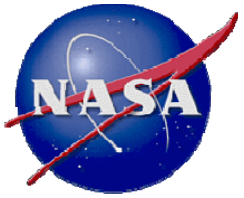
National Aeronautics and Space Administration



Growth of Orbital Debris

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The 4th ASEAN Regional Forum (ARF) Workshop on Space Security

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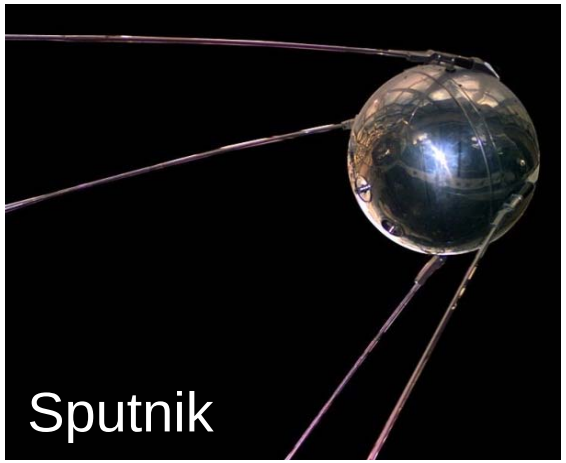
Presentation Outline

- **Historical and Current Orbital Debris Environment**
- **Danger of Orbital Debris**
- **Orbital Debris Mitigation Policy**

