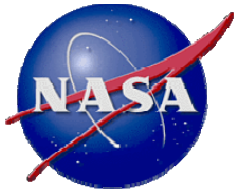
National Aeronautics and Space Administration



Orbital Debris Mitigation Policy and Unique Challenges for CubeSats

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NRC Committee on Achieving Science Goals with CubeSats

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Outline

- Overview of the Orbital Debris Environment
- Putting the Potential CubeSat Issues in Perspective
- Ongoing Efforts to Quantify the Risks
- Challenges and Forward Plan

How Much Junk is Currently Up There?

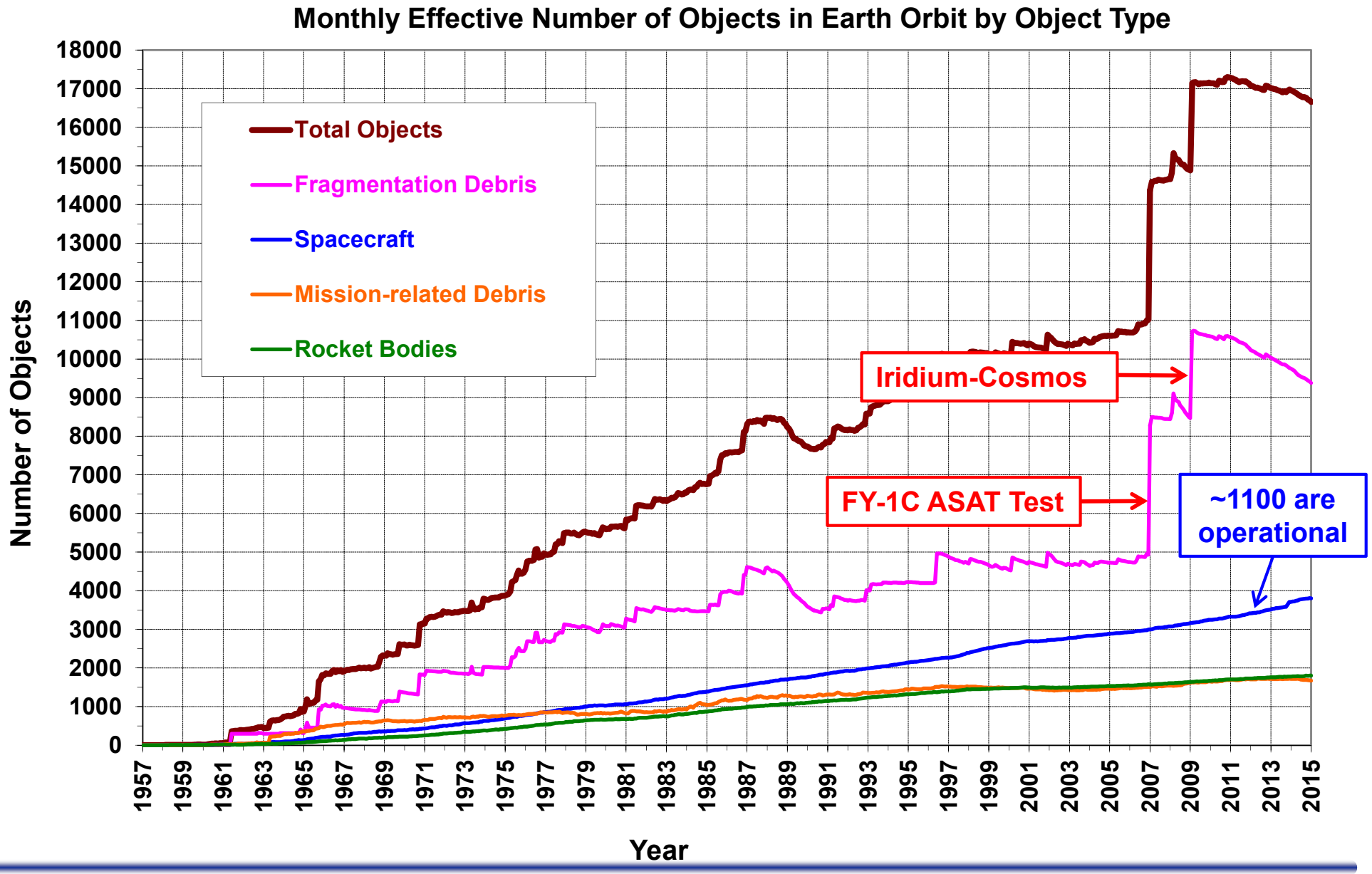
Softball size or larger (≥10 cm): ~23,000
(tracked by the U.S. Space Surveillance Network, SSN)

