Reducing vulnerabilities of space activities: A call for coordinated leadership at the global level

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abstract

Orbital congestion, contestation and competition are on the rise, and space activities are expected to align with treaties, arrangements, and guidelines elaborated at a time when the space ecosystem was simpler - and it is becoming more complex. To cope efficiently with this changing situation, at a time when space systems have become an indispensable enabler for an ever-increasing range of socio-economic activities, new rules of the road are necessary. Indeed, these should ensure the sustained stability and security of the space environment, providing norms and standards beyond transparency and confidence building measures, laying the ground for the founding elements of a space traffic coordination (management?). Hence, for us to be dependent on a reliable space-enabled information flow will require a significant decrease of their vulnerability; protection as well as "fail safe" are becoming the chief concerns. This paper will first review the current legal and regulatory provisions under which space activities take place, pointing out some limitations of the international dialogue, which is quite complex, anarchic, and with no clear global leadership, complicated by the dual use (civil and military) of space. Moreover, enforcement appears to be ineffective. It will then consider new public, as well as private, initiatives that are underway, evaluating the robustness of their foundations. Possible avenues are proposed in support of the most recent prominent initiatives, including the possibility for an international agreement on standards and behaviours, or an international civil space organisation inspired by the International Civil Aviation Organisation - ICAO. Emphasis will be placed on the urgency of bringing together these initiatives and processes under a common umbrella, or at least to achieve the convergence of a set of rules noting that international hard law provisions are far reaching. A step-by-step approach is suggested, addressing immediate, mid-term, and long-term actions to provide a stable space environment favourable to LEO large constellations, in-orbit refuelling/repairing, active debris removal, human commercial space-flight, cis-lunar/interplanetary traffic, space resources exploitation, and security/defence operations.

1. Introduction

It is common to underline that today space is congested, contested, competitive and indeed complex with over 3600 (1st April 2021) active satellites, and more than 8500 smallsats in 2028 according to a recent Euroconsult forecast. Not forgetting the 23,000-space debris with an average dimension greater than 10 cm, essentially in low Earth orbit (LEO). Orbits and orbital slots can be contested by operators including radio-frequency allocations, while there is an increasing competition on the way to and the quality of delivered services, be it for launchers or satellites.

This growing complexity is inescapable since the pervasiveness of space applications continues to span throughout the whole of society, rending the socio-economic activities evermore dependent on space as-sets. Hence robust, reliable, and resilient services must be maintained, implying that their vulnerability ought to be minimal. Existing legal and regulatory provisions, or guidelines have become insufficient to cope

Abbreviation: ADR, Active debris removal; ASAT, anti-satellite; CD, UN Conference on Disarmament; DARPA, Defense Advanced Research Projects Agency; EEAS, EU External European Action Service; ESA, European Space Agency; GEO, Geosynchronous Orbit; GGE, UN Group of Governmental Experts; GNSS, Global Navigation Satellite Systems; HCoC, The Hague Code of Conduct; IADC, Inter-Agency Space Debris Coordination Committee; ITU, International Telecommunication Union; ICoC, International Code of Conduct; LEO, Low Earth Orbit; OST, Outer Space Treaty (1967); PPWT, Draft treaty on the prevention of placement of weapons in outer space, the threat of use of force against outer space objects; SDA, Space Domain Awareness; SSA, Space Situational Awareness; SSC, Space Safety Coalition; SSTL, Surrey Satellite Technology Ltd; STCM, Space Traffic Coordination and Management; TCBM, Transparency and Confidence Building Measures; UNCOPUOS, United Nations Committee on the Peaceful Uses of Outer Space; UNGA, United Nations General Assembly; WMD, Weapons of Mass Destruction.

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with the enormous challenges ahead tied to the constant augmentation of orbital traffic[1], namely in LEO.

Indeed, the 1967 Outer Space Treaty (OST) [1] was drafted at a time when the number of space faring nations could be counted on the fin-gers of one hand, essentially meant to avoid the placement in orbit and on celestial bodies of weapons of mass destruction (WMD), ensuring sta-bility of nuclear deterrence among the two superpowers to start with. It lays the fundamental frame under which space operations are practiced till today. Yet articles prescribing good behaviour in space, in particu-lar (VI-States responsible for international space activities; VII-damage liability; VIII-jurisdiction and control by State Parties of space objects; IX- international cooperation to deal with potential harmful interfer-ence; XI- information about the nature, conduct, locations, and results of space activities to be disseminated to the greatest extent feasible and practicable) remain too general for today's and future space operations regarding the booming number of satellites. Since the entry into force of the OST, several breaches did happen and have never been enforced (e.g., intended creation of space debris in LEO by China in 2007 and India in 2019, deliberate interference of Iran on Eutelsat broadcast into Iranian territory in 2012, Russian satellite LUCH siding up since 2014 to a number of GEO satellites, several of them belonging to Intelsat, raising concerns that it could be intercepting data or carrying distant satellite inspection. Such behaviours clearly contravene articles VII and IX of the OST).

