Orbital Debris Environment – Now and the Future

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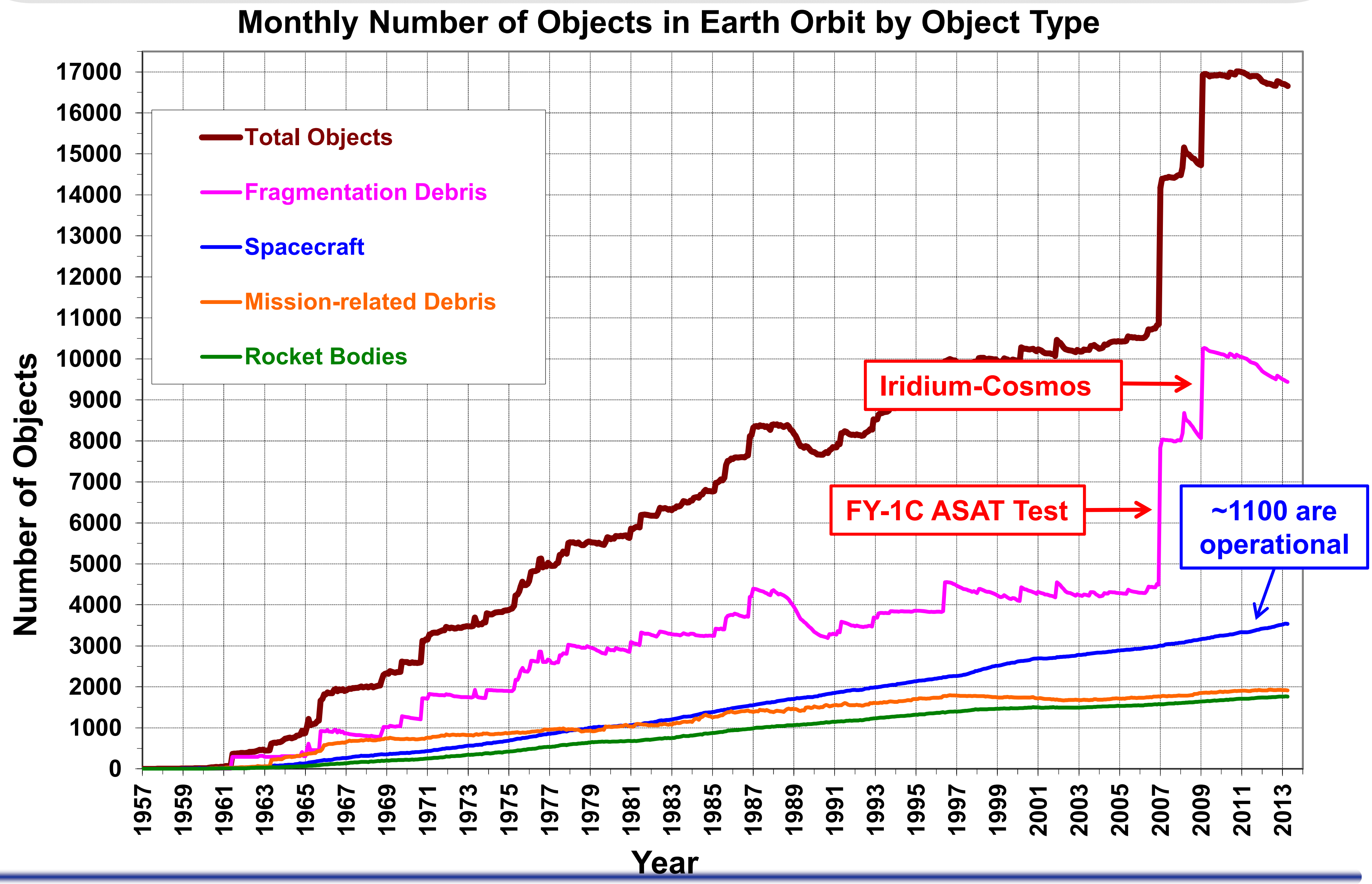
Growth of the Cataloged Populations



