Orbital Debris Challenges for Space Operations

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Presentation Outline

• Historical and Current Orbital Debris Environment
• Danger of Orbital Debris
• Orbital Debris Mitigation Policy
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)
Evolution of the Cataloged Population

- The U.S. Joint Space Operations Center (JSpOC) is tracking ~23,000 large objects and maintains most of their orbits in the U.S. Satellite Catalog.
- JSpOC conducts conjunction assessments and provides warnings to all satellite owners/operators around the world.

![Graph showing the evolution of the cataloged population with significant events such as the Collision of Cosmos 2251 and Iridium 33, and the Destruction of Fengyun-1C. The graph displays the number of objects over time, with categories including Total Objects, Fragmentation Debris, Spacecraft, Mission-related Debris, and Rocket Bodies. The graph highlights that ~1300 are operational.]
The material mass in Earth orbit continues to increase and has exceeded 7000 metric tons.

No sign of slowing down!
• The threat from orbital debris is real
  – 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)
  – Impacts by small, untracked debris could be responsible for many satellite anomalies
    • A 17-cm Russian retro reflector, Ball Lens In The Space (BLITS), was damaged and shed a piece of trackable debris in January 2013
Robotic Spacecraft Collision Avoidance Maneuvers

• 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 maneuvers

• During 2015 NASA executed or assisted in the execution of 26 collision avoidance maneuvers by robotic spacecraft
ISS Collision Avoidance Maneuvers

- The International Space Station (ISS) conducted 4 debris collision avoidance maneuvers in 2015
- In addition, due to a late notification of a high probability conjunction, the crew was directed to “shelter-in-Soyuz” on July 16th
  - Fortunately the conjunction did not lead to a collision
• 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 adopted a similar set of space debris mitigation guidelines in 2007

• The international space community needs to follow the existing mitigation guidelines to better preserve the near-Earth space environment for future space operations