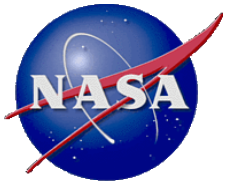
National Aeronautics and Space Administration

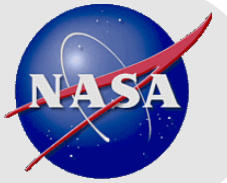


NASA & US Government Orbital Debris Mitigation Policies

Jack Bacon
NASA Orbital Debris Program Office

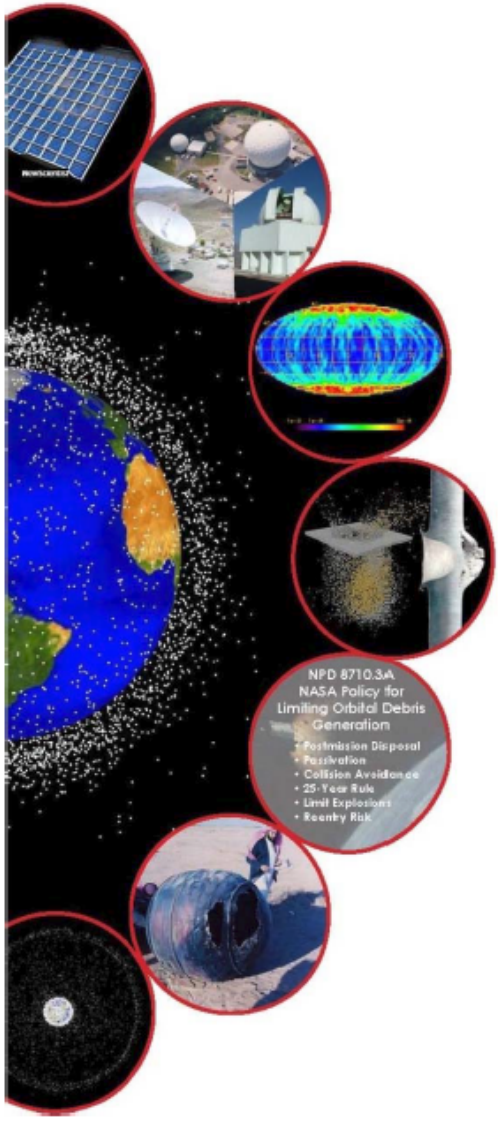
8th Range Safety Conference Tel Aviv Israel December 23-24 2019

Outline



- **NASA's Orbital Debris Office & how we fit within the US Govt. broader space activities**
- **The basics of space risks addressed by US and international standards**
- **The flow, history, and applicability of NASA, US, and international space safety requirements**
- **The VERY recent update to US Govt. Orbital Debris Standard Practices (~400 hours…)**

NASA Orbital Debris Program Office



- **The ODPO is the only organization in the U.S. Government (USG) conducting a full range of research on orbital debris (OD)**
  - This unique NASA capability was established at JSC in 1979 (D. Kessler, J. Loftus, B. Cour-Palais, *etc.*)
  - ODPO's roles and responsibilities are defined in NASA Procedural Requirements NPR 8715.6B
- **ODPO provides technical and policy support to NASA HQ, OSTP, NSpC, and other USG and commercial organizations**
- **ODPO represents the USG in international fora (IADC, United Nations, *etc.*)**
- **ODPO is recognized as a pioneer and leader in environment definition and modeling, and in mitigation policy development**

Roles and Responsibilities of the ODPO

a. *Develops, maintains, and updates the orbital debris environment models and associated uncertainties to support the Chief, SMA, and programs and projects with the mitigation of orbital debris risk, and compliance with this NPR.*

b. *Conducts measurements of the orbital debris environment and conducts other research as needed to support the development of the orbital debris environment models.*

c. *Assists NASA mission project managers in technical orbital debris assessments by providing information and completing evaluations of the Orbital Debris Assessment Reports (ODARs) and End of Mission Plans (EOMPs) on behalf of the SMA Technical Authority.*

