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Long-term sustainability of outer space activities

Inputs to the Working Group on the Long-term Sustainability of Outer Space Activities: India

The present conference room paper was prepared by the Secretariat on the basis of information received from India. The information was reproduced in the form it was received. A shorter related text is available in all the official languages of the United Nations in document A/AC.105/C.1/L.409/Add.1.

* A/AC.105/C.1/L.405.

Submission by India to the Working Group on the Long-term Sustainability of Outer Space Activities of Scientific and Technical Sub-Committee of COPUOS

1. India places a high priority on the safety and sustainability of outer space activities in the rapidly changing space scenario and in this regard, has welcomed the adoption of 21 guidelines for the Long-Term Sustainability of outer space activities. It is necessary for all space actors to implement the LTS guidelines to preserve outer space for safe and sustainable utilisation by current and future generations. India is committed to the implementation of these guidelines in its space activities to the extent possible. India also recognises that it is equally important to continue to identify the challenges to long-term sustainability, share the experiences and lessons learnt from the practical implementation of adopted guidelines, and contribute towards awareness raising and capacity building, especially in developing countries and emerging space fairing nations.
2. During the fifty-ninth session of the Scientific and Technical Subcommittee, the Working Group on the Long-term Sustainability of Outer Space Activities agreed that the Chair of the Working Group, with the support of the Secretariat, would invite States members of the Committee, organisations having permanent observer status with the Committee and relevant United Nations entities, subject to the relevant provisions of paragraphs 15 and 16 of the Working Group's terms of reference, methods of work and workplan (A/AC.105/1258, Appendix to Annex II), to provide information and views on the topics in paragraphs 4 and 6 of the Working Group's terms of reference, methods of work and workplan, in a format deemed appropriate.
3. India submits to the Working Group, via this report, its inputs on the information and views on the following topics:

(a) Identifying and studying challenges and considering possible new guidelines for the long-term sustainability of outer space activities

1. India's attention is focussed on the challenges to the long-term sustainability of outer space activities that arise in the context of the safety of spaceflight, especially while operating in the presence of large constellations and small satellites.
2. In recent times, CubeSats and nanosats have emerged as preferred options for affordable access to space and their deployment typically takes place through ride share and in batches. Due to their small size, they are often difficult to track as well as to be identified immediately after injection. Such satellites usually lack manoeuvrability and hence, the onus of collision avoidance falls single-handedly on the owner/operators of manoeuvrable satellites. In most cases of on-orbit conjunctions with small satellites, the lack of information to contact spacecraft operators proves to be a major challenge to initiate the requisite coordination and data exchange for collision risk mitigation.

3. Unlike space debris, which are non-manoeuvrable objects, the trajectory of manoeuvrable spacecraft, especially those equipped with ion thrusters, cannot be predicted by the straight-forward application of conventional flight dynamics. Hence, the exchange of operational ephemeris is essential for any meaningful decision-making on collision avoidance. The present mode of inter-operator coordination is primarily through exchange of e-mails, which involves considerable latency mainly due to time zone differences. Given the phenomenal growth in the number of operational satellites, especially due to the deployment of several large constellations, contacting the operators individually to resolve close approach situations on a case-by-case basis will prove to be impractical in the long run. Therefore, a common operational mechanism for inter-operator coordination, suitably supplemented with a standardised protocol for relevant information exchange needs to be evolved to cope with future challenges.
4. In the near future, LEO (Low Earth Orbit) is expected to host not just one, but multiple large constellations simultaneously, each typically consisting of a few hundred to several thousand satellites. The cumulative addition of such a large number of satellites in LEO will lead to a drastic increase in the likelihood of on-orbit collisions. Multiple close conjunctions occurring in very short time intervals will be particularly tricky to resolve and necessitate intensive inter-operator coordination in case both the assets are operational. The anticipated increase in collision avoidance manoeuvres will incur significant penalties in terms of service disruption, fuel consumption, additional operational overhead, associated cost, etc. This added complexity would be difficult to be borne by emergent space actors.
5. Operators often utilise higher-accuracy orbital data of their own space assets and relatively less accurate, externally accessible orbital data of the threat objects to assess the collision risks. Furthermore, different operators adopt different methodologies for risk estimation and also, apply different criteria for identifying critical conjunctions. In the absence of a standardised method of risk assessment and a common protocol for collision avoidance, any decision to conduct an evasive manoeuvre to mitigate a close approach risk essentially hinges on the discretion of the operator.
6. In particular, many of the large constellations are proposed to be deployed in very low Earth orbit (VLEO), below 400 km altitude. Furthermore, as per the recommendations on limiting orbital life-time, the satellites of large constellations are initially deployed at 350 km to undergo testing and qualification. They are also de-orbited at end-of-life below this altitude. Hence cumulatively they also contribute to a sizable population of objects in VLEO. As a result, launch vehicles transiting through this lower Earth orbital regimes will face multiple conjunctions with the satellites of these constellations. All human spaceflight missions to outer space have to traverse multiple shells of the constellations during their forward as well as the return journey. Therefore, the proliferation of VLEO constellations will severely restrict the availability of conjunction-free liftoff timings within a launch window as well as pose a significant risk to the safety of human spaceflight missions.

