31st Workshop on Space Technology for Socio-Economic Benefits:
"Space Sustainability as a Game-Changer for Development"

The Dark Side of Space: addressing the space debris crisis

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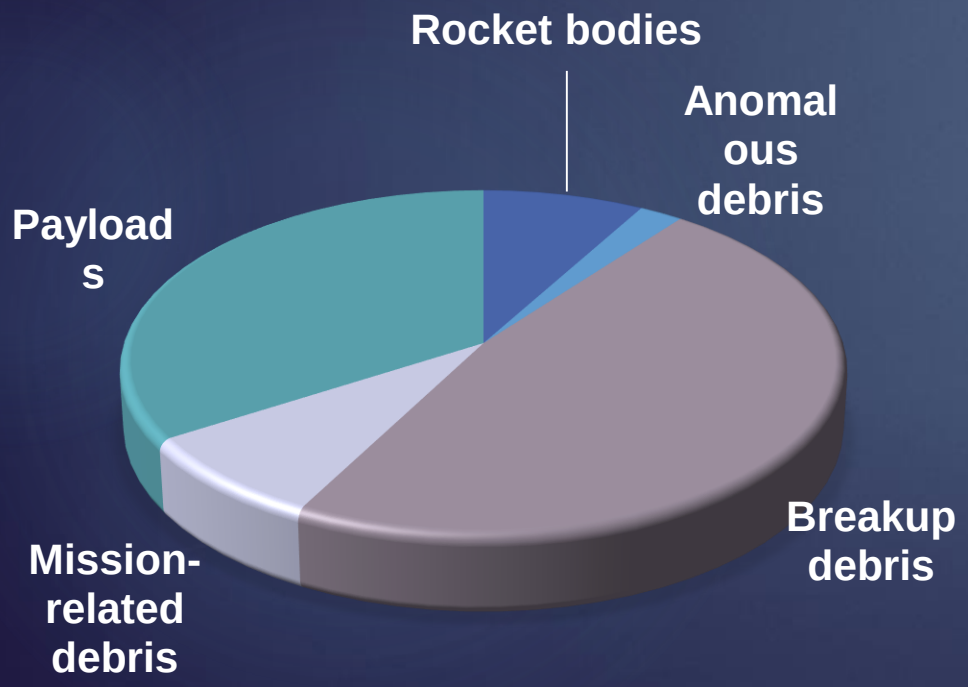
Space Debris

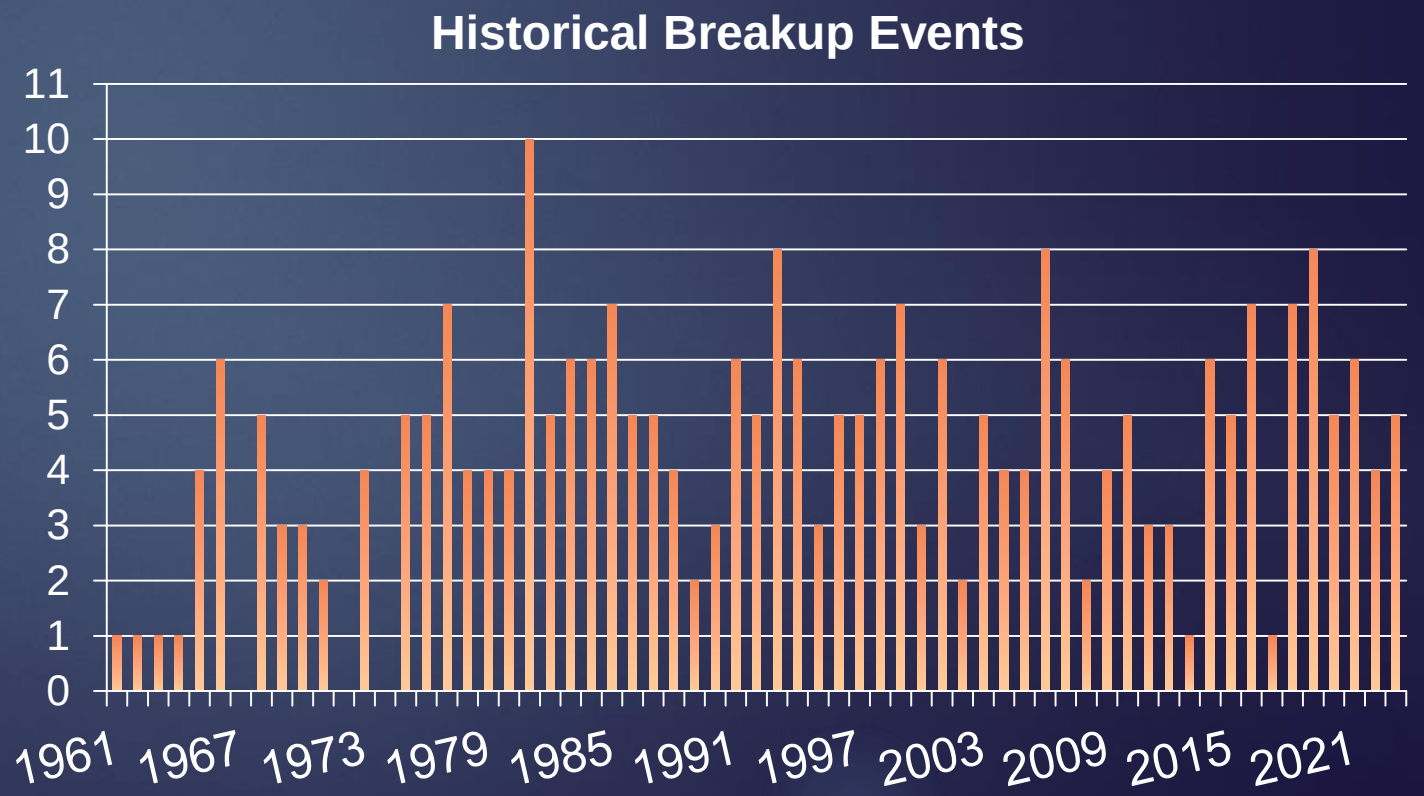
Size	# of space objects
> 10 cm	40500
1m - 10cm	110000
1mm -1cm	130 million

