# Small Satellite Debris Mitigation Guidelines - A Community Effort

International Academy of Astronautics (IAA) Study Group 4.23
lead by
Darren McKnight, Alex da Silva, Peter Martinez & Rei Kawashima

Presented on behalf of the IAA SG 4.23 by
René Laufer
Baylor University / University of Cape Town
IAA Permanent Committee on Small Satellite Missions

**Space for Humanity**

# A Journey with a Reason – Started with a Question

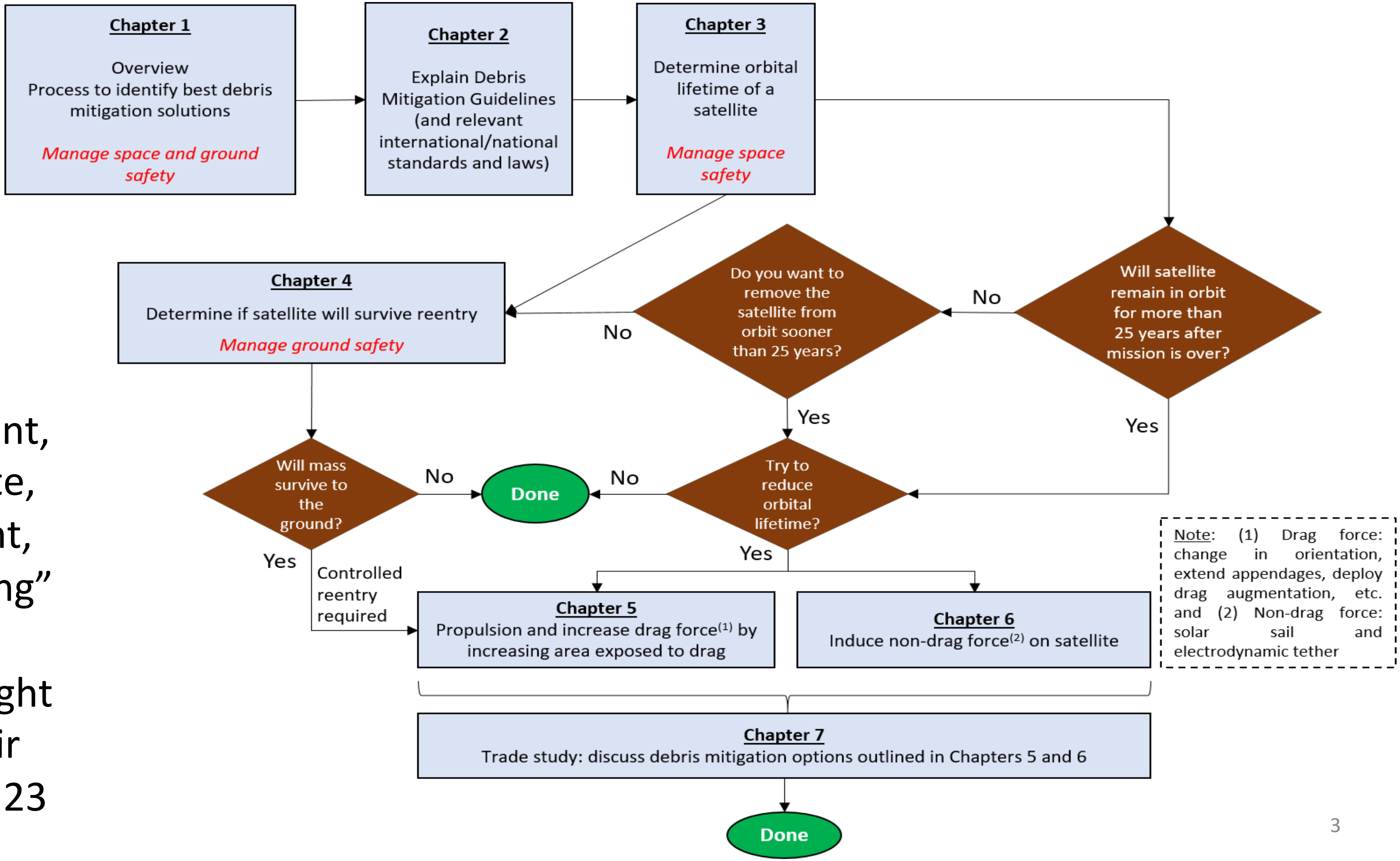
**Conducted by key experts and interest groups members of the space debris and small satellite community for members of the community (YOU!)**

