Orbital Debris Environment
– Now and the Future

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Growth of the **Cataloged Populations**

**Monthly 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**

Approximately 1100 are operational.
Mass in Space

Monthly Mass of Objects in Earth Orbit by Object Type

No sign of slowing down!
How Much Junk Is Currently Up There?

- Due to high impact speed in space (~10 km/s in LEO), even sub-mm debris pose a realistic threat to human spaceflight and robotic missions
  - 1-cm Al sphere @ 10 km/s = 400 lb safe @ 60 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): ~20,000 to 22,000
(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)
Is the threat from orbital debris real?
- The gravity-gradient boom of an operational French satellite (CERISE) was cut in half by a tracked debris 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.
  - The U.S. GOES-13 Satellite experienced an attitude drift of >2 deg/sec in May 2013. Fortunately there was no permanent damage and GOES-13 was returned to normal operations in June.
Future Projection – The Worst Case Scenario (Regular Satellite Launches, Without Mitigation Measures)

Non-Mitigation Projection (averages and 1-σ from 100 MC runs)

- **LEO (200-2000 km alt)**
- **MEO (2000-35,586 km alt)**
- **GEO (35,586-35,986 km alt)**

Effective Number of Objects (>10 cm) vs. Year

(Liou, 2010)
Collision fragments replace other decaying debris through the next 50 years, keeping the total population approximately constant. Beyond 2055, the rate of decaying debris decreases, leading to a net increase in the overall satellite population due to collisions.
International Consensus

• Future orbital debris population growth in LEO has been investigated by the Inter-Agency Space Debris Coordination Committee (IADC) since 2008

• An official comparison study was completed in 2012
  – The objectives were to confirm the instability of the current LEO debris population and to reach a consensus on the need to use active debris removal to stabilize the future LEO debris environment
  – Study participants: ASI, ESA, ISRO, JAXA, NASA (lead), UKSA
  – Results from the six different models are consistent with one another: (1) even with no future explosion and a global 90% compliance of the 25-year rule, the LEO debris population is expected to increase in the next 200 years and (2) catastrophic collisions involving intact objects are likely to occur every 5 to 9 years
Problems and Solutions

• LEO debris population will continue to increase even with a good implementation of the commonly-adopted mitigation measures
  – The root-cause of the increase is catastrophic collisions involving large/massive intact objects (rocket bodies and spacecraft)
  – 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)

• A solution-driven approach is to seek
  – Concepts for removal of massive intacts with high $P_{\text{collision}}$
  – Concepts capable of preventing collisions involving intacts
  – Concepts for removal of 5-mm to 1-cm debris
  – Enhanced impact protection shields for valuable space assets
Threat Regimes

Notional Size Distribution of LEO-Crossing Objects

~80% of all >5 mm debris are in the 5-mm to 1-cm regime

Main threat to operational S/C

Degradation threat to operational S/C

Main driver for population growth

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Challenges for the Next 30 Years

• Environment management
  – Improve global compliance of orbital debris mitigation measures
  – Invest in innovative concepts and technologies for long-term remediation of the near-Earth orbital debris environment

• Risk mitigation
  – Increase the capabilities in space situational awareness to identify and track the majority of ~cm debris with good accuracy
  – Develop cost-effective, low mass impact shields against mm-to-cm orbital debris