources and provide advanced warnings of drought[31]. As an example, thermal imaging used in the Sultante of Oman shows areas where ground water causes surface cooling. This information is used to provide for the area's growing population[32].

PNT is another satellite application that allows farmers to increase productivity. Farm machinery can be automated through computers using PNT technology. With the data collected from GPS satellites and remote sensing satellites, the machines are able to harvest, supply water, fertilise, and sow fields of vegetation with precision and efficiency far beyond the capabilities of human operators[33].

II.V Health and Education

The UN's MDGs are crucial to the long term development and sustainment of humanity and Earth. Universal healthcare and education underpin half of these goals and are issues commonly faced in the Global South. Over two-thirds of the world's 793 million illiterate adults are found in only eight countries, all of which are in the Global South (Bangladesh, China, Egypt, Ethiopia, India, Indonesia, Nigeria and Pakistan)[34]. Sub-Saharan Africa accounts for 11 percent of the world's population, but bears 24 percent of the global disease burden[35]. Therefore, health and education through tele-reach is a critical need for communities of the Global South.

Tele-reach is described as "technologies and applications which allow remote presence, participation, interaction or control"[36]. It is a valuable tool for the Global South to address these issues through tele-medicine and teleeducation. Tele-reach services increase the quality of life in developing nations by improving

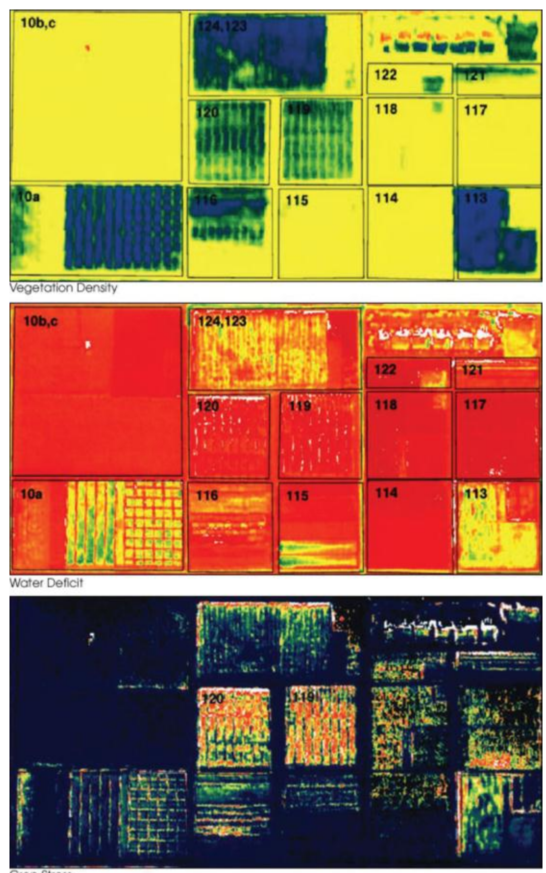

Fig. 3: View of crops from three different remote sensing services[30]

education, health, governance, food security, law, and commerce[36].

Tele-medicine provides doctor-patient interaction across vast distances to medical consultants[37]. In India, for example, 75 percent of qualified doctors are found in urban centres, yet the majority of the population resides in rural areas[38]. In most cases, the lack of physical doctor-patient contact does not prevent proper treatment. A study by Intel World Ahead found that "99 percent of the time, people who are unwell do not require an operation and do not need physical contact with a doctor"[39].

Tele-education enables rural students to connect with universities and schools. The Indian Space Research Organization (ISRO) has set up almost 500 Village Resource Centres (VRC) across India, with the installation of another 2000 currently planned[40, 41]. These centres provide otherwise unattainable education in the form of electronic libraries and information centres to numerous rural communities around the country at the relatively minimal cost of approximately US$10,000 per terminal[42].

Case Study: Pan-Africa e-Network

The Pan-Africa e-Network Project is a cooperative venture between India and the African Union to link India and the African states via satellites and fibre optics, to provide remote electronic services such as tele-health and tele-medicine. The project is being funded with US$117 million from the Indian Government[43].

As of 2013, 47 of the 53 African Union states are signatories to the project[43]. The network is working to provide uniform healthcare and education where needed, which is essential to the development and the prosperity of the partner nations.

