Space Security and Sustainable Space Operations: A Commercial Satellite Operator Perspective

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Abstract

The increasing need of commercial Satcom services (for governments, economy, social, and cultural purposes) augments the call for a coherent "space security" discussion which will lead to the development of rules and guidelines for sustainable space operations. Two main items of utmost importance to commercial space operators are elaborated in this chapter: the management of space operations in increasingly "crowded orbits" and the protection satellite services should receive, both in space and on Earth. During the last two decades at least, guidelines, best practices, agreed principles, and "soft law," have been the pragmatic answer to move forward. However, the exponential increase of space-based services will call for a "governance framework" which should strengthen the principles of the Outer Space Treaty and ensure that the Treaty will remain effective in the coming decades.

Views expressed in this article are the author's one only, and cannot be Eutelsat ones.

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Introduction

Since the United Nations Group of Governmental Experts (GGE), established in 2011 (GA Res A/RES/65/68, January 5th 2011) and concluded its report on "Transparency and Confidence Building Measures in Outer Space activities" (A/68/189 of July 29, 2013) (TCBM) in 2013, the discrepancy between space security requirements and space risks and challenges have significantly increased.

The TCBM proposal identified by the UN GGE has been largely ignored in terms of implementation, and the failure of the EU Code of Conduct proposal as well as the deadlock on the discussion of the long-term sustainability (LTS) guidelines created a sense of "no hope" on the diplomatic discussions. At the same time, the large and rapid changes that have taken place in the last 5 years in the field of space-based services and applications, as well as the disruptive innovations that supported a lot of new projects especially in low orbits (including the so-called mega-constellations), have increased the urgency for a more space security organized environment, considering the overall sustainability of space activities.

The 50th anniversary of the Outer Space Treaty in 2017 was not an occasion for many events. This low attention probably reflected a more substantial question about the extent to which the Treaty and its framework of international conventions (first of all the International Liability for damage caused by space objects Convention of 1972 and the Registration of objects launched in outer space Convention of 1975) would still shape the coming developments of human activities in and from space in the future. In addition, how the Treaty and related Conventions provisions would be resilient enough and inclusive enough to shape and regulate all coming developments which are under preparation.

The nonappropriation of outer space, along with the freedom of exploration, the liability for damage caused by space objects, the prevention of harmful interference with space activities, and the obligation to notify the international community and to register space activities are all legally acknowledged principles. (But, during the last period of time, different projects seem to assume that the nonappropriation of Outer Space could allow for the privatization of the mining of asteroids.) Yet, they are challenged, either because they are bypassed, or because they are discreetly ignored, or even openly violated.

Last but not least, and even if the prohibition of placement of nuclear weapons or other weapons of mass destruction in outer space seems to be still in force, the number of warnings that a new round of technologies could prepare for a militarized space is obvious. To quote the famous assessment from the US National Security Space Strategy of 2011, "space, a domain that no nation owns but on which all rely, is becoming increasingly congested, contested and competitive." (US Office of the Director of National Intelligence: "National Security Space Strategy," January 3, 2011.)

All these trends are feeding the sense that space could become an out-of-rule domain, a kind of jungle of the twenty-first century which will undermine many coming projects, or even destabilize the most established space-based services.

Because a part of the new revolution links together space-based systems and commercial services, in an increasing number of applications, be they civilian, military, or dual, commercial operators (be they "old" or "new" space) perceive the forthcoming environment as challenging. The concerns include not only an increasing lack of regulation, but also essential space dependency for many more activities on earth. According to the US Commerce Secretary Wilbur Ross, "today, the global space economy is roughly 400 billion dollars, about 80% of which is commercial activity" but "Morgan Stanley projects the global space industry could reach 1.1 trillion dollars by 2040." (Remarks by US Commerce Secretary Wilbur L. Ross at the US Chamber of Commerce Space Summit, December 6th 2018. Office of Public Affairs, US Department of Commerce.) As an observer remarked, "so the department (of commerce) is trying to deregulate the industry, making it easier for entrepreneurs to jump in, and to lure capital from venture capital firms, hedge funds, sovereign wealth funds and even mainstream pension funds." (Tett 2018; see as well, Donohue 2018.)

As space becomes a truly essential service base for a large spectrum of human activities on Earth, security of all the stakeholders (States, private, and international organizations), resilience of the regulations which allow and organize those services, sustainability of the infrastructure deployed in space, and finally, predictability of the upcoming rules based on a truly world-wide consensus constitute the ingredients of a safe and secure space for the future. No need to say that to overcome this challenge, which is multilateral by nature, requires a lot of effort and willingness from all stakeholders.

