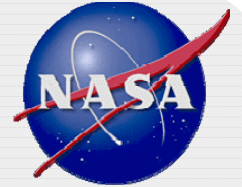


The Orbital Debris Problem

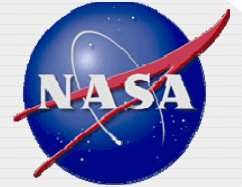
J.-C. Liou, PhD
NASA Chief Scientist for Orbital Debris

Space Tech Conference
Pasadena, California, 24-26 May 2016



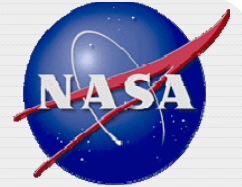
Outline

- **Overview of the orbital debris problem**
 - What is orbital debris
 - Danger of orbital debris
- **Orbital debris mitigation policy**
 - NASA
 - U.S. Government
 - International community (IADC and United Nations)
- **Challenges for orbital debris environment management**



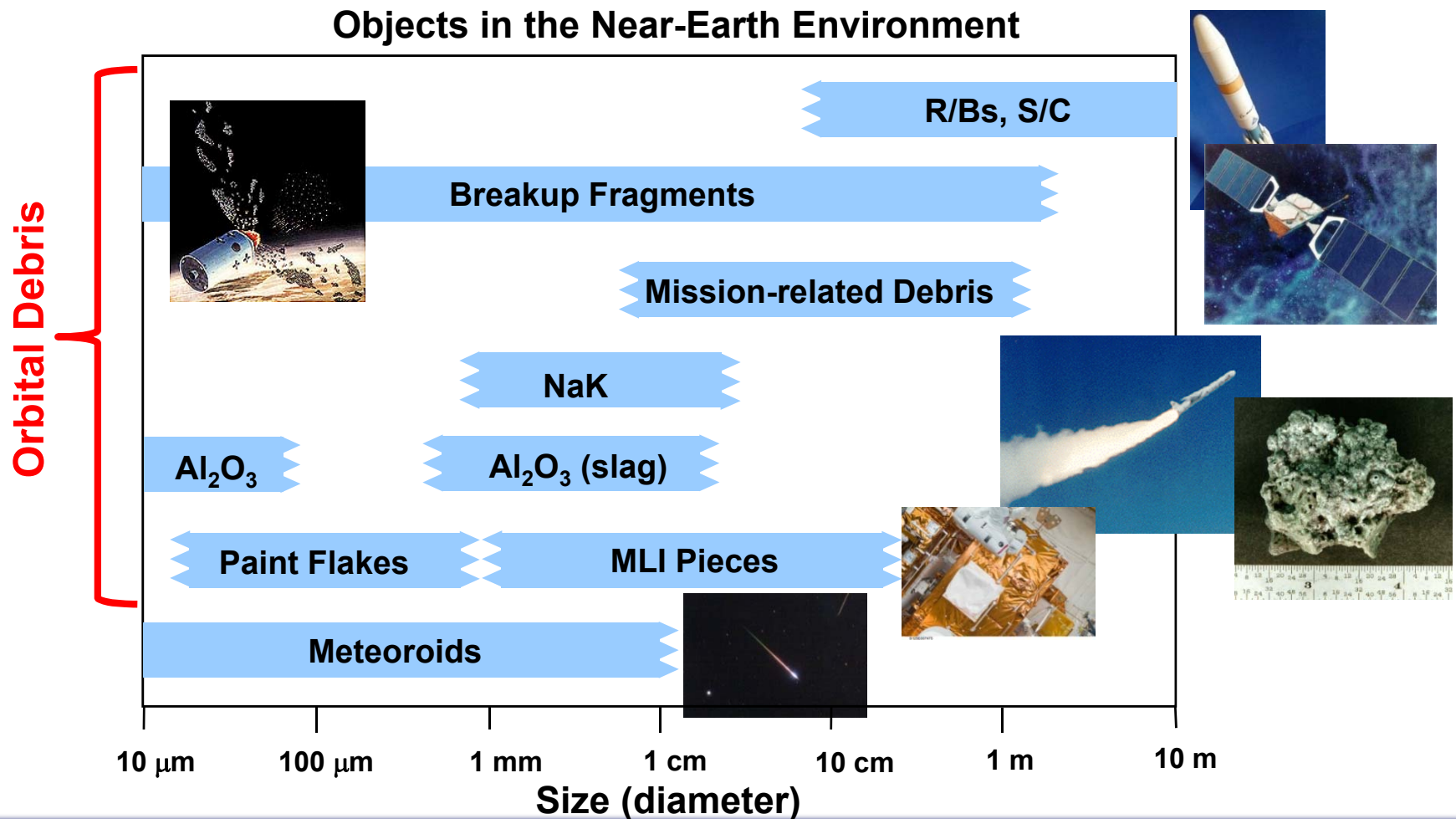
Overview of the Orbital Debris Problem





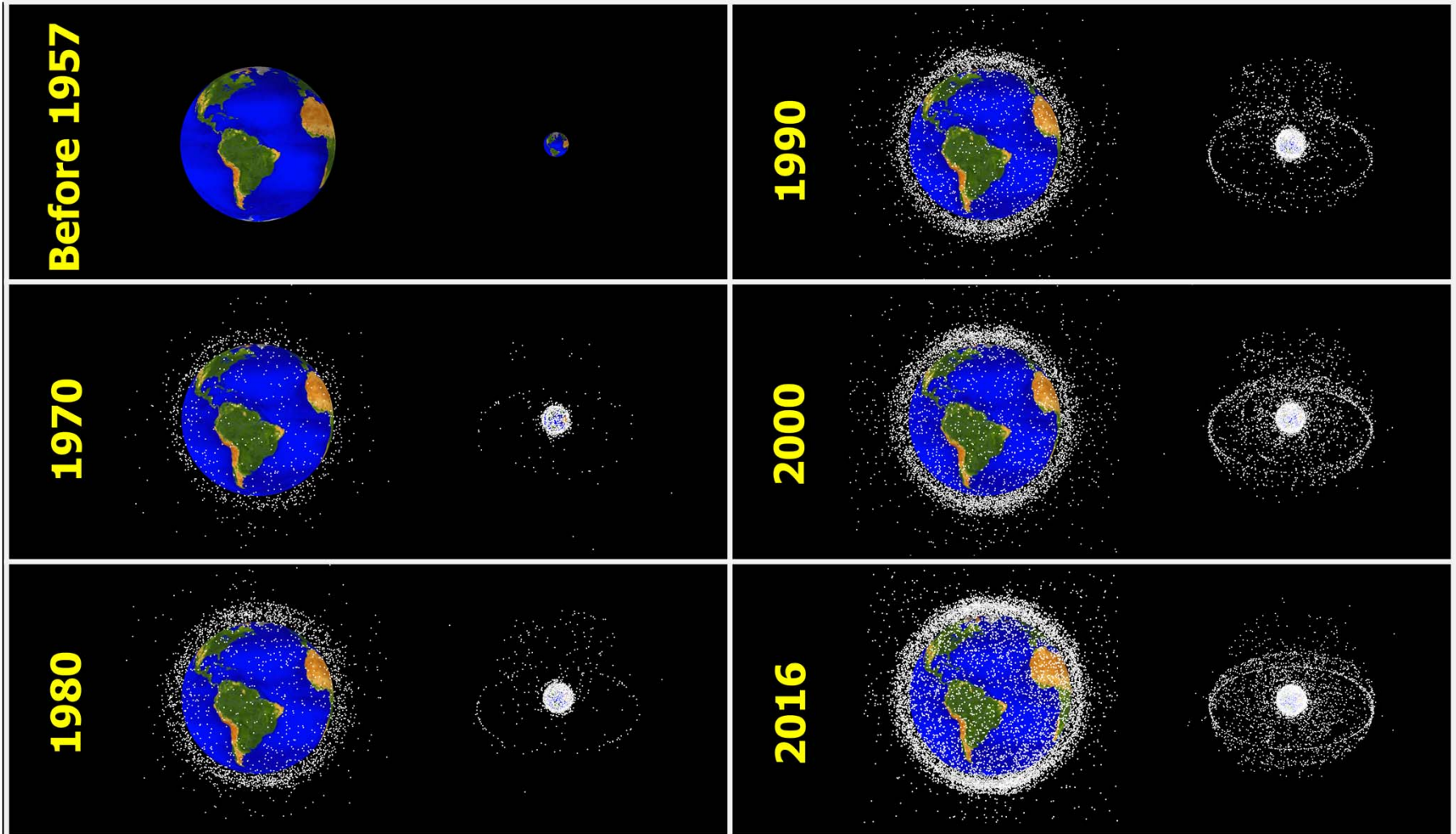
What Is Orbital Debris?