The project currently links over 149 sites, including universities, hospitals, and learning centres in regional and metropolitan areas as shown schematically in Figure 4. Ongoing medical training programs ensure that doctors and nurses are kept up to date with the latest knowledge. Around 1,127 sessions had been held across participating regions as of February 2011[43]. The tele-education service connects universities (including seven in India and five in Africa) and education hubs, provides online and offline services to students[44]. Educational materials are supported by established universities, such as the University of Delhi, which continues to develop a portfolio of high quality e-resources[45].

The project provides a flexible, powerful, and modern working example of how satellite technologies can be integral to improving and sustaining education and health systems across a range of countries, communities, and cultures.

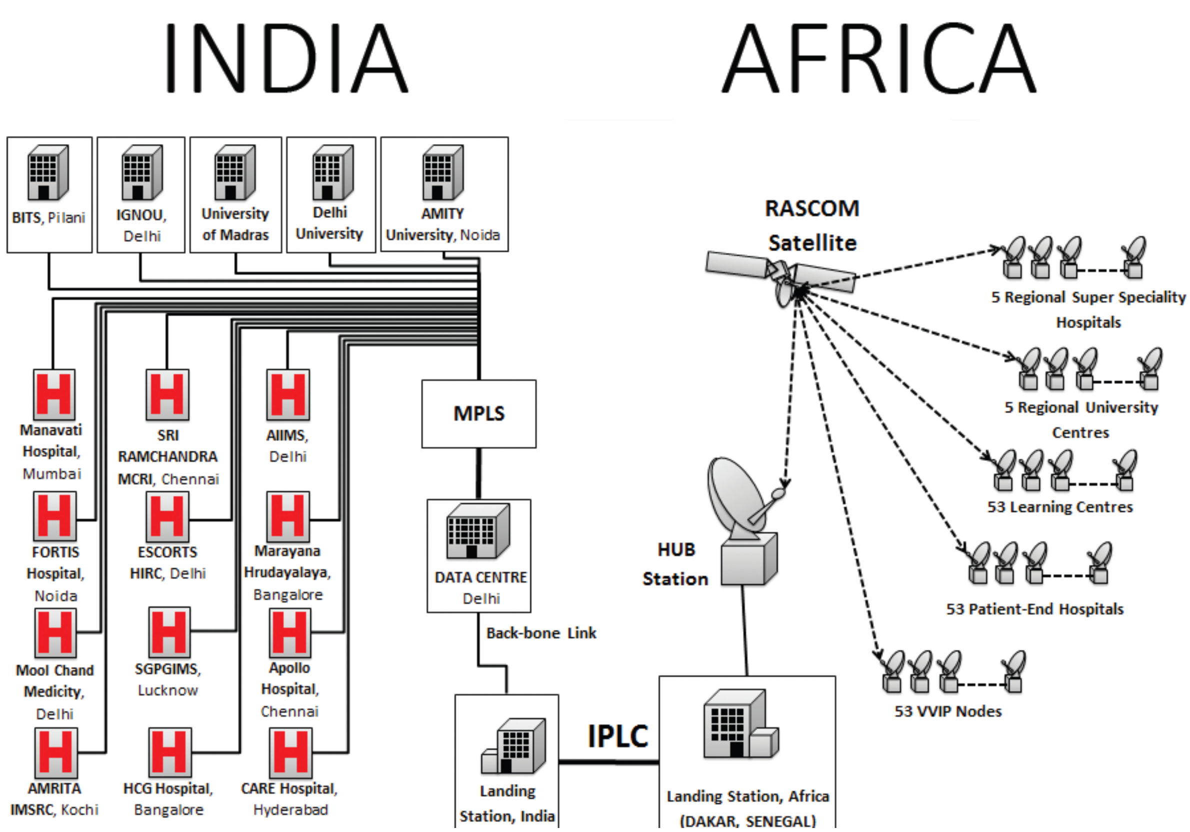

Fig. 4: Network architecture of Pan African e-Network project

III. THE EARTH AND SPACE RELATIONSHIP

Space sustainability is an Earth issue. The increasing use of satellite applications and services to benefit our lives has resulted in society becoming increasingly dependent on these services to support our globalising world and aid sustainable development of Earth. The significance of understanding the dependence of Earth on space capabilities is crucial to ensure space sustainability.

The sustainability of the near-Earth space environment is at risk and it is critical that we ensure this environment is used in a sustainable manner to allow future generations to benefit from an ever increasing range of space technologies. Use of these technologies is under threat from increases in orbital debris, overcrowding of certain orbits, limited availability of radiofrequencies and the hostility of space weather.

