Some Observations on Outer Space from Earth and Some Observations on Earth from Outer Space*

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ABSTRACT

This paper will present the author's views on the use of outer space, and the impact of space activities on terrestrial undertakings. The main focus of this essay will be on satellites, which have radically changed the way we communicate, and also how we perceive our planet. The influence of South American countries on space activities and space policy will be surveyed. The military use of satellites will not be considered in depth, except to provide a context for the development of satellite technology. Rather, this paper focusses on satellites – Earth observation / remote sensing and communications, on the impact they have had, and continue having in our daily lives.

Key words: satellites for earth observation/remote sensing, communications, social impact.

Algunas observaciones sobre el espacio desde la tierra, y algunas observaciones de la tierra sobre el espacio

RESUMEN

En este ensayo se presentan los puntos de vista de la autora sobre el uso del espacio exterior y el impacto de actividades espaciales en actividades terrestres. El enfoque principal será en

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satélites, los cuales han cambiado radicalmente la manera en que nos comunicamos, y también cómo percibimos nuestro planeta. Asimismo, se estudiará la influencia de países suramericanos en actividades y en políticas espaciales. El uso militar de satélites no será considerado a fondo, a excepción de proveer contexto para el desarrollo de tecnología satelital. Más bien, este ensayo se enfoca en satélites –observación terrestre/teledetección y comunicaciones–, y en el impacto que han tenido, y continúan teniendo, en nuestras vidas diarias.

Palabras clave: satélites para observación de la Tierra y comunicaciones, impacto social.

INTRODUCTION

Humans seem to have been - and remain- fascinated with outer space. Many myths and legends from different cultures, and stories found in sacred writings attest to this attraction. For example, a Greek legend tells us that Icarus wanted to fly, so his father, Daedalus, made him some wings, but warned him not to get too close to the sun, lest the sun's heat melt the wax which kept the wings on Icarus (Gill). But like many sons, Icarus disobeyed his father, his wings fell off, and he plunged to his death in the sea. And so we have an account of the first aviation accident. Another story tells of chariots of fire lifting the prophet Elijah up to heaven in a whirlwind. Precursor to aerospace flight?

In more recent times, in 1865, Jules Verne wrote "From Earth to the Moon", suggesting that traveling to the Moon was possible (Verne, 1993). This book inspired the concept of space flight and travel to the Moon, which in the 20th century became reality. This book inspired other authors to write what is now considered science fiction, and inspired many films and television shows, including the design of *Star Trek*'s starship *Enterprise* [1]. The space vehicles which have been developed in the 20th century, such as the USA's Space Shuttle are quite different in design from the *Enterprise,* and the launch vehicles used at present are definitely quite different from Verne's cannon, which was used to catapult humans to the Moon (Verne, 1993). Sometimes reality is more remarkable than fiction[2].

Even with the many launches of scientific probes, and of astronauts to the International Space Station, until now the most remunerative use of outer space has been the deployment of thousands of satellites, the majority for communications, some for earth observation or remote sensing (EO/RS), and others for global navigation (GNSS) or global positioning systems (GPS).

The success of communications satellites owes its beginnings to another visionary, Arthur Clarke, a British engineer who in 1945

1 "Star Trek's" spaceship, the *Enterprise* was designed by Matt Jeffries. A replica of the *Enterprise* hangs in the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

2 The US "Apollo" program, and man's landing on the Moon, the advent of the Space Shuttle, and other space programs will not be discussed in detail. Suffice it to say that we have learned from writers of science fiction, and have realized some of their prophetic visions.

proposed placing three communications satellites in geostationary orbit (GSO), thus providing coverage to nearly all the Earth (Clarke, 1945). Geostationary orbit (GSO) is defined as being approximately 35,787 km (22,237 miles) above the Equatorial line. Satellites located in GSO have a period equal to the Earth's rotation on its axis, and remain geostationary over the same point on the Earth's equator (Poole). GSO is often referred to as the Clarke Orbit, or Clarke Belt, in tribute to this scientist and science fiction writer (Info, 2013).

