De-orbiting Strategies

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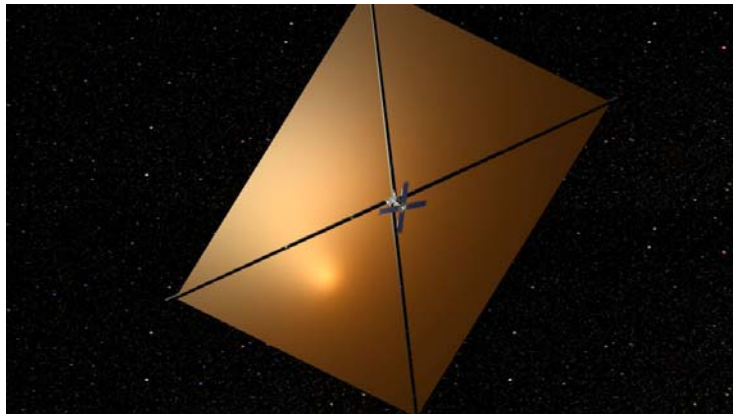
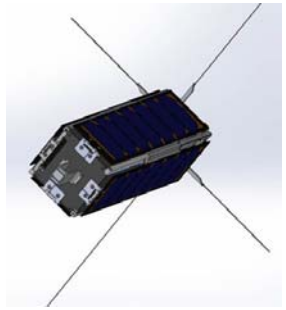
KNOWLEDGE

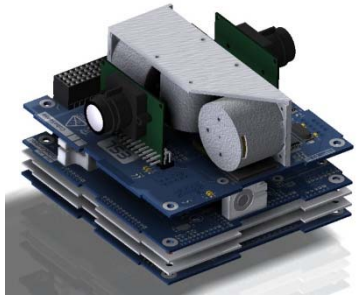
Participant in FP7 EU projects

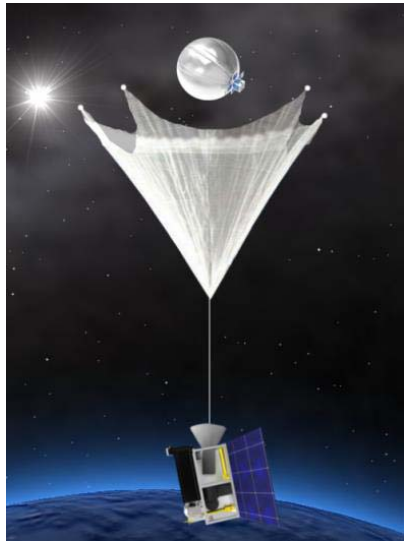
- **DeOrbitSail**:
  - Coordinator: Surrey Space Centre (SSC)
  - SU contributing the ADCS of 3U CubeSat
  - Launch date July 2015
  - Project Aims:
    - Deploy 16m^2 drag sail at 600 km
    - Do active attitude control for maximum aerodynamic drag during de-orbiting



- **RemoveDebris**:
  - Coordinator: Surrey Space Centre (SSC)
  - SU contributing the ADCS for DebrisSats (2 x 2U CubeSats)
  - Launch date possibly in 2017
  - Project Aims:
    - Chaser microsatellite release 2 Debris CubeSats
    - Demonstrate automatic removal using net and harpoon to capture “debris”
    - De-orbit “debris” using inflateable balloon & tether