- Orbital debris mitigation is becoming increasingly important
- Technology improvements and cost reduction of access to space: easier to deploy missions
- Small satellite systems can provide significant benefit
- Earth orbital environment is a limited resource - requires coordination and careful understanding in small satellite implementation in order to ensure long term sustainability

IAA has formulated a study group to bring together a range of advice and practical steps that can be taken to help new and more experienced developers of micro, nano & pico satellites

- Understand obligations, international guidelines, standards, and national laws related to ensuing they sustainably develop their small satellite missions: openly available manual

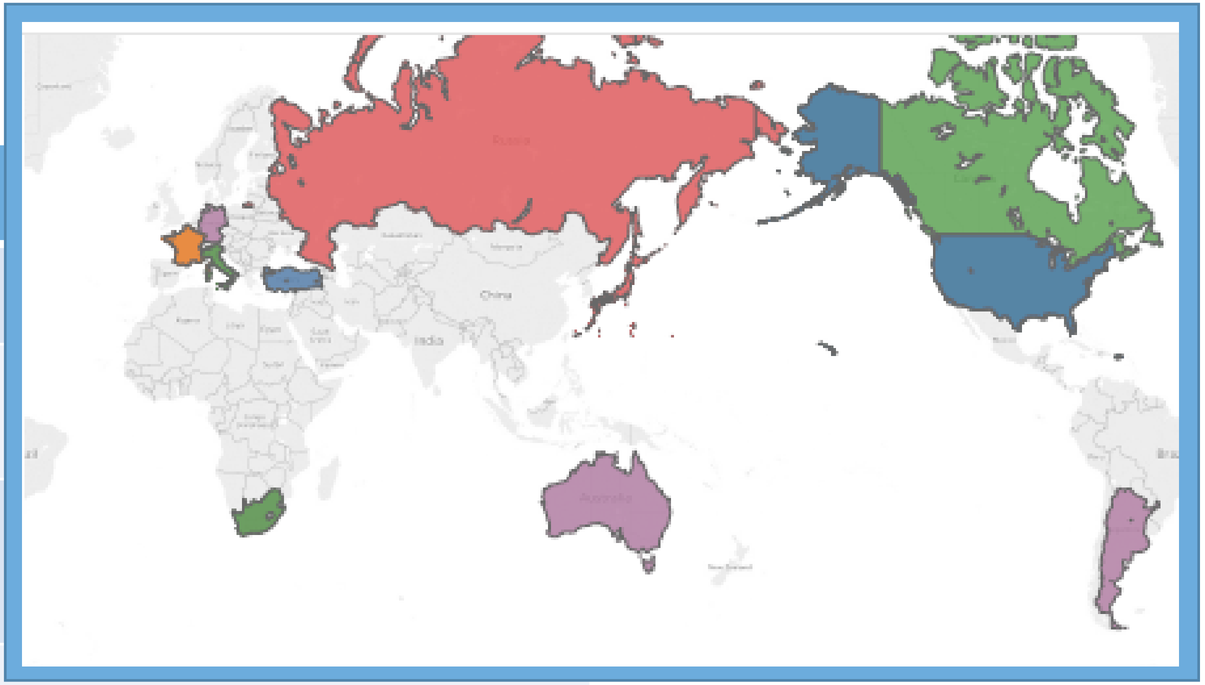
# Logical Plan




“Compliant, Complete, Coherent, Compelling”

