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Orbital Debris Activities at NASA

J.-C. Liou (NASA)

The NASA Orbital Debris Program Office (ODPO) was established at the NASA Johnson Space Center in 1979. The ODPO is the only organization in the U.S. government conducting a full range of research activities on orbital debris. The activities include radar, optical, in-situ, laboratory measurements; near- and long-term environment modeling; risk assessments and mission support; and policy development. This overview presentation will focus on three areas. The first is an assessment of the current and future orbital debris environment and the key aspects of long-term environment management. The second is a review of the top risk to NASA missions in low Earth orbit and the efforts to collect direct measurement data on the risk driver, the millimeter-sized orbital debris, to improve the safe operations of future missions. The third is a review of the history of the orbital debris mitigation policy development and an on-going effort to update the U.S. Government Orbital Debris Mitigation Standard Practices per the U.S. Space Policy Directive-3, the U.S. National Space Traffic Management Policy.

Biography

J.-C. Liou

Dr. J.-C. Liou is the NASA Chief Scientist for Orbital Debris and the Program Manager for the NASA Orbital Debris Program Office. He has more than 20 years of experience leading various orbital debris measurement and modeling projects. Dr. Liou serves as the Head of the NASA delegation to the Inter-Agency Space Debris Coordination Committee (IADC) and is a member of the U.S. government delegation to the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS).

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Orbital Debris Activities at NASA

J.-C. Liou, PhD
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The 8th JAXA Space Debris Workshop
JAXA Chofu Aerospace Center, 3-5 December 2018

Outline

- **Assessments of the current and future orbital debris (OD) environment**
- **Top OD risk to NASA missions**
- **OD mitigation and Space Policy Directive-3 (SPD-3)**

Orbital debris = human-made debris in Earth orbit
Space debris = micrometeoroids and orbital debris (MMOD)

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Current and Future Orbital Debris Environment

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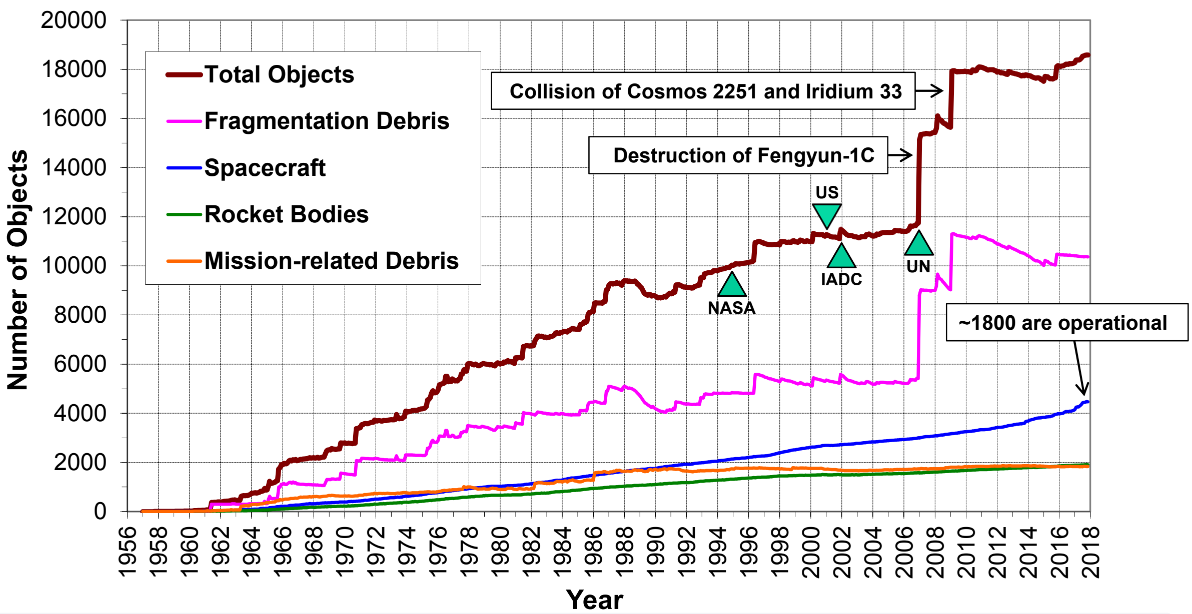
Growth of the Cataloged Populations

- **The U.S. Combined Space Operations Center (CSpOC) tracks ~23,000 large objects and catalogs most of their orbits**



