PARIS PEACE FORUM de PARIS sur la PAIX

NET ZERO SPACE

Sustainable outer space by 2030

Developing Reference Modelling to Assess Risks of Collision in Orbit

WORKING GROUP 2

WHITE PAPER | November 2022

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Outer space is a shared environment offering important economic, scientific, and strategic benefits for all humankind. However, as activities in outer space have entered a new era of growth, the amount of orbital debris is increasing dangerously, jeopardizing key services of our daily lives and endangering the possibilities of exploiting and even accessing space in the medium term.

Since its launch in November 2021, the Net Zero Space initiative to protect the Earth's orbital environment has been calling for concrete actions commencing from 2021 onwards to tackle the pressing challenge of space debris, with the ultimate aim of achieving sustainable use of outer space by 2030. The Net Zero Space declaration especially states the following[1]:

> *By launching the "Net Zero Space" initiative, we are calling for a global commitment to achieving sustainable use of outer space for the benefit of all humankind by 2030. We recommend urgent action from 2021 onwards to rapidly contain and then reduce the ongoing pollution of Earth's orbital environment:*
>
> - *by avoiding further generation of hazardous space debris, and*
> - *by remediating existing hazardous space debris.*

Over the past year, the Net Zero Space coalition has been looking into developing further policy recommendations in relation to the observation and commitments of the Net Zero Space declaration. This White Paper summarizes key conclusions of the discussions that took place in the framework of Working Group #2, focusing on advancing international efforts towards a more interoperable way of stipulating the existence of a risk of collision in orbit, and clearer and more transparent protocols whenever anti-collision maneuvering is deemed necessary, as well as better understanding the carrying capacity of Earth's orbits.

All quotes, data and examples are from participants' contributions during the meetings and are anonymized in line with the agreed norms for the discussions.

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[1] The Paris Peace Forum. *Net Zero Space Declaration*. Available here: [Net Zero Space | Paris Peace Forum]

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About the Net Zero Space initiative

Launched at the 2021 Paris Peace Forum, The Net Zero Space initiative aims at underlining the consensual assessment among the space industry that there is a need to urgently address rising orbital pollution. Its supporters call for political authorities, both nationally and internationally, to take urgent steps to protect the Earth's orbital environment in other to achieve a sustainable use of outer space by 2030.

It is now supported by 51 stakeholders, including 13 in-orbit services and Space Situational Awareness (SSA) providers, 10 satellite operators, 6 civil society and academics, 5 space agencies and public authorities and 4 launchers. It gathers actors from 24 countries around the two core principles of avoiding further generation of hazardous space debris (mitigation) and remediating the existing ones (remediation).

About the Paris Peace Forum

In a world requiring more collective action, the Paris Peace Forum is a platform open to all seeking to develop coordination, rules, and capacities that answer global problems. Year-round support activities and an annual event in November help better organize our planet by convening the world, boosting projects, and incubating initiatives.

Composition of the Working Group

This Working Group gathered experts representing formal supporters of the Net Zero Space initiative. This White Paper summarizes the outputs of the year-long reflection and was agreed by consensus.

Astroscale
Japan/United Kingdom
Kumar Singarajah

Avanti
United Kingdom
Lorenzo Arona

CGSTL
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ClearSpace
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Observers

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Observer status implies that the entity has participated in the discussions but has not taken part in the consensus agreement.

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I- Introduction

Outer space is internationally recognized as the province of all mankind whose exploration and use for peaceful purposes and in the benefit of all must be protected[2]. In coherence with this principle, ensuring equitable access to space for all nations regardless of their degree of economic or scientific development is also a clear principle of international space law, repeatedly reaffirmed in guidelines and statements produced in many international and regional fora[3].

However, the actual implementation of such principles is currently threatened by the staggering increase in the number of objects in Earth orbits. On the one hand, market trends such as the massive recourse to CubeSats and other small satellites, which are cheaper than larger ones, or the emergence of the first megaconstellation projects, are causing the population of space objects to grow at an unprecedented rate. While 1,743 smallsats were launched into space in 2021 (compared to 389 in 2019 or 52 in 2012)[4] (fig. 1), the mega-constellation phenomenon is leaving behind such impressive numbers as the projected 42,000 satellites of the Starlink constellation[5], or the even more spectacular request for license approval of nearly 330,000 satellites made by the Rwandan Space Agency[6].

[2] This is notably established in articles 1-4 of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (or Outer Space Treaty); Articles 4 and 11 of the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement); Preamble of the Convention on International Liability for Damage Caused by Space Objects (or the Liability Convention); and Preamble of the Convention on Registration of Objects Launched into Outer Space (or the Registration Convention). This principle can also be found in soft law mechanisms and regional initiatives such as the UN Long-Term Sustainability Guidelines (par. 5), the draft EU proposal for an international Space Code of Conduct (par. 28); the Group of 77 and China (Statement during the 55th Session of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space) (par. 3); or the Bylaws of the African Space Agency (art. 5, par. j).

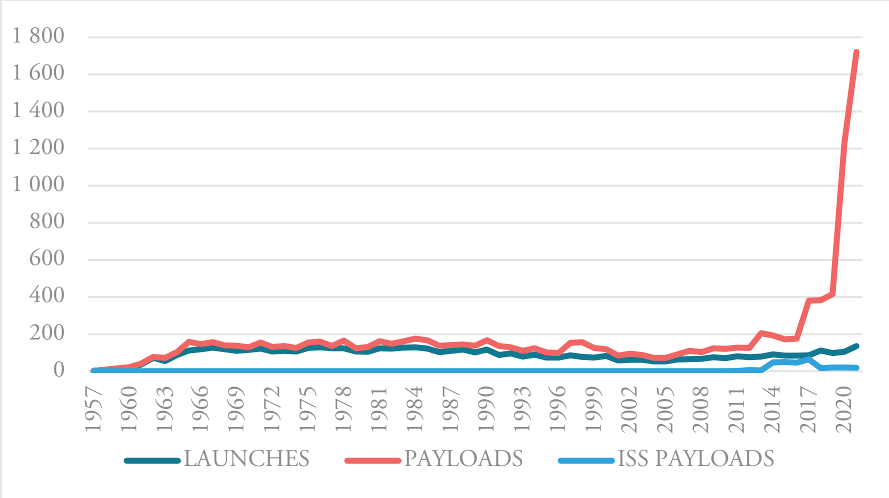
[3] This principle is crystallized in several international and regional documents, notably the Outer Space Treaty (art. 1), the Moon Agreement (art. 4), the Liability Convention (Preamble); the Registration Convention (Preamble); the UN Long-Term Sustainability Guidelines (par. 8), the EU proposal for an international Space Code of Conduct (par. 25); or the Group of 77 and China (Statement during the 55th Session of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space) (par. 4.a).

[4] BryceTech. (7 February 2022). *Smallsats by the Numbers 2022*. Available here: BryceTech - Reports. Accessed 9 September 2022.