Source: ESA Space Environment Statistics

Catalogued Objects	Approx. #
Active payloads	10500
Defunct satellites	3000
Debris objects	19000
Analyst objects	17000

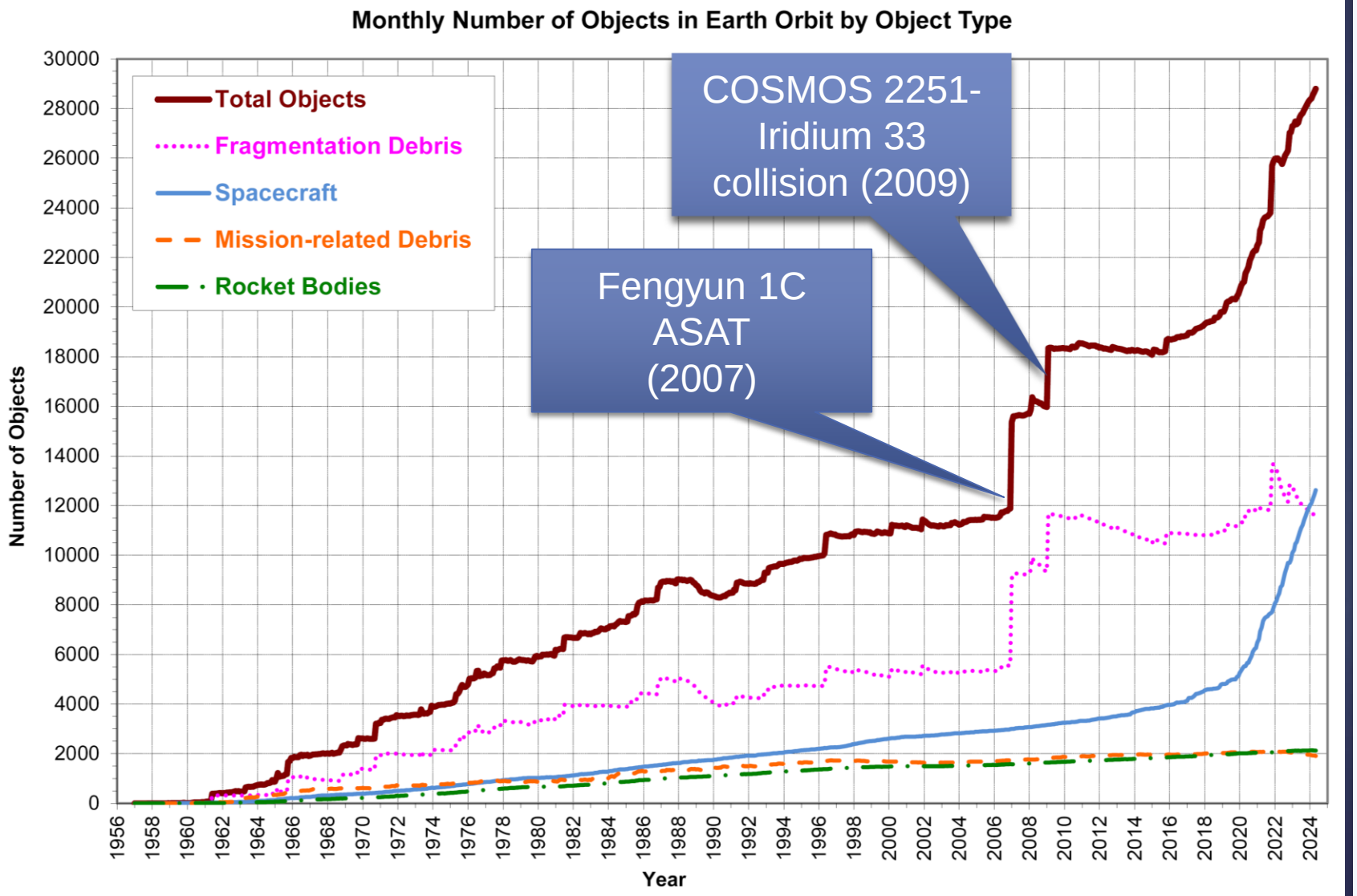
Source: Space-Track/USSPACECOM

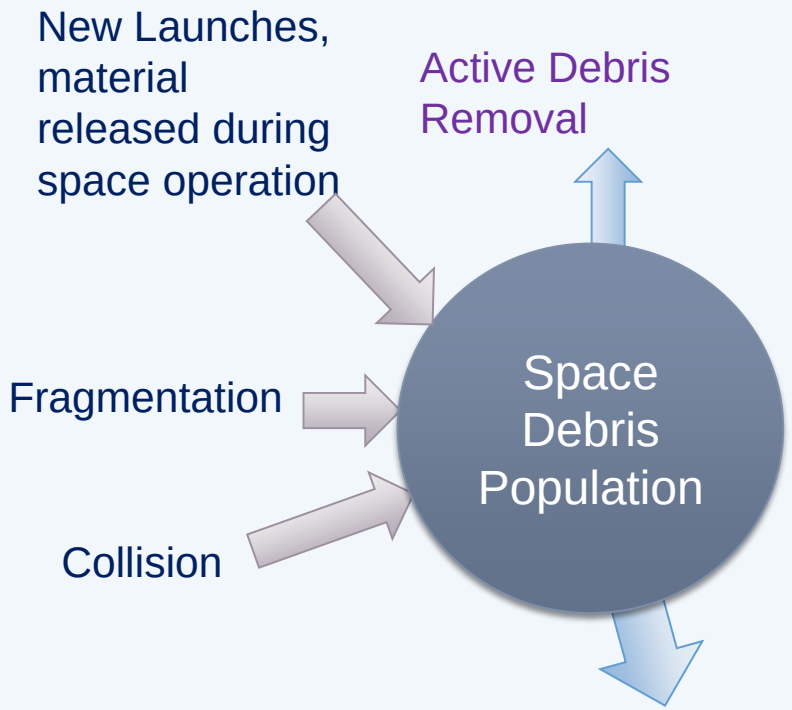




History of On-orbit Satellite Fragmentations, 16th Edition, ODPO, NASA

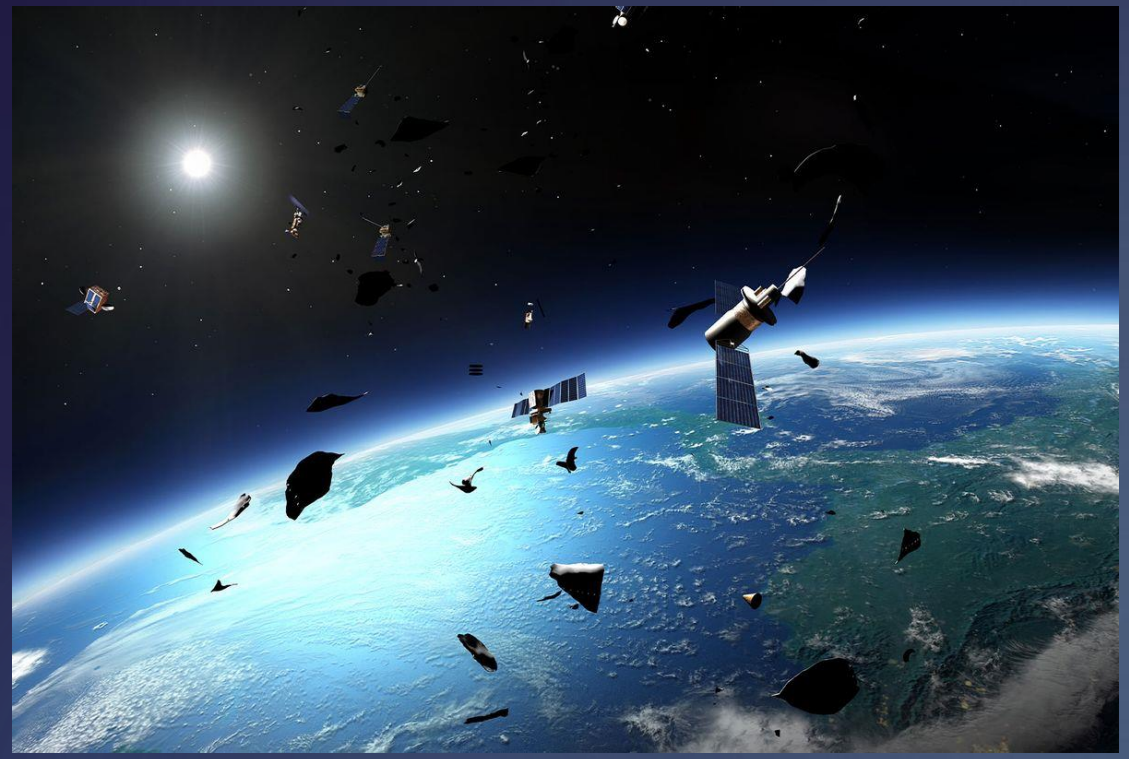
Historical accumulation of debris



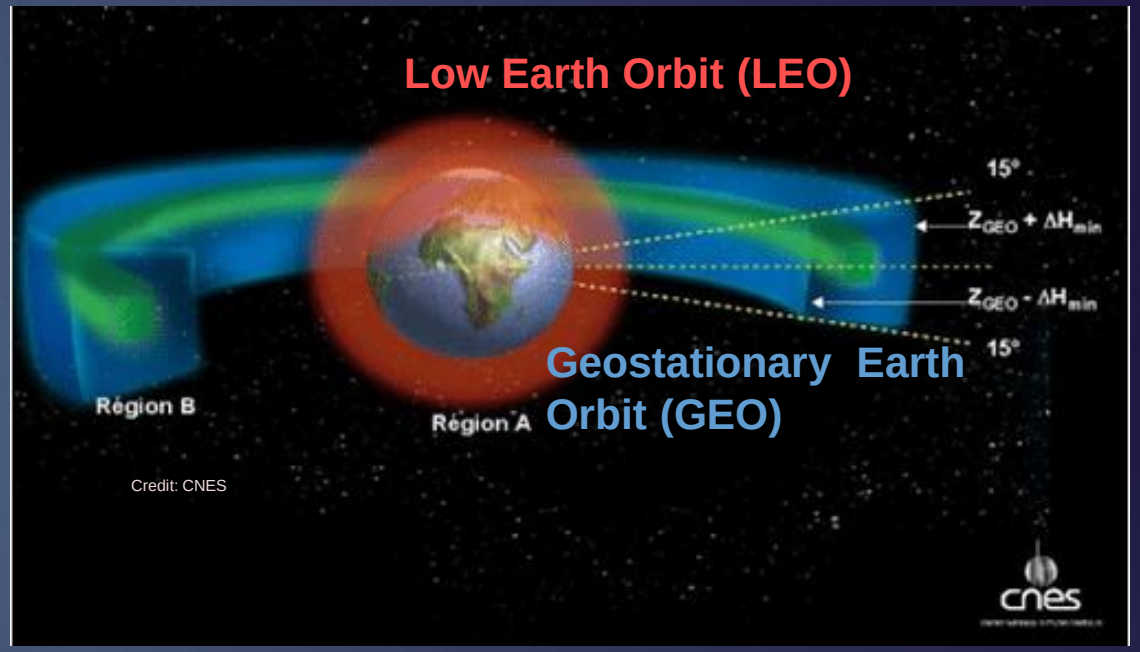


