National Aeronautics and Space Administration

Orbital Debris and the NASA Orbital Debris Program Office

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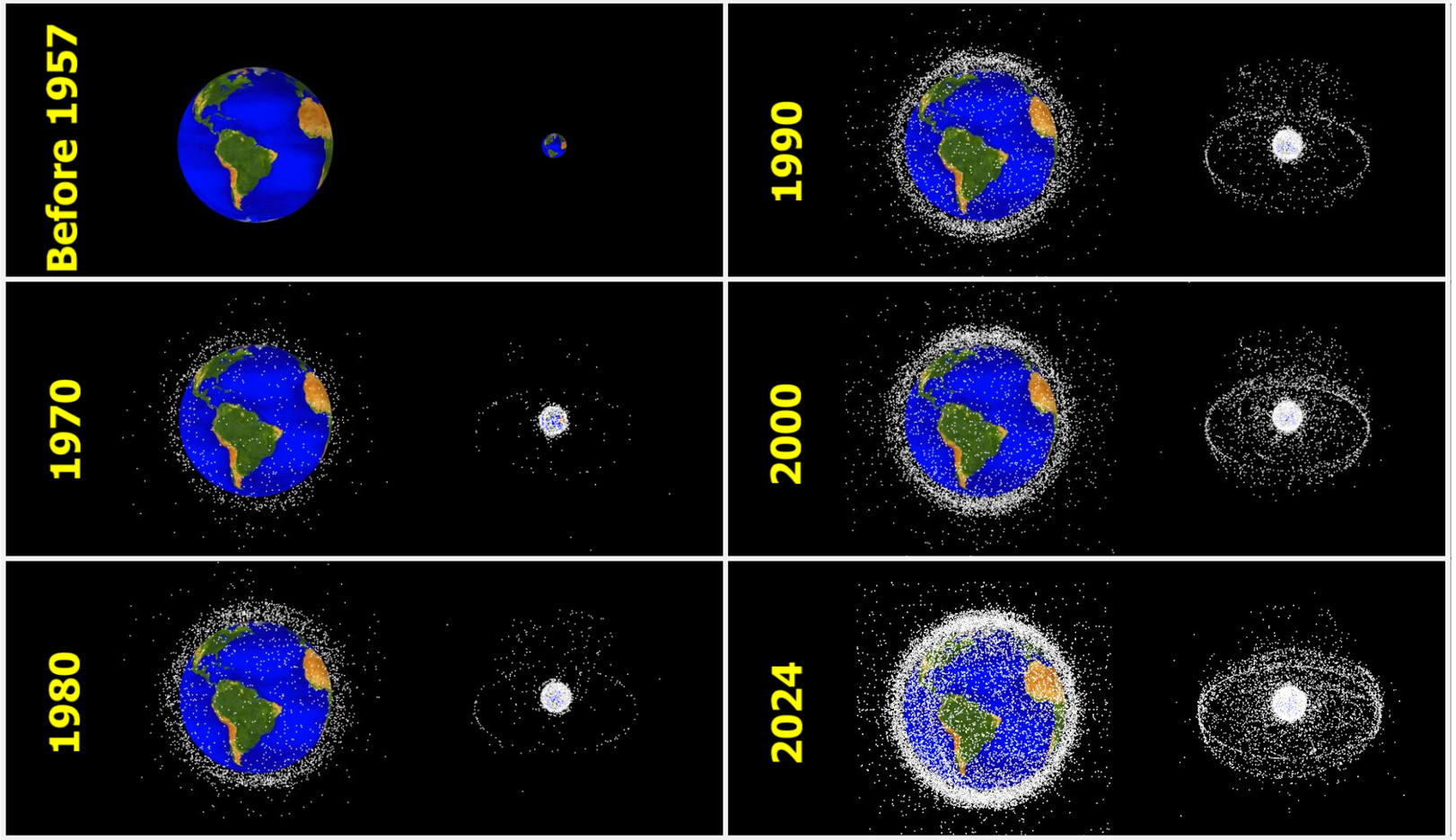
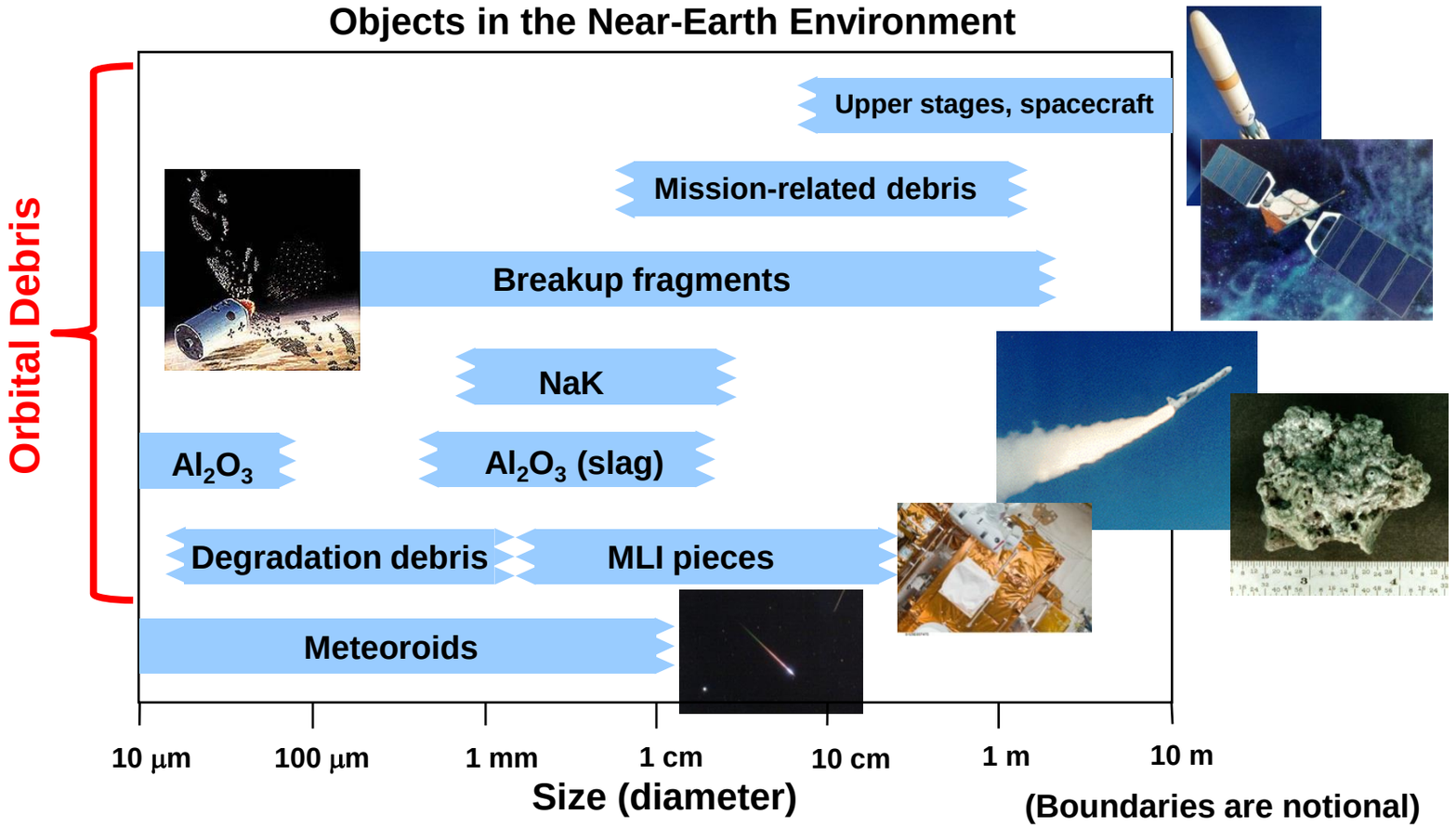
The Historical Orbital Debris Environment