D. McKnight
Co-Chair
IAA SG 4.23

# An International Effort



| Chapter | Authors |
|---|---|
| 1. Overview | Darren McKnight (USA) |
| 2. Mitigation Guidelines | Christophe Bonnal (France) |
| 3. Determine Orbital Lifetime | Darren McKnight (USA) and Alim Rustem Aslan (Turkey) |
| 4. Reentry Survival | David B. Spencer (USA) |
| 5. Propulsion and Drag Force | Norman Fitz-Coy (USA), Aaron Rogers (USA), Alfred Ng (Canada), Fabio Santoni (Italy), and Lourens Visagie (South Africa) |
| 6. Non-drag Force | Sergey Trofimov (Russia) and Satomi Kawamoto (Japan) |
| 7. Trade Study | Juan Carlos Dolado Perez (France) and Marlon Sorge (USA) |
| Reviewers | Peter Martinez (South Africa), Barnaby Osborne (Australia)<br>Livio Gratton (Argentina), Klaus Schilling (Germany), Roberto Opromolla (Italy), Christophe Bonnal (France), Vera Pinto Gomes (Portugal), Rene Laufer (Germany), and many others |

# Debris Mitigation Guidelines

- In general, all the space debris mitigation rules (such as ISO 24113) apply to any spacecraft, whatever its size.
- Debris mitigation guidelines for this handbook basically present four major requirements:

   1. Passivate energetic sources (e.g., batteries and capacitors) and vent excess propellant.

   2. Eliminate creation of all debris greater than 1 mm; especially avoid explosions and collisions.

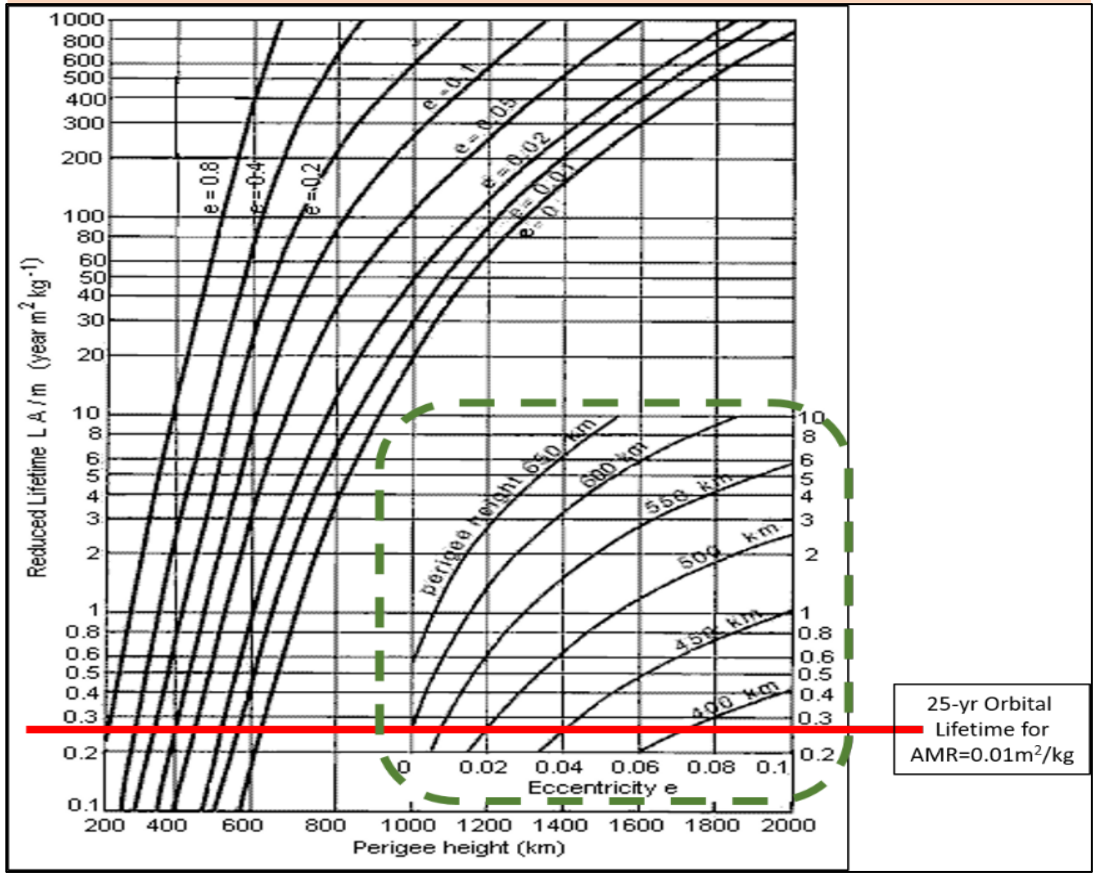
   3. Ensure that all objects left on-orbit are reentered or moved to an acceptable graveyard orbit within 25 years after their operational life with a probability of 90%.