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

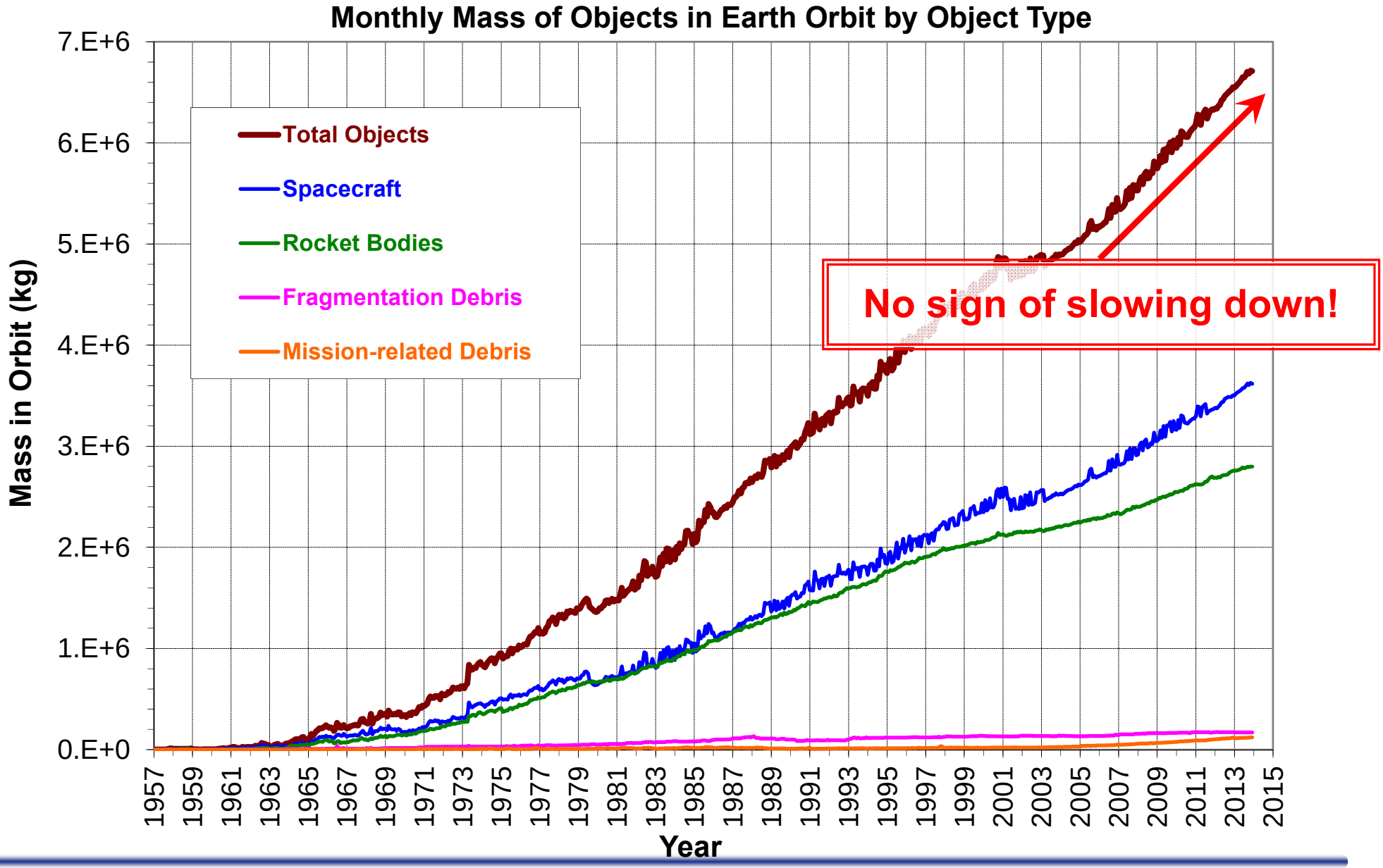
Dot or larger (≥1 mm): >100,000,000
(a grain of salt)

