Interagency Operations Advisory Group

Space Operations Sustainability (SOS) Working Group

A Subcommittee Under the Interagency Operations Advisory Group

Issue B

Ref.:
Date: May 25, 2022

Membership of the Interagency Operations Advisory Group (IOAG) Space Operations Sustainability Working Group (SOS WG)

Co-chairmen:

European Space Agency (ESA)	–	Klaus Merz
Centre National d'Etudes Spatiales (CNES)	–	Jean-Marc Soula
Agenzia Spaziale Italiana (ASI)	–	Fabio D'Amico

Members:

Australian Space Agency (ASA)	–	Marie Le Pellec
	–	Martin Nussio
Canadian Space Agency (CSA)	–	Viqar Abbasi
	–	Babiker Fathelrahman
Centre National d'Etudes Spatiales (CNES)	–	Hubert Fraysse
Deutsches Zentrum für Luft- und Raumfahrt (DLR)	–	Sebastian Löw
Japan Aerospace Exploration Agency (JAXA)	–	Shinichi Nakamura
Korea Aerospace Research Institute (KARI)	–	Okchul Jung
National Aeronautics and Space Administration (NASA)	–	William Horne
	–	Danford Smith
Indian Space Research Organisation (ISRO)	–	A R Srinivas

Participants:

Japan Aerospace Exploration Agency (JAXA)	–	Tsutomu Shigeta
Canadian Space Agency (CSA)	–	Marc Sauvageau
	–	Peter Kazakoff

Table of Contents:

List of Acronyms

API	Advance Publication Information
CCSDS	Consultative Committee for Space Data Systems
CDM	Conjunction Data Message
COLA	Collision Avoidance
DISCOS	Database and Information System Characterising Objects in Space
EESS	Earth Exploration Satellite Service
GNSS	Global Navigation Satellite System
IADC	Inter-Agency Space Debris Coordination Committee
IOAG	Interagency Operations Advisory Group
IOP	Interoperability Plenary

ISO	International Standards Organization
ISS	International Space Station
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
LEO	Low Earth Orbit
NEO	Near Earth Object
RB	Radiocommunication Bureau
RFI	Radio Frequency Interference
RR	Radio Regulations
RRB	Radio Regulations Board
SDM	Short-Duration Mission
SFCG	Space Frequency Coordination Group
SO	Space Operation (service)
SOS WG	Space Operations Sustainability Working Group
SRS	Space Research Service

1. INTRODUCTION

1.1. PURPOSE

The Interagency Operations Advisory Group (IOAG) established the Space Operations Sustainability Working Group (SOS WG) because its member Space Agencies were sharing the same concerns on the evolution of the operations in Space:

- There is a rapid increase in the population of operational satellites, in particular on the non-institutional side, with new types of operations (cubesats, constellations, maneuvering satellites, …), and
- There is a growing population of debris in Space and the catalogues will contain smaller and smaller debris, and
- There is a need to assess the new risks on the operations conducted in Space (including collisions, spectrum, space weather, proximity operations, etc) and to evaluate if the existing processes and coordination are sufficient to deal with these new paradigms.

In a meeting of the governing body of the IOAG, the Interoperability Plenary (IOP-4), held in Oberpfaffenhofen, Germany on 18~20 December 2018, the IOP delegates recommended that the IOAG:

a. evaluates the relevant issues and potential threats related to sustainable space operations and its implications for space traffic management initially in the vicinity of the Earth.
b. deals with the technical and operational perspective.
c. produces a situational report including recommendations on mitigation measures.

The IOAG has therefore formed the Space Operations Sustainability Working Group (SOS WG), with this Charter.

Therefore, the SOS WG is to respond to actions that have been received from the IOAG in the technical and operational domain of Sustainability of Operations in Space in order to produce a report that will include recommendations on possible improvements and on the potential future role of the IOAG.

It is reminded that the IOAG is not a regulatory body and that this report, including its findings and recommendations, remains non-binding and subject to decisions by individual agencies and nations. The decision on how to convey the SOS WG recommendations/requests, as will be endorsed by the IOAG, to external international organizations, is left to the IOAG who may decide to use formal interfaces, to rely on the Agencies representatives in such organizations or to use liaison interfaces, as will be found most appropriate.

1.2. MOTIVATION

The objective of the SOS WG is to analyze the situation of how operations are conducted in Space and the trends related to the new users and the new usages of Space, to:

- Verify the understanding of what the new or increasing risks are to be taken into account in various domains of the operations in Space (disposal operations, collision avoidance, maneuver coordination, space weather, re-entries, spectrum, interferences, in orbit servicing, proximity operations, etc...);
- Identify the international organizations that already address at least part of these challenges;
- Analyze what they adequately cover or what could be improved;
- Formulate recommendations/requests for endorsement by the IOAG, that could be addressed to
  - such identified organizations, or
  - standardization organizations, as required, or
  - the IOAG itself who could adopt and promote messages in Space Operations fora;
- Propose what role the IOAG could play in the future with respect to the SOS issues.

The SOS WG may coordinate activities addressing those risks with other international organizations such as the IADC, the SFCG or the ITU, or any other relevant community.

1.3. STUDY SCOPE AND METHODOLOGY

To meet the objectives assigned by the IOAG, the SOS WG has elected to initiate a study on each of the following domains of concern:

- Space Debris and Collision avoidance
- End of life activities
- Spectrum and interferences
- Space Weather
- Proximity operations, in-orbit services (TBC/TBD)

For each domain, new and growing risks to the sustainability of Space Operations were identified by the WG. These risks require measures to be taken by corresponding national and international entities. Such entities were identified and specific recommendations were directed to them by the WG. Before issuing the final report, these recommendations were discussed and improved upon with domain-specific experts. The experts were either members of the IOAG Agencies or of other international organizations.

As the domains explored by the SOS WG cover a wide range of expertise, they could not be addressed and completed in the same time frame. It was then agreed that the report would be incremental and some domains would be included later. Any version available on the public website of the IOAG, even if only completed for only a few of the domains, is assumed to be approved by the SOS WG Members and endorsed by the IOAG.

The recommendations contained in this study often increase in usefulness and value as more organizations chose to implement them. Although this report has been developed by multiple civilian Space Agencies, many of the concepts apply to all space asset organizations, including:

- Civilian Space Agencies
- Government military space organizations
- Commercial satellite organizations
- Independent research and club satellite organizations
- Academia – including University and even High School satellite developers
- Launch operators

Catalogs or registries of orbiting objects, for example, are only as valuable as the collection of information available from the missions (although many objects can be independently identified).

Awareness across the broad satellite community, and not only within government space organizations, is essential for the sustainability of operations in Space and this idea drives the formulation of the study recommendations. Whereas the SOS WG considers it is beneficial to achieve adherence to the outlined recommendations by as many operators as possible it is essential that future policies, plans, and procedures take into account the variety of satellite organization types and ability to comply.

1.4. REPORT STRUCTURE

Each of the following sections provides, for each of the domains, the findings of the working group in the analysis of the risks and the recommendations formulated by the SOS WG and directed to the various actors of the domain. There is no priority order in the presentation of findings and recommendations below; they are just listed in the order they were collected. The same recommendations are presented per actor, in Annex A to the present report, for every domain.

Then, the report shows an analysis on the standards already in place to help mitigate the risks and issues identified in the domain related to Space Debris. The objective of this analysis was to identify the specific needs for improvements or the missing standards. Annex B to the present report provides the list of the standards that were considered in this analysis.

Finally, concerning the domain of Spectrum and Interferences, the report provides a snapshot of the relevant recommendations and resolutions of the ITU and SFCG, either in force or at work in their respective organizations, as they were at the time of establishment of the present report. Annex C to the present report

provides the list of these recommendations and resolutions and their relevance with respect to the findings in section 4.

2. DOMAIN OF SPACE DEBRIS AND COLLISION AVOIDANCE (COLA)

The WG has expressed concerns with respect to the proliferation of Space Debris and the need to perform more frequent collision avoidance maneuvers. This section summarizes participants' findings and recommendations with regard to these concerns.

Finding 1. Proliferation
Proliferation of Space Debris can be associated with the increase of players in space: risks of collisions increase due to the increase of the numbers of objects in the near-Earth environment. Due to the short term vision of some new comers (e.g. short term benefit; short lifetime), due to their small investments (e.g.: no propulsion; low reliability) and their lack of experience or of awareness such new comers may contribute to the proliferation of Space Debris and an increased need of avoidance maneuvers in a disproportionate way.