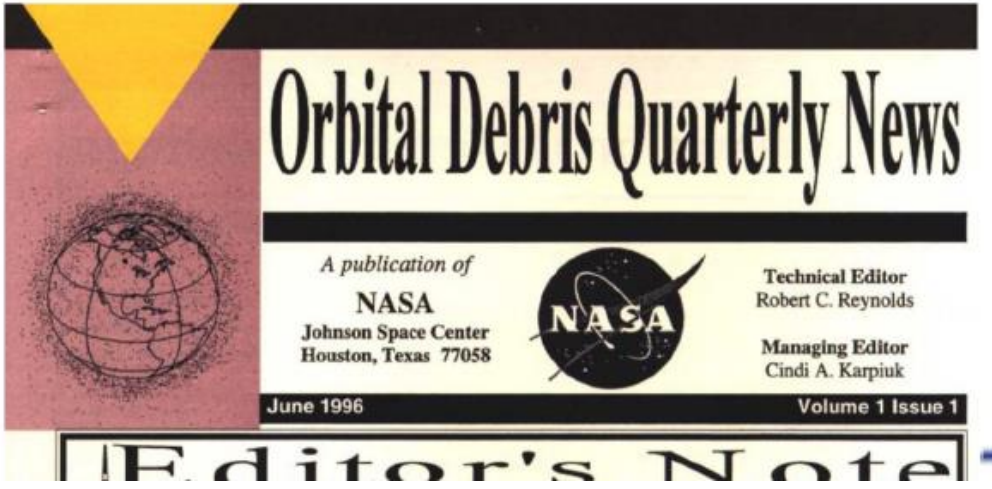
d. *Assists the Department of Defense and other U.S. Government departments and organizations on matters related to the characterization of the orbital debris environment and the application of orbital debris mitigation measures and policies.*

e. *Contributes to the determination, adoption, and use of international orbital debris mitigation guidelines through international forums such as the United Nations Committee on the Peaceful Uses of Outer Space, the IADC, and ISO.*

(NASA Procedural Requirement 8715.6B, 16 Feb 2017)

Inquiries and Outreach

- **The ODPO responds to inquiries from USG (Congress, OMB, OSTP, *etc*.) and media on a regular basis**
- **The ODPO maintains a website and publishes the NASA Orbital Debris Quarterly News (ODQN)**
- – ODPO's website: https://orbitaldebris.jsc.nasa.gov/
- – ODQNs cover the latest events in orbital debris news, research,
- statistics, project reviews, meeting reports, and upcoming events
- – There are 1650+ ODQN subscribers from the global space community