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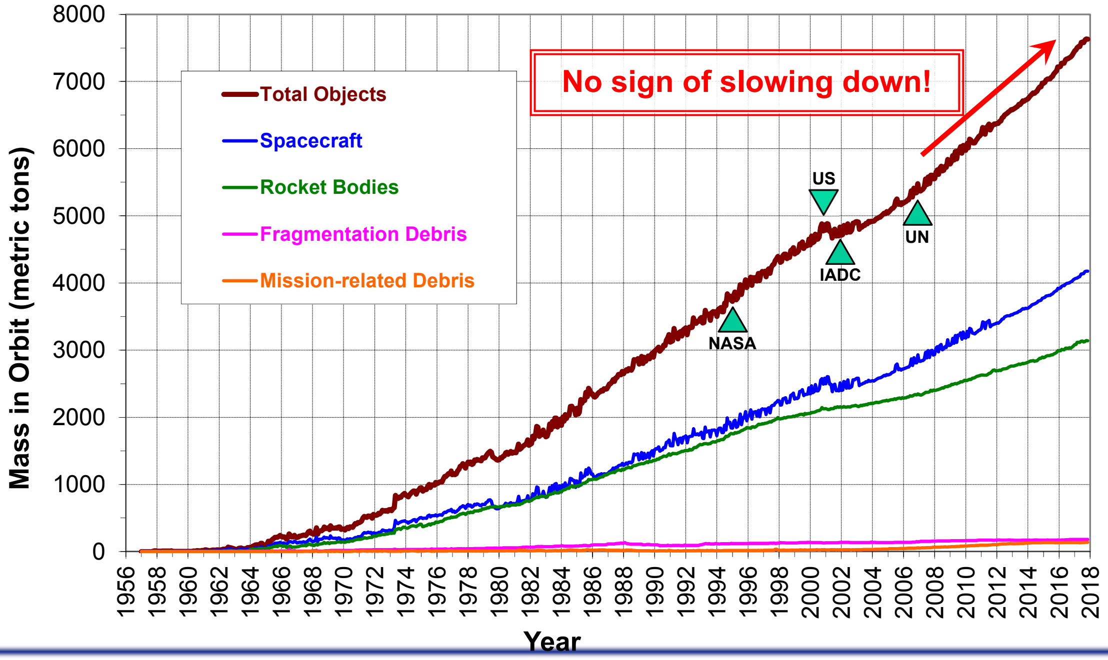
Mass in Orbit Continues to Increase

- The material mass in Earth orbit continues to increase and has exceeded 7600 metric tons



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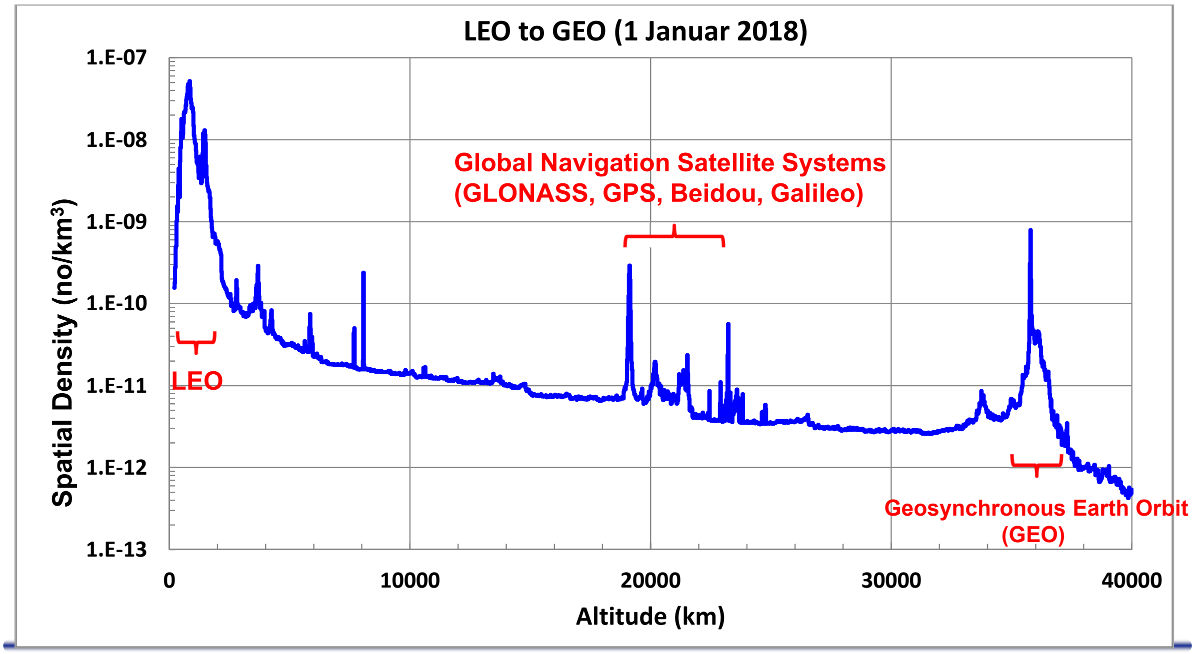
Distribution of the Cataloged Objects, LEO-to-GEO

- The low Earth orbit (LEO, the region below 2000 km altitude) has the highest concentration of the cataloged objects, followed by GEO.



