Implementing space technology into sustainable development and resilience theory

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Sustainable development is a relatively recent concept that started to be used in the early 1980s. In 1983, the United Nations General Assembly created the World Commission on the Environment and Development. As a result, the Commission recognized that "many critical survival issues are related to uneven development, poverty and population growth. They all place unprecedented pressures on the planet's land, waters, forest and other natural resources, not least in developing countries". The report focused on the importance of the principle of intergenerational equity- namely, that we must take into account the uncomfortable notion that unborn generations may pay for our environmental excesses for lifetimes to come. It also outlined common but differentiated responsibilities that succinctly defined sustainable development as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs".

Today the concept of sustainable development and its corollaries have been incorporated into hundreds of international economic, environment, and development-related treaties and instruments: even so, many would acknowledge that the concept has just barely started making inroads into our political and economic culture.

Two more recent initiatives may help illustrate how sustainable development is envisioned today, at the highest multilateral level. The most recent major global conference on the topic – Rio+20, which took place in June of 2012, –concluded that sustainable

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development could be achieved by promoting sustained, inclusive, and equitable economic growth, creating greater opportunities for all; reducing inequalities; raising basic standards of living; and fostering equitable social development and inclusion. It was further suggested that the promotion of an integrated, sustainable management program of natural resources and ecosystems must become a key factor to support *inter alia* economic, social, and human development while facilitating ecosystem conservation, regeneration, restoration, and resilience in the face of new and emerging challenges.

The results of Rio+20 were set forth in a document – *"The World We Want"* – which reaffirms the commitment of the international community to the Hyogo Framework for action 2005-2015: Building the Resilience of Nations and Communities (UNISDR). Environmental disasters continue to affect global society, and thus the call has been made for additional action by the United Nations and other international organizations, as well as states at the national, regional, and sub-regional levels (with critical support given by international financial institutions and civil society). The participation of these many actors is necessary to accelerate the implementation of the Hyogo Framework and to achieve its goals.

The document calls for a new sense of urgency in addressing disaster risk reduction and building of resilience to disasters in the context of sustainable development and poverty eradication; whenever appropriate, this strategy should be integrated into policies, plans, programs, and budgets at all levels, and should be considered within relevant future frameworks (especially as a new development agenda will begin in 2015).

Rio+20, as well the post-2015 development agenda, advocates bringing into the mainstream the consideration of the socio-economic impacts and benefits of the conservation and sustainable use of biodiversity and its components, as well as of ecosystems that provide essential services, into relevant programs and policies at all levels; in accordance with national legislation, circumstances, and priorities. The process of Rio+20 encourages investments through appropriate incentives and policies, which support the conservation and sustainable use of biodiversity and the restoration of degraded ecosystems, all seen as consistent and in harmony with the Convention and other relevant international obligations.

As an immediate follow-up to Rio, in July of 2012, the UN Secretary General appointed a High-Level Panel of Eminent Persons[1] on the Post-2015 Development Agenda, which produced a report entitled "A new global partnership: eradicate poverty and transform economies through sustainable development" (Naciones Unidas, 2013) which outlines five transformational shifts, applicable to developed and developing countries alike, including a new Global Partnership as the basis for a single,

[1] For the Latin America and Caribbean region: Vanessa Petrelli Correa (Brazil); Maria Angela Holguín (Colombia); Gisela Alonso (Cuba) and Patricia Espinosa (Mexico)

universal post-2015 agenda that will deliver this vision for the sake of humanity.

From all the preceding, we may extract that the concept of sustainable development includes a need for balanced integration of social equitability, inclusive and sound economic growth, and protection of environmental features and habitats. We may also deduce that the previous elements rely to an extent on a fourth component dealing with security and peace. We may also emphasize the fluid, dynamic nature of the concept. According to the High-Level Panel on Global Sustainability, sustainable development is not a destination *per se*, but a dynamic progress of adaptation, learning, and action. It is a process of recognizing, understanding, and acting on interconnections of a wide variety between the economy, society, and the natural environment[2].