Natural decay (primarily atmospheric drag + luni-solar perturbations, solar radiation pressure) followed by re-entry

Kessler Syndrome & Protected Regions



A. Low Earth orbit (LEO) protected Region
till 2000 km altitude
B. Geosynchronous protected Region
GEO altitude +/-200 km and +/-15 deg latitude



Kessler's Syndrome

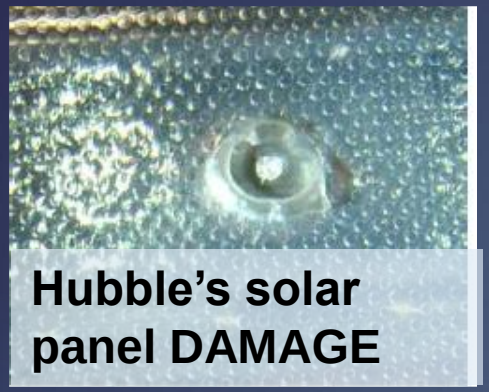
- A hypothetical scenario postulated by Donald Kessler (1978)
- Fragments generated from collisions between debris result in catastrophic cascade of collisions among orbiting objects

Unique, densely populated and highly utilised ⇒ Any debris creation within these protected zones severely affects safety and sustainability of space operation.

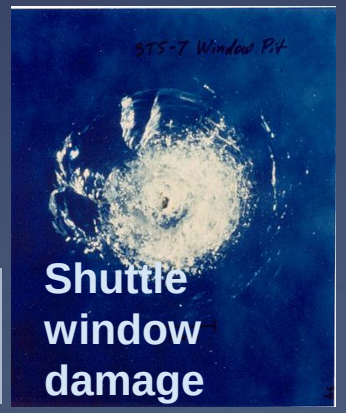
Aftermath of Debris Impact

Hyper velocity Impacts: even a paint flake can cause significant damage !

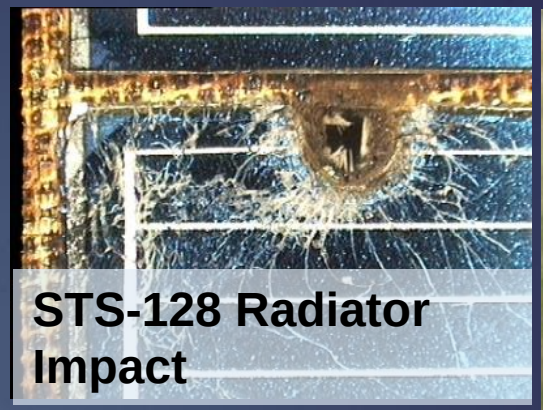
Impact with objects > 10 cm size is catastrophic.