Orbital Debris Quarterly News

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Robert C. Reynolds

Managing Editor
Cindi A. Karpiuk

June 1996 Volume 1 Issue 1

Editor's Note


National Aeronautics and Space Administration

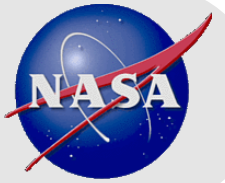
Orbital Debris
Quarterly News

Volume 22, Issue 2
May 2018

Inside...
2018 UN COPUOS Meeting 2

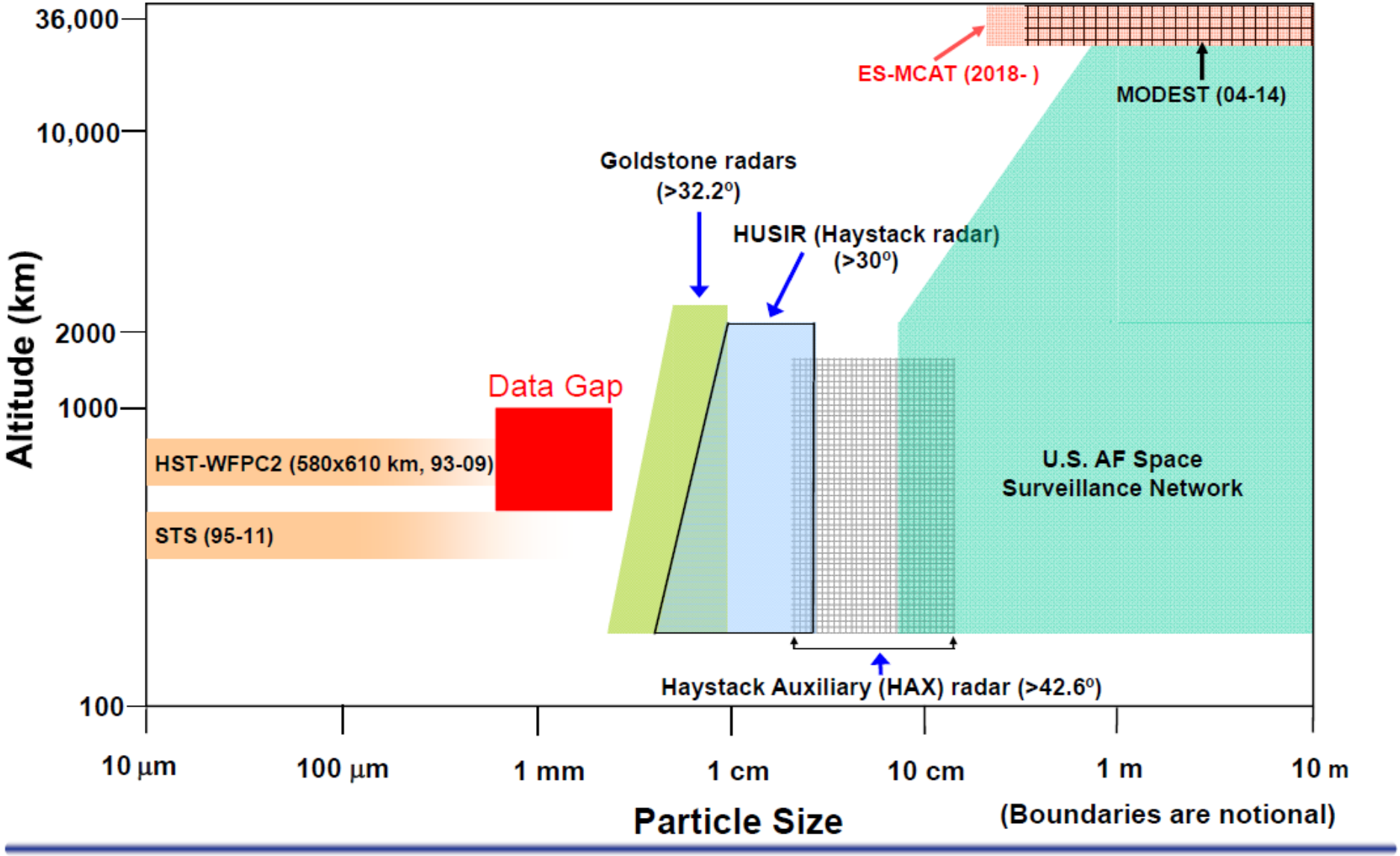
Space Debris Sensor On Orbit Status

ODPO Tasks



- **The ODPO is charged with:**
  - **Sensing and counting orbital debris populations**
  - **Modeling the past, present, and future debris environments**
  - **Assessing mitigation measures to limit the growth of orbital debris**
  - **Assessing safety of spacecraft re-entry**
  - **Contributing technical support to US debris policy**
  - **Participating on behalf of the US Government in international space policy negotiations**
  - **Writing and enforcing NASA policies and standards for orbital debris and safe disposal practices**

NASA Measurement Coverage on Small Debris



Highest Risk to Space Missions in LEO

- **Millimeter-sized orbital debris represents the highest penetration risk to most operational (robotic) spacecraft in LEO**
  - As concluded by a recent NASA Engineering and Safety Center panel study (NASA/TM 2015-218780)
- **Currently, more than 400 missions operate between 600 and 1000 km altitudes**
- **There is a lack of data on such small debris above 600 km altitudes**
  - Direct measurement data on such small debris is needed to support the development and implementation of cost-effective protective measures for the safe operations of future missions

