US Government and NASA Documents Related to Orbital Space Debris Mitigation

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Contents

Abstract

The US Governmental Agencies most concerned with orbital space debris and its mitigation are NASA, the Federal Communications Agency, the Department of Defense, the Department of Commerce and its Office of Commercial Space, the Department of Transportation and its Office of Commercial Space Transportation in the Federal Aviation Agency (FAA-AST), and the National Space Council. The National Space Council has just approved for distribution in November 2019 the latest version of the US Government Orbital Debris Mitigation Standard Practices (ODMSP). This is provided below and also can be found on line (NASA, Orbital debris mitigation standard practices. https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf. November 2019).

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J. N. Pelton (ed.), *Handbook of Small Satellites*,
https://doi.org/10.1007/978-3-030-36308-6_108

The summary of this report from Space News highlighted its five key elements as follows: "The new document retains four objectives from the original version regarding control of debris in normal operations, minimizing debris from accidental explosions, use of safe flight profiles and operational configurations, and post-mission disposal of space structures. The new version adds a fifth objective to cover additional issues, such as operation of cubesats and large constellations as well as satellite servicing." (Jeff Frost, U.S. government updates orbital debris mitigation guidelines. Space News, Dec 9, 2019. https://spacenews.com/u-s-government-updates-orbital-debris-mitigation-guidelines/)

Also provided is the reference documents compiled the NASA that prepared the ODMSP update in coordination with all relevant agencies concerned with orbital space debris issues. It is hoped that these procedures will be considered the U.N. Committee on the Peaceful Uses of Outer Space and the UN Office of Outer Space Affairs updates to the U.N. COPUOS prepared guidelines as official agreed in 2007 and ratified by the U.N. General Assembly.

Keywords

Accidental explosions · Department of Defense · FAA Office of Commercial Space Transportation FAA-AST · FCC · International practices · NASA · Operational orbital regimes · Orbital debris · Orbital debris mitigation · Postmission disposal of space structures · Safe Flight profile · Standard practices · U.N. Committee on the Peaceful Uses of Outer Space · U.N. General Assembly · Upper stages of rockets

1 US Government Orbital Debris Mitigation Standard Practices (ODMSP), November 2019 Update

1.1 Preamble

The United States Government (USG) Orbital Debris Mitigation Standard Practices (ODMSP) were established in 2001 to address the increase in orbital debris in the near-Earth space environment. The goal of the ODMSP was to limit the generation of new, long-lived debris by the control of debris released during normal operations, minimizing debris generated by accidental explosions, the selection of safe flight profile and operational configuration to minimize accidental collisions, and post-mission disposal of space structures. While the original ODMSP adequately protected the space environment at the time, the USG recognizes that it is in the interest of all nations to minimize new debris and mitigate effects of existing debris. This fact, along with increasing numbers of space missions, highlights the need to update the ODMSP and to establish standards that can inform development of international practices.

This 2019 update includes improvements to the original objectives as well as clarification and additional standard practices for certain classes of space operations. The improvements consist of a quantitative limit on debris released during normal operations, a probability limit on accidental explosions, probability limits on accidental collisions with large and small debris, and a reliability threshold for successful postmission disposal. The new standard practices established in the update include the preferred disposal options for immediate removal of structures from the near-Earth space environment, a low-risk geosynchronous Earth orbit (GEO) transfer disposal option, a long-term reentry option, and improved move-away-and-stay-away storage options in medium Earth orbit (MEO) and above GEO. The update also incorporates new sections to clarify and address operating practices for large constellations, rendezvous and proximity operations, small satellites, satellite servicing, and other classes of space operations.

The updated standard practices are significant, meaningful, and achievable. The 2019 ODMSP, by establishing guidelines for USG activities, provides a reference to promote efficient and effective space safety practices for other domestic and international operators. The USG intends to update and refine the ODMSP as necessary in the future to address advances in both technology and policy. The USG will follow the ODMSP, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the conduct of tests and experiments in space. When practical, operators should consider the benefits of going beyond the standard practices and take additional steps to limit the generation of orbital debris. Together with continued development of standards and best practices for space traffic management, the updated ODMSP will contribute to safe space operations and the long-term sustainability of space activities.

2 Objective 1. Control of Debris Released During Normal Operations

Programs and projects will assess and limit the amount of debris released in a planned manner during normal operations. Objects with planned functions after release should follow standard practices set forth in Objectives 2 through 5.