The importance of GSO lies in the fact that with three satellites, (as proposed by Clarke), most of the Earth is covered, and the antennas or Earth stations do not have to be constantly repointed, thus making it more economical to operate a satellite in GSO. Earth stations or ground stations for satellites in lower orbits have to track the satellite(s), and thus are more costly to operate.

The first satellite to be launched to a lower, elliptical orbit was the Russian *Sputnik* in 1957, and so began the "space race" between the United States and the USSR. The first *commercial* communications satellite launched to geostationary orbit was COMSAT/INTELSAT's "Early Bird", launched in 1965 (Intelsat, 2014). Since then, thousands of satellites have been launched into various orbits, the most remunerative being the communications satellites in GSO. These include satellites for telephony, data transmissions, and broadcasting. Several weather satellites are also located in GSO, such as USA's NOAA's (National Weather Service). The European EUMETSAT has satellites located in both GSO and lower orbits, including polar orbits (Eumetsat, 2014).

A look at satellite communications systems and at Earth observation / remote sensing (EO/RS) satellites, their similarities and differences, as well as their use and impact in the Andean region follows.

SATELLITE SYSTEMS AND EARTH STATIONS

Satellites are man-made objects launched to orbit the Earth or another celestial body. Communications satellites are specialized wireless receivers/transmitters that are launched by a rocket and placed in orbit around the Earth. They use different radio frequencies to transmit from the Earth (uplink) and to transmit from the satellite to Earth (downlink).

Earth stations are essential components of all satellite systems. The operation and control of Earth stations utilized by communications satellite systems differ from those used with remote sensing / Earth observation satellites in several respects. Earth stations associated with communications satellites are usually operated by the local/national telecommunications companies, using frequencies in the Fixed-Satellite Services (FSS), Broadcast-Satellite Services (BSS), Mobile-Satellite Services (MSS), and even the Earth Exploration-Satellite Services (EESS) bands[3].

[3] The International Telecommunication Union (ITU) has designated particular parts of the radiofrequency spectrum (RFS) to be used for these different satellite services. *See* ITU (2014).

Most countries and companies have several Earth stations to receive from and transmit to various communications satellite systems; consequently, there are thousands of Earth stations accessing the communications satellites, the majority owned and operated by non-governmental service providers.

Compared to communications satellite systems, there are fewer remote sensing / Earth observation satellite systems in operation, and consequently fewer Earth receiving or ground stations. Many, if not most of these are "passive", receive-only antennas. To retransmit the data to a center where they can be interpreted, the radio frequencies associated with communications satellites are used. Further, the receiving Earth stations are usually operated by the government (military) sector, using different radio frequencies (the military band, or X-Band).

It used to be that the satellite services, as designated by the ITU, were quite distinct from each other. At present, however, the differences are being blurred, with satellites operating in the Fixed-Satellite Service (FSS) bands now providing broadcasting services, and satellites originally made for Earth observation now provide messaging and other mobile communication services, using the MSS frequency bands. A few examples follow.

A BRIEF OVERVIEW OF THE PRINCIPAL REMOTE SENSING SATELLITE SYSTEMS

In the 1960s, satellite surveillance, or remote sensing[4], gained a foothold, first in the USA and in other countries, including the USSR. The US LANDSAT Program was an outgrowth of the 1960s' Apollo Moon missions, when photographs of Earth's land surface were taken from space for the first time. Landsat 1, launched on July 23, 1972, was the first Earth observing satellite to be launched with the express intent to study and monitor our planet's landmasses[5]. The information gathered by the satellites was of great utility not only to the USA, but to other countries as well. At the same time, the former Soviet Union developed its remote sensing capabilities, also under military auspices[6].

In 1986, SPOT (Satellite Pour l'Observation de la Terre), the French remote sensing satellite program was launched. Currently, the SPOT system is comprised of five satellites, three of which are still operational (Gillan, 2014).

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4 For the purposes of this paper, the terms "remote sensing", and "Earth observation" satellite systems will be used interchangeably, even though differences may exist between such systems.