7. The satellites of large constellations, when illuminated by sunlight at lower altitudes, appear as streaks in the images of ground-based optical telescopes, significantly degrading their object detection capability.
8. Cubesats and nanosats are often mass-produced using COTS components and are more prone to on-orbit failures. For large constellations, the resilience of the overall system is given preference over the resilience of individual satellites. Deployment of multiple large constellations in LEO would result in a non-trivial number of failed satellites adding to the already dense population of space debris in this region. A few of these constellations are proposed to be deployed above 1000 km where any defunct objects tend to remain in space for hundreds of years. The long-term presence of these defunct objects significantly increases the chances of collisions in crowded orbital regimes.
9. At present, there is no internationally accepted limit on the number of satellite licenses that States can issue to private companies at present. An unabated increase in the number of satellites would invariably affect accessibility to outer space, equitable utilisation, as well as the ability to sustain safe space operations in future. Unless concrete steps are initiated, in the worst case, the excessive congestion may trigger the “Kessler syndrome”.

(b) Sharing experiences, practices and lessons learned from voluntary national implementation of the adopted Guidelines

India has been taking all the possible efforts in implementing the adopted guidelines in its space activities to the maximum practicable extent. India is ready to share its experiences and lessons learnt from implenatation of the adopted guidelines.

A) **Guidelines on policy and regulatory framework for space activities**

1. India is a party to all major international treaties and regulations related to outer space, including Outer Space Treaty, the Rescue Agreement, the Liability Convention and the Registration Convention. Until 2020, the national space agency Indian Space Research Organisation (ISRO) was mandated to carry out all the space operations from India. All outer space activities carried out by ISRO are in accordance with UN treaties, conventions, resolutions, and guidelines. When the space sector in India was decided to be opened for private participation, actions were taken to revise the national regulatory framework for outer space activities in conformance to the obligations under the Outer Space Treaty and other conventions and as suggested in guideline A1.
2. ISRO while conducting space operations, follows internationally accepted Space Debris Mitigation Guidelines of UNCOPUOS and IADC. During the design, implementation and on-orbit operation of launch vehicle and satellite missions, risks to people, property, public health and the environment associated with every launch are taken into consideration. ISRO also implemented standards like ISO and CCSDS in the design and development of space-based systems and operations in several missions in the past, and such standards are being increasingly adopted in ongoing missions. The national regulatory framework under

preparation also considers, among others, India's obligations under the UN treaties and internationally accepted guidelines for space debris mitigation.

3. As per guideline A3, India has put in place a concrete system to monitor its space activities. While the Department of Space (DOS) of Government of India drafts policies for the space sector of the country, IN-SPACe (Indian National Space Promotion and authorisation Centre) under DOS is the nodal agency mandated to authorise and supervise all space activities of non-governmental Indian entities. At the national level, an exclusive system named 'ISRO System for Safe and Sustainable Space Operations Management' (IS^4OM) has been established to ensure that ISRO's outer space activities are conducted in a safe and sustainable manner. Contact points have been identified for communication with relevant authorities to facilitate efficient and timely sharing of information on space activities, and to handle potentially urgent matters related to the safety and sustainability of outer space activities.