- Orbital debris is any human-made object in orbit about the Earth that no longer serves any useful purpose

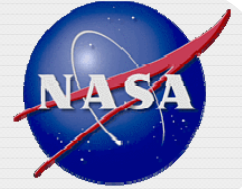




Historical Orbital Debris Environment



- Only objects in the U.S. Space Surveillance Network (SSN) catalog are shown
- Sizes of the dots are not to scale



How Much Junk Is Currently Up There?

**Softball size or larger (≥ 10 cm): ~23,000
(tracked by U.S. Joint Space Operations Center, JSpOC)**



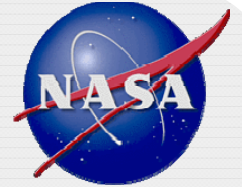
Marble size or larger (≥ 1 cm): ~500,000



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

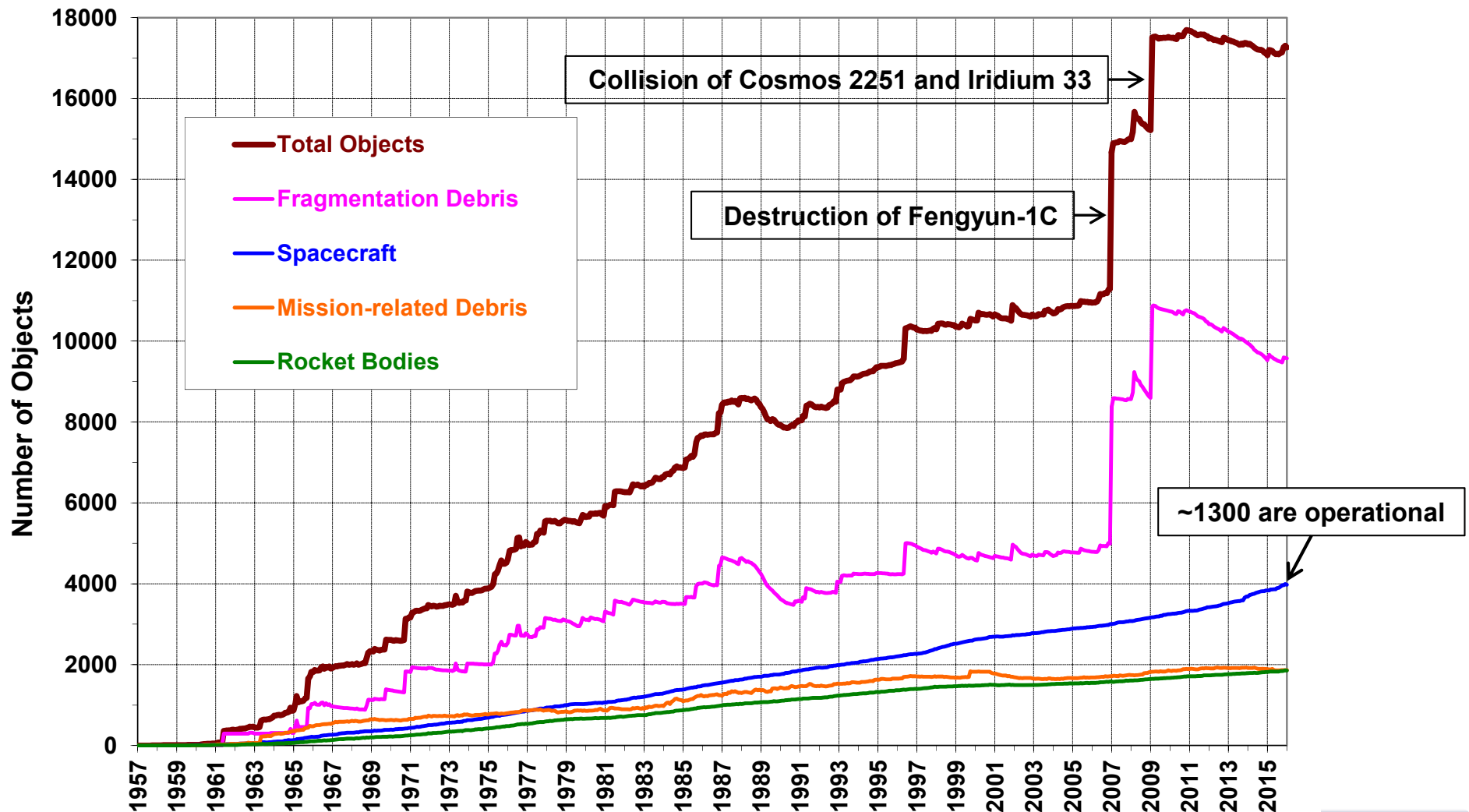


- Due to high impact speed in space (~10 km/sec in LEO), even **sub-millimeter** debris pose a realistic threat to human spaceflight and robotic missions
 - 10 km/sec = 22,000 miles per hour (the speed of a bullet ~1,500 miles per hour)
- Total mass: >7000 tons LEO-to-GEO (~2700 tons in LEO)



