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
• Put the Potential CubeSat Issues in Perspective
• Ongoing Efforts to Quantify the Risks
• Challenges and Forward Plan
How Much Junk is Currently Up There?

- 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 Al sphere @ 10 km/s = 200 kg safe @ 90 mph
  - 5-mm Al sphere @ 7 km/sec could penetrate a 2.54-cm thick Al wall
- Total mass: ~6300 tons LEO-to-GEO (~2700 tons in LEO)

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)
Growth of the Cataloged Populations

Monthly Effective Number of Objects in Earth Orbit by Object Type

- **Total Objects**
- **Fragmentation Debris**
- **Spacecraft**
- **Mission-related Debris**
- **Rocket Bodies**

Key Events:
- FY-1C ASAT Test
- Iridium-Cosmos

Notable Observation:
- ~1100 are operational
Mass in Space

Monthly Mass of Objects in Earth Orbit by Object Type

- Total Objects
- Spacecraft
- Rocket Bodies
- Fragmentation Debris
- Mission-related Debris

No sign of slowing down!
Altitude Distribution of the Cataloged Objects

15 October 2015 Catalog

Spatial Density (no/km³)

Altitude (km)

- ISS
- HST
- A-Train
- Iridium
- Orbcomm
- Globalstar
The root cause of long-term debris population increase is 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 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

- **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.
  - Key requirements include:
    - limit accidental explosions.
    - limit accidental collisions with large objects.
    - follow post-mission disposal (e.g., the 25-year rule in LEO, graveyard orbit in MEO and GEO).
    - limit reentry casualty risk.
  - 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).
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 their 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

LEO Objects, >10cm, PMD 60%, 2015-2214, (120MC)

Preliminary Results
Forward Plan

• 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.
Backup Charts
### National Aeronautics and Space Administration

**History of Orbital Debris Mitigation Policies and Requirements**

<table>
<thead>
<tr>
<th>U.S. Orbital Debris Mitigation Policy and Standard Practices (SP)</th>
<th>NASA Debris Mitigation Policy and Requirements</th>
<th>IADC and UN Guidelines</th>
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- **IADC SDMG, 2002 (minor rev 2007)**
- **UN SDMG, 2007 (General Assembly)**
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.

• IADC developed 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
- LEO: Low Earth Orbit
- 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
- STMD: Space Debris Mitigation Guidelines
- STSC: Scientific and Technical Subcommittee
- UN: United Nations