It is here that we may begin to explore the idea that space applications- whether in the field of scientific research or pathbreaking technologies used by the public or private sectors- can make a unique contribution to the efforts of humankind to promote sustainable development in all countries and regions of the world. After all, information and communication infrastructure is a fundamental element of development in any nation, and space technology is a key tool for gathering information at a global level, with the universal coverage to reach extremely remote areas as well as crowded metropolises.

Information obtained from space, and derived from geospatial data, provides essential inputs for decision-making in areas such as disaster management and emergency response. The potential value of such data for use in a wide range of applications had been predicted even prior to the beginning of the Space Age, and was confirmed following the successful launch and operation of the first remote-sensing satellites. As commercial and state-owned satellite technology began to expand beyond the original spacefaring pioneers to the rich world and gradually to developing nations, the suite of economic advantages came to be ever more widely appreciated.

In the area of trade & commerce, for instance (a necessary consideration in any discussion of sustainability) space-based technologies have served to assist international cooperation aimed at improving productivity, commodity diversification and competitiveness, entrepreneurial capacity, and improved transportation infrastructures.

One of the most interesting related developments is the recent inclusion of space security to the World Economic Forum (WEF) by creating a Global Agenda Council on Space Security. The council will focus on better defining the contribution of space industries and technologies to the global economy, and improving the state of the world through the promotion of "resilient dynamism". This economic capacity-building may serve to enhance the ability of poorer developing countries to achieve the Sustainable Development Goals (Post-2015/UN Development Agenda), as

[2] Letter from the co-Chairs of the High-level Panel on Global Sustainability to the Secretary-General of the UN.

horizontal prosperity may be defined as a key factor in the health of any nation[3].

We may also determine that where space applications are introduced to sustainability issues, it is as a technology that can be leveraged into invaluable data for community-interest professionals ranging from urban planners to geologists to disaster workers. In that regard, satellites are particularly suitable to improve the resilience of socio-ecological systems, as demonstrated in the following select cases:

SUSTAINABLE DEVELOPMENT MAY BE COMPLEMENTED BY SPACE-BASED INFRASTRUCTURE FOR SOUND *ECONOMIC* GROWTH

The economic dimension of sustainable development is very much related to the eradication of poverty. In the Latin American region, for example, statistics forecast a sharply rising population, reaching 177 million people as of 2010. 884 million people in the world still do not have access to safe drinking water and 2.6 billion people lack basic sanitation services, such as toilets or latrines. A leading priority in low income countries is to find the means to enhance water, energy, and food security. Current and prospective satellite technology might provide some innovative new methods to approach this area- even so, there are severe and binding limitations. This paper does not seek to suggest that there is any high-tech replacement for the hard work of confronting these awful and titanic lacunae of neglect directly: the chief challenge, as Acemoglu & Robinson point out, lies with the direct provision of basic services and infrastructure by responsible and accountable local and state authorities (Acemoglu & Robinson, 2012). Yet space-based technologies may offer an array of indirect but complementary options to help meet the complex, inter-related challenges of sustainable development, a means that has the potential advantage of application and deployment on a truly global scale.

Energy

Development that relieves poverty relies in large part upon access to energy. At the global level, 1.3 billion people have no access to electricity; consequently, their educational, agricultural, business, and industrial activities are severely compromised. Half of the world population has no access to clean cooking fuels, relying instead upon such basic energy sources as wood, coal, and biomass to fuel cook stoves and to heat their homes. According to the World Health Organization (WHO), two million people are killed by diseases caused by indoor pollution. As a tool for detecting natural energy resources, satellite data is increasingly used for planning new alternative energy power sites, such as the positioning of eolic generators and locating the ideal areas for solar panels to maximize their output.

3 The United Nations System Task Force on the Post 2015 Development agenda has presented its report to the Secretary General of the United Nations entitled "Realizing the Future We Want for All". In this report there are many areas where space-based technologies and data are of crucial importance for sustainable development.