[5] Space News. (15 October 2019). SpaceX submits paperwork for 30,000 more Starlink satellites. Accessed: 7 September 2021.

[6] SpaceWatch Africa. (22 October 2021). *Rwanda files at ITU for nearly 330,000 satellites*. Available here: Rwanda files at ITU for nearly 330,000 satellites. Accessed: 2 September 2022.

Fig. 1. Number of objects sent into space per year since 1957.

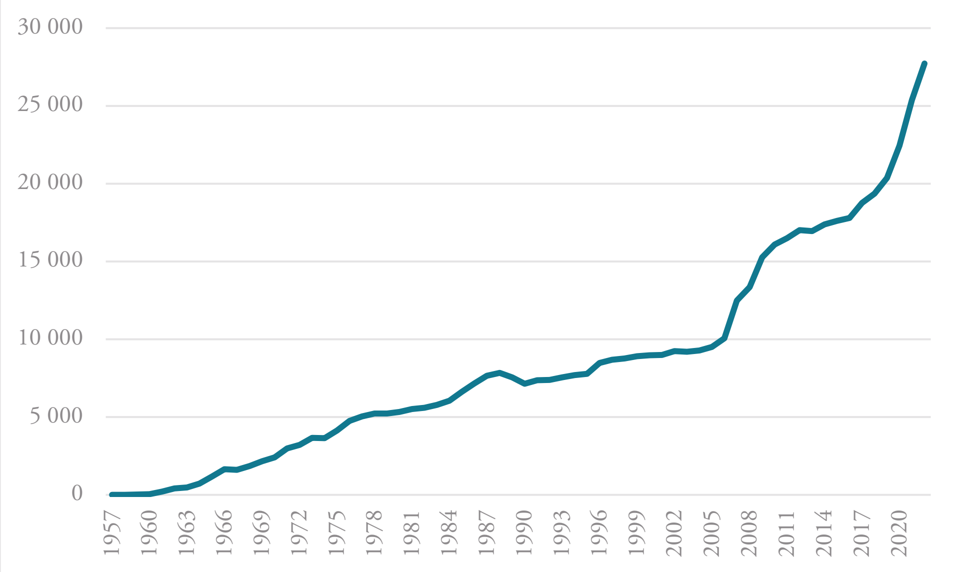


Source: Space Track. *Space Ops Tempo*. Space-Track.Org.

On the other hand, these active space objects coexist in outer space with millions of pieces of space junk that are a permanent threat to the life and correct performance of the active assets in orbit. The total number of space debris orbiting Earth is currently estimated at more than 36,500 objects greater than 10 cm, over one million objects between 1 cm and 10 cm, and over 130 million pieces of debris from 1 mm to 1 cm[7]. These figures shall continue to rise even if no more assets are placed in orbit[8], due to collisions happening between pieces of debris, as well as to debris-on-active collision events. This issue is further enhanced by the fact that current space situational awareness (SSA) limitations cannot ensure proper cataloguing and monitoring of all of them. To date, over 27,000 objects (both active and debris) are regularly tracked by the global Space Surveillance Network (SSN) sensors of the US Department of Defense[9], a figure that rises to 31,620 according to ESA[10] (fig. 2).

[7] ESA. (11 August 2022). *Space Debris by the Numbers*. Available here: ESA - Space debris by the numbers [Accessed: 19 August 2022]. NASA. *Space Debris and Human Spacecraft*. Available here: Space Debris and Human Spacecraft | NASA. Accessed: 02 September 2022.
[8] ESA Sustainability report. Page 8.
[9] NASA. *Space Debris and Human Spacecraft*. Available here: Space Debris and Human Spacecraft | NASA. Accessed: 02 September 2022.
[10] ESA. *Space debris by the numbers*. Available here: ESA – Space debris by the numbers. Accessed : 02 September 2022

Fig. 2. Aggregate number of catalogued resident space objects by Space Track since 1957.



Source: Public Catalog Object Count. Space Track. *Space Ops Tempo*. Space-Track.Org.

With exponential growth of both space debris and objects sent into space (especially in the framework of large constellation plans), it increasingly is obvious that more clarity is need on how we can fairly manage the orbital resource. Safe and sustainable operation in orbit, and especially in LEO, requests to take into account that useful orbits are not infinite and to develop urgent common understanding about orbital carrying capacity as well as minimum standards for cooperation in the development of large-sized constellations. Numerous voices across the Globe, including astrophysicists, scientists, think tankers, policymakers and regulators have expressed concerns about growing orbital congestion in LEO and unduly risky behaviour[11].

[11] For instance see: "We are making as much of a mess of the space surrounding our planet as we are of the planet itself." H.E. S. Bint Yousif Al Amiri, Minister of State for Advanced Technology, U.A.E.. Source: The Economist (17 November 2020). *Easier access to space imposes new environmental responsibilities on humanity*. Available here : https://www.economist.com/the-world-ahead/2020/11/17/easier-access-to-space-imposes-new-environmental-responsibilities-on-humanity. "It's a race to the bottom in terms of getting as much stuff up there as possible to claim orbital real estate." Dr. M. K. Jah, Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin. Source: The Wall Street Journal. (19 April 2021). *Elon Musk's Satellite Internet Project Is Too Risky, Rivals Say*. Available here: https://www.wsj.com/articles/elon-musks-satellite-internet-project-is-too-risky-rivals-say-11618827368?mod=searchresults_pos1&page=1. "The grabbing-up of all the good territory is a reasonable complaint" Astrophysicist Dr. J. McDowell, Harvard-Smithsonian Center for Astrophysics. Source: The Verge. (27 January 2021). *Elon Musk's shot at Amazon flares monthslong fight over billionaires' orbital real estate / Real concerns or billionaire ballyhoo?*. Available here: https://www.theverge.com/2021/1/27/22251127/elon-musk-bezos-amazon-billionaires-satellites-space. "[T]he rise of mega-constellations in low Earth orbit poses the risk of denying access to LEO and radio spectrum by making it impossible for late arrivals to operate there safely and sustainably. 'It should concern us all and it's time to do something about it.'" M. Alotaibi, Deputy Governor for Radio Spectrum, Saudi Communications and Information Technology Commission (CITC). Source : Space Intel Report. (16 September 2021). *Saudi regulator: ITU must address LEO crowding, debris and sustainability before the orbit is rendered unusable*. Available here: https://www.spaceintelreport.com/saudi-regulator-itu-must-address-leo-crowding-debris-and-sustainability-before-the-orbit-is-rendered-unusable/. "When we launch dozens of satellites every few weeks, we remove the environment's ability to inform us of the unintended consequences of our actions and we cannot predict what the dynamic equilibrium state actually is." A. Lawrence, M. L. Rawls, M. Jah, A. Boley, F. Di Vruno, S. Garrington, M. Kramer, S. Lawler, J. Lowenthal, J. McDowell, and M. McCaughrean. Source: Nature Astronomy. (22 April 2022). *The case for space environmentalism*. Available here: https://www.nature.com/articles/s41550-022-01655-6. "As the

Most concerns and analysis raised by these experts and policymakers especially meet to alert on the risk of loss of safe access to LEO, possible monopolization of orbital resources by a few actors, and beyond the orbital environment itself, harm to the night sky, the Earth's atmosphere, and the human environment. They also highlight possible threats to the continued safe and reliable operation, and future innovative deployment, of space systems around the world on which consumers, commercial enterprises, scientific research, and defense alike rely—including those that provide vital communications, Positioning, Navigation, Timing (PNT), and Earth observation data and services.