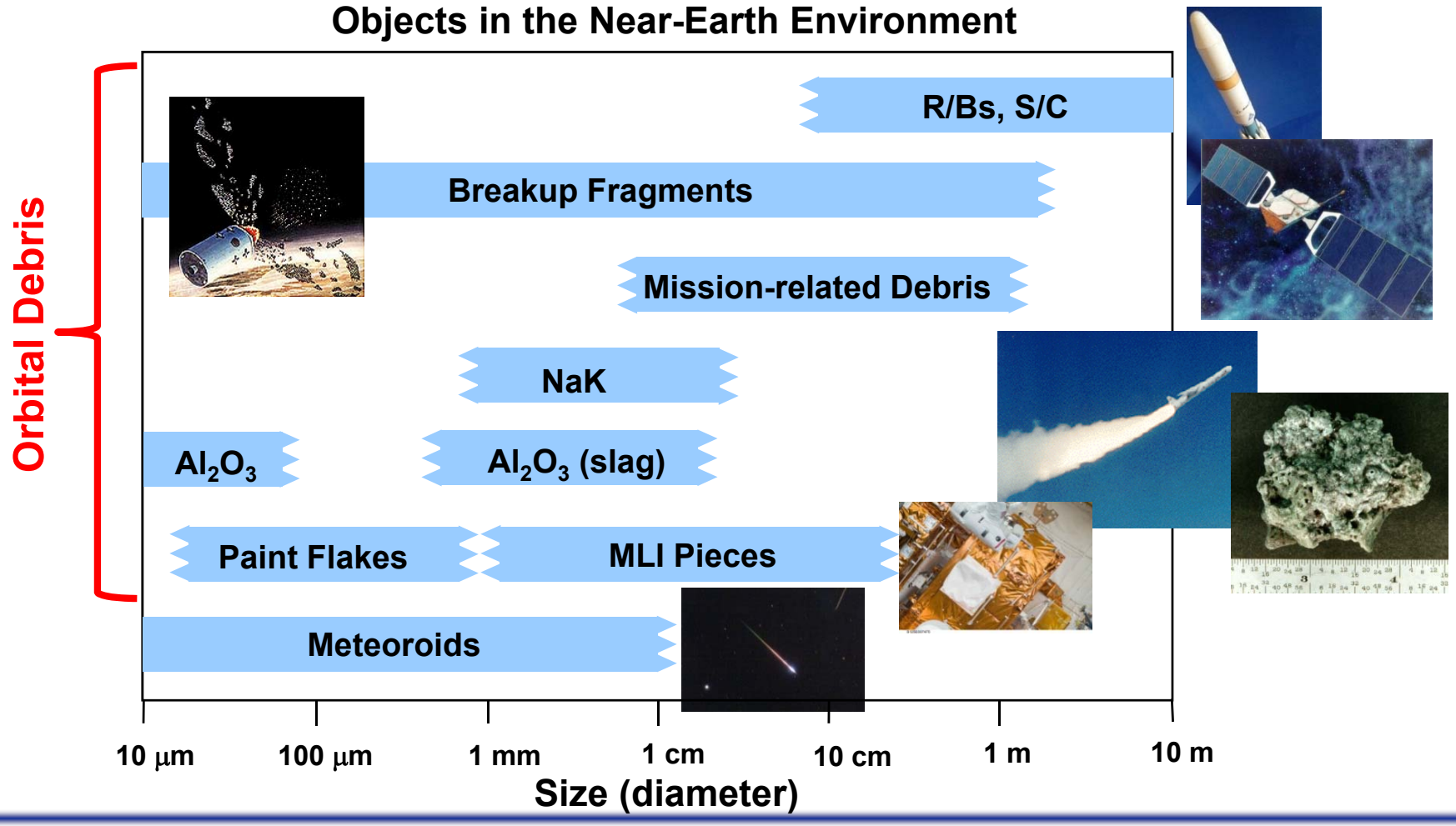
The Space Age

- **The first human-made satellite, Sputnik, was launched to study the atmosphere by the Soviet Union on October 4th, 1957**
- **Since then, more than 4700 launches have ben conducted worldwide**
- **Benefits of space activities**
  - Communications
  - Environment and weather monitoring
  - Explorations
  - Technology advancements
  - Many others
- **But…**