General statement
The IOAG/SOS WG adheres to the IADC guidelines and to the ISO standards, and invites all satellite operators to comply with them.
However, the IOAG/SOS WG recognizes improvements are needed to streamline the utilization of Space and the practices of the new operators in Space

Finding 2. Harmonization of risk assessment methods and manoeuver decisions

As much smaller debris will be detected, together with the increase of non-maneuverable satellites, there is a good chance that the number of collision avoidance maneuvers will increase and may reduce the mission operational lifetime for any satellites in general as well for the most expensive satellites.
In this context it becomes more urgent to harmonize and define common approaches
- on the input data used to forecast the level of the risk; Providers with known data quality and employing standard formats are to be sought i.e. CDM from the U.S. Space Force's 18th Space Defense Squadron (18 SDS) (not TLE), EUSST, data base DISCOS
- on the calculation methods (algorithm; probability)
- on the minimum alert and decision thresholds (lethal risks and object size; probability threshold; specifics for manned flights; decision timeline)

Moreover, as the database volumes will become huge, the catalogue size will be more difficult to maintain and there should be more analysis on some specific questions such as:
- should the catalogue be centralized to avoid divergence between catalogues?
- should methods be developed to fuse data from different catalogues?
- which data types/formats need be harmonized / standardized across catalogue output products?

Recommendation to maintainers of catalogues

The IOAG/SOS WG recommends that the catalogues
- be easily available for access of products by entities supporting COLA operations
- use standardized product formats to distribute conjunction information
- provide auxiliary information supporting avoidance maneuver decisions (e.g. expected time of next update, object size estimates)

Recommendation to operators of satellites

The IOAG/SOS WG recommends that operators start sharing the full details as much as possible
- on the calculation methods (algorithm; configuration parameters; probability) allowing mutual cross-verification,
- on the minimum alert and decision criteria and thresholds (lethal/environmental risks and object size; probability threshold; specifics for manned flights; decision timeline)

Recommendation to national and international regulators

The IOAG/SOS WG recommends that national and international regulators standardize, harmonize and define common approaches, as soon as possible
- on the calculation methods (algorithm; configuration parameters; probability)
allowing mutual cross-verification,
- on the minimum decision criteria and thresholds (lethal/environmental risks and object size; probability threshold; specifics for manned flights; decision timeline)

Finding 3. Best practices / regulations on utilization of Space

Poor reliability and non-maneuverability of satellites increase the risks of collisions in some special orbit regimes of particularly high value; this applies e.g. to the orbits of manned missions (e.g.: ISS), of large-constellations (intra and extra constellation), of sun-synchronous orbits for Earth Observation or to the Geo Arc. Moreover, the cubesats and smallsats are often launched as rideshare co-passengers with bigger satellites with which they may share the same orbit regimes for very long durations. Multiple non-maneuverable smallsats may also share the same orbit while they cannot perform any manoeuver to avoid collisions among themselves, increasing the risk for a collision reaction chain.
Authorizations for launch of such satellites should include a number of criteria so as to protect the high value orbits and to mitigate the risks on any orbit regime.
Depending on the satellite and the target orbit, such pre-launch criteria could include:
- reliability requirements satisfied or not
- mandatory propulsion system to avoid orbital collision.
- orbit sharing (short / long term) forbidden with identified co-passengers (big ones or non-maneuverable ones)
- use of a qualified Conjunction Analysis (CA) service (can be internal or external to operator and possibly include avoidance maneuver recommendation) and COLA process validation.
Satellites failing to meet such criteria should only be authorized to use certain orbits (e.g. below 400 km if no propulsion) far from the highest value orbits (e.g. ISS or other ones to be identified).

<u>Recommendation to research, academia, IADC</u>

The IOAG/SOS WG recommends that studies are conducted and best practices elaborated to identify the “highest value orbits” and the ways to protect them, e.g. by developing methods allowing to assess the risks added by a planned spacecraft to the sustainable use of these orbits and deriving criteria or thresholds on the risk of collision and its consequences.
This may also result in new avoidance decision criteria and thresholds for avoidance maneuvers, e.g. related to potential fragment cloud sizes and lifetimes.

Note: Special focus should be given to the potential increase of human spaceflight activities in LEO and its consequences on collision avoidance needs. Research should investigate whether the typically stricter criteria on collision avoidance maneuver thresholds may require dedicated protection measures, such as protected orbital regimes (sub-regime within LEO) in which unmanned spacecraft have to satisfy special requirements.

<u>Recommendation to national and international regulators</u>

The IOAG/SOS WG recommends that authorizations for launch address a number of criteria so as to protect the high value orbits and to mitigate the risks on any orbit regime. This could include:
- reliability requirements satisfied,
- compulsory propulsion system to avoid orbital collisions
- orbit sharing (short / long term) forbidden with identified co-passengers (big ones or non-maneuverable ones)
- use of a qualified “COLA service” (can be internal or external to operator) and have some sort of validation of the COLA process.
Where it is not possible to meet such criteria, regulators should consider only authorising satellites to use certain orbits (e.g. below 400 km if no propulsion) far from the highest value orbits (e. g. ISS or other ones to be identified) or orbits for which their risk impact is acceptable.

Finding 4. Uncontrolled satellites after bankruptcy of operators
Following bankruptcy or transfer of ownership of a satellite operator company, there is a risk that some satellite systems remain unattended and uncontrolled. Such cases should be addressed, through international agreements as well as corresponding national rules, so that there is always an obligation of continuity of control, even if there is no continuity of mission for such satellite systems, to be ensured

somehow (e.g.: insurance, initial deposit, state guarantee…). Obligation of active debris removal could also be considered at least for satellites with long orbital lifetime.

Recommendation to national and international regulators

The IOAG/SOS WG recommends that regulations address the issue of continuity of control (not necessarily the mission) including the final disposal, so that it is ensured by insurance, initial deposit, state guarantee or the like, in particular to cope with the cases after bankruptcy of operators or transfer of ownership of a satellite operator company.

Finding 5. Information sharing between operators and catalogue maintainers on planned manoeuvers

The organizations maintaining catalogues of objects and their orbit may have difficulty predicting and confirming close approaches for the maneuvering satellites, as there may be orbit changes after the last known orbit bulletin.
A coordination, between satellite operators with the surveillance systems operators, on orbit control and candidate avoidance maneuver plans should be added to an improved coordination on orbit parameter exchanges, to mitigate the risk of receiving conjunction assessments based on invalid data.

An increasing number of spacecraft are visible from ground by astronomical telescopes which poses the danger of rendering images from such observations useless and potentially putting whole research programs at risk. Initial research on understanding the extend of the problem and potential mitigation measures have started. Operators may ease the problem via sharing trajectory data and/or taking measures limiting brightness.

Recommendation to operators of satellites

The IOAG/SOS WG recommends that a coordination, between satellite operators and the surveillance systems operators, on orbit control as well as candidate avoidance maneuvers, be added to an improved coordination on orbit parameter exchanges, both in the planning stage as well as after maneuver execution (or cancellation), so as to mitigate the risk of receiving conjunction assessments based on invalid data. This shall be assisted by contact information database(s) and standardized data exchange mechanisms.
Operators of bright and/or many spacecraft are recommended to share predicted trajectories with telescope operators and investigate and employ feasible operation modes limiting brightness and request designs for small brightness from their manufacturers.

Recommendation to maintainers of catalogues

The IOAG/SOS WG recommends that the maintainers of catalogues include in their close approach assessment process up to date information received from the operators of satellites using standardized data exchange mechanisms allowing an improved coordination via orbit parameter exchanges, on orbit control as well as candidate avoidance maneuvers (pre-maneuver plans and post-maneuver result).

Recommendation to Space Agencies

The IOAG/SOS WG recommends that Space Agencies promote the need for an improved exchange of orbit and maneuver information and jointly play an active role in defining and facilitating such exchanges. This could extend to other communities, e.g. astronomers, and address related data sharing policies.

Finding 6. Need to educate the new operators
New Space operators and other new comers need to be educated to further improve their awareness of the risks as well as their knowledge on their obligations and of the possible mitigation measures. This might be addressed by offering dedicated conferences or including such topics in key existing conferences targeting space operators.

Recommendation to national and international regulators

The IOAG/SOS WG recommends that national and international regulators be more active in educating New Space operators and other newcomers on their obligations and of the possible mitigation measures.

Recommendation to Space Agencies

The IOAG/SOS WG recommends that Space Agencies support their national regulators and be active in educating New Space operators and other newcomers on operational aspects and techniques of collision avoidance.

Findings 7. Satellite design related to maneuver capabilities
Satellite designers should be prepared to embark enough fuel to cope with an increasing number of COLA maneuvers (also see End of Life for fuel budget).

Satellite designers may need to plan for continuity of the mission payload operations during the collision avoidance maneuvers.

Recommendation to satellite designers

The IOAG/SOS WG recommends that satellite designers include enough fuel to cope with an increasing number of COLA maneuvers.

Recommendation to satellite designers

The IOAG/SOS WG recommends that wherever needed and practical satellite designers plan for continuity of the mission payload operations during the execution of collision avoidance maneuvers.

