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English only

Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Fifty-ninth session
Vienna, 7–18 February 2022
Item 8 of the provisional agenda*
Space debris

Research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

The present document has been prepared by the Secretariat on the basis of information provided by Japan on 29 October 2021 and by CANEUS International on 29 October 2021, and contains figures and pictures related to space debris, not included in A/AC.105/C.1/120. The document is issued without formal editing.

* A/AC.105/C.1/L.392.

Japan

Report on Space Debris Related Activities in Japan

1. Overview

This report contains debris related activities mainly conducted by the Japan Aerospace Exploration Agency (JAXA), as requested by the Office for Outer Space Affairs.

The following debris related activities were conducted by JAXA in 2019 and 2020. Further information is introduced in the next section.

(1) Conjunction Assessment (CA) results and research on core technology for Space Situational Awareness (SSA)

(2) Research on technology to observe LEO and GEO objects and determine their orbits

(3) In-situ micro-debris measurement system

(4) Development of composite propellant tank

(5) Active debris removal

2. Status

2.1 Conjunction Assessment (CA) results and research on core technology for Space Situational Awareness (SSA)

JAXA regularly receives conjunction notifications from the Combined Space Operations Center (CSpOC). In 2020, JAXA executed 2 debris avoidance manoeuvres (DAM) for low earth orbit (LEO) spacecraft. The number of DAM has decreased in comparison to that in 2019, since CSpOC introduced new criteria for identifying high risk events. As a satellite operator, JAXA recognized that the conjunction risk posed by space debris remains high, as the space environment deteriorates year after year.

Core technology for space situational awareness (SSA)

The current analysis system at Tsukuba Space Center in JAXA determines the orbit of space objects using a radar sensor located at Kamisaibara Space Guard Center (KSGC). Additionally, optical sensors located at Bisei Space Guard Center (BSGC) predict close approaches using the latest orbit ephemerides of JAXA satellites and calculate the probability of collisions.

At present, a new KSGC radar, which is currently being developed, can track smaller space debris than the old radar. The new radar will cover in particular altitudes around 500 to 800 km, where most of JAXA’s LEO satellites are orbiting. JAXA is also refurbishing its 1.0-meter and 0.5-meter telescopes to maintain their current capabilities for observations of GEO objects. In addition, JAXA is developing a new analysis system that will be able to handle more data than the current system, and will be able to run by automated processes as much as possible.

Note that operation of the old KSGC radar was terminated in August 2020 in preparation for the new radar. The new SSA system including the new KSGC radar will be available in 2023.

JAXA has also developed tools that help plan DAMs, once the Agency receives CDM (conjunction data message) from CSpOC. Based on experience, all of the DAM procedures simplified and reduced workload. Last March, JAXA released the Risk Avoidance assist tool named “RABBIT” free of charge for all satellite operators.

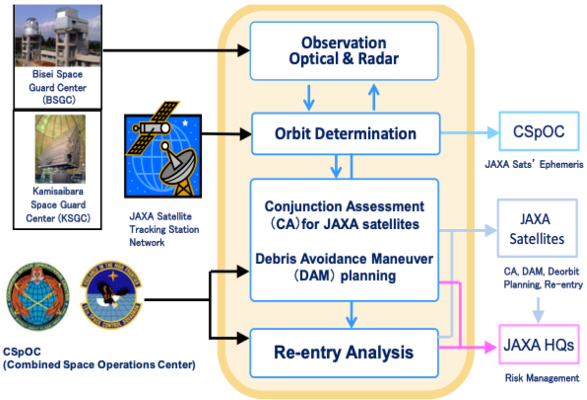


Fig. 1 Activity for the SSA in JAXA

Research on technology to observe LEO and GEO objects and determine their orbits

Generally, the observation of LEO objects is mainly conducted by radar system, but JAXA has been working to develop an optical system to reduce the cost for both construction and operation. A large CMOS sensor for LEO observation was developed (Fig.-2). Analysing the data from the CMOS sensor with FPGA-based image-processing technologies can help us detect LEO objects that are 10cm or less. In order to increase the observation opportunities of LEO and GEO objects, a remote observation site in Australia (Fig.-3) was established in addition to the Mt. Nyukasa Observatory in Japan. One 25cm telescope and four 18cm telescopes are available for various objectives. Another remote observation site will be established in western Australia, which will enable us to carry out precise orbital determinations and altitude estimation of LEO objects using the data from both sites in Australia.