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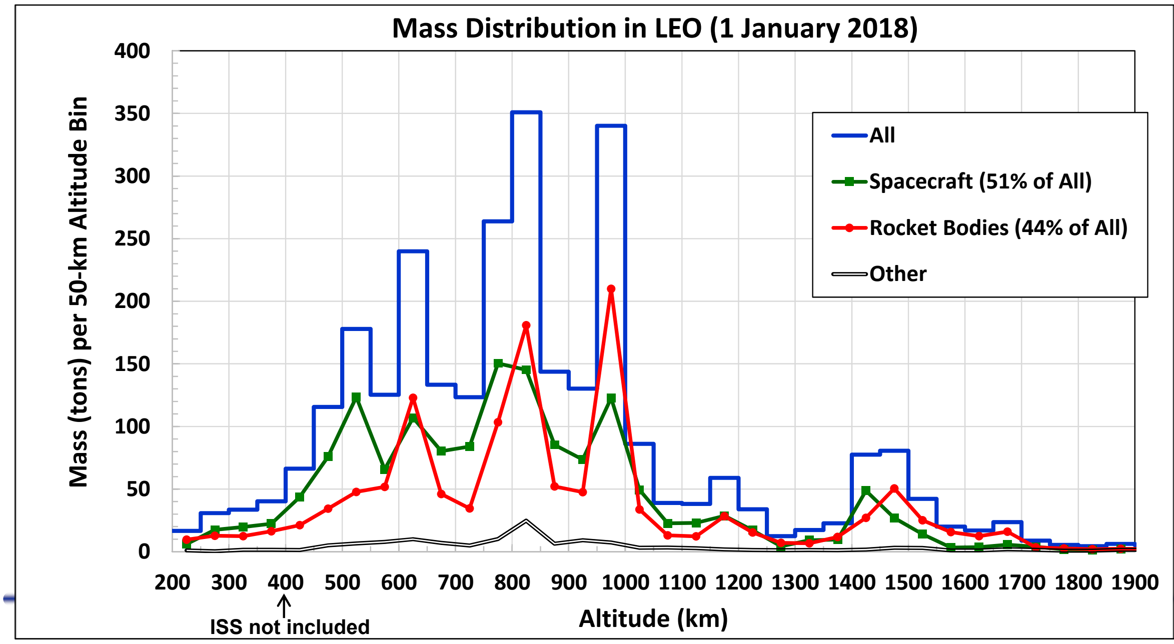
Current Mass in LEO

- **Mass distribution is dominated by rocket bodies and spacecraft.**
- **Large constellations, consisting of thousands of ~150-300 kg class spacecraft, will dramatically change the landscape in LEO.**



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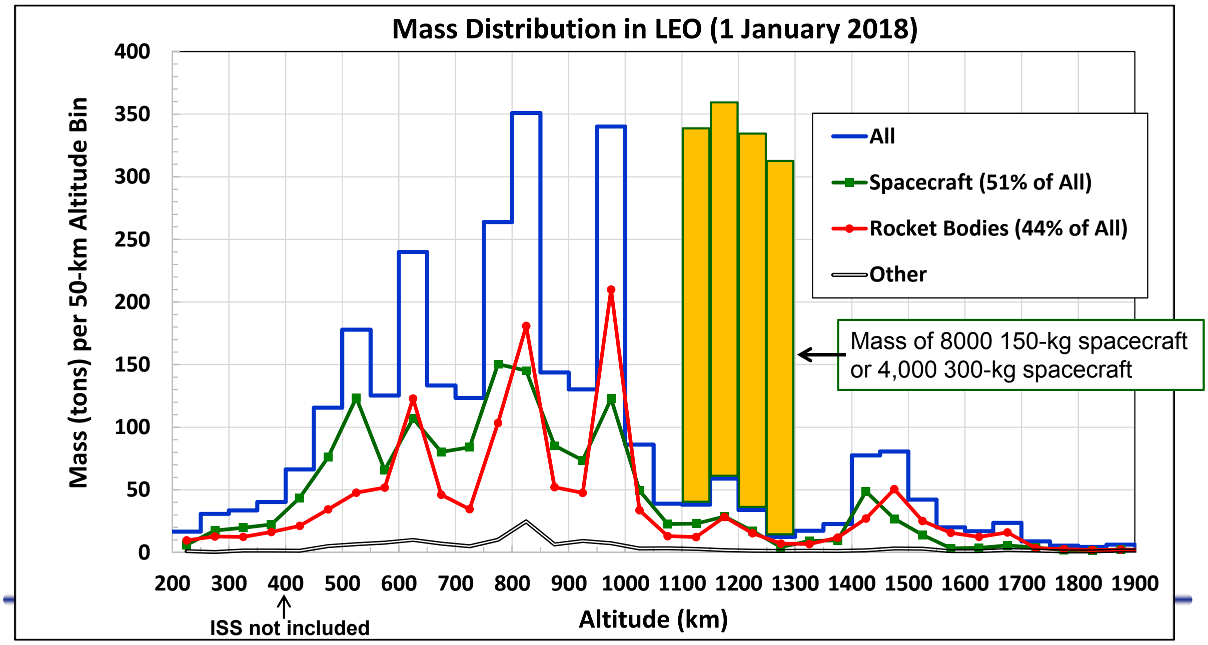
LEO with Large Constellations

- **Eight thousand 150-kg-class spacecraft at 1100-1300 km altitudes will add 1200 tons of material to the region, and all spacecraft are planned to be replenished every ~5 years.**



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OD Environment Management

- **"Prevention is better than cure"**
  - (*Prov*.) It is better to try to keep a bad thing from happening than it is to fix the bad thing once it has happened.
- **"An ounce of prevention is worth a pound of cure"**
  - (*Prov*.) It is better/cheaper to stop something bad from happening than it is to deal with it after it has happened.