   4. Reentry casualty risk to humans must be less than $10^{-4}$.

- This handbook primarily focuses on the last two requirements.

# Calculating Orbital Lifetimes: An Art and Science

**Empirical – Simple, Intuitive**




**Analytical – Complete, Accurate**

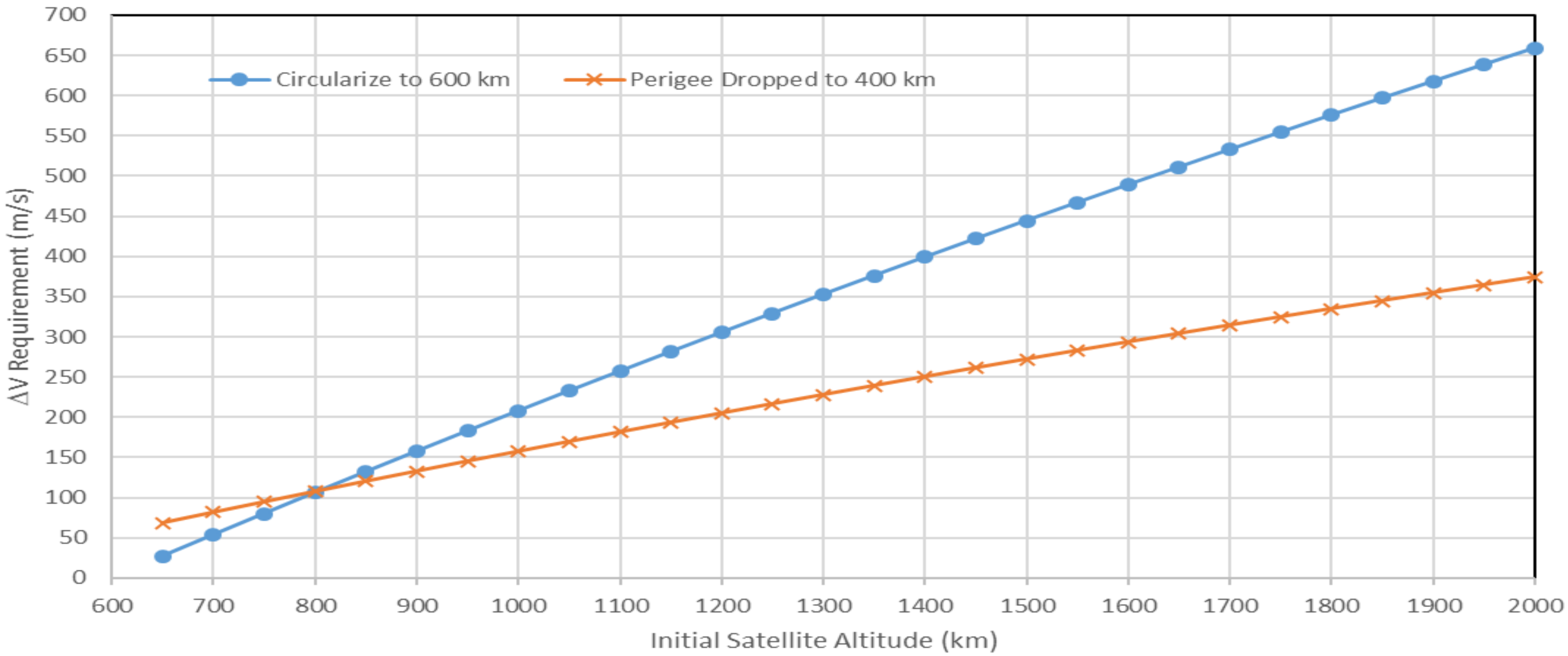
- STELA
  - ✓**S**emi-analytic **T**ool for **E**nd of **L**ife **A**nalysis
  - ✓Designed by *CNES* to support the *French Space Operations Act*
  - ✓STELA is available for download
    - ❑ https://logiciels.cnes.fr/en/content/stela
- Provides more flexibility in dealing with varying spacecraft orientations, solar activity levels, and altitudes/orbits