Findings 8. Satellites frequently changing orbit

Certain categories of frequently orbit changing satellites can generate orbit prediction uncertainty and cause a risk of inaccurate conjunction alerts or of unidentified conjunctions. There is an additional need for coordination with other satellites sharing orbits in their vicinity, both to inform of their short term predictions, possibly including models, and to be updated on the other satellites accurate data.
This applies, among others, to satellites with:
- low-thrust propulsion
- electric propulsion
- autonomous orbit control
- proximity operations
- end of life operations

Recommendation to operators of satellites

The IOAG/SOS WG recommends that the operators of satellites changing orbit frequently (e.g. low-thrust propulsion; electric propulsion; autonomous orbit control; proximity operations) provide the maintainers of catalogues with propagation models, near term predictions (e.g. ephemeris data) and / or real time information, so as to mitigate the risk of inaccurate conjunction alerts or of unidentified conjunctions.

Recommendation to maintainers of catalogues

For satellites changing orbit frequently (e.g. low-thrust propulsion; electric propulsion; autonomous orbit control; proximity operations), the IOAG/SOS WG recommends that the maintainers of catalogues adapt their trajectory and uncertainty predictions to take into account up to date information received from the operators of satellites.

Findings 9. Launches with multiple satellites

For multiple satellite launches, if the concept of operations relies on the availability of catalogue data (e.g. for ground station pointing), there is a risk of mission loss if the newly launched spacecraft cannot be identified by a surveillance system.
To assist the cataloguing process, more appropriate and novel satellite identification methods are an active area of research.

Recommendation to launch service providers

The IOAG/SOS WG recommends that, in the case of launches with multiple satellites, the separation sequence and the trajectory plans are properly designed and communicated in advance to the surveillance

service providers to enable identification and tracking of each object shortly after separation. This is necessary to assist the cataloguing process.

Recommendation to satellite designers

The IOAG/SOS WG recommends that, in the case of launches with multiple satellites, satellite designers implement devices to overcome the difficulty of object identification and help mitigate the risk of collision at launch. Such devices should be designed to also ease the tracking of small satellites during routine operations. Examples could be beacons, passive or active optical markers (such as patterns of stickers, reflectors or LEDs) or transmission of satellite identifiers or onboard-GNSS solutions.

Note: This may also be relevant in case the concept of operations relies on the availability of catalogue data e.g. for ground station pointing.

3. DOMAIN OF END OF LIFE ACTIVITIES

When missions get close to their end, insufficient preparation of their end of life operations increase risks for fragmentation, collision and debris creation. This section summarizes participants' findings and recommendations with regard to these concerns.

Findings 1: Proliferation

Introduction of the domain: risks increase due to the growing population of satellites with insufficient preparation of their end of life operations. Guidelines and regulations in this respect exist while they may still be further developed. Whether existing or new, a key aspect is for all of them to be applied by all users of Space.

General statement

The IOAG/SOS WG adheres to the IADC guidelines and the statement on Large Constellations of Satellites in Low Earth Orbit and to the ISO standard 24113. The WG invites all satellite operators to comply with them.

Recommendation to IADC:

The IOAG/SOS WG recommends that the IADC establishes a top-level reporting on the status of the guidelines and reporting on their implementation globally where possible.

Recommendation to satellite operators:

The IOAG/SOS WG recommends that the end of life operations be prepared and resources be planned from the design phase, to be able to adopt and comply with the latest IADC guidelines and ISO standards on matters such as lifetime in Space, graveyard orbits, risks of casualties or reliability of disposal operations.

Finding 2: Application of the 25 years end of life rule in LEO

These guidelines could be improved by identifying when reducing further the lifetime should be recommended. They could also take into account the status of the satellite at the time of end of life operations. Definitions and calculation methods may also need to be clarified.

Recommendation to IADC:

The IOAG/SOS WG fully supports the existing guidelines. The IOAG/SOS WG recommends that studies are conducted to develop specific guidelines on the conditions when the rule should ask for less than 25 years lifetime for LEO satellites and for more than the 90% successful disposal objective. For instance, consideration could be given to:

- differentiate how the 25 years should be counted (e.g.: ISO:24113:2019 counts from injection if not maneuverable)
- relate allowed decay time to duration of active mission
- relate allowed decay time to the consequence on the orbital environment of an unsuccessful disposal of the satellite (long and short term)
- revisit the required probability of successful disposal accordingly

- take into account the reliability and tolerance conditions for ageing missions and their hardware capabilities

Recommendation to ISO:

The IOAG/SOS WG recommends that standard ISO 27852 on the orbit lifetime estimation be improved to better specify how to compute the estimated lifetime and the associated uncertainty (e.g. varying drag area for tumbling spacecraft), and to provide criteria to validate the tools for the lifetime estimation.

Finding 3: Selection of disposal orbits

It is not always clear, in particular for new comers or for old satellites in LEO, in which conditions are the disposal operations safer for other satellites, for instance if elliptical orbit (lower perigee) or if circular orbit should be used. The best approach may be hardware or capability dependent (e.g. sensors at very low altitude). Experience is available from many different Agencies / Operators and lessons learned could now be formulated into guidelines.

Recommendation to Space Agencies:

The IOAG/SOS WG recommends Space Agencies share past experiences and developing specific guidelines on the best practices on disposal operations for different spacecraft configurations and capabilities. Workshops or conferences should be used to identify which best practices could be established as new standards.

Finding 4: Satellite status information

There is a need to establish and maintain a data base with the status of the known satellites, including dead or active, maneuverable or not, … as well as some characteristics (e.g. radius). There are attempts to make such information available, but wherever available (e.g. Space-Track, DISCOS) this information is not kept up to date by many operators.

Recommendation to Space Agencies

The IOAG/SOS WG recommends that Space Agencies promote the need for a data base to be established and maintained for sharing more effectively the status of satellites, especially, after a failure or their end of life operation.

Recommendation to satellite operators:

The IOAG/SOS WG recommends that each satellite owner input data into a data base of satellite status, to share more effectively whether satellites are maneuverable or passivated, especially, after end of life operation. This should be done as soon as there is a known change of the status of the satellite.

Finding 5: Application of the 2019 ISO standard 24113

It has been observed that a number of missions have experienced failures during extended life phase with no possibility of executing their EOL disposal plans. The third edition of the ISO standard 24113 published in 2019 requires a non-conditional probability of successful disposal greater than 0.9 by design in terms of reliability of the subsystems needed for disposal.
It also requires the assessment of the risk that a space debris impact will prevent a spacecraft from being disposed of.

Recommendation to satellite operators:

The IOAG/SOS WG recommends that the satellite operators continuously monitor, during the operation phase, the probability of successful disposal, for continued compliance and that corrective actions are applied if degradation is observed.

Recommendation to satellite operators:

The IOAG/SOS WG recommends that the satellite operators, during mission lifetime, continuously conduct the assessment of the risk of a space debris impact on the execution of disposal operations, to avoid compromising the success of the disposal.

Recommendation to national and international regulators:

The IOAG/SOS WG recommends that national and international regulators require license for mission extension demonstrating required Post Mission Disposal success.

Finding 6: Launcher bodies, risks of collision and re-entries

It is not clear if the good practices recommended by IADC are well applied by new / emerging launcher organizations.

Recommendation to satellite operators:
The IOAG/SOS WG recommends that the satellite operators encourage the new / emerging launch operators to comply with internationally recognised guidelines and standards applying to launchers from their launch to their re-entry operations.

Recommendation to national and international regulators:
The IOAG/SOS WG recommends that regulators request the new / emerging launch operators to comply with internationally recognised guidelines and standards applying to launchers from their launch to their re-entry operations.

4. DOMAIN OF SPECTRUM AND INTERFERENCES

Increasing difficulties in sharing the spectrum and in avoiding Radio Frequency Interferences (RFI) have been identified, in the frequency bands used for Space Operation (SOS), Space Research (SRS) and Earth Exploration Satellite (EESS) services. This section summarizes participants' findings and recommendations with regard to these concerns.

Finding 1. Reporting on environment of radio frequency interference to SOS/SRS/EESS communication services

The growing number of space stations increases the potential for radio frequency interferences and the need for frequency coordination. However, the current coordination is sometimes based on rather simple models and geometric constraints while at the same time there is a lack of actual data on past occurrences of interferences which would potentially allow to establish more stringent constraints under which interferences may occur for SOS/SRS/EESS communication services.

The Resolution SFCG A36-2R1 asks SFCG members to report on RFI cases for passive sensors. Similarly, it is useful that the Space Agencies report and collect information on actual interference events (frequency band, geometry, antenna characteristics and frequency of occurrence) for conducting above researches, calibrating the refined models with the reported data and extrapolating to a future with the increased traffic. Further, a report of these findings should be published for usage by other entities including commercial tracking service operators.