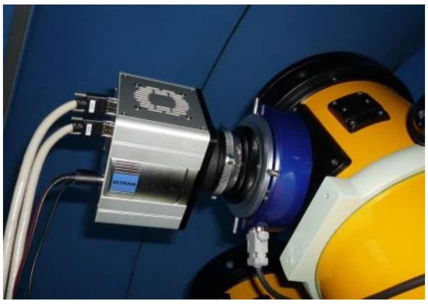


Fig.-2 The CMOS sensor manufactured by Bitran which can detect 10cm LEO objects analyzing the data with FPGA-based image-processing technologies

Fig.-3 The remote observation site in Australia. The left figure shows the sliding roof where all the observation devices are installed. One 25cm telescope and four 18cm telescopes (the right figure) are available for various objectives.

2. In-situ micro-debris measurement system

The space debris monitor (SDM) is an in-situ micro-debris sensor focusing on micro to milli sized debris under 1000km orbit. A recent flight experience was conducted by H-II Transfer Vehicle “KOUNOTORI” (HTV) 5. Information based on actual measurements of these small debris is essential to properly understand the vast amount of small debris orbiting near our earth as they are becoming a dominant risk factor on orbit.

The unique properties of the SDM are its simple detection system which does not need any special calibrations before flight and the potential to collaborate easily with other sensors. The SDM consists of a debris-detection area and circuit areas. The debris-detection area is made of very thin polyimide film and there are thousands of 50 µm-wide conductive grid lines capable of detecting the diameter of collided debris sized from 100 µm to millimetres.

JAXA jointly collaborates with NASA Orbital Debris Program Office (ODPO) to develop a new in-situ micro-debris measurement system in order to understand the number of small debris on orbit under 1,000 km.

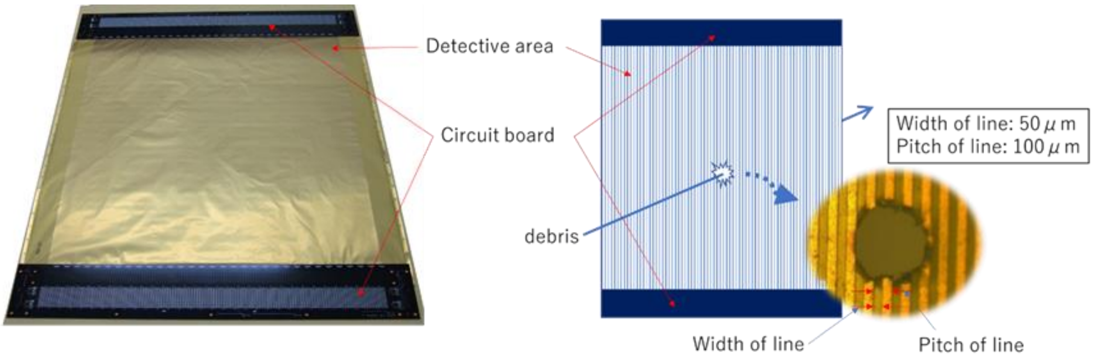


Fig.-4 Conductive grid sheet of SDM Bread Board Model (left) and Schematic picture of the SDM (right)

3. Development of composite propellant tank

A propellant tank is usually made of titanium alloy, which is superior because of its light weight and good chemical compatibility with propellant. But its melting point is so high that such a propellant tank would not demise during re-entry, and would pose a risk to people on the ground.

For several years, JAXA conducted research to develop an aluminium-lined, carbon composite overwrapped tank with a lower melting temperature. As a feasibility study, JAXA conducted fundamental tests including a liner material aluminium compatibility test with a hydrazine propellant and an arc heating test.

After the manufacturing and test of a shorter sized EM#1 tank, JAXA manufactured a full-sized EM#2 tank. The shape of the EM#2 tank is identical to the nominal tank, which includes PMD. Using the EM#2 tank, a proof pressure test, vibration test (for wet and dry conditions), an external leak test, a pressure cycle test, and a burst pressure test were conducted and all showed good results. Subsequently, the critical design review was completed.

This composite propellant tank has a shorter delivery period and lower cost compared to a titanium propellant tank. Its demisability during atmospheric re-entry, experimental and analytical evaluation is ongoing.