- **Due to high impact speeds in space (~10 km/s in LEO), even sub-millimeter debris pose a realistic threat to human spaceflight and robotic missions**
  - **7 km/sec = 25,200 km/hr; 10 km/sec = 36,000 km/hr**
  - **1-cm aluminum sphere @ 10 km/s = 200 kg safe @ 90 mph**
  - **5-mm aluminum sphere @ 7 km/sec could penetrate a 2.54-cm thick aluminum wall**
- **Total mass: ~6300 tons LEO-to-GEO (~2700 tons in LEO)**

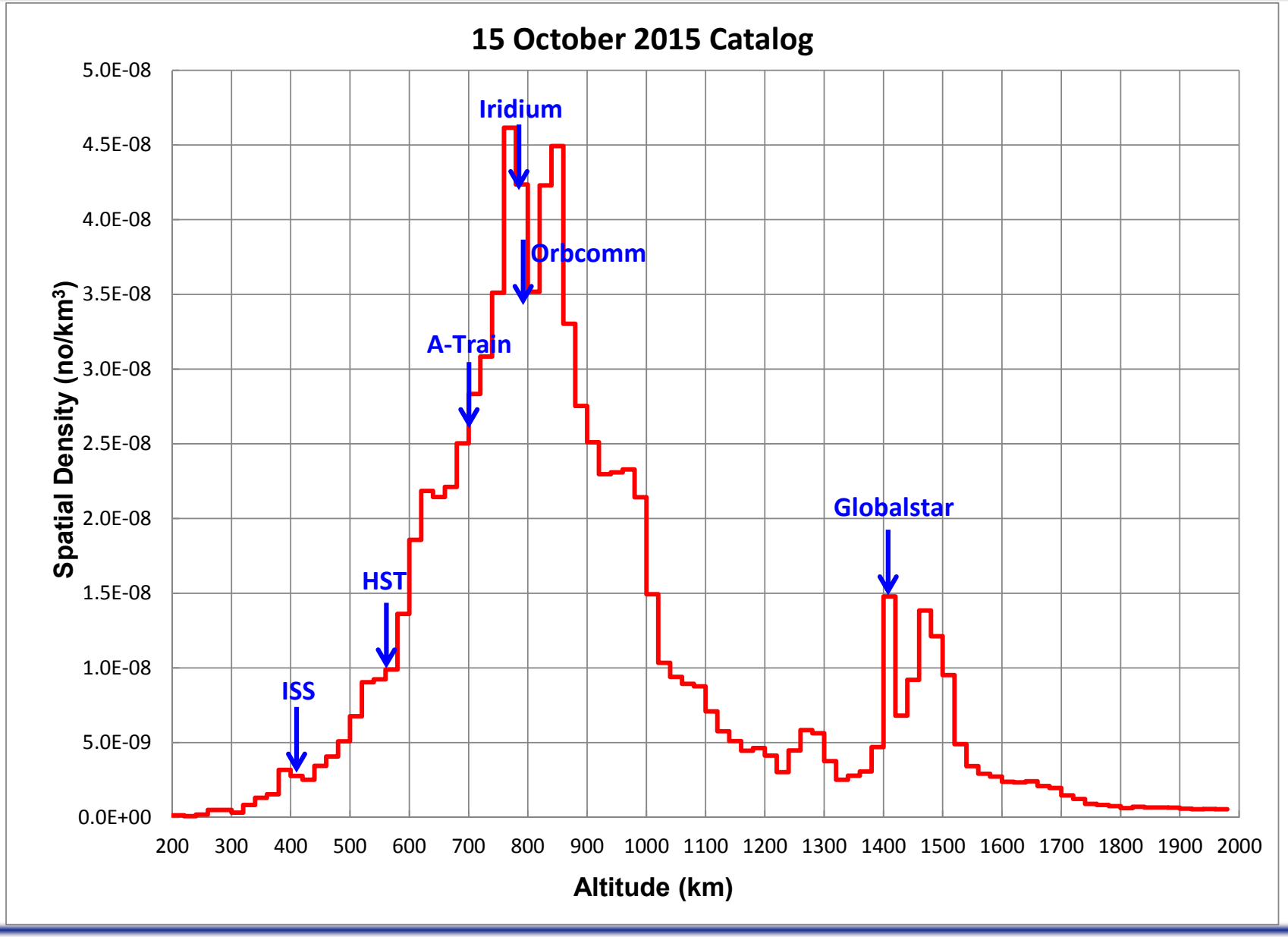
Growth of the Cataloged Populations



Mass in Space



Altitude Distribution of the Cataloged Objects



The Orbital Debris Problems

- **In the future, the long-term debris population increase is expected to be driven by accidental collisions involving large/massive rocket bodies or spacecraft.**
  - How much do CubeSats contribute to the future debris population growth?