Orbital debris is "man-made objects in orbit that are not, or are no longer, carrying out a useful function"[46]. There are serious implications for the sustainability of space if orbital debris continues to be generated at current rates, which could result in the Kessler Syndrome. This theory proposes that as more debris is created, the likelihood of on-orbit collisions that would cause additional debris increases, thus causing a cascading affect. This could lead to the establishment of a ring of debris around the Earth making the space environment inaccessible for all people of the world[47].

A further issue is the limited nature of satellite orbital slots. With an increasing number of satellites entering operation, the available space for specific orbits is diminishing. Orbits such as the GEO and the sun-synchronous polar orbits serve unique functions and it is paramount that they are managed efficiently for future use. Coordination among States is currently the only mechanism to regulate the launch and operation of satellites in Earth orbit.

Space weather also constitutes a threat to the space and Earth environments. It consists of the interaction of energetic particles and radiation ejected from active regions of the Sun, with the Earth's magnetic field. This interaction can disrupt spacecraft operations by causing failures to the onboard electronics that control critical systems such as communications and navigation. In severe cases satellites may be rendered non-operational, which contributes to space debris. Space weather also has a direct effect on Earth. It can produce dangerous amounts of radiation at high latitudes and high altitudes as well as damage electrical infrastructure on Earth.

On a global risk scale, threats to space sustainability were considered by the World Economic Forum in 2012 and 2013 to have a little impact on society and the planet[48, 49]. Society needs to realise the humanitarian and utilitarian value of satellite applications. Public awareness and STEM (science, technology, engineering and mathematics) education, emphasising our increasing reliance on satellite technologies, are important in establishing the crucial relationship between Earth and space.

III.I Education

Education is key to raising awareness about the relationship between Earth and space activities. This can be encouraged through Science, Technology and Mathematics (STEM) education. STEM education focused on space activities can lead to a clearer understanding and appreciation of the relationship between Earth and space activities. Space agencies, including NASA, ESA, JAXA, and ISRO all promote space activities using educational media and other interactive programs.

In contrast, the lack of STEM education can create obstacles to progress within this sphere. For this reason, increased access to educational resources is essential to inspire and engage public interest. Not only can education and public awareness ensure the public is informed of the relationship between Earth and space, it can also ensure that a new generation of STEM experts are prepared to lead in sustainability efforts in their global and local economies. In order for the Global South to take an active role in developing sustainable space solutions, education and public awareness are key.

The nations of the world need to continue to encourage the development of educational programs and initiatives which promote space sciences, as well as adapt existing educational activities to engage the younger generation.

III.II Public Awareness

In order for countries to invest in space activities for their own benefit they must understand those benefits and the role they have in improving their standard of living and economic growth. Social media outlets are tools to spread public awareness on space sustainability by providing a forum for people to connect. Social media can play a strong role in promoting awareness of the role space plays in the modern world.

The significance of space applications for humankind can also be seen through humanitarian efforts worldwide. Currently more than one billion people living below the poverty line rely on space based technologies for aid, basic education and health services[50]. Without access to space applications, humanitarian programs based on the MDGs, such as tele-education and tele-health, would not be possible. Space applications contribute to the progress of achieving the UN MDGs[51]. For this reason, space sustainability is crucial to ensure the continued progress of these goals.

Satellite technology also plays a major role in the economies of developed nations in the Northern Hemisphere. The European Commission has estimated that between six and seven percent of the European Union's Gross Domestic Product is reliant on PNT space technologies (€800 billion)[52]. In acknowledging this dependence, the EU has developed its own global navigation satellite system, Galileo, which is anticipated to generate between €60 and €90 billion of economic and social benefits over the next 20 years[52]. In the US the main industry sectors that rely on PNT are: delivery services, utilities, banking and financial management, agriculture, and communications[53]. The sectors reliant on space technologies contribute an estimated total of 9.5 percent ($1,342Bn) to the US Gross Domestic Product[53]. The link between the economic sector and space applications highlights a vested interest in ensuring the development of a sustainable space future.

In Africa 80 percent of internet[54] and 60 percent of the 500 million cell phones are dependent on satellites[55]. The growing population depends on satellite technology because of a lack of terrestrial infrastructure, meaning that outer space is the only medium for sufficient broadcast of tele-reach services[56]. Internet use requires high bandwidth, and satellite transmission is the only method capable of providing this service to most rural areas[57].