- **The U.S. Space Force (USSF) uses the Space Surveillance Network (SSN) to track large objects in space and maintain their orbits in the U.S. Satellite Catalog**
- **Only objects in the Catalog (~10 cm and larger) are shown**
  - Sizes of the dots are <u>not</u> to scale

Sources of Orbital Debris



- **<u>Orbital debris</u> is any human-made object in orbit about the Earth that no longer serves any useful function**

Current Orbital Debris Population

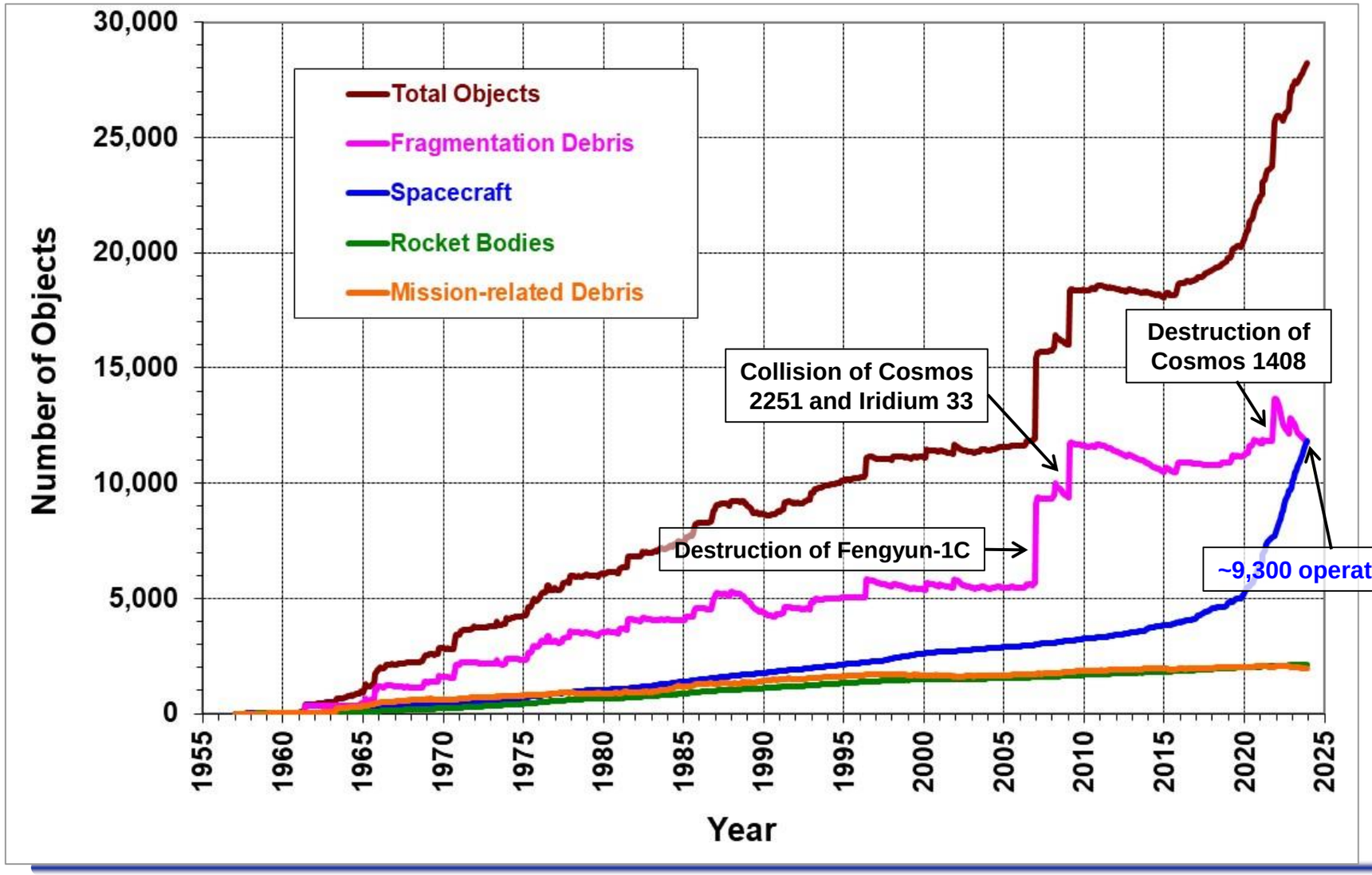
Baseball size or larger (≥10 cm): ~28,000 (tracked/cataloged by the USSF)