Fig.-5 EM#2 tank

Fig-6 Evaluation Tests by Arc Heating Wind Tunnel

Active Debris Removal

JAXA has organized and structured a research program which aims to realize low-cost Active Debris Removal (ADR) missions. As shown in Fig.-7, the ADR key-technology R&D has three major themes: non-cooperative rendezvous, capture technology for non-cooperative targets, and de-orbiting technology to remove massive intact space debris. JAXA is cooperating with Japanese private companies to realize low-cost ADR on a commercial basis and working to provide these essential key-technologies for this purpose.

JAXA is also leading the Commercial Removal of Debris Demonstration (CRD2) program. As shown in Fig.-8, this program is comprised of two phases aimed at conducting the world's first ADR in partnership with private enterprises. During the first phase of this program, demonstration of key technologies such as non-cooperative rendezvous, proximity operation, and inspection of H-IIA second stage are planned for Japanese fiscal year (JFY) 2022. During the second phase, demonstration of active debris removal and re-entry of H-IIA second stage is planned after JFY 2025. As a partner company of phase one, Astroscale Japan Inc. was selected thorough competition in February 2020.

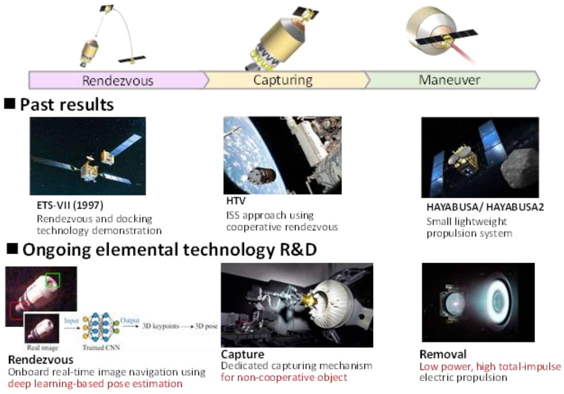


Fig.-7 Active Debris Removal research activities

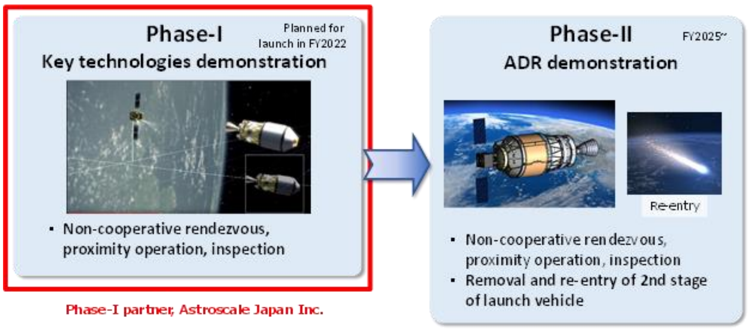


Fig.-8 Demonstration of the removal of large-sized debris in two phases

CANEUS International

Multi-Satellite Low-Earth-Orbit Constellations: Interferences for Routine Space Activities & Astronomical Observations — Threats To Uncontrolled Space Debris Formation

Overview

CANEUS proposes to the Scientific and Technical Subcommittee (STSC) to initiate system studies to address the problem of the influence of multi-satellite Low-Earth-orbit (LEO) constellations on traditional tasks solving both in outer space and from space (within mandate of the Committee on the Peaceful Uses of Outer Space (COPUOS)).

Based on the results of such studies, which are advisable to carry out, the leading space powers at the national level can be offered real measures to exclude or mitigate the effects of physical and energy interference created by mega-groups to traditional space systems.

In the short term, this kind of measures may be associated with a number of actions by satellite operators of low-orbit constellations of micro-, nano- and pico- classes: darkening the surface of satellites, sun shielding, and refusing to use non-rigid reflective materials on the parts of the small satellites looking in nadir to reduce its glares; changing the orientation of the small spacecraft in order to avoid the projection of light reflected from the onboard equipment, while ensuring the general availability of ephemeris with the highest possible accuracy.

In the long term, within the institutes and working groups of COPUOS, additional measures can be developed and proposed to eliminate or mitigate the effects of physical and energy interferences, created by mega-groups to traditional space systems, as well as reduce the risk of collision in orbits and the formation of space debris.

Near-term Mitigation Measures:

A. For satellite operators:

- Surface eclipse.
- Sun shielding.
- Adjusting attitude to avoid flares projecting onto major ground-based observatory sites.
- Monitoring satellites control within power constraints to ensure effective reflectivity and maximum prediction of the nadir-facing specular surfaces in direction of ground-based observatories.

