

Orbital Debris Mitigation Policy and Unique Challenges for Small Satellites

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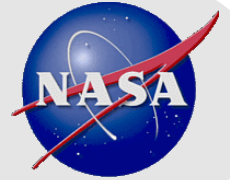
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Small Satellite Conference, Logan, Utah, 10 August 2015



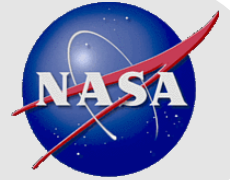
Outline

- **Orbital Debris Mitigation Policies and Guidelines**
 - NASA
 - United States
 - International community
- **Challenges for the Small Satellite Community**
 - Proliferation of CubeSats
 - Mega-Constellations



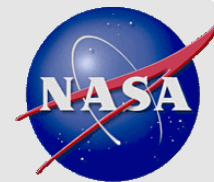
Objective of Orbital Debris Mitigation

- **Objective of Orbital Debris Mitigation:**
 - **To prevent the generation of new and long-lived orbital debris in the environment**



NASA and USG Orbital Debris Mitigation

- **NASA was the first organization to develop orbital debris mitigation policy and guidelines in the 1990s.**
 - NASA Management Instruction (NMI) 1700.8 “*Policy for Limiting Orbital Debris Generation*” was established in 1993.
 - NASA Safety Standard (NSS) 1740.14 “*Guidelines and Assessment Procedures for Limiting Orbital Debris*” established the first detailed set of mitigation guidelines for NASA missions in 1995.
- **NASA and DoD led the effort to establish the U.S. Government Orbital Debris Mitigation Standard Practices (approved in 2001).**
- **The U.S. National Space Policy of 2006 and 2010 directs agencies and departments to implement the U.S. Government Orbital Debris Mitigation Standard Practices.**