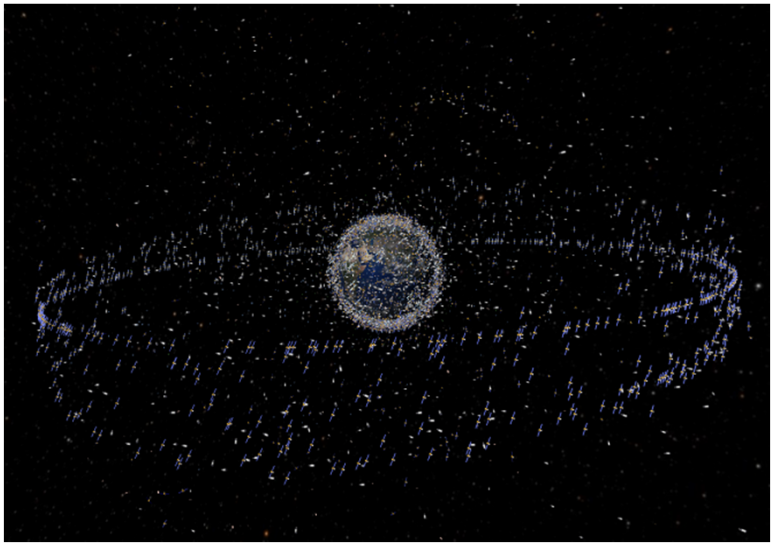


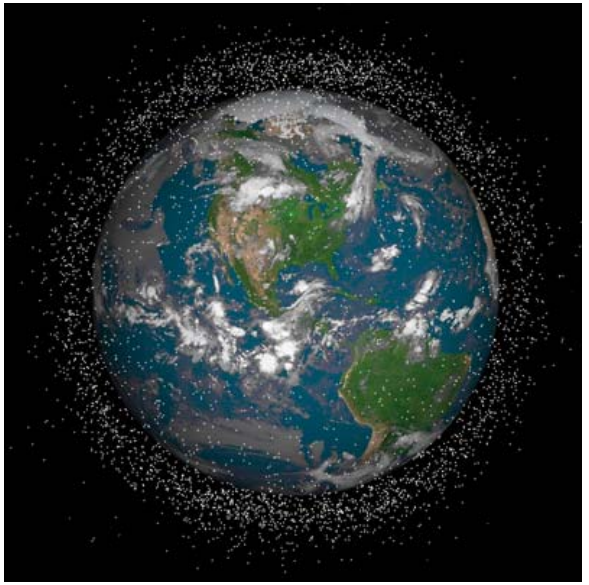




Why De-orbit ? (Orbital Debris)

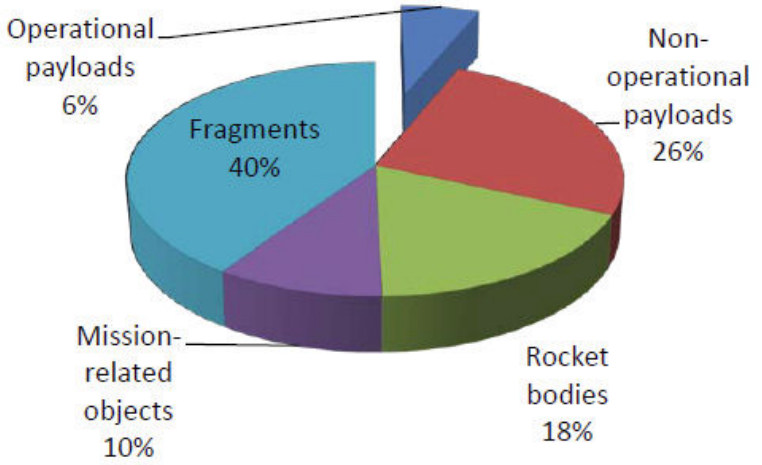
- Abandoned satellites and rocket upper stages litter the environment around Earth
- Increased probability of collisions in Earth orbit
- Uncontrolled growth of Earth orbiting population risks the safety of future operations
- Collisions have already occurred:
  - 1996: Cerise satellite & Ariane rocket stage
  - 2007: Chinese rocket destroyed a satellite (produced ≈ 150 000 fragments > 1 cm)
  - 2009: Iridium satellite & Cosmos 2251 (produced ≈ 61 000 fragments > 1 cm)
- Increase in debris fragments can start an uncontrolled cascade effect
- ≈ 370 000 pieces of junk (> 1 cm) and only ≈ 1 100 satellites in LEO