In particular, an increasing number of these leading voices look to underscore the idea that limits exist on what types of and how many satellites sustainably can occupy LEO, with such limits depending on the specific characteristics of each LEO system and the impact of a steadily worsening space debris environment. One early study commissioned by the U.S. National Science Foundation (NSF) indicates that it may not be feasible to sustain even just one LEO system and study forecasts a dramatic increase in both space collisions and new debris starting within a few years. In the longer term, the NSF study predicts that "satellites are destroyed [by collisions with debris] faster than they are launched."[12]

This increase in the population of objects in outer space, both active and derelict, necessarily leads to an increase in the number of close proximity events that are detected every day, generating more and more collision alerts for entities operating in orbit[13]. Although risk dwindles most of the time in the days that follow the alert, it is sometimes considered high enough for further action to become necessary. In that case, actors operating in outer space need to make critical decisions in a very short amount of time with limited – and often, fragmented – information.

Earth orbital environment is getting increasingly congested, concerns about its long-term sustainability, potential overexploitation, and risk of interference are becoming increasingly clear and shared among policymakers, industry leaders, and academia." European Space Policy Institute. Source: European Space Policy Institute. (11 April 2022). *Space Environment Capacity: Policy, regulatory, and diplomatic perspectives on threshold-based models for space safety and sustainability*. Available here: https://www.espi.or.at/reports/space-environment-capacity/."We now stand at a crossroads: if we do not find ways to manage space traffic, our past and present space activities will jeopardise the safety, security and sustainability of outer space and, as a result, our future ability to rely on space as enabler of key services in benefit of humankind." European Commission. Source: European Commission. (15 February 2022). *Joint Communication to the European Parliament and the Council: An EU Approach for Space Traffic Management; An EU Contribution Addressing a Global Challenge*. Available here: https://ec.europa.eu/info/law/better-regulation/. "[S]ignificant domestic and international changes to the use of near-Earth space are urgently needed to preserve access to — and the future utility of — the valuable natural resources of space and our shared skies." J. C. Barentine, et. al. Source: J. C. Barentine, et. al. (Spring 2022). *Reimagining Near-Earth Space Policy in a Post-COVID World*, Virginia Policy Review, Vol. XV, Issue 1, pp. 58–86.

[12] G. Long. (November 2020). *The Impacts of Large Constellations of Satellites*, JASON – The MITRE Corporation, JSR-20-2H, (Updated: Jan. 21, 2021), at 97. Available at https://www.nsf.gov/news/special_reports/jasonreportconstellations/JSR-20-2H_The_Impacts_of_Large_Constellations_of_Satellites_508.pdf.

[13] Between August 8, 2022 and September 7, 2022, SpaceTrack registered over 20,000 Conjunction Data Messages (CDM). SpaceTrack. *CDM_public*. Space-Track.Org. Accessed: 7 September 2022.

If not managed correctly, these events could derive in a catastrophic collision event known as the "Kessler syndrome", which has the potential of disrupting space-dependent services of our daily lives and even of forever putting an end to the possibility of exploiting the orbits[14]. Recently, in a presentation by a major national space agency it was indicated that "A cascading effect (Kessler syndrome) can currently be observed between 700 – 1100 km altitude" [15]. Another study concluded that "[…] Kessler Syndrome is expected to occur in low-Earth orbit around 2048 under recent historical sectoral growth trends and may occur as early as 2035 if the space economy grows consistent with projections by major investment banks." [16] These are very significant observation and highlight the real risks increasing populations of space debris already pose to use of some important LEO orbits.

In ESA's most recent Space Environment Report, the following is indicated in its executive summary[17]:

> The extrapolation of the current changing use of orbits and launch traffic, combined with continued fragmentations and limited post mission disposal success rate could lead to a cascade of collision events over the next centuries. Even in case of no further launches into orbit, it is expected that collisions among the space debris objects already present will lead to a further growth in space debris population.'

The same ESA report indicates in Section 7 that:

> The simulation of the future evolution of the debris population can be used to assess the efficacy of proposed mitigation actions and of current behaviours. In particular, two scenarios are presented in this section:
>
> - A defined extrapolation of the current behaviour in terms of launch traffic, explosion rates, and disposal success rates;
> - No future launches (NFL), where it is assumed that no launch takes place after 2021.
>
> Under the current extrapolation conditions, the amount of catastrophic collision could rise quickly. Even under the no further launches scenarios, the amount of space debris objects is observed as increasing in all cases.

The above are again very significant observation and it highlights the real risks increasing populations of space debris already poses to use of LEO orbits. It should be noted that the ESA report only considered impact of space debris larger than 10 cm in

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[14] The Kessler syndrome is named after NASA scientist Donald J. Kessler, who first laid out the idea of in his paper: D. J. Kessler and B. G. Cour-Palais. (1978). *Collision frequency of artificial satellites: The creation of a debris belt*. Journal of Geophysical Research, pags. 2637–2646. Recent contributions to the topic include W. Liao and L. Junkins. (2022). *Simulating Kessler Syndrome and the Space Debris Problem*. Proceedings of the West Virginia Academy of Science, 94(1). https://doi.org/10.55632/pwvas.v94i1.902; Ayala Fernández, L., Braun, V., and Wiedemann, C. (2022). *Evolution in Post-Mission Disposal Behaviour of Space Launch Vehicles*. 44th COSPAR Scientific Assembly. Held 16-24 July, 2022., S. Singh and S. Purbey. (June 2022). *Space Debris – It's Effect on the Earth*. IJRAMT, vol. 3, no. 6, pags. 13–16.

[15] Bonnal, C. (19 May 2022). *Some High Level Reflections On How To Catalyse ADR*. Presentation at the 6th European Workshop On Space Debris Modelling and Remediation, Politecnico Milan.

[16] A. Rao and G. Rondina. *Open access to orbit and runaway space debris growth*. Available here: https://arxiv.org/pdf/2202.07442.

[17] ESA 'Space Environment Report' (May 2022), Executive Summary and Section 7.

the above cited analysis. It is clear consideration of additional collision risks with hazardous non-trackable debris (e.g., between 1 to 10 cm in size) would lead to an even more negative situation.