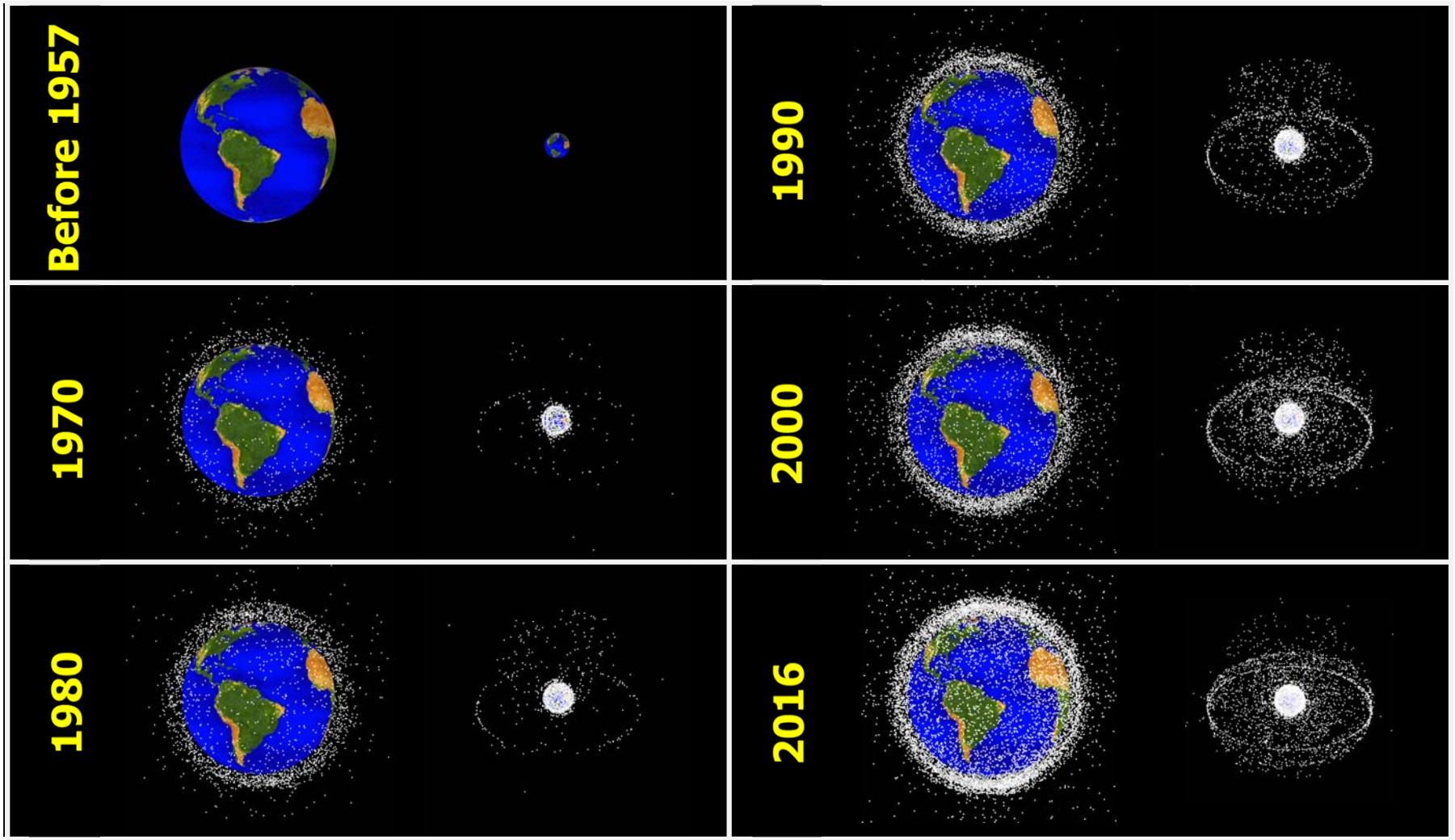

Sputnik

What is Orbital Debris

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



The Near-Earth Space Environment



- Only objects in the U.S. satellite catalog (~10 cm and larger) are shown
- Sizes of the dots are not to scale

How Much Debris is Currently Up There?