The mounting challenges of space debris prevention and mitigation became a pressing issue to deal with, triggering the creation in 1993 of an Inter-Agency Space Debris Coordination Committee (IADC) which produced a set of guidelines in 2002, laying the ground for the recom-mendations endorsed by the United Nations General Assembly (UNGA) in 2007.

Sensing the need for additional rules of the road, e.g., responsible be-haviour in space, transparency and confidence building measures were established to ensure that space activities would continue to be carried out in a safe, secure and sustainable manner, a range of national, multi-national, institutional and private initiatives have burgeoned during the last twenty years or so.

These produced some results but to a limited extent, with the no-ticeable exceptions of the UN recommendations regarding space debris, and the recent adoption (2019) by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) of a series of guidelines destined to improve the long-term safe, secure and sustainable space ac-tivities. On its side, industry, including major space operators, released in September 2019, under the banner of a Space Safety Coalition (SSC), a call of "Best Practices for the Sustainability of Space Operations".

Technical improvements regarding space surveillance and tracking (SST), bringing in the private sector, as well as in the space situational awareness (SSA) / space domain awareness (SDA) arenas with improved automated collision avoidance processes, more data sharing and trans-parency undoubtedly has created better confidence among operators who share the same vested interests.

Yet, these valuable efforts, which will be detailed in the next sec-tion, show insufficient international coordination and acceptance, some-times even anarchic, lacking global leadership. The continuous pile up of so numerous initiatives have been disappointing, being largely in-dependent of each other, and essentially non-synergistic. To match the formidable stakes in front of us, we probably need to come up with a new paradigm capable of lowering rampant defiance of some communities, looking at mechanisms that would strengthen confidence to build con-sensus on a common set of rules involving the different nature of space actors and missions, promoting best practices, norms and standards for a safe and responsible behaviour in space. First and foremost, freedom of access to and circulation in outer space shall be reinstated. Hard law should be avoided because it will be unacceptable by major players, but some degree of enforcement could be introduced as it already exists for ground, maritime, air and cyber activities.

[1] For instance, SpaceX will complete the 1st tranche of the 1584 Starlink LEO satellites by the end of 2021 dedicated to low latency internet connectivity.

2. Legal and regulatory provisions, guidelines

Some of the most noticeable initiatives since the turn of the century are briefly summarised here under.

2.1. Multilateral mandated processes and fora

- Space debris mitigation guidelines

During a 2003 session of the UNCOPUOS scientific and technical subcommittee, the IADC presented its proposals on debris mitigation, based on consensus among the IADC members. A revised draft for a set of space debris mitigation guidelines was circulated at the national level to secure consent for adoption of the guidelines by the subcommittee at its session in 2007. Final guidelines were endorsed by the UNCOPUOS in 2007 and by the UNGA in December the same year, inviting Mem-ber States to implement those voluntary guidelines through relevant na-tional mechanisms.

The guidelines are as follows [2]:

1. Limit debris during normal operations
2. Minimize the potential for break-ups during operational phases
3. Limit the probability of accidental collision in orbit
4. Avoid intentional destruction and other harmful activities
5. Minimize potential for post-mission break-ups resulting from stored energy
6. Limit the long-term presence of spacecraft and launch vehicle or-bital stages in the low-Earth orbit (LEO) region after the end of their mission
7. Limit the long-term interference of spacecraft and launch vehicle or-bital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission.

Guidelines 6 and 7 are less stringent than those recommended by the IADC proposal introduced in 2002 [3]. Namely, i) the 25-year lifetime limit for objects in the LEO region is replaced by "avoid long-term pres-ence in the LEO region"; and ii) the parameters of the graveyard orbit in the GEO region are not mentioned, although explicit in the initial IADC guidelines.

It is estimated, according to [4], that for LEO satellites reaching end of life in 2015, only 32 % of those having a mass in the 10-1000 kg range abide by guideline 6; while 60 % of the GEO satellites did not comply with guideline 7.

- Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects (PPWT)

This draft treaty was introduced by China and Russia in the Confer-ence on Disarmament (CD) in 2008 and revised in 2014 [5]. In essence, it calls for not placing any weapon in outer space; not resorting the threat or use of force against outer space objects; not engaging in outer space activities, as part of international cooperation, inconsistent with the subject matter and the purpose of the Treaty; and not assisting or inciting other States, groups of States, international, intergovernmental and any non-governmental organizations, including non-governmental legal entities established, registered or located in the territory under their jurisdiction and/or control to participate in activities inconsistent with the subject matter and the purpose of the Treaty. It recalls the in-herent right of state parties to individual or collective self-defence, as recognized by Article 51 of the UN Charter.