Growth of the Cataloged Populations

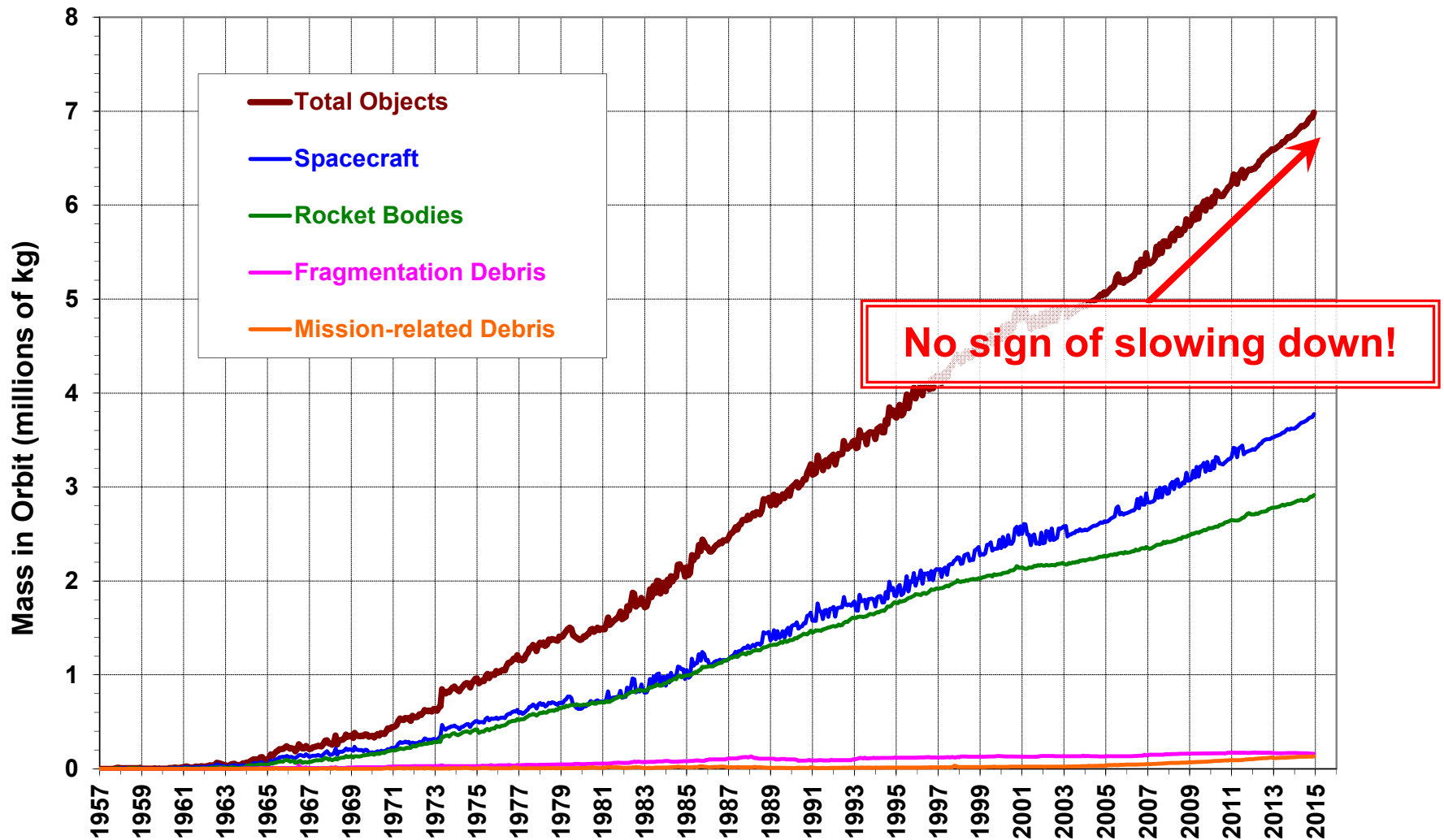
- JSpOC is tracking ~23,000 large objects and maintains most of their orbits in the U.S. Satellite Catalog