Recommendation to SFCG:

The IOAG/SOS WG recommends SFCG to consider establishing a resolution similar to the Resolution SFCG A36-2R1 for encouraging SFCG members to report to the SFCG meeting instances of harmful interference to the SOS/SRS/EESS communication services and to recommend realistic models which should be used to assess the conditions under which interferences happen.

Finding 2. Filing of satellites at the ITU-R

Commercial operators of non-geostationary satellite systems, in particular in the case of constellations, do not systematically follow the basic principle of using the frequency resource as efficiently as possible. Their initial filing (API) often doesn't contain detailed and accurate information on frequency bands, orbit

parameters, location of ground stations, etc. In many cases, the whole of the frequency allocation is reserved.

As a result, other administrations have no means to perform meaningful study on the potential impact on existing or future satellites that their operators may have. Administrations may issue comments, but after a time, the filing will be considered approved and, as a result, will have precedence over other satellite systems that will be filed at later dates. The planned target orbit, the exact frequencies or the ground segment are provided at the time of notification. That is, only at the time of notification, issues with pre-existing systems may be discovered, which would make the coordination difficult at a late stage of the new system implementation.
Providing details long in advance to the launch can be challenging. However, seeking precedence at the time of the API filing should not be at the expense of providing the necessary detailed information.

The ITU-R WP7B is currently addressing the issue and is developing recommendations for S-band (SOS/SRS/EESS) so that the National Frequency Administrations may improve the practices and therefore the filing declaration manner (Refer to Annex C for recommendations being developed). In particular, submitting a filing with generic parameters should be discouraged and provision of details on actual frequency bandwidth, station locations and other technical parameters should be requested for initial compatibility assessment.

Recommendation to Space Agencies;

The IOAG/SOS WG recommends that the Space Agencies approach their National Frequency Administrations to facilitate the initiative of the ITU-R WP7B in improving the filing process and the details to be provided for new satellite systems in all frequency bands. The IOAG/SOS WG recommends to include constellations in such ITU-R recommendation.

Recommendation to satellite operators:

The IOAG/SOS WG recommends that the satellite operators provide the necessary set of parameters (orbit, actual center frequency, actual frequency bandwidth, ground station locations…) in the filing of their satellite(s) from the API stage, to allow the proper evaluation of the risks of interference, at early stage, with other satellite systems.

Recommendation to national and international regulators:

The IOAG/SOS WG recommends that the national and international regulators add to the criteria to get the authorizations for launch, a necessary set of conditions relative to the declaration of satellite systems at the ITU-R, in particular to make sure sufficient information is available, long in advance to the launch(es), to enable a proper coordination with other satellite systems.

Finding 3. Protection of the S-Band

The SOS/SRS/EESS S-Band needs to be protected as it is a unique asset used by all the members of IOAG and a large part of the space community. Recognizing that the utilization of the frequency band is increasing for uplink and downlink of multiple missions, the risk of interference is growing and mitigation techniques are required.

For instance, mitigation techniques to be considered include:
- reducing further the allowed bandwidth to avoid the band is used extensively for mission data,
- making the usage of limited bandwidth for housekeeping data become the rule again,
- establishing a reasonable ground station antenna size and recommending the minimum EIRP,
- using multiple frequencies per satellite to allow hopping,
- using CDMA spread spectrum,
- using higher level protocols to secure retransmission of the lost frames (e.g. CCSDS COP-1; DTN),

On the ground, the cases of high or low latitude stations, small or large dishes, multi band antennas, collocated antennas should be taken into account. Onboard the satellites, among other aspects, the antenna patterns should also be considered.

The ITU-R WP7B and SFCG have already a set of recommendations and resolutions in place, to define limitations and to mitigate the risks of interferences in the S-Band (Refer to ANNEX C for relevant Recommendations/Resolutions).

Further, the SFCG is currently discussing the issue of using small dishes and will study further the conditions to use small antenna dishes for uplink and may define if a hard limit on minimum antenna diameter should be recommended.

These issues need be addressed globally, at system and network level, considering the contributions of ground and space systems to the risks of interferences on the uplink and downlink. They must be formulated so that they are applicable to commercial operators as well.

The ITU-R WP7B is in the process of developing recommendations on better sharing of the spectrum (e.g. bandwidth limitation, CDMA Spread Spectrum…). While the issue of small dishes is not elaborated in the draft recommendations, strict conditions are developed.

Recommendation to SFCG:

The IOAG/SOS WG recommends that the SFCG continues to recommend techniques for the efficient usage of the SOS/SRS/EESS S-Band so as to mitigate the risks of interferences in that Band, both for uplink and downlink, and which corresponding recommendations should be put urgently in place to address the growing demand from new operators. This should be addressed at system level and must consider the latitude of the stations and the type of antennas, in particular if combined with X-Band or Ka-Band (26 GHz).

Recommendation to Space Agencies:

The IOAG/SOS WG recommends that Space Agencies approach their National Frequency Administrations to facilitate the initiative of the ITU-R WP7B to develop S-Band recommendations and adopt the techniques that best guarantee long term sustainability for both uplink and downlink.

Recommendation to satellites designers:

The IOAG/SOS WG recommends that the satellite designers adopt the recommended techniques that allow to mitigate the risks of interferences in the SOS/SRS/EESS S-Band, and in particular to limit the usage of wide antenna beams on the satellite Tx antenna (e.g. isoflux antennas) to special phases of the mission such as LEOP or Emergency, to the extent it is practical.

Recommendation to satellite operators:

The IOAG/SOS WG recommends that the satellites operators adopt the techniques recommended by the ITU WP7B that allow to mitigate the risks of interferences in the SOS/EESS/SRS S-Band at system level, and to limit the usage of the band for housekeeping data and use those techniques that make the links less sensitive to short interferences.

Recommendation to the national and international regulators:

The IOAG/SOS WG recommends that the national and international regulators add to the criteria to get the authorizations for launch, a necessary set of conditions relative to the efficient usage of the SOS/SRS/EESS S-Band and the application of RFI mitigation techniques. Such criteria could be elaborated with the National Frequency Administrations and be made consistent with ITU-R recommendations.

Finding 4. Protection of the 8 GHz Band

The use of this frequency band by EESS operated by various Space Agencies and commercial entities for data downlink operations, as well as by other terrestrial services, has been increasing and could result in harmful interference among these operators. Potential difficulties in sharing the heavily used 8 GHz spectrum may be avoided if EESS satellite designers and operators could apply suitable mitigation methods provided in ITU-R and SFCG Recommendations (Refer to Annex C for relevant Recommendations).

Recommendation to satellite designers and operators:

The IOAG/SOS WG recommends that the satellites designers and operators comply with the recommendations of the ITU-R and SFCG for the protection of the 8.025 to 8.4 GHz frequency band.

Finding 5. Protection of the 26 GHz Band

Future EESS/SRS and space research missions will rely on the 26 GHz band to downlink their data. A regulatory framework is needed worldwide to safeguard these missions. The possible coexistence of International Mobile Telecommunications (IMT), which will operate in the newly allocated 26 GHz-band, may generate aggregate interferences in EESS/SRS Earth stations. The ITU has published the ITU-R Recommendation SA.2142 to provide necessary coordination area for the EESS/SRS receiving Earth stations in the 26 GHz band. (Refer to Annex C for relevant ITU-R/SFCG Recommendations)
Adopting such a recommendation on national and international level would be helpful.

Recommendation to Space Agencies:

The IOAG/SOS WG recommends that the Space Agencies approach their National Frequency Administrations to facilitate the adoption of the ITU-R Recommendation SA.2142 for ensuring the protected use of existing and planned EESS/SRS receiving Earth stations and for future deployment of Earth stations in the 26 GHz band.

Recommendation to the national and international regulators:

National Frequency Administrations should support regulatory measures in their respective jurisdiction, to ensure the protected use of existing and planned EESS/SRS receiving Earth stations and for future deployment of Earth stations in the 26 GHz band.

Finding 6. Increasing difficulties of frequency coordination and avoidance of interferences

The increase in the number of (planned) active satellites (e.g. SmallSats and constellations) that use EESS/SRS/SOS radio frequency increases the risk of interference and thus necessitates an increased need for coordination. Beyond this increase, avoiding interferences is complicated by

- New operators often lack the knowledge and manpower on the ITU-R process and the RR, and the knowledge of mandatory procedures like frequency management is often insufficient.
- NGSO satellite systems with short duration missions (SDM) and not subject to coordination may make the resolution of potential conflict difficult. The notifying administrations may have problems to provide accurate orbital characteristics at the beginning of the development cycle and, in some instances, not even prior to the launch of the satellites. (Resolution 32 (WRC-19))
  Note: Resolution 32 (WRC-19) does not relief SDM from the requirements of the RR Articles 9 and 11
  Note: Resolution 32 (WRC-19) prevents SDM from extending the mission beyond the original 3 years or replacing such SDM, or applying the suspension provision in the RR. While the WG is not aware of an actual case where an SDM has been extended beyond 3 years, future violations could lead to longer lasting missions without proper coordination in place.
- A space station is required to ensure immediate cessation of its radio emissions by telecommand, per RR 22.1, however, it is not clear how the BR could enforce this requirement.
  Note: This is a concern mainly for interferences in the GEO regime as in LEO interferences typically occur for very short durations and at non-systematic times only.