Hubble's solar panel DAMAGE



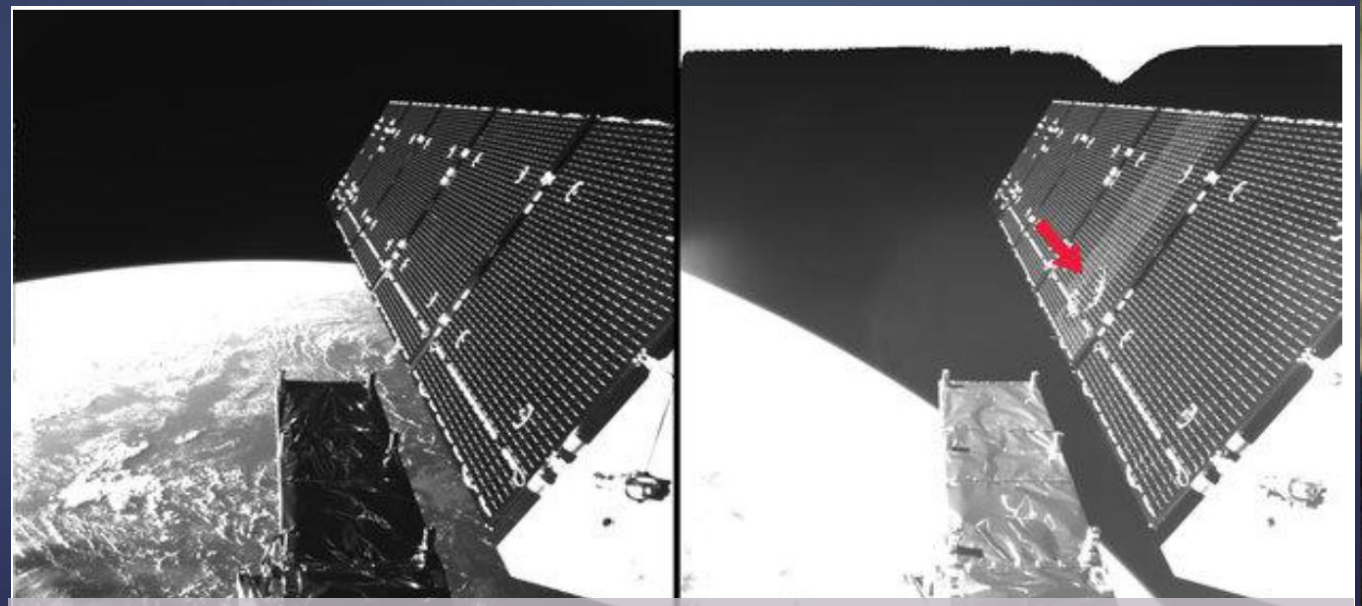
Shuttle window damage



STS-128 Radiator Impact

Lottie Williams hit by surviving debris from Delta-II Rocket

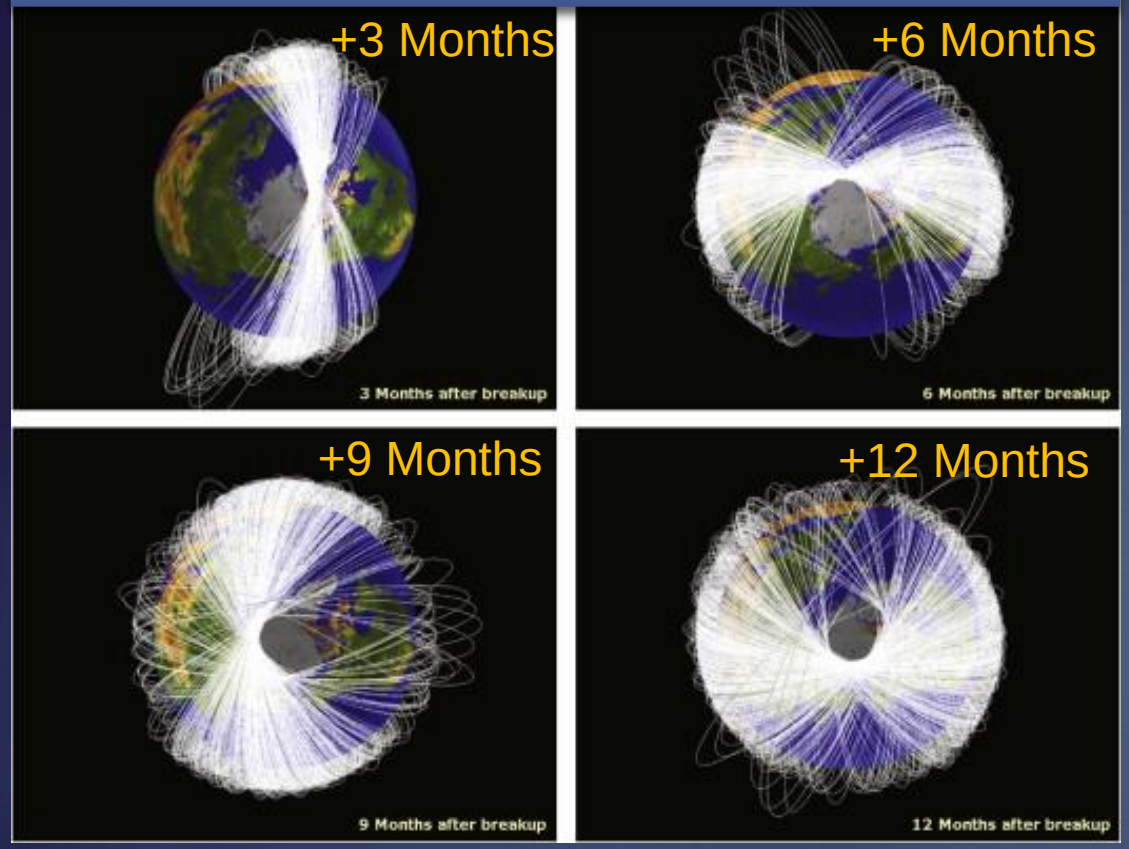
Smaller sized debris more difficult to "**catalog**"