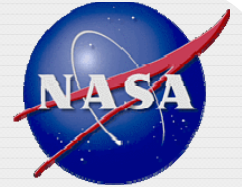




Mass in Orbit Continues to Increase

- The material mass in Earth orbit continues to increase and has exceeded 7000 metric tons



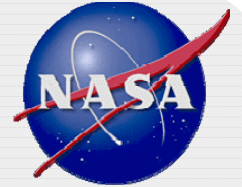


Threat from Orbital Debris

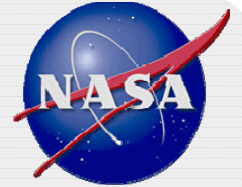
- **Examples of the threat from orbital debris**

- 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 a retired Russian satellite (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)
- **Satellite operators, including the International Space Station (ISS) Program, conduct collision avoidance maneuvers against the tracked objects on a regular basis**
 - **The ISS carried out four debris collision avoidance maneuvers and one “shelter-in-Soyuz” in 2015**
- **Impacts by small, untracked debris could be responsible for many satellite anomalies**





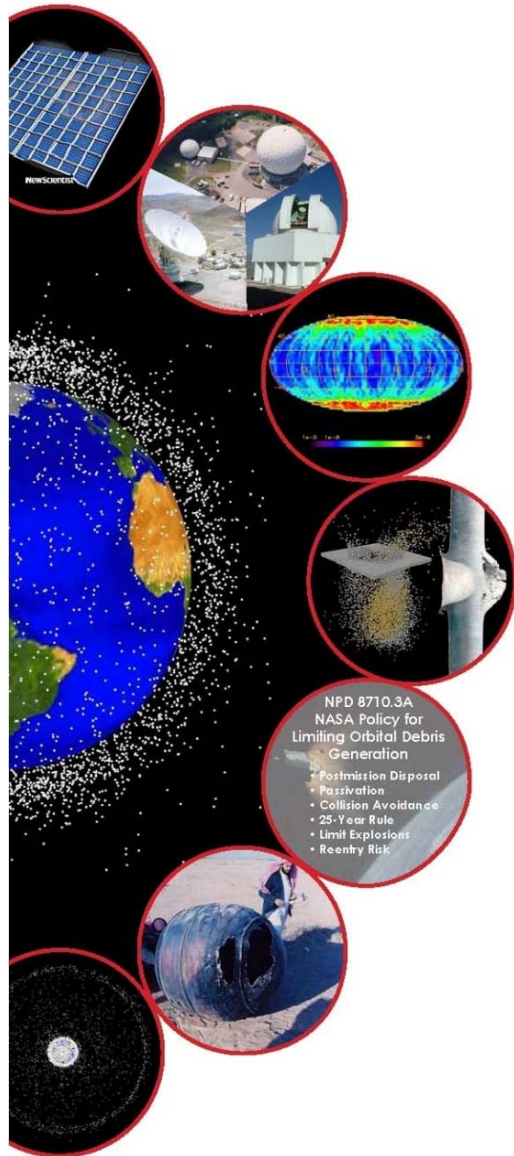
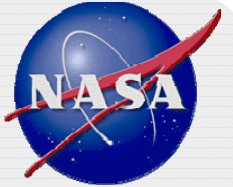
Orbital Debris Mitigation Policy



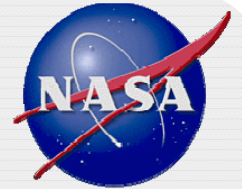
Orbital Debris Environment Management

- **“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 happening than it is to deal with it after it has happened.
- **Orbital Debris Mitigation (“Prevention”)**
 - To prevent the generation of new and long-lived orbital debris in the environment.
- **Orbital Debris Remediation (“Cure”)**
 - Active removal of orbital debris already exists in the current environment.