5 The LANDSAT Program comprises a series of Earth observing satellite missions, which at first were jointly managed by NASA and the U.S. Geological Survey. LANDSAT's operations were shifted to NOAA, and in 1984, attempts were made to privatize LANDSAT, but were not very successful. For more information *see* LANDSAT (2014).

6 A detailed account of the USSR's role in the development of satellites is beyond the scope of this paper. Suffice it to say that with the 1957 launch of "Sputnik" the "race in space" began, raising international concerns about keeping space for peaceful purposes, which in turn led to the establishment of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) in 1958.

They were designed, built, and operated by the French Centre Nationale d'Études Spatiales (CNES) in association with the SSTC (Belgian scientific, technical and cultural services) and the Swedish National Space Board (SNSB). The most recent satellite, SPOT 7, was launched on 30 June, 2014, by the Indian launch system. Spot Image now is a subsidiary of Astrium, which funded and owns the system (satellites and ground segments) (Centre National d'Etudes Spatiales, 2008).

SPOT was originally established to commercialize its images, but has transformed itself from an Earth observation satellite system to a global positioning system (GPS) for tracking, and uses the Globalstar satellite network to provide text messaging and GPS tracking[7]. In early 2013, a variation of the SPOT Satellite GPS Messenger called SPOT Connect was released, allowing the user to compose a message in real time using a smartphone (SPOT Satellite Messenger). The use of remote sensing / Earth observation satellites for global positioning, and for transmitting messages, is a good example of the blurring of distinctions in satellite services.

EARTH OBSERVATION / REMOTE SENSING IN THE ANDEAN REGION

Aerial surveillance/monitoring in South American countries began with the support of the military, rather than the civilian sector of the governments, and to a great extent, remains in the hands of the military sector. Early legislation establishing government agencies to make use of monitoring/aerial surveillance and of satellite imaging was based on the need to do so because of border disputes[8]. With the development of aerial surveillance in the 1930s, and of remote sensing satellites in the 1970s and '80s, some of the border disputes among the South American countries are being resolved by diplomatic means, rather than by open warfare (Ospina, 2010).

Earth observation / remote sensing satellites are currently used for more than monitoring borders; they provide information or data on a variety of resources, such as land use, crops, fishing, agriculture, water levels, urban planning, etc. The cost of obtaining data or images is a factor that has inhibited potential users until recently. However, the growth of the Internet, and of some satellite systems offering their images for free, has greatly expanded the

7 Globalstar is a mobile communication satellite system, comprised of 48 satellites in orbit. In late 2007, SPOT LLC, a Globalstar subsidiary, launched a handheld satellite messaging and tracking personal safety device, the SPOT Satellite Messenger.

8 For example, the Colombian "Instituto Geográfico Militar" was established by Decree1440 of 13 August, 1935, as a dependency of the National Army. This institute was created as a result of border wars between Colombia and Peru, and the need to have more precise mapping of the territories. It is now called the Insituto Geográfico Agustín Codazzi (IGAC). *See* IGAC (2014), for more history and legislation.

availability of data. An example of this transformation is the China-Brazil Earth Resources Satellite (CBERS) program[9].

Brazil and China have cooperated for many years on the CBERS program. The first CBERS satellite was launched in 1999, and the most recent launch, CBERS-3, took place in 2013, but the satellite failed to reach its proper orbit, and the satellite was declared a loss (Barbosa, 2013).

Despite this loss, the CBERS program has succeeded in making thousands of images and data available to countries in South America and Africa through the Internet, at no cost. This Brazilian policy has enabled South American countries to regularly use CBERS-2 data for their remote sensing development and surveying policies (Kramer). The Chinese Academy of Space Technology (CAST) and the Brazilian INPE operate and maintain their own ground segment infrastructure, consisting of telemetry, tracking and control (TT&C) stations and a Satellite Control Center (SCC). Having this type of control is of great importance in making use of the data obtained by the satellites[10].

Another 'newcomer' to Earth observation is Venezuela's "Miranda" satellite, built and launched by the Chinese on 28 September, 2012. One objective of the Venezuelan government is to assess crop production, and also to evaluate available water resources and prevent droughts in areas that could be subject to them. Another objective is to facilitate urban planning, and make use of seismological data to prevent disasters (Jaé, 2012).

