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 postmission 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.

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.

MITIGATION STANDARD PRACTICES

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.

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.

MITIGATION STANDARD PRACTICES

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 1,000) 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.

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.

MITIGATION STANDARD PRACTICES

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 1,000). 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.

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.

MITIGATION STANDARD PRACTICES

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 operational 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.

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 the additional standard practices for orbital debris mitigation set forth in this section.

MITIGATION STANDARD PRACTICES

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 postmission 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 × 10 cm × 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.

5-4. *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.