Marble size or larger (≥1 cm): ~500,000

Dot or larger (≥1 mm): >100,000,000 (a grain of salt)

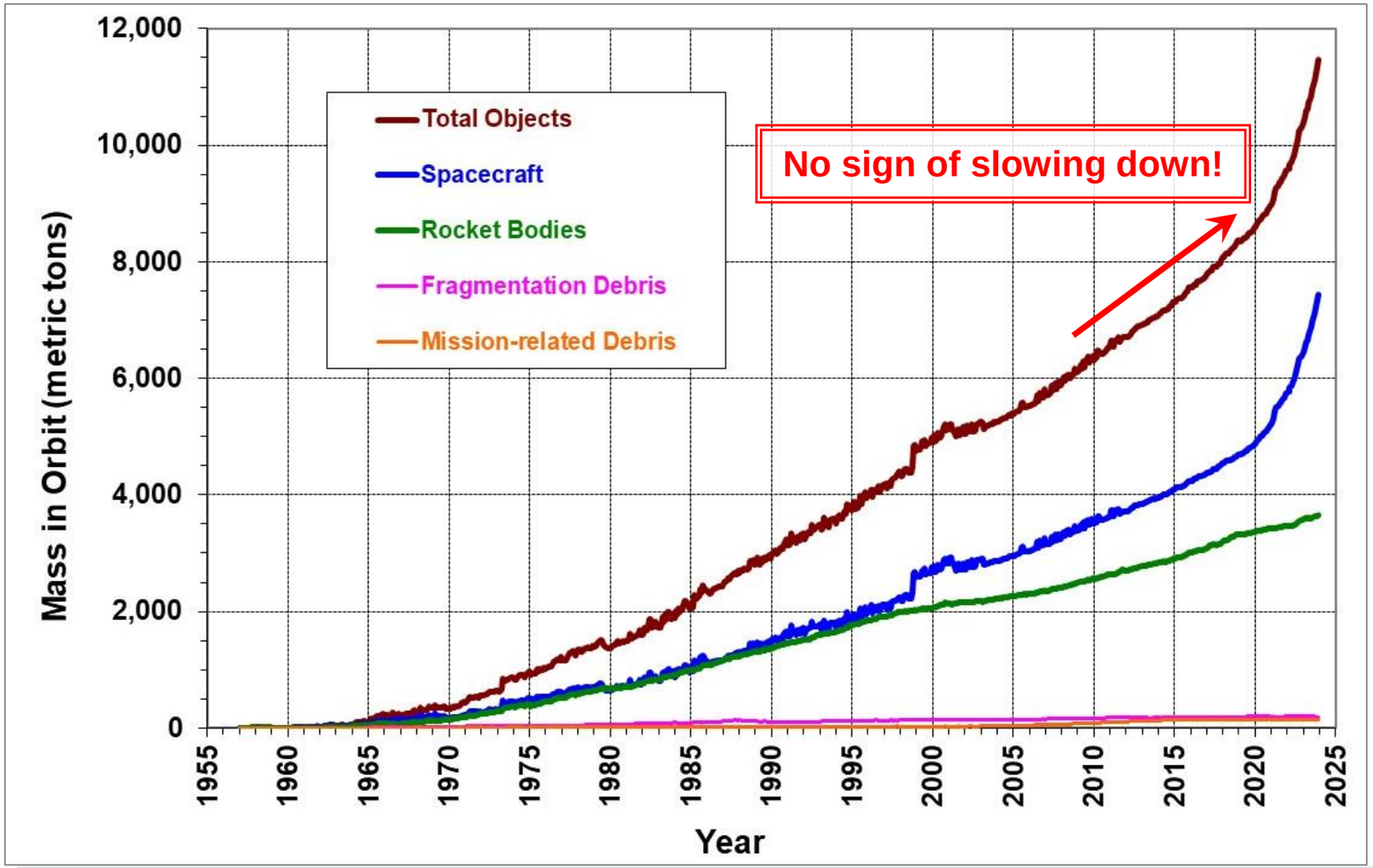
- **Due to high impact speed in space (~10 km/sec in LEO), even sub-millimeter debris poses a realistic threat to human spaceflight and robotic missions**
  - 10 km/sec ~22,000 MPH
  - Speed of a bullet ~1,500 MPH
- **Mission-ending threat is dominated by small (millimeter-sized) debris impacts**