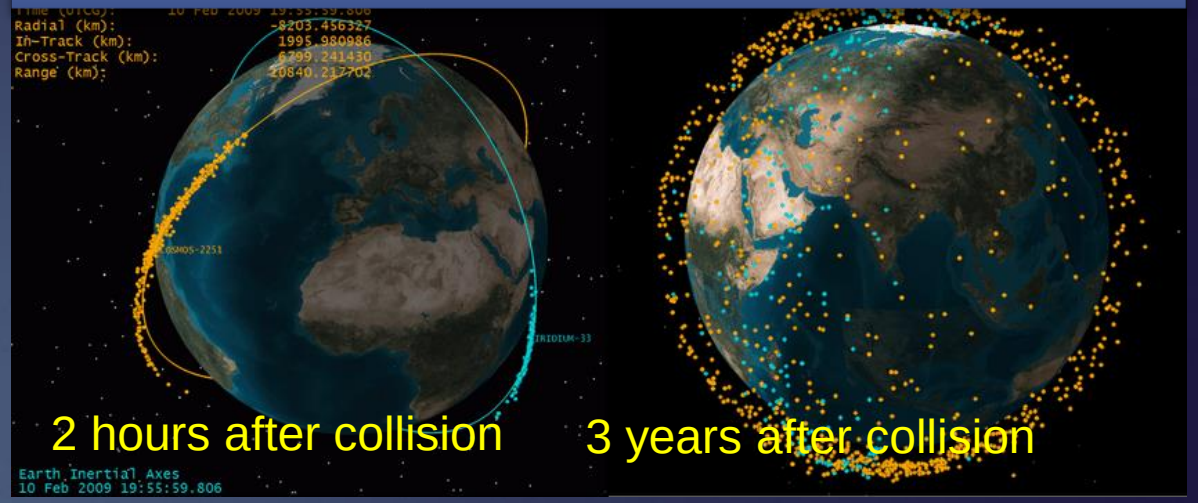
Sentinel 1A Solar Panel Damage

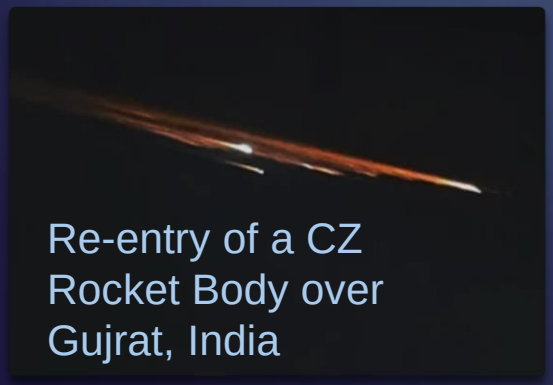
On-Orbit Collision, Fragmentation, Re-entry

Fengyun-1C Anti Satellite Test



Debris cloud due to COSMOS Iridium Collision





Re-entry of a CZ Rocket Body over Gujrat, India

Recovery of debris @Zimbabwe

Vega Avum composite overwrapped pressure vessel recovery at Tamil Nadu, India

Observation

Extrapolation of incomplete data, statistical models

- Detected samples from ground based sensors
- Returned spacecraft (LDEF, Solar Max)
- Active, in-situ measurements in orbit (ISS, EURECA, US Space Shuttles)

Regular tracking and monitoring with ground and space based sensors Radar, Optical Telescopes, Lasers, passive RF

Collision avoided in this region using orbital info of debris objects

Altitude (km)