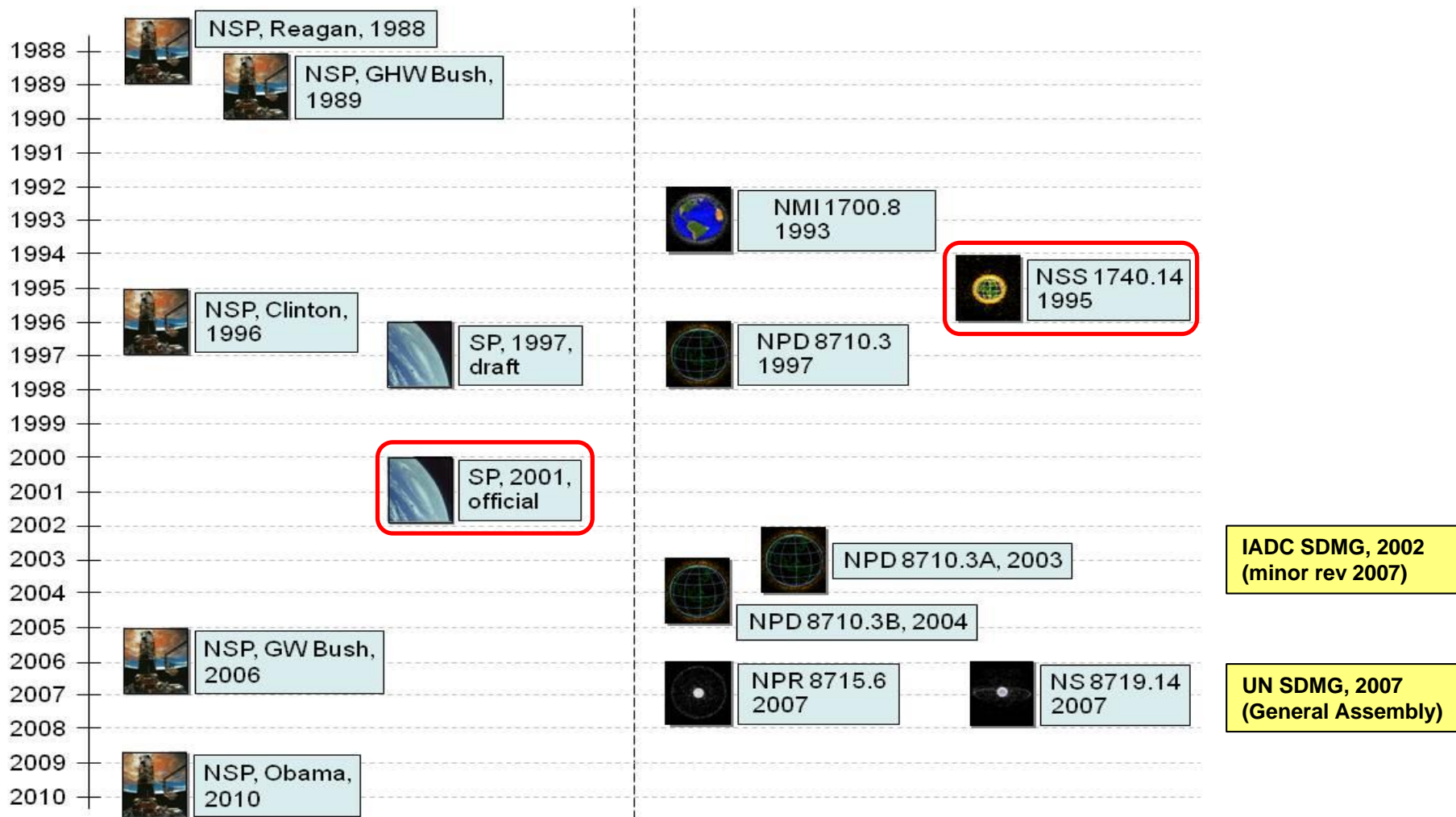


History of Orbital Debris Mitigation Policies and Requirements

U.S. Orbital Debris Mitigation Policy and Standard Practices (SP)