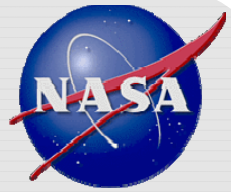
- **The major mission-ending risks for most operational spacecraft, however, come from impacts with orbital debris just above the threshold of the protection shields (~5 mm to 1 cm).**
  - How much do CubeSats add to the risks to operational spacecraft?

Current Policy for CubeSats (1/2)

- **CubeSats are subject to current orbital debris mitigation policy, guidelines, and requirements.**
  - The NASA Procedural Requirements for Limiting Orbital Debris, the U.S. Government Orbital Debris Mitigation Standard Practices, the IADC Space Debris Mitigation Guidelines, and the UN Space Debris Mitigation Guidelines have no automatic exclusions for any satellite due to its size or mass limit and apply to each satellite separately.
  - Key mitigation elements include:
    - **limit accidental explosions.**
    - **limit accidental collisions with large objects.**
    - **follow post-mission disposal (*e.g.*, the 25-year rule* or graveyard orbit in LEO, graveyard orbit in MEO and GEO).**
    - **limit reentry casualty risk.**

***All NASA CubeSats launched through June 2015 complied with the 25-year rule.**

Current Policy for CubeSats (2/2)



- Compliance with the current policy may require:
  - **good quality and mission assurance (to limit accidental explosions).**
  - **trackability and maneuverability* (for collision avoidance and post-mission disposal).**
  - **adequate spacecraft design (to limit reentry casualty risk).**

***NASA is investing in technology development and demonstration to improve tracking, control, and deorbit of CubeSats.**