36000

10000

2000

1000

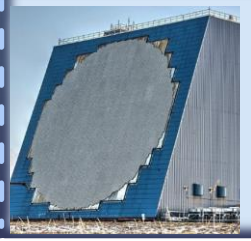
100

Mission ending impact

catastrophic breakup

Requires Protection

Non-catalogued

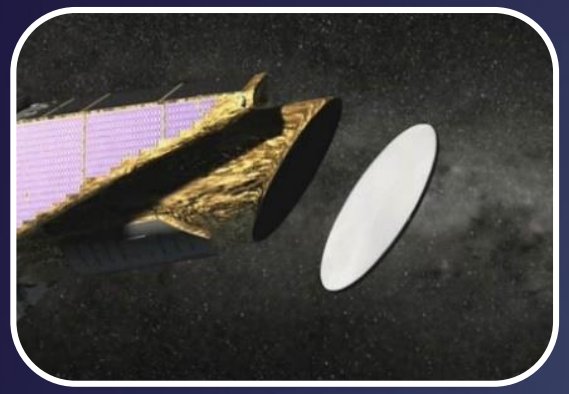


Catalogued

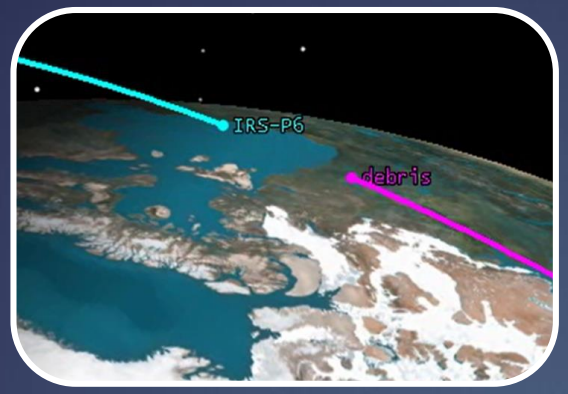
1 mm | 1 cm | 10 cm | 1 m | 10 m

Object Size/diameter

Space Debris Mitigation

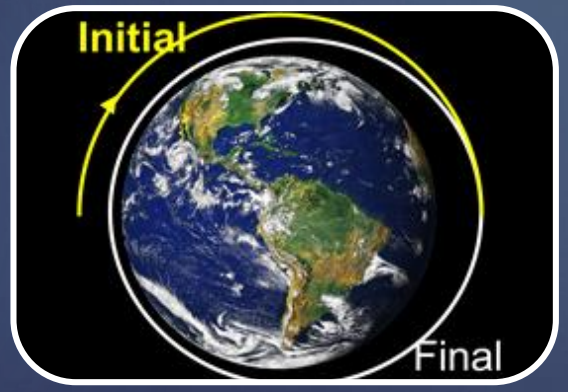


Limiting debris release during normal operations



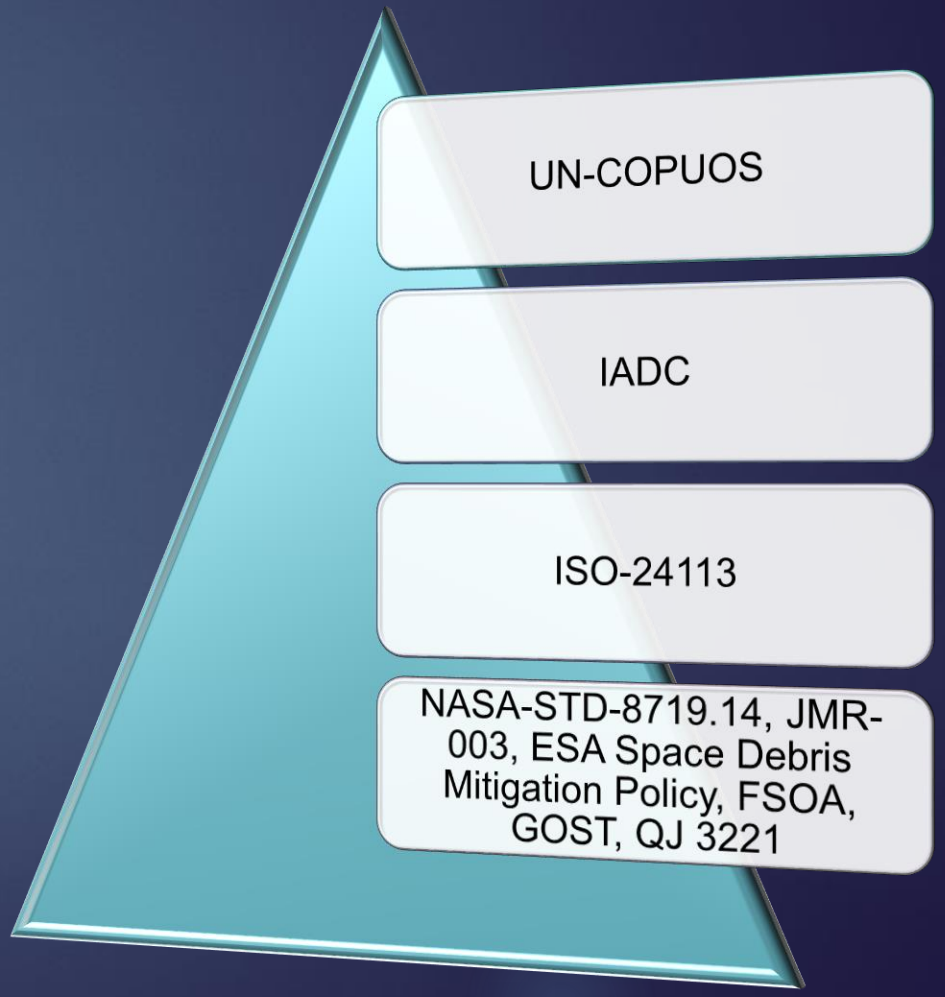
Collision Avoidance

Preventing on-orbit break-ups



Post Mission Disposal

21 UN-accepted guidelines for Long-term sustainability of outer space activities



Remediation

Active Debris Removal (ADR)