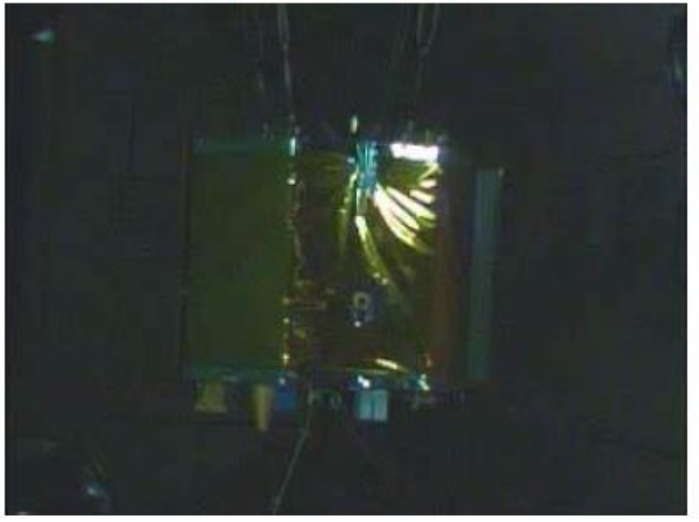
UN Space Debris Mitigation Guidelines

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) **AND the Semi-Synchronous (MEO)** region after the end of their mission.

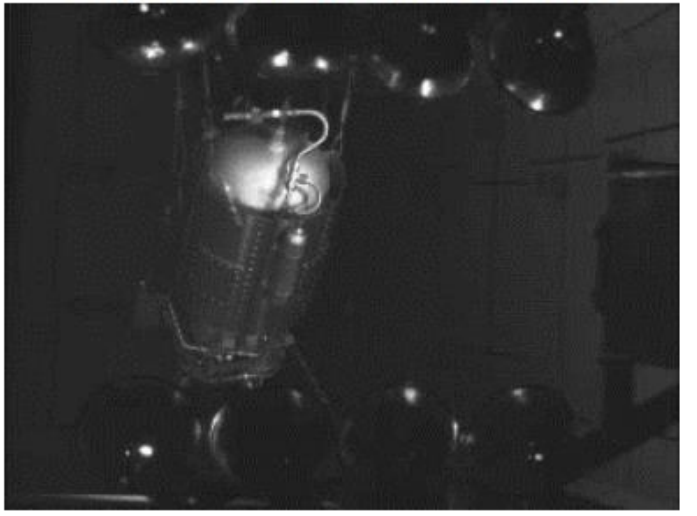
DebriSat and DebrisLV

- **The DebriSat test and a pre-test shot on a small launch vehicle markup ("DebrisLV") were conducted in 2014**
- **Post-test fragment processing and characterization efforts are underway**
  - ~172,000 fragments (≥2 mm) extracted from foam panels so far
  - More than 26,000 fragments fully characterized

A ~9 cm, 570-g projectile impacted DebriSat at 6.8 km/s



A ~9 cm, 598-g projectile impacted DebrisLV at 6.9 km/s



ORSAT

- **Reentry risk assessments are required for all NASA missions**
  - For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 1 in 10,000 (NASA Standard 8719.14A)
- **Object Reentry Survival Analysis Tool (ORSAT) is a high fidelity reentry model developed/maintained by the ODPO to support NASA missions**

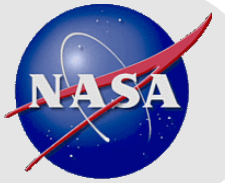
Delta II propellant tank (Georgetown, TX, 1997)

Titanium casting of STAR-48B SRM (Saudi Arabia, 2001)

Titanium casting of STAR-48B SRM (Argentina, 2004)