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

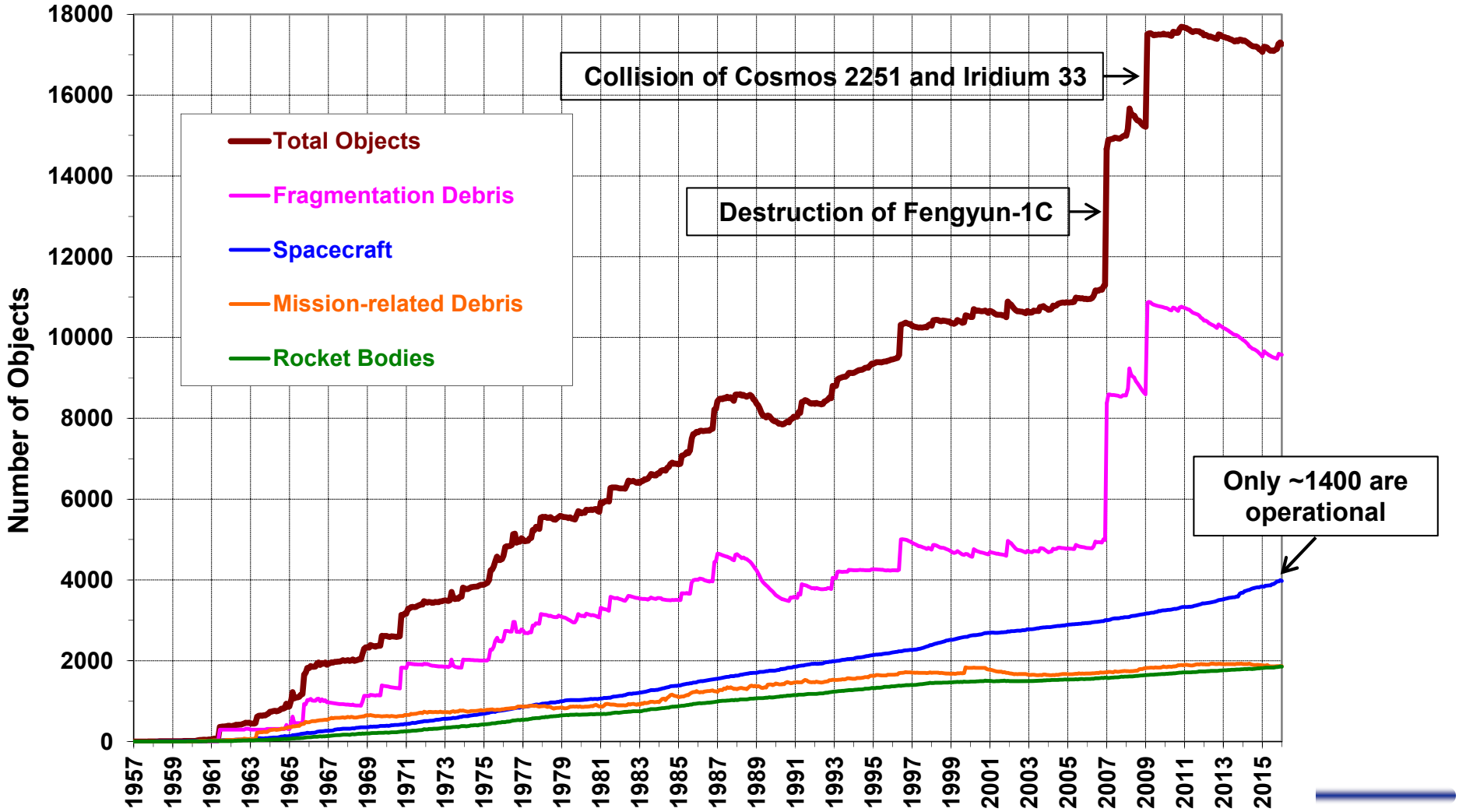
Marble size or larger (≥1 cm): ~500,000

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)**
  - **5-mm aluminum sphere @ 7 km/sec could penetrate a 2.54-cm thick aluminum wall**
- **Total mass: >7000 tons LEO-to-GEO (~2700 tons in LEO)**