This draft suffers from three weaknesses: i) no provision for credi-ble means of verification to ban weapons in space; ii) not taking into account directed energy ground-based and direct ascent ASATs such as

those used in January 2007 against a defunct Chinese weather satellite, or planned by China, or more recent direct ascent counterspace capabil-ities under development by China and Russia[2]; and iii) not addressing correctly the risks posed by space debris, an important percentage of them being generated by Soviet/Russian and Chinese space activities.

The draft being rejected by many states, no progress is contemplated in a foreseeable future for this joint Beijing / Moscow proposition.

- UN Group of Governmental Experts (GGE) on TCBMs in outer space activities

This GGE was established by the UN Secretary General pursuant to a UNGA resolution in December 2010. The report prepared by the GGE on a set of TCBM recommendations, co-sponsored by China, Russia and the United States (a "first" for this kind of work in the UN First Committee) was endorsed by the UNGA in December 2013 [6]. Its conclusions and recommendations include:

i) Efforts to pursue political commitments in the form of unilateral dec-larations, bilateral commitments, a multilateral code of conduct to encourage responsible action in outer space.

ii) Review and implementation by States the proposed TCBM through relevant national mechanisms on a voluntary basis, to the greatest extent practicable an in a way consistent with States' national inter-est.

iii) Building confidence and trust among States through 'universal par-ticipation in, implementation of and full adherence to the existing legal framework relating to outer space activities in which they are parties or subscribe'.

iv) Requests the UNGA's endorsed recommendations to be considered by the UNCOPUOS, the UN Disarmament Commission and the CD. In addition, the Group recommends that the Member States take the measures to implement, as much as they can, principles and guide-lines endorsed on the principle of consensus by the UNCOPUOS and the UNGA.

These recommendations are undergoing a procedural phase, some countries have begun to implement some of them.

- Long-Term Sustainability of Space Activities Guidelines (LTSSA)

Within the UNCOPUOS, a Working Group on LTSSA was established in 2010, the objectives of which included identifying areas of concern for the long-term sustainability of outer space activities, proposing mea-sures that could enhance sustainability, and producing voluntary guide-lines to reduce risks to long-term sustainability. The Working Group and its expert groups addressed four thematic areas including:

A. Policy & regulatory framework for space activities
B. Safety of space operations
C. International cooperation, capacity building & awareness
D. Scientific and technical R&D

At its June 2019 session, the UNCOPUOS adopted 21 of the long-awaited guidelines [7]:

- Under A: Adopt, revise, and amend, as necessary, national regula-tory frameworks for outer space activities; Consider a number of elements when developing, revising or amending, as necessary, na-tional regulatory frameworks for outer space activities; Supervise national space activities; Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites; Enhance the practice of registering space objects.
- Under B: Provide updated contact information and share informa-tion on space objects and orbital events; Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects; Promote the collection, shar-ing and dissemination of space debris monitoring information; Per-form conjunction assessment during all orbital phases of controlled flight; Develop practical approaches for pre-launch conjunction as-sessment; Share operational space weather data and forecasts; De-velop space weather models and tools and collect established prac-tices on the mitigation of space weather effects; Design and oper-ation of space objects regardless of their physical and operational characteristics; Take measures to address risks associated with the uncontrolled re-entry of space objects; Observe measures of precau-tion when using sources of laser beams passing through outer space.
- Under C: Promote and facilitate international cooperation in sup-port of the long-term sustainability of outer space activities; Share experience related to the long-term sustainability of outer space ac-tivities and develop new procedures, as appropriate, for information exchange; Promote and support capacity-building; Raise awareness of space activities.
- Under D: Promote and support research into and the development of ways to support sustainable exploration and use of outer space; Investigate and consider new measures to manage the space debris population in the long term.

For the following additional (regrouped) guidelines, part of the con-templated compendium, the most contentious ones, agreement could not be reached [8]:

- Commit to conducting space activities solely for peaceful purpose.
- Take measures to identify, mitigate and manage the risk to terrestrial infrastructure that supports the operation of orbital systems [launch vehicles and spacecraft].
- Observe procedures for preparing and conducting operations on ac-tive removal [and intentional destruction] of space objects.
- Observe measures of precaution when preparing or conducting op-erations for active [debris] removal [of in-orbit space objects].
- Develop procedures for outer space activities involving non-registered objects.
- Observe measures for the safe conduct of proximity space operations.
- Observe measures of precaution when using natural space environ-ment modification techniques for peaceful purposes.
- Raise awareness of the need to exclude the use of information and communications technology products compromising the safety and security of space objects and related equipment.

It is worth noting that some of the adopted guidelines address several recommendations of the GGE report, namely information exchange on space policies, information exchange and notifications related to outer space activities, and risk reduction notifications: thus, forming a sort of bottom-up implementation of some of the GGE recommendations.