✓ **Meet 25 year threshold in LEO: circular below ~625 km or perigee below ~400 km**

✓ **Effect of increased area increasing drag is evident…**

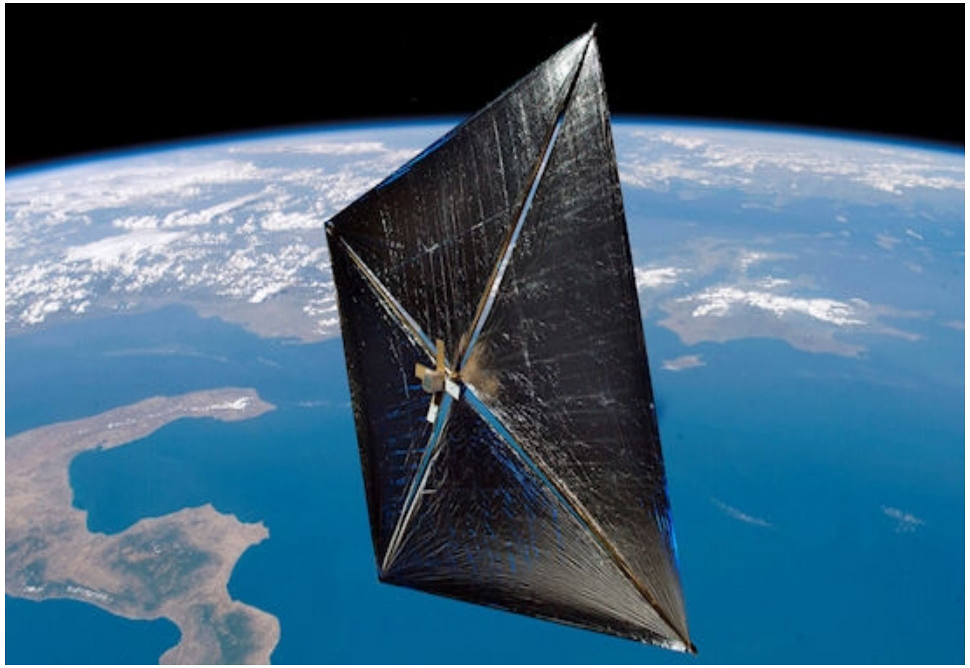
# Reduce Lifetime by Propulsion

✓Strategy varies across LEO: require 10s to 100s m/s of delta velocity