Other countries in different regions of the world have launched their own remote sensing / Earth observation systems, leading to an increased number of Earth receiving stations as well.

Compared to communications satellite Earth stations, however, their number is still minuscule, in part due to the fact that remote sensing satellites are still operated to a great extent by the defense/security/military sectors, rather than operated on a broader commercial basis, like the communications satellites.

While the number of distributors of satellite images has grown, the number of ground stations / processing centers has not increased in the same manner. Thus, most developing countries remain dependent on the developed ones for the technology they need to use, to build or operate a remote sensing / Earth observation satellite system. Acquiring data, and having trained personnel to interpret them and the images are expensive competencies, often beyond the reach of many emerging economies.

'One exception seems to be the China-Brazil CBERS programs mentioned above: images may be downloaded from the Internet

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9 Although Brazil is not a country in the Andean Region, CBERS has had an impact on many countries in South America and in Africa. See CBERS (2011) on the agreement reached by the Brazilians with several countries in Africa.

10 In South America, there are few ground stations capable of producing images from data collected from the LANDSAT and SPOT systems. One of these is at Cuiabá, Brazil, which has been able to produce black and white and color images for over 20 years, and another is at the INPE (Grosso, Tarnowski & Turek, 2008)

for free. Another exception may be the French government's decision to make older SPOT Images available free of charge to researchers. However, only images more than five years old will be available to non-commercial users. Another restriction is that the older images will have a limited resolution, and potential users will have to sign a licensing agreement with the French government that the images will only be used for research) (Selding, 2014). Thus, the usefulness of these older images may also be limited.

Other factors that impinge on the availability and usefulness of Earth observation / remote sensing images and data are national laws and policies that restrict their distribution. These laws and policies may apply to both the 'exporters' and the 'importers' of such data and images. These restrictions may be economic (to protect other providers of images) (Selding, 2014) or legal (for security reasons, no image beyond a certain resolution may be made available). Ironically, many of the new Earth observation systems have had to file for bankruptcy protection, or merge with other remote sensing companies[11]. Other financial issues may arise, such as questions related to copyright and intellectual property protection and royalty payments and the distribution of images/data, but these will not be addressed in this paper (Doldirina, 2009; Smith & Doldirina, 2008).

Most of the Latin American countries rely heavily on developed countries' space industries and agencies, not only for hardware but also for technical assistance. (Exceptions do exist, however: Argentina just launched ARSAT I, a communications satellite built in Argentina, and tested prior to launch at INPE's facilities in Brazil)[12].

Argentina, Brazil, Chile, Ecuador, Mexico are among the countries that have entered into several bilateral agreements with ESA, NASA, the Canadian Space Agency, the Indian Space Research Organisation (ISRO), as well as with the Chinese and Japanese governments. These agreements vary in scope; in some instances, the Latin American countries assist the foreign space agencies with tracking activities (For example, Chile's Easter Island was a potential emergency landing site for the US Space Shuttles). Other countries (Argentina, Brazil and Chile) are involved with the French SPOT and the US LANDSAT remote sensing programs, as well as with the tracking of launches and satellites, and data collection.

CHALLENGES FACING SPACE ACTIVITIES IN SOUTH AMERICA

The challenges faced by most of the developing countries fall into three broad categories: *technical* (lack of facilities to build or manu-

11 Rapideye, a German remote sensing system launched in 2009, declared bankruptcy in 2011. It was acquired by a Canadian company later in 2011, and changed its name to Blackbridge (Rapideye, 2014) In the USA, DigitalGlobe and GeoEye two 'private' remote sensing companies, were to compete with LANDSAT and with each other, but DigitalGlobe acquired GeoEye in 2013 (Digital Globe, 2004).

12 ARSAT I was successfully launched by Arianespace on 16 October, 2014.

facture hardware related to space activities or to operate them); *economic* (lack of financing of the infrastructure); and *legal* (little, if any legislation related to space activities). Some general observations follow.