The UNCOPUOS "encouraged States and international intergovern-mental organizations to voluntarily take measures to ensure that the guidelines were implemented to the greatest extent feasible and prac-ticable" [9]. It also decided to establish, under a five-year workplan, a working group to further identifying and studying challenges and con-sidering possible new guidelines for the long-term sustainability of outer space activities. The framework and the proposed two streams of work of this new Working Group on long term sustainability of outer space activities as of 15 March 2021 are detailed in [10].

- UNCOPUOS / CD exchange of information

Since space activities are by essence of dual nature, civil and military, one could have expected that for the last 50 years a fruitful exchange of views between the CD and the UNCOPUOS would have occurred, giving rise to some principles of behaviour in space whatever be the satellite. Unfortunately, it did not happen, each organisation still sticking to its mandate well formatted by the ancient stakes of the Cold War. Tenta-tively, during the French presidency of the UNCOPUOS (2006-08), the latter tried to enhance some dialogue with the CD which resulted in sev-eral meetings and presentations but did not go much further. Moreover:

[2] India also has demonstrated its ASAT capabilities by destroying a LEO in-digenous microsat in March 2019

In 2015 a joint ad hoc meeting of the Fourth Committee (Special Po-litical and Decolonization) and the First Committee (Disarmament and International Security) of the UNGA stressed the need for a holistic han-dling of outer space security and sustainability. Delegates from both sides gave their views, some saying that the international community could no longer make a distinction between civilian and military satel-lites, space debris being created by both types of activities, while others advocating strongly for continuing to address civilian and military as-pects in separate instances. This meeting did not lead to any concrete steps for action.

In October 2019, both these Committees held a joint meeting to ad-dress possible challenges to space security and sustainability. Statements were made by the Director and Deputy to the High Representative for Disarmament Affairs, the Director of the UN Office for Outer Space Af-fairs, a fellow of the Observer Researcher Foundation, the Chief Coun-sel for Space Commerce of the Department of Commerce of the United States and the Co-founder and President of the Secure World Foundation with no specific decisions.

In late 2020, the United Kingdom pushed a proposal to "Reducing Space Threats through Norms, Rules and Principles of Responsible Be-haviours" — aimed at looking at problems in space through a bottom-up approach [11]. In particular, it offered operational approaches en-couraging "Member States to study existing and potential threats and security risks to space systems, including those arising from actions, ac-tivities or systems in outer space or on Earth, characterize actions and activities that could be considered responsible, irresponsible or threat-ening and their potential impact on international security, and share their ideas on the further development and implementation of norms, rules and principles of responsible behaviours and on the reduction of the risks of misunderstanding and miscalculations with respect to outer space". Calling on the U.N. Secretary General to get views from Member States in a report to be submitted to the General Assembly in Septem-ber 2021 for additional discussion. Certainly, a welcomed initiative, ad-dressing the right issues, but with no visibility on the outcome, and probably to be entangled in the same silo-type difficulties of the past.

2.2. "Minilateral" processes

- The Hague Code of Conduct (HCoC) [12]

The Hague Code of Conduct against Ballistic Missile Proliferation (HCoC) is the result of efforts of the international community to interna-tionally regulate the area of ballistic missiles capable of carrying WMD. It was formally adopted in November 2002 by the first group of sub-scribing states, open to all states on a voluntary basis, with no legally binding measures.

The role of the Code is to prevent and curb the proliferation of ballistic missile systems capable of delivering WMD; create a politi-cal framework for ballistic missile non-proliferation; build transparency through the sharing of pre-launch notifications and annual declarations; strengthen existing non-proliferation objectives and mechanisms. By subscribing, states make a political commitment to exercise maximum possible restraint in the development, testing, deployment of ballistic missile capable of delivering WMD.

The HCoC is a typical example of adherence to a corpus of be-haviours on a voluntary basis, requesting some transparency declara-tions, but with non-existent enforcement mechanisms that could address concealed information. Yet the information provided regularly remains a confidence enhancer for the international community.

As of March 2021, 143 countries have subscribed to the Code, ex-cept China, Iran, Israel, and North Korea space launch capable states. Subscribing states to the HCoC agree to ratification or accession to the OST, the "Liability Convention (1972)," and the "Registration Conven-tion (1975)."

- The International Code of Conduct (ICoC)

The draft International Code of Conduct for Outer Space Activities stemmed from a document proposed by the European Union (EU) under the French Presidency and was released to the international community in December 2008. It was one of the first opportunities for the EU, under the 2009 Lisbon Treaty, to engage in foreign and security policy making. Feedback on this draft was solicited from countries outside Europe and a series of international expert open-ended consultations followed.

