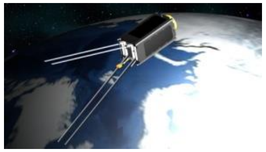


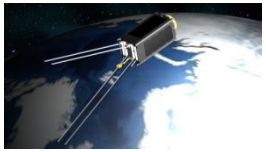
# De-orbiting Device Competition

## 20 Oct 2016 – Kamchia Bulgaria

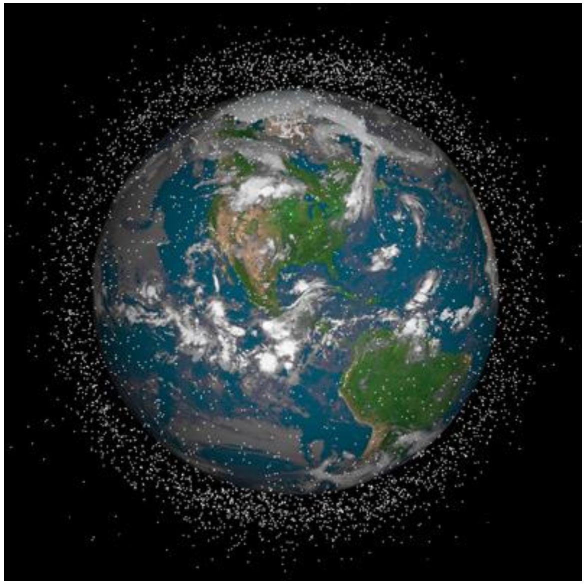

**Prof Herman Steyn**

whsteyn@sun.ac.za

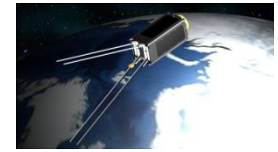
# Why De-orbit ? (Orbital Debris)



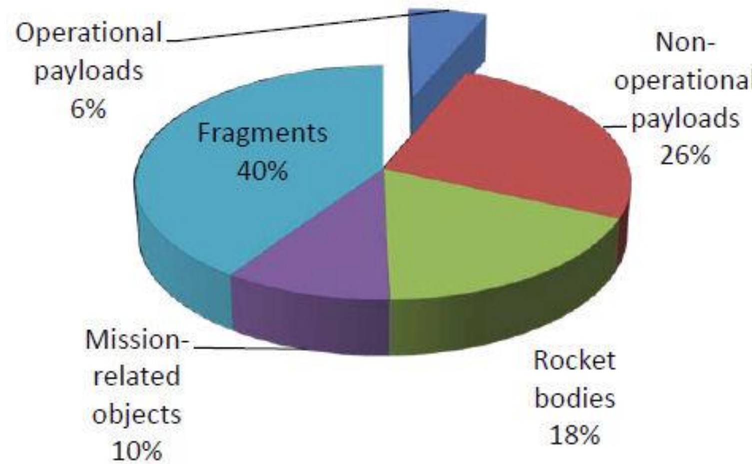
- Abandoned satellites and rocket upper stages litter the environment around Earth
- Increased probability of collisions in Earth orbit
- Uncontrolled growth of Earth orbiting population risks the safety of future operations
- Collisions have already occurred:
  - 1996: Cerise microsatellite & Ariane rocket  stage
  - 2007: Chinese rocket destroyed their Fungyun weather satellite (produced ≈ 150 000 fragments
  - 2009: Iridium 33 satellite & Cosmos rocket stage (produced ≈ 1500 fragments)
  - 2013: Debris from Chinese Fungyun satellite & the Russian BLITS nano-satellite
  - 2013: Two CubeSats, Ecuador's Pegaso and Argentina's Cubebug-1 & the debris cloud particles around a Tsyklon-3 upper stage
- Increase in debris fragments can start an uncontrolled cascade effect (Kessler effect)
- ≈ 370 000 pieces of junk (> 1 cm) and only ≈ 1 100 satellites in LEO