Recommendation to Space Agencies

The IOAG/SOS WG recommends that Space Agencies approach their National Frequency Administrations to provide operators, which often lack the knowledge and manpower on the ITU-R process and the RR, with guidance/advice for them gaining sufficient knowledge of the ITU-R mandatory procedures for frequency management and coordination.

Recommendation to Space Agencies

The IOAG/SOS WG further recommends that Space Agencies approach their National Frequency Administrations to work towards ITU-R to establish

- a requirement on to-be-operators of SDM and constellations to share immediately technical and operational information of their network/system with the ITU-R in order to be easily accessible by concerned administrations/operators and a mechanism in place in the Radiocommunication Bureau (RB) so that the ITU-R via its RB could intervene quickly to resolve a case of a complaint effectively,
- a requirement for SDM that the period of comments to SDMs filings should be reduced in order to have a quicker processing period,
- a mechanism for an implementation of RR 22.1 which require space stations to ensure immediate cessation of its radio emissions by telecommand, in case of harmful inference being occurring or predicted during a long or repetitive time span.

Recommendation to national and international regulators

The IOAG/SOS WG recommends that national and international regulators be more active in educating new operators and other newcomers on their ITU-R obligations and mandatory procedures for frequency management and coordination.

Recommendation to national and international regulators

The IOAG/SOS WG recommends that national and international regulators establish, apply and enforce rules preventing missions previously registered as SDMs from extending their mission beyond 3 years.

Finding 7. Coordination on the downlink times

The increase in number of EESS spacecraft, combined with an increase in mission payload data volume (per SC) lead to an increase of the risk of interference which may not be possible to avoid on mission ground segment design level (e.g. by selecting ground stations never visible simultaneously from spacecraft having potential of causing interference).

As a means of avoiding interference in actual or potential operations, the SFCG Recommendation SFCG REC 12-4R3 recommends that Space Agencies be prepared to temporarily switch off emissions from the spacecraft concerned, in accordance with the priority guidelines laid down in Chapter 4 of the SFCG Procedures for Inter-Agency Frequency Coordination (RES SFCG A12-1R3). (Refer to Annex C for SFCG Recommendation/Resolution)

Further to the above means, advance coordination of timing of the planned downlink may allow to use nearby/collocated ground stations (e.g. via taking planned downlinking times of one spacecraft into account in mission planning of transmission by other spacecraft). There could possibly be a concept of mutually defining priority handling. Mechanism of exchanging downlinking times and frequencies (channels) used, and possibly the agreed priorities, may lead to CCSDS data message.

Recommendation to Space Agencies:

The IOAG/SOS WG recommends that Space Agencies elaborate a concept of operations on the required coordination between satellite operators (or ground station operators) on the downlinking times of their EESS spacecraft on nearby/collocated ground stations, for frequency bands of interest, and in particular to study the required exchanges of information in the process, e.g. the CCSDS Service Management data message. In order to make this operation concept more pragmatic, it is further recommended that the Space Agencies study how this operations concept can be extended to the commercial entities.

Finding 8. Sharing of information on which regulations apply to each ground station
In general, regulations being more and more complex, not only at the ITU-R level, but also at national frequency coordination or national regulation level. Being different from country to country and changing partially from year to year, it makes it hard to plan a long term mission and, in particular, the usage over specific ground station. Wrong assumptions based on some historical information may lead to delays in projects integration.

Recommendation to Ground Station operators and service providers:

The IOAG/SOS WG recommends that the ground station operators and service providers include, in their User's Guide, up to date information on the applicable regulations for each ground station, concerning the

possibilities to use the ground station, in each of the frequency bands. This way any regulatory restrictions or necessary preparation process can be taken into account in early phases of space projects, for instance when issuing the declaration to the ITU-R and in designing future operations.

5. DOMAIN OF SPACE WEATHER

To be completed in a later issue.

6. DOMAIN OF PROXIMITY OPERATIONS, IN-ORBIT SERVICING (TBC)

To be completed in a later issue.

7. SPECIAL FOCUS ON STANDARDIZATION RELATED TO SPACE DEBRIS

Annex B to the present report provides the list of the standards that were identified by the WG and considered relevant for the discussions on the domains of Space Debris, Collision Avoidance and End of Life activities. In the first issue of the report, that list is informative only. At a later stage and for a next issue of the WG report, a thorough analysis will be conducted by the WG with the objective to identify the standards to be improved or the standards to be developed, i.e. those needed to support the recommendations in the previous sections.

8. SPECIAL FOCUS ON RECOMMENDATIONS RELATED TO SPECTRUM

Annex C to the present report lists the ITU-R Recommendations and the SFCG Recommendations/Resolutions which are relevant for the contents of the Findings in Section 4, the domain of Spectrum and Interferences. The SFCG member agencies have been developing a variety of recommendations and resolutions through their efforts in facilitating efficient spectrum usage and avoiding radio frequency interferences.

ANNEX A: SOS WG RECOMMENDATIONS SORTED OUT BY ACTORS OF THE DOMAINS OF CONCERN

A1.1 – RECOMMENDATIONS IN THE DOMAIN OF SPACE DEBRIS AND COLLISION AVOIDANCE (COLA)

The IOAG/SOS WG adheres to the IADC guidelines and to the ISO standards, and invites all satellite operators to comply with them.
However, the IOAG/SOS WG recognizes improvements are needed to streamline the utilization of Space and the practices of the new operators in Space

Recommendations to operators of satellites

- The IOAG/SOS WG recommends that operators start sharing the full details as much as possible
  - on the calculation methods (algorithm; configuration parameters; probability) allowing mutual cross-verification,
  - on the minimum alert and decision criteria and thresholds (lethal/environmental risks and object size; probability threshold; specifics for manned flights; decision timeline)

- The IOAG/SOS WG recommends that a coordination, between satellite operators and the surveillance systems operators, on orbit control as well as candidate avoidance maneuvers, be added to an improved coordination on orbit parameter exchanges, both in the planning stage as well as after maneuver execution (or cancellation), so as to mitigate the risk of receiving conjunction assessments based on invalid data. This shall be assisted by contact information database(s) and standardized data exchange mechanisms.
  Operators of bright and/or many spacecraft are recommended to share predicted trajectories with telescope operators and investigate and employ feasible operation modes limiting brightness and request designs for small brightness from their manufacturers.

- The IOAG/SOS WG recommends that the operators of satellites changing orbit frequently (e.g. low-thrust propulsion; electric propulsion; autonomous orbit control; proximity operations) provide the maintainers of catalogues with propagation models, near term predictions (e.g. ephemeris data) and / or real time information, so as to mitigate the risk of inaccurate conjunction alerts or of unidentified conjunctions.

Recommendations to maintainers of catalogues

- The IOAG/SOS WG recommends that the catalogues
  - be easily available for access of products by entities supporting COLA operations
  - use standardized product formats to distribute conjunction information
  - provide auxiliary information supporting avoidance maneuver decisions (e.g. expected time of next update, object size estimates)

- The IOAG/SOS WG recommends that the maintainers of catalogues include in their close approach assessment process up to date information received from the operators of satellites using standardized data exchange mechanisms allowing an improved coordination via orbit parameter exchanges, on orbit control as well as candidate avoidance maneuvers (pre-maneuver plans and post-maneuver result).

- For satellites changing orbit frequently (e.g. low-thrust propulsion; electric propulsion; autonomous orbit control; proximity operations), the IOAG/SOS WG recommends that the maintainers of catalogues adapt their trajectory and uncertainty predictions to take into account up to date information received from the operators of satellites.

Recommendations to Space Agencies

- The IOAG/SOS WG recommends that Space Agencies promote the need for an improved exchange of orbit and maneuver information and jointly play an active role in defining and facilitating such exchanges. This could extend to other communities, e.g. astronomers, and address related data

sharing policies.

- The IOAG/SOS WG recommends that Space Agencies support their national regulators and be active in educating New Space operators and other newcomers on operational aspects and techniques of collision avoidance.

Recommendations to satellite designers

- The IOAG/SOS WG recommends that satellite designers include enough fuel to cope with an increasing number of COLA maneuvers.