- **Orbital Debris Mitigation = Prevention**
- **Orbital Debris Remediation = Cure**

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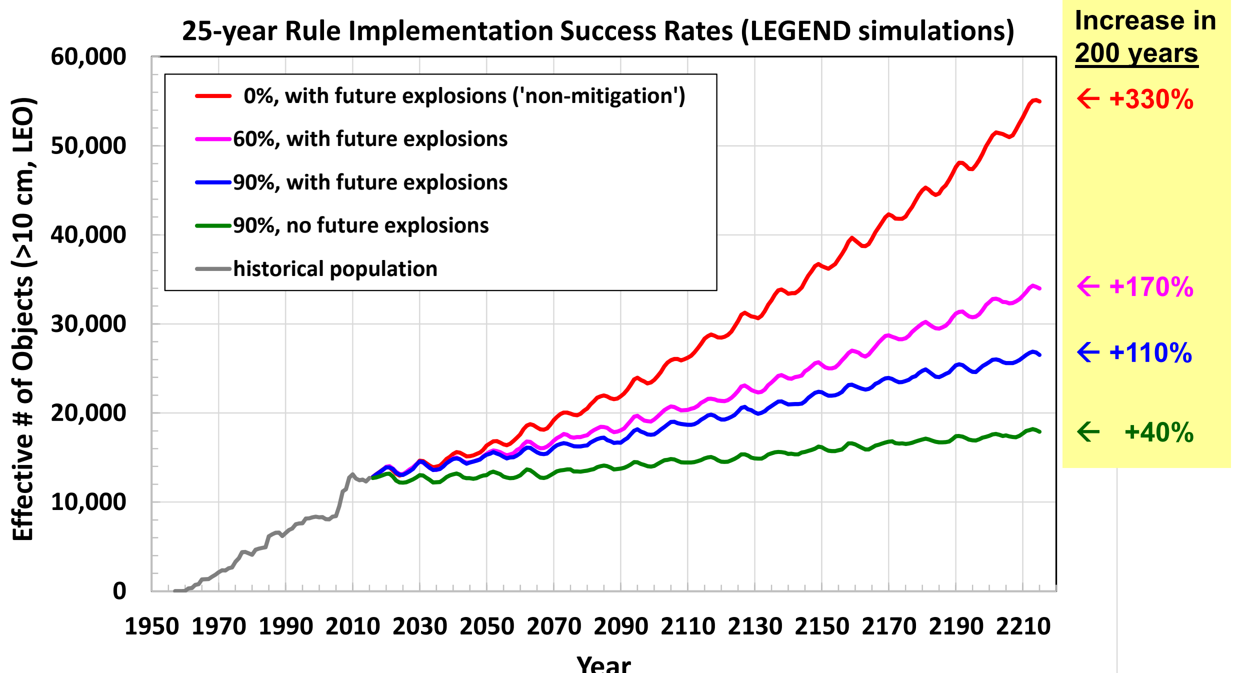
Effectiveness of OD Mitigation



(Liou, et al., *ODQN*, 2018)

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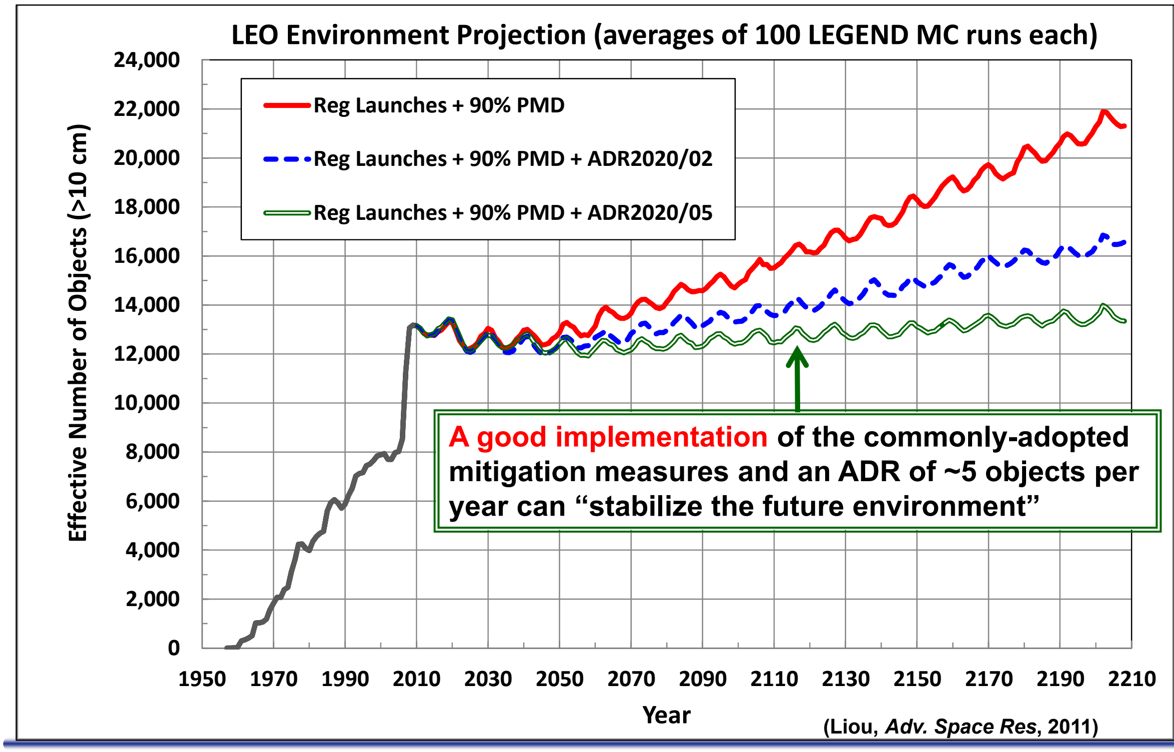
Long-Term Environment Management with ADR



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Active Debris Removal in the U.S.