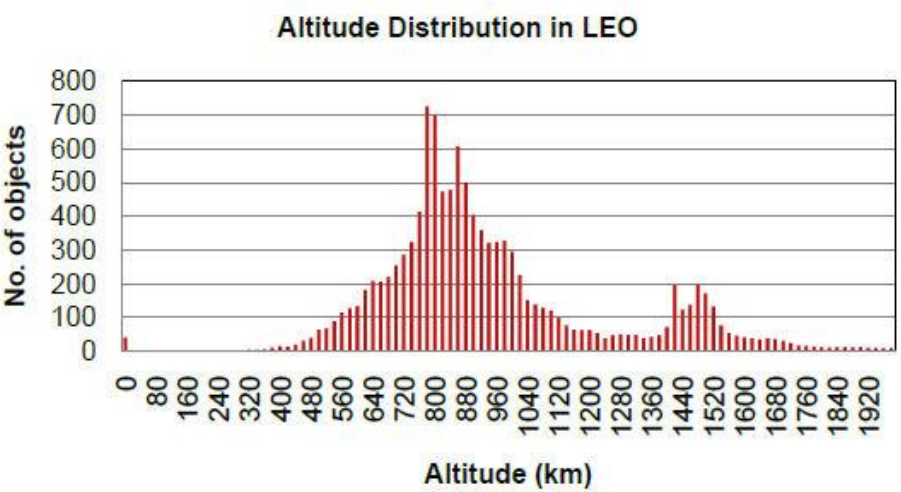


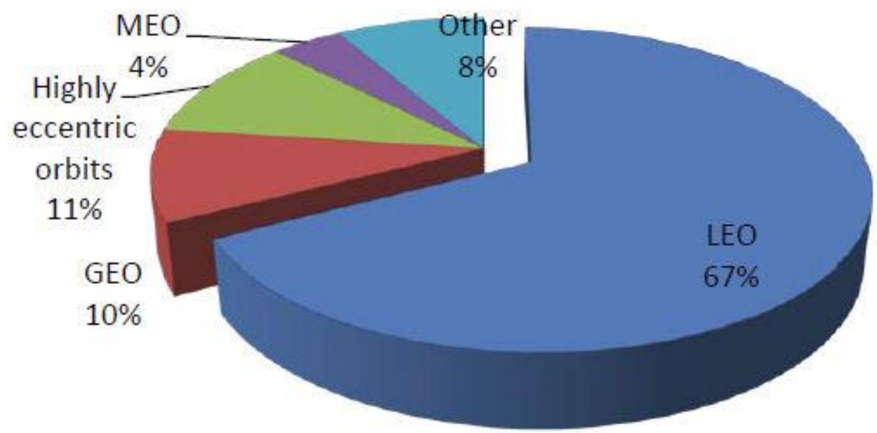
# Orbital Debris Distribution



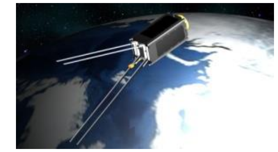
- Largest portion (2/3) of orbital debris is concentrated in LEO
- Only 6% of Earth orbiting objects are operational payloads
- LEO altitude distribution shows peak at 780km



# Orbit Debris Predictions

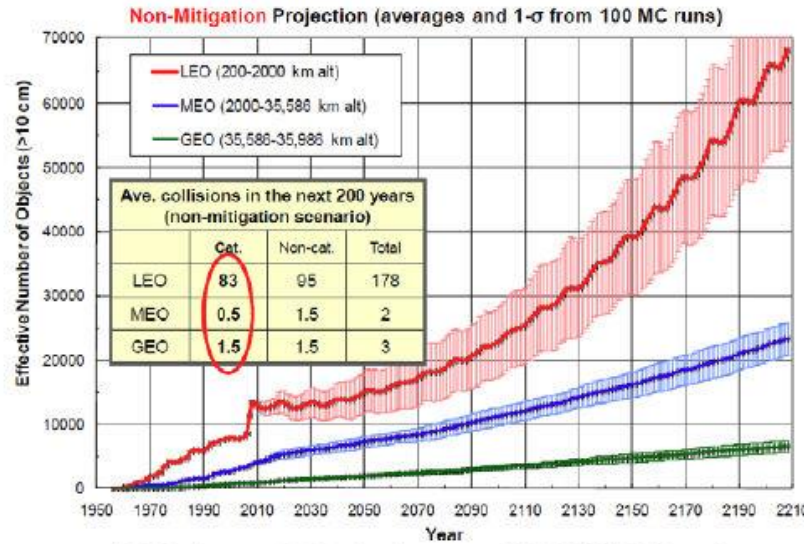


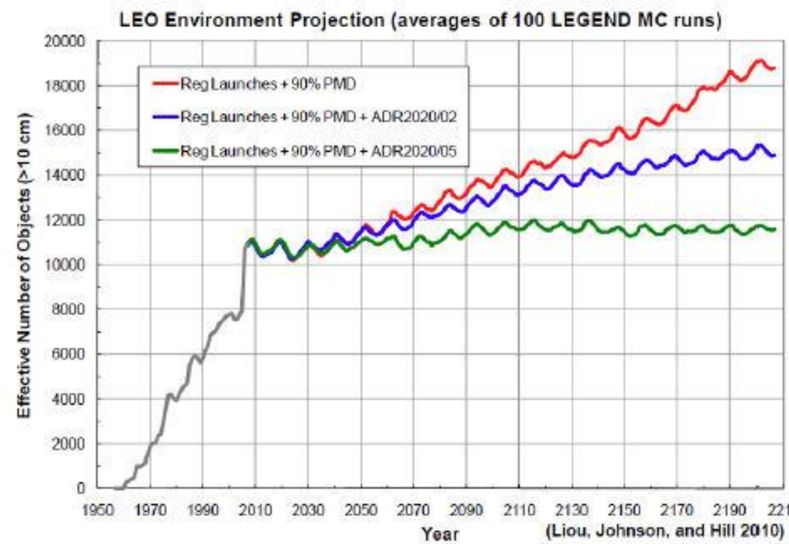
- Euroconsult forecast for next 10 years shows: 400 out of 1200 anticipated launches will be in LEO – this forecast only includes satellites > 50kg

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

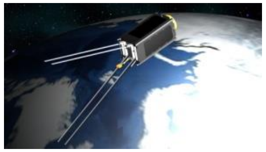
- To have a sustainable LEO population requires: Implementation of commonly adopted mitigation measures (PMD – Post Mission Disposal)

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



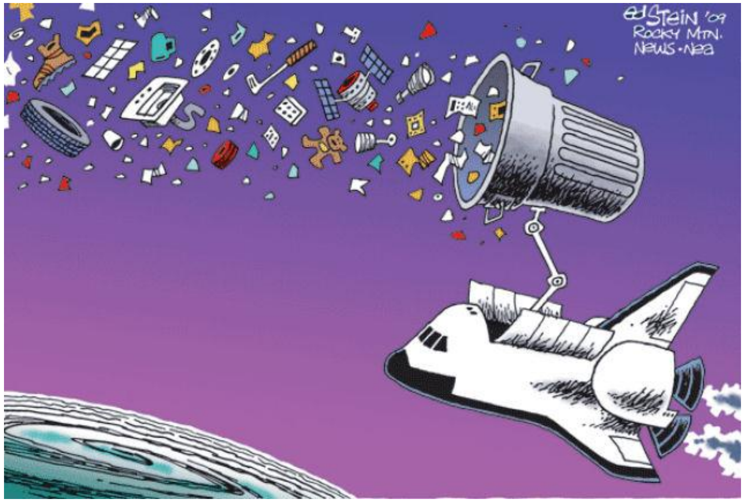



# De-orbiting Solutions

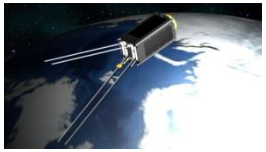


- **Self-induced removal solutions:**
  - Chemical propulsion
  - Electric propulsion
  - Electrodynamic tethers
  - Drag augmentation (sails, balloons)
- **Active debris removal (ADR):**
  - Use of a robotic arm
  - Ejection of a catch net
  - Firing of a harpoon to attach
  - Then, attaching of a de-orbiting device or de-orbit jointly
- **Problems with ADR:**
  - Reach an identical orbit to rendezvous and reach a zero relative speed
  - Non-cooperative target (in high spin)
  - Possibility of collision and generation of more debris