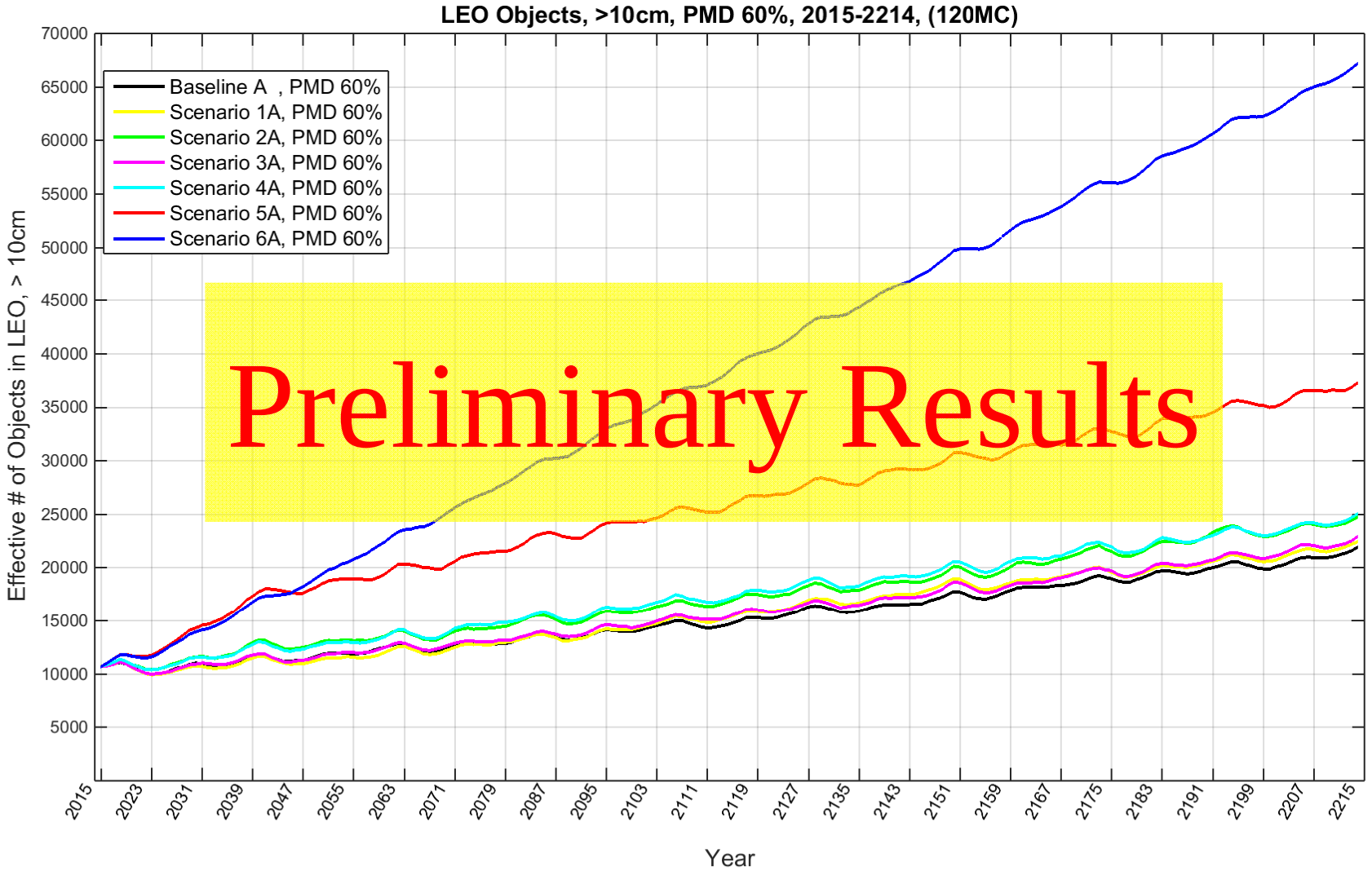
Challenges for CubeSats

- **Due to the likelihood of large and frequent deployments, CubeSats present several new and unique challenges to the space environment (LEO, MEO, and GEO) and to other operational spacecraft.**
  - Increased collision risks to other operational spacecraft if the CubeSats cannot be tracked and cannot maneuver.
  - Increased collision risks to further debris population growth.
    - **Adding hundreds or more CubeSats to the environment on a regular basis may significantly increase collision activities in the environment.**
  - Collective reentry human casualty risks.
- **These risks depend on the number of CubeSats deployed, deployment frequency, deployment orbits, deployment sequence, and orbital lifetimes.**

Quantify the Risks

- **The NASA Orbital Debris Program Office (ODPO) is currently conducting a parametric study to quantify the potential negative environmental impacts of CubeSats in LEO.**
  - Long-term population (number and mass) increase.
  - Collision activities.
- **Several international space agencies, including members of the Inter-Agency Space Debris Coordination Committee (IADC), are working on similar studies.**

One Example from the Current ODPO Study

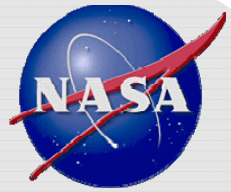


Forward Plan

- **Follow JSpOC's recommendations for CubeSat operations.**
- **Reach a technical consensus on the impact of CubeSats to the orbital debris environment.**
- **If necessary, provide recommendations for a new policy at the national and international levels.**
  - Follow the same path for the establishment of the U.S. Government Orbital Debris Mitigation Standard Practices (2001), the IADC Space Debris Mitigation Guidelines (2002), and the UN Space Debris Mitigation Guidelines (2007).

Backup Charts

History of Orbital Debris Mitigation Policies and Requirements



U.S. Orbital Debris Mitigation Policy and Standard Practices (SP)

NASA Debris Mitigation Policy and Requirements

IADC and UN Guidelines

1988
1989
1990
1991
1992
1993
1994
1995
1996
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1998
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2002
2003
2004
2005
2006
2007
2008
2009
2010