Growth of Cataloged Population



- **The cataloged objects continue to increase**
  - Such large objects only represent the tip of the iceberg for the orbital debris population
  - ~100,000,000 additional debris too small to be tracked but large enough to threaten missions exist in the environment
- **The rapid increase in spacecraft is due to CubeSats and large constellations**

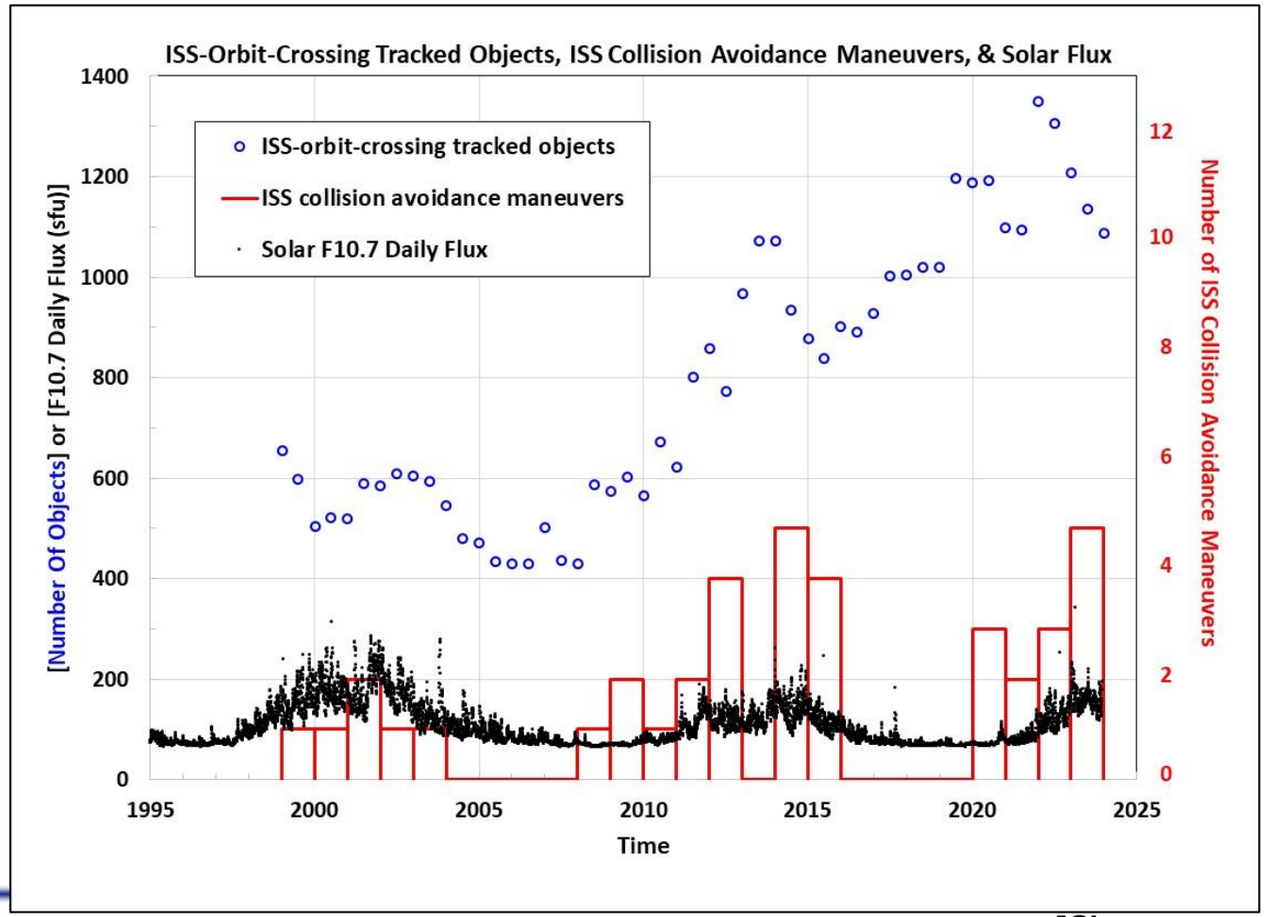
Mass in Orbit Continues to Increase



- **The mass in orbit also continues to increase**
- **At the end of 2023, the total mass in orbit exceeded 11,000 metric tons**
  - The mass was dominated by spacecraft (~65% of the total) and rocket bodies (~32% of the total)
  - Approximately half of the mass concentrated in low Earth orbit (LEO)