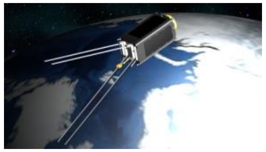
MIR re-entry: 23 March 2001



# Uncontrolled De-Orbiting Risk



# De-orbiting Comparison



| Attribute \ Concept | IUE | EMT | BSFA | GGT | RSI | PROPULSIVE |
|---|---|---|---|---|---|---|
| Risk of Large Debris Object Generation | Low | Low | Medium | Low | Highest | Lowest |
| Risk of Disabling Other Satellites | Low | Highest[‡] | Low | High | Low | Lowest |
| Variable De-Orbit Rate | Yes | Yes | No | No | No | Yes |
| Targeted Reentry | Yes | No | No | No | No | Yes |
| Works with Tumbling Derelict Satellites | Yes | No | Yes | No | Yes | No |
| Works Equally Well for Any Orbit Inclination | Yes | No | Yes | Yes | Yes | Yes |
| Works for Any Spacecraft Attitude | Yes | No | No[¥] | No | Yes[†] | No |
| Works for Any Orbit Altitude | No | No | No | No | No | Yes |
| Relative Mass | Low | Low | Low | Low | High | High |
| Cost to Add to Satellite | Medium | Medium | Low | Low | Low | Highest |

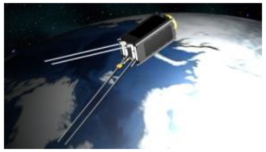
**Legend:**

**IUE** = Inflation-maintained Ultra-thin Envelope sphere, **EMT** = Electromagnetic Tether, **BSFA** = Boom-supported Film Aerobrake, **GGT** = Gravity Gradient Tape, and **RSI** = Rigidizable Space Inflatable.

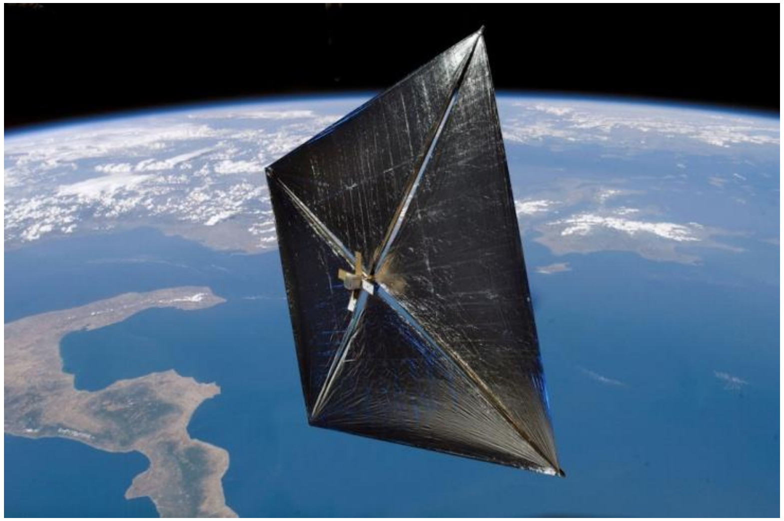
**¥** - Above a certain altitude, gravity gradient and solar pressure forces dominate drag forces, **†** - Only if near spherical

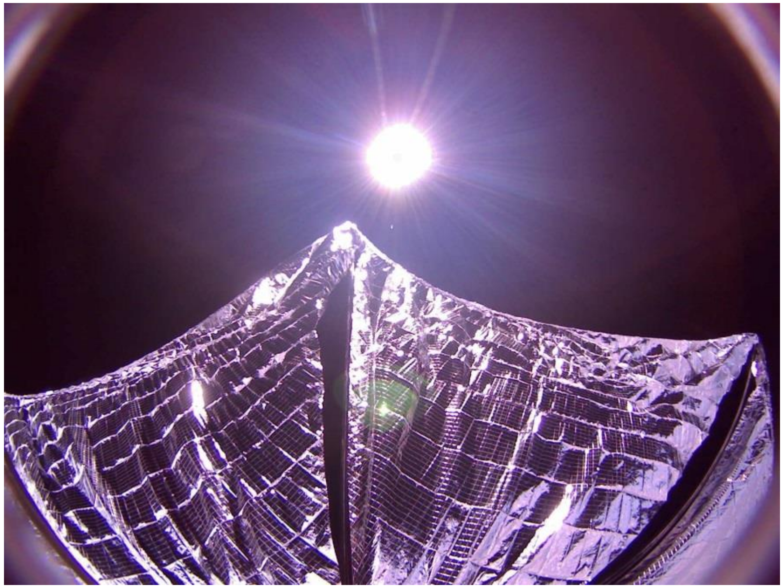
‡ - Without avoidance manuevers by either spacecraft.