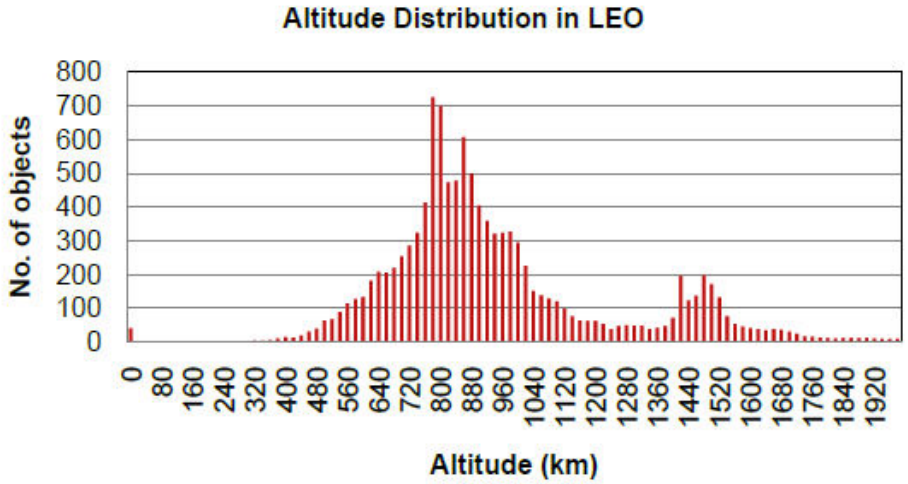


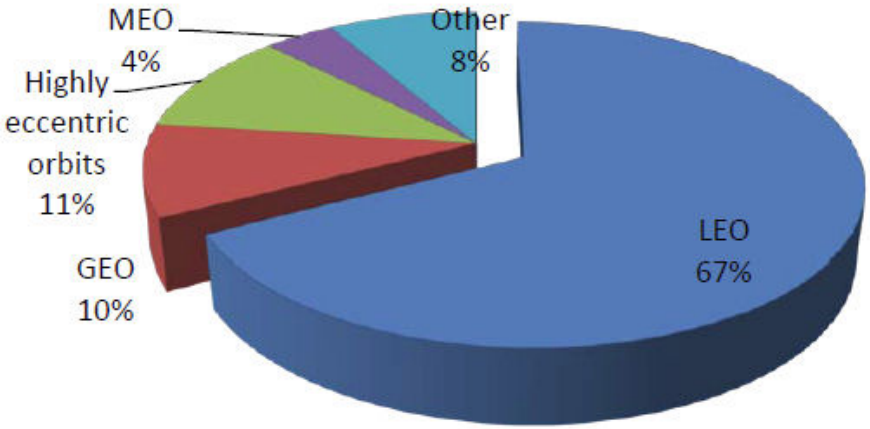


Orbital Debris Distribution

- Largest portion (2/3) of orbital debris is concentrated in LEO
- Only 6% of Earth orbiting objects are operational payloads
- LEO altitude distribution shows peak at 780km