In South America, Brazil has rough terrain and dense forests, resulting in difficult and expensive terrestrial telecommunication networks. Issues of deforestation, tracking the movements of drug traffickers, and the monitoring of crops and water has led to the introduction of a domestic space program and satellite applications. Domestic satellite technology will improve Brazil's autonomy and sovereignty[58]. In Argentina, the National Space Activities Commission (CONAE) and the commercial company INVAP promote and build satellites for scientific missions, including remote sensing missions such as the SAC-E to collect data for water monitoring and the agriculture industry[59].

In Southeast Asia, Indonesia, an archipelago with 6000 inhabited islands, terrestrial communications infrastructure is expensive to build. Until the introduction of its first domestic satellite, Palapa, in 1976, Indonesian citizens were using unreliable HF radio communications. The introduction of modern satellite technology revolutionised domestic communication, improving coordination in agricultural and economic activities[60].

Society has become increasingly dependent on satellites for the services they provide. How the Global South manages its use of space resources will contribute to the continuity of these services that benefit global humanity.

IV RECOMMENDATIONS

During the course of the ISU SHS-SP three recommendations to ensure the sustainability of the Earth and Space environments were formed. This section describes both the details of the recommendations and their rationale for being chosen.

IV.I Recommendation 1

Increase involvement of Global South nations in international organisations focussed on space sustainability

Emerging space States of the Global South will want to use outer space to support their own efforts at achieving sustainability. These States should hence involve themselves in the process of developing the Guidelines and Best Practices for the sustainability of space activities. This involvement is best achieved through participating in pre-existing organisations and committees, such as the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) Long Term Sustainability of Space Activities (LTSSA) Working Group.

With 74 members, the UNCOPUOS is one of the largest committees in the United Nations. Good representation has been achieved from nations of the Global South, with over 36 member States below the Tropic of Cancer. In 2010 the UNCOPUOS established the LTSSA Working Group, with four Expert Groups each focussing on different, yet pressing space sustainability issues. Only a small number of Global South nations are directly involved in these groups, specifically South Africa as LTSSA Chair and Mexico and Australia chairing the LTSSA, Expert Group A and Expert Group D respectively.

It is important that developing space nations take part in these and other discussions about space sustainability. They face different circumstances compared to spacefaring nations, and hence must approach the issues of space sustainability from a different angle. For example for launch vehicles, it is more difficult to implement controlled upper stage re-entry for space debris mitigation when the state does not yet have a functioning launch vehicle. On the other hand, nations of the Global South have the opportunity to ensure that their entire programs are sustainable from the start. Some of them also have unique geographical advantages that can contribute to space sustainability, particularly in terms of Space Situational Awareness.

Widespread involvement in groups such as the LTSSA would ensure that the emerging space States of the Global South both remain engaged with space sustainability on the global scale, and have a means to affect international policy change with respect to their differing needs and requirements.

The emerging space nations of the Global South however should not limit themselves to being active members of the LTSSA. There are a number of other international groups with a focus on space sustainability. Potential groups that emerging space nations should participate in are the UN Conference on Disarmament, the ITU, and the UN General Assembly Group of Governmental Experts (GGE) on Transparency and Confidence-building Measures for Space Activities.

IV.I Recommendation 2

Raise Public Awareness of Space Sustainability

The general public, especially the youth, should be made aware of the current trends and problems we are facing in the world of space activities. These challenges cannot be resolved quickly, or without the skill and knowledge given to the next generation.

Current activities such as Yuri's Night and World Space Week are great outreach activities, and already create more awareness about the space industry and issues around the use of space. Such events can be leveraged even further to create more awareness around space activities.

Chris Hadfield, recent Commander of the International Space Station, demonstrated the power of social media in educating the public about space. His constant presence on the Social media outlets Twitter and Facebook has generated a large number of loyal followers, with over 900,000 followers on twitter, around the world and has thrust space back into the spotlight.

A strong marketing campaign through social media channels is the norm for the engagement of the youthful demographics. Social media provides space agencies the ability to statistically track in fine grain detail users' behaviours and responses to the communication put out to them. This allows organizations to conduct small tests to fine tune the messaging and response to improve user engagement. This is a methodology referred to as Growth Hacking.

Tools for the management of Social Media as a centralised platform simplify the process of monitoring and tracking across different platforms. Hootsuite.com is such an example of Social media Aggregation, and simplifies the reporting and management aspects of social media.

Occasionally Google will release a new Google Doodle, which is a satire of the Google's logo to highlight something significant in relation to the date. The Google doodle has being successful at raising awareness for a variety of issues. A novel way of engaging the public would be the creation of a Google Doodle, designed to promote the awareness of Space Sustainability, as part of a large movement around education users in Space sustainability.