As to the *technical* challenges, except for Brazil and Argentina, most of the countries do not have a dynamic aerospace industry; they need to import most of the equipment, which can be costly as well as delayed by legal/political factors, such as the USA's International Traffic in Arms Regulations (ITAR) that affect the exporting of certain hardware and software to countries that would like to develop their native aerospace industry. The countries also need to have local technical 'know-how', properly trained engineers and technicians to operate the equipment being used. But frequently, they don't have the appropriate hardware or needed tools.

Other major challenges facing the potential members of the 'satellite club'[13] are the *economic /financial* aspects of any satellite system. While financing of a satellite system remains one of the major hurdles, some countries, such as China, France and the United States, have facilitated the financing of several satellite systems (Kaufman, Wiss, & Segal, 2011). China's Development Bank has financed the development, manufacture and launch of Venezuela's "Simón Bolivar" and "Miranda" satellites, and Bolivia's "Tupak Katari" communications satellite, among others[14]. Technicians from Venezuela and Bolivia were trained in China, and Chinese technicians are present in both countries, assisting with the satellites' operations.

These projects seem to be the exception, as in many cases the country may receive funds to purchase a satellite, but no funds to develop the necessary infrastructure. The infrastructure includes not only hardware and software related to the satellite itself, but more importantly, facilities and trained personnel to interpret images and data (in the case of EO/RS satellites.) Lack of infrastructure also includes lack of access to reliable telecommunications, computer systems, internet facilities and connections at reasonable costs. Lack of funding affects local or national research and development related to the space (and telecoms) sectors, which are also dependent on reliable communication services, such as the Internet.

The International Telecommunication Union (ITU), through its Broadband Commission[15] and its Development Bureau (ITU-D),

13 This author defines the "satellite club" as those developing countries that have launched a satellite, frequently for political reasons, and without the infrastructure that would lead to its usefulness.

14 Whether these satellites are providing the services they were intended for is an open question (Urguelles, 2012). Most official news releases about the Venezuelan satellites pre-date their launch, although in October 2014 the Ministry in charge stated that "Miranda", the EO/RS satellite had already captured more than 170,000 images. Another press release stated that Venezuela and China will team up again, to launch the "Sucre" satellite (Morales, 2014).

15 The Broadband Commission for Digital Development, established in May 2010, is a joint initiative of the ITU and UNESCO, and aims at promoting broadband connectivity to underserved areas of the world. Its goals are similar to those of the FCC's National Broadband Plan, but encompass the world, not only one country (Broadband Commission, 2013)

and the United Nations[16] have been attempting to narrow the "digital divide"[17] for years, with some success, but many areas of South America and other regions of the world are still underserved, and lack reliable, affordable telecoms services. If the basic infrastructure is weak, due to lack of funding, how will the country finance costly aerospace projects, as well as a national satellite and space agency? Even the US's NASA and the European Space Agency (ESA) face budgetary restrictions that limit many of their projects. Would investing in information technology and communications (ITC) infrastructure be a better use of limited funds?

Regarding *legislation* pertinent to the aerospace sector, many countries do not have sector-specific laws, except for legislation issued by the entity in charge of satellite communications, usually the Ministry of Communications. These laws are usually based on the ITU's Radio Regulations and Recommendations, and thus, limited to mostly technical issues related to satellite communications and use of the radio frequency spectrum (RFS).

Thus, prior to drafting sector-specific laws, countries should ask themselves whether there is a need for such legislation. Should they decide that they need national space laws, they should keep in mind the principles embedded in the main outer space treaties, drafted by the UN's Committee on the Peaceful Uses of Outer Space (UNCOPUOS)[18]. The treaties, which have become 'customary international law', would provide a broad, basic legal framework for their space activities, but unfortunately, not all the South American countries have signed or ratified them[19].

National legislation, setting forth the country's policies regarding its space activities would provide a more solid base, and would possibly help attract investors, since they would provide some legal certainty. However, if a country decides to draft some legislation, based on the law of another state, it should take into consideration differences in legal systems (common law, civil law), since terms such as "liability", "responsibility", "assets", "property" have different meanings in these two legal regimes (Ospina, 2002).