In addressing this problem, one stumbles upon two major obstacles. First, the lack of consensus on the definition of what constitutes a risk of collision in orbit, what parameters and thresholds should be used to determine its existence or what models should be put in practice to quantify it. The second obstacle concerns the lack of harmonized "Rules of the Road" detailing the procedure that shall be adopted in the event of a collision warning requiring further maneuvers. This hinders the efficiency of the decision-making process by making the success of the operation dependent on factors such as the willingness of the counterparty to respond, or the ability of the parties to agree on a case-by-case basis on who should carry out a collision maneuver.

The 2021 Starlink/China Space Station incident serves as the perfect example of the need to further work on these two issues. The Permanent Mission of China to the United Nations addressed a verbal note to the UN Secretary General informing him of two close encounters the Chinese Space Station had had with satellites of the SpaceX's Starlink constellation, which had triggered collision avoidance maneuvers[18]:

> In accordance with the above-mentioned article [*article V of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies 1 (the Outer Space Treaty)*], China hereby informs the Secretary-General of the following phenomena which constituted dangers to the life or health of astronauts aboard the China Space Station.
>
> [...]
>
> **The First Collision Avoidance:**
>
> As from 19 April 2020, the Starlink-1095 satellite had been travelling stably in orbit at an average altitude of around 555 km. Between 16 May and 24 June 2021, the Starlink-1095 satellite manoeuvred continuously to an orbit of around 382 km, and then stayed in that orbit. A close encounter occurred between the Starlink-1095 satellite and the China Space Station on 1 July 2021. For safety reasons, the China Space Station took the initiative to conduct an evasive manoeuvre in the evening of that day to avoid a potential collision between the two spacecraft.
>
> **The Second Collision Avoidance:**
>
> On 21 October 2021, the Starlink-2305 satellite had a subsequent close encounter with the China Space Station. As the satellite was continuously manoeuvring, the manoeuvre strategy was unknown and orbital errors were hard to be assessed, there was thus a collision risk between the Starlink-2305 satellite and the China Space Station. To ensure the safety and lives of in-orbit astronauts, the China Space Station performed an evasive manoeuvre again on the same day to avoid a potential collision between the two spacecraft.

[18] Permanent Mission of China to the United Nations. (6 December 2021). *Note verbale dated 3 December 2021 from the Permanent Mission of China to the United Nations (Vienna) addressed to the Secretary-General*. Available here: AAC105_1262E.pdf (unoosa.org).

The United States responded to this note by claiming that the Space Command[19]:

> [...] did not estimate a significant probability of collision between the China Space Station and the referenced United States spacecraft [...] because the activities did not meet the threshold of established emergency collision criteria, emergency notifications were not warranted in either case. If there had been a significant probability of collision involving the China Space Station, the United States would have provided a close approach notification directly to the designated Chinese point of contact.

The note went on to say that[20]:

> The United States is unaware of any contact or attempted contact by China with the United States Space Command, the operators of Starlink-1095 and Starlink-2305 or any other United States entity to share information or concerns about the stated incidents prior to the note verbale from China to the Secretary General.

As illustrated by this example, adopting a common framework that allows for transparent monitoring and uniform assessment of space events to support an unquestionable stipulation of the existence of a conjunction risk, or lack thereof, would undoubtedly facilitate rapid and efficient decision-making in the event of an emergency, possibly even allowing for the standardization of behaviors the involved stakeholders may adopt. It would also more generally enhance the overall operational and legal enforcement of the entities by dwindling the likelihood of disputes with other stakeholders, reducing the employees' work burden, and ease the insurance process for space assets. Finally, a better understanding of the risk of collision in orbit is of the utmost importance to ensure concrete actions from regulatory authorities, for instance with regard to the way in which they evaluate the safety of new assets at the licensing stage, and secure the development of a prosperous and sustainable space market.

This Working Group decided to contribute to advance the space sustainability discussion by providing their assessment of the situation, thought leadership and information on how they themselves define the risk of collision in orbit, what parameters they use to do so, and what internal decision-making process they follow in the event that the alert becomes a warning. Thus, the main objective of the present Working Group was to identify the main key issues/blocking points on this technical subject, which nevertheless contains a part of political choice, and give recommendations for progress.

The Paris Peace Forum collected these answers by means of a questionnaire that was distributed to the members of the group and later to other actors outside of the Net Zero Space initiative. The responses obtained will be presented in the following section, anonymously for the most part in order to respect the confidentiality of the answers.

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[19] Permanent Mission of the United States of America to the United Nations. (28 January 2022). *Note verbale dated 28 January 2022 from the Permanent Mission of the United States of America to the United Nations (Vienna) addressed to the Secretary-General.* Pags. 2-3. Available here: V2200346.pdf (un.org).

[20] Ibidem.

II- Empirical experience: consultation of stakeholders

The questionnaire was divided into three parts, covering 1) the definition of a risk of collision in itself; 2) the decision-making process that determines its existence and the appropriate reaction to it; and 3) the evolution (if any) of the entity's approach to the concept of risk of collision.

It should be noted that this survey involved entities belonging to the different types of stakeholders impacted by Conjunction Analysis (CA) activities, notably:

a. Software and Support Systems providers
b. Satellite Operators
c. In-Orbit Servicing and SSA providers, and
d. Space Agencies and Public Authorities.

Indeed, considering actors whose activities and approach to CA vary so greatly poses an extra difficulty when compiling and summarizing the answers. However, it is an essential prerequisite to have a holistic view of the issue of understanding the risk of collision in orbit and thus to be able to identify interesting lines of work on which to formulate policy recommendations.

a) On the definition of collision risk

A good way to define what is a collision risk in orbit is by stating the scenarios in which a collision risk is considered to exist in practice. In this sense, the answers of all participants can be summarized as follows:

a. a collision risk exists when there is a certain probability that two resident space objects collide, or
b. when a certain distance established as the maximum acceptable is exceeded.

These two cases are applicable both for events occurring between two active objects (active-on-active), one active object and a piece of debris (active-on-debris), or two pieces of debris (debris-on-debris). In this sense, participants agreed that the most common conjunction profile is active-on-debris. However, it is also indicated that this is expected to change in the future due to the increase of active objects in space, notably in LEO, giving way to a greater number of active-on-active events.

To reach the point of determining the existence of a risk of collision, it is first necessary to identify the cases that could eventually lead to a risk situation. Given the number of elements orbiting the Earth, and the many that are yet to arrive, performing a first screening to avoid all-on-all analyses becomes essential. This first filtering, according to the respondents to the questionnaire, is done by establishing a security volume around each object. Examples cited in the answers include volumes of a 5km radius in LEO and 20km in MEO/GEO.