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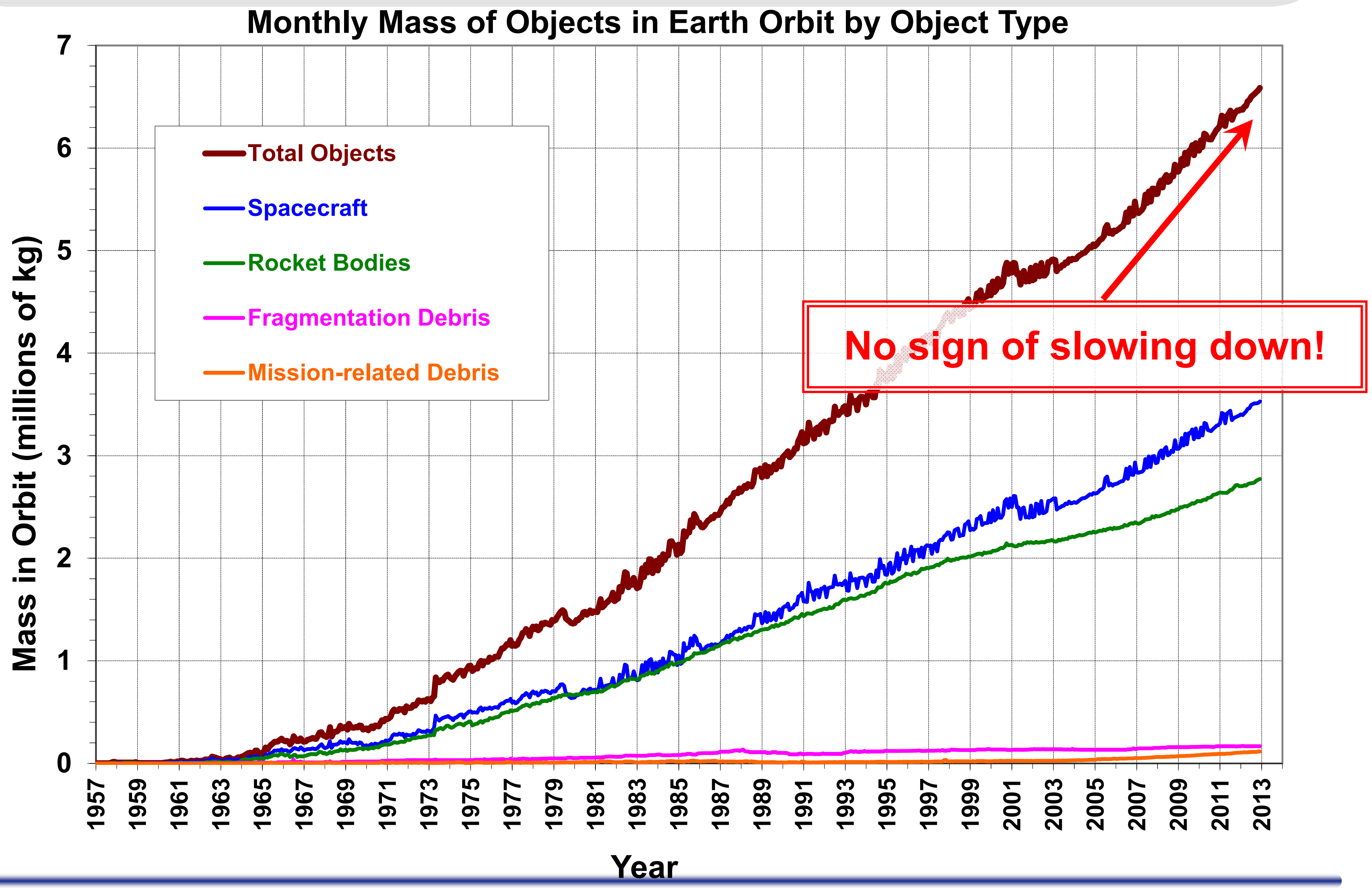
Mass in Space



How Much Junk Is Currently Up There?

Softball size or larger (≥10 cm): ~20,000 to 22,000 (tracked by the U.S. Space Surveillance Network, SSN)