On the conceptual plane, and over the long term, satellite technology might develop a different high-tech response to energy demands on Earth: space-based solar power (SBSP or SSP for short). First envisioned in the 1941 short story "Reason" by Isaac Asimov, SSP has attracted the intermittent interest of engineers and policymakers since the 1960s, only recently making the jump to a concept that is within the medium-term reach of current technologies.

In a concept investigation paper published for NASA, Space Studies Institute Senior Advisor John Mankins suggests that fully executed SSP might be able to deliver "power on demand" to 90% of the world's population (Mankins, 2012). Though initial research has been carried out by Russia, Japan, and the United States, the development costs of comprehensive space infrastructure are currently seen as too prohibitive for SSP to be a feasible project. In addition, most cost-benefit ratio analyses, including a recent report by the International Energy Agency, show a distinct preference for earth-bound solar thermal energy and solar photovoltaic energy for a far more effective allocation of resources (IEA, 2011). Several reputed scientists, including the SpaceX entrepreneur Elon Musk, have questioned the inefficient conversion rate of such a system (Doyle, 2012). If, however, future decades see a significant change in space budgetary dynamics, coupled with large-scale investment in orbital building projects with a large fleet of satellites that require refueling, SSP may gain in potential as a rewarding solution to sustainable energy problems, even if it is not a cost-effective application at present.

Food Security

Food Security covers three dimensions: availability, access, and utilization, in order to obtain social, political and economic stability. Precision Agriculture is an innovative way to handle the food production system, since it provides information to the farmers who want to know the right amounts of water, chemicals, pesticides, and herbicides they should use, as well as precisely where and when to apply them. Thanks to the combination of remote sensing data with GIS and GPS software tools – as well as the use of on-tractor variable rate technologies –farmers no longer need to treat a field of crops as one homogeneous unit. India, for example, launched the RISESAT, a specialized satellite solely dedicated to rice production, a staple crop that feeds two-thirds of the global population.

The allocation of precise crop amounts to seed in each portion of the field is calculated to maximize efficiency, rather than by uniform seed broadcasts over non-uniform fields. Perhaps more significantly, this method can reduce the negative environmental impact of chemical runoff from farms. Additionally, rather than guessing about a crop's *potential* need for water based upon weather variables, farmers can use remote sensors to measure how much water their crop is actually using, and this would give them a more accurate measure of how much more water is needed (Moran, 2000, pp. 1-10).

One of the main obstacles to the broad use of space-derived technologies in agriculture is the cost of the individual images as well as selecting the most relevant data. One good example of the effective sharing of space data information in precision technologies is that given by Colombian sugar growers, who have excelled in their collective use of GIS systems for recordkeeping and data mining. When farmers sell sugar cane, 0.55% of the value of the crop goes to Cenicaña (Centro de Investigación de la Caña de Azúcar of Colombia) to fund sugar cane research and outreach programs. Records for nearly every sugar cane field in the Valle del Cauca are kept and used to source this information to judge the impact of varieties, planting and harvesting dates and methods, and fertilization techniques. This information is kept in a web-accessible database for query and interpretation by member growers and mills (Cenicaña, s. f.).

SUSTAINABLE DEVELOPMENT SHOULD HAVE A POSITIVE GLOBAL *ENVIRONMENTAL* IMPACT

Space-based capabilities can be used to protect and manage the impacts of the global ecosystems interaction by developing large environmental systems, including the Eye on Earth Network and the Global Earth Observation System of Systems (GEOSS). Regional and inter-regional efforts are taking place to collect environmental data, which are vital to implement the Rio+20 recommendations on climate change.

Space agencies are supporting better monitoring and mitigation of climate transformation and their impacts on the environment (IAA, 2010). The need to reinforce institutions such as the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS) should include an international commitment of the continuous long-term availability for all nations without discrimination on economic grounds of all dependent Essential Climate Variables[4]; and the elaboration of a GEO Data Sharing Principles agreement acceptable for all parties.