# Drag Sailing history

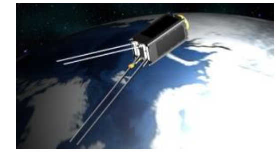


- **Nanosail-D2 (NASA)**
  - 3U Cubesat with 10 m$^2$ sail deployed on 19$^{th}$ Jan 2011
  - **Passively stabilised** using aerodynamic drag force from initial 650 km LEO
  - De-orbit in 240 days, re-entry on 17$^{th}$ Sept 2011
- **LightSail-1 (Planetary Society)**
  - 3U Cubesat with 32 m$^2$ sail deployed June 2015
  - **Passively stabilised** using aerodynamic drag force from initial 356 x 705 km LEO
  - De-orbit within 7 days due to the initial low perigee

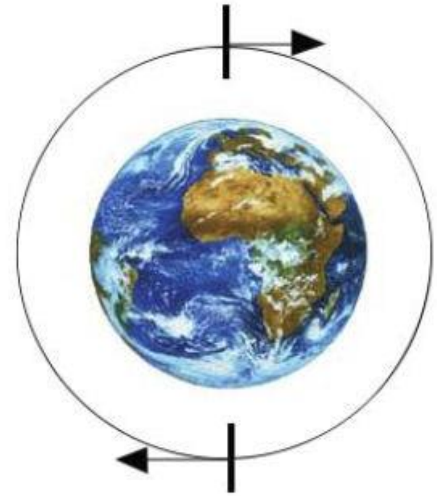




# *DeorbitSail* Mission Concept

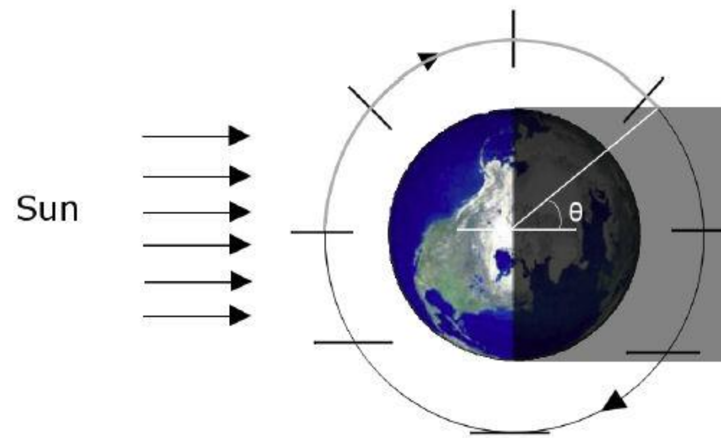


- De-orbit using aerodynamic drag
  - Increased drag area shortens time for orbit to decay



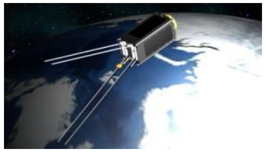
$$F_{drag} = 0.5\rho A C_d |\mathbf{v}_{rel}|^2$$

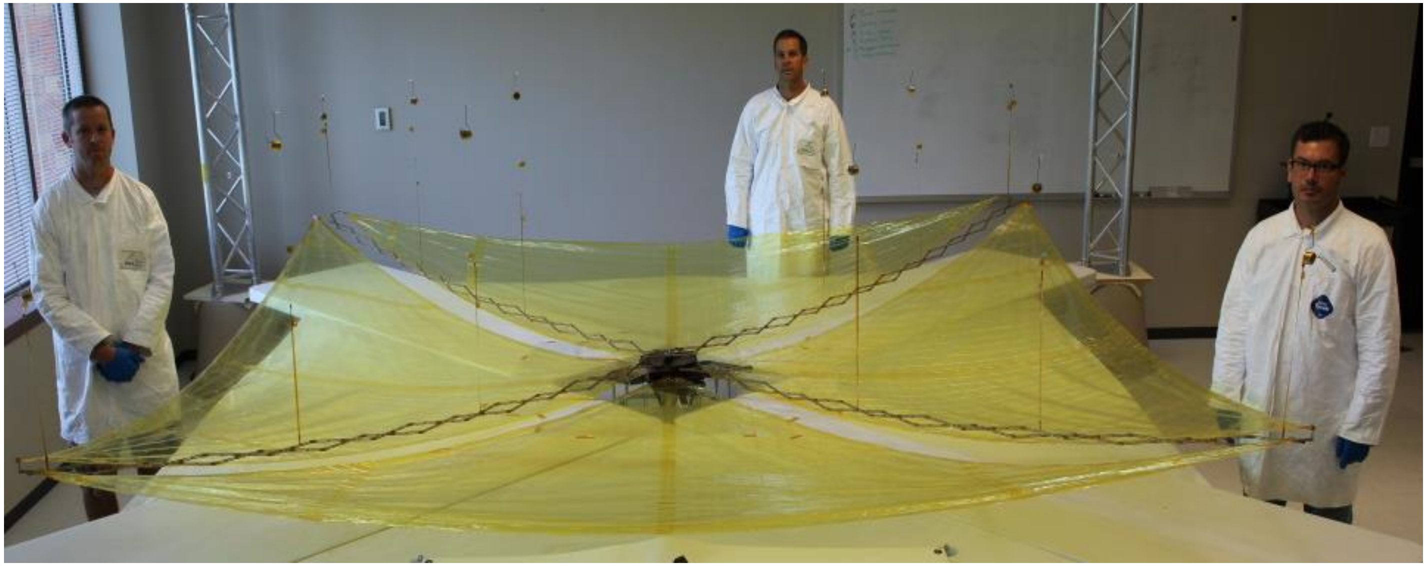
- De-orbit using solar radiation pressure
  - Can be used to manoeuvre to higher or lower orbits