IV.I Recommendation 3

Establish a Global South Space and Earth Sustainability Prize Foundation

A series of prizes are proposed that act as incentives to encourage innovation, collaboration, and investment in space and Earth sustainability capabilities in the Global South. Throughout history, prizes and competitions have been used to spur innovative solutions to many different challenges, such as the 1927 $25,000 Orteig prize, awarded to Charles Lindbergh for flying across the Atlantic Ocean. The technical demonstration and awareness raised by this feat is believed to have been a major contributor to creation of the modern aviation industry.

A recent example of the use of prizes to spur innovation is the Ansari X Prize. In the mid-1990s, Peter Diamandis proposed and the X-Prize Foundation implemented the $10 million prize, challenging industry to demonstrate the capability to complete two sub-orbital spaceflights within a two-week period, carrying the equivalent of three people. In 2004, Burt Rutan's Scaled Composites won the prize using its SpaceShipOne craft. Since the completion of the Ansari X-prize, several companies have moved forward with the development of technologies to regularly launch tourists into space. This prize approach has successfully demonstrated the establishment of a nascent industry, and is an effective model to help solve major challenges.

The aim of the Global South Space and Earth Sustainability Prize Foundation would be twofold; the cultivation and growth of new fledgling space and space related industries and the development of space proven technologies. Possible commercial opportunities that could be cultivated include the collection, analysis and dissemination of space situational awareness data, space based sensors for detecting space debris, novel methods and services for active debris removal, and the manufacture and provision of 'green fuels' for launch vehicles. The prizes would also aid in the development of space proven technologies, by providing an impetus for investors to invest in their development. One of the major issues in the space industry is the minimisation and mitigation of risk. Once a new technology has been proven in space, it is more likely to be adopted by the wider space community. Prize guidelines would assist in validating market potential for the technology and prove the value of commercial investment. The prizes would provide a motivation for the development and space verification of new hardware.

The proposed series of prizes could be set up under the administration of a single non-governmental foundation to develop solutions for the major technical challenges that face Space and Earth sustainability. The funding for this foundation would be sought from governments, corporate entities, research institutions, non-governmental organizations and private individuals. All of these investors have potential vested interest in ensuring space sustainability, because it provides a means of creating a suitable jobs program through a sustainable Earth initiative.

Examples of sustainable space and Earth issues that might be included would be active debris removal, more efficient use of the radio-frequency spectrum, or innovative approaches to locating ground water in arid zones. Criteria for judgement of these technologies could include profitability and repeatability as well as the inherent sustainability of the activity. If profitability and repeatability can be demonstrated by the recipient of the prize, interest from other commercial entities should arise.

Given the large number of developing spacefaring states in the Global South, we recommend that the prize be focused on initiatives based in this region. A regional focus could also promote collaboration between these developing space states and their industries. Groups from outside the Global South are not excluded from the prize, but are encouraged instead to participate through collaboration with other companies, organizations, and countries in the region. This participation could promote industry growth, capability development, and encourage expertise and technology transfer to States of the Global South. Participants must be able to demonstrate that the majority of the economic benefits of their operations return to Global South.

As our world develops, our reliance on space systems will grow ever larger. The technical challenges of sustaining the space environment will require innovative solutions. It is, therefore, an opportunity as well as a responsibility for the Global South to contribute to meeting these challenges. A Global South Space and Earth Sustainability Prize Foundation will provide an avenue both to tackle these challenges and develop the fledgling space industries of the region.

V. CONCLUSIONS

Space sustainability and Earth sustainability are inexorably linked. Space technologies support numerous sustainable initiatives on Earth, including food and water management, natural disaster response, medicine and health, urban planning and climate change analysis. On the other hand, the support and investment in space sustainability remains tied to public education, interest and support. These challenges need to be met concurrently to ensure a sustainable future for humanity.

This paper has provided three recommendations to help address these issues. First, increasing the involvement of Global South nations in international organisations focussed on space sustainability; second, raising public awareness of space sustainability; and third, the establishment of a Global South Space and Earth Sustainability Prize Foundation.

These recommendations will help to ensure that the Global South, and the international community at large, can meet the pressing and intermingled issues of Earth and Space sustainability.