B. For observatories:

- Image post-processing to identify, model, subtract and mask affected pixels associated with the satellite trail.
- Maintaining precise ephemerides of entire constellation suites, and for those facilities where it may be practical, close shutters of the ground telescopes for the seconds around the predicted satellite passage.
- Pointing avoidance when possible.

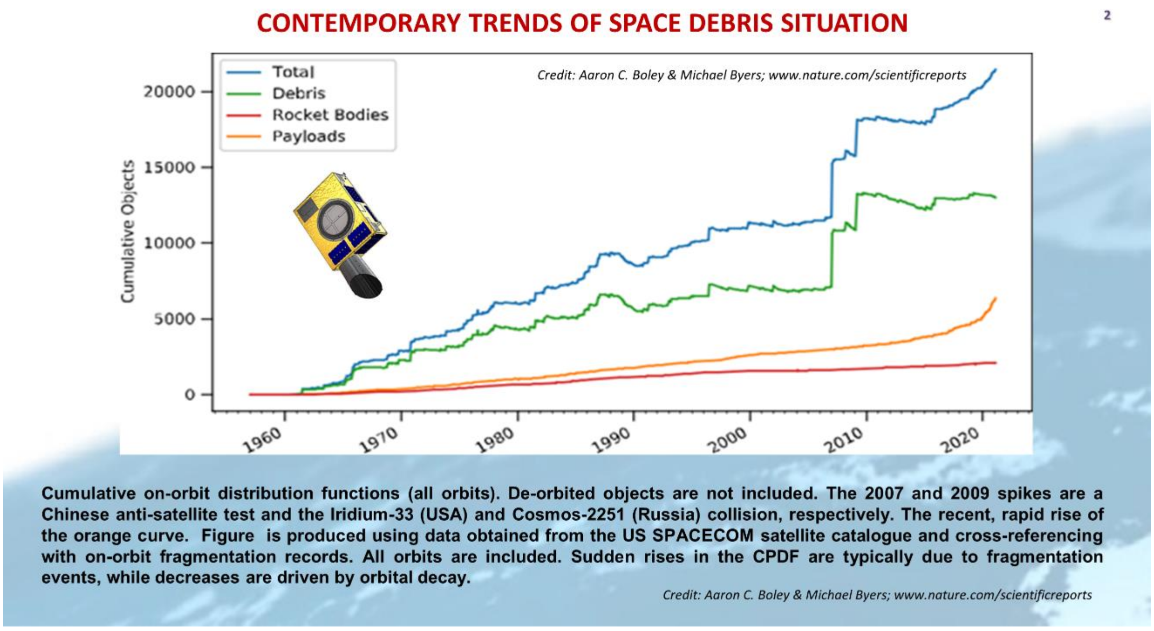
Background:

Over the past few years, several LEO (Low-Earth-Orbit) multi-satellite constellations have been actively created and deployed mainly by private and government owned corporations in the USA, Great Britain, Canada, China and other countries.

Specific examples include the most widely-known constellations of commercial small satellites for broadband communications and space Internet; StarLink and OneWeb

ERS – Dove (Flock); Internet of Things – SpaceBEE; and Automated vehicles Identification System (AIS) – Lemur-2.

Corporations are placing satellites into orbit at an unprecedented frequency to build “mega- constellations” of communications satellites in low-Earth-orbit. Some estimates show that more than 100,000 satellites could orbit our planet by 2030.



Cumulative on-orbit distribution functions (all orbits). De-orbited objects are not included. The 2007 and 2009 spikes are a Chinese anti-satellite test and the Iridium-33 (USA) and Cosmos-2251 (Russia) collision, respectively. The recent, rapid rise of the orange curve. Figure is produced using data obtained from the US SPACECOM satellite catalogue and cross-referencing with on-orbit fragmentation records. All orbits are included. Sudden rises in the CPDF are typically due to fragmentation events, while decreases are driven by orbital decay.

Credit: Aaron C. Boley & Michael Byers; www.nature.com/scientificreports

In general, the current situation with “population density” of near-Earth orbits is characterized in a recent article by Aaron C. Boley and Michael Byers in “Nature” online Scientific reports, finding reveals that the number of active and defunct satellites in LEO has increased by over 50 per cent, to about 5000 (as of 30 March 2021) in two years.