- The IOAG/SOS WG recommends that wherever needed and practical satellite designers plan for continuity of the mission payload operations during the execution of collision avoidance maneuvers.

- The IOAG/SOS WG recommends that, in the case of launches with multiple satellites, satellite designers implement devices to overcome the difficulty of object identification and help mitigate the risk of collision at launch. Such devices should be designed to also ease the tracking of small satellites during routine operations. Examples could be beacons, passive or active optical markers (such as patterns of stickers, reflectors or LEDs) or transmission of satellite identifiers or onboard-GNSS solutions.

  Note: This may also be relevant in case the concept of operations relies on the availability of catalogue data e.g. for ground station pointing.

Recommendations to launch service providers:

- The IOAG/SOS WG recommends that, in the case of launches with multiple satellites, the separation sequence and the trajectory plans are properly designed and communicated in advance to the surveillance service providers to enable identification and tracking of each object shortly after separation. This is necessary to assist the cataloguing process.

Recommendations to research, academia, IADC

- The IOAG/SOS WG recommends that studies are conducted and best practices elaborated to identify the “highest value orbits” and the ways to protect them, e.g. by developing methods allowing to assess the risks added by a planned spacecraft to the sustainable use of these orbits and deriving criteria or thresholds on the risk of collision and its consequences.
  This may also result in new avoidance decision criteria and thresholds for avoidance maneuvers, e.g. related to potential fragment cloud sizes and lifetimes.

  Note: Special focus should be given to the potential increase of human spaceflight activities in LEO and its consequences on collision avoidance needs. Research should investigate whether the typically stricter criteria on collision avoidance maneuver thresholds may require dedicated protection measures, such as protected orbital regimes (sub-regime within LEO) in which unmanned spacecraft have to satisfy special requirements.

Recommendations to national and international regulators

- The IOAG/SOS WG recommends that national and international regulators standardize, harmonize and define common approaches, as soon as possible
  - on the calculation methods (algorithm; configuration parameters; probability) allowing mutual cross-verification,
  - on the minimum decision criteria and thresholds (lethal/environmental risks and object size; probability threshold; specifics for manned flights; decision timeline)

- The IOAG/SOS WG recommends that authorizations for launch address a number of criteria so as to protect the high value orbits and to mitigate the risks on any orbit regime. This could include:
- reliability requirements satisfied,
  - compulsory propulsion system to avoid orbital collisions
  - orbit sharing (short / long term) forbidden with identified co-passengers (big ones or non-maneuverable ones)

- use of a qualified “COLA service” (can be internal or external to operator) and have some sort of validation of the COLA process.

Where it is not possible to meet such criteria, regulators should consider only authorising satellites to use certain orbits (e.g. below 400 km if no propulsion) far from the highest value orbits (e. g. ISS or other ones to be identified) or orbits for which their risk impact is acceptable..

- The IOAG/SOS WG recommends that regulations address the issue of continuity of control (not necessarily the mission) including the final disposal, so that it is ensured by insurance, initial deposit, state guarantee or the like, in particular to cope with the cases after bankruptcy of operators or transfer of ownership of a satellite operator company.

- The IOAG/SOS WG recommends that national and international regulators be more active in educating New Space operators and other newcomers on their obligations and of the possible mitigation measures.

A1.2 – RECOMMENDATIONS IN THE DOMAIN OF END OF LIFE ACTIVITIES

The IOAG/SOS WG adheres to the IADC guidelines and the statement on Large Constellations of Satellites in Low Earth Orbit and to the ISO standard 24113. The WG invites all satellite operators to comply with them.

Recommendation to satellite operators:

- The IOAG/SOS WG recommends that the end of life operations be prepared and resources be planned from the design phase, to be able to adopt and comply with the latest IADC guidelines and ISO standards on matters such as lifetime in Space, graveyard orbits, risks of casualties or reliability of disposal operations.

- The IOAG/SOS WG recommends that each satellite owner input data into a data base of satellite status, to share more effectively whether satellites are maneuverable or passivated, especially, after end of life operation. This should be done as soon as there is a known change of the status of the satellite.

- The IOAG/SOS WG recommends that the satellite operators continuously monitor, during the operation phase, the probability of successful disposal, for continued compliance and that corrective actions are applied if degradation is observed.

- The IOAG/SOS WG recommends that the satellite operators, during mission lifetime, continuously conduct the assessment of the risk of a space debris impact on the execution of disposal operations, to avoid compromising the success of the disposal.

- The IOAG/SOS WG recommends that the satellite operators encourage the new / emerging launch operators to comply with internationally recognised guidelines and standards applying to launchers from their launch to their re-entry operations.

Recommendations to Space Agencies:

- The IOAG/SOS WG recommends Space Agencies share past experiences and developing specific guidelines on the best practices on disposal operations for different spacecraft configurations and capabilities. Workshops or conferences should be used to identify which best practices could be established as new standards.

- The IOAG/SOS WG recommends that Space Agencies promote the need for a data base to be established and maintained for sharing more effectively the status of satellites, especially, after a failure or their end of life operation.

Recommendations to IADC:

- The IOAG/SOS WG recommends that the IADC establishes a top-level reporting on the status of the guidelines and reporting on their implementation globally where possible.
- The IOAG/SOS WG fully supports the existing guidelines. The IOAG/SOS WG recommends that studies are conducted to develop specific guidelines on the conditions when the rule should ask for less than 25 years lifetime for LEO satellites and for more than the 90% successful disposal objective. For instance, consideration could be given to:
    - differentiate how the 25 years should be counted (e.g.: ISO:24113:2019 counts from injection if not maneuverable)
    - relate allowed decay time to duration of active mission
    - relate allowed decay time to the consequence on the orbital environment of an unsuccessful disposal of the satellite (long and short term)
    - revisit the required probability of successful disposal accordingly
    - take into account the reliability and tolerance conditions for ageing missions and their hardware capabilities

Recommendations to ISO:

- The IOAG/SOS WG recommends that standard ISO 27852 on the orbit lifetime estimation be improved to better specify how to compute the estimated lifetime and the associated uncertainty (e.g. varying drag area for tumbling spacecraft), and to provide criteria to validate the tools for the lifetime estimation.

Recommendations to national and international regulators:

- The IOAG/SOS WG recommends that national and international regulators require license for mission extension demonstrating required Post Mission Disposal success.

- The IOAG/SOS WG recommends that regulators request the new / emerging launch operators to comply with internationally recognised guidelines and standards applying to launchers from their launch to their re-entry operations.

A1.3 – RECOMMENDATIONS IN THE DOMAIN OF SPECTRUM AND INTERFERENCES

Recommendations to SFCG:

- The IOAG/SOS WG recommends SFCG to consider establishing a resolution similar to the Resolution SFCG A36-2R1 for encouraging SFCG members to report to the SFCG meeting instances of harmful interference to the SOS/SRS/EESS communication services and to recommend realistic models which should be used to assess the conditions under which interferences happen.

- The IOAG/SOS WG recommends that the SFCG continues to recommend techniques for the efficient usage of the SOS/SRS/EESS S-Band so as to mitigate the risks of interferences in that Band, both for uplink and downlink, and which corresponding recommendations should be put urgently in place to address the growing demand from new operators. This should be addressed at system level and must consider the latitude of the stations and the type of antennas, in particular if combined with X-Band or Ka-Band (26 GHz).

Recommendations to Space Agencies;

- The IOAG/SOS WG recommends that the Space Agencies approach their National Frequency Administrations to facilitate the initiative of the ITU-R WP7B in improving the filing process and the details to be provided for new satellite systems in all frequency bands. The IOAG/SOS WG recommends to include constellations in such ITU-R recommendation.

- The IOAG/SOS WG recommends that Space Agencies approach their National Frequency Administrations to facilitate the initiative of the ITU-R WP7B to develop S-Band recommendations and adopt the techniques that best guarantee long term sustainability for both uplink and downlink.

- The IOAG/SOS WG recommends that the Space Agencies approach their National Frequency Administrations to facilitate the adoption of the ITU-R Recommendation SA.2142 for ensuring the

protected use of existing and planned EESS/SRS receiving Earth stations and for future deployment of Earth stations in the 26 GHz band.

- The IOAG/SOS WG recommends that Space Agencies approach their National Frequency Administrations to provide operators, which often lack the knowledge and manpower on the ITU-R process and the RR, with guidance/advice for them gaining sufficient knowledge of the ITU-R mandatory procedures for frequency management and coordination.

- The IOAG/SOS WG recommends that Space Agencies approach their National Frequency Administrations to work towards ITU-R to establish
    - a requirement on to-be-operators of SDM and constellations to share immediately technical and operational information of their network/system with the ITU-R in order to be easily accessible by concerned administrations/operators and a mechanism in place in the Radiocommunication Bureau (RB) so that the ITU-R via its RB could intervene quickly to resolve a case of a complaint effectively,
    - a requirement for SDM that the period of comments to SDMs filings should be reduced in order to have a quicker processing period,
    - a mechanism for an implementation of RR 22.1 which require space stations to ensure immediate cessation of its radio emissions by telecommand, in case of harmful inference being occurring or predicted during a long or repetitive time span.