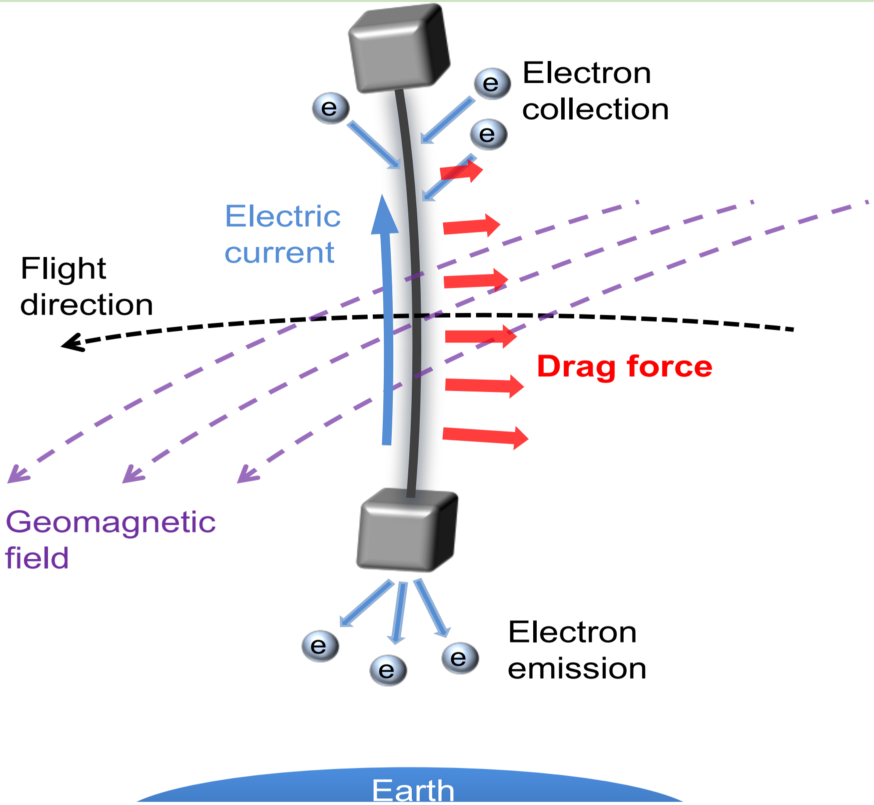


# Reduce Lifetime by Non-Drag Forces

- Solar Radiation Pressure



- Electrodynamic Tether (EDT)



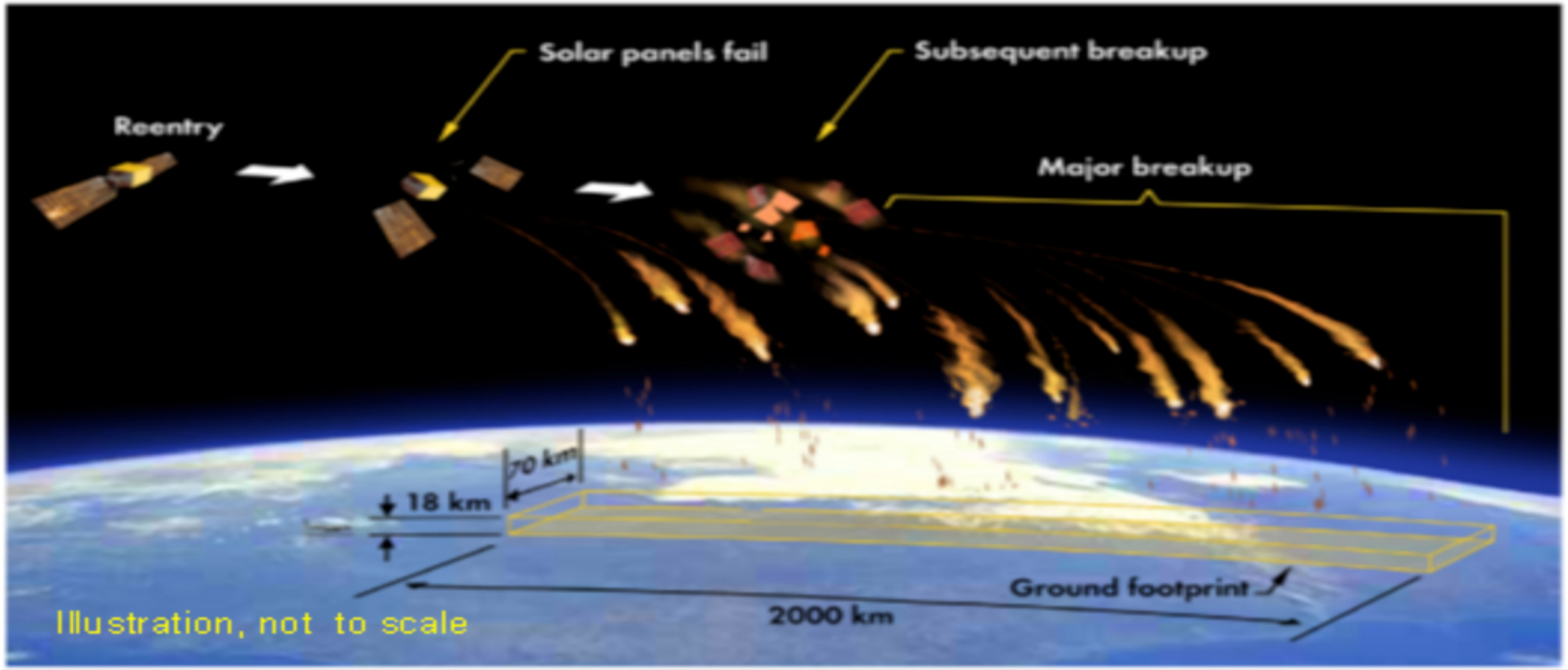

✓ **Solar – simple, slow**; deal with stability, durability, & collision cross-section issues