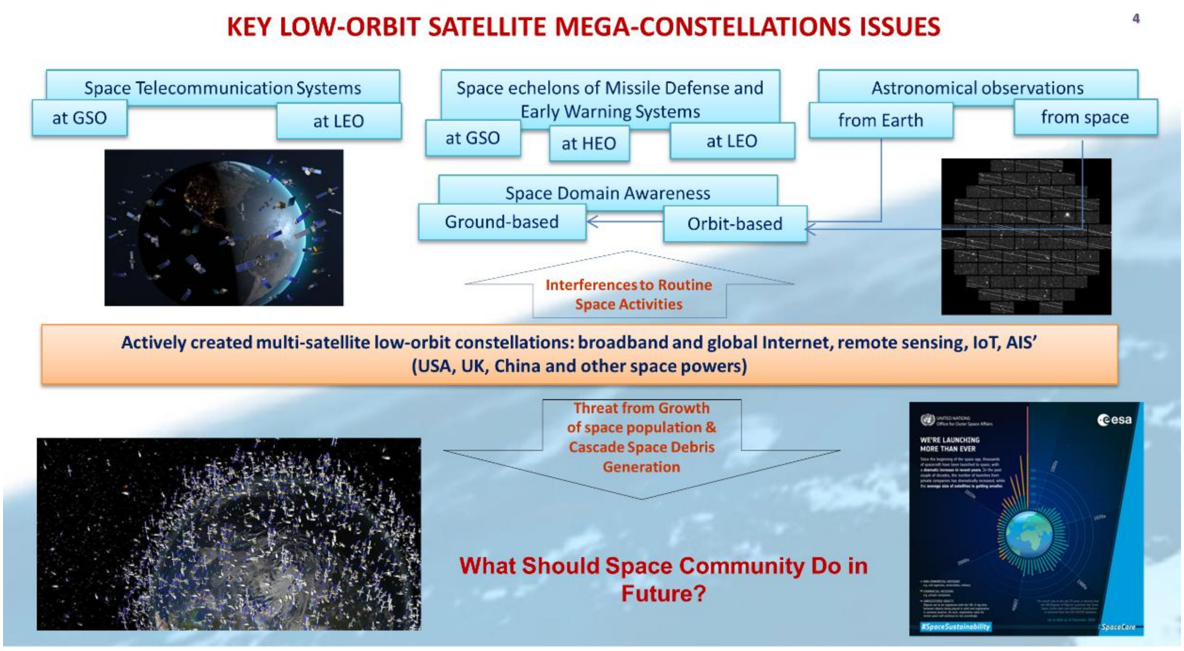
SpaceX alone is on track to add 11,000 more satellites as it builds its Starlink mega-constellation and has already filed for permission for another 30,000 satellites with the Federal Communications Commission. Others have similar plans, including Chinese state-owned company GW (Guowang) 13,000 satellites, OneWeb (6,372), Amazon (3,236) and Telesat (Lightspeed 298). The current governance (control) system for LEO, while slowly changing, is ill-equipped to handle multi-satellite space systems.

In just a short term, the process will only grow. So, like mushrooms after rain, the aforementioned orbital constellations of broadband Internet, Internet of things, Earth remote sensing, and Automatic Identification Systems are already appearing in the last two years.

According to a recent Canadian presentation at the last STSC session, of “*space photometric measurements of the Starlink orbital constellation*" collected via NEOSSat Mission, revealed that in the next 10 years, up to 10 thousand small (micro-, nano-, pico-, and femto-) satellites are predicted in orbits.

Key issues:

The emergence of new threats and risks that are directly or indirectly related to the problem of space debris exist in two self-sufficient dimensions.



The first dimension is energy (information) interferences from low-orbit multi-satellite constellations for routine (day by day) space activities, which is associated with the functioning of the satellite systems that ensure strategic stability and international security.

These are, first of all, national (China, Russia, USA) and international (EU) high-orbit broadband communication and data relay systems, information components of missile attack warning and anti-missile defence systems, as well as control of near-earth space, low-altitude strategic intelligence systems (control compliance with treaties) and special communications in the interests of military and paramilitary departments.

Interferences to astronomical observations are carried out from Earth and are directly related to missile attack warnings, missile defence, and space control systems since the ground-based optical facilities contribute to the solution of defence tasks.

So, it is impossible to exclude radio interference created by the uninterrupted operation of military and civil satellite communications in the frequency ranges of Ka, Ku (from 22 GHz) and V (60 GHz). In addition, a global and poorly-controlled threat to physical and information security in the space sector is being created by all the above multi-satellite constellations, not limited to telecommunications.