Coastal ecosystems

The coastal littorals that border our oceans boast some of the most biologically diverse ecosystems on the planet, as well as some of the most concentrated population densities of humans. About 40% of the world's population lives in a 100 km wide strip along the coast, which constitutes only 20% of Earth's total surface. In certain cases, over-exploitation of the mining sector, combined with an enormous and expanding population – as shown, for example, on the Colombian Caribbean coast – inevitably inflict a great pressure on coastal resources.

A large number of coastal habitats in various regions of the world – especially fragile ecosystems like coastal wetlands, mangroves, and coral reefs – are in danger of being destroyed through overexploitation of resources, pollution, sedimentation, and erosion, in addition to urban and industrial development and tourism activities. The sustainable management of these coastal zones is clearly one of

[4] As defined by the Global Climate Observation System (GCOS).

the main challenges that humanity faces at the outset of the 21st century (Santos, 2011).

The physical interdependencies of co-ecosystem countries require new eco-system focused management and related institutional frameworks based on information, data analysis and research based policies and programs of action. The main challenge for adequate responses has always been the lack of adequate data and information and related research and analysis.

Natural disasters

One concept that is increasingly used in association with the challenges of sustainable development is *resilience*. According to a consensual multilateral opinion expressed in COPUOS, resilience of an adaptive complex system may be defined as the measure of its ability to absorb changes, such as perturbations or disturbances, and still continue to function. It is a flexible term with a wide range of potential subjects- households, small towns, or states-whose ability to "successfully" withstand hazards, risks, or stresses of any conceivable sort is the subject under consideration. As Pelling & High put it, the adaptations implemented to enable better resilience can range from "infrastructural, technological, administrative, organizational, legal or legislative, regulatory, or financial [measures]" (Pelling and High, 2005). The related term adaptive capacity relates to "experimenting and learning to foster innovative solutions to complex social and ecological systems" (Randolph, 2012, p. 128).

For example, we can consider the resilience of a socio-ecological system to natural disasters, such as geophysical extreme events, including earthquakes, tsunamis and volcanic eruptions, as well as meteorological events (including hurricanes, tornadoes and tropical cyclones) and climatological events (including extreme temperatures, heat waves, droughts and forest fires). The area of disaster management is in fact the field in which resilience has gained the most traction recently (Bohórquez-Tapia and Eakin, s. f., p. 153).

Satellite communications are becoming essential in disaster mitigation and relief operations. Some of the main natural disasters that have occurred in the last few years, such as the 2004 tsunami in Japan, demonstrated that satellite communications are vital in situations where ground-based infrastructures have been destroyed and rendered nonoperational. The invaluable services that satellites perform in this critical area will be increasingly relied on, as the scale, frequency, and intensity of climatological and meteorological events shall be set to rise with the cumulative process of climate change over and beyond the next century. Tomkins & Adger note that even if climate change may be a gradual process in some senses, sharp spikes in extreme weather events are to be expected at unpredictable intervals, and should factor in to any natural hazards mitigation planning (Tompkings and Adger, 2003, p. 133).

Global navigations satellite systems (GNSS) are being used to enhance the safety and effectiveness of transportation by land, sea, and air. With their extremely high accuracy, global coverage, all-weather capability, and usefulness at high velocity, GNSS applications support and improve emergency response and disaster reduction. At the UN level, the General Assembly has created the UN-SPIDER that conducts program activities related to knowledge management, horizontal cooperation, and capacity building for both disaster risk-reduction and emergency response. Over the long term, such integrated approaches may help solve what is termed the disaster-relief-disaster syndrome (D-R-R-D), whereby vulnerable communities take little heed of preventative mitigation and rebuild in a fashion that is highly exposed to another disaster: a pattern that modern disaster relief agencies, including FEMA, attempt to remedy through a variety of approaches (Randolph, 2012, p. 133).

