IADC-15-03
September 2017

Inter–Agency Space Debris Coordination Committee

IADC Statement on Large Constellations of Satellites in Low Earth Orbit

Issued by IADC Steering Group

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Revision History

Issue	Revision	Date	Reason for Revision
Draft	0	2015-10-12	Initial Draft
Draft	1	2016-01-14	Incorporation of comments from Steering Group
Draft	2	2017-03-24	Inclusion of first findings from simulations and identification of some first recommendations
Draft	3	2017-09-27	Incorporating additional comments for Steering Group
Draft	4	2017-11-10	Version after SG and WG2/WG4 sanity check

List of Abbreviations

Abbreviation	Description
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Administration
CSA	Canadian Space Agency
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
ESA	European Space Agency
ISRO	Indian Space Research Organisation
JAXA	Japan Aerospace Exploration Agency
KARI	Korea Aerospace Research Institute
NASA	National Aeronautics and Space Administration
ROSCOSMOS	Russian State Space Corporation ROSCOSMOS
SSAU	State Space Agency of Ukraine
UKSA	United Kingdom Space Agency

1 Background

The Inter-Agency Debris Coordination Committee (IADC) was established to exchange information on space debris research activities between its member space agencies. The IADC currently comprises the Italian Space Agency (ASI), the Centre National d'Etudes Spatiales (CNES), China National Space Administration (CNSA), Canadian Space Agency (CSA), Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), the European Space Agency (ESA), the Indian Space Research Organisation (ISRO), Japan Aerospace Exploration Agency (JAXA), the Korea Aerospace Research Institute (KARI), the National Aeronautics and Space Administration (NASA), the Russian State Space Corporation ROSCOSMOS (ROSCOSMOS), the State Space Agency of the Ukraine (SSAU), and the UK Space Agency (UKSA).

In addition to reviewing all on-going cooperative space debris research activities between its member organizations, the IADC recommends new opportunities for cooperation, serves as the primary means for exchanging information and plans concerning orbital debris research activities, and identifies and evaluates options for debris mitigation.

As appropriate, the IADC communicates the findings of its work to the wider space community such as the IADC Space Debris Mitigation Guidelines first published in 2002, and subsequently updated in 2007. These IADC Guidelines informed, and provided the basis for, the development of the Space Debris Mitigation Guidelines of the United Nations (UN) Committee on the Peaceful Uses of Outer Space which were endorsed by the UN General Assembly in its resolution 62/217, dated 22 December 2007.

2 Rationale

At its 33rd meeting in Houston in March 2015, the IADC noted the emerging plans for large constellations of satellites in Low Earth Orbit (LEO) and recognised the potential for such systems to have an important influence on the evolution of the space debris environment and consequent impact on the population of man-made satellites orbiting the Earth. Accordingly, in March 2015, the IADC committed to conduct a series of investigations and analyses to investigate the potential risk posed by such constellation systems and consider potential mitigation actions which could help inform the design and operation of such distributed architectures to ensure that they are developed in a predictable and sustainable manner. A number of its independent member agencies undertook to perform a series of coordinated computer simulations and conduct a comparative study to evaluate the results and identify key issues/influences, and seek to communicate its findings to the wider space community. Finally, in April 2017, the IADC is scheduled to converge on a study program bundling the expertise of space debris environment modeling experts in order to assess the outcome of such constellation traffic as a function of various technical factors. This will be done with the help of independent models, leading to a consolidated view on the influence of key parameters. Some member agencies have further progressed with their internal studies, which could help to properly shape and focus the IADC study program.

Recognising that a number of constellation architectures are already in the process of development, and that timely guidance could help to inform the design and operation of such systems, the IADC intends to follow a two-track approach to address this issue. First, on the basis of the outcome of initial reflections, it offers a number of preliminary qualitative observations that operators could consider in their conceptual design, and subsequently, as more substantive and comprehensive modelling data becomes available from the coordinated international studies, offer more detailed, quantitative guidance to inform the design and operation of such constellation systems.

3 Preliminary space debris considerations for the development of large constellations of satellites in LEO

The IADC first seeks to reinforce the relevance of its existing space debris mitigation measures to constellation architectures, as reflected in the IADC and UN Space Debris Mitigation Guidelines, the most pertinent aspects of which can be summarised as follows:

- Spacecraft and orbital stages should be designed not to release debris during normal operations
- The potential for break-ups during mission should be minimised
- All space systems should be designed and operated so as to prevent accidental explosions and ruptures after end-of mission
- In order to limit the risk to other spacecraft and orbital stages from accidental break-ups after the completion of mission operations, all on-board sources of stored energy of a spacecraft or orbital stage, such as residual propellants, batteries, high-pressure vessels, self-destructive devices, flywheels and momentum wheels, should be depleted or safed when they are no longer required for mission operations or post-mission disposal
- During the design of spacecraft or orbital stages, each program or project should demonstrate, using failure mode and effects analyses or an equivalent analysis, that there is no probable failure mode leading to accidental break-ups.
- During the operational phases, a spacecraft or orbital stage should be periodically monitored to detect malfunctions that could lead to a break-up or loss of control function. In the case that a malfunction is detected, adequate recovery measures should be planned and conducted; otherwise disposal and passivation measures for the spacecraft or orbital stage should be planned and conducted.
- Intentional destruction of a spacecraft or orbital stage, (self-destruction, intentional collision, etc.), and other harmful activities that may significantly increase collision risks to other spacecraft and orbital stages should be avoided.
- Whenever possible spacecraft or orbital stages that are terminating their operational phases in orbits that pass through the LEO region, or have the potential to interfere with the LEO region, should be de-orbited (direct re-entry is preferred) or where appropriate manoeuvred into an orbit with a reduced lifetime. Retrieval is also a disposal option.
- A spacecraft or orbital stage should be left in an orbit in which, using an accepted nominal projection for solar activity, atmospheric drag will limit the orbital lifetime after completion of operations to maximum of 25 years.
- If a spacecraft or orbital stage is to be disposed of by re-entry into the atmosphere, debris that survives to reach the surface of the Earth should not pose an undue risk to people or property.
- In developing the design and mission profile of a spacecraft or orbital stage, a program or project should estimate and limit the probability of accidental collision with known objects during the spacecraft or orbital stage's orbital lifetime. If reliable orbital

data is available, avoidance manoeuvres for spacecraft and co-ordination of launch windows may be considered if the collision risk is not considered negligible.

- Spacecraft design should limit the consequences of collision with small debris which could cause a loss of control, thus preventing post-mission disposal.

At this initial stage, it is clear that the significant numbers of satellites envisaged in the planned constellation architectures represent a step change in the number of satellites operating in the low Earth orbit regime, and may question the validity of the assumptions used to derive the existing space debris mitigation guidelines (e.g. launch traffic models and the numbers of objects in orbit). There is also a question regarding the robustness of the existing debris mitigation guidelines to effectively manage the new constellations and their impact on the orbital environment in a sustainable manner (e.g. the 25-year lifetime may need to be reduced to limit residence times in orbit).

Another key consideration is the reliability of critical systems and functionality such as end of life disposal which, amongst other things depends on technological maturity, design choices, and operational concepts and practices. It is clear that significant improvements in the reliability of the disposal function at end of life will be needed for the new constellations compared with that currently demonstrated by space systems on orbit.

With the anticipated number of orbital objects required to establish, maintain and refresh the new architectures, the greatest impact, at least in the short term will be on the constellations themselves, in terms of possible close approaches, and the consequent potential burden in terms of conjunction assessment and the possible need for avoidance manoeuvres, which will ultimately affect fuel margins and platform lifetimes.

4 IADC Considerations in View of Large Constellation Deployment in Low Earth Orbit

4.1 General

Most proposed concepts for large constellations in LEO target at operational altitudes above 1000km. This is far higher than the average space traffic into LEO. It is well known that average natural atmospheric drag induced orbital lifetimes (from end of mission to natural atmospheric re-entry) increase exponentially with altitude. For typical spacecraft, above 1000km these average orbital lifetimes are quasi eternal. Therefore, reliable and effective measures to reduce the postmission orbital lifetime to acceptable limits should be a prime focus for such missions. The IADC has identified the success of such disposal actions as one of the key drivers for the environmental sustainability of these missions.

It is obvious that the negative environmental consequences of failure to implement guidelines are significantly more severe for constellations compared to the common space mission architectures, solely driven by the large numbers of satellites involved.

All constellations spacecraft including spares and launcher stages should at the very least follow the IADC mitigation guidelines. The purpose of this chapter is to provide additional considerations on how adherence to the IADC mitigation guidelines (see previous chapter) can be achieved by such missions. It should be noted that these do not mean additional or expansion of IADC guidelines, but technical guidance on how to best comply with them. This guidance will be given along with the following technical parameters:

4.2 Constellation Design

4.2.1 Altitude Separation

- *It is recommended to consider sufficient altitude separation between all parts of the constellation and with respect to other large constellations and crowded orbits in order to minimise the potential collision risk.*

4.2.2 Number of spacecraft

There is a relationship between the number of spacecraft failures on orbit and the associated impact on the space environment. This also has direct consequences for the workload connected with conjunction assessment and potential collision avoidance

- *It is recommended to consider higher probability of success of the Post Mission Disposal for large constellations.*