From a satellite operator perspective, three sets of key issues can be listed, which could, altogether, jeopardize the future of its activities, in terms of development, sustainability, and affordability. In this time of "crowded orbits," (refer to Moltz 2014) (1) it is tempting to identify these challenges at the geostationary orbit; (2) at the juncture between the geostationary orbit on one side, and the medium-earth orbit and low-earth orbit on the other; and (3) finally on earth as presented in the following sections.

Space Operations in GEO

As already suggested, the most crowded and congested orbit is the geostationary orbit where 548 of the 1886 existing satellites are positioned, 1186 being in LEO orbit and 112 in MEO. (Data provided by the Union of Concerned Scientists "Satellite database" in its update of August 10th 2018, Accessed 12 Dec 2018.) It is interesting to notice that in 2012, 1050 satellites were in operation, among which 432 were in geostationary orbit, 73 in medium-earth orbit, and 503 in low-earth orbit. (The figures are provided by J. C. Moltz, in "Crowded orbits," op.cit pp. 20–23.) These figures deliver quite a strong message: the GEO orbit is now growing very slowly in terms of new satellite populations, as opposed to LEO that is witnessing a dramatic increase of resident space objects.

GEO orbit is crowded and congested to such large extent that the management rules for the fleets raise more constraints. Yet the core of the International Telecommunications Union (ITU) regulation of the space-based services for telecommunications is still mainly based today upon the noninterference principle as it was at the beginning of the 1970s, when the management of the orbital positions was far less constrained. The change is such that, at that time, the management of the orbital positions was also complemented by another implicit rule – first arrived, first served – which cannot any longer be implemented. Of course, the principle of noninterference is of much importance as it allows for proper technical functioning of the satellites at close orbital positions, through coordination agreements among operators, but appears too limited to address all potential situations.

Among them, the dynamic management of fleets, the appearance of a graveyard orbit, and the emergence of "clinging satellites" are quite troubling and may illustrate the extent to which existing regulations are not able to face the coming challenges. Basically, the need for enduring transparency about what is happening at the GEO orbit and "who" does what may have to be on the top of the to-do list the international community could set up. It is assumed that one key obstacle of such transparency has been, in the past, the importance of military services which were provided by military satellites at this orbit, especially for nuclear testing detection, early warning of missiles launching, or detection of preparations for a military offensive. Such missions are for sure still needed even if the geopolitical and strategic environment is nowadays profoundly different from the Cold War one, and the satellites associated with them may legitimately receive a different treatment.

However, managing transparency at the activities which take place at the GEO orbit, from the satellites which are registered by the UN Register now ratified by 68 nations and some intergovernmental organizations (like Eumetsat, Eutelsat, ESA, or Intersputnik) at the end of 2018, would also be the beginning for more security in orbit, keeping in mind that, according to the UNOOSA, 91% of all satellites, probes, landers, crewed spacecraft, and space station flight elements launched into Earth orbit or beyond have been registered with the Secretary-General. (UN Office for Outer Space Affairs (UNOOSA) website, Register of Objects Launched into Outer Space, Accessed 12 Dec 2018.) From that standpoint, it is important to notice that the Registration Convention is still attracting new signatures, like the Luxembourg one, a nation which has recently decided to join the Registration Convention. However, registration should probably be based on a wider basis than a very administrative process. Like ships and planes have received an identification once the management of their movements was obviously needing a way to track them to prevent fatal collisions, providing an ID to the registered satellites may be the next needed step to ensure that the Registration Convention will still be a significant tool for space governance.

As we shall see, absence of even minimal rules related to transparency at the GEO orbit is providing an avenue to behaviors which are obviously dangerous, and which could become common because of the impunity the players which are behaving so do feel. The fact that impunity prevails over responsibility and accountability is obviously not a good situation.