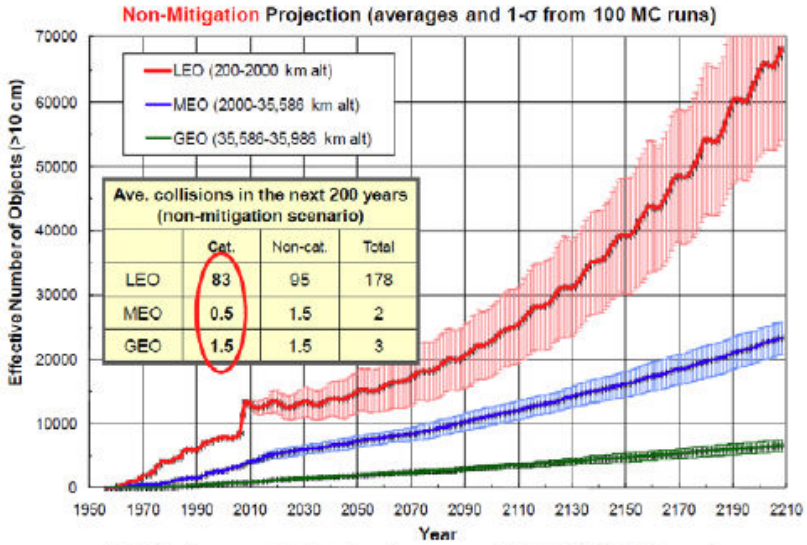
Orbit Debris Predictions

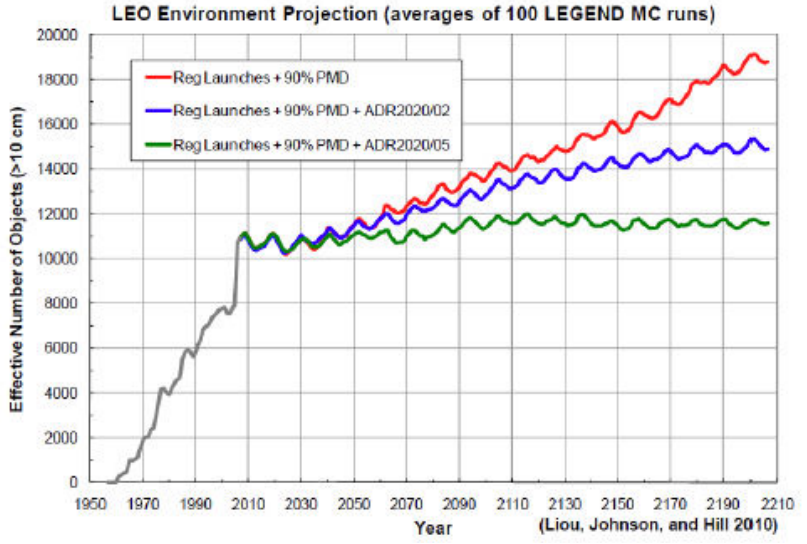
- Euroconsult forecast for next 10 years shows: 400 out of 1200 anticipated launches will be in LEO – this forecast only includes satellites > 50kg

- NASA LEGEND study predicts non-linear growth for LEO region, if no mitigation is followed

- To have a sustainable LEO population requires: Implementation of commonly adopted mitigation measures (PMD – Post Mission Disposal)

- Active Debris Removal (ADR) of 5 large objects or more per year





De-orbiting Solutions

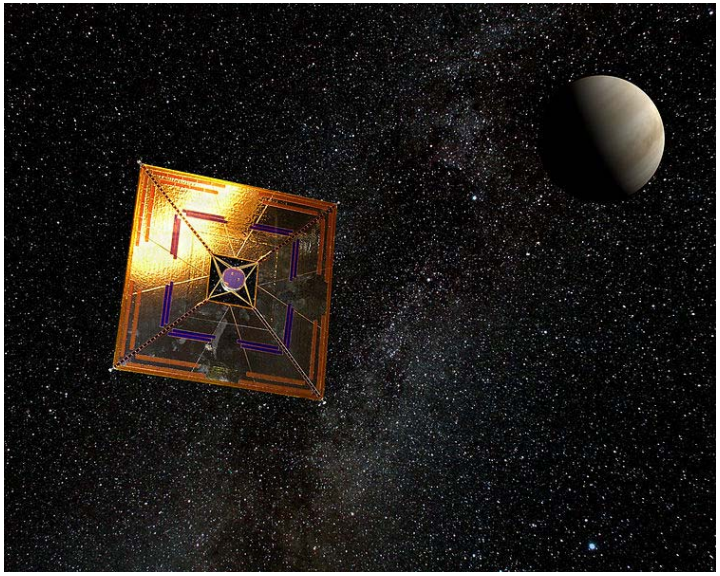
- **Many proposed solutions:**
  - Chemical propulsion
  - Electric propulsion
  - Electrodynamic tethers
  - Drag augmentation

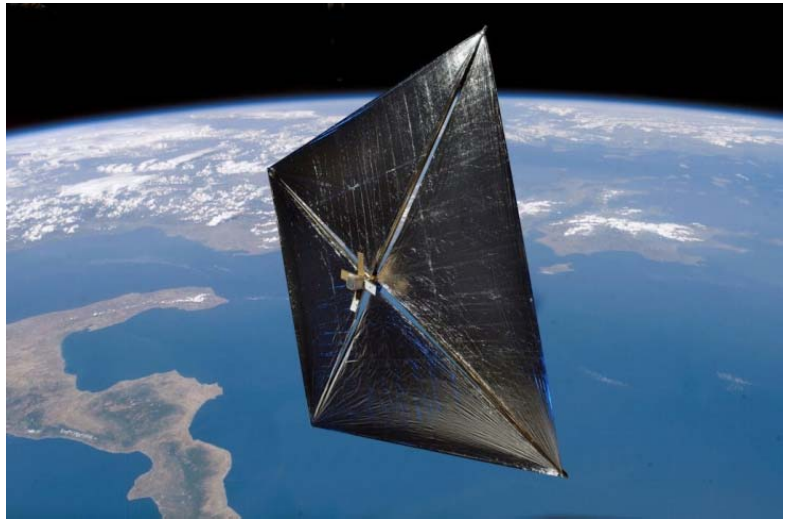
MIR re-entry: 23 March 2001

- **DeOrbitSail:** A de-orbiting device that uses aerodynamic drag pressure force for de-orbiting
- Low complexity and low parasitic mass
- Does not require any propellant