✓ **EDT - flexible, fast**; deal with stability, durability, & collision cross-section issues

# Reentry Survival

- Four primary characteristics that drive reentry survival:
  - ✓Material: typically aluminum and circuit boards
  - ✓Mass: under 100 kg (for micro satellites and smaller)
  - ✓Construction: no hardened or high density devices
  - ✓Reentry Trajectory: due to contraction from atmospheric drag

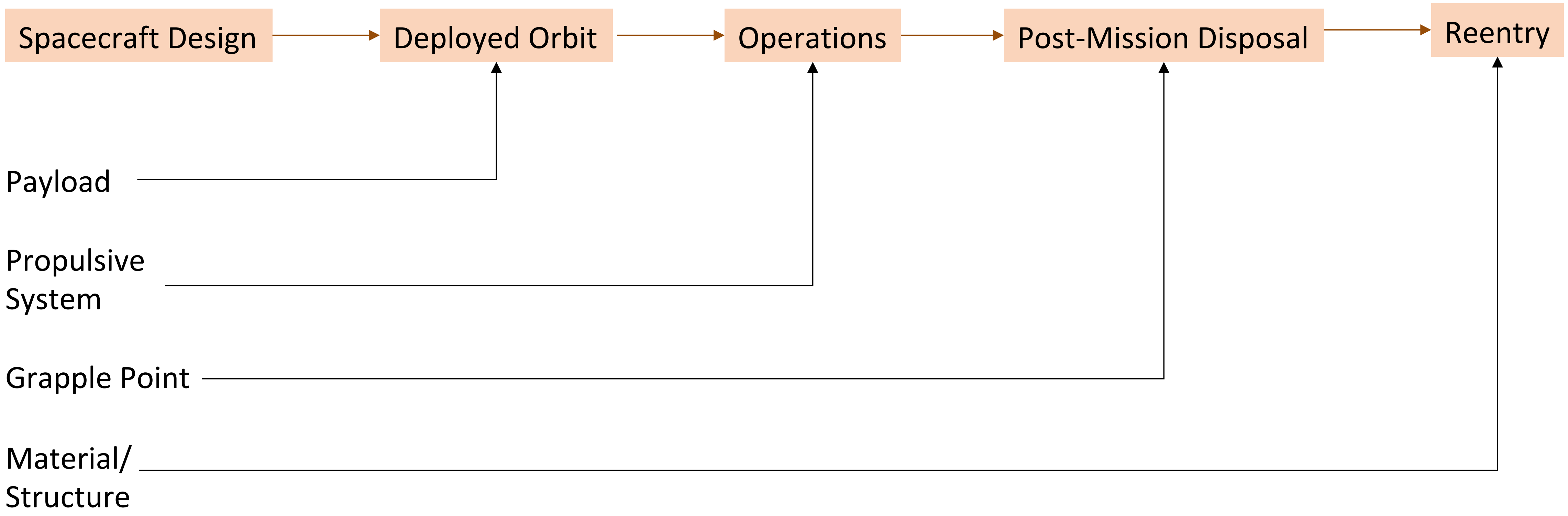
Material | Mass | Construction | Reentry Trajectory




Micro satellites and smaller satellites will pose little air or ground impact risks
*- Beware of densely-built components such as control moment gyros and batteries*

# Trade Study – What is Best for you?

- What can you control and what will provide greatest effects?



# Summary

- This manual complements other standards…
  - ✓ISO 24113, Space Systems – Debris Mitigation
  - ✓ISO/TS 20991, Space Systems – Requirements for Small Spacecraft
- Encourages and enables micro satellite (and smaller) operators to be responsible space users
- Choice for assuring adherence of a specific micro satellite or smaller to debris mitigation guidelines depends on…
  - Operational altitude, functional capabilities, and resources available
- **Completion of the final draft planned for 15 January 2019**

  **Study group leadership and members are working very hard for you!**