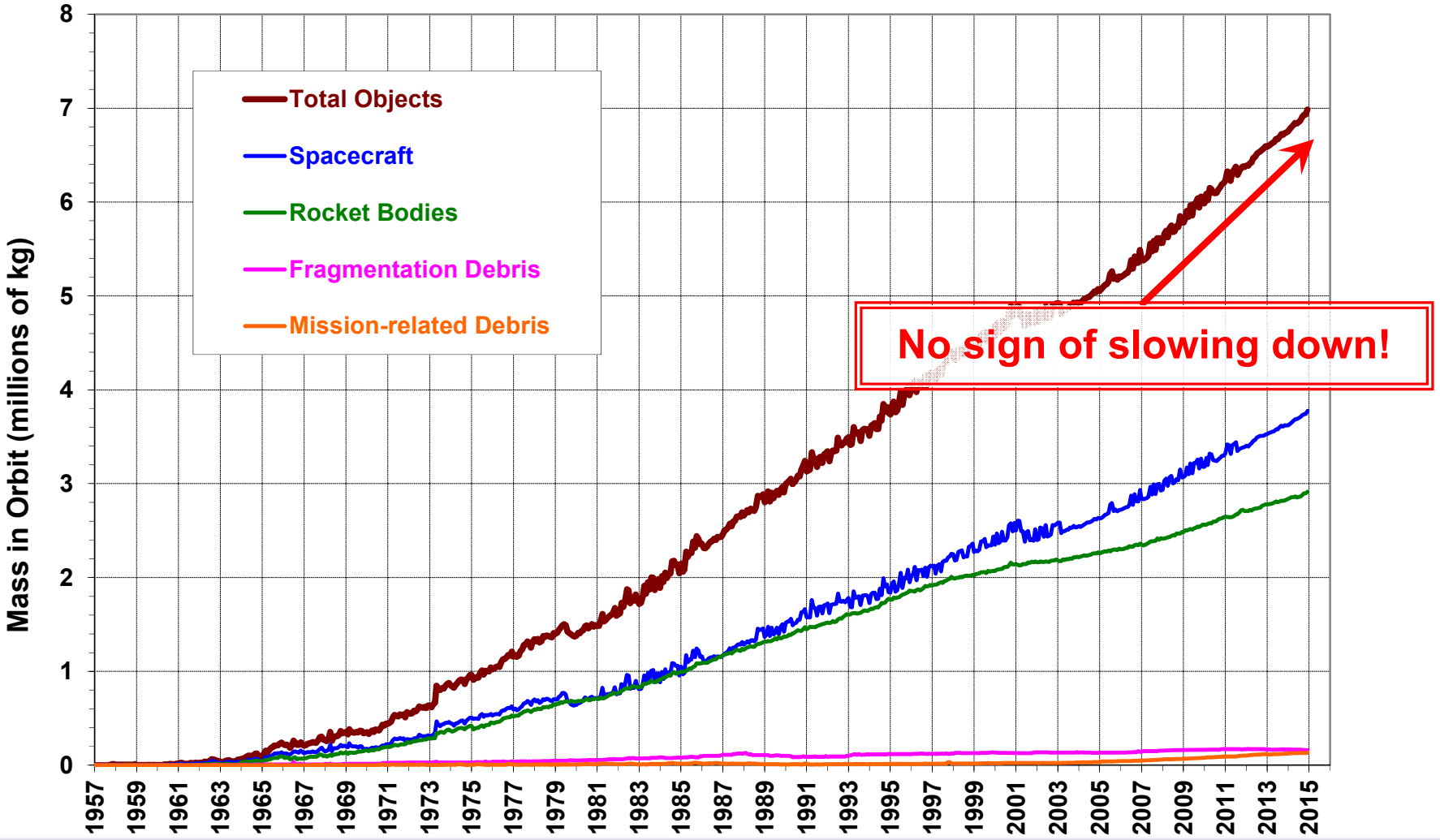
Growth of the Cataloged Population

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



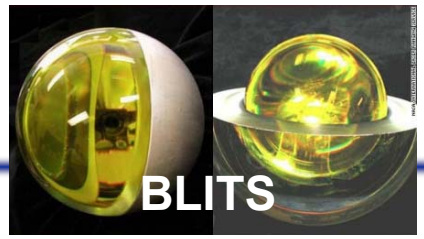
Mass in Near-Earth Space Continues to Increase

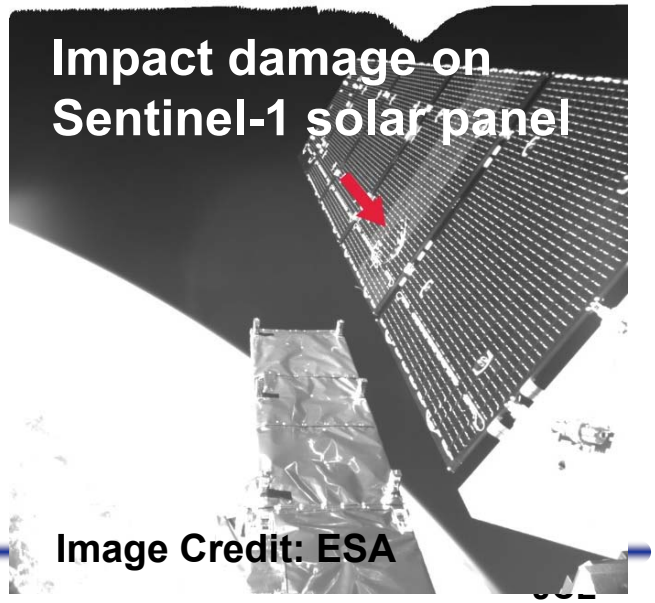
- **The material mass in Earth orbit continues to increase and has exceeded 7000 metric tons**