Because of the saturation at the GEO orbit, operators need to develop a very dynamic "fleet management" which includes increasingly frequent satellites movements along the orbit. (As an example Eutelsat which owns close to 40 satellites has had to manage an average of 5–6 moves each year since 2011 (however of very different magnitude), and there is no doubt that the frequency of these moves has increased along these years.) For that reason – ensuring that close movements by different satellites will not create harmful interferences or even collision risk among them – the satellite telecommunications operators have established a shared and common database of technicalities associated with each satellite they operate, which can facilitate safe movements and close locations, and by itself could illustrate the kind of best practice and transparency which could be extended to all registered satellites. (The database is managed by the "Space data association" (SDA). SDA "is to seek and facilitate improvements in the safety and integrity of satellite operations through wider and improved coordination among satellite operators and to facilitate improved management of the shared resources of the space environment and the radiofrequency spectrum" (SDA website consulted December 13, 2018). SDA is now looking at enlarging its database to other orbits than GEO.) From a regulatory perspective, and in order to comply with ITU rules related to the orbit management, satellite operators have noted that a frequency assignment can be brought into use only if a satellite is maintained at the orbital position for a continuous 90-day period so fighting against "paper satellites," and that from another standpoint, a frequency assignment cannot be suspended for a period exceeding 3 years. All these rules which ITU has developed in order to better manage the orbit and allow access to it to all newcomers are also aimed at limiting the cases where "force majeure" is claimed. It is fair to say that these rules, because they are more and more constraining, are also creating business opportunities among satellite operators, which will need each other more often to ensure the continuity of service to their customers, when the scarcity of orbital positions and frequency assignations do not allow for mismanagement of these "rights."

It must be added that national legislations can also contribute to this transparency. In the case of France, satellites movements are notified 1 month in advance to the French space authorities, as an obligation deriving from the French Space Operations Act of 2008. However, there is no binding international rule creating the same obligation at the moment, even if recommendations to notify such movements have been adopted by UN member states. In a nutshell, guidelines based upon transparent behaviors and explicit rules for the orbit management to be followed by all parties to the Register Convention will be ever more needed, and in the interest of all stakeholders, will be.

National Space Laws (like the 2008 French one) also include provisions aimed at ensuring the protection of the space environment during the satellites' life cycle, which means proper control of the satellite during its in-orbit life (station-keeping, relocations) and deorbiting at the end of its operational cycle in ways which will minimize the risks for health and the environment. Those rules are directly derived from some guidelines and best-practices recommendations established under the UNOOSA via its COPUOS technical works, as part of the space debris management

issue. However, for this last part, the guideline is based upon the principle that the satellite must be able to reach a position (the "graveyard orbit") located at 300 km above the GEO orbit, and that, once at that final position, the satellite has been totally passivated and will no longer be a threat of any kind (energy, mechanics, radio-frequency, health). For sure, this deorbiting rule is providing a rule aligned with the fact that those satellites, beyond any kind of reach from earth at 36,000 km, cannot be of any use. However, it should be recognized that we are only at the starting point of this "graveyard policy" and that many satellites launched since the beginning of the last decade has still to reach the graveyard. Hence, there is some doubt that this rule will be sustainable in the long term, as the number of out-of-cycle satellites will quickly increase in the next 5/10 years because satellites launched in the 2000s will have to be replaced, in order for operators to keep the orbital positions they have been authorized to use and from which they provide services.

Finally, the principle of "noninterference" does not prevent "passive hostile" attitudes like the situation by which an unidentified satellite is coming so close to your satellite that it enters the "box" where this last one is supposed to be maintained in order to serve properly and in due compliance with the noninterference principle, and this unidentified satellite clings to your satellite for a period of time which can be a matter of months, and not only of hours or days. Despite the obvious danger such a behavior entails, this passive hostile attitude does not allow for complain, in absence of interference. However, a satellite which is stationed for a long time close to another one which has the full rights to stay at its orbital position, in its "box," is potentially dangerous, even from an orbit management perspective, and finally, could be considered as a serious threat, and as such in breach of the basic rules of peaceful uses of outer space. Every behavior of such nature should be accountable, and transparency rules should request for compulsory statements by which the nation responsible would have to explain the reasons of such close presence at an orbital position (the "box") which is not supposed to be the harbor of a passive, but potentially hostile, clinging satellite. It is obvious that along the last years this story of clinging satellites has expanded to a point that, after US officials raised the issue during the Space 50 Conference, the French ministry of Armed Forces also made it publicly when she revealed that a French-Italian satellite (ATHENA-FIDUS) had been spied by a Russian satellite (Luch (Olymp-K)) without any kind of governmental comment or official justification. It is well known that other Russian satellites have behaved in the same way along the last years with different commercial satellites owned by several different satellite operators. That the existing rules, or more precisely their weakness, can allow such movements and "passive aggression" demonstrate the magnitude of the gap which is now created between what could be considered as a responsible management of the GEO orbit and what is taking place. The next step in such an escalation of dangerous behavior will obviously be that a commercial satellite is facing a situation where its integrity is at stake and takes initiatives for movements which could, at the end, turn into a collision between the two objects. Even if the article IX of the Outer Space Treaty calls for a conduct of all space activities "so as to avoid harmful contamination" and asks countries to notify other countries before engaging in any activity that might cause "harmful