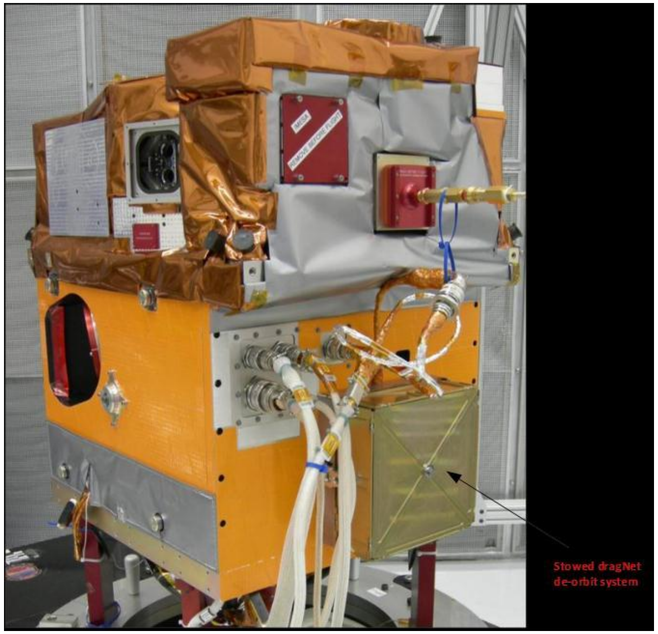


# MMA’s Dragnet

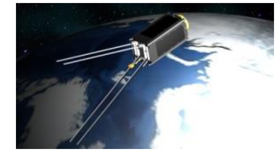
## 2.6 kg, 14 m$^2$

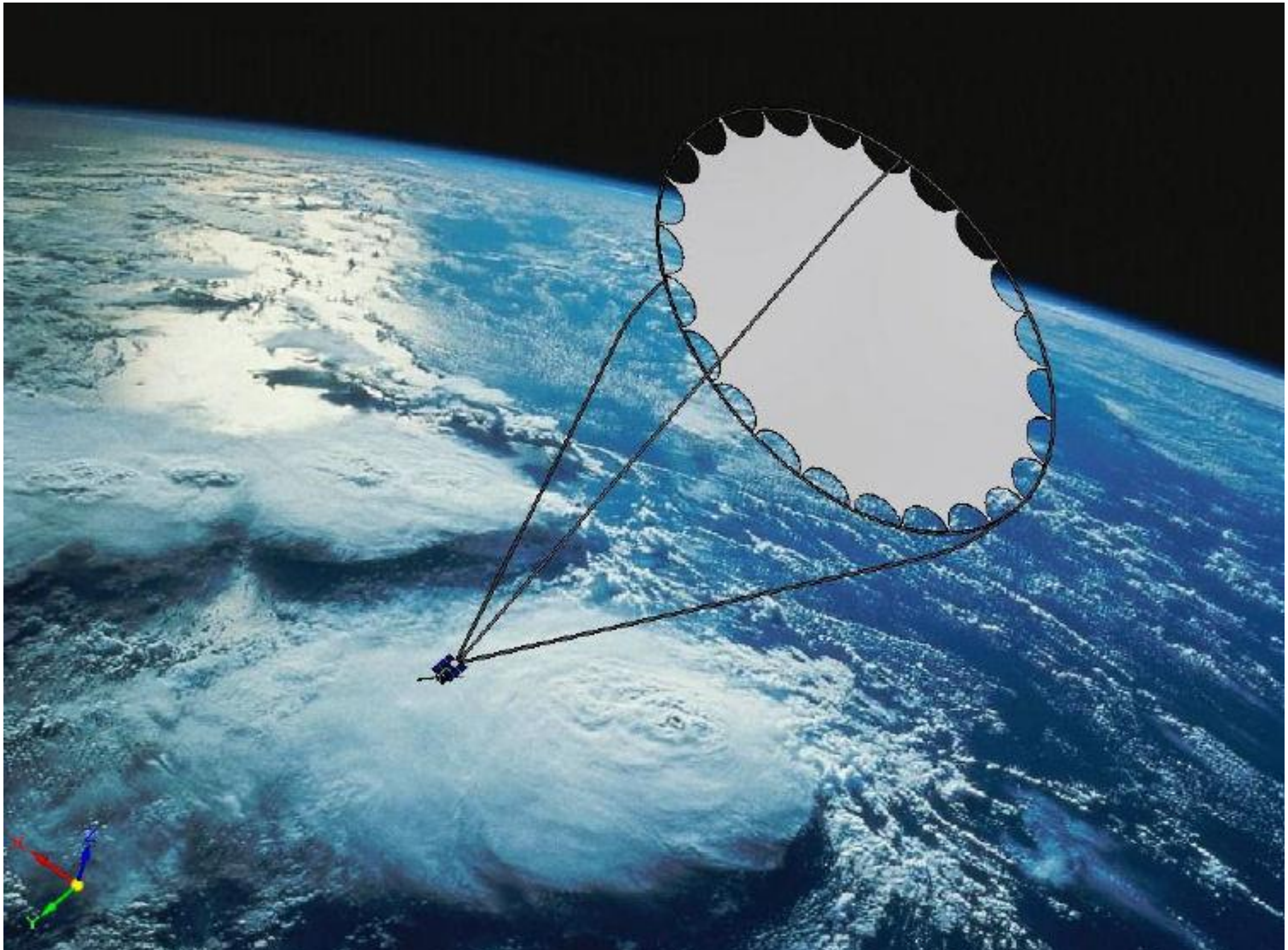




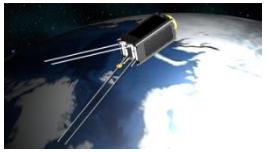


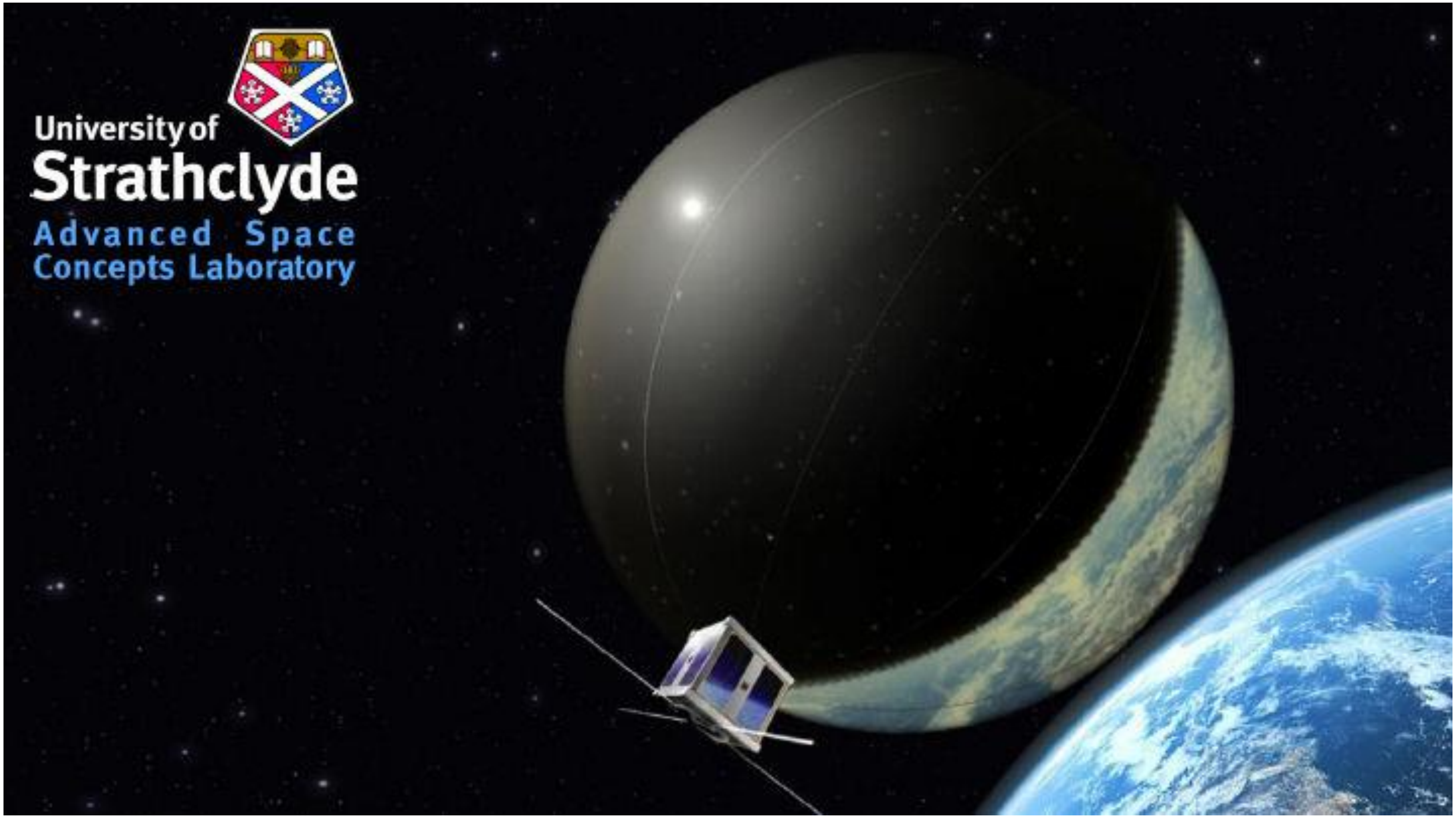
# SSC InflateSail proposal



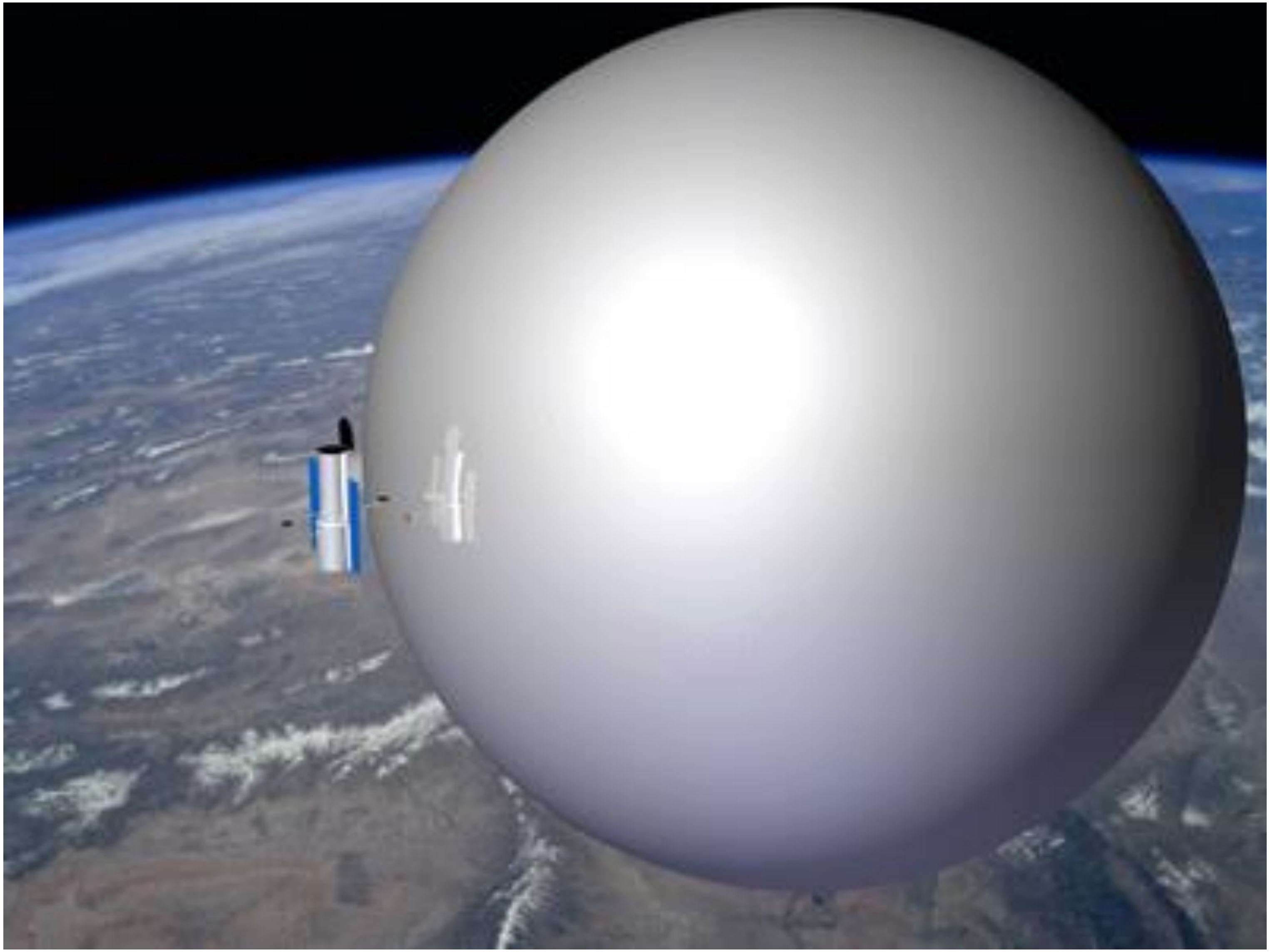


# University of Strathclyde
# (Reflective Balloon)

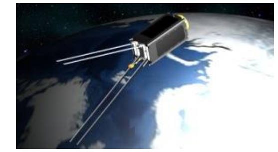


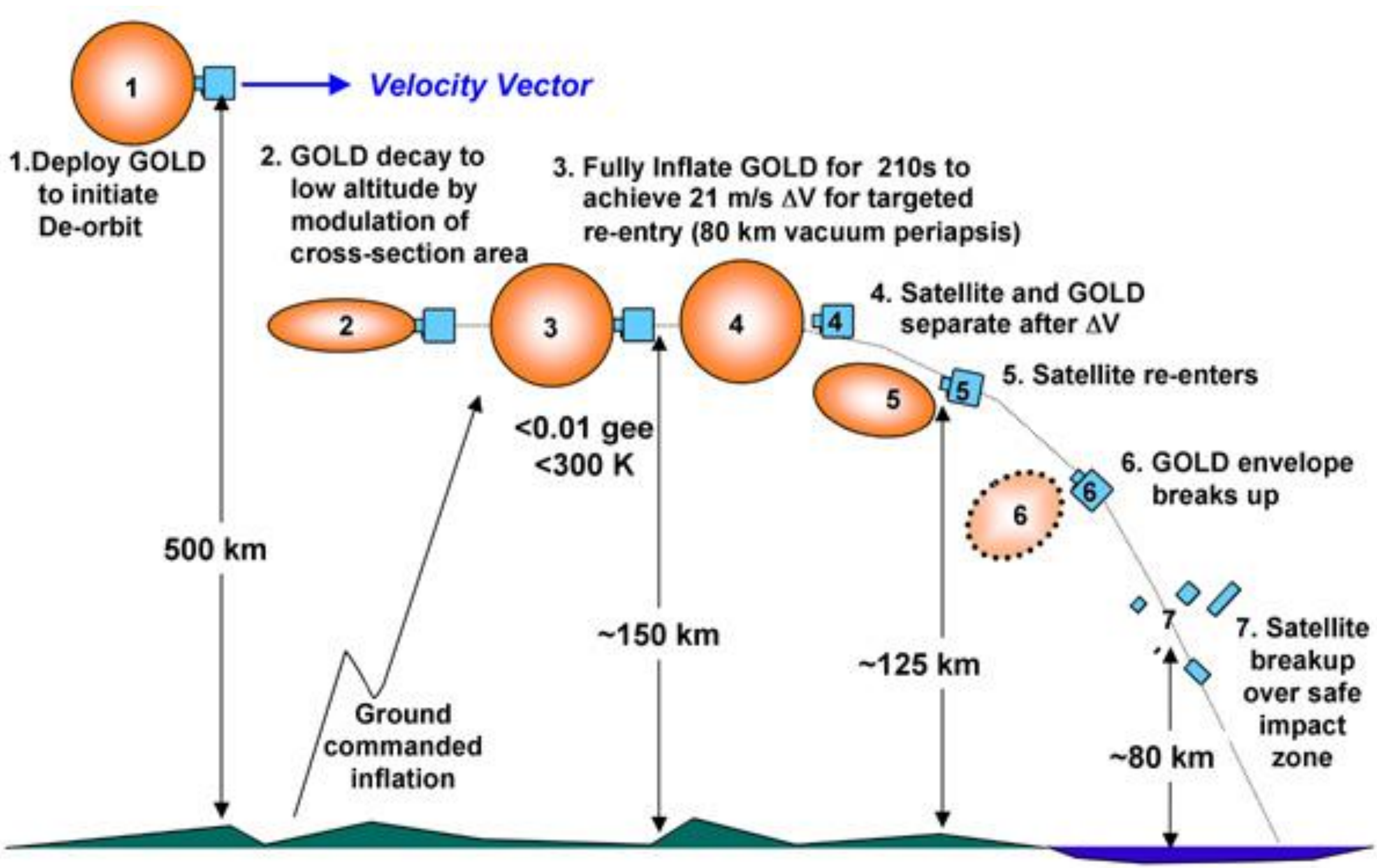


# Global Aerospace's GOLD

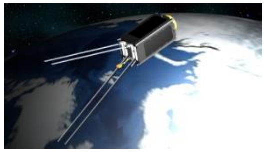


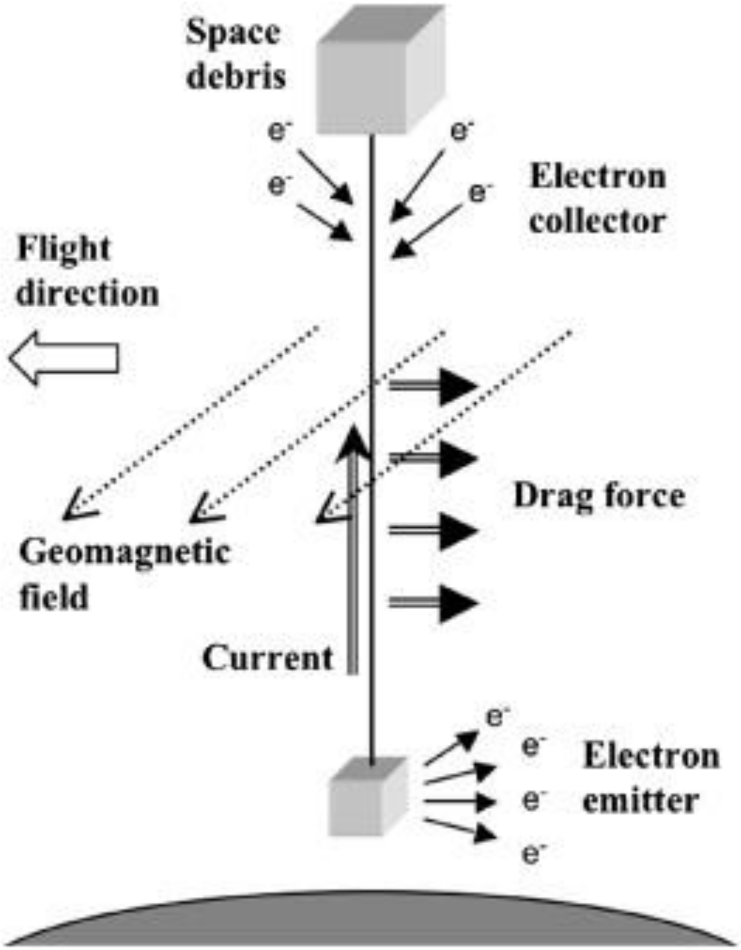
# GOLD's Controllable Re-entry



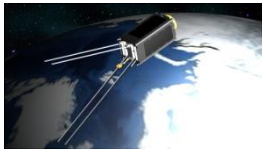


# Electrodynamic Tether De-orbit





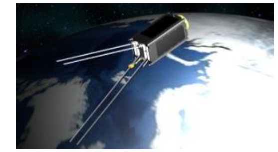

# DDC Participation



- **22 Abstracts:**