NASA Debris Mitigation Policy and Requirements

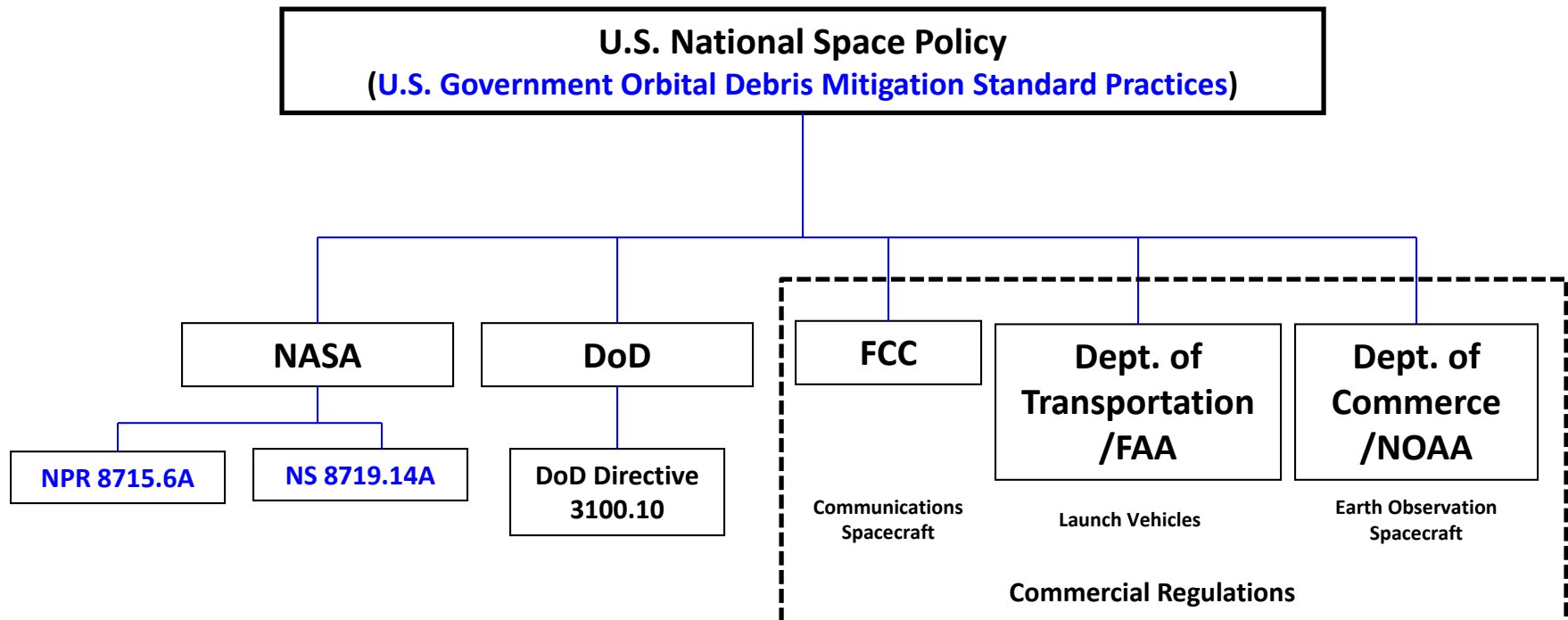
IADC and UN Guidelines

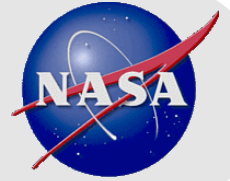




U.S. Orbital Debris Mitigation Policies

- All current U.S. government requirements and commercial regulations for orbital debris mitigation are derived from the 2001 U.S. Government Orbital Debris Mitigation Standard Practices, which are cited in U.S. National Space Policy in 2006 and 2010.





USG OD Mitigation Standard Practices, Objective 1

- **Eliminate or minimize mission-related debris. Limit the orbital lifetime of such debris to 25 years.**

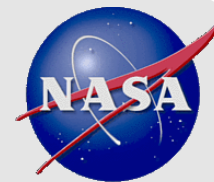
OBJECTIVE

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.

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 on the basis of cost effectiveness and mission requirements.



USG OD Mitigation Standard Practices, Objective 2

- **Use design and procedures to avoid accidental explosions during mission operations and after disposal (passivation).**

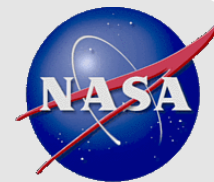
OBJECTIVE

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 during mission operations:* In developing the design of a spacecraft or upper stage, each program, via failure mode and effects analyses or equivalent analyses, should demonstrate either that there is no credible failure mode for accidental explosion, or, if such credible failure modes exist, design or operational procedures will limit the probability of the occurrence of such failure modes.
- 2-2. *Limiting the risk to other space systems from accidental explosions 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.



USG OD Mitigation Standard Practices, Objective 3

- **Avoid collisions with large debris and protect against collisions with small debris.**

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 man-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 known objects during orbital lifetime.
- 3-2. *Collision with small debris during mission operations:* Spacecraft design will consider and, consistent with cost effectiveness, limit the probability that collisions with debris smaller than 1 cm diameter will cause loss of control to prevent post-mission disposal.
- 3-3. *Tether systems* will be uniquely analyzed for both intact and severed conditions.



USG OD Mitigation Standard Practices, Objective 4

- **Postmission disposal**
 - LEO: follow the 25-year rule and limit human casualty reentry risk to 1 in 10,000
 - GEO: Maneuver to a graveyard orbit ~300 km above GEO

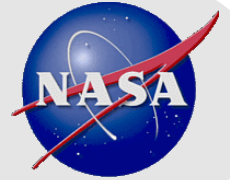
OBJECTIVE

4. POSTMISSION DISPOSAL OF SPACE STRUCTURES

Programs and projects will plan for, consistent with mission requirements, cost effective disposal procedures for launch vehicle components, upper stages, spacecraft, and other payloads at the end of mission life to minimize impact on future space operations.