As soon as an object enters the security volume, its trajectory is tracked, and a projection is made of the position at which it may be found for a given timeframe. This variable (known as ephemeris, pl. ephemerides) allows for the determination of the Time of Closest Approach between the two objects (TCA), as well as of how far apart they will be in that moment (Miss Distance). The Probability of Collision (PoC) is in turn computed on the basis of the TCA. The results of these calculations will be confronted with a series of user-defined thresholds that delimit the maximum risk that the actor is willing to assume before considering the need to perform an anti-collision maneuver. The table below lists the most frequently cited thresholds among survey participants:

Fig. 3. Most common thresholds in defining the existence of a risk of collision, by event severity (when the distinction is established by the actor).

<table>
<tr><th></th><th colspan="2">Probability of Collision (PoC)</th><th colspan="2">Miss distance</th></tr>
<tr><th></th><th>Warning/Yellow</th><th>Alert/Red</th><th>Warning/Yellow</th><th>Alert/Red</th></tr>
<tr><td rowspan="2">LEO</td><td>PoC ≥ $1e^{-4}$
PoC ≥ $1e^{-5}$</td><td>PoC ≥ $5e^{-4}$
PoC ≥ $1e^{-4}$</td><td colspan="2" rowspan="2">Miss Distance < 1km*</td></tr>
<tr><td colspan="2">PoC ≥ $1e^{-5}$*</td></tr>
<tr><td>MEO</td><td>N/A</td><td>PoC ≥ $1e^{-5}$</td><td>Miss Distance < 9km</td><td>N/A</td></tr>
<tr><td>GEO</td><td colspan="2">PoC ≥ $1e^{-5}$</td><td>Miss Distance < 10km and Radial Separation <1km</td><td>Miss Distance < 5km and Radial Separation <500m</td></tr>
</table>

* These two thresholds belong to the same entity and must occur simultaneously. That is, only when PoC > $1e^{-5}$ *and* Miss Distance <1km will potential anti-collision maneuvers be computed (if the satellite in question is maneuverable).

Several observations can be made about the table:

1. First, certain respondents establish two levels of severity of events, which they categorize as "Warning/Alert" and "Yellow/Red". This division does not occur in all entities.
2. Different combinations of thresholds: some respondents use thresholds focused only on PoC, others only on Miss Distance, and others use combinations of both (which may have to occur simultaneously or alternatively). A participant explicitly made the case for the latter, arguing that having only a PoC threshold may lead to situations with concerning miss distances but good covariances (and thus, unproblematic PoCs), and that cumulative use may also lead to unacceptably risky situations, since both thresholds have to be exceeded for action to become necessary.
3. Finally, the distinction at the level of the threshold itself. The most striking example occurring in LEO, where one entity's warning threshold ($1e^{-4}$) corresponds to another's alert threshold. This example replicates what happened in the Starlink/Chinese Space Station incident and support the

hypothesis that there is a need to unify the metrics used in determining on-orbit collision risk to avoid future misunderstandings. However, this may also happen within the same entity, as the metrics are defined on a case-by-case basis with the clients according to their risk aversion/tolerance. In these cases, the entity has provided in its responses the most common thresholds.

Although some respondents mentioned the time remaining to the event (time to TCA) as playing a central role in the consideration of the performance of an anticollision maneuver, only one of them provided specific data around this issue. Concretely, this actor specified that for a high interest event taking place in the immediate 24 hours, a maneuver proposal will be computed; if scheduled for the following 72 hours, high-precision PoC will be calculated based on observations and orbit determinations provided by an independent system.

In addition to the aforementioned differences, which reduce the possibility of defining the existence of a collision risk in an incontestable manner, this process is also hampered by other types of limitations. When the participants were asked about the main challenges that affect the determination of the existence of a conjunction risk, the two most frequently cited were 1) easy and timely access to relevant SSA data for debris during active-on-debris conjunction assessments, especially so-called "lethal non trackable" debris, which tracking coverage and detected size vary depending on orbital regimes (LEO, MEO or GEO) in the order of 1 to 10 cm, and 2) the execution of collision avoidance maneuvers in a context where one of the objects employs an autonomous collision avoidance system and the accuracy of SSA data available to feed into automated systems (garbage in, garbage out)

Regarding the former, there seems to be a consensus that lethal non-trackable debris cannot be effectively handled today. The only possibility is that satellite manufacturers shield their satellites to increase the survivability rate in case of collision, and to invest in companies working on building a catalog that includes objects of these sizes. As for the second matter, concerning the procedure when payloads with autonomous collision avoidance systems are involved, a process is usually pre-agreed on between operators. According to participants, megaconstellations with these autonomous systems usually take responsibility on maneuvering.

b) On the decision-making process that determines the existence of a risk of collision and the appropriate reaction to it

Further differences can be observed concerning the decision-making process that is triggered once the existence of such a risk is confirmed.

The first one occurs namely among those actors who class events into severity levels (Alert and Warning) and concerns the conception of said division. In fact, while in some cases it is the "Warning" concept that triggers the computation anti-collision maneuvers, in others this does not occur until the "Alert" stage. This represents a significant mismatch in the decision-making process, which will become relevant in those cases where close proximity events occur between two active objects.

The second divergence that this experience sheds light onto has to do with the sources of SSA data. The population sample of the questionnaire is divided between those stakeholders who have their own autonomous capacities to obtain their original SSA data; and those who need to rely on data provided by other actors. Among the latter, there are those who rely on data from public platforms such as the 18th US Space Control Squadron's Space Track, or those who rely on commercial SSA providers. However, it is common practice among respondents to combine several of these sources as a mean to ratify the results obtained separately.

As far as communication channels are concerned, different levels of interactions can be established:

- Firstly, there are communications between involved parties when the risk of collision concerns two active objects. In this case, it is clear from this experience that, once the data have been checked and the risk of collision between two active objects has been confirmed, not all satellite operators are in the position to communicate directly with the other concerned party. This is especially relevant, since in the current absence of standardized rules of the road, direct contact between the parties on a case-by-case basis is the only way to agree on how to proceed.
- Secondly, the participants were asked whether communications are carried out with third parties whenever the need for further action is ruled. The responses here were also divided between those who shared their plans with open-source data providers or state actors such as the Ministry of Defence, and those who said that they would bring the situation to the attention of the highest competent authority at a national level. A significant point was made regarding the fact that such actions are shared only when commercial satellites are involved. This opens the door to the debate on the management of military satellites and dual-use technologies, which is much more complex due to their strategic nature.
- Finally, further public communications about close proximity events are not the general rule. When the event occurs between two active objects, it is up to all involved parties to decide the extent to which they wish to inform the public about the event. If, on the contrary, the event occurs between an active object and a piece of debris, statements indicate that there is not necessarily any external communication to inform the rest of the actors about its occurrence.

c) On the evolution of the entity's approach to the concept of risk of collision

The last item of the questionnaire was aimed at exploring the evolutions of the entities in the conception of the risk of collision in orbit. The numerous variations listed by the participants in the survey lead to the satisfactory conclusion that the entities are likely to adapt their conception of the risk of collision in orbit according to the evolutions of the environment in which they operate. Among the variations implemented, the following stand out:

- Updating of the propulsion system in order to enhance maneuverability.
- Putting into place a procedure to request additional measurements from different SSA providers in case of risky conjunctions.
- Adapting the procedures to take into account objects tracked by the entity's sensors but not yet catalogued.
- Setting in place a LARGE vs LARGE screening in order to identify risky close approaches between inactive objects and prepare the management of a potential fragmentation.
- In the concrete case of EUSST, a dedicated platform has been developed in its Service Provision Portal to allow CA users to facilitate communication and coordination when potential connections have been detected. Similar initiatives can be found in the commercial sector[21].