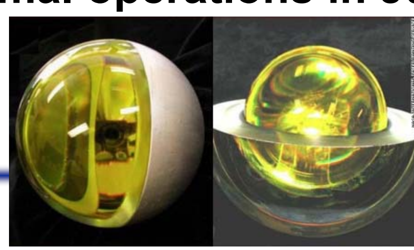
Marble size or larger (≥1 cm): ~500,000

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

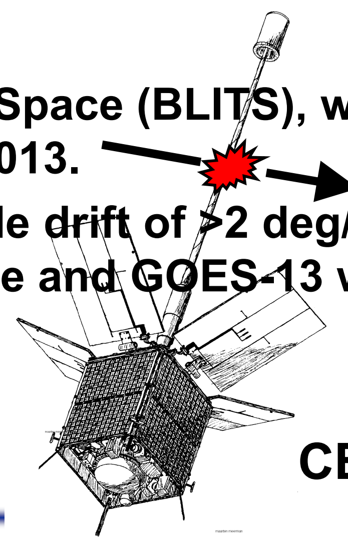
- **Due to high impact speed in space (~10 km/s in LEO), even sub-mm debris pose a realistic threat to human spaceflight and robotic missions**
  - **1-cm Al sphere @ 10 km/s = 400 lb safe @ 60 mph**
  - **5-mm Al sphere @ 7 km/sec could penetrate a 2.54 cm thick Al wall**
- **Total mass: ~6300 tons LEO-to-GEO (~2700 tons in LEO)**

Threat From Orbital Debris

- **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.**



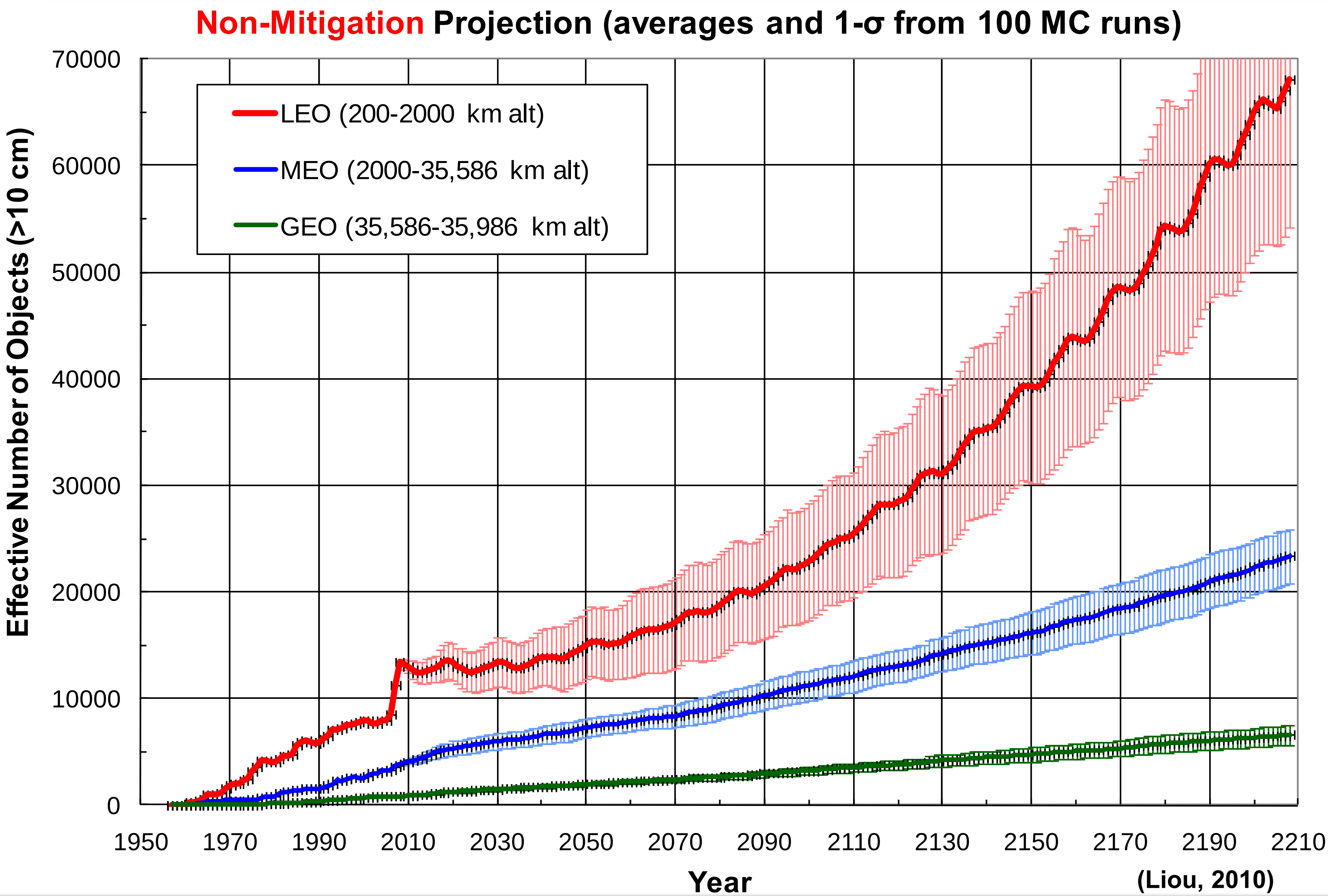
BLITS



CERISE

Future Projection – The Worst Case Scenario

(Regular Satellite Launches, Without Mitigation Measures)