All photos courtesy The Aerospace Corporation

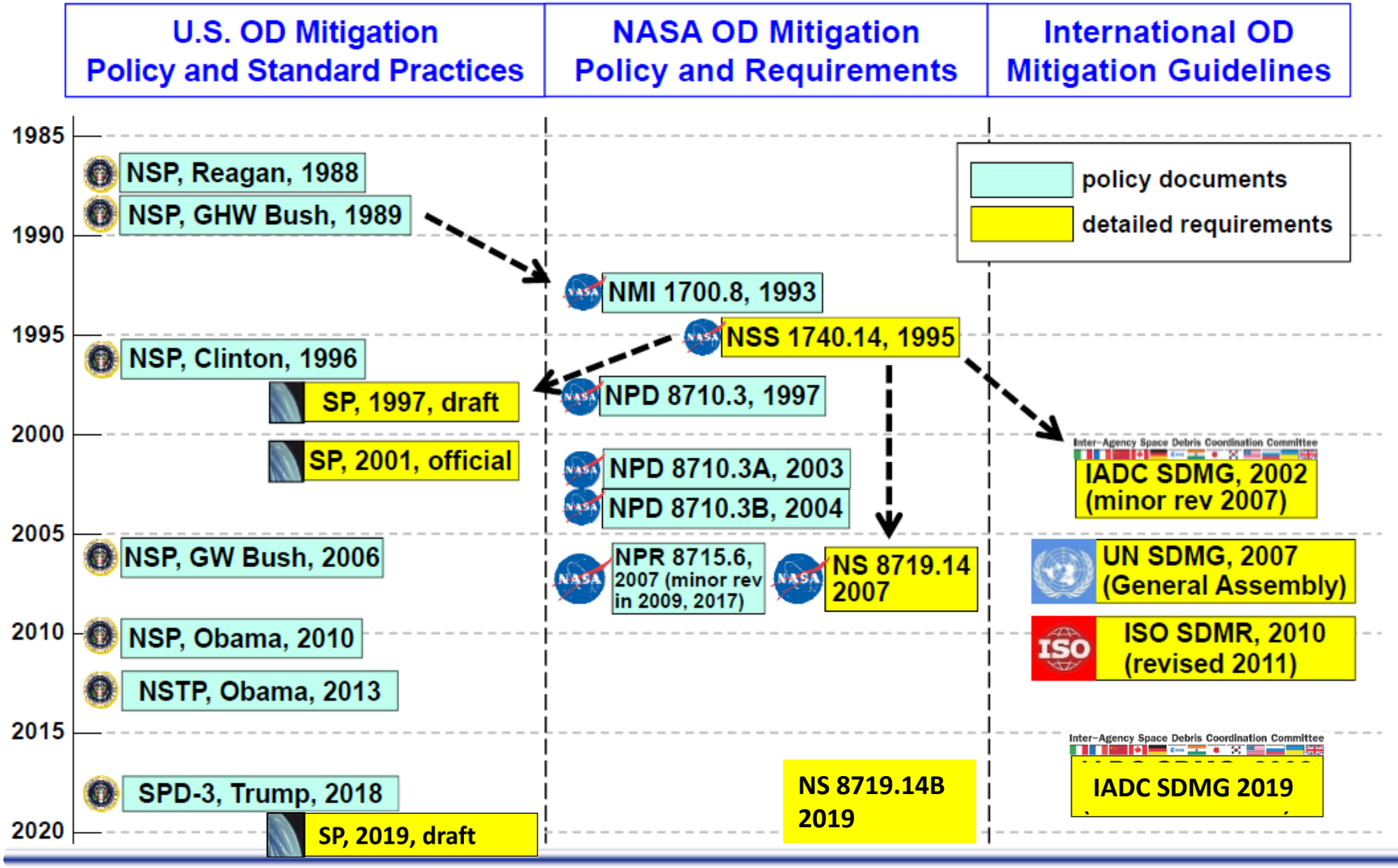
NASA and USG Orbital Debris Mitigation



- **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 directed agencies and departments to implement the U.S. Government Orbital Debris Mitigation Standard Practices. (ODMSP)**
- **The current administration's Space Policy Directive #3 (June 2018) directs all US agencies to collaborate on and to implement a major revision to the ODMSP**
  - **Draft is complete: ~~Now in final review~~ Officially released Dec 9, 2019**
  - **Implementation likely to have a 9-12 month window**