At present, a good example of regional cooperation on disaster management is the Mesoamerican Regional Visualization and Monitoring System (SERVIR) based in Panama City, which provides support for monitoring the environment to assist local officials in responding faster to natural disasters. Within Central America and the Caribbean, the SERVIR team at the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) has, to date, responded to over twenty natural disasters and ten environmental threats across the region.

CATHALAC's team has also developed a geospatial portal that provides improved access to regional data and metadata. "The Honduras earthquake in May 28, 2009, was a perfect example of SERVIR at its best," says Emil Cherrington, Senior Scientist at SERVIR's regional operational facility at CATHALAC in Panama. "It was like a chain reaction. People from agencies and organizations in several countries worked together after the earthquake to pinpoint precise locations where support was needed" (NASA). As a result of the successful inter-regional cooperation of the SERVIR project in Central America, an African node is being established in Nairobi, Kenya.

The SERVIR case demonstrates that, despite the tragic and egregious failures of planning during the course of the 2004 South Asian Tsunami, there is hope that with careful and judicious preparation, high-level intervention can succeed in disseminating urgent information to vulnerable developing regions quickly and efficiently- in effect, to succeed in its role, which is in essence about effective communication. In a field traditionally associated with "top-down, techno-economic planning" satellite assistance greatly enhances the availability of rapidly updated physical information in a dynamic disaster environment, and permits much more sophisticated and knowledgeable response plans. They may even play a small part in the sometimes neglected role of local communities to strengthen their adaptive capacities, using localized methods such as community based disaster preparedness (CBDP)- used successfully in the Philippines, and where mapping plays a role in citizen risk appraisal exercises- and participatory vulnerability assessment (PVA). Both methods are designed to synergize well with broader sustainable development strategies and the emerging concept of resilience, and where local and community-based action can be assisted by high-tech reconnaissance (Randolph, 2012, p. 137).

SUSTAINABLE DEVELOPMENT ASSURES *SOCIAL EQUITABILITY*

Space-based capabilities can greatly assist developing countries in narrowing the digital divide, creating digital opportunities, and promoting information and communication tools to build new governance for sustainability aimed to eradicate poverty. Like cellular phones- a related, wildly successful communications technology- satellites may offer a limited but important scope to "leapfrog" structural impediments in developing countries to deliver cutting-edge economic, educational, and health applications to those who need them in spite of poor local infrastructure. Telemedicine is one innovative area– the de-isolation professional care tool used to strengthen health systems in developing countries – and is now employed by the Medical Missions for Children Global Distance Learning Network. (GDLN) These projects can connect more than 100 hospitals simultaneously.

Humanitarian Telemedicine

Telemedicine allows transferring expertise rather than people, which is important in rural areas of developing countries where the distance to a hospital, and the effort to get there, might pose a significant challenge and, in itself, often poses significant health risks. By using space-related technologies, medical staff can provide from their hospitals or medical centers expertise to remote areas, for example tele-consultations and tele-diagnostic services. In another context, it is important in the sense of 'teaching the teachers,' and educating local health workers, who may then become instructors and pass on their skill set, thereby creating self-reinforcing virtuous circles of knowledge dissemination in previously semi-isolated communities.

For example, the Pan-American Telemedicine Network Project (PATN), sponsored by the International Telecommunications Union (ITU) and Hopitaux Universitaire de Geneve (HUG), provides tele-consultations using an integrated system capable of managing patients, storing and forwarding medical records and images, and providing second opinions to remote patients. The system is in compliance with international standards in medical imaging and Electronic Medical Records (EMR), facilitating interoperability and exchange of patient information[5].

Tele-education in remote areas: education for refugees

The largest refugee camp in the world is located in Dadaab, in North-Eastern Kenya, 100 km from the Somali border. More than 500,000 refugees reside here, many of them displaced by the civil war taking place in southern Somalia. The United Nations High Commissioner for Refugees (UNHCR) has been working to provide not only food and healthcare for the camp's residents, but also educational opportunities for its more than 80,000 young people.