(Liou, 2010)

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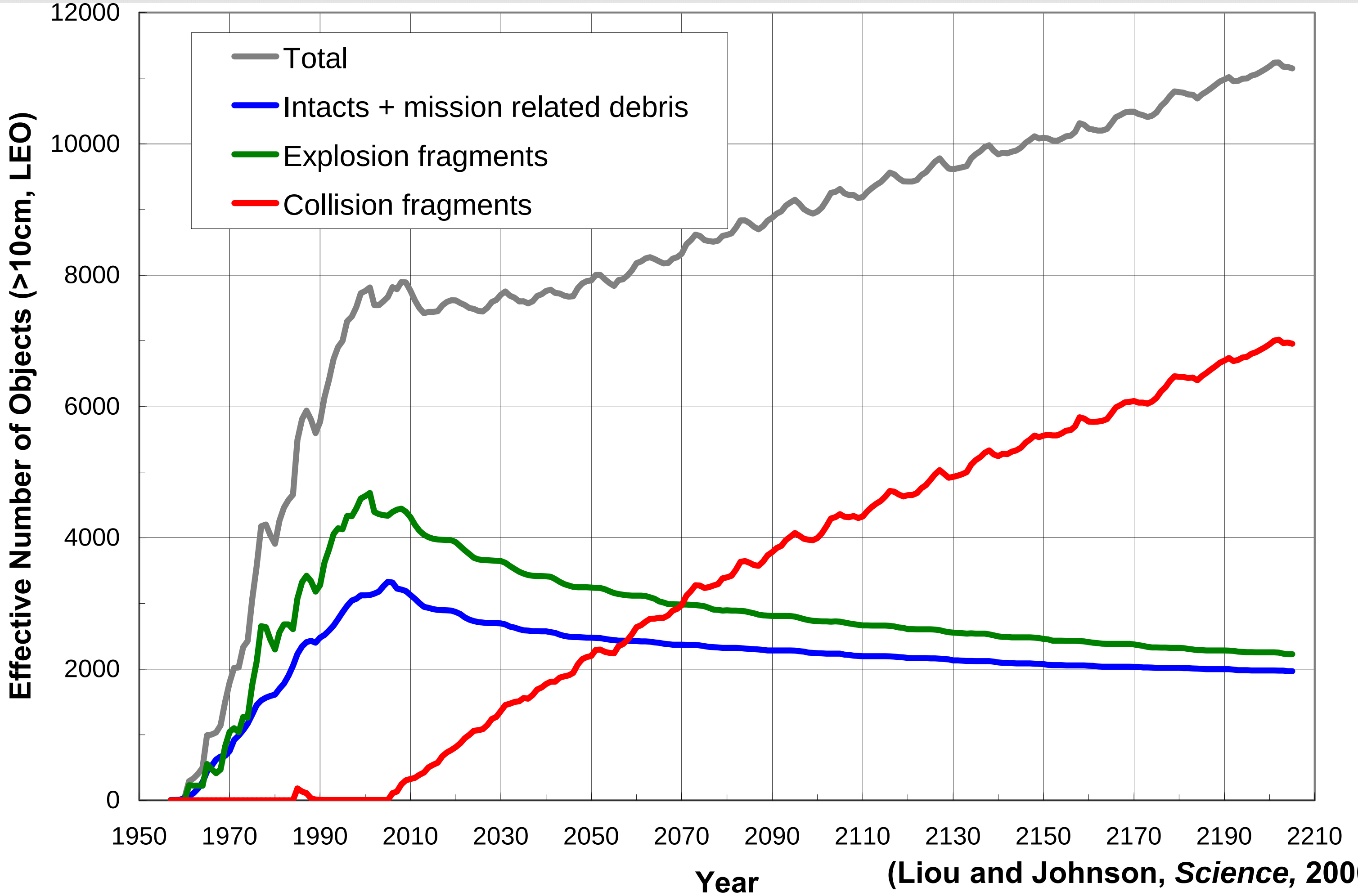
Future Projection – The Best Case Scenario
(No New Launches Beyond 1/1/2006)