Regarding the evolutions in the conception of risk that the respondents would like to see generalized in the short term, the majority highlighted the need for space agents to measure the risk of the space environment globally and not at the scale of a single mission, as is traditionally done, consistent with the increasing number of objects orbiting the Earth.

III- Main blocking points identified

The experience described in the previous section allowed for the identification of a number of issues that need to be addressed in priority if the foundations are to be laid for convergent modeling of on-orbit collision risk.

a) Assessing and acting on collision risk: multiple data sources, unknown factors, lack of consensus on the metrics and best practices

First is the fact that **space operators rely on different sources to obtain SSA data** (Space Track, private commercial providers, etc.). Effective SSA and space traffic management (STM) rely on the coordinated efforts of public and private operators and space object trackers, all of which hold essential, but incomplete, data and information about the position of their own and others' space assets. Considering the size of the space

[21] Owner'sMag. (26 November 2021). *Slingshot Aerospace Launches Communication Tool After Acquiring Stellatus Solutions*. Available here: https://ownersmag.com/slingshot-aerospace-acqauires-stellatus-solutions/

environment, this is a daunting task. Also, as a result of the fragmented and incomplete nature of current SSA data sources -including free Government conjunction assessment services-, operators still need to make their own assessment of the collision risk, and, due to a high and growing frequency of conjunction warnings and notable costs associated with moving the satellite, may choose to ignore some of them[22]. All of these facts imply that the evidence upon which the risk thresholds are applied is not the same and constitutes the first level of divergences leading to inconsistent results between stakeholders and possible disagreements, if not conflict, in reacting to an alleged close proximity event.

To the use of different data sources are added the potential inaccuracies inherent to technology, such as sensor limitations or outages, visibility problems, sensor availability for a given observation which can be impacted by maintenance or higher priority observation tasking, errors in sensor calibration or pointing, etc. These gaps in the data capture process contribute to the idea that complete reliance on one source of the data is not safe and that space actors should always count on at least two different data sources to compare their results.

A second major obstacle in defining the risk of collision in orbit is the commonly cited issue of **dealing with an unknown risk posed by untrackable pieces of debris**. Present technological capabilities do not allow for the tracking of all space debris objects, especially those below 1 or 2 cm. Although small in size, the speed at which these objects travel through orbits has the potential of making them lethal to other resident space objects. As such, efforts should focus on technology advancements that shall allow for the proper surveillance of these smaller pieces of debris. In the meantime, any apprehension of the risk of collision should take into account this unknown variable. This could be partly solved by including this uncertainty in the computation of the risk of collision, for instance by establishing a more demanding apprehension on other criteria to compensate for this additional non-measurable risk. However, this is only a temporary solution that in no case contributes to greater reliability of the results for it continues to be conditioned by the other errors mentioned above that affect any risk calculation.

Finally, there is the **lack of a clear consensus on the metrics** used to determine the existence of a) an event that should be monitored (security volumes), and more importantly b) an alarming situation, reflecting the different level of risk acceptable by each stakeholder (PoC, Miss Distance or TCA-based thresholds). Differences in metrics are not exclusive to respondent entities but can also be perceived at the level of national space agencies. For reference, the European Space Agency (ESA) and

[22] Regarding the multiplicity of SSA sources and its implication on risk assessment, the OECD indicates that Government conjunction assessment services, which are free of charge and commonly used by operators, remain inaccurate and do not provide essential data, such as, for example, debris and satellite object dimensions and mass or spacecraft altitude (Oltrogge and Alfano, 2019[39]). OCDE (2022), Earth's Orbits at Risk : The Economics of Space Sustainability, Éditions OCDE, Paris, https://doi.org/10.1787/16543990-en.

Germany's DLR's threshold for High Interest Events (HIEs) requiring maneuver consideration is set at PoC > $1e^{-4}$ [23]. By contrast, NASA has a tiered approach, dividing events in green, yellow and red (the latter involving maneuver planning and analysis)[24]. The respective thresholds per case can be summarized as follows:

Green	Yellow	Red
	PoC = $1e^{-7}$ (Green/Yellow)	PoC = $4.4e^{-4}$ (Yellow/Red)

For its part, JAXA uses a set of thresholds that must be met simultaneously for HIE determination: PoC > $1e^{-3}$ and Miss Distance < 1km[25]. The Canadian Space Agency, on the contrary, resorts to a double threshold and collision avoidance maneuvers shall be performed in the event that any of them is surpassed individually: PoC > $1e^{-4}$ or Miss Distance < 125m[26].

As illustrated by the Starlink and the Chinese space station incident, if the metrics used are not the same, one of the actors may consider that there is a risk and even that they need to act upon it, whereas the other one may not receive a warning and therefore will not prioritize the event. When viewed in this way, it may seem that the problem is merely a question of improving communication. However, the China/Starlink incident was just an isolated event; given the increase in the number of resident space objects and in the frequency with which these close approach incidents will occur in the coming years, this obstacle takes on a much larger scope. Therefore, measures must be taken towards a convergence in the thresholds or, at least, fully transparent communication on the limits acceptable for each entity in order to avoid future misunderstandings.

b) On the decision-making process: the technical/political dilemma, differences in communication, the "burden" question, non-responsive counterpart

The responses of the entities illustrate a **lack of homogeneity and transparency in the decision-making process** that is triggered in the event of a confirmed collision risk. Disparities occur at various levels, beginning with the moment in which possible anti-collision maneuvers are specifically computed (when the Warning or Alert thresholds are surpassed). It follows in terms of the conception of the event itself, varying among entities from being either a technical or a political issue, and whether the decision to perform a maneuver is ultimately taken at a C- or a working level.

It is also reflected in terms of communication protocols, as pointed out above, with certain entities informing the competent authority from the start while others limit their

[23] Schiemenz, F., Utzmann, J., & Kayal, H. (2019). Survey of the operational state of the art in conjunction analysis. *CEAS Space Journal*, *11*(3), 255-268, pags. 256 - 257. Available here: [Survey of the operational state of the art in conjunction analysis | SpringerLink]
[24] Idem, pag. 258.
[25] Idem, pag. 260.
[26] Idem, pag. 261.

exchanges to a dialogue with the implicated counterpart exclusively. The latter arises the issue of what to do in case two objects involved in the conjunction are operational and the interlocutor does not respond, or the communication does not reach its destination. This is the case of the 2019 event between the ESA satellite AEOLUS and a Starlink satellite, where ESA contacted SpaceX to coordinate in performing an anticollision maneuver, but the email apparently never reached the relevant team[27]. Once again, this highlights the need for a transparent protocol and well-established communication channels, where a point of contact can be easily reached and that will guarantee a responsive reaction.