1-1. In all operational orbit regimes: Spacecraft and upper stages should be designed to eliminate or minimize debris released during normal operations. Each instance of planned release of debris larger than 5 mm in any dimension that remains on orbit for more than 25 years should be evaluated and justified. For all planned released debris larger than 5 mm in any dimension, the total debris object-time product in low Earth orbit (LEO) should be less than 100 object-years per upper stage or per spacecraft. The total object-time product in LEO is the sum, over all planned released objects, of the orbit dwell time in LEO.

3 Objective 2. Minimizing Debris Generated by Accidental Explosions

Programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.

2-1. Limiting the risk to other space systems from accidental explosions and associated orbital debris during mission operations: In developing the design of a spacecraft or upper stage, each program should demonstrate, via commonly accepted engineering and probability assessment methods, that the integrated probability of debris-generating explosions for all credible failure modes of each spacecraft and upper stage (excluding small particle impacts) is less than 0.001 (1 in 1000) during deployment and mission operations.

2-2. Limiting the risk to other space systems from accidental explosions and associated orbital debris after completion of mission operations: All on-board sources of stored energy of a spacecraft or upper stage should be depleted or safed when they are no longer required for mission operations or postmission disposal. Depletion should occur as soon as such an operation does not pose an unacceptable risk to the payload. Propellant depletion burns and compressed gas releases should be designed to minimize the probability of subsequent accidental collision and to minimize the impact of a subsequent accidental explosion.

4 Objective 3. Selection of Safe Flight Profile and Operational Configuration

Programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with human-made objects or meteoroids.

3-1. Collision with large objects during orbital lifetime: In developing the design and mission profile for a spacecraft or upper stage, a program will estimate and limit the probability of collision with objects 10 cm and larger during orbital lifetime to less than 0.001 (1 in 1000). For the purpose of this assessment, 100 years is used as the maximum orbital lifetime. 3-2. Collision with small debris during mission operations: Spacecraft design will consider and limit the probability to less than 0.01 (1 in 100) that collisions with micrometeoroids and orbital debris smaller than 1 cm will cause damage that prevents planned postmission disposal.

5 Objective 4. Postmission Disposal of Space Structures

Programs and projects will plan for disposal procedures for a structure (i.e., launch vehicle components, upper stages, spacecraft, and other payloads) at the end of mission life to minimize impact on future space operations.

4-1. Disposal for final mission orbits: A spacecraft or upper stage may be disposed of by one of the following methods:

(a) Direct reentry or heliocentric, Earth-escape: Maneuver to remove the structure from Earth orbit at the end of mission into (1) a reentry trajectory or (2) a heliocentric, Earth-escape orbit. These are the preferred disposal options. For direct reentry, the risk of human casualty from surviving components with impact kinetic energies greater than 15 joules should be less than 0.0001(1 in 10,000). Design-for-demise and other measures, including reusability and targeted reentry away from landmasses, to further reduce reentry human casualty risk should be considered.

(b) Atmospheric reentry: Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to as short as practicable but no more than 25 years after completion of mission. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit. The risk of human casualty from surviving components with impact kinetic energies greater than 15 joules should be less than 0.0001(1 in 10,000).

(c) Storage between LEO and GEO: I. Maneuver to an eccentric disposal orbit (e.g., GEO transfer) where (1) perigee altitude remains above the LEO zone for at least 100 years, (2) apogee altitude remains below the GEO zone for at least 100 years, and (3) the time spent by the structure between 20,182 +/− 300 km is limited to 25 years or less over 200 years; or, II. Maneuver to a near-circular disposal orbit to (1) avoid crossing 20,182 +/− 300 km, the GEO zone, and the LEO zone for at least 100 years, and (2) limit the risk to other