Space Sailing history

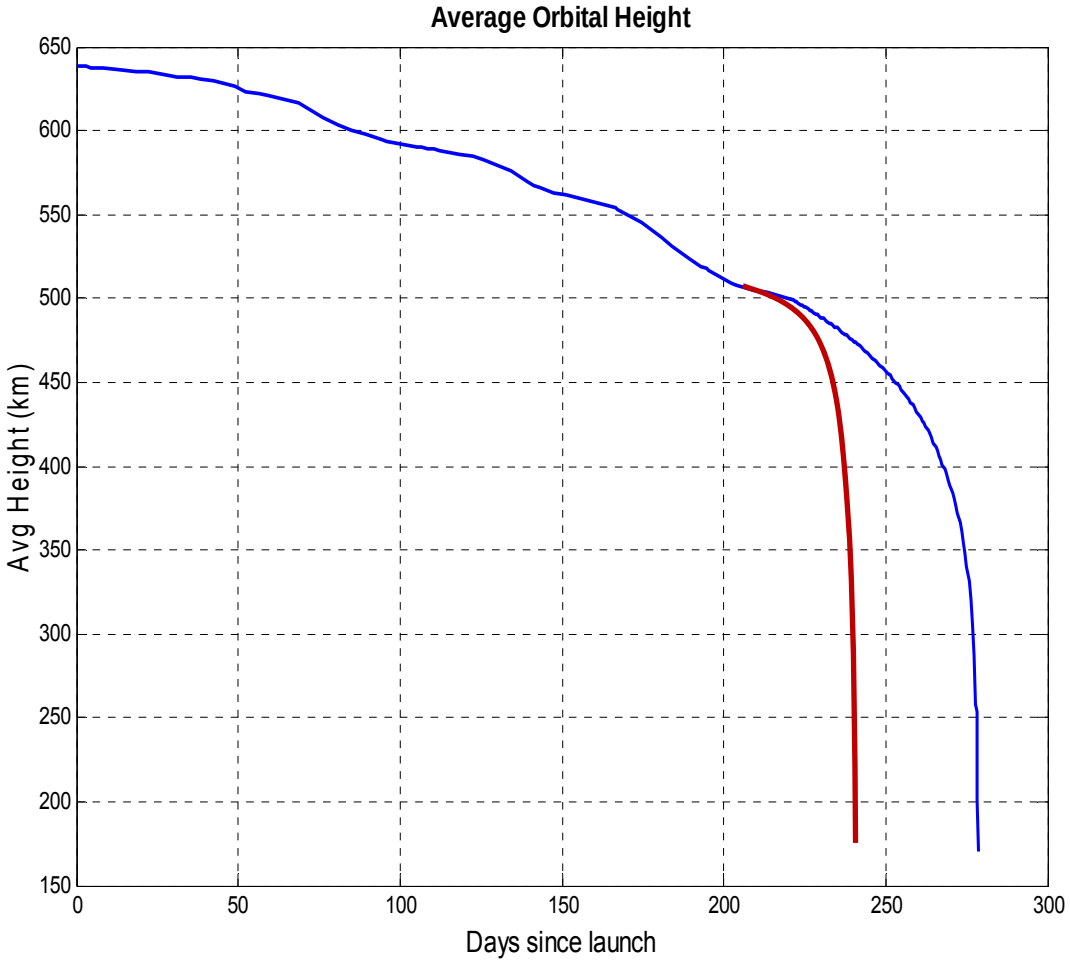
- **Jaxa Ikaros**
  - 200 m^2 sail deployed in June 2010 enroute towards Venus
  - 2 RPM spin stabilised
  - LCD panels adjust reflectance to control spin vector
- **Nanosail-D2**
  - 3U Cubesat with 10 m^2 sail deployed in Jan 2011
  - Passively stabilised using drag force in 650 km LEO
  - Use sail drag force to de-orbit





Nanosail-D2 de-orbiting

- 10 m^2 Sail deployed on 19th Jan 2011
- Orbit life since deployment: 240 days
- Re-entry date: 17th Sept 2011