The Code addresses both civilian and military uses of outer space fo-cusing on principles of responsible behaviour, with no intention whatso-ever to regulate the placement of weapons in space. The recommended guidelines call for not damaging or destroying space objects, minimis-ing risks of collisions, minimising debris collisions, and implementing IADC debris mitigations guidelines. The Transparency and confident building measures (TCBM), concern notifications of launches, manoeu-vres, re-entries, malfunctions, and collision risks, including site visits and demonstrations. They also address information sharing on policy, research programmes, and the potential sharing of SSA-related infor-mation. The Code also includes a consultation mechanism allowing sub-scribing states to request consultations to find mutually acceptable solu-tions should they potentially be affected by activities of other subscrib-ing states (OST Article IX conveys a similar disposition).

Considering the purpose of and the scope covered by the Code, con-ceived out of the traditional instances which showed their difficulties to deliver palpable progress so far, it was anticipated that the proposed Code would be well received by spacefaring as well as non-spacefaring nations. In addition, the process for an open-ended consultation was per-ceived as a positive mechanism susceptible to attract as many as possible potential subscribing states. It was felt too that the nature and level of the required TCBMs could be implemented easily and quickly. Although not being the panacea, the proposed Code could serve as a first step in the right direction materialising what several initiatives have tried to achieve during the past two decades but failed to deliver [13].

But difficulties of substance as well as of procedural nature along the process of sensitisation and consultation that spread almost over seven years brought the start of multilateral negotiations in view of adopting the Code to a standstill in August 2015. These include: i) fear that the measures the subscribers are asked to commit would raise some thresh-olds limiting their recent and / or future space activities; ii) is the non-legally binding nature of the Code enough to ensure what is meant to enhance safety, security, and sustainability of all outer space activities pertaining to space objects, as well as the space environment? China and Russia, co-drafters of the PPWT (see above in 2.1) underlined that the current efforts to prevent an arms race in outer space via legally-binding instruments should not be distracted by the Code initiative; iii) the specific issue of self-defence via the use of force in space, an exten-sion to space of the inherent right of states as recognised in the Charter of the United Nations was not accepted by some countries; iv) the way the Code was generated and developed through open-ended multilat-eral consultation meetings was perceived as being insufficiently inclu-sive, bearing the EU footprint in its genes and not really evolving by taking into account critiques and suggestions raised during those con-sultations; and v) since the Code had no UN mandate it prevents some Member States to offer alternative to texts to the Code.

The Code is now in the doldrums.

- EU Safety, Security and Sustainability of Outer Space (3SOS)

Through its European External Action Service, the EU has launched a 3SOS public diplomacy initiative in September 2019 to promote ethical conduct in space, considering that the increasing orbital congestion will necessitate some safeguards. For instance, placing transponders on satel-lites, deorbiting capabilities, should become an obligation. As a start, 3SOS focuses on discussions with space agencies, industry and think tanks. 3SOS plans to develop its action in clarifying and streamlining an approach to Space Traffic Coordination and Management (STCM), considering that the current governance is complex, chaotic, sometimes

multi-layered with a stack of national, international organisations, multilateral and bilateral initiatives / agreements, regulations.

3SOS implementation steps will require gaining consensus of the EU as well as ESA spacefaring member states; a clear mandate delivered by the EU member states to the EU High Representative; and engaging the EEAS on a COP 21 like strategy. EEAS proposes a first set of minimum accepted common standards within five years, conducive to a mecha-nism for a future STCM. To that end, two paths could be explored: i) a short term one, regarding space debris mitigation involving separate technological developments depending on the maturity of their tech-nology content; ii) a longer term one figuring preoccupations related to cis-lunar traffic and the use of solar system resources.

It is still premature to anticipate the real impact of this EU initiative in the coming years compared to others. Unfortunately, the Covid-19 health crisis has slowed down the 3SOS developments during 2020 and early 2021.

2.3. The United States unilateral initiative

- US positions on the freedom of movement and action in outer space

The US posture on the freedom of the right of movement and action in space is clearly stated in the here under documents:

i) National Space Policy of the United States of America (June 2010) [14], where,

– Principle 1 states that "… The United States considers the sustain-ability, stability, and free access to, and use of, space vital to its na-tional interests. Space operations should be conducted in ways that emphasize openness and transparency to improve public awareness of the activities of government and enable others to share in the benefits provided by the use of space."

– Principle 4 reads as "…The United States considers the space sys-tems of all nations to have the rights of passage through, and conduct of operations in, space without interference. Purposeful interference with space systems, including supporting infrastructure, will be con-sidered an infringement of a nation's rights."

– Principle 5 expresses the right of self-defence: "The United States will employ a variety of measures to help assure the use of space for all responsible parties, and, consistent with the inherent right of self-defense, deter others from interference and attack, defend our space systems and contribute to the defense of allied space systems, and, if deterrence fails, defeat efforts to attack them."

ii) US Space Command (USSPACECOM) Campaign Plan releasing a new mission statement in accordance with the doctrine of the recently established US Space Force [15]: "*To conduct operations in, from, and through space to deter conflict, and if necessary, defeat aggression, deliver space combat power for the Joint/Combined force, and defend U.S. vital interests with allies and partners".*

This is an example of a nation clearly stating its willingness to ensure the freedom of ciculation in space, having the appropriate means to guarantee a secure and sustainable environment for space operations. It could inspire other nations adopting a similar line.