US Government Orbital Debris Mitigation Standard Practices, November 2019 Update 6operational constellations, for example, by avoiding crossing the altitudes occupied by known missions of 10 or more spacecraft using near-circular orbits, for 100 years. d. Storage above GEO: Maneuver to an orbit with perigee altitude sufficiently above 35,986 km (upper boundary of the GEO zone) to ensure the structure remains outside the GEO zone for at least 100 years. e. Long-term reentry for structures in MEO, Tundra orbits, highly inclined GEO, and other orbits: Maneuver to a disposal orbit where orbital resonances will increase the eccentricity for long-term reentry of the structure. In developing this disposal plan, the program should (1) limit the postmission orbital lifetime to as short as practicable but no more than 200 years, (2) limit the time spent by the structure in the LEO zone, the GEO zone, and between 20,182 +/− 300 km to 25 years or less per zone; and (3) limit the probability of collisions with debris 10 cm and larger to less than 0.001 (1 in 1,000) during orbital lifetime. To limit human casualty risk from the reentry of the structure, surviving components with impact kinetic energies greater than 15 joules should have less than 7 m^2 total debris casualty area or less than 0.0001 (1 in 10,000) human casualty risk. f. Direct retrieval: Retrieve the structure and remove it from orbit preferably at completion of mission, but no more than 5 years after completion of mission. 4-2. Reliability of disposal: The probability of successful postmission disposal should be no less than 0.9 with a goal of 0.99 or better. The geosynchronous Earth orbit (GEO) zone is defined as the region between the altitudes of 35,586 and 35,986 km. The low Earth orbit (LEO) zone is defined as the region below 2000 km altitude. The medium Earth orbit (MEO) is the region between LEO and GEO. Because of fuel gauging uncertainties near the end of mission, a program should use a maneuver strategy that reduces the risk of leaving the structure near an operational orbit regime.

6 Objective 5. Clarification and Additional Standard Practices for Certain Classes of Space Operations

These classes of space operations and structures should follow Objectives 1 through 4 plus additional standard practices for orbital debris mitigation set forth in this section.

5-1. Large Constellations: A constellation consisting of 100 or more operational spacecraft cumulative is considered a large constellation. a. Each spacecraft in a large constellation should have a probability of successful postmission disposal at a level greater than 0.9 with a goal of 0.99 or better. In determining the successful postmission disposal threshold, factors such as mass, collision probability, orbital location, and other relevant parameters should be considered. b. For large constellations, Objective 4-1.a. is the preferred post-mission disposal option for the spacecraft. In developing the mission profile, the program should limit the cumulative reentry human casualty risk from the constellation. 5-2. Small satellites, including CubeSats, should follow the standard practices set forth in Objectives 1 through 4. For spacecraft smaller than 10 cm $\times$ 10 cm $\times$ 10 cm when fully deployed: a. Any spacecraft in LEO should be limited to an orbital lifetime as short as practicable but no more than 25 years after completion of mission. b. The total spacecraft object-time product in LEO should be less than 100 object-years per mission. 5-3. Rendezvous, proximity operations, and satellite servicing: In developing the mission profile for a structure, the program should limit the risk of debris generation as an outcome of the operations. The program should (1) limit the probability of accidental collision and (2) limit the probability of accidental explosion resulting from the operations. Any planned debris generated as a result of the operations should follow the standard practices for mission-related debris set forth in Objective 1.

US Government Orbital Debris Mitigation Standard Practices, November 2019 Update 85-4. Safety of Active debris removal operations: In developing the mission profile for an active debris removal operation on a debris structure, the program should limit the risk of debris generation as an outcome of the operation. The program should (1) avoid fragmentation of the debris structure, (2) limit the probability of accidental collision, and (3) limit the probability of accidental explosion resulting from the operations. Any planned debris generated as a result of the operations should follow the standard practices for mission-related debris set forth in Objective 1. The operations should be designed for the debris structure to follow applicable postmission disposal practices set forth in Objective 4. 5-5. Tether systems will be uniquely analyzed for both intact and severed conditions (a) for collision risk with large objects during orbital lifetime and collision risk with small debris during mission operations and (b) when performing trade-offs between alternative disposal strategies.