- The IOAG/SOS WG recommends that Space Agencies elaborate a concept of operations on the required coordination between satellite operators (or ground station operators) on the downlinking times of their EESS spacecraft on nearby/collocated ground stations, for frequency bands of interest, and in particular to study the required exchanges of information in the process, e.g. the CCSDS Service Management data message. In order to make this operation concept more pragmatic, it is further recommended that the Space Agencies study how this operations concept can be extended to the commercial entities.

<u>Recommendations to satellite operators</u>:

- The IOAG/SOS WG recommends that the satellite operators provide the necessary set of parameters (orbit, actual center frequency, actual frequency bandwidth, ground station locations…) in the filing of their satellite(s) from the API stage, to allow the proper evaluation of the risks of interference, at early stage, with other satellite systems.

- The IOAG/SOS WG recommends that the satellites operators adopt the techniques recommended by the ITU WP7B that allow to mitigate the risks of interferences in the SOS/EESS/SRS S-Band at system level, and to limit the usage of the band for housekeeping data and use those techniques that make the links less sensitive to short interferences.

- The IOAG/SOS WG recommends that the satellites operators comply with the recommendations of the ITU-R and SFCG for the protection of the 8.025 to 8.4 GHz frequency band.

<u>Recommendations to national and international regulators</u>:

- The IOAG/SOS WG recommends that the national and international regulators add to the criteria to get the authorizations for launch, a necessary set of conditions relative to the declaration of satellite systems at the ITU-R, in particular to make sure sufficient information is available, long in advance to the launch(es), to enable a proper coordination with other satellite systems.

- The IOAG/SOS WG recommends that the national and international regulators add to the criteria to get the authorizations for launch, a necessary set of conditions relative to the efficient usage of the SOS/SRS/EESS S-Band and the application of RFI mitigation techniques. Such criteria could be elaborated with the National Frequency Administrations and be made consistent with ITU-R recommendations.

- National Frequency Administrations should support regulatory measures in their respective jurisdiction, to ensure the protected use of existing and planned EESS/SRS receiving Earth stations

and for future deployment of Earth stations in the 26 GHz band.

- The IOAG/SOS WG recommends that national and international regulators be more active in educating new operators and other newcomers on their ITU-R obligations and mandatory procedures for frequency management and coordination.

- The IOAG/SOS WG recommends that national and international regulators establish, apply and enforce rules preventing missions previously registered as SDMs from extending their mission beyond 3 years.

Recommendations to satellites designers:

- The IOAG/SOS WG recommends that the satellite designers adopt the recommended techniques that allow to mitigate the risks of interferences in the SOS/SRS/EESS S-Band, and in particular to limit the usage of wide antenna beams on the satellite Tx antenna (e.g. isoflux antennas) to special phases of the mission such as LEOP or Emergency, to the extent it is practical.

- The IOAG/SOS WG recommends that the satellites designers comply with the recommendations of the ITU-R and SFCG for the protection of the 8.025 to 8.4 GHz frequency band.

Recommendation to Ground Station operators and service providers:

- The IOAG/SOS WG recommends that the ground station operators and service providers include, in their User's Guide, up to date information on the applicable regulations for each ground station, concerning the possibilities to use the ground station, in each of the frequency bands. This way any regulatory restrictions or necessary preparation process can be taken into account in early phases of space projects, for instance when issuing the declaration to the ITU-R and in designing future operations.

A1.4 – RECOMMENDATIONS IN THE DOMAIN OF SPACE WEATHER

A1.5 – RECOMMENDATIONS IN THE DOMAIN OF PROXIMITY OPERATIONS, IN-ORBIT SERVICES (TBC)

ANNEX B: STANDARDS IDENTIFIED BY THE SOS WG RELEVANT TO SPACE DEBRIS, COLLISION AVOIDANCE AND END OF LIFE

The list provides the standards that were identified by the WG and considered relevant for the discussions on the domains of Space Debris, Collision Avoidance and End of Life activities.

ISO 24113 THIRD EDITION 2019-07

"Space systems — Space debris mitigation requirements"
6.2 Avoiding break-ups in Earth orbit
6.2.3 Accidental break-up caused by a collision
6.2.3.1 A spacecraft that will operate in the GEO protected region shall have a recurrent maneuver capability.
6.2.3.2 A spacecraft that will operate in Earth orbit with a recurrent maneuver capability shall be designed and operated to actively manage collision risk until the end of life.
6.2.3.3 For a spacecraft with the capability to actively manage collision risk, if the risk of collision with other space objects is assessed to be above the corresponding risk threshold set by an approving agent then collision avoidance maneuvers shall be conducted to reduce the risk of collision below the threshold.

OTHER ISO TC20/SC14 REFERENCES

WG3 Operations
16158.1 Avoiding collisions with orbiting objects [Tech Rep] PUBLISHED
16164.1 Disposal of satellites operating in or crossing Low Earth Orbit - PUBLISHED
16699.1 Disposal of orbital launch stages – PUBLISHED
23339.1 Unmanned spacecraft residual propellant mass estimation for disposal maneuvers - PUBLISHED
24330.1 Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic Principles and Practices - DIS - 8/16/2021 Pub - 8/16/2022
26872.2 Disposal of satellites operating at geosynchronous altitude - PUBLISHED
26900.2 Space data and information transfer systems — Orbit data messages DIS - 12/11/2019 Pub - 12/11/2020 (with SC13)
27852.2 Estimation of orbit lifetime - PUBLISHED
27875.2 Re-entry risk management for unmanned spacecraft and launch vehicle orbital stages – PUBLISHED
27875 Amd1 1 Re-entry risk management for unmanned spacecraft and launch vehicle orbital stages — Amendment 1 [for Edition 2] FDIS - 11/22/2020 Pub - 5/22/2021

WG7 ORBITAL DEBRIS
11227.1 Test procedures to evaluate spacecraft material ejecta upon hypervelocity impact - PUBLISHED
11227.Amd1 1 - Test procedures to evaluate spacecraft material ejecta upon hypervelocity impact — Amendment 1: Oblique impacts and Annex C update - DIS - 12/14/2019 Pub - 12/14/2020
16126.1 Assessment of survivability of unmanned spacecraft against space debris and meteoroid impacts to ensure successful post-mission disposal PUBLISHED
16126. 2 Survivability of unmanned spacecraft against space debris and meteoroid impacts for the purpose of space debris mitigation DIS - 11/13/2021 Pub - 11/13/2022
16127.1 Prevention of break-up of unmanned spacecraft PUBLISHED
18146.2 Space debris mitigation design and operation guidelines for spacecraft [Tech Rpt] DTR - 1/10/2021 Pub - 1/10/2022
20590.1 Debris mitigation design and operation guidelines for launch vehicle orbital stages [Tech Rpt] PUBLISHED
20893.1 Detailed space debris mitigation requirements for launch vehicle orbital stages DIS - 3/24/2020 Pub - 3/24/2021
23312.1 Detailed space debris mitigation requirements for spacecraft DIS - 3/20/2020 Pub - 3/20/2021
24113.3 Space debris mitigation requirements PUBLISHED

CCSDS BLUE BOOK ON CONJUNCTION DATA MESSAGES (ALSO UNDER ISO TC20/SC13 REFERENCES)

NAVIGATION WG DATA MESSAGES
- Conjunction Data Message 5 Year Review Revision Blue 508.0-B-2 Approved On Schedule First draft circulated to WG 01/14/2019 12/31/2021
- Orbit Data Message (ODM) 5 Year Review Revision Blue 502.0 Approved On Schedule

Second draft circulated to WG 04/16/2015 2/28/2022
- Tracking Data Message (TDM) 5 Year Review Revision Blue 503.0 Approved On Schedule
RID Resolution 2 10/09/2013 5/15/2020
- Tracking Data Message Version 3 Blue 503.0-B-3 Approved On Schedule First draft comments due
05/06/2019 11/30/2024
- Attitude Data Message (ADM) 5 Year Review Revision Blue 504.0 Approved On Schedule
Second draft circulated to WG 04/16/2015 4/30/2022
- Navigation Data Messages XML Specification Five Year Revisions Blue 505.0 Approved
On Schedule Second draft comments due 07/13/2016 10/31/2021
- Navigation Events Message Blue 507.0 Approved On Schedule First draft comments due
11/07/2017 11/30/2022

ECSS-U-AS-10C Rev.1 3 December 2019

"Space sustainability
Adoption Notice of ISO 24113: Space systems - Space debris mitigation requirements"

CEN JTC5 WG2 "Space Situational Awareness Monitoring"

EN 16604-30-03 Space - Space Situational Awareness Monitoring - Part 30-03:
Observation System Data Message (OSDM)
EN 17350 SCM - Scheduling and Commanding Message

This WG plans on adopting the CCSDS (ISO SC13) standards: CDM, ODM, TDM, ADM, XML for Nav.