NSP, Reagan, 1988


NSP, GHW Bush, 1989


NSP, Clinton, 1996


SP, 1997, draft

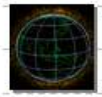

SP, 2001, official

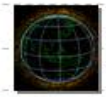

NSP, GW Bush, 2006


NSP, Obama, 2010

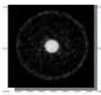

NMI 1700.8 1993


NSS 1740.14 1995


NPD 8710.3 1997


NPD 8710.3A, 2003


NPD 8710.3B, 2004


NPR 8715.6 2007

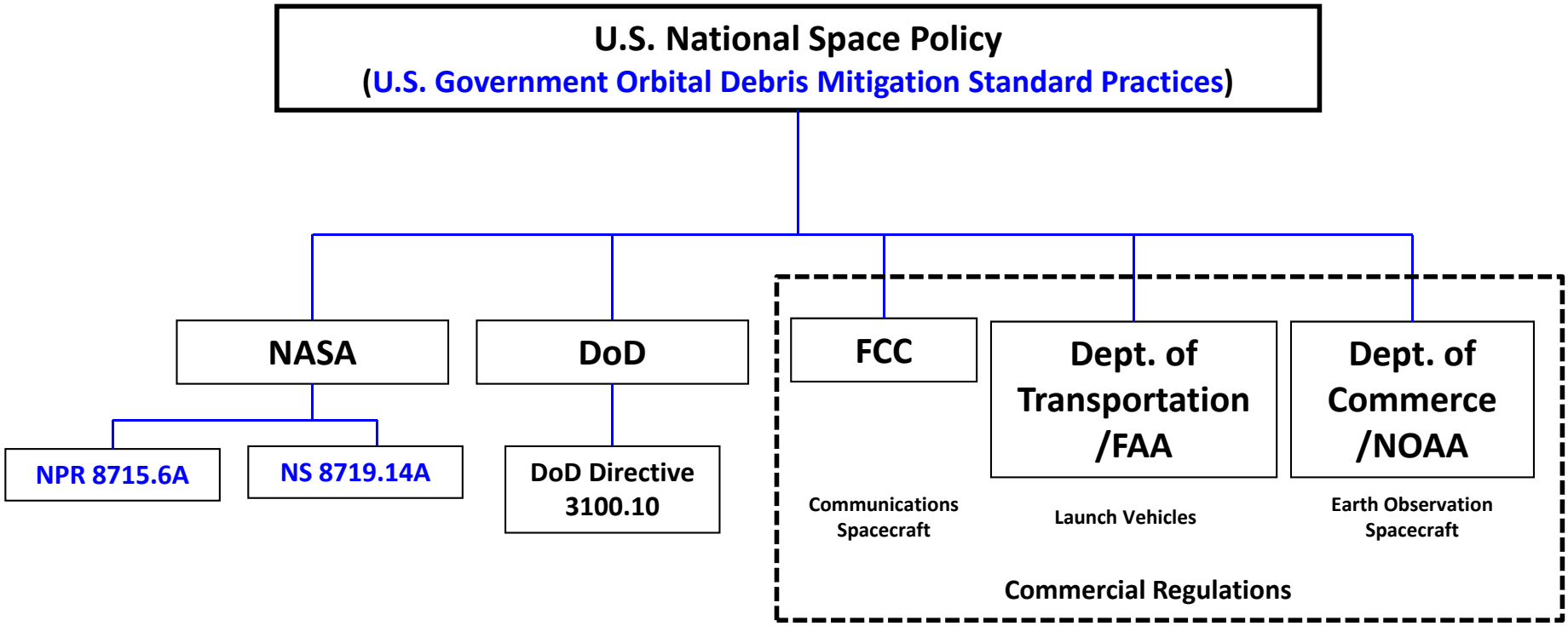

NS 8719.14 2007

IADC SDMG, 2002 (minor rev 2007)

UN SDMG, 2007 (General Assembly)

U.S. Orbital Debris Mitigation Policies

- **All current U.S. government requirements and commercial regulations for orbital debris mitigation are derived from the 2001 U.S. Government Orbital Debris Mitigation Standard Practices, which are cited in U.S. National Space Policy in 2006 and 2010.**



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.**
- **The IADC developed the first consensus on international orbital debris mitigation guidelines in October 2002; subsequently submitted to the United Nations.**

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.**

Acronyms

- COPUOS: Committee on the Peaceful Uses of Outer Space
- GEO: Geosynchronous Earth Orbit
- IADC: Inter-Agency Space Debris Coordination Committee
- JSpOC: Joint Space Operations Center
- LEO: Low Earth Orbit
- MC: Monte Carlo
- MEO: Medium Earth Orbit
- NMI: NASA Management Instruction
- NPD: NASA Policy Directive
- NPR: NASA Procedural Requirements
- NS: NASA Technical Standard
- NSP: National Space Policy
- NSS: NASA Safety Standard
- ODPO: Orbital Debris Program Office
- PMD: Post-Mission Disposal
- SSN: Space Surveillance Network
- SDMG: Space Debris Mitigation Guidelines
- STSC: Scientific and Technical Subcommittee
- UN: United Nations