6.1 Orbital Debris Program Office Reference Documents – NASA

orbitaldebris.jsc.nasa.gov/reference-documents.htm

1. **Technical Report on Space Debris (Adobe PDF 579 kb)**
   This is a report published by the Scientific and Technical Subcommittee (STSC) of the United Nations on space debris in 1999. This report summarizes the reviews within the STSC between 1996 and 1998 on orbital debris measurements, modeling, risk assessments, and mitigation measures.
2. **US Government Orbital Debris Mitigation Standard Practices (Adobe PDF 117 kb)**
   The United States Government has formally stated in this document its objectives and practices of limiting the amount of space debris. The four objectives are (1) control of debris released during normal operations, (2) minimizing debris generated by accidental explosions, (3) selection of safe flight profile and operational configuration, and (4) postmission disposal of space structures.
3. **History of On-Orbit Satellite Fragmentations (Adobe PDF 2,251 kb)**
   The 14th edition of this document was published in 2008. This document summarizes all known satellite and upper stage fragmentations prior to 1 August 2007. Available information includes breakup date, breakup altitude, number of debris generated, and references to each event. Gabbard diagrams for many breakup clouds are also included in the document.
4. **Orbital Debris: A Technical Assessment (Adobe PDF 9,371 kb))**
   This is a document published by US National Research Council in 1995. It examines the methods used to characterize the orbital debris environment and assesses the hazards a debris population poses to spacecraft. Recommendations to improve debris research and the protection of spacecraft and specific recommendations on methods to reduce future debris creation are also included in the document.
5. **Interagency Report on Orbital Debris (Adobe PDF 7,456 kb)**
   This document was published by the National Science and Technology Council Committee on Transportation Research and Development in 1995. It contains an up-to-date portrait of the orbital debris measurement, modeling, and mitigation efforts and a set of recommendations outlining specific steps necessary to minimize the potential hazards posed by orbital debris.
6. **IADC Space Debris Mitigation Guidelines (Adobe PDF 99 kb)**
   This document describes the guidelines adopted by the 11 members of the Inter-Agency Space Debris Coordination Committee (IADC) in 2002 and slightly revised in 2007. The guidelines were developed via consensus within the IADC, with an emphasis on cost effectiveness that can be considered during planning

and design of spacecraft and launch vehicles in order to minimize or eliminate generation of debris during operations.

7. **UN Space Debris Mitigation Guidelines (Adobe PDF 1,382.4 kb)**
   This document describes the guidelines adopted by the Scientific and Technical Subcommittee (STSC) of the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) in February 2007. The guidelines were developed via consensus within the STSC, and the full COPUOS endorsed the guidelines in June 2007, followed by General Assembly endorsement later in 2007. These guidelines are consistent with the US Government Orbital Debris Mitigation Standard Practices and the IADC Space Debris Mitigation Guidelines.
8. **NASA Procedural Requirements for Limiting Orbital Debris – NPR 8715_006B (Adobe PDF 102 kb)**
   NPR8715.6B became effective on 16 Feb 2017. It reflects NASA's policy to limit future orbital debris generation. The applicability, authority, and references of the requirements and the responsibility within NASA organizations are all clearly stated in the document.
9. **NASA Standard 8719.14 (Adobe PDF 445 kb)**
   NASA has adopted a policy to control the generation of orbital debris in NASA Procedural Requirements 8715.6A and has implemented this policy in NASA Standard 8719.14. All NASA flight projects are now required to provide debris assessments and end-of-mission planning as a normal part of the project development.
10. **Handbook for Limiting Orbital Debris – NASA-HDBK 8719.14**
    This NASA-HDBK serves as a companion to NASA Procedural Requirements (NPR) 8715.6A, NASA Procedural Requirements for Limiting Orbital Debris and NASA-STD 8719.14, Process for Limiting Orbital Debris and contains the background and reference materials to aid in understanding the foundation and science for predicting and limiting orbital debris.

7 Conclusion

The current plans for deployment of a significant number of small satellite constellations populated by a large number of satellites numbering in the thousands have greatly raised concerns about orbital space debris and the need for new procedures to be adopted that require more stringent guidelines for the mitigation of the formation of new space debris. The analysis that has been undertaken by the Aerospace Corporation has suggested that all of the large constellations that are being deployed or that have been proposed could result in unintended collisions both during deployment and during removal at end of life (Muelhaupt et al. 2019).

The USA has undertaken several efforts to devise stricter controls to monitor all launches so as to prevent the formation of new debris and ensure safe removal of space structures at end of life. It has sought to share this information with the international community to seek tighter procedures that are enforced around the world.

8 Cross-References

- ▶ Analysis of Orbit Debris
- ▶ Companies Involved in Design, Manufacture, and Testing of Small Satellites
- ▶ Forms for Registration of Small Satellites Consistent with the Registration Conventions
- ▶ Global Launch Vehicle Systems for Potential Small Satellite Deployment
- ▶ Partial Listing of Small Satellite Constellations and Related System Infrastructure
- ▶ UN Sustainable Development Goals for 2030
- ▶ US Space Policy Directive-3: National Space Traffic Management Policy

References

T.J. Muelhaupt, M.E. Sorge, J. Morin, R.J. Wilson, Space traffic management in the new space era. J. Space Saf. Eng. **6**(2), 80 (2019)