Recommendations/Guidelines International-level

IADC
https://www.iadc-home.org/

"IADC Space Debris Mitigation Guidelines", IADC-02-01 Rev. 3 June 2021 (earlier issues 2002/2007/2020)

"Support to the IADC Space Debris Mitigation Guidelines", IADC-04-06 Rev 5.8, June 2021

"IADC Statement on Large Constellations of Satellites in Low Earth Orbit", IADC-15-03 Rev. 1.1, July 2021

IADC also collects external guidelines

UN COPUOS

"Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space"
http://www.unoosa.org/pdf/publications/st_space_49E.pdf

"Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space"
https://www.unoosa.org/oosa/en/ourwork/topics/long-term-sustainability-of-outer-space-activities.html

UNCOPUOS also has a "Compendium of space debris mitigation standards adopted by States and international organizations"
http://www.unoosa.org/oosa/en/ourwork/topics/space-debris/compendium.html

Recommendations/Guidelines State/Agency-level

European Space Agencies
"European Code of Conduct for Space Debris Mitigation"
http://www.unoosa.org/pdf/spacelaw/sd/2004-B5-10.pdf

National Aeronautics and Space Administration
"NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook" (December 2020)
https://nodis3.gsfc.nasa.gov/OCE_docs/OCE_50.pdf

FRANCE
Decree concerning the technical regulation regarding the decree N° 2009-643 of 9th June 2009 concerning licenses issued pursuant to the Act N° 2008-518 of 3rd June 2008 relating to Space Operations.

RECOMMENDATIONS/GUIDELINES PRIVATE

SPACE SAFETY COALITION
"Best Practices for the Sustainability of Space Operations"
https://spacesafety.org/best-practices/

SATELLITE INDUSTRY ASSOCIATION
"Principles of Space Safety for the Commercial Satellite Industry"
https://sia.org/space_safety/

ANNEX C: STATUS OF SFCG AND ITU RECOMMENDATIONS RELEVANT TO SPECTRUM AND INTERFERENCE CONCERNS IN THE PRESENT REPORT

The table below lists the ITU-R Recommendations and the SFCG Recommendations/Resolutions which are relevant for the contents of the Findings in Section 4, the domain of Spectrum and Interferences. The SFCG member agencies have been developing a variety of recommendations and resolutions through their efforts in facilitating efficient spectrum usage and avoiding radio frequency Interferences.

Legend:
ITU-R = Recommendation
SA series = Space applications and meteorology
SFCG REC = Recommendation
SFCG RES = Resolution

Finding 1.Reporting on environment of radio frequency interference to SO/SRS/EESS communication services	
Relevant SFCG resolution	SFCG SFCG A36-2R1 REPORTING OF RADIO FREQUENCY INTERFERENCE TO EARTH EXPLORATION-SATELLITE SERVICE (PASSIVE) SENSORS
Document status	Published
Finding 2. Filing of satellites at the ITU	
Relevant ITU-R recommendation	ITU-R Rec. SA.[S-BAND DL USE OPT] and ITU-R SA.[S-BAND UL USE OPT], Guidelines on the use of the 2 025-2 110 MHz and 2 200-2 290 MHz frequency bands by SRS/EESS/SOS satellites
Document status	Working documents towards the Preliminary Draft New Recommendation is being discussed in WP7B.
Finding 3. Protection of the S-Band	
Relevant ITU-R recommendation	ITU-R Rec. SA.[S-BAND DL USE OPT] and ITU-R SA.[S-BAND UL USE OPT], see under finding 1; also applies to finding 2
Document status	
Relevant ITU-R recommendation	ITU-R Rec. SA.1154 Provisions to protect the space research (SR), space operations (SO) and Earth exploration-satellite services (EESS) and to facilitate sharing with the mobile service in the 2 025-2 110 MHz and 2 200-2 290 MHz bands
Document status	Published
Relevant ITU-R recommendation	ITU-R Rec. SA.2078 Protection of SRS earth stations from mobile (aircraft) stations in the 2 200-2 290 MHz band
Document status	Published
Relevant SFCG recommendation	SFCG REC 12-4R3 Methods for Reduction of Potential Interference Between Systems in the Space Science Services in Densely Occupied Bands
Document status	Published
Relevant SFCG recommendation	SFCG REC 21-2R4 Efficient Spectrum Utilisation for Space Research Service (Category A) and Earth Exploration-Satellite Service on Space-to-Earth Links
Document status	Published
Relevant SFCG recommendation	SFCG REC 12-5R2 Limitations on Earth - Space Link Power Levels in the 2025 – 2110 MHz band

Document status	Published
Relevant SFCG resolution	SFCG RES 24-1R1 INTERFERENCE MITIGATION TECHNIQUES FOR FUTURE SYSTEMS PLANNING TO OPERATE IN THE 2200-2290 MHZ BAND
Document status	Published
Relevant SFCG resolution	SFCG RES 27-1 NTERFERENCE MITIGATION TECHNIQUES FOR FUTURE SYSTEMS PLANNING TO OPERATE IN THE 2025-2110 MHZ BAND
Document status	Published
Relevant SFCG resolution	SFCG RES 17-1R2 Protection of Space Science Services from Terrestrial Service Systems in the Band 2025-2110 MHz and 2200-2290 MHz
Document status	Published

Finding 4. Protection of the 8 GHz Band

Relevant ITU-R recommendation	ITU-R Rec. SA.1810-1 System design guidelines for Earth exploration-satellites operating in the band 8 025-8 400 MHz
Document status	Published
Relevant SFCG recommendation	SFCG REC 14-3R10 USE OF THE 8025-8400 MHz BAND BY EARTH EXPLORATION SATELLITES
Document status	Published (similar recommendation is published as ITU-R Rec. SA.1810-1)
Relevant SFCG recommendation	SFCG Rec 12-4R3 Methods For Reduction of Potential Interference Between Systems in the Space Science Services in Densely Occupied Bands
Document status	Published
Relevant SFCG recommendation	SFCG Rec 18-2 Minimum Earth Station G/T Requirements for Reception of Non-Geostationary EESS in the 8025-8400 MHz Bands
Document status	Published
Relevant SFCG recommendation	SFCG REC 21-2R4 Efficient Spectrum Utilisation for Space Research Service (Category A) and Earth Exploration-Satellite Service on Space-to-Earth Links
Document status	Published

Finding 5. Protection of the 26 GHz Band

Relevant ITU-R recommendation	ITU-R Rec. SA. 2142, Methodologies for calculating coordination zones areas around Earth exploration satellite and space research earth stations to avoid harmful interference from IMT-2020 systems in the frequency bands 25.5-27 GHz and 37-38 GHz
Document status	Published
Relevant ITU-R recommendation	ITU-R Rec. SA.1862 Guidelines for efficient use of the band 25.5-27.0 GHz by the Earth exploration-satellite service (space-to-Earth) and space research service (space-to-Earth)
Document status	Published

Relevant SFCG recommendation	SFCG REC 29-1 Efficient Sharing of the 25.5 - 27.0 GHz Band between EESS (s-E) and SRS (s-E)
Document status	Published (same recommendation is published as ITU-R Rec. SA.1862)
Relevant SFCG recommendation	SFCG REC 30-2 Efficient Use of the 25.5 - 27.0 GHz Frequency Band by Future Earth Exploration-Satellite Systems and Space Research Satellite Systems
Document status	Published
Relevant SFCG recommendation	SFCG REC 21-2R4 Efficient Spectrum Utilisation for Space Research Service (Category A) and Earth Exploration-Satellite Service on Space-to-Earth Links
Document status	Published
Finding 5. . Increasing difficulties of frequency coordination and avoidance of interferences	
Relevant ITU-R resolution	Resolution 32 (WRC-19) Regulatory procedures for frequency assignments to non-geostationary-satellite networks or systems identified as short-duration mission not subject to the application of Section II of Article 9
Document status	Published
Relevant ITU-R Radio Regulation	ARTICLE 11; Notification and recording of frequency assignments, provision 11.49 ARTICLE 22; Space services; provision 22.1
Document status	Published, Edition 2020
Finding 7. Coordination on the downlink times	
Relevant SFCG recommendation	SFGC 12-4R3 Methods for Reduction of Potential Interference between Systems in the Space Science Service in Densely Occupied Bands
Document status	Published
Relevant SFCG resolution	RES A12-1R3 Establishment of Procedures for Interagency Frequency Coordination
Document status	Published