Last but not least, there is the question of the "burden", or how to decide whose responsibility it is to perform a maneuver each time. In such a case, transparency in the decision-making process becomes especially relevant, as such an event involves several implications in terms of fuel, workforce labor, potential service disruptions, etc. This issue is further exacerbated by the increasing use of space objects equipped with autonomous CA systems, that entail the extra risk of potentially deciding to both carry out a maneuver and ending up colliding anyway.

c) On the evolution on the concept of risk of collision: the individual vs. aggregated risk approach

The last blocking point stems from the point identified by respondents according to which the risk should be apprehended in a holistic manner, taking into account the space environment as a whole, and not at the scale of a single mission.

A concrete example in practice arises at the level of the process of approval for license for multiple space-craft systems (e.g., megaconstellations). In assessing each dossier, the national regulator must do a full evaluation on the overall probability of collision of the system relative to a particular benchmark probability. While traditionally the authority has taken into account the risk of collision of each satellite/mission separately, it is the opinion of the participants to the present Working Group that the evolution of the environment requires in fact to widen the scope of this evaluation and do it on an aggregate basis.

This way of conceiving risk takes into consideration the additional risk posed by the fact that the object is part of a multi-spacecraft system (ex. the risk of all potentially failed satellites in the system or that of non-maneuverable satellites). Consequently, it implies tougher mission assurance standards for constellation applicants to uphold and has the potential to culminate in a revision on the entities' understanding and

[27] Kerr, E., & Ortiz, N. S. State of the Art and Future Needs in Conjunction Analysis Methods, Processes and Software'. In *Proceedings of 8th European Conference on Space Debris (virtual edition, SDC8)*, pag. 7. Available here: SDC8-paper64.pdf (esa.int)

measurement of the risk of collision. This process has the potential of leading to fewer failed or uncontrollable satellites and thus less increase in overall collision risk[28].

In a context where the space debris problem increasingly requires urgent and effective action, understanding how new missions will impact the orbital environment takes on the utmost importance. One of the ways to approach this question is precisely through the notion of the carrying capacity of orbits. The underlying idea to the use of this concept is to figure out what is the maximum volume of debris and satellites that a given orbit can carry in order to appropriately design, adapt and incentivize more environmentally friendly missions and satellites that can be sustainably supported by the space environment.

Although there is no commonly accepted definition of what carrying capacity is today, the state of the art does allow a numerical approximation of the aggregate risk posed by each new system to the total environment (based on elements like the reliability of satellites, the number of them, their lifetime or the debris background, to name a few). Knowing the maximum carrying capacity of an orbit would allow for strategic decisions to be made accordingly, both in terms of mission design (less mass, fewer satellites, lower cross-sectional area) and resource utilization (eventually limiting the number of objects per orbit), all measures that would contribute significantly to the preservation of a safe space environment.

d) Creating trust and confidence in the space market through modern Space Traffic Management

Even in a scenario where all the aforementioned obstacles were to be overcome, there shall always remain certain restrictions (especially at the Defence level) and imperfections (fragmented SSA data sources, technological frontiers, etc.) that will continue to add uncertainty to the issue. For instance, it is likely that military activities benefit from dedicated waivers for any transparency obligation that shall be adopted, given their strategic nature and the sovereign rights of States.

In addition to the above, there remains the key governance question of mutual trust between key actors: nations, space operators and market participants. In this regard, some encouraging advancements have been documented. Despite persistent divergences in approaches to Space Traffic Management (STM), some States across the Globe are leading the discussion constructively, making it priority and suggesting some core elements or principles by which STM should be established[29].

[28] Lindsay et al. (2022). *The efficacy of managing space environmental risk by regulating probability of collision with large objects*. Journal of Space Safety Engineering 9, pags. 245-250. Available here: [The efficacy of managing space environmental risk by regulating probability of collision with large objects - ScienceDirect]().

[29] Examples of this prioritization can be found in the following documents:
State Council Information Office of the People's Republic of China. (28 January 2022). *China's Space Program: A 2021 Perspective.* Available here: [Full Text: China's Space Program: A 2021 Perspective (www.gov.cn)]()
II. Development of Space Technology and Systems.

In this view and bearing in mind the strategic importance that outer space has for all humankind, a basic practical and effective step forward starts with the establishment of functional communication channels to help create trust between actors and overcome arising challenges in a cooperative manner.

In line with the principles of protecting outer space for the benefit of all and guaranteeing equitable access to it to all nations, this process shall include all stakeholders, from States to commercial entities and beyond, and especially those actors who are not naturally prone to speak to each other. From this point of view, the issue of developing a common reference model to assess collision risk in orbit, build trust and modern Space Traffic Management should continue to be handled from the global governance perspective, but with robust leadership at the national level to advance this issue at pace.

IV- Recommendations

On the basis of the main obstacles identified and the discussion in the previous section, participants to this Working Group developed key policy recommendations to address all of these critical governance issues.

a) Ensuring an assessment of the risk of collision in orbit of new satellite systems in an aggregate manner

States and space industry stakeholders should assess or apprehend in the short term the collision risk posed by new LEO satellite systems (which each comprise multiple LEO satellites) in an aggregate manner for each such LEO satellite system over its operating mission lifetime, and taking into consideration projected satellite failure rates, is recommended. States should consider in the short term such assessments when

In the next five years, China will continue to expand its space environment governance system. It will: Strengthen space traffic control; […].
VI. International Cooperation
China will actively participate in discussions on international issues and the development of relevant mechanisms, such as those in the fields of space environment governance, near-earth objects monitoring and response, planet protection, space traffic management, and the development and utilization of space resources.
The White House (18 June 2018). *Space Policy Directive-3, National Space Traffic Management Policy. Available here :* [Space Policy Directive-3, National Space Traffic Management Policy – The White House (archives.gov)] :
To maintain U.S. leadership in space, we must develop a new approach to space traffic management (STM) that addresses current and future operational risks. This new approach must set priorities for space situational awareness (SSA) and STM innovation in science and technology (S&T), incorporate national security considerations, encourage growth of the U.S. commercial space sector, establish an updated STM architecture, and promote space safety standards and best practices across the international community.
European Commission. (15 February 2022). Joint communication to the European Parliament and the Council. Available here: https://ec.europa.eu/info/law/better-regulation/
Building autonomous – yet interoperable with our main partners – EU Space Surveillance and Tracking capacities to support STM is therefore of paramount importance. A global STM effort would also contribute to transparency and confidence building in general, and help avoid misunderstandings and deescalate tensions in case of incidents.