interference" with activities of others, there is no regulation, procedure, and even concrete sanctions that could limit such attitudes and even prevent them. If there is a will to restore a safe and secure use of the space domain, the most efficient way to prevent such an escalation is to make such attitudes public (as the US and French officials did recently), make them transparent, and strengthen the rules which must prevent them. The shame of the present situation is that such behavior is even not clearly in breach of the rules, despite the very significant danger posing for the stability and safety of space-based activities and services. An increase of global space situational awareness (SSA) capabilities and a "naming and shaming policy" should put an end to the impunity that some stakeholders make use of.

Space Operations in LEO, MEO, and Transit Orbits

It has already been noted that one of the most disruptive changes taking place at the moment is the quick and significant development of projects planning to use the low-earth orbit (LEO), and to a lesser extent the medium-earth orbit (MEO). The magnitude of change is such that some consultants foresee 6500 smallsats to be launched in LEO orbit before 2027. (NSR press release about its report "Small satellite markets," 5th edition, Accessed 28 Nov 2018.) Other figures have even been mentioned, like 11,943 satellites, authorized by the FCC, which are planned by M. E. Musk constellation "Starlink," (Wall Street Journal (online), Accessed 18 Dec 2018) or the 3500 satellites One Web is intending to deploy. Should all the projects already made public by developers and startups be implemented, a total of 18,000 satellites could reach the LEO orbit before the end of the next decade.

Obviously, such an order of magnitude is creating a lot of unknown challenges, but the significance of this change can be measured against the fact that the world aeronautics industry looks for more than 36,000 planes in service in the world in 2032 (against 17,740 in 2013) which will transport 6.3 billion travelers. In other words, and assuming that most of the current projects will be implemented, where we were seeing roughly 1 satellite against 10 planes in the mid of the 2010s, the ratio could become 1 satellite against 2 planes in the mid of the 2030s. In addition, it must be noted that, in many cases, these new low-orbit constellations will aim at providing connectivity in planes, like many key geostationary already decided (e.g., Eutelsat VHTS) will do. This new connection between telecommunications satellite deployments and air fleets development could be of structural consequence for both domains in the next future.

These disruptive figures may give a sense of one new and key issue which will have to be faced: the organization of the management of the different orbits, and the notion that the different orbits will have to be understood in their dynamic interaction.

At the moment, the main regulatory guideline, issued by the ITU in 2007 along with the "noninterference principle," states that the signal coming from the GEO satellites shall not be interfered by signal from satellites at lower orbits, the GEO signal being far less powerful when it reaches the earth than the other signal,

especially those emitted from LEO satellites. These rules have been set up for the Ku and Ka bands which are providing the most significant services (Ku for television by satellites, Ka for internet and connectivity by satellites).

The wording of the ITU stands as follows (Radio Regulation No 22.2, as decided by WRC-07):

> 22.2§ 2*Non-geostationary-satellite systems shall not cause unacceptable interference to and,* unless otherwise specified in these Regulations, *shall not claim protection from geostationary-satellite networks* in the fixed-satellite service and the broadcasting-satellite service operating in accordance with these Regulations. No. 5.43A does not apply in this case.

These rules may have to be strengthened. However, new parts of the spectrum, like Q- and V-bands, will be extensively used by satellites systems, notably to connect the earth gateways and the satellites in the coming decade. Most of the "very high throughput satellites" (VHTS), like those designed by Thales Alenia Space and/or Boeing, will make use of these Q- and V-bands.

Those issues are listed on the WRC19 agenda (Agenda Item 1.6 of WRC19). In order to prepare for that discussion, the WRC15 (2015) asked to conduct and complete in time for WRC-19:

> 1 *studies of technical and operational issues and regulatory provisions for the operation of non-GSO FSS satellite systems* in the frequency bands 37.5–42.5 GHz (space-to-Earth) and 47.2 48.9 GHz (limited to feeder links only), 48.9–50.2 GHz and 50.4–51.4 GHz (all Earth-to-space), *while ensuring protection of GSO satellite networks* in the FSS, MSS and BSS, without limiting or unduly constraining the future development of GSO networks across those bands, and without modifying the provisions of Article 21; (. . .).