The second dimension is a threat of a cascade growth in the population of space debris associated with the observed intensification of the use of small (micro-) and ultra-small (nano, pico, and femto formats) satellites in the context of the use of automated control over them based on micro-nanotechnologies and artificial intelligence.

Potentially dangerous mutual encounters of such small spacecraft as part of "swarm" constellations at critical distances, and the threat of possible collisions as a result of loss or control errors will force (and already have forced) operators of large low-orbit space objects (such as unique and expensive strategic reconnaissance satellites or ISS) to resort to frequent defensive manoeuvring with all the ensuing consequences, among which is the disruption of the solution of target tasks or the consumption of the mission's energy resources.

Related efforts:

STSC COPUOS, during its last session, drew particular attention to these problems; paragraph 98 of its outcome document (A/AC.105 /1240) contained a provision that "**there are serious concerns about the deployment of large multi-satellite constellations in low orbits and the consequences of such deployment, and several**

delegations were therefore of the opinion that the Subcommittee should consider this topic as a priority in order to mitigate the impact of space debris".

Considering the fact that the problem of space debris has been considered by United Nations COPUOS for many years, including attempts to regulate the debris level in NEO by special measures at the national and international levels, the introduction of recommendatory norms and the creation of specialized United Nations institutions to solve the problem of interference and long-term threats to everyday space activities as a result of the emergence of multi-satellite constellations in low orbits seems **unlikely constructive**.

Suggested modifications:

Alternatively, the current traditional (in accordance with GA Resolution No. 75/92) mandate of item 7 of the STSC agenda, "Research on the problem of space debris, the safety of space objects with onboard nuclear power sources and problems related to their collision with objects artificial origin", in particular, should **replace (or added to) in its wording the phrase "**...**with onboard nuclear power sources"** by "**low-orbit multi-satellite constellations"**.

Rationale for the proposed modifications:

I will dwell on the rationale for the proposed adjustment.

First, space objects with onboard nuclear power sources have not been launched, at least for the last two years. The exception was for radioisotope energy sources, used for long-term (usually interplanetary) space missions.

In the short term, such objects do not reflect an obvious a threat as multi-satellite low-orbit constellations, neither from the point of view of collisions in orbits, nor from the point of view of the consequences of such collisions for the ecology of the Earth and space.

Secondly, the problem of the influence of low-orbit multi-satellite constellations both on the efficiency of astronomical observations and routine space activities in its various aspects, including ensuring strategic stability and international security, **was not posed by the STSC COPUOS**.

The fresh studies of its first component were further carried out in the USA by the American Astronautical Society with the support of the National Science Foundation (SATCON1 and SATCON2 workshops held in July 2020 and July 2021) to minimize the negative impacts of satellite constellations on astronomy and the night sky; however, the second component **was ignored by analysts' research.**

If specific measures have been proposed to guide both observatories and satellite operators now and in the future (when the international community comes to a more detailed understanding of the impact of multi-satellite low-orbit constellations on astronomical observations and ways to mitigate such impacts), then in the case of the influence of low-orbit multi-satellite constellations on stabilizing space activities (global communications, relaying, reconnaissance from space, space echelons of Missile Defense and Early Warning Systems and Space Domain Awareness), such measures in an open format **have not been considered**. Moreover, the dominant use of certain orbital regions by a select few countries might also result in a de facto exclusion of other actors from them, violating the 1967 Outer Space Treaty.

Proposed recommendations:

All these issues and challenges mentioned above could be considered and addressed in a coordinated manner **through multilateral law-making only, whether in the United Nations, Inter-Agency Debris Committee (ADC) or an ad hoc process, rather than in an uncoordinated manner through different national laws**.

However, no binding international rules exist on other aspects of mega-constellations. In 2007, ADC, which currently represents 13 space agencies, indicated that direct re-entry at the end of a satellite's operational life was preferred, but only recommended de-orbiting satellites **within 25 years**. This is an **unaccepted guideline for mega-constellations** made up of thousands of satellites with short operational periods. It also overlooks placement, with satellites at higher altitudes producing relatively high collision probabilities when de-orbiting timescales are too long.

Regardless of the law-making forum, mega-constellations require a shift in perspectives and policies: from looking at single satellites, to evaluating systems of thousands of satellites, and doing so within an understanding of the limitations of Earth's environment, including its orbits.

Thus, based on the above, **CANEUS proposes to STSC to initiate system studies of the problem of the influence of multi-satellite low-Earth-orbit constellations** on traditional solvable problem at outer space and from outer space.