VI. ACKNOWLEDGEMENTS

The authors of this report would like to thank the International Space University and the University of South Australia for the organisation and hosting of the Southern Hemisphere Summer Space Program, held in Adelaide in January 2013, all sponsors and supporters of the program, as well as all of the program participants who contributed to the creation of the White Paper *Common Horizons* which formed the basis for this paper.

[1] Secure World Foundation, 2013. *Space Sustainability 101* [Online]. Available: http://swfound.org/space-sustainability-101/

[2] Levander, C. and Mignolo, W., 2011. Introduction: The Global South and World Dis/Order, *The Global South*, 5 (1), pp. 1-11.

[3] World Meteorological Organization, 2011. *Space and Climate Change: Use of Space-Based Technologies in the United Nations System* [online]. Geneva, Switzerland. Available from: <http://www.wmo.int/pages/prog/gcos/Publications/UNOOSA_WMO_brochure.pdf>

[4] Intergovernmental Panel on Climate Change (IPCC), 2007. *Climate Change 2007: Synthesis Report Summary for Policymakers* [online]. Valencia, Spain. Available from: <http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf>

[5] ESA, 2010. *Earth from Space: Giant wind farm opens* [online]. European Space Agency Observing The Earth. Available from: <http://www.esa.int/Our_Activities/Observing_the_Earth/Earth_from_Space_Giant_wind_farm_opens>

[6] NASA, 2012. "World of Change: Arctic Sea Ice" [online]. Available from: <http://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice.php>

[7] NASA, 2008. *Orbiting Carbon Observatory* [online]. Available from: <http://www.nasa.gov/mission_pages/oco/mission/index.html>.

[8] Mcphaden, M.J. *et al*, 1998. The Tropical Ocean-Global Atmosphere observing system: A decade of progress, *Journal of Geophysical Research*, 103, pp.14,169-14,240.

[9] Levitus, S., *et al*, 2010. World Ocean Heat Content and Thermosteric Sea Level Change (0-2000m), 1955-2010, *Geophysical Research Letters*, 39 (10).

[10] Japan Aerospace Exploration Agency (JAXA), 2012. *Overview of the "IBUKI" (GOSAT)* [online]. Available from: <http://www.jaxa.jp/countdown/f15/overview/ibuki_e.html>.

[11] National Institute for Environmental Studies, 2012. *On the Public release of carbon dioxide flux estimates based on the observational data by the Greenhouse gases Observing SATellite* [online]. Available from: <http://www.gosat.nies.go.jp/eng/result/download/GOSAT_L4_Release_20121205_en.pdf>.

[12] Committee on Earth Observation Satellites (CEOS), 2012. *Committee on Earth Observation Satellites (CEOS)* [online]. Available from: <http://ceos.org/>.

[13] Geoscience Australia, 2007. *Natural Hazards in Australia: Identifying Risk Analysis Requirements* [online]. Available from: <http://www.ga.gov.au/webtemp/image_cache/GA10757.pdf>.

[14] ACIL Tasman, 2010. *The economic value of earth observation from space* [online]. Geoscience Australia, Canberra. Available from: <http://www.ga.gov.au/webtemp/image_cache/GA19989.pdf>.

[15] United Nations, 2012. *What We Do: Emergency Communications for Disaster Relief Deployment Archive* [online]. Available from: <http://www.unfoundation.org/what-we-do/legacy-of-impact/technology/disaster-relief-deployments/>.

[16] Queensland Government, 2011. *Operation Queenslander: The State Community, Economic and Environmental Recovery and Reconstruction Plan* [online]. Queensland Government. Available from: <http://www.qldreconstruction.org.au/publications-guides/reconstruction-plans/state-plan>.

[17] Arklay, T.M. 2012. *Queensland's State Disaster Management Group: An all agency response to an unprecedented natural disaster* [online]. Australian Government: Attorney-General's Department, Canberra. Available from: <http://www.em.gov.au/Publications/Australianjournalofemergencymanagement/Currentissue/Pages/AJEMvolume27%20no%203/QueenslandsStateDisasterManagementGroupAnallagencyresponsetoanunprecedentednaturaldisaster.aspx>.

[18] Geoscience Australia, 2007. *Natural Hazards in Australia: Identifying Risk Analysis Requirements* [online]. Available from: <http://www.ga.gov.au/webtemp/image_cache/GA10757.pdf>.

[19] Hudson, D. and Mueller, N., 2013. *Satellite imagery assists flood emergency response and recovery* [online]. Geosciences Australia. Available from: <http://www.ga.gov.au/ausgeonews/ausgeonews201106/satellite.jsp>.