- **U.S. Space Policy Directive-3**
  - On June 18, 2018, during the third meeting of the National Space Council, the President signed Space Policy Directive-3 (SPD-3), the first National Space Traffic Management Policy
  - Active debris removal in SPD-3:

Sec. 5. Guidelines

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.

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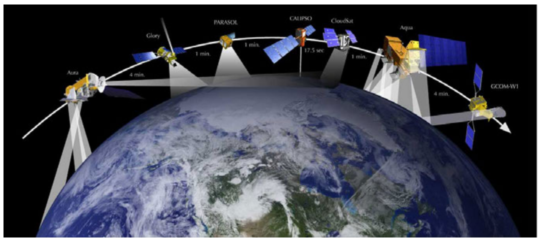
Top OD Risk to NASA Missions





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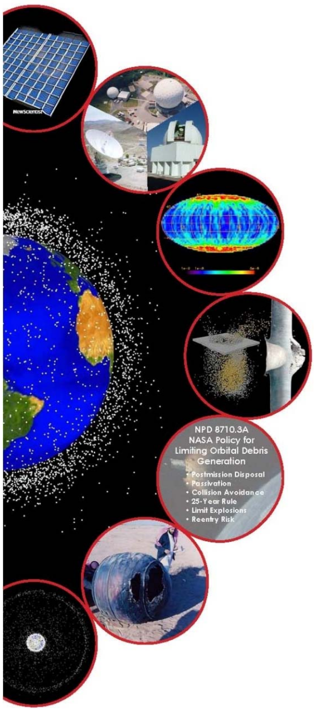
NASA Orbital Debris Program Office (ODPO)



- **The ODPO is the only organization in the U.S. Government conducting a full range of research on orbital debris**
  - 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 NPR 8715.6B
  - ODPO is currently funded through HQ/OSMA
- **ODPO provides technical and policy level support to NASA Centers, NASA HQ, OSTP, NSpC, other U.S. Government agencies and the commercial sector**
- **ODPO represents the U.S. Government in international fora, including the Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations**
- **ODPO is recognized as the world leader in environment definition and modeling, and in mitigation policy development**

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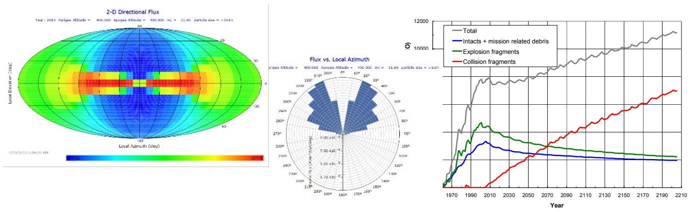
End-to-End Orbital Debris Activities at ODPO



Measurements
Radar
Optical
In-situ
Laboratory

→

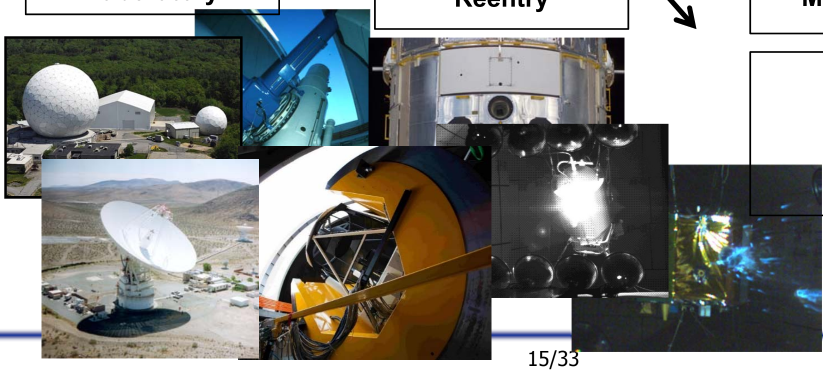
Modeling
Breakup
Engineering
Evolutionary
Reentry

→

Mission Risk Assessments
NASA space assets
(ISS, Orion, robotic missions, *etc.*)
Reentry

Environment Management
Mitigation
Remediation
Policy
Mission Requirements

Coordination
U.S. Government
IADC, ISO
United Nations



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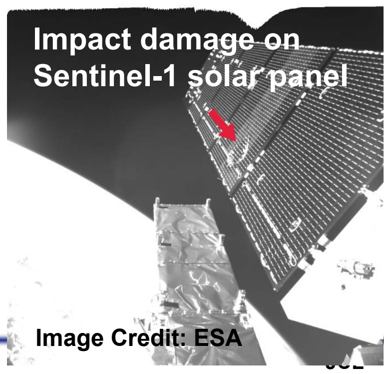
Threat from Orbital Debris - Examples

- The gravity-gradient boom of an operational French satellite (CERISE) was cut in half by a tracked debris fragment in 1996
- The fully operational Iridium 33 was destroyed by the retired Russian Cosmos 2251 in 2009
- Near the end of the Space Shuttle Program, the Loss of Crew and Vehicle risks from MMOD impact damage were in the range of 1 in 250 to 1 in 300 per mission (OD to MM ~2:1 at ISS altitude)
- Impacts by small, untracked debris could be responsible for many satellite anomalies
  - **A 17-cm Russian retro reflector, BLITS, was damaged and shed a piece of trackable debris in January 2013**
  - **The European Space Agency's Sentinel-1 was hit by a small debris, leading to some power loss and 6 trackable debris in August 2016**