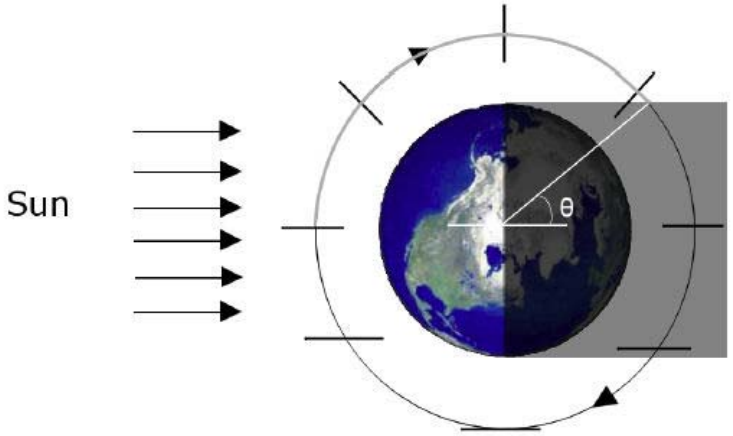


DeorbitSail Mission Concept

- De-orbit using aerodynamic drag
  - Increased drag area shortens time for orbit to decay

$$F_{drag} = 0.5\rho A C_d |\mathbf{v}_{rel}|^2$$

- De-orbit using solar radiation pressure
  - Can be used to manoeuvre to higher or lower orbits