considering authorizing LEO space systems - for example states should settle the need for regulators/licensing authorities to assess the risk of collision in orbit in an aggregate manner when assessing applications for new LEO space missions.

b) Conduct work into models of carrying capacity of orbital resources

States and space industry stakeholders should conduct further studies to:

1) **Conceive Earth's orbits as a finite resource**: States should consider setting up discussions and studies on the concept of the carrying capacity of the orbits.
    a. Short term: States should engage in efforts related to estimating the projected carrying capacity of orbits taking into account projections of orbital utilization models and technological advances.
    b. Long term: once an analytical framework for assessing carrying capacity limits has been developed, States should consider employing it to maximize equitable use of orbits and ensure room for future competitive entry, including by considering incentivizing deployment of smaller, less massive, satellites and/or requiring certain types of constellations to operate in specific orbital altitude bands that are best suited for the risks they present.
2) **Considering the impact on the carrying capacity of the entire orbital resource as an indicative reference when assessing the impact and risk of new space missions**:
    a. Short term:
        i. States should settle the need for regulators/licensing authorities to conceive the risk of collision in orbit in an aggregate manner, thus assessing application forms for new space missions according to their impact on the whole orbital environment (especially those involving an important number of space assets).
        ii. States should also engage in international discussions to define a minimum common understanding on what key environmental protection principles should be followed to protect Earth's orbits.
    b. Long term: As per 1b above. Considering the impact on the carrying capacity of the entire orbital resource as an indicative reference when assessing the impact and risk of new space missions.

c) Towards a uniformed definition and assessment of collision risk

The main blocking points identified in this area were the use of different data sources, possible technological inaccuracies, dealing with the unknown factor and the use of different metrics and thresholds. In addressing these issues, States could:

3) **Contribute to improving the quality of available SSA data:**

a. Short term: States should lead by example and facilitate data on their satellites to the extent possible to a centralized publicly available platform (on facts such as ephemerides, but also size, mass, attitude, scheduled maneuvers, etc.), thus contributing to the emergence of a climate of trust among actors. States shall also pledge to communicate and update these data on a regular basis.
b. Long term: States should formalize their commitment to share relevant data concerning their proprietary in-orbit infrastructures and other public missions.

4) **Incentivize and promote the development and use of techniques and methods to improve the accuracy of orbital data and spaceflight safety information:**
   a. Short term: States could offer incentives or anchor client contracts for commercial SSA service providers that can enhance the data, services and space object catalogue of public free services and the resilience of the larger space sector.
   b. Long term: States should put in place a modern Space Traffic Management framework while supporting space safety innovation directly and through investing in the commercial ecosystem.
5) **On the use of different thresholds for assessing collision risk and implementing collision avoidance:**
   a. Short term:
      i. States should communicate their thresholds to a centralized platform, organism or body that will make them available for free consultation. States should also establish incentive measures to encourage their commercial actors to transfer their standards to this organism. In the case of an entity which sets its thresholds on a case-by-case basis with its client, they shall communicate the agreed upon conditions of each contract provided that both parties agree.
      ii. States should engage in efforts to standardize the thresholds of 1) collision risk existence and levels, and 2) emergency maneuver for collision avoidance.
   b. Long term: States should commit to enshrining the results of the aforementioned discussions into their respective legal and STM frameworks by use of the appropriate mechanisms.

d) On the lack of transparency in the decision-making process

Finally, the main obstacles detected on this topic included the issue of who and at what stage decides that the performance of an anticollision maneuver is necessary; lack of functioning communication channels and clear protocols in such a case, and lack of concrete rules of the road to reduce uncertainty around the burden question. In dealing with these issues, States could:

6) **Channels of communication:**

a. Short term: States should pledge to identifying their point of contact referent for each competent national authority (according to national traditions), in copy of the exchanges between operators and to standardize the information shared so that operators can cross-check the information between them.
b. Long term: States should engage in discussions towards the establishment of a fine or other penalty to non-responsive actors, in addition to the obligations that shall stem from binding international treaties such as the Liability Convention.

7) **Identifiable points of contact:** In an emergency situation such as a collision risk, it is also of vital importance that the responsible persons are easily identifiable and that their details are up to date and available to all other actors. With a view to facilitating the identification of the relevant counterparts in a crisis situation, States should ensure that all relevant details of each space object, notably the point of contact within the entity responsible for them, are recorded in a register.
    a. Short term: States will ensure that all space objects authorized under their jurisdiction have an identified, reactive point of contact.
    b. Long term: an international registry should be created where information about each organization's point of contact will be poured by their national authorities. Actors who fail to communicate to the competent national authority any changes in this regard may be subject to a fine or other penalty.
8) **Towards the establishment of generally accepted convergent rules of the road** and the automation of the decision-making process. Software systems would be developed to resolve conjunctions between active satellites according to previously agreed rules of the road in space. Manual process and human-to-human interactions could be minimized. This is especially relevant with the increase in the number of active vs. active conjunction events to be faced in the coming years as a consequence of the deployment of megaconstellations and thousands of cube- and nano-satellites, which frequently do not have the capability to maneuver.
    a. Short term: on the burden question, States should engage in international efforts to establish rules of the road for behavior of satellites equipped with an automated collision avoidance system.
    b. Long term: States shall pledge to transfer onto their national legal and STM frameworks the aforementioned guidelines and rules of the road, by means of the appropriate mechanism, and develop ways of ensuring proper implementation and enforcement.

e) On making future satellites safer and ready for the environment they will be operating in

9) **Adapting the technological developments in various fields, which are already tested, and making** all **future spacecrafts maneuverable, trackable, operable**

and prepared for de-orbit (in case their primary de-orbit or collision avoidance systems fail) to avoid foreseeable disastrous collision events.

a. Short term:
    i. States should enforce the relevant UN COPUOS / UNOOSA, IADC and ISO guidelines, recommendations or standards as applicable of maneuvering capability in all future satellites, at least to reduce the operational collision risks. States should pledge to mandate that within the scope of licensing of the satellites, satellites be maneuverable.
    ii. States should enforce the IADC recommendation on trackability of all future satellites. They should pledge to mandate that satellites be trackable using any of the tracking systems, to the level which the orbits can be determined by the national or international moderating agency / institute.
    iii. States should mandate on communication between the satellite owners and operators to ensure availability and responsiveness.
b. Long term:
    i. States pledge to get involved in the creation of a centralized coordination system, facilitated or maintained by national or international authorities. Such a system shall develop a mechanism to safeguard the national interests and Intellectual Property Rights of commercial actors in case of fully automated spacecrafts, and provide required support to all actors and international coordination for routine operations.
    ii. States should pledge to communicate to the central national/international coordinating systems in case of automated collision avoidance systems.

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