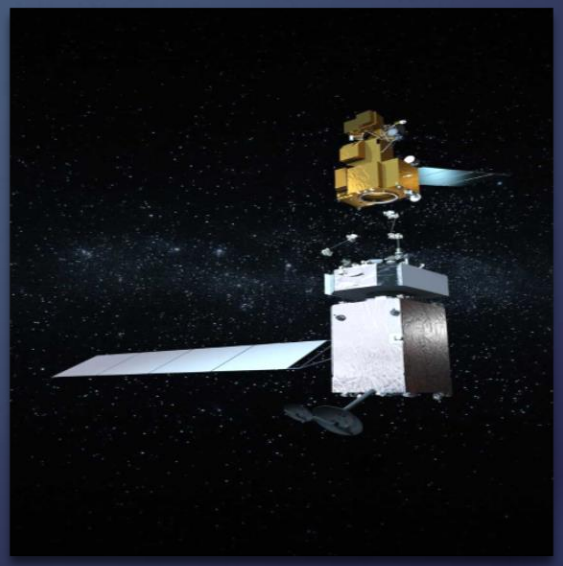
- Removal/relocationof debris by active means (instead of relying on passive, natural perturbative forces for its removal).
- Permanent removal from highly utilised regime - drastically reduce the collisional threat posed by a defunct object.

Mitigation ≈ Prevention

Remediation ≈ Cure

On-orbit servicing (OOS)

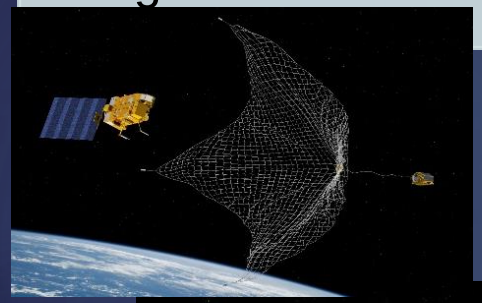
- Aim: extend mission life of an operational spacecraft by refueling and/or repairing hardware
- Prevents the object from becoming space debris
- Avoids additional launches (and consequent debris) for its on-orbit replacement.



Active Debris Removal Techniques

Capture Mechanisms

- Net
- Harpoon
- Robotic arm
- Tentacles
- Sweeper
- Chaser / Space Tug

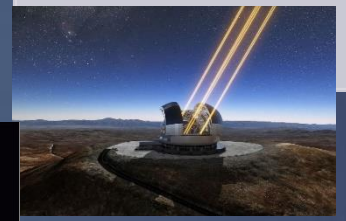


Drag Augmentation

- Expanding Foam
- Inflated balloon
- Fibre based

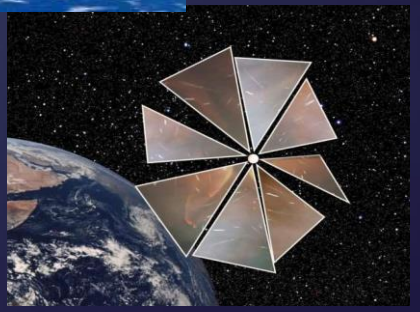
Contactless devices

- Ion Beam Shepherd
- Laser ablation
- Artificial atmosphere influence



Others

- Electrodynamic Tether
- Solar sail



Current and Future Challenges, Way forward

- Accurate observations of growing population demand more measurements
  - More observational facilities with geographic diversity
  - Data sharing
  - Space based surveillance to complement ground-based measurements
- Small satellites without trackability and maneuverability, failure-proneness
- Proliferation of large constellations –increase in on-orbit collision risks and interference by several orders- increased complexity for traditional space actors
- Lack of standardized methods for coordination and risk assessments regarding spaceflight safety
- Cumulatively adverse effect on upper atmosphere due to re-entering debris and increased ground casualty risks

- Existing procedures & mechanisms inadequate to cope with future needs
- Conflicting requirements of ensuring sustainability without stifling innovation
- Public-private Partnerships can offer novel solutions

Space Traffic Management: Evolve rules and regulations for launch, in-orbit operations, re-entry phase

Space Domain awareness: Supplement SSA with additional information and intelligence

Conclusion

- Space debris are undesirable consequences of space activities, pose collision risks to space assets and ground casualty risks upon atmospheric re-entry
- Accurate knowledge of debris position and characteristics essential for informed decision making to safeguard space based infrastructures vital for economy and security
- Observation and modelling of debris environment and risk assessment through space situational awareness is the crux of sustainable and safe space operations
- As of today, mitigation is the only way to control the space debris growth, growing awareness contributes to better compliance.
- Remediation (Active Debris Removal, on-orbit servicing) is essential to stabilize LEO object growth, but challenges remain in technological and policy-related fronts
- Multiple large constellations and small satellites without maneuverability and trackability add to on-orbit collision risks and proliferation of debris.
- Present situation – a call to action by all space actors to preserve the sustainability of space activities, where International cooperation plays a crucial role.

Thank You