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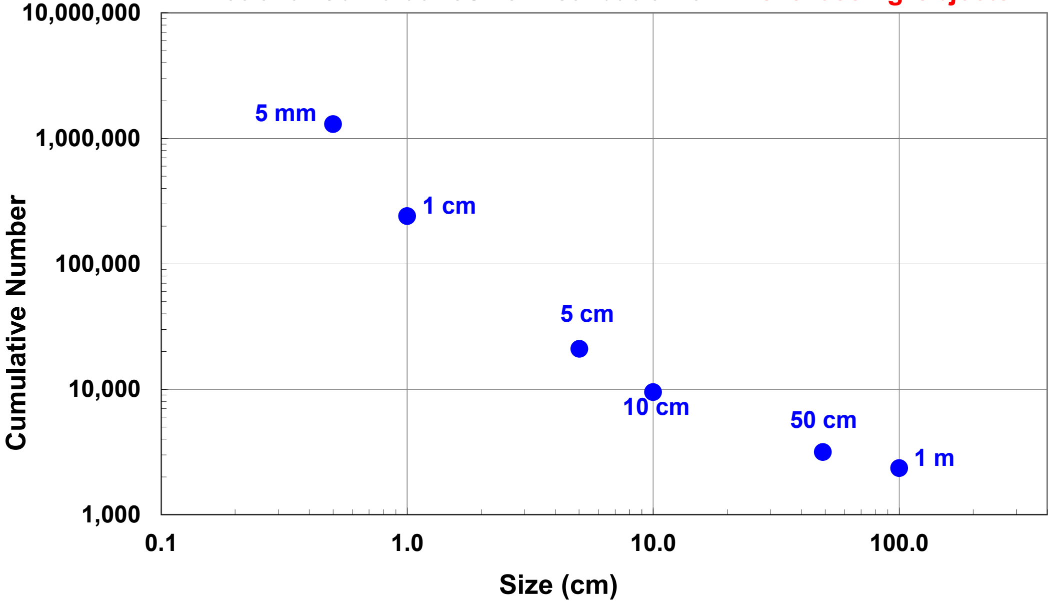
Orbital Debris Size Distribution

Notional CumulativeSize Distribution of LEO-Crossing Objects



Mission-ending threat is dominated by small debris impacts

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Top Risk to NASA Missions in LEO

- **NASA currently operates more than 20 missions in LEO**
  - Thirteen missions at 600-1000 km altitude: Aqua, Aura, CALIPSO, CloudSat, OCO-2, QuikSCAT, Terra, SORCE, TIMED, NuSTAR, IRIS, O/OREOS, SMAP
  - Seven missions for NOAA and USGS at 600-1000 km altitude: NOAA-15, -18, -19, Suomi NPP, JPSS-1, Landsat 7, Landsat 8
  - Seven missions below 600 km alt: ISS, HST, GPM, Fermi, AIM, Swift, CYGNSS (8 spacecraft)
- **Millimeter-sized orbital debris represents the highest penetration risk to most operational (robotic) spacecraft in LEO**
  - However, there is a lack of data on such small debris above 600 km altitude for reliable OD impact risk assessments

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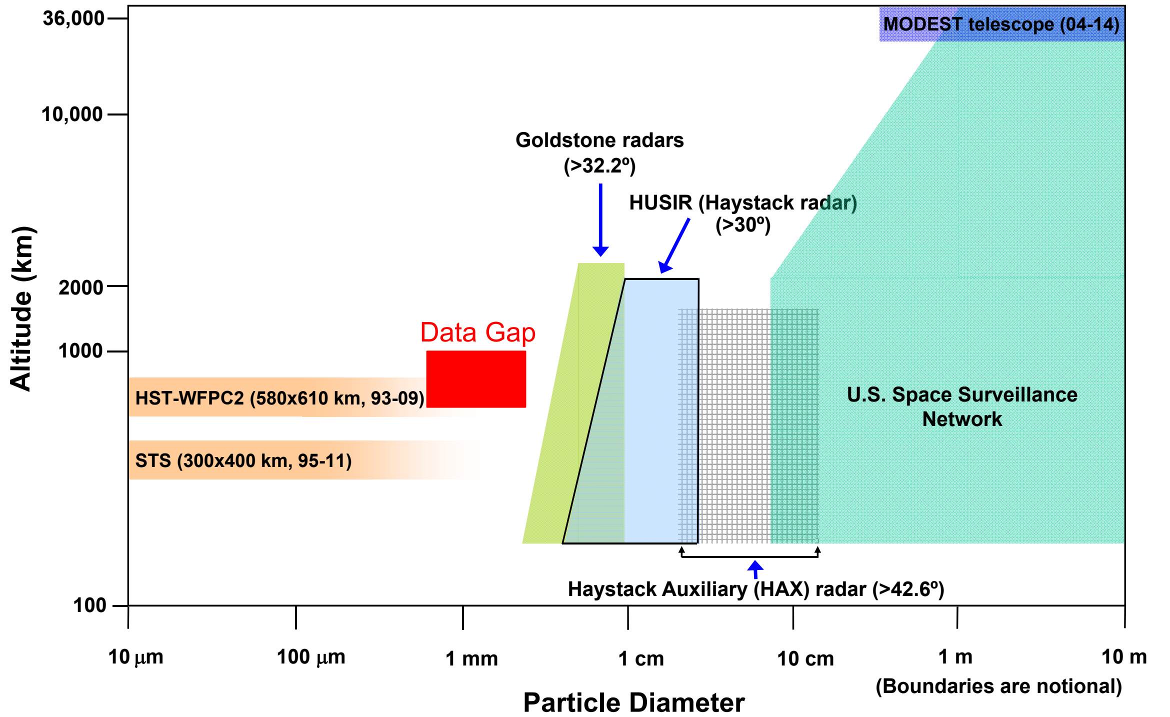
Current NASA Orbital Debris Database