(Liou and Johnson, *Science,* 2006)

- **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

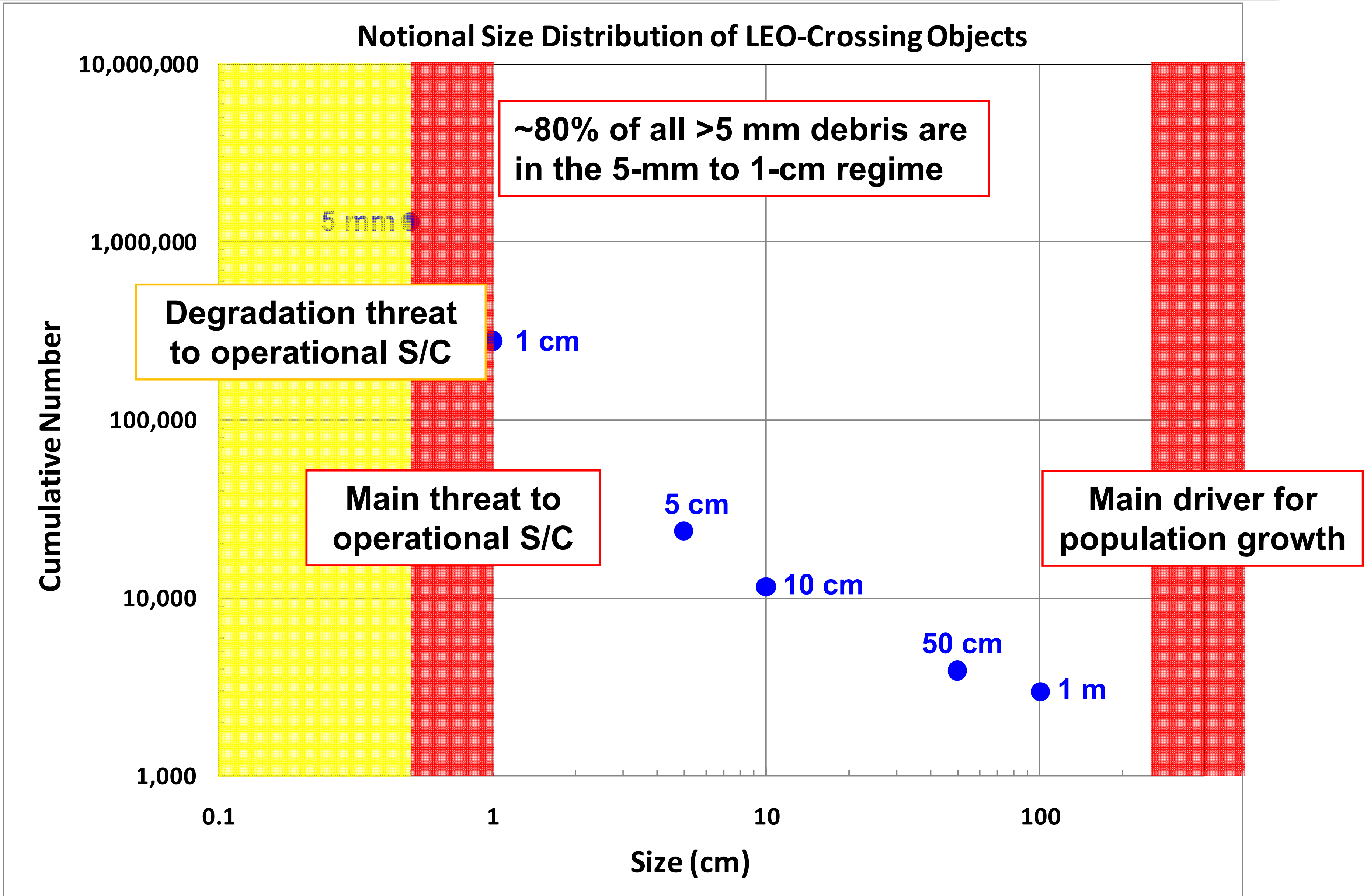
- **Future orbital debris population growth in LEO has been investigated by the Inter-Agency Space Debris Coordination Committee (IADC) since 2008**
- **An official comparison study was completed in 2012**
  - The objectives were to confirm the instability of the current LEO debris population and to 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 <u>solution-driven</u> approach is to seek**
  - Concepts for removal of massive intacts with high $P_{collision}$
  - 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



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