Protecting Assets From Large/Tracked Objects

- **NASA has established conjunction assessment processes for missions to avoid accidental collisions with large objects tracked by the SSN**
- **The International Space Station (ISS) has conducted 38 collision avoidance maneuvers since 1999**
  - Including five times in 2023
  - Frequency of the avoidance maneuvers depends on solar activity, number of objects crossing the ISS orbit, the SSN tracking capability, and other factors



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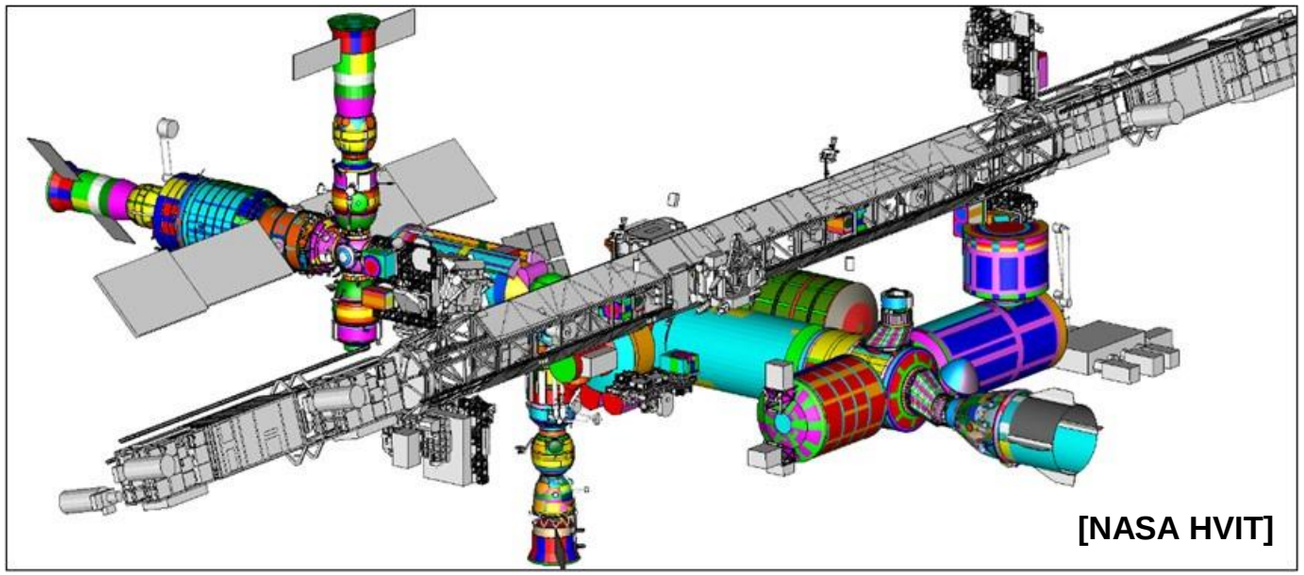
Protecting the ISS From Small Orbital Debris

- **The ISS is equipped with various micrometeoroid and orbital debris (MMOD) impact protection shields**
  - U.S. modules: protected against debris smaller than ~8 mm
  - Russian modules: protected against debris smaller than ~3 mm
  - The biggest threat to the ISS comes from debris too small to be tracked but large enough to penetrate the protection shields

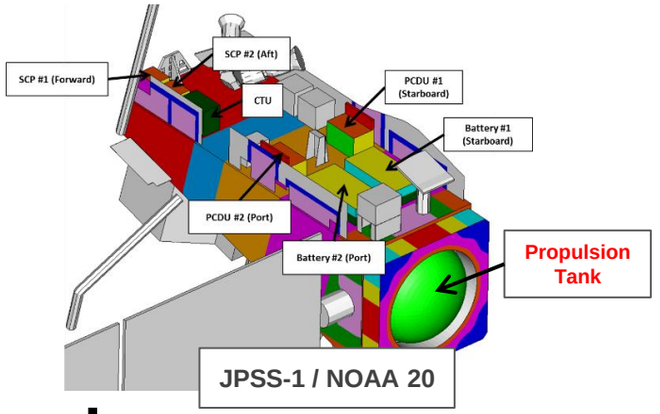

[NASA HVIT]

The ISS MMOD shielding models: each color represents a different MMOD shield configuration