2.4. Non-governmental examples

– Space Safety Coalition (SSC) best practices for the sustainability of space operations

The SSC is an ad hoc coalition of companies, organizations, and other government and industry stakeholders (48 as of 09.04.21) that actively promotes responsible space safety through the adoption of relevant international standards, guidelines and practices, and the development of more effective space safety guidelines and best practices.

Adoption and development of best practices may warrant to:

– Create conditions favourable to share relevant space information and operator-to-operator coordination of space activities,

– Address manoeuvre prioritisation in the event that two spacecraft with manoeuvre capability conjunct,

– Address coordination between new large constellations satellite mis-sions and operators existing in the targeted new mission orbit as early as possible to prevent unnecessary co-location or repeating conjunction once-on-orbit,

– Promote the collaboration of endorsees with spacecraft manufactur-ers, governments, and intergovernmental agencies to strive to de-orbit all spacecraft after their operational life to achieve ultimate sustainability of the space environment.

– The best practices, detailed in [16], read as follows:

1 Spacecraft owners, operators and stakeholders should exchange information relevant to safety-of-flight and collision avoidance,

2 In selecting launch service providers, space operators should con-sider the sustainability of the space environment,

3 Mission and constellation designers and spacecraft operators should make space safety a priority when designing architectures and oper-ations concepts for individual spacecraft, constellations and/or fleets of spacecrafts,

4 Spacecraft operators and designers should design spacecraft that meet the nine best practices specific to this section [16],

5 Spacecraft operators should adopt space operations concepts that enhance sustainability of the space environment.

This set of best practices are of very practical nature, overlapping some of the 21 LTSSA guidelines.

3. Technical approaches

Some of the technical means contributing to the reduction of space operations' vulnerabilities are briefly reminded here under for:

Space debris. They constitute a major threat to the safety of satel-lite operations. Most of the available data is provided by the United States Space Surveillance Network (USSSN) which maintains a catalogue of space objects tracked by optical and radar means, collecting ground and space-based information using public and private sensors. The US are pursuing the development of a space fence that would bring this catalogue up to 150 000 objects in 2025, significantly enhancing the reliability of the data base used for collision avoidance predictions. The information produced by the SSA/SDA capabilities is improving via the automation of Conjunction Data Messages-CDM, Data sharing through international bilateral agreements between governmental departments and/or space operators, contributing to enhance transparency and con-fidence.

The private sector is also getting increasingly involved, mostly in Northern America, developing means of tracking (e.g., LeoLabs) and of collision avoidance software (e.g., ExoAnalytic Solutions, AGI).

The European Union is also engaged in strengthening its surveillance and tracking capabilities through the EU SST Consortium.

Active debris removal (ADR) is making some progress too. For in-stance, in 2018 and 2019, SSTL has successfully demonstrated the ef-fectiveness of a net and harpoon captures of mock-up satellites in LEO. The Japanese company Astroscale is also developing missions that incor-porate innovative solutions for capture and removal of environmentally critical debris, including rocket upper stages and defunct satellites to be brought down to lower orbits for disintegration in the upper atmo-sphere layers[3]. ESA works on a Clean Space initiative, while NASA is limiting its orbital debris removal work to research and development. Developments in the DARPA project "Consortium for the Execution of Rendezvous and Servicing Operations" (CONFERS) also will be of inter-est for ADR advances. More specifically, CONFERS aims at leveraging

[3] Astroscale ELSA-d microsatellite was launched on 22.03.21 to begin ADR demonstration this year.

best practices from government and industry to research, develop, and publish non-binding, consensus-derived technical and operations stan-dards for OOS (On-Orbit Services) and RPO (Rendezvous and Proximity Operations). These standards would provide the foundation for a new commercial repertoire of robust space-based capabilities and a future in-space economy.

Once ADR capabilities will be available, the rules of engagement will need to be worked out very closely, since liability and responsibility issues are not solved for the moment. In addition, the obvious dual use nature of such a capability will certainly put additional constraint on its usage.

Electromagnetic interferences. These are on the rise since large con-stellations in LEO will generate increased inter- satellite electromag-netic waves density as well as space-ground more dense communica-tions, hence operators fearing some possible harmful interference. While frequency attributions are in the remit of the ITU, clearly, the orbital congestion will pose issues regarding radio-frequency protection with sufficient band guard.