4. Towards implementation of guideline A4, India follows the provisions of ITU Radio Regulations in operating its fleet of satellites and using the orbit-spectrum resources by coordinating with other satellite operators/countries and ensures that India does not violate ITU's basic principle of equitable, rational and efficient use of the limited orbit-spectrum resources available.. ISRO takes the best possible efforts in designing its satellites to minimise interference with other adjacent satellites. In our experience, there have been cases of interferences in spite of all precautions and such situations have been efficiently resolved by coordination with the corresponding satellite operator.

5. As part of the efforts for efficient use of orbital regions, ISRO meticulously carried out post-mission disposal (PMD) of GEO satellites by manoeuvring them away from the GEO protected region, followed by passivation to minimise post-mission break-up risk. These measures are being followed for GEO satellites for nearly the last two decades, and at present, India is fully compliant with UN and IADC guidelines on post-mission disposal of GEO objects. Efforts have been initiated for post-mission disposal of LEO objects to limit their presence in the LEO region. The restartable upper stages of PSLV for PSLV-C38 and PSLV-C40 missions were de-boosted to bring their perigee around 350 km altitude. Consequently, both the rocket bodies re-entered the atmosphere within 1 year. In 2020, the perigees of two LEO satellites (Cartosat-2 and Microsat-TD) have been de-boosted through a series of manoeuvres to minimise their post-mission lifetime.

6. In line with guideline A5, India maintains a national registry of all the Indian space objects launched and regularly notifies the UN Secretary General about the details of the launched objects. A mechanism has been established through the national space regulator IN-SPACe to obtain relevant information for the registration of space objects of non-governmental Indian entities as well. The required information regarding the details of the objects to be launched is sought from the applicants of non-governmental entities through specific pro forma, and unique registration numbers are assigned for internal bookkeeping.

B) Guidelines on Safety of space operations

1. Based on itsexperience in handling potential conjunction events, India agrees to and supports developing standards for monitoring, maintaining, and sharing information regarding space objects and orbital events and also developing a platform for sharing such information. India has been providing contact details of Indian space objects as part of the registration as suggested by guideline B1. IS^{4}OM acts as the nodal entity for timely coordination and relevant data exchange in response to on-orbit conjunctions. The contact information of operational satellites is made available on the Space-track website (maintained by Combined Space Operations Centre, USSPACECOM). These details are regularly updated to facilitate proper coordination for the safety of spaceflight. In our view, establishing points of contact *a priori* among agencies is found to be helpful to establish the authenticity of the communicator, which enables the safe and expedited exchange of relevant information toward collision risk mitigation. The present mode of inter-operator coordination is primarily through emails, which is likely to be highly inadequate in future as the number of conjunctions is expected to increase significantly with the rapidly growing space object population.
2. Taking cognizance of the fact that Space Situational Awareness (SSA) is now an integral and indispensable part of safe and sustainable space operations, India has undertaken projects to set up observational facilities (radars and optical telescopes) for dedicated tracking and monitoring of space objects. The NETRA (NEtwork for space object TRacking and Analysis) project aims to enhance space object monitoring capabilities and to bring all SSA efforts under a common umbrella for more efficient management and coordination. Under the ambit of NETRA, observational facilities are being set up. Software capabilities are also being established to process the observational data and carry out object identification and cataloguing. Continual efforts are also underway for improving the accuracy of orbit determination, collision probability estimation, orbit propagation, etc.
3. ISRO regularly conducts conjunction assessment and performs collision avoidance manoeuvres for its operational satellites as and when needed. Space Object Proximity Analysis is carried out to identify potential collision threats to operational satellites. The more accurate ephemerides of the secondary bodies, wherever available from the operator, are utilised to improve the accuracy of the analysis. In case of conjunction with another operational satellite, necessary coordination with the concerned operator is carried out to exchange ephemerides and arrive at a commonly accepted strategy to mitigate the risk. This ensures that only one of the satellites undergoes a propulsive manoeuvre to avert the collision. Any manoeuvre plan for maintenance of mission orbit is subjected to conjunction assessment to ensure that post manoeuvre orbit of the satellite is clear from collision threat. Conjunction assessments are carried out to similarly screen all manoeuvre plans for post-mission disposal of LEO and GEO satellites.
4. ISRO carries out pre-launch conjunction assessment for all of its launches. Launch COLlision Avoidance (LCOLA) analysis is carried out for different lift-off timings within the entire launch window to detect any close approach of space objects during the ascent (and descent) phase of the launch vehicle and the initial orbital phase of the payload(s) after the injection.