About 500 different shields protect ISS modules and external pressure vessels

Top Orbital Debris Risks to Robotic Missions in LEO

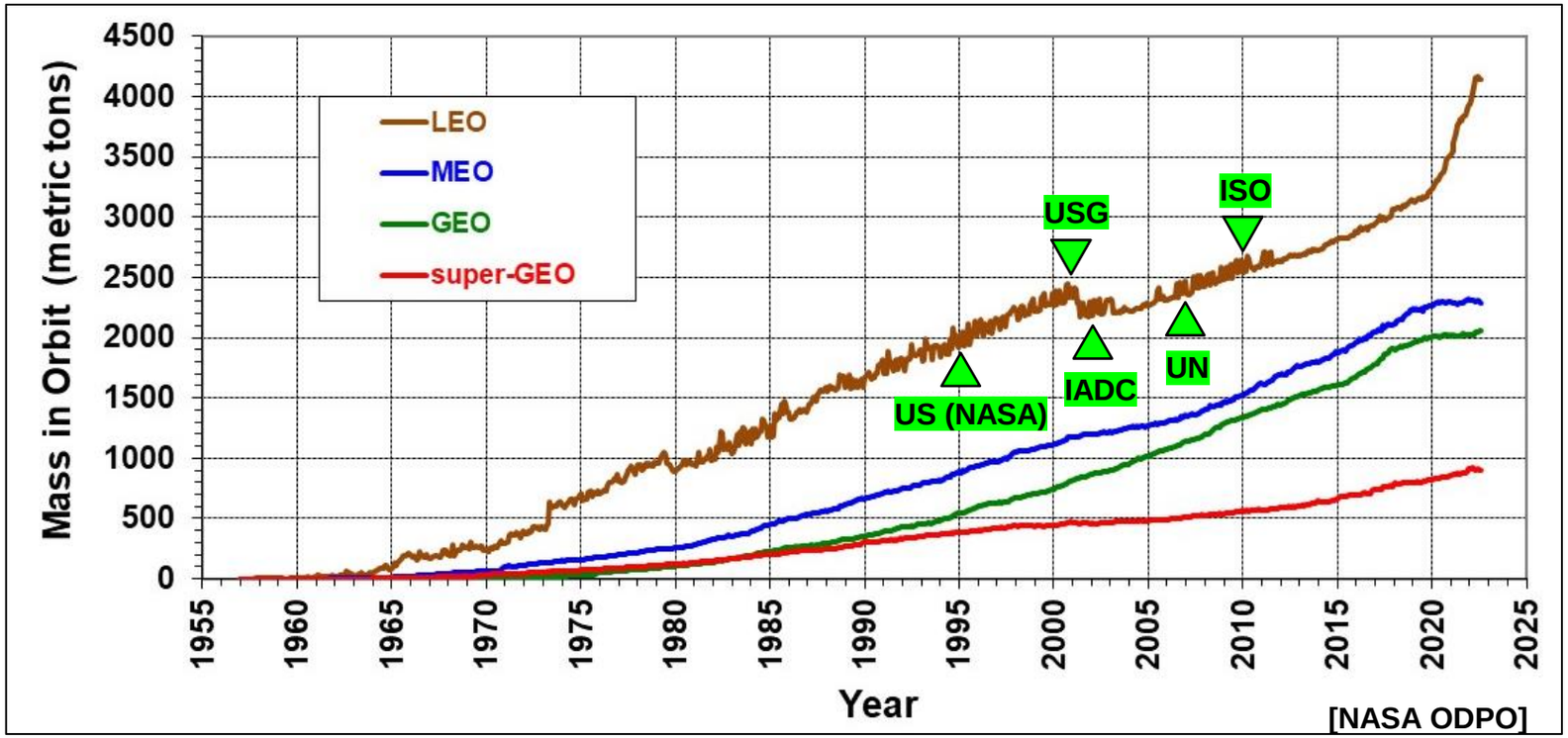
- **Millimeter-sized orbital debris represents the highest penetration risk to most operational spacecraft in LEO**
  - As concluded by, for example, a NASA Engineering and Safety Center panel study (NASA/TM 2015-218780)
- **Currently, more than 400 missions operate at 600–900 km altitudes**
  - Including 18 NASA missions (A-Train@705km, NOAA@825km, IXPE@600km, *etc*.)



- **There is a lack of measurement data on millimeter-sized orbital debris above 600 km altitude**
  - 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

Orbital Debris Mitigation

- **Four guiding principles to limit the generation of new, long-lived debris**
  - Control the generation of mission-related debris
  - Limit accidental explosions (during and post mission)
  - Limit accidental collisions
  - Conduct post-mission disposal, limit reentry risk
- **OD mitigation guidelines and best practices have been developed by the international community since 1995**

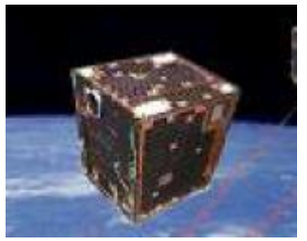


Managing the Long-term Orbital Debris Problem

- **OD Mitigation = Prevention**
  - Limiting the generation of new debris
- **OD Remediation = Cure**
  - Dealing with objects that already exist in the environment (*i.e.*, active debris removal, ADR)

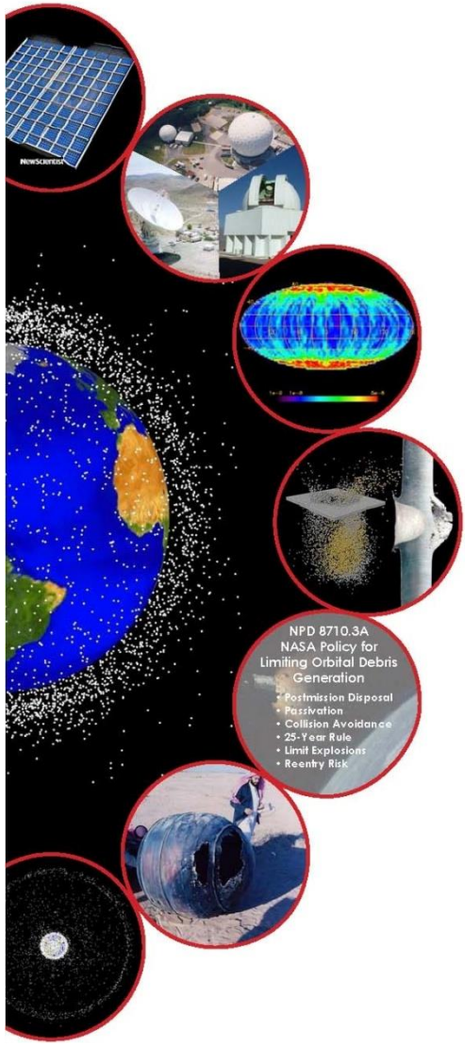
- **"An ounce of prevention is worth a pound of cure"**
  - (*Prov.*) It is better/cheaper to stop something bad from happening than it is to deal with it after it has happened