CONCLUSIONS

Are there lessons to be learned from the successful and failed attempts to acquire and

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16 The World Summit of the Information Society (WSIS) is part of the UN's Millennium Development Goals, and together with the Broadband Commission, aims at using information technologies for sustainable development and bridging the digital divide (wsis, 2013).

17 The 'Digital Divide' is defined as "inequality of access to information technology; the difference in opportunities available to people who have access to modern information technology and those who do not (Encarta, 2009).

18 For text of treaties see UNOOSA (2014)

19 The International Institute of Space Law (IISL) has a Standing Committee on the Status of International Agreements Relating to Activities in Outer Space. Its 2014 Annual Report (2009) tracks the most recent ratifications, and also provides a 'history' thereof.

launch a satellite, whether for remote sensing or for communications? Since the 1980s, many 'emerging economies' have joined the 'satellite club'; i.e. they have acquired their own satellite, so that satellites are no longer the purview of only industrialized nations, although these remain the major manufacturers of the hardware and software required to have a viable satellite system. Further, industrialized countries own and operate the majority of the communications and Earth observation satellite systems, while most emerging economies remain users of these systems.

Perhaps the Venezuelans and Bolivians have overcome the initial economic hurdle, having accepted financing from the Chinese. The Chinese have also trained engineers from both those countries, and Chinese engineers are likely working in those countries as well. The issue of adequate training is one that countries wanting to launch a satellite need to address. Is it sufficient to send national engineers to China for a six-month stay, or would they do better to institute local training programs and facilities, to benefit a larger number of technicians? Do they have national research and development programs, adequately funded, or will they rely on external sources for funding and trained personnel?

Though mentioned last, legal issues should be the first to be addressed, taking into account existing international treaties and laws, as well as current national legislation. Some recommendations follow, on some of the issues mentioned above.

RECOMMENDATIONS

Ten years ago, this author made some of the following recommendations, which, in her estimation, remain valid (Office for Outer Space Affairs , 2004). A few preliminary measures should be taken prior to drafting national space laws, even if a national space agency has already been established[20]. One such measure should be the government's awareness that any space agency, commission, or program that it has established requires adequate long-term funding, and ideally, those monies should be available *ab initio*, so that its operations can be sustained, without the fear of lacking funds in the near future.

Another important step would be to ensure that the state signs and ratifies the outer space treaties, thereby giving notice that it is committed to upholding the principles embodied in them, since these have become customary international law. A third measure that should be taken is to study and analyze other current national laws, to avoid conflicts and discrepancies at the national level. Then, should a national space law be drafted, the State would be in a better position to ensure that there are no discrepancies between provisions in its national laws and the international laws related to space activities (e.g., the WTO

[20] All the countries in South America now have space agencies or commissions, the newest being the Paraguayan Space Agency, created in 2013.

Agreement on Telecoms[21], the ITU-RR, and of course, the UN treaties).

In addition, prior to acquiring a satellite, a thorough survey should be carried out of the different national entities –governmental agencies, non-profit organizations and private entities– that may be using satellite capacity, as well as data or images obtained from EO/RS satellites. In some countries, the government itself has no idea how much its various dependencies are paying for satellite images, and in some instances, paying more than once for the same data. Duplication of expenditures (and efforts) could thus be avoided.

An argument against undertaking this kind of initial survey could be based on lack of trained personnel, and lack of funds for such endeavors. A counterargument is that in most countries there are institutions (public and private) that specialize in carrying out surveys, and could undertake one related to space activities. Furthermore, once an in-depth survey is carried out, and the results properly analyzed, the government and other investors would be in a better position to determine what is more cost-effective: leasing capacity from existing systems or launching a national satellite, taking into account the technical, economic and legal factors mentioned in this paper.

Space-related activities are expensive propositions, and should be carried out after undertaking a thorough cost/benefit analysis, relatively free from pressure from manufacturers' intent on selling their hardware or other equipment, and not based only on a desire to be a bigger player in the satellite or space club.

While the countries in South America have made much progress in the last ten years, such as setting up national space agencies and acquiring satellites, much remains to be done. Thus, many opportunities are available on the road ahead them to become major players in the aerospace sector.

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