The analysis is initiated 6 days before the launch and repeated every day with the updated launch vehicle trajectory, space object orbital information, and space weather related inputs. Based on the minimum approach distance from the objects, the zones within the launch window where a lift-off would result in critically close approaches to other objects are marked as blackout periods. The launch is not recommended within these time zones. In case a critically close approach is detected with an operational satellite for a particular lift-off timing, the owner/operator of the spacecraft is notified well in advance, and necessary coordination is undertaken to acquire more accurate operator ephemerides to improve the accuracy of analyses for risk assessment. Apart from LCOLA, exhaustive studies are carried out to design the separation sequence for multiple satellite injections to ensure that the separated bodies are free from any collision risk.

5. India’s experience in implementing guidelines B4 and B5 shows that in the absence of accurate orbital information of other space objects, a wider threshold on close approach distance is necessary to identify the potential close approach threats for a preliminary assessment. The assessment can then be refined with more accurate orbital data of the object under conjunction, wherever available, with a narrower threshold. In the case of conjunction with an active satellite, coordination between the involved parties for sharing and exchange of information, and space situational assessment play a key role in decision making on risk mitigation. Initiating coordination in advance proves to be beneficial, however, the final decision on collision avoidance manoeuvre cannot be taken too much in advance of the conjunction to contain the errors in orbit prediction over a longer duration. On the other hand, collision avoidance should be performed well in advance of the closest approach epoch to allow a second opportunity for manoeuvring in case the first attempt fails due to any unforeseen exigencies. Therefore, the time of performing collision avoidance manoeuvre is a trade-off between operational feasibility and accuracy of risk estimation. The availability of accurate orbital data of manoeuvring satellites governs the fixing of the lift-off time within the launch window. Thus, in practice, the collision-free lift-off timing can be finalised only about a day before the launch and the go/no-go decisions for collision avoidance manoeuvre be made not before 36 hours from the time of closest approach.

6. Regarding guidelines B6 and B7, ISRO is working on developing space weather models and tools from various observational facilities across the country. Space weather events are monitored regularly and spacecraft operations teams are alerted to undertake required measures to mitigate potentially adverse effects. India’s Chandrayaan-2 Orbiter currently operating in lunar orbit carries two instruments capable of aiding space weather studies. Large Area Soft X-ray Spectrometer (CLASS) yields valuable data for a better understanding of space weather around the moon. The X-ray spectral measurements of the Solar X-ray Monitor, XSM, will be useful in improving understanding of the Solar corona and space weather. The Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) in collaboration with Physical Research Laboratory (PRL) has been regularly organising courses on Space Weather for candidates from the Asia Pacific region. The courses focus on the sources of space

weather disturbances originating at the Sun (i.e., solar flares, coronal mass ejections, solar energetic particles), and their potentially disruptive effects on the Near-Earth environment.

7. While small satellites offer an attractive option for new actors to start space ventures, such satellites usually lack manoeuvring capability, as well as unique identifiability and means for tracking. The benefits of implementing guideline B8 by incorporating features for tracking and unique identification to support safe and sustainable operations need to be impressed upon the small satellite operators through suitable awareness-raising mechanisms.

8. Over the years, a number of methodologies have been developed in-house by ISRO to predict the re-entry timing and impact location for a space object undergoing uncontrolled re-entry into the Earth's atmosphere, as suggested by guideline B9. Coordination with other space agencies is also taken up in case of uncontrolled re-entries. Analysis to assess re-entry risks of ground impacts over Indian territory within the re-entry window and issuance of warnings to the concerned authorities are being carried out by IS^{4}OM. ISRO regularly participates in IADC's re-entry campaign as a part of its exercises to hone re-entry prediction skills. Knowledge of structural and mass details of the re-entering objects helps improve the accuracy of predictions.