[20] International Charter: Space and Major Disasters (International Charter), 2013a. *Charter Activations (disaster types)* [report].

[21] International Charter: Space and Major Disasters (International Charter), 2013b. *International Charter: Space and Major Disasters* [online]. Available from: <http://www.disasterscharter.org/home>.

[22] United Nations Population Fund, 2007. *State of World Population 2007: Unleashing the Potential of Urban Growth* [online]. Available from: <http://www.unfpa.org/webdav/site/global/shared/documents/publications/2007/695_filename_sowp2007_eng.pdf>.

[23] Teriman, S. Yigitcanlar, T. and Mayere, S., 2009. *Urban growth management for sustainable urbanization: examples from Asia-Pacific city regions*. In: Proceedings of the International Postgraduate Conference, 5-6 June 2009, Hong Kong Polytechnic University, Hong Kong.

[24] Bouissou, J., 2012. With Google Earth, India Can No Longer Hide Its Shantytowns and 'Slumdogs'. *Time World*, [online]. Available from: <http://www.time.com/time/world/article/0,8599,2110387,00.html>.

[25] Eva, J.E.M., 2010. *Legazpi Plan 2020: Urban Redesigning of a Safer Legazpi City with Remote Sensing and GIS Software* [online]. Diliman, University of the Philippines. Available from: <http://www.academia.edu/506689/Legazpi_2020_Urban_Redesigning_of_Legazpi_City_with_Remote_Sensing_and_GIS_Software>.

[26] DigitalGlobe, 2013. *Caracas Slums, Venezuala* [online]. Available from: <http://goo.gl/maps/7UoKi>.

[27] Joshi, P., *et al*, 2002. Experiences with surveying and mapping Pune and Sangli slums on a geographical information system (GIS), *Environment & Urbanization* [online journal], 14 (2). Available from: <http://www.ucl.ac.uk/dpuprojects/drivers_urb_change/urb_governance/pdf_comm_act/IIED_Joshi_Hobson_Pune_GIS.pdf>.

[28] Ministry of Housing and Urban Poverty Alleviation, 2011. *Rajiv Awas Yojana…Towards a Slum-Free India* [online]. Government of India. Available from: < http://mhupa.gov.in/ray/02-RAY-Guidelines.pdf>.

[29] National Intelligence Council, 2012. *Global Trends 2030: Alternative Worlds* [online]. Available from: <http://globaltrends2030.files.wordpress.com/2012/12/global-trends-2030-november2012.pdf>.

[30] NASA, 2001. *Precision Farming* [online]. NASA Earth Observatory. Available from: <http://earthobservatory.nasa.gov/IOTD/view.php?id=1139>.

[31] Young, S., 2010. Satellite data provide a new way to monitor groundwater aquifers in agricultural regions. *Stanford News*, [online]. Available from: <http://news.stanford.edu/news/2010/december/agu-water-imaging-121310.html>.

[32] El-Baz, F., *et al*, 2000. *Using Satellite Images for Groundwater Exploration in the Sultanate of Oman* [online]. Boston University Center for Remote Sensing. Available from: <http://www.bu.edu/remotesensing/research/completed/oman-groundwater/>.

[33] National Coordination Office for Space-Based Positioning, Navigation, and Timing, 2012. *Agricultural Applications* [online]. Available from: <http://www.gps.gov/applications/agriculture/>.

[34] UNESCO Institute for Statistics, 2012. *The Official Source of Literary Data* [online]. Available from: <http://www.uis.unesco.org/literacy/Pages/default.aspx?SPSLanugage=EN>.

[35] International Finance Corporation, 2013. *The Business of Health in Africa* [online]. World Bank Group. Available from: <http://www.unido.org/fileadmin/user_media/Services/PSD/BEP/IFC_HealthinAfrica_Final.pdf>

[36] International Space University: Southern Hemisphere Summer Space Studies Program 2012 (ISU SHS-SP 12), 2012. *Reach 2020: Telereach for the Global South.* Adelaide, South Australia.

[37] World Health Organization, 2010. *Telemedicine: Opportunities and developments in Member States. Report on the second global survey on eHealth* [online]. Available from: <http://www.who.int/goe/publications/goe_telemedicine_2010.pdf >.

[38] Indian Space Research Organization (ISRO), 2005. *Telemedicine healing touch through space: Enabling Specialty Healthcare to the Rural and Remote Population of India* [online]. Available from: <http://www.isro.org/publications/pdf/Telemedicine.pdf>.