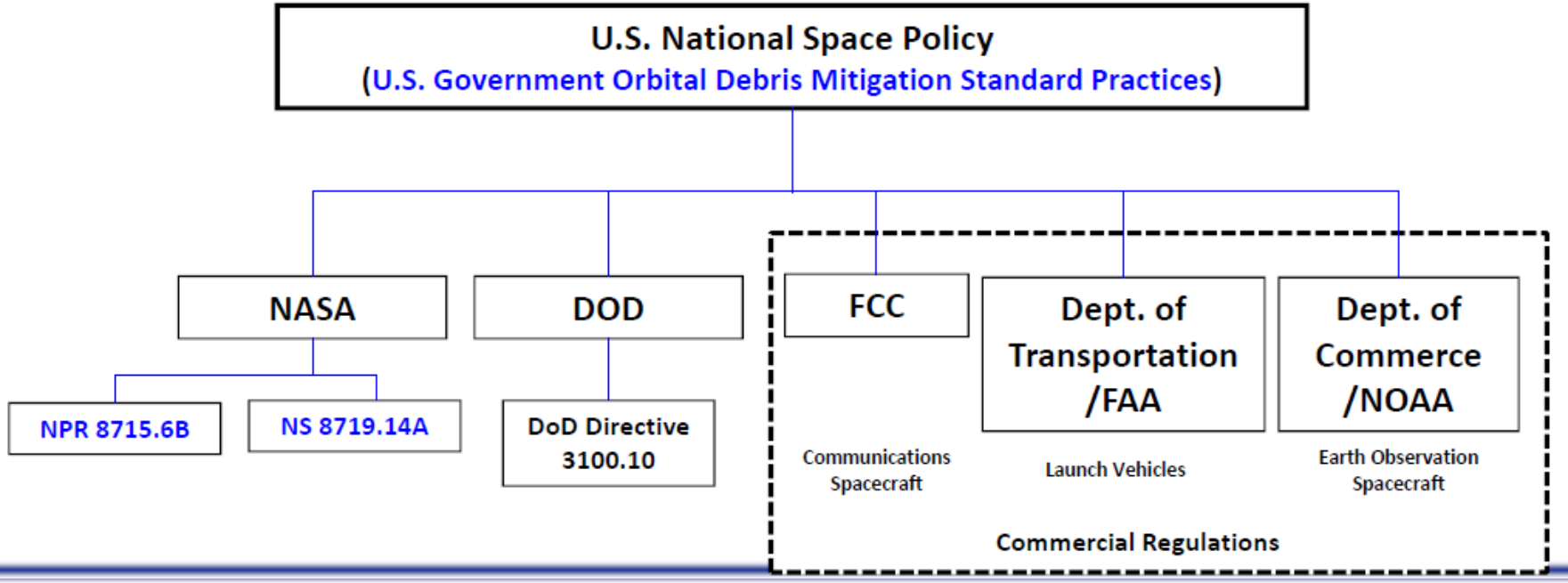
National Aeronautics and Space Administration

History of NASA, USG, and International OD Mitigation Policies and Requirements



USG Orbital Debris Mitigation Standard Practices

- NASA and DOD led the effort to establish the USG Orbital Debris Mitigation Standard Practices (2001)
- The U.S. National Space Policies of 2006 and 2010 direct agencies and departments to implement the USG Orbital Debris Mitigation Standard Practices



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.**
  - **Consensus on 25 year rule in 2019**
  - **Current work on influences of Large Constellations**
  - **NOTE: Not a Space Traffic Management Organization.**

SPD 3 (June 18, 2018)

Sec. 5. Guidelines….

(a) Managing the Integrity of the Space Operating Environment

…

(iii) Mitigating Orbital Debris. It is in the interest of all space operators to minimize the creation of new orbital debris. Rapid international expansion of space operations and greater diversity of missions have rendered the current U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP) inadequate to control the growth of orbital debris. These standard practices should be updated to address current and future space operating environments.

The United States should develop a new protocol of standard practices to set broader expectations of safe space operations in the 21st century. This protocol should begin with updated ODMSP, but also incorporate sections to address operating practices for large constellations, rendezvous and proximity operations, small satellites, and other classes of space operations. These overarching practices will provide an avenue to promote efficient and effective space safety practices with U.S. industry and internationally.

The United States should pursue active debris removal as a necessary long-term approach to ensure the safety of flight operations in key orbital regimes. This effort should not detract from continuing to advance international protocols for debris mitigation associated with current programs.

*See: https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

SPD 3 (June 18, 2018)

Sec. 6. Roles and Responsibilities…:

(a) ….

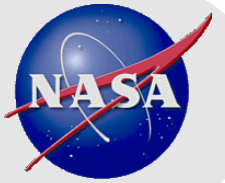
(b) Mitigate the Effect of Orbital Debris on Space Activities.