In addition to the large and (maybe) numerous constellations in LEO related to telecommunications services, the coming Internet of Things (IoT) constellations and the maturation of the observation market which will drive the deployment of dedicated constellations, like Planet6Labs which plans for 140 low orbit satellites, must be considered. These two kinds of applications will, for sure, include an increasing number of artificial intelligence (AI) assets, which will be on-board small (like shoe boxes) and unexpansive satellites. (The New York Times International was referring to satellites of 7000 $ a piece, Accessed 12 Dec 2018.)

With these new developments, space-based services are reaching a kind of industrial age which they ignored until now, despite the more than 42,000 TV channels currently broadcasted globally by satellite. AI and IoT will for sure drive a standardization process, in terms of production, and a development of satellite-based services unknown until now. In addition, new assets, like balloons, high altitude pseudo satellites (HAPS), and drones, will become part of the connectivity networks deployed in space. As well, suborbital flights will have to be considered in terms of legal and regulatory terms, and it will have to be decided whether they should be regulated by the air-space rules or by the space

management principles, both systems needing to be (at least partially) aligned to be manageable.

The industrial age of the space-based applications will entail new services like in-orbit services. These services intend to extend the life cycle of the satellites by refueling them (when their propulsion is mainly chemical) and/or repairing some of their major components like solar antennas. A few companies are currently planning for such in-orbit services. However, this next step is already raising a lot of questions: if space services ability to extend the life cycle of the satellite can be affordable, do we need to plan for 15 years of life cycle for the telecommunications satellite, as it was done until recently or should we think about less duration for the satellites (8–10 years for example) with a better ability to adapt the services to the consumers expectation, when planning for the market in 2030 is so difficult?

Such in-orbit services would entail an increasing level of space movements and traffic which would need specific regulations but are still to come. It has been said that soon the first "mission extension vehicle" (or "space tug") will be launched to extend the life duration of Intelsat 901. Assuming that this interest in life-extension of the satellites could be shared by other satellite operators, what will be the legal status of these objects? Should they be registered like satellites? What is the consequence if such an object fails to provide the service it was assumed to? What is the status of such an object if left in space? Is it a debris, and if so, could the Liability Convention apply? All these questions need to be addressed quite urgently as there is no common rule already agreed. Furthermore, because of the growing number of LEO projects, which will entail hundreds of launches, the overall effect of this change will be an increasing number of debris, even in absence of military activities aimed at testing anti-satellite weapons.

Space surveillance, including space surveillance and tracking, will therefore receive a growing attention from all space users. SSA and Space Traffic Management (STM) are, for the time being, sovereign missions, developed by governments or groups of governments (the EU plans to develop its own capacities). The condition under which these data could be shared with commercial operators, will have to be decided. At the commercial level, the SDA has outsourced a capacity of that kind, adjusted against commercial needs (of course very different from the military needs, and much more limited than them) and allow for access to data to the contributing operators. In the future, the growing importance of such SSA/STM data is so great that the US government has decided that the US Department of Commerce would become the interface with the commercial satellite operators in terms of SSA data sharing. This recent change could also open the door to established commercial SSA and STM services which would complement the governmental ones. If that is the case, they need to decide how these SSA/STM data from different sources will be shared, and along which rules these will be of much importance.

Two questions will be of key importance in order to ensure a sustainable space operations environment:

- How will all stakeholders of the space-based infrastructures, among them the private satellite operators, have access to the space surveillance awareness data? It

can easily be assumed that not all data will be accessible, but according to the "need-to-know" principle, there is room to decide which of them are of interest for the commercial operators.

- To which extent the dedicated tools, implemented and managed by governments or groups of governments, will be phased with the pace of the commercial services development? If it is recognized that the SSA data could be shared if and when a denial of service could be intended, an obvious threat to some assets could be experienced, or more broadly, in order to better understand the new developments which could put satellite operators at risks, then SSA policies would strengthen private policies aimed at ensuring continuity of service and agreed service levels.

For sure, satellite operators will consider SSA and STM as key strategic issues which should be inclusively designed. The way to proceed and the roadmaps to de defined will become major issues of the relationship these commercial operators will have with governments. However, if we take into account GEO management challenges, LEO/MEO developments, and multiplication of space objects (like space tugs), there is no doubt that the entire Space Situational Awareness and/or Space Surveillance and Tracking purposes and methodologies have to be redesigned in accordance with the disruptive changes which are going to take place in the way all space stakeholders will make use of this common good.