C) Guidelines on International cooperation, capacity-building and awareness

1. India actively cooperates with various countries towards better implementation of LTS guidelines. India also cooperates with other countries and intergovernmental entities for sharing data on monitoring, detecting, and tracking space objects through appropriate mechanisms.

2. As a member of IADC, IAA Space Debris Working Group, the IAF Space Traffic Management Technical Committee, and ISO Working Group 7, ISRO actively contributes to various activities and studies related to LTS.

3. India has been promoting and supporting space capacity building for developing countries through various programs. The institutes under the Department of Space regularly provide courses regarding spacecraft design, flight dynamics, etc. ISRO has been sharing its experiences, expertise and facilities in the application of space science and technology through the United Nations (UN) affiliated Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP). The centre, in addition to the regular courses, has organised special courses on disaster risk reduction and emergency management for the Asia Pacific region jointly with UN-ESCAP, UN-SPIDER and SAARC Disaster Management Centre. CSSTEAP and Indian Institute of Remote Sensing regularly conduct "Small Satellite Management Course" to support capacity building for the developing nations in the Asia-Pacific region.

4. ISRO has conducted training on Geospatial Technologies for drought, water management and various other remote sensing applications for professionals and students from developing countries. As part of its UNISPACE+50 initiatives, ISRO has been conducting a unique capacity building programme on small satellite realisation named UNNATI (UNispace

Nanosatellite Assembly & Training by ISRO), an 8-week long programme with 4 weeks of hands-on training.

5. As a member of International Charter on Disaster Management Support, India regularly shares satellite data for disaster monitoring, impact assessment, and relief operations. ISRO, as the signatory of International Charter "Space and Major Disasters" and APRSAF initiative Sentinel Asia, supports disaster management activities across the globe by planning, acquiring, and disseminating data from various Indian Remote Sensing Satellites.

D) Guidelines on Scientific and technical research and development

1. ISRO has initiated the development of environment-friendlier technologies for space, such as the usage of green propellants for its launch vehicle and satellite propulsion. ADN (Ammonium Dinitramide) and HAN (Hydroxylammonium Nitrate) based mono-propellants, and Hydrogen Peroxide and Kerosene based bi-propellants are being actively studied and have been ground-tested at subscale engine level.
2. ISRO has been implementing all applicable measures on space debris mitigation such as passivation of launch vehicle upper stages at end-of-mission, monitoring atmospheric re-entry of upper stages, operational collision avoidance, post-mission disposal of GEO satellites followed by passivation, etc. Specific initiatives have been undertaken to improve compliance with the UN-COPOUS guideline on post-mission disposal for LEO satellites. Some cases of India's experiences in implementing guidelines D2 are reported as follows. At the end-of-mission, Cartosat-2 satellite was de-orbited through a series of 31 manoeuvres to reduce its perigee from 630 km to 380 km. Consequently, its post-mission orbital life, which would have been more than 30 years without de-orbiting, has been reduced to less than 5 years. Another LEO satellite, Microsat-1 was also de-orbited to minimise its post-mission lifetime, the left-over fuel was depleted to minimise accidental break-up risk. After de-orbiting, the achieved orbit was 236×250 km and the satellite re-entered the atmosphere within the next 10 days.
3. Improvements are currently underway for ISRO's in-house developed simulation tools to evaluate the long-term evolution of the space debris environment. Spacecraft shielding related studies and development are under progress in ISRO to improve the protection against micrometeoroid impact risk for the upcoming missions. India will continue the pursuit of devising new procedures and techniques to contain the space debris population.

(c) Raising Awareness and Building Capacity

India is keen to participate in the capacity building initiatives for LTS organised by other spacefaring nations. India is also willing to explore the opportunity of sharing its expertise through bilateral/multilateral mechanisms with other nations aspiring to enter the space arena.