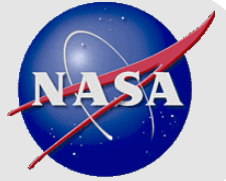
MITIGATION STANDARD PRACTICES

- 4-1. *Disposal for final mission orbits:* A spacecraft or upper stage may be disposed of by one of three methods:
- a. *Atmospheric reentry option:* Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer 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



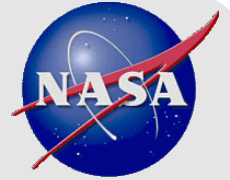
The 25-year Rule and the Reentry Risks

- **NASA Safety Standard 1740.14 (1995) first established the guideline for all LEO spacecraft and upper stages to remain in orbit for no more than 25 years after end-of-mission to protect the space environment.**
 - This guideline is now accepted by the U.S. Government and many foreign space agencies and international bodies.
- **However, such uncontrolled reentries shift on-orbit satellite collision risks to human casualty risks on Earth.**
 - If a random reentry results in a human casualty risk greater than 1 in 10,000, then a controlled reentry must be conducted to ensure the risk is below the acceptable threshold.



Inter-Agency Space Debris Coordination Committee (IADC)

- **The IADC is an international forum of national and multi-national space agencies for the coordination of activities related to space debris.**
 - IADC members: ASI, CNES, CNSA, CSA, DLR, ESA, ISRO, JAXA, KARI, NASA, ROSCOSMOS, SSAU, and UKSA.
- **More than 100 orbital debris specialists meet annually to exchange information and to work on specified Action Items.**
- **IADC developed first consensus on international orbital debris mitigation guidelines in October 2002; subsequently submitted to the United Nations.**



Orbital Debris at the United Nations (UN)

- **The subject of orbital debris has been on the agenda of the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) since 1994.**
- **The IADC Space Debris Mitigation Guidelines were reviewed and discussed at STSC in both 2003 and 2004.**
- **STSC Member States adopted a similar set of space debris mitigation guidelines in Feb 2007, followed by adoption of the full COPUOS in June 2007 and by the full General Assembly in late 2007.**



UN Space Debris Mitigation Guidelines

- 1. Limit debris released during normal operations.**
- 2. Minimize the potential for break-ups during operational phases.**
- 3. Limit the probability of accidental collision in orbit.**
- 4. Avoid intentional destruction and other harmful activities.**
- 5. Minimize potential for post-mission break-ups resulting from stored energy.**
- 6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission.**
- 7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with geosynchronous Earth orbit (GEO) region after the end of their mission.**



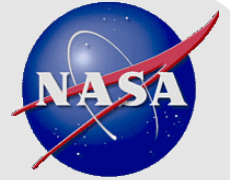
Orbital Debris Mitigation for Small Satellites

- **Small satellites are subject to current orbital debris mitigation policy, guidelines, and requirements.**
 - The NASA Procedural Requirements for Limiting Orbital Debris, the FCC debris mitigation regulations, the U.S. Government Orbital Debris Mitigation Standard Practices, the IADC Space Debris Mitigation Guidelines, and the UN Space Debris Mitigation Guidelines have no automatic exclusions for any satellite due to its size or mass limit.
 - Key requirements include: limit accidental explosions, limit accidental collisions with large objects, follow post-mission disposal, and limit reentry casualty risk.



New and Unique Challenges for Small Satellites

- **Due to the likelihood of large deployments and the recently proposed mega-constellations, small satellites present several new and unique challenges to the space environment and to other operational spacecraft.**
 - Increased collision risks to other operational spacecraft if the small satellites, especially CubeSats and smaller, cannot be tracked and cannot maneuver.
 - Increased collision risks to further debris population growth.
 - **Adding hundreds or more CubeSats to the environment on a regular basis will increase collision probabilities in the environment.**
 - **Placing hundreds or thousands of small satellites on similar 25-year decay orbits about the same time is problematic.**
 - Collective reentry human casualty risks.
 - Increased debris-generating chain reaction potential at the mega-constellation mission altitude.



Solutions

- **Trackability**
 - Ensure CubeSats or larger above operational spacecraft can be tracked by JSpOC.
 - Ensure large deployments of picosats and femtosats above operational spacecraft can be tracked by JSpOC.
- **Maneuverability**
 - Ensure smallsats can maneuver for collision avoidance and post-mission disposal (graveyard or 25-year orbits, controlled reentry if necessary), and include development of collision avoidance plans and procedures in mission planning.
- **Reliability**
 - Ensure high mission reliability (spacecraft and formation maintenance) for mega-constellations.
- **Careful post-mission planning for mega-constellations**
 - Conduct direct reentry or post-mission disposal in phases.



Questions?