Protection of Satellites Services from and at Earth

Since the core business of telecommunications by satellites has moved from direct-to-home (DTH) TV broadcasting to internet and broadband services, the value of the different components has faced a major shift: when the DTH broadcasting was mostly an investment in the space segment in the 1990s, which represented more than 90% of the total (space + terrestrial) investment, the space segment is about 60% of the total investment when it comes to broadband services by high throughput satellites (HTS) which are based upon a multispots coverage. In other words, around 40% of the investment is nowadays related to the terrestrial segment of the space-based system. This terrestrial segment is mainly distributed between gateways which connect the final user equipment (antenna + modem) to the internet, through the satellite. The network of gateways, installed in different places (nations) throughout the coverage of the satellite, constitutes a distributed hub managing the traffic and the spectrum allocation to and from different satellite spots.

This architecture which is becoming the standard of connectivity provision in the GEO high and very high throughput satellites (VHTS) will become even more essential in the LEO constellations in order to ensure continuity of service when the constellation "flies" over a location.

Hence, protecting the terrestrial gateways and networks from interferences, be they technical (deliberate or not), legal, or even political, is crucial. This matter is mostly regulated by nations, according to their conceptions of "internet freedom,"

the resilience of the technical solutions selected by the internet service providers (ISP), the security regulations which apply to these networks, and more widely, to the broadband policies decided by governments.

The freedom of information has been defined in 1948 by the UN Charter on Human Rights as: "Everyone has the right to freedom of opinion and expression; this right includes freedom to hold opinions with-out interference and to seek, receive and impart information and ideas through any media and *regardless of frontiers*." (article 19).

The UN Covenant on Civil and Political Rights (1966) developed its consequences as follows:

> Article 19.1. Everyone shall have the right to hold opinions without interference.
>
> 2. Everyone shall have the right to freedom of expression; this right shall include freedom to seek, receive and impart information and ideas of all kinds, regardless of frontiers, either orally, in writing or in print, in the form of art, or through any other media of his choice.
>
> 3. The exercise of the rights provided for in paragraph 2 of this article carries with it special duties and responsibilities. It may therefore be subject to certain restrictions, but these shall only be such as are provided by law and are necessary: (a) For respect of the rights or reputations of others; (b) For the protection of national security or of public order (ordre public), or of public health or morals.

The fact that both of these documents state that freedom of information must not be limited by frontiers receives a special meaning in the case of internet by satellite, which is by nature, the most efficient tool to disseminate information "regardless of frontiers." However, the worldwide trend seems to look for more constraining rules, in many cases for security reasons. How to ensure free provision of space-based services and freedom of information at the internet age, on one hand, and security requirements, on the other hand, at the same time needs to be considered not only at the level of the governments, in charge of setting national rules, but also at the international level, which is appropriate to set rules aimed at implementing the principles as stated by the UN Covenant, which is binding for ratifying states. Previous attempts to move forward in this direction have failed in the past, when TV dissemination was the main satellite service. However, the new development of space-based services will call for more determined actions to update the implementation of these lasting principles which have to be protected in this new situation, as well.

From another standpoint, the new era of space-based services will look at the convergence between telecommunications and navigation services (like GPS and Galileo). If connectivity has to support mobility, both kinds of services will be needed at the same time, and the satellite will be, again, an indispensable tool because of its territorial coverage, when terrestrial telecommunications network (i.e., fiber, 4G) basically address urban and concentrated populations. With the 5G coming, the end user will ask for a seamless connectivity, every time and everywhere. This expectation, which will ensure continuity of service, will request hybrid and complementary networks, terrestrial and space together providing a resilient

service based on a large interoperability of the networks, able to match any kind of unexpected situation as the satellite will also provide the back up to the terrestrial network in case of need, or in case of urgency. Such architecture will allow for satellite to serve remote, distant areas, and mobility needs when terrestrial networks will first of all provide services in highly dense and urban areas. Furthermore, the resilience of the overall supply will extend the spectrum of applications, especially to the very demanding services related to defense and security, as we already noticed.