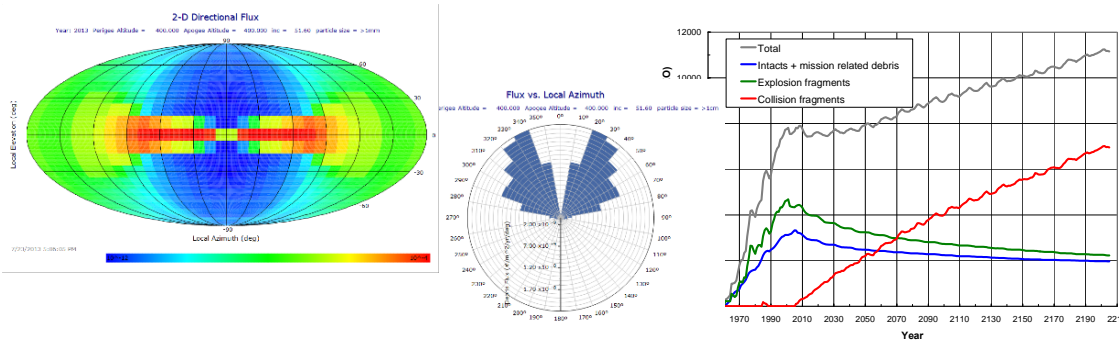
NASA Orbital Debris Program Office (ODPO)



- **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, B. Cour-Palais, H. Zook, etc.)
 - ODPO's roles and responsibilities are defined in NPR 8715.6
 - ODPO is currently funded through HQ/OSMA
- **ODPO provides technical and policy level support to NASA HQ, OSTP, 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**



End-to-End Orbital Debris Activities at ODPO



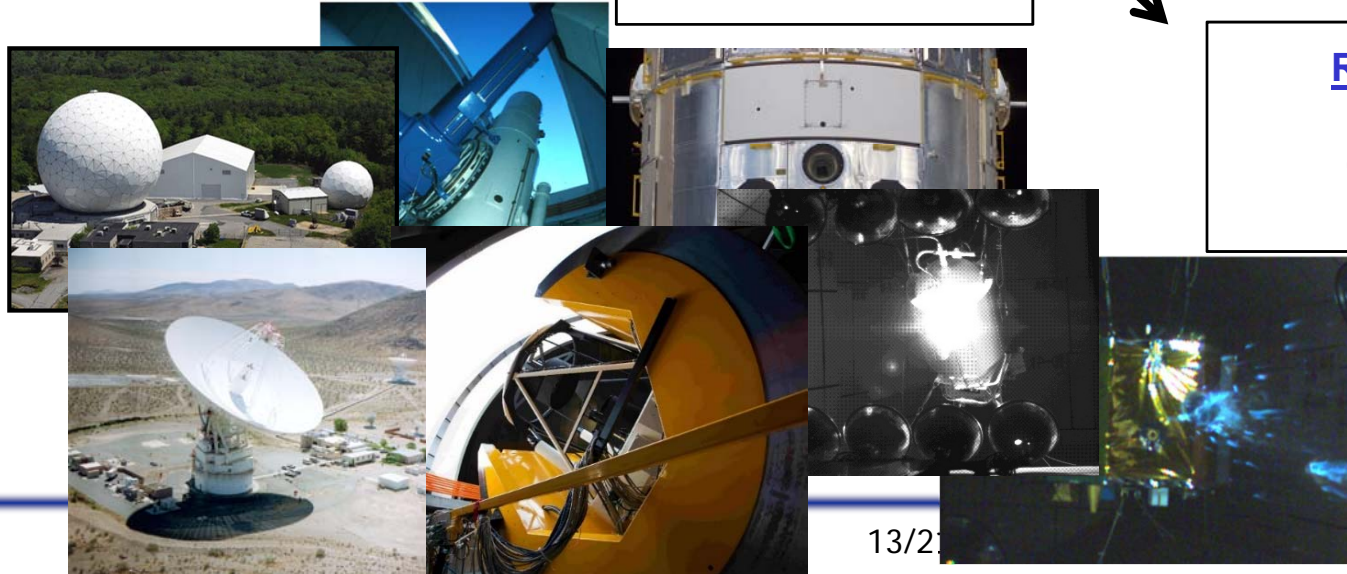
Environment Management
Mitigation
Remediation
Policy
Mission Requirements

Measurements
Radar
Optical
In-situ
Laboratory

Modeling
Breakup
Engineering
Evolutionary
Reentry

Coordination
U.S. Government
IADC
United Nations

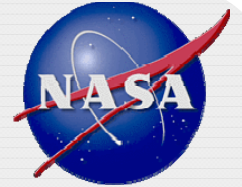
Risk Assessment
Space assets
(ISS, Orion, etc)
Reentry