  - Drag sail derivatives - 13
  - Nano-propulsion systems - 8
  - Electrodynamic tethers - 2
  - Unworkable solutions - 1
- **12 Finalists (10 papers, 2 posters):**
  - Drag sail derivatives - 9
  - Nano-propulsion systems - 3
  - Electrodynamic tethers - 1
- **2 Withdrawals**

- **12 Finalists are from 10 countries:**
  - Belarus, France, Italy, Japan (2), Poland, Portugal, Russia, South Africa (2), Turkey, USA

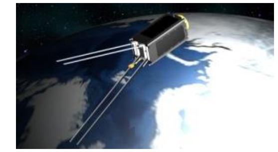
# De-orbit Device Requirements



1. The device must be mounted on a CubeSat (1U, 2U or 3U) that complies with <u>CubeSat Design Specification</u> given by California Polytechnic State University

2. The device will be activated at 21:00:00 UTC, 21$^{st}$ October 2018, with the following orbit elements:
   - semi-major axis : 6930 km
   - orbital inclination : 97.6 degree
   - eccentricity : 0.002
   - R.A.A.N. : 30 degree
   - Argument of Perigee : 210 degree
   - Mean Anomaly : 190 degree

# Evaluation/Selection Criteria



**1. Effectiveness (10)**

How effectively and how fast can the device make the satellite de-orbit?

**2. Mass and envelope at launch (10)**

Does the device fit CubeSat (1U-3U) at launch?

**3. Cost (10)**

Is it affordable for university satellites?

**4. Technical feasibility - Mechanical and electrical design (10)**

Is the device designed to function properly?

**5. Impact on the satellite (10)**

Is the device (power, mass, weight, etc.) suitable for CubeSat?

**6. Reliability (10)**

Is the device designed to fail with a low probability?

**7. Safety (10)**

Can the device influence other satellites/rocket when launched?

**8. Maintenance before launch (10)**

Is the device robust and hard to break?

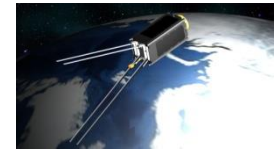
**9. User friendliness (10)**

Is the device easy to interface to the satellite?

**10. Debris risk (10)**

Does the device generate risks in producing additional debris? Will it function even if the satellite has a problem in functioning ?

# DDC Reviewers Final



1. Herman Steyn – Univ of Stellenbosch (Chair)
2. Rustem Aslan – Istanbul Technical Univ
3. Mengo Chu – Kyushu Institute of Technology
4. Yasuyuki Miyazaki – Nihon Univ
5. Lorenzo Arena – Univ of Rome la Sapienza
6. Ryu Funase – Univ of Tokyo

20 Pre-final reviewers are listed on page 8 of Program

Thank you to all participants and reviewers !