Along this change, the clear-cut separation between defense/security needs and commercial needs will continue to blur. There is already a lot of security/defense needs which are fulfilled by commercial objects and operators; military planners are now including the commercial assets in their assessment of the resources which could be mobilized in case of need by governments (because of the flexibility provided by large commercial fleets), and commercial operators consider the governmental needs as a key driver for their future development (i.e., EU Govsatcom in Europe which should include services provided by commercial operators; DISA reform in the United States by which the Air Force Space Command will "oversee management of nearly all military and commercial SATCOM for the DoD" (US Air Force Space Command press release, Accessed 12 Dec 2018). Furthermore, disruptive technologies like software-driven satellites will allow the best provision of the power and of the spectrum based on end user needs. (The "Quantum" satellite, to be launched in 2019, and built by Airbus in UK, will be the first 100% software-driven satellite.)

If governments and operators together develop collaborative policies and solutions to fulfill the security needs, more robust rules will have to ensure that hostile actions against commercial satellites will be treated in the same way as hostile actions against sovereign satellites. However, the requisite for such approach is the ability to designate the origin of the hostile action, in other words the ability to attribute. Here, the challenge is probably of the same nature as it is when it comes to cyber-attacks. In both cases, satellite jamming and cyber-attacks, the actors bet on the impunity they can expect from the difficulty to identify their behavior and to attribute the unlawful practice. Hence, and even if new satellite technologies allow for anti-jamming equipment and geo-localization mechanisms on-board the satellite, which become quite conventional on commercial satellites, it seems that satellite manufacturers need to invest in research and development to ensure that those which are tempted to make use of cyber-attacks or jamming of the signal will be deterred from such behavior because of the increasing risk of being identified. Again, being able to "name and shame" the origin of the infringement and the identity of the rule breaker, like a whistleblower, is a must. To the extent that such infringement is facing a sanction!

Government's responsibility in case of jamming of the satellite signal falls under the ITU rule: however, despite recent progress from the ITU Pleny Potentiary of 2014 (resolution to set up a database of the geo-localized jamming), the fight against deliberate jamming (for political reasons, to prevent the reception of a signal in a territory) must be strengthened. Western nations are currently the only ones which may be ready to recall the principles, and more important, to ensure that they are still implemented by the community of nations which are UN members.

Space security must be understood in a comprehensive way: it is not only about protection of the space segment. A space-based infrastructure is a system combining a space asset and a network of terrestrial gateways/infrastructure which are as important as the space segment in order to provide the service. This terrestrial component of the space-based system has an increasing strategic value as it is the service provider component to reach the end user: we can observe an increasing pressure from governments to receive a right to have access to or even to be able to control the flows of data coming from (or going to) the satellite. There are good reasons for that (e.g., fight against terrorism), but there are also very serious threats resulting from that trend (reduction or even suppression of freedom of information). The international community has established strong grounds which have supported the development of the space applications (like TV and internet services provision), which is the freedom to access to information "without borders consideration"; (art 19 UDHR; art 19 of ICCPR; EU HR Chart): these principles are obviously challenged in an increasing number of situations.

Space operations and space services are at the core of the discussion about cybersecurity in space. They all need very dynamic and robust cryptology methods in order to ensure that the very quickly increasing number of services based upon space infrastructure will be resilient to adverse behaviors. New technological developments like laser transmission of data (EDRS in EU; NASA next generation relay satellite/post TDRSS) is giving the space-based solution some kind of advantage to ensure the security of the data transmissions: the space community (governments, industry and operators) should identify the contribution the space-based solutions can bring to a more secure cyber environment, and set up the rules which will strengthen this key advantage at the moment when satellite services are even more needed.

Conclusion

Along the last decade, it has been expected that this need for a more regulated environment for space-based activities could be fulfilled by guidelines, best practices, and agreed principles. This set of rules will be even more needed in the coming future than it already is. As the governmental, economic, and social value of the space-based applications multiply, such rules will only protect the proper management of the humanity "common good" which is the space domain.

If there is no deployment of offensive weapons systems (like ASW) in space, this "soft law" recommendation should concentrate on two main issues, which unite most of the described situations: service (and access to) denial; attribution of action (transparency/responsibility/liability).

However, it should be recognized that, with its code of conduct proposal, the EU tried to make steps forward towards a more sustainable space environment. The failure of such proposal to reach the consensus shows how important it is to strengthen the efforts. It seems that far from being the "common good" subject to peaceful activities, as described by the Outer Space Treaty of 1967, it moves towards

a kind of jungle where survival and security of the services, whatever their nature, will not be granted.