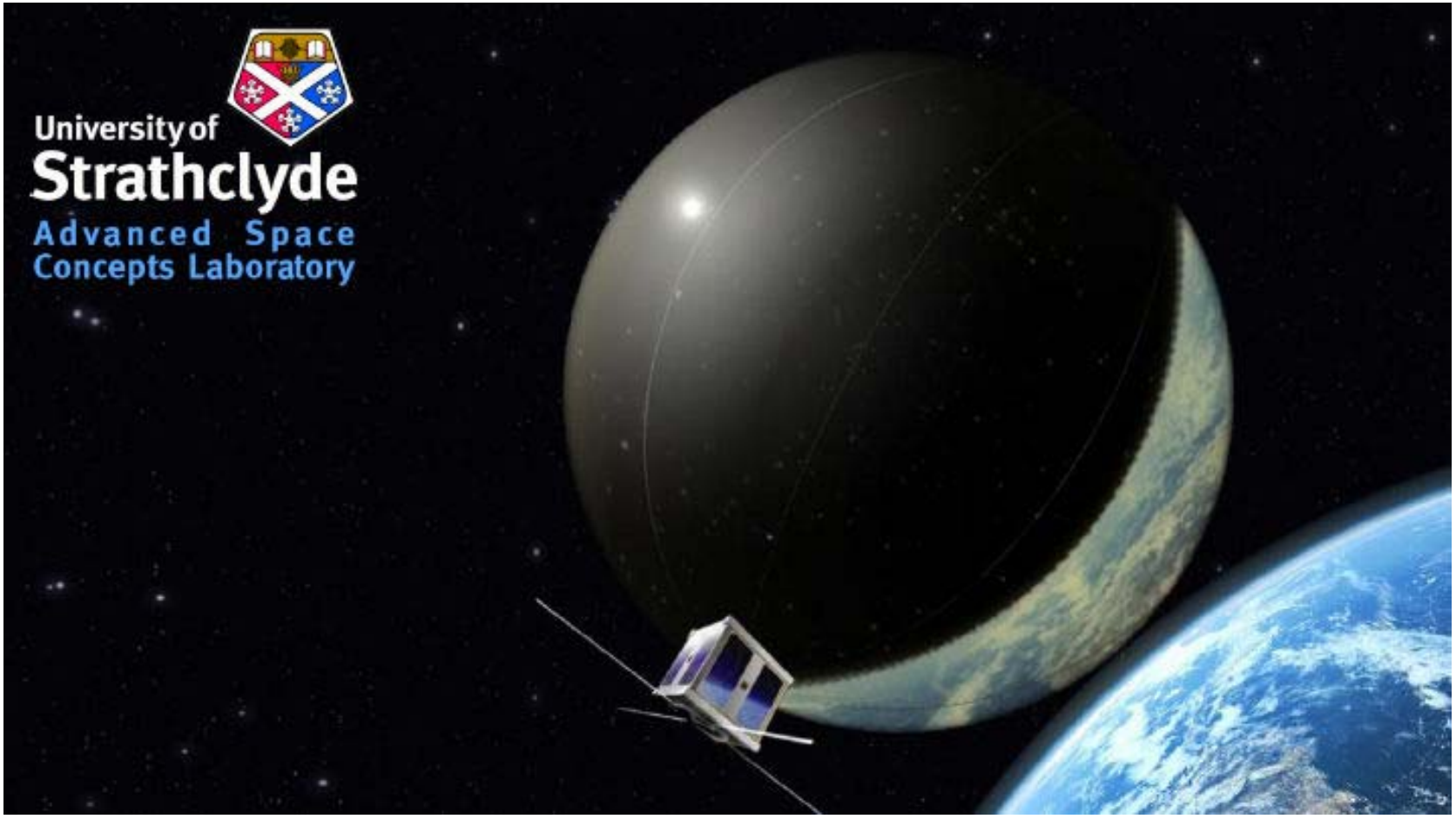


SRP & Drag De-orbiting

- **Phase 1:** Increase orbit eccentricity to reach atmosphere through SRP and J_2.

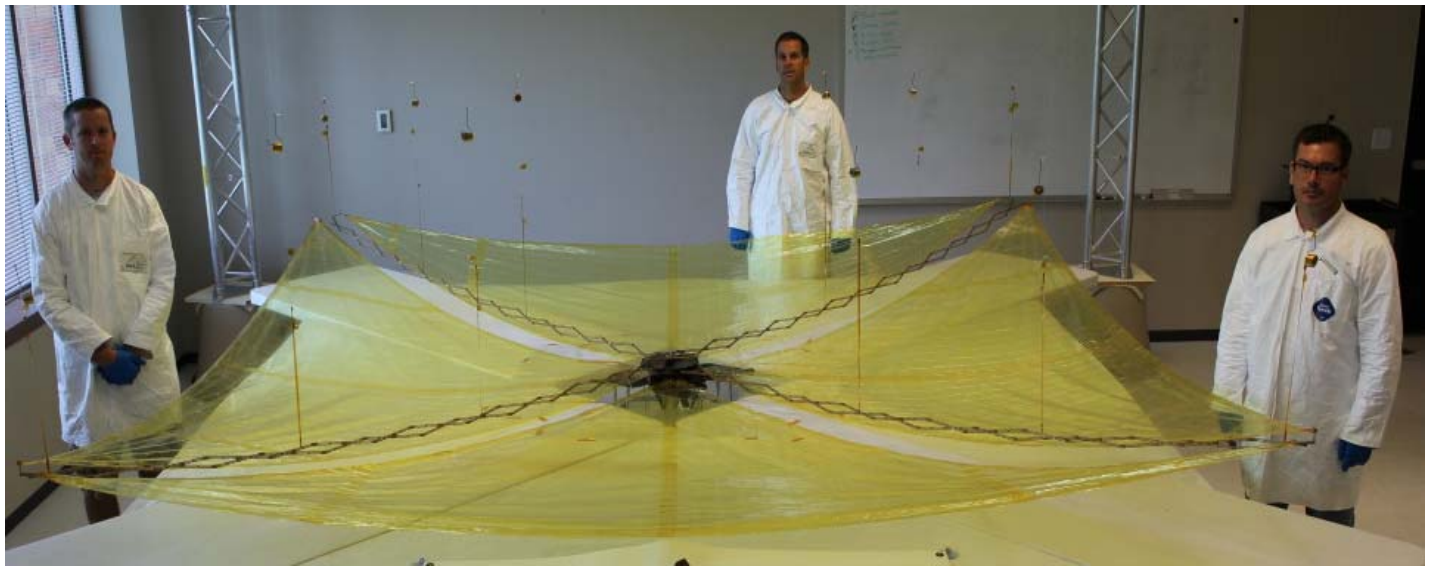
- **Phase 2:** Decrease orbital energy until final decay through aerodynamic drag.

University of Strathclyde
(Reflective Balloon)



MMA's Dragnet

2.6 kg, 14 m^2



Electrodynamic Tether De-orbit