The recent decision of the US Federal Communications Commission (FCC) to authorise Ligado Networks to create a ground-based 5G net-work using the L-band spectrum between 1 and 2 GHz may threaten the GPS frequencies currently used within the same band slot. The FCC con-tends that the GPS frequencies will continue to be protected since suf-ficient band guard is provided, while the Department of Defense claims the opposite anticipating some interferences with the GPS receiving sig-nals [17]. While in January 2021, the FCC denied the petition against Ligado Networks, the Executive Branch, which is separate from the FCC, remains concerned because Ligado's proposed transmission power ex-ceeds the thresholds established by the GPS Adjacent Band Compatibil-ity study to protect GPS users from harmful interference.

Cyber Security which affects integrity, confidentiality, security, or availability of data which can translate into degradation, disruption, or denial of transportation, banking, power, telecommunications, air, sea, and land navigation, distress detection, GNSS timing, to name a few. There are many examples in the open literature of satellites, both in LEO and GEO, which have suffered cyber-attacks. For instance: Terra EOS & Landsat 7 experienced cyber interference, hackers achieving the required steps to assume Command & Control but did not issue com-mands (2011); US National Oceanographic and Atmospheric Agency was denied space-based information for 48 hours (2014); the US Mar-itime Administration reported the first GPS spoofing attack against over 20 ships in the Black Sea (2017).

Efforts are made to level up the protection of the ground segment, im-peding penetration by closing gaps, putting new locks, and training staff to tighten security procedures when dealing with command & control activities. The level of control of the supply chain is also continuously upgraded to guarantee that electronic components and / or software do not contain embedded cyber penetration capabilities awaking over time.

The Space Policy Directive-5 (SPD-5), signed by President Trump in September 2020, establishes cybersecurity principles for space systems, including cybersecurity measures to be incorporated into all stages of space-system development and operations, such as protected software, or vetting everyone who touches command lines of a spacecraft, etc. [18].

Space weather can become a serious threat to the functioning of satellites when it turns into solar storms which are difficult to pre-dict. Ideally, threatened satellites should be turned off when receiving a warning signal of an approaching storm. To better apprehend means of predictability, two approaches are currently considered: i) gain a better understanding of solar physics to possibly predict when a solar storm may happen to a reasonable degree of certainty and if it may impact the Earth orbit; and ii) place sentinel satellites at two Lagrange points of the Sun-Earth system to detect incoming storms, giving sufficient warning lead time for operators to take the appropriate protective measures.

Space weather services are under development in the United States and in Europe.

It should be also reminded that one of the 21 LTSSA guidelines refers explicitly to the necessary efforts to "develop space weather models and tools and collect established practices on the mitigation of space weather effects" [7]. And that the UNCOPUOS has a dedicated Working Group on space weather to prepare some recommendations.

Other threats such as physical molestation of a satellite, laser blind-ing, kinetic kill, are not reviewed in this paper.

4. A way forward

The abundance of the summarised initiatives displays a range of com-mon trends. Namely, except for the draft Treaty PPWT, recourse to soft law calling for non-legally binding recommendations, transparency and confidence building measures, looking for norms and standards of re-sponsible behaviour in space, protect the space environment, ensure the freedom of circulation in space. None of them mention enforcement pro-cedure in case of one or several recommendations / guidelines may be infringed, whatever be the space actor. The unilateral position of the United States, part of its space strategy and the USSPACECOM mission, stands aside, off multilateral / multi-actor initiatives or proposals. Al-though there is clearly no appetite for legally binding new treaties, yet non-binding mechanisms that States can agree on are not completely de-void of legal consequence, a State deciding to commit to non-binding in-struments as part of a national space law. Such a demarche would carry a certain legal weight, possibly influencing other space fairing States to undertake a similar approach.

Today we lack a global approach, with a sense of direction and lead-ership, regarding the sustainability of space activities. To continue re-leasing new tailor-made initiatives throughout this decade, often over-lapping partially each other, is not the way to address the challenges posed by the advent of large LEO constellations, the mounting number and diversity of missions and space actors, all contributing to the build-ing up of a new Earth-space ecosystem on which human activities will increasingly depend upon.

To respond to such unprecedented challenges, we first propose to put up an overarching plan devoted to deliver rapidly a set of rules of the road applied primarily to circumterrestrial space traffic, and later to cis-lunar traffic and beyond. Preparation of such a plan would involve a variety of protagonists: governments and space agencies of major space fairing nations, major space operators, space industries, and recognised legal institutions for their achievements in space law. The plan's objec-tive in bringing together these stakeholders is to reach consensus on a roadmap together with a strict timeline consistent with easy practical measures to implement first, implementation of the more complicated ones taking place later. Bearing in mind that such measures be the neces-sary driver to rapidly alleviate today's constraint on the safety, security, and sustainability of near-Earth orbital activities. Naturally, part of the feeding inputs could incorporate some of the recommendations resulting from existing initiatives, including the long-term LTSSA guidelines and the SSC best practices. Indeed, such recommendations adopted by two different organisations representing governments and industry respec-tively are good ingredients for preparing such a plan, since they already offer several worthwhile principles the implementation of which is con-sidered feasible.