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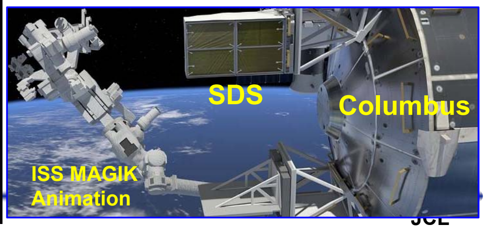
In-Situ Measurements of Small Debris

- **NASA, the Naval Academy, the Naval Research Lab, Virginia Tech, and the University of Kent (Canterbury, UK) have developed new technologies for in-situ measurements of small debris from space**
  - The Space Debris Sensor (SDS) / Debris Resistive/Acoustic Grid Orbital NASA-Navy Sensor (DRAGONS) combines several particle impact detection principles to measure time, location, speed, direction, energy, and the size of each impacting particle
    - **SDS was launched as a technology demonstration mission and installed on the ISS on 1 January 2018**
    - **The sensor collected good test and calibration data for more than 3 weeks, but also experienced two serious computer-related anomalies and ceased to function on Jan 26th**
  - The ODPO continues to pursue new mission opportunities



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CapSat-DRAGONS and DRAGONS-J

- **NASA and JAXA established a collaborative effort in 2017 to explore the feasibility of upgrading DRAGONS with JAXA's state-of-the-art conductive grids**
  - DRAGONS-J: Debris Recording Acoustic/conductive Grid Orbital NASA-JAXA Sensor
  - JAXA provided four conductive grid panels to NASA for evaluation and hypervelocity impact testing in 2018
- **A CapSat-DRAGONS mission proposal submitted by the ODPO received initial approval from the NASA HQ in July 2018**
  - Mission budget as part of the NASA FY2020 budget request is currently under review
  - If approved, the mission will collect direct measurement data on the millimeter-sized OD at 700-1000 km altitude in 2023-2026

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Diagnosis of the OD Problem

- **LEO debris population will continue to increase even with a good implementation of the commonly-adopted mitigation measures**
  - The root-cause: catastrophic collisions involving existing large/massive intact objects (*i.e.*, rocket bodies and spacecraft)
  - The symptom: mission-ending risk from millimeter-sized OD, which comes from large/massive intacts, to operational spacecraft
- **A mission to collect direct measurement data on the millimeter-sized OD will also provide information on the state of the OD problem and guide the necessity for ADR**
  - A CapSat-DRAGONS-J mission will highlight the leadership role of NASA and JAXA and their key contribution to the global community to address the OD problem

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OD Mitigation and Space Policy Directive-3

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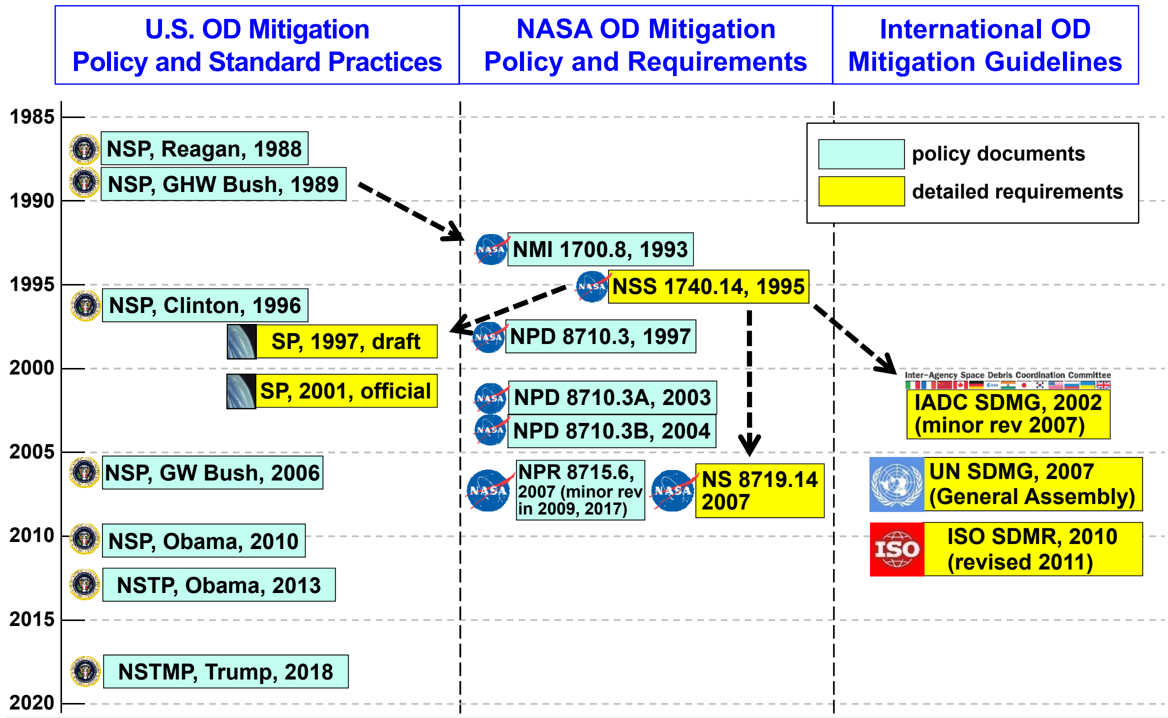
History of U.S., NASA, and International OD Mitigation Policies and Requirements