Looking at the plans to develop new activities related to space exploration and the prospect of "celestial commercialization," a commentator was stressing that "the time has come to clarify international space law and allow commercial ventures to go ahead subject to sensible safeguards." Noting that "a full-scale revision of the Outer Space Treaty might be desirable but is not necessary," this comment was suggesting that "a governance framework agreed by all spacefaring countries would do the job." (See Financial Times, "The world should update its laws on outer space," Accessed 28 Dec 2018.) This cautious approach was taking stock of the very difficult challenges a revision of the Treaty would entail at a moment of hardened competition among the space nations, and despite the benefit all humanity could find from an updated treaty which could decide for the regulations of the coming and extended space activities. However, far worse, deciding for a revision of the Treaty could open a Pandora box which could, finally, undermine the principles which the Treaty has recognized and which are still very meaningful for the future. Should a Treaty revision be decided, it should aim at strengthening those principles, and set regulations which would help to manage the coming challenges, not destroy the "space order" which is still based upon the Treaty.

Obviously, and in absence of a "consolidated" Treaty, the governance framework which is required is more than urgent, and not only because of the asteroids commercialization. Space is at the juncture of sovereign and commercial activities, national and international projects, closely related to the emerging data and digital needs and technologies, close to extend significantly the number of industries and services which will rely on it on a constant basis. More than an infrastructure, space-based activities are becoming the most ubiquitous domain which most not to say all future human development plans will require. Absence of governance, allowing all these plans and services to find their path will become a challenge from which, in absence of significant progress, the mere future of this attractive and even exciting new area could collapse without delivering its promise.

International organizations, governments, and private actors must now bend their efforts to establish this governance framework which is so much needed.

In that respect, commercial operators should build upon their own experience of space-based services to further contribute to shaping this framework. Among the different items they could raise, some seem more urgent.

A first priority could be to develop the *transparency* of movements in space. As an example, adding a satellite identification to the registration obligation could help monitoring movements at the different orbits, facilitate their notifications during the 15 years of the life cycle of many satellites, and discriminate satellites from space tugs and high altitudes balloons or drones, for example. History shows that such transparency (based on an ID) was the condition for a safe and secure use of the airspace by planes, and seas by ships. It can be doubtful that the huge increase of

space objects in the near future will allow for an enduring regime of quasi-secrecy about the movements in space, even more if collisions between space objects were to remain nonliable.

The second aspect could be to develop a *responsibility* scheme where international norms, best practices, and/or national space laws, financial incentives finally could combine to promote a sustainable use of space. The launching industry has demonstrated a significant capability to reduce the risks of failures in the launching business because of the attention the operators paid to the insurance cost of the launchings they ordered. The need for an insurance could be extended to more space activities, and could act as an incentive to develop designs which could reduce the number of debris, extend the life time of space assets, or reduce the collision risks (especially at low orbits).

The third aspect should tackle the absolute need to ensure the *continuity* of service which end users are expecting from the space rules and actors. The guarantee of service continuity is the condition for an area of large recourse to space-based services, especially if these services deal with connectivity and mobility. It should encompass the prevention of deliberate interferences, the technical developments which will ensure the robustness of the signals against cyber-attacks, the ability to identify and designate the parties which are threatening the continuity of service. A lot of investment (technical and financial) is paid to achieve this service continuity objective, but it needs to be backed by rules which will penalize the actors undermining it.

A final dimension could set up the appropriate forum where all issues related to space sustainability and governance could be discussed between international organizations (CD, COPUOS, ITU...), governments, and private actors (the list of which is extending quite quickly). At the moment, all concerned entities develop their "own" framework for discussion, but these different discussions are not coordinated along with a *common agenda* which could have been agreed by all stakeholders. The need for an agreed "space agenda" which would answer the questions – what are the issues at stake? what are the key priorities to address? to which extent proposals and identified solutions can be implemented by the actors, need "soft law" solutions (best practices, standards...), or need an urgent "hard law" (conventions, revised OST) – all these issues need to be addressed in a forum which could report to the UN, as the ultimate responsible for a safe and secure space.

Security and sustainability of space-related activities is facing a very serious challenge. Commercial space operators have an insight on technological developments (which they very much drive when ordering the space-based and ground-related infrastructure), affordability of coming services (especially in terms of connectivity and data management), added value of space-based services (by comparison to terrestrial solutions), and regulations which could support the space based economy. All these issues cannot be solved by one government, or even one international organization. They are multifaceted, evolving, and pressing at the same time.

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