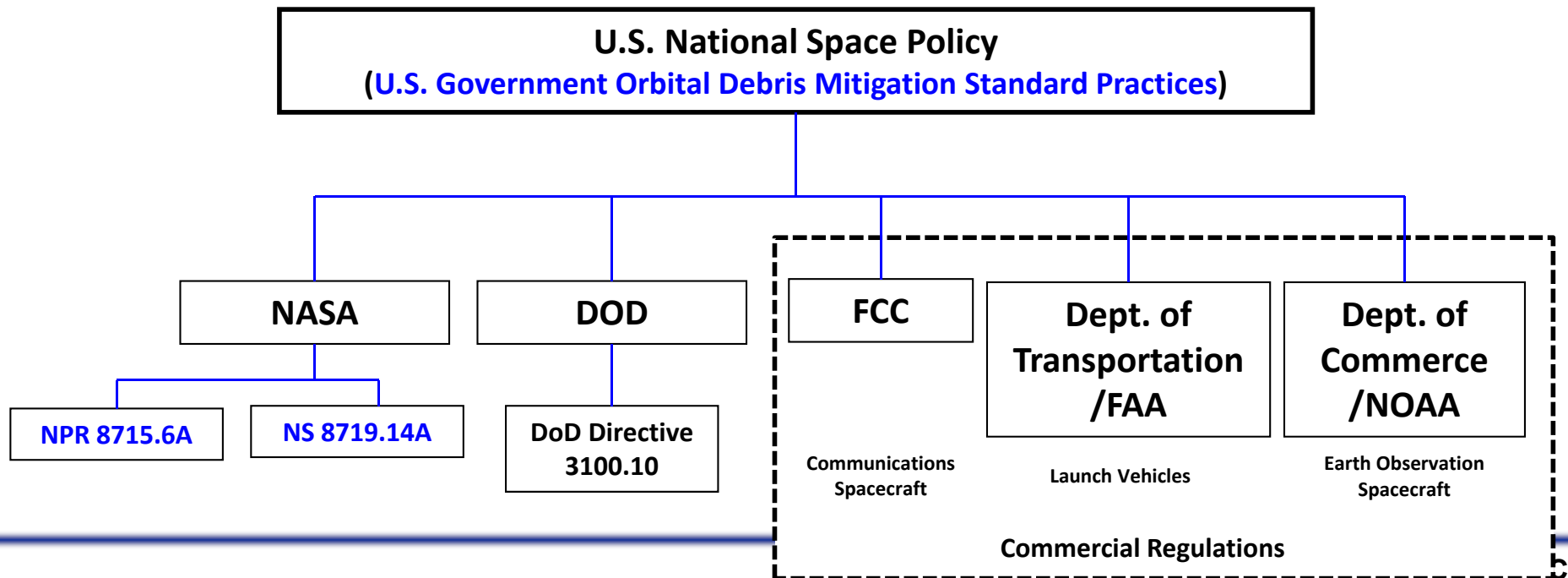
Orbital Debris Mitigation at NASA

- **NASA was the first organization in the world 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
- **The current NASA orbital debris mitigation policy is documented in NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6 (2007)**
 - Specific mission requirements are defined in NASA Technical Standard NS 8719.14, Process for Limiting Orbital Debris (2007)



U.S. Government Orbital Debris Mitigation Standard Practices

- NASA and DOD led the effort to establish the **U.S. Government (USG) Orbital Debris Mitigation Standard Practices** (approved in 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**
 - Current IADC members: ASI, CNES, CNSA, CSA, DLR, ESA, ISRO, JAXA, KARI, NASA, ROSCOSMOS, SSAU, and UKSA
 - NASA represents the U.S. Government to the IADC. The NASA delegation also includes representatives from State, OSD, AF, FAA, and FCC
- **IADC is recognized as the technical authority on orbital debris by the international space community**
- **The IADC developed the first consensus on international [orbital debris mitigation guidelines](#) in October 2002; subsequently submitted to the United Nations**