[39] Intel, 2009. *TeleHealth – Remote Diagnostics: Using the Telehealth model to improve healthcare delivery to citizens in rural areas through remote diagnostics* [online]. Available from: <http://www.intel.com/Assets/PDF/casestudies/WA-322096.pdf>.

[40] Mercado, C.S. and Ravichandra Rao, I.K., 1992. *An Evaluation of the village information centres in India* [online]. Available from: <idlbnc.idrc.ca/dspace/bitstream/10625/12436/1/96732.pdf>.

[41] Indian Space Research Organization (ISRO), 2007. *Space Technology Enabled Village Resource Centre* (VRC) [online]. Available from: <http://www.isro.org/publications/pdf/VRCBrochure.pdf>.

[42] Council for Advancement of People's Action and Rural Technology (CAPART), 2006. *Scheme of Village Knowledge Centre* [online]. Available from: <http://capart.nic.in/scheme/vrc.pdf>.

[43] Pan-African e-Network, 2013. *Pan-African e-Network* [online]. Available from: <http://www.panafricanenetwork.com/>.

[44] Telecommunications Consultants India Limited, 2013. *Pan-African e-Network Heralding new era in providing Tele-Education & Tele-Medicine* [online]. Available from: <http://www.tcil-india.com/new/html/Pilot_Proj.pdf>.

[45] University Of Delhi, 2013. *University of Delhi Pan-African e-Network Project Brochure* [online]. Available from: <http://col.du.ac.in/pdf/PanAfricanBrochure.pdf>.

[46] Pisacane, V. L. 2008. Meteoroids and Space Debris. In: *The Space Environment and Its Effects on Space Systems.* American Institute of Aeronautics and Astronautics, pp. 319-346.

[47] Kessler, D. J. and Cour-Palais, B.G., 1978. Collision Frequency of Artificial Satellites: The Creation of the Debris Belt. *Journal of Geophysical Research,* 1 June, 83(A6), pp. 2637-2646.

[48] World Economic Forum, 2012. *Global Risks 2012,* Seventh Edition. Cologny/Geneva.

[49] World Economic Forum, 2013. *Global Risks 2013*, Eighth Edition. Cologny/Geneva.

[50] The World Bank Group, 2013. *Poverty: Data* [online]. Available from: <http://data.worldbank.org/topic/poverty>.

[51] Millennium Development Goals (MDG) Monitor, 2007. *Tracking the Millennium Development Goals* [online]. The United Nations Development Programme. Available from: <http://www.mdgmonitor.org>.

[52] European Commission, 2012. *Mission Growth: Europe at the Lead of the New Industrial Revolution*. Available from: <http://ec.europa.eu/enterprise/newsroom/cf/itemdetail.cfm?item_id=5968>.

[53] Amos, J., 2011. *The small matter of a few billion sat-nav euros* [online]. British Broadcasting Corporation. Available from: <http://www.bbc.co.uk/blogs/thereporters/jonathanamos/2011/02/the-small-matter-of-a-few-bill.shtml>.

[54] Wadyalla, B., 2008. *Africa still dependent on satellite net access* [online]. SciDev.Net. Available from: <http://www.scidev.net/en/news/africa-still-dependent-on-satellite-net-access.html>.

[55] De Rosen, M., 2012. *Open Forum 2012: A Day Without Satellites* [online]. The World Economic Forum. Available from: <http://www.noodle.org/learn/details/317088/open-forum-2012-a-day-without-satellites>.

[56] Flournoy, D. 2004. *The Broadband Millennium: Communication Technologies and Markets*, Chicago: International Engineering Consortium.

[57] Jakhu, R., 2012. *Open Forum 2012: A Day Without Satellites* [online]. The World Economic Forum. Available from: <http://www.noodle.org/learn/details/317088/open-forum-2012-a-day-without-satellites>.

[58] Programa Nacional De Atívides Espaciais, 2012. *National Program of Space Activities 2012-2021.* Brazil, The Brazilian Space Agency, Ministry of Science, Technology and Innovation.

[59] Commission Nacional de Actividades Especiales (CONAE), 2012. *SAC-E (Sabia)* [online]. Available from: <http://www.conae.gov.ar/eng/satelites/sac-e.html>.

[60] Djiwatampu, A., 2004. Braving the Challenge of Satellite Technologies: National Breakthroughs and Indonesia's Role in International Role in International Forums. *Online Journal of Space Communication,* 8.