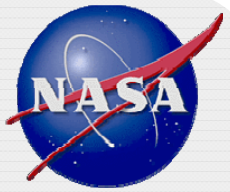
Threat from Orbital Debris - Examples

- 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**





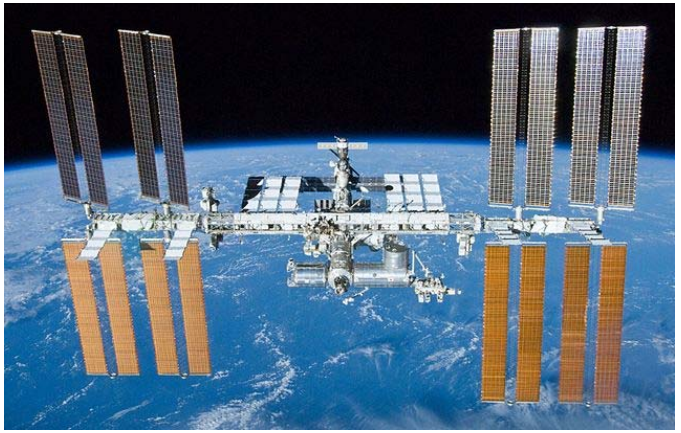
Robotic Spacecraft Collision Avoidance Maneuvers

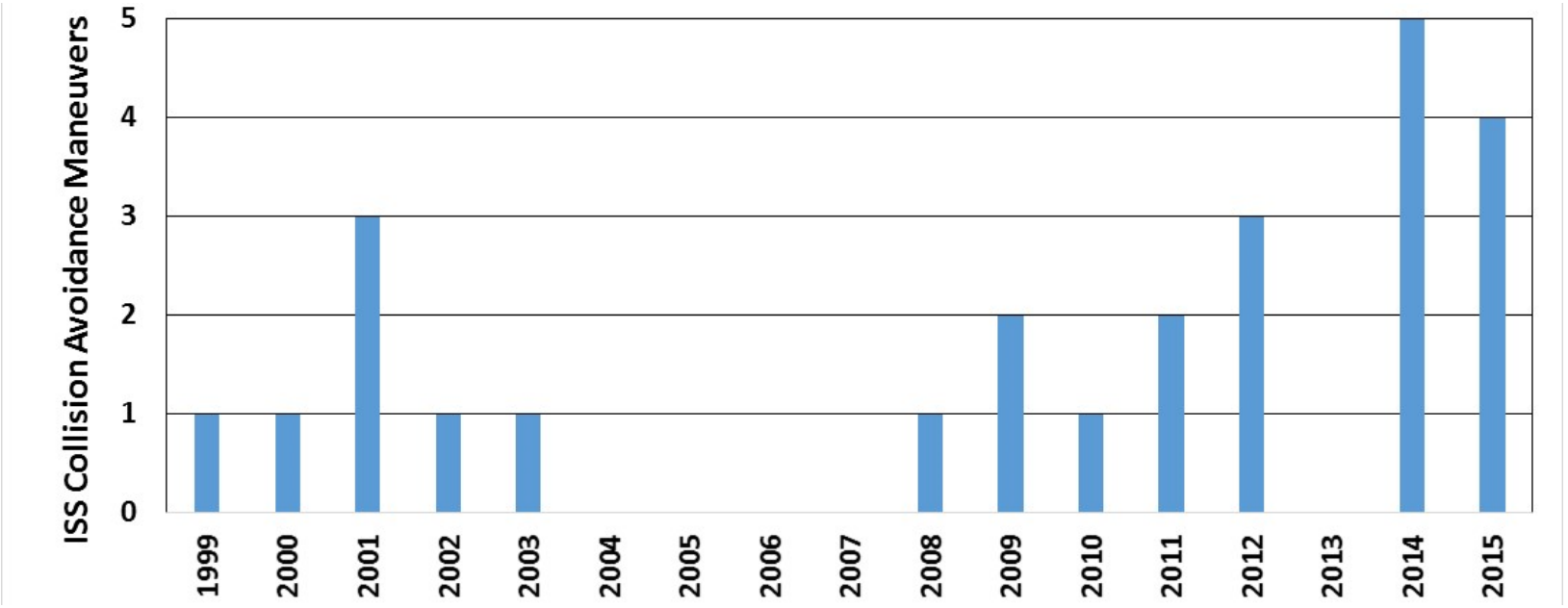


- **The U.S. JSpOC conducts conjunction assessments and provides warnings to all satellite owners/operators around the world**
- **Since 2007 NASA has required frequent satellite conjunction assessments for all of its maneuverable spacecraft in LEO and GEO to avoid accidental collisions with objects tracked by JSpOC**
- **NASA also assists other U.S. government and foreign spacecraft owners with conjunction assessments and subsequent avoidance maneuvers**