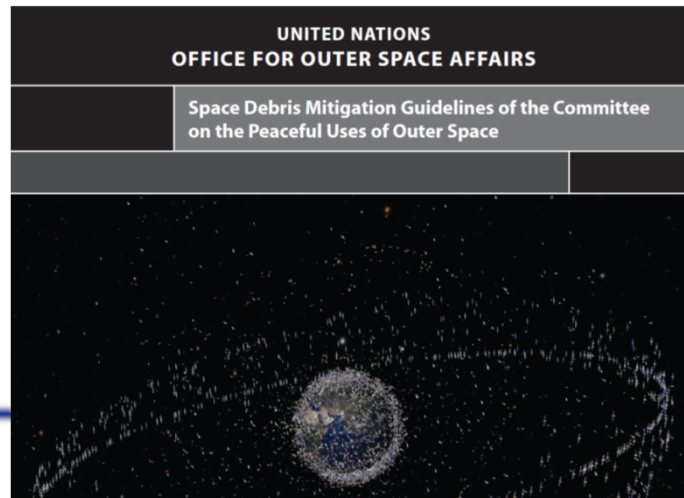
Inter-Agency Space Debris Coordination Committee

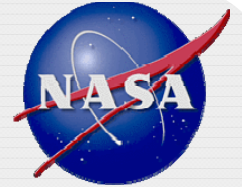




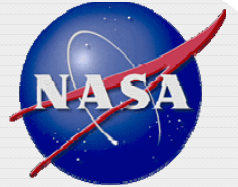
Orbital Debris at the United Nations (UN)

- Orbital debris has been on the agenda of the Scientific and Technical Subcommittee (STSC) of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) since 1994
- STSC Member States adopted a set of **space debris mitigation guidelines** similar to the IADC guidelines in Feb. 2007, followed by adoption by COPUOS in Jun. 2007 and by the full UN General Assembly in Dec. 2007
- There is an on-going effort by COPUOS to develop a new set of guidelines on the long-term sustainability of outer space activities





Challenges for Orbital Debris Environment Management



U.S. National Space Policy and Orbital Debris

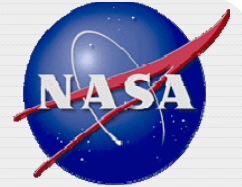
- **Orbital debris has been included in all U.S. national space policies since 1988**
- **Orbital debris removal was mentioned for the first time in the 2010 U.S. National Space Policy**

Preserving the Space Environment and the Responsible Use of Space

Preserve the Space Environment. For the purposes of minimizing debris and preserving the space environment for the responsible, peaceful, and safe use of all users, the United States shall:

- Lead the continued development and adoption of international and industry standards and policies to minimize debris, such as the United Nations Space Debris Mitigation Guidelines;
- ...
- Pursue research and development of technologies and techniques, through the Administrator of the National Aeronautics and Space Administration (NASA) and the Secretary of Defense, to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment; and
- ...

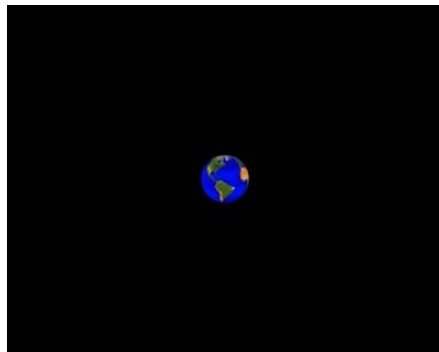
(page 7, 2010 U.S. National Space Policy)



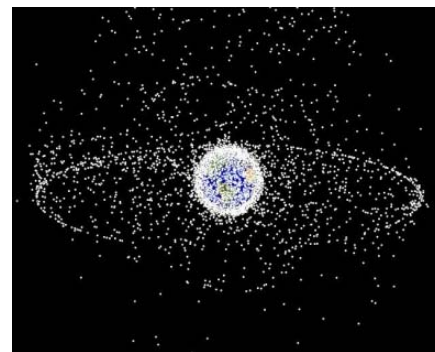
Forward Challenges

- **Improve compliance with the existing orbital debris mitigation policy, requirements, and guidelines at NASA, in the United States, and by the international space community**
- **Develop near- and long-term **cost-effective** orbital debris mitigation and remediation strategies**
- **Advance space situational awareness coverage**
- **Explore options for space traffic management**

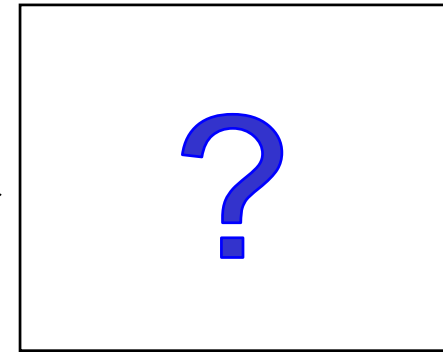
Preserving the Near-Earth Space Environment for Future Generations



Pre-1957



2016



2216