[5] See www.itu.int/net/ITU-D/CDS/gq/generic/asp-reference/gq

To achieve this, they have been integrating solar-powered technologies to support ICT delivery in the 39 primary and secondary schools and four vocational centers in the camp (eLearning Africa).

CONCLUSIONS

One of the more original recent public education initiatives that manages to showcase a combination of climate change, sustainable development, and satellite data has been the 2011 award-winning educational computer game *Fate of the Earth*, designed in collaboration with Oxfam and built with climate change modeling by Professor Myles Allen, head of the Climate Dynamics group at Oxford University[6]. The premise is straightforward: taking a satellite view of the Earth, the player is asked to enact region-based policies that will help avert catastrophic climate change over the next 200 years, and complex computer models proceed to calculate impact at five year intervals, often with unexpected results. The immense difficulty of implementing policies powerful enough to arrest traumatic upheaval- which include critical water shortages, agricultural failure, toxic environments, refugee crises and political turmoil- is sobering, and vividly illustrate for the layman the scale of the challenges policymakers, scientists, and vulnerable communities the world over face over the coming decades. Also revealing about the game is the secondary role emerging technologies play: they may help as an auxiliary mitigating force against climate change, but can only be truly effective within a larger framework of decisive socio-economic reforms, and a cultural paradigm shift away from the culture of consumption prevalent today as the most prestigious and desirable model of society.

All this serves to show that sustainable development, in all its complexity as a holistic, long-term approach to find lasting solutions to our socio-economic problems, is "a unique platform for the state of the world" as the debate in the World Economic Forum/ Global Agenda Council on Space Security put it. It is one of the best avenues to provide a context on how to respond to the social, economic, environmental, and institutional challenges the world is facing. It is, in fact, a process where according to our specialty and particular preoccupation, we are free to emphasize the subfield that interests us the most, making it a broad church that welcomes a diverse workforce.

In addition to contributing to this emerging, critical field, space-based technology may also offer some overlap with the complementary and nascent question of resilience. With some creativity and flexibility of mind, more applications for space-based tools will surely be found, and the visibility of the role of space applications for the post-2015 development agenda will be set to increase.

From a technical perspective, more can be done to facilitate and expand the role of satellites. Some proposals concern the need

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6 The computer game was originally inspired by the BBC's popular *Climate Challenge*. See http://www.fateoftheworld.net/about

to establish sustainable national spatial data infrastructures; the enhancement of autonomous national capabilities in the area of space-derived geospatial data, including the development of associate infrastructure and institutional arrangements. These are, and remain, key components to harnessing space-derived data for sustainable development.

Engaging in and expanding international cooperation in the area of space-derived geospatial data, and increasing awareness of existing initiatives and data sources, are fundamental to achieve the Millennium Development Goals, as well as being prepared for the post-2015 development agenda. In addition, it is crucial for public and private entities to support the United Nations in its efforts to access and use geospatial information, in its mandated programs to assist all.

To achieve sustainable development, we need to reinforce an effective framework of institutions and decision-making processes under a new global governance umbrella. If we want to anticipate the new type of challenges and crisis we are facing, then we must overcome the legacy of fragmented institutions established around single issues, "silo" deficits, or both. Such ephemeral concepts as leadership and political will are integral to overcome the lack of understanding of the environmental challenges we face. An appreciation of the utility of space-derived data in this context follows as a logical subsequent step.

The importance of space technology based data, *in situ* monitoring, and reliable geospatial information for sustainable policy-making, programming, and project operations should be reinforced. In fact, it would not be a stretch to view sustainable development and space applications as ultimately complementary. A green socio-economic approach that pledges to take into account planetary climate change in designing and building long-term industries, transport, and energy infrastructure can only benefit from data-collecting instruments that are also planetary in scope. In that sense, satellites and green technologies may both be popularly perceived as "industries of the future" that will gain in traction and sophistication over the course of the 21st century.

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