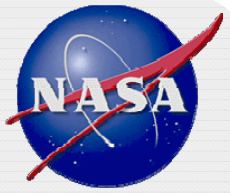
ISS Collision Avoidance Maneuvers

- **The International Space Station (ISS) has conducted 25 debris collision avoidance maneuvers since 1999**
  - Including 4 debris collision avoidance maneuvers and 1 shelter-in-Soyuz in 2015



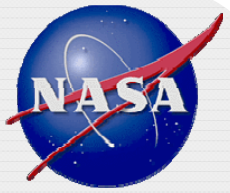


U.S. Government Orbital Debris Mitigation Policy and Standard Practices



- **NASA was the first organization to develop orbital debris mitigation policy and guidelines in the 1990s**
- **NASA and the Department of Defense (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**
  - Control of debris released during normal operations
  - Minimizing debris generated by accidental explosions
  - Selection of safe flight profile and operational configuration
  - Postmission disposal of space structures

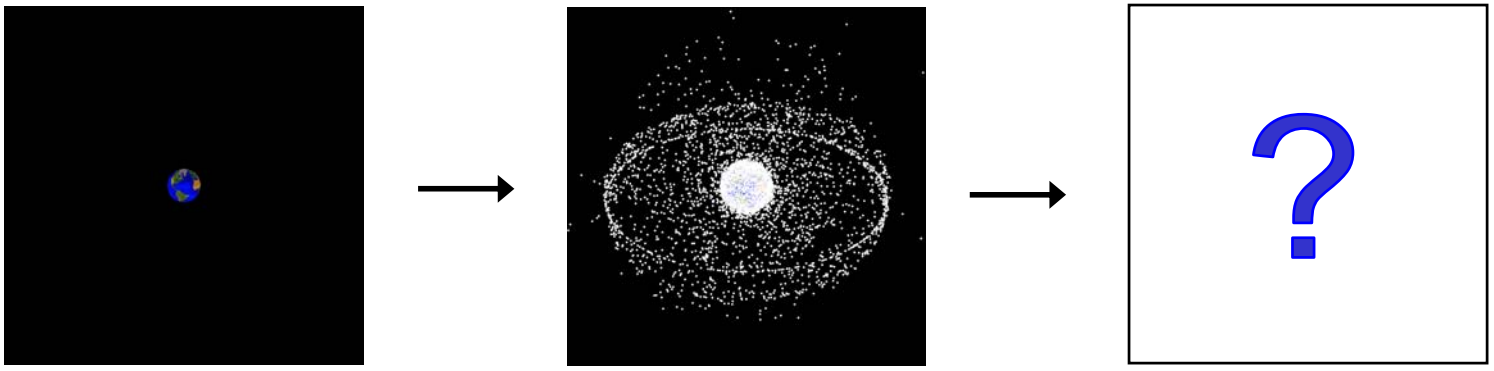
International Orbital Debris Mitigation



- **Many major spacefaring nations have established orbital debris mitigation policies similar to the U.S. Government Orbital Debris Mitigation Standard Practices**
- **The Inter-Agency Space Debris Coordination Committee (IADC) established the first consensus on international orbital debris mitigation guidelines in 2002**
  - IADC members: ASI, CNES, CNSA, CSA, DLR, ESA, ISRO, JAXA, KARI, NASA, ROSCOSMOS, SSAU, and UKSA
- **The United Nations (UN) adopted a similar set of space debris mitigation guidelines in 2007**
- **The International Organization for Standardization (ISO) developed its space debris mitigation requirements in 2010**

Forward Challenges

- **The international space community needs to follow the existing orbital debris mitigation guidelines to limit the generation of new and long-lived debris**
- **Proliferation of small satellites, including CubeSats and the proposed mega-constellations, presents new challenges to preserve the environment while continuing to use near-Earth space to benefits the global community**



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