(i) The Administrator of the National Aeronautics and Space Administration (NASA Administrator), in coordination with the Secretaries of State, Defense, Commerce, and Transportation, and the Director of National Intelligence, and in consultation with the Chairman of the Federal Communications Commission (FCC), shall lead efforts to update the U.S. Orbital Debris Mitigation Standard Practices and establish new guidelines for satellite design and operation, as appropriate and consistent with applicable law.

(ii) The Secretaries of Commerce and Transportation, in consultation with the Chairman of the FCC, will assess the suitability of incorporating these updated standards and best practices into their respective licensing processes, as appropriate and consistent with applicable law.

*See: https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

USG OD Mitigation Standard Practices, Objective 1



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

U.S. Government
Orbital Debris Mitigation Standard Practices, November 2019 Update

OBJECTIVE

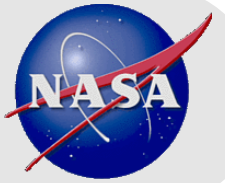
1. CONTROL OF DEBRIS RELEASED DURING NORMAL OPERATIONS

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.

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 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.

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

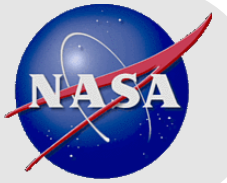
Programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with human-made objects or meteoroids.

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.

USG OD Mitigation Standard Practices, Objective 4



- **Postmission disposal:**
- **4 Options: Heliocentric, Targeted/Accelerated Entry, Natural Entry, Graveyard**
  - **Natural decay limited to < 25 years**
  - **Several graveyard regions are indefinitely stable, away from LEO, GEO, and MEO**

OBJECTIVE

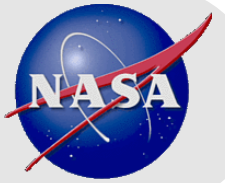
4. POSTMISSION DISPOSAL OF SPACE STRUCTURES

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

…(a very detailed and lengthy section)…

USG OD Mitigation Standard Practices, Objective 5



- **NEW Practices for Evolving Space Operations Regimes:**
  - **Large Constellations**
  - **Small Satellites**
  - **Satellite Servicing**
  - **Active Debris Removal**
  - **Tether systems* (*relocated)**

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.

Objective 5 (Part 1)

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.

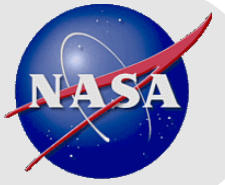
Objective 5 (Part 2)

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

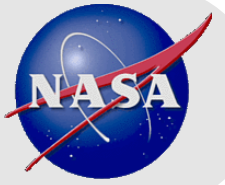
b. when performing trade-offs between alternative disposal strategies**.**

The 25-year Rule and the Reentry Risks



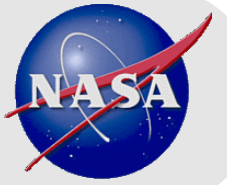
- **NASA Safety Standard 1740.14 (1995) first established the guideline for all LEO spacecraft and upper stages to remain in orbit for no more than 25 years after end-of-mission to protect the space environment.**
  - This guideline is now accepted by the U.S. Government and many foreign space agencies 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.

Orbital Debris at the United Nations (UN)



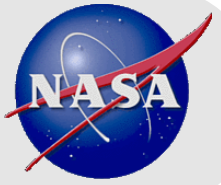
- **The subject of orbital debris has been on the agenda of the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) since 1994.**
- **The IADC Space Debris Mitigation Guidelines were reviewed and discussed at STSC in both 2003 and 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.**

Summary



- **NASA's ODPO is a global center of expertise in all aspects of orbital debris and spacecraft entry.**
- **The US government's regulations in such matters are subject to government-wide coordinated guidelines, but enforced at the agency level**
- **Government-to-Government coordination of regulations and global agreements is through the IADC and UN**

- **The US Government policy for orbital debris has undergone a major update within the last 2 weeks to respond to the evolving space environment.**
  - **And all the wheels listed above are in motion….**



Questions?

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