- **Cost of ESA's ClearSpace-1 mission to remove a 94 kg smallsat (Proba-1): €100M**
- **Between 600 and 2000 km altitudes**
  - Number of spent upper stages and retired spacecraft : >2200
  - Total mass of spent upper stages and retired spacecraft: >1,700,000 kg
    - **58% Russia, 20% U.S., 11% China, 11% others**



Probe-1 (60 cm x 60 cm x 60 cm)

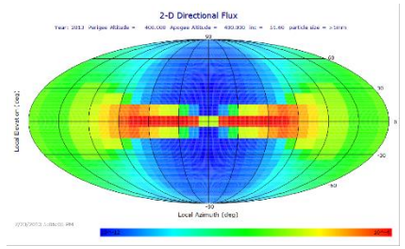
NASA Orbital Debris Program Office (ODPO)

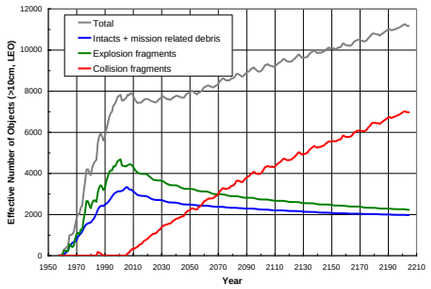


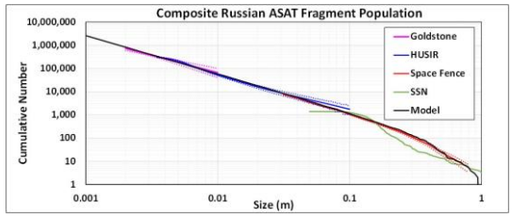
- **ODPO is the only organization in the USG conducting a full range of research on orbital debris**
  - Is a Delegated Program in NASA/HQ OSMA
  - This unique NASA capability was established by pioneers led by Don Kessler, Joe Loftus, and others at NASA JSC in 1979
- **ODPO provides technical and policy support to NASA HQ, NASA missions, USG (Congress, NSpC, OMB, OSTP, *etc*.) and commercial organizations**
- **ODPO represents the USG in international fora (United Nations, IADC*, ISO, *etc.*)**
- **ODPO is recognized as a pioneer and leader on orbital debris environment definition, modeling, and mitigation policy development**

*IADC = Inter-Agency Space Debris Coordination Committee

End-to-End Orbital Debris Activities at ODPO







Mission Support

Compliance assessments
Risk assessments
(ISS, Orion, robotic missions, *etc.*)
Reentry assessments