How such a plan could be initiated? Because of the challenge's mag-nitude concerning worldwide end-users, this new initiative should be launched at the highest possible political level to bear any chance of success. The G7 Summit framework may be the right platform since, on the occasion of some such Summits, high impact techno-socio initiatives such as the Human Frontier programme in the late 80s', the Intelligent Manufacturing System (IMS) at the Tokyo Summit in 1993, and more recently climate initiatives were announced. Every party to the G7 is a major space fairing country, including Russia when it may return under a G8 format.

The difficulty ahead is to convince the different G7 governments of the importance of this pressing challenge in a first instance: awareness of

the importance of this is uneven among the different G7 Heads of State or of government. Although this may begin to change with the creation of a space force in the United states and moves along the same direction in France since 2019, and very recently with the establishment of a UK space command. Once consensus is reached on the matter, the following step is to get the overarching plan as a Summit agenda item leading to requesting G7 governments to deliver a draft overarching plan at the next G7 Summit, including the designation of an overall coordinator. The plan should embed timed and prioritised implementing milestones to achieve a first set of commonly agreed measures within five years. This may sound ambitious, but a yearly increase of the satellite popula-tion in the thousands requires a prompt action.

But such a G7 demarche would by-pass two significant space pow-ers, China and India which have been involved in the UNCOPUOS LTSSA Working Group and have endorsed the 21 guidelines. To get around this difficulty, both the President of the People's Republic of China, and the Indian Prime Minister should be invited as guests / observers, being full participants to the agenda item regarding the discussion of this overar-ching plan both at the G7 Summit where the plan would be launched, and also to the following Summit where it should be adopted. Indeed, the format of the Summit allows nowadays to have non G7 countries to be invited on an ad hoc basis.

To maximise an as large as possible adoption of this plan, it would be circulated promptly to other space fairing nations for consultation, com-ments, and suggestions before implementation. In doing so, one would avoid the lengthy process inherent to a UN type consultation mecha-nism, certainly a fair and desirable procedure, but which is too much time consuming in view of the urgency of the matter. To put things in perspective for delivering new rules of the road, one should be re-minded that the OST, during the rising Cold War period, was negotiated and signed by the United States, the USSR and the UK in about four years, while, 40 years later, it took about 6 years to have a UNGA en-dorsed space debris mitigation guidelines when space debris were less than half they are today, and 9 years to have an incomplete set of LTSSA guidelines adopted by the UNCOPUOS.

At a later stage, one may ask if a space traffic organisation would be useful to ensure that rules of the road are respected, maintained and revised as does, for instance, i) the International Civil Aviation Organ-isation (ICAO), a UN Specialised Agency looking after standards, rec-ommended practices concerning air navigation, its infrastructure, flight inspection, prevention of unlawful interference, safety, etc; or ii) the In-ternational Maritime Organisation (IMO), also a UN Specialised Agency whose primary purpose is to develop and maintain a comprehensive regulatory framework for shipping, with today's remit including safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping.

Such topic is beyond this paper's scope but will have to be addressed at some point, see for instance [19].

5. Discussion

Critics to such an overarching plan proposal may argue that the con-templated process is insufficiently inclusive and may end up as the ICoC did in 2015 after 7 years of open-ended consultations. A counter argu-ment would content that, i) the actors that would be involved in the elaboration of the masterplan are multinational, representing over 90

% of space players, and probably even a higher percentage in the years to come. They belong to a broad variety of space professions and activ-ities be it civilian, commercial, or military; ii) although the UN is not involved directly in the making of the overarching plan, the latter will be presented to the UNCOPUOS, for receiving comments and suggestions; and iii) the objective in a first instance is not to receive immediate con-sent of the UN for an implementing string of actions, but to get these activated as quick as possible as agreed by the makers of the masterplan.

The proposed approach is not, whatsoever, anti-UN minded, it sim-ply seeks to offer a fresh perspective on how to harness institutions of the existing international order to implement efficient and timely mea-sures to cope with the space traffic problem looming before the interna-tional community. Indeed, the current timescales for reaching an effec-tive international agreement are simply too long when compared with the rate of growth within the sector, both of volume and of problems. The situation is likely to become fragmented leading to a "Tragedy of the Commons" and increased international tensions as states take unilateral actions to protect their interests. Just as with climate change, we need first an as large as possible political determination to make significant progress, and then being able to deliver a mechanism that is effective.

Credit authors statement

Serge Plattard (SP)/Alan Smith (AS): concept of the paper, method-ology and outline.

SP: original draft preparation.

SP/AS: reviewing and editing.

Declarations of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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