4.2.3 Altitude separation at orbital plane intersection

- *Altitude separations at intersections between orbital planes of a constellation have shown to provide positive environmental effects if significant enough to avoid inter-plane conjunctions*

4.3 Spacecraft Design

4.3.1 Reliability of the Post Mission Disposal (PMD) Function

The reliability of the post mission disposal function will have a major impact on the orbital environment, in particular for constellations that consist of a large number of satellites operating at high altitudes within LEO. The following measures are therefore recommended:

- *Design for sufficient on-board redundancies of all functions involved in the post mission disposal*

- *Design of a monitoring function for the post mission disposal capability*

4.3.2 Design measures to minimize consequences of break-ups

- *Consider spacecraft design that will minimise the likelihood of explosions*

- *Consider capability for collision avoidance in the design.*

4.3.3 On-ground Risk

During the operation of one or more large constellations, several hundred uncontrolled re-entries can be expected per year. To reduce the on ground risk, the following is recommended:

- *Consider performing a controlled re-entry*
- *Or/and consider spacecraft design options that reduces the number/size of harmful fragments impacting ground*

4.3.4 Structural Integrity

Today, accidental explosions are responsible for a significant number of fragments in LEO. Sound implementation of passivation measures according to the IADC guidelines and the associated support documents are, thus, essential.

- *Consider high overall spacecraft reliability design to minimise the probability of accidental explosions during operation and improve the likelihood of successful post mission disposal*

Often, critical components/designs leading to accidental explosions are only identified years after launch/operation in orbit, if at all. For example, battery designs which have resulted in favouring explosions during or after operations have only become apparent after a few years in space, after a certain number of duty cycles, or as soon as certain temperatures are reached in non-nominal attitude or non-nominal orbits (often years) after operations.

For large constellations, systemic problems may be manifested due to the large numbers of the same spacecraft series and the associated short production times involved. It is possible that the first of such unanticipated failures occurs once the whole of the series is launched so that design retrofit is not a viable option.

New technology has the potential to allow automatic passivation of spacecraft after loss of contact in a safe manner (e.g. electromagnetic cable cutters / valves that react upon loss of voltage)

4.3.5 Trackability

The load on surveillance systems will grow dramatically with the deployment of large constellations. Likewise, the number of conjunction events in these altitudes will grow. Enhancing trackability, e.g. by adding onboard active and/or passive components can improve the orbit determination and prediction. This would have positive impact on conjunction analysis.

- *It is recommended to enhance trackability by adding onboard active and/or passive components*

- *It is recommended to provide information on planned trajectories prior to performing orbit transfer manoeuvres (e.g. during deployment to the operational orbit and disposal)*

4.4 Operations

4.4.1 Launcher Stages

Upper stages may operate near the constellation altitude, which raises the same mitigation issues as for the spacecraft they deliver to orbit. The uncontrolled re-entry of upper stages might also raise on-ground safety issues. Strict adherence to the same mitigation guidelines is therefore essential.

4.4.2 Collision Avoidance

Active collision avoidance brings benefit, both, to the integrity of the constellation and the remainder of the space environment. The overall number of conjunction alerts raised for the constellation spacecraft may have a strong impact on operations of the constellation and other operators. Efficient processes are required to manage this process. The many avoidance manoeuvers could come on top of routine manoeuvres for constellation management, including during the ascent and descent phase. This means that efficient and open communication with surveillance networks and/or other concerned operators is required for the timely sharing of relevant data.

- *Operational collision avoidance should be performed*
- *Manoeuvre plans should be communicated to the relevant actors in a timely manner*

4.4.3 Disposal Strategy

IADC simulations have clearly shown that a post mission disposal towards sufficiently low altitude is preferred over orbit raising to above 2000km. In view of the large constellations, the latter could ultimately lead to the onset of collisional cascading in altitudes above 2000km, with consequent negative effects to lower altitudes.

- *Following the 25-year lifetime limit has fewer negative long-term effects to the environment than some other disposal options.*

- *To further limit the potential negative effects to the environment, operators are encouraged to consider additional measures beyond the* *existing guidelines, such as shortening post mission disposal lifetime and maintaining the collision avoidance capability during the post mission disposal phase.*

- *Monitor on a regular basis the availability of the post mission disposal function and initiate disposal actions as soon as post mission disposal reliability drops to a critical level, even if design lifetime is not reached*

4.4.4 Launch and Early Operations

Interaction with the environment can be reduced by using an intermediate (lower) injection altitude. Using sufficiently low intermediate injection altitudes also provides the opportunity to check-out the system in an environment that is compliant w.r.t. the 25-year rule.

In light of the reliability issues discussed prior, strict operational procedures aimed at discovering issues with the associated series manufacturing for constellations should be implemented. This can include performing the early operations in a region without direct consequence for the space environment before reaching the operational altitude.