Measurements

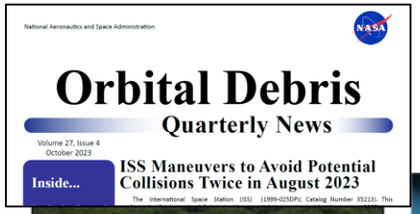
Radar
Optical
In-situ
Laboratory

Modeling

Breakup
Engineering
Evolutionary
Reentry

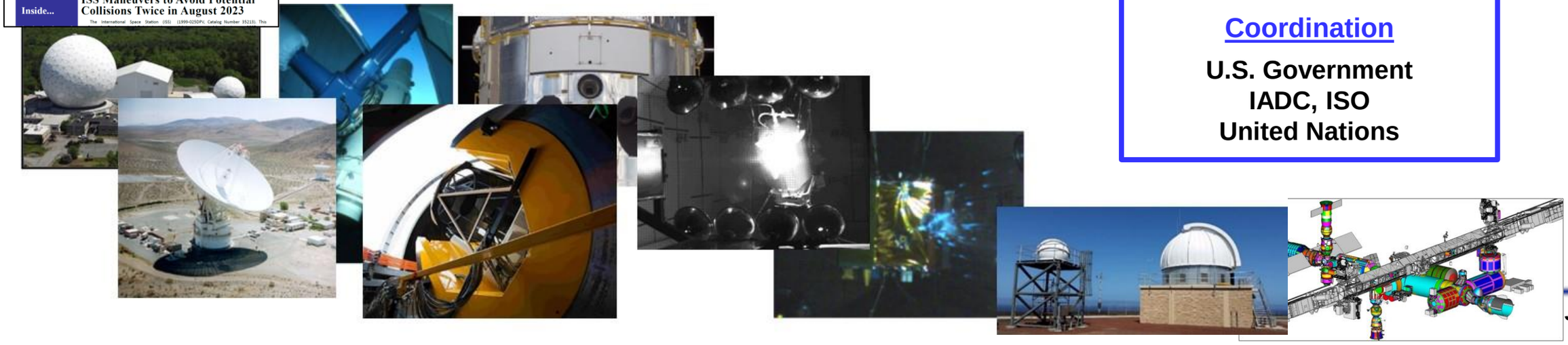
Environment Management

Mitigation
Remediation
Mission Requirements
Policy



Coordination

U.S. Government
IADC, ISO
United Nations

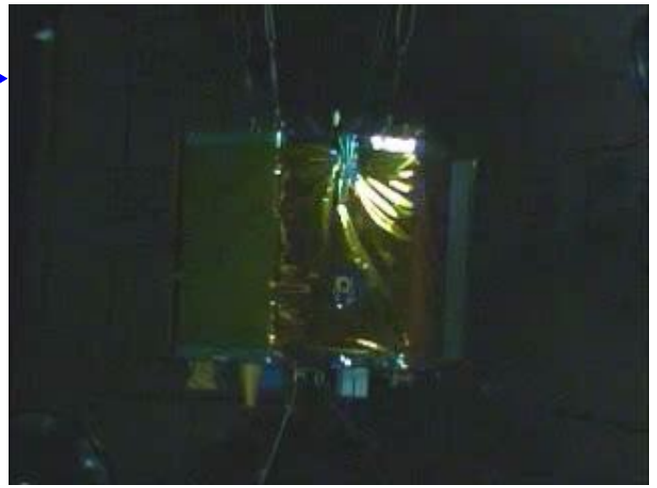


ODPO's Roles and Responsibilities (1/3)

- **Monitor the ever-changing OD environment**
  - ODPO has led the characterization of OD too small to be tracked by the DOD but large enough to threaten human spaceflight and robotic missions for more than 30 years.
    - **Collect/analyze radar measurement data on OD in LEO**
    - **Build/operate telescopes, collect/analyze optical measurement data on OD from LEO to GEO**
    - **Collect/analyze space-based in-situ measurement data on sub-millimeter OD, develop in-situ sensor technologies and pursue mission opportunities to address the millimeter-sized OD data gap**
    - **Design/conduct laboratory experiments and collect/analyze test data for debris characterization and assess risk from OD**

MACS
MULTILAYER ACOUSTIC CONDUCTIVE-GRID SENSOR

A 9-cm, 570-g projectile impacted the 56-kg DebriSat at 6.8 km/sec

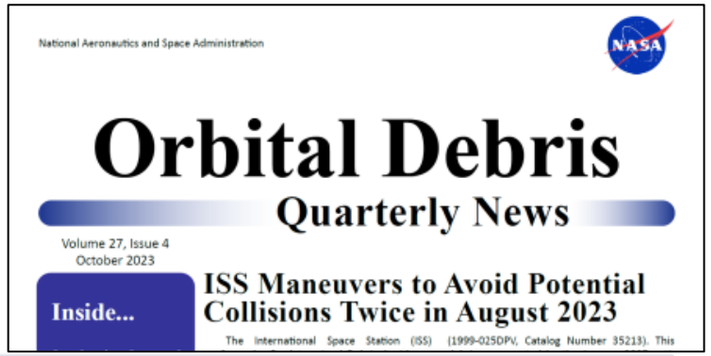


ODPO's Roles and Responsibilities (2/3)

- **Develop/update OD models and mission support tools**
  - ODPO has led the development of OD environment, risk assessment, reentry, and mission compliance models and tools for more than 30 years
  - ODPO's models and mission support tools are used by hundreds of operators (NASA, USG, commercial), academia, and research groups around the world
- **Provide OD mitigation compliance and mission support**
  - ODPO oversees NASA mission compliance with OD mitigation requirements per NS 8719.14, which is NASA's implementation of the USG ODMSP
    - **ODPO reviews NASA mission Orbital Debris Assessment Reports (ODARs) and End of Mission Plans (EOMPs) and maintains NASA mission compliance records**
  - ODPO conducts high-fidelity reentry assessments and supports NASA missions to explore design-for-demise options to mitigate reentry human causality risk
  - ODPO provides real-time risk assessments and mitigation support for the ISS and other critical assets after new on-orbit fragmentation events

ODPO's Roles and Responsibilities (3/3)

- **Provide USG interagency, international, commercial, and outreach support**
  - ODPO has led the development of OD mitigation best practices in the U.S. and has promoted the adoption of the USG ODMSP by the international community since 1995
    - **USG ODMSP (2001, 2019): ODPO led the interagency working group on the efforts.**
    - **IADC Space Debris Mitigation Guidelines (2002, 2007, 2020, 2021): ODPO leads the U.S. delegation to the IADC. ODPO has supported the development of and update to the IADC Guidelines.**
    - **UN COPUOS Space Debris Mitigation Guidelines (2007) and UN COPUOS LTS Guidelines (2019): ODPO supported the U.S. delegation to UN COPUOS on the development efforts.**
    - **ISO Space Debris Mitigation Standard (2010, 2019, 2021, 2023): ODPO has supported the development of and update to the standard.**
    - **Commercial support (via Space Act Agreements)**
    - **NASA Orbital Debris Quarterly News (ODQN): 2000+ subscribers from the global space community**
    - **International Orbital Debris Conference (IOC)**
    - ***Etc.***



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