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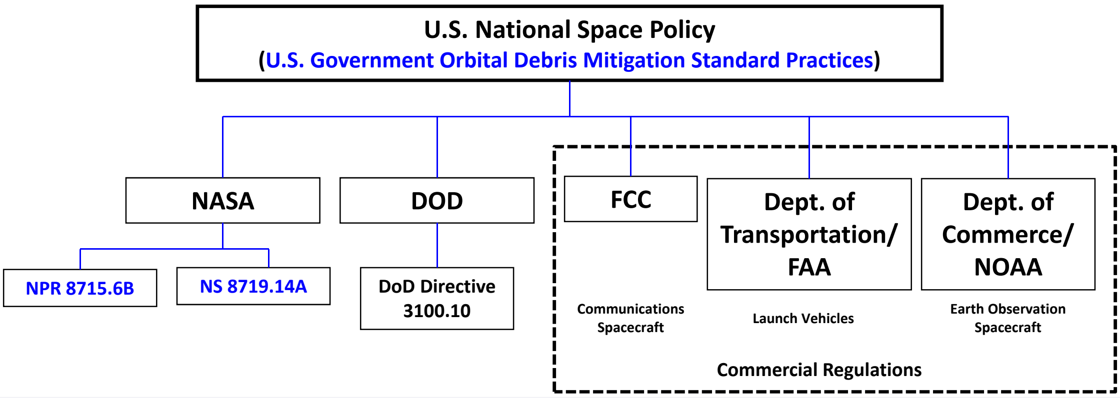
U.S. Government OD Mitigation Standard Practices

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



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U.S. Space Policy Directive-3 (SPD-3)

- **On June 18, 2018, during the third meeting of the National Space Council, the President signed Space Policy Directive-3, the first National Space Traffic Management Policy**
  - https://www.federalregister.gov/documents/2018/06/21/2018-13521/national-space-traffic-management-policy
- **The policy provides guidelines and direction on space traffic management generally, and contains key references and guidelines specific to orbital debris**

> ➢ “Orbital debris” appears 32 times in SPD-3
> ➢ “Safe” or “safety” appears 30 times in SPD-3

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Space Policy Directive-3
- Threat from Orbital Debris

Sec. 3. Principles

(c) Orbital debris presents a growing threat to space operations. Debris mitigation guidelines, standards, and policies should be revised periodically, enforced domestically, and adopted internationally to mitigate the operational effects of orbital debris.

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Space Policy Directive-3
- Space Situational Awareness

Sec. 4. Goals

(a) Advance SSA and STM Science and Technology. The United States should continue to engage in and enable S&T research and development to support the practical applications of SSA and STM. These activities include improving fundamental knowledge of the space environment, such as the characterization of small debris, advancing the S&T of critical SSA inputs such as observational data, algorithms, and models necessary to improve SSA capabilities, and developing new hardware and software to support data processing and observations.

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Space Policy Directive-3
- Mitigate the Effects of OD

Sec. 4. Goals

(b) Mitigate the effect of orbital debris on space activities. The volume and location of orbital debris are growing threats to space activities. It is in the interest of all to minimize new debris and mitigate effects of existing debris. This fact, along with increasing numbers of active satellites, highlights the need to update existing orbital debris mitigation guidelines and practices to enable more efficient and effective compliance, and establish standards that can be adopted internationally. These trends also highlight the need to establish satellite safety design guidelines and best practices.

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Space Policy Directive3
- U.S. Gov. OD Mitigation Standard Practices

Sec. 5. Guidelines

(a) (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.

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Space Policy Directive-3
- Global Engagement

Sec. 5, Guidelines

(c) (iii) Global Engagement. In its role as a major spacefaring nation, the United States should continue to develop and promote a range of norms of behavior, best practices, and standards for safe operations in space to minimize the space debris environment and promote data sharing and coordination of space activities. It is essential that other spacefaring nations also adopt best practices for the common good of all spacefaring states. The United States should encourage the adoption of new norms of behavior and best practices for space operations by the international community through bilateral and multilateral discussions with other spacefaring nations, and through U.S. participation in various organizations such as the Inter-Agency Space Debris Coordination Committee, International Standards Organization, Consultative Committee for Space Data Systems, and UN Committee on the Peaceful Uses of Outer Space.

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Space Policy Directive-3
- ODMSP Update

Sec. 6. Roles and Responsibilities

(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.

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Forward Challenges for the Global Community

- **Conduct space-based in-situ measurements on millimeter-sized OD in low Earth orbit**
  - Use the data to improve impact risk assessments and develop/implement cost-effective protective measures for the safe operations of future missions
- **Improve mission compliance with the existing OD mitigation policies, guidelines, and best practices**
  - Limit the generation of new debris and slow down the OD population growth
- **Develop near- and long-term cost-effective OD mitigation and remediation strategies to preserve the near Earth space environment for future generations**