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A Handbook for Post-Mission Disposal of Satellites Less Than 100Kg

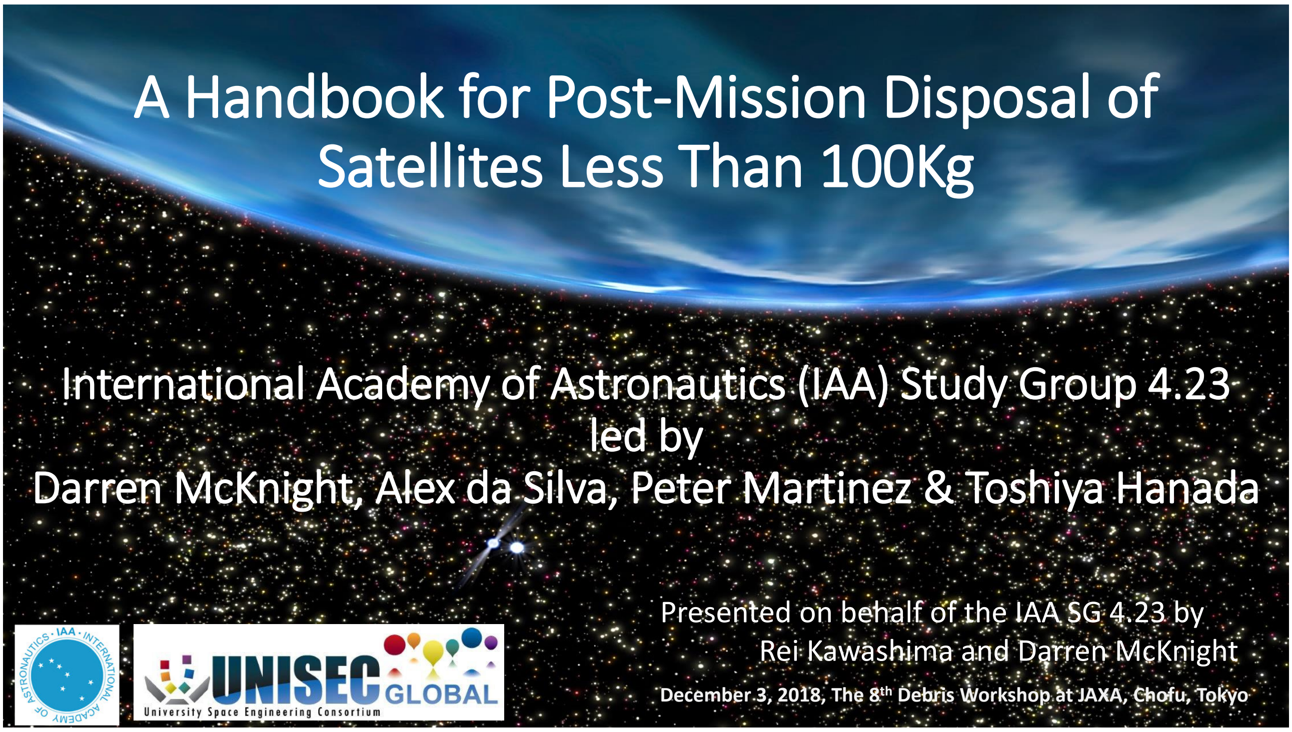
Rei Kawashima (UNISEC-Global) and Darren McKnight (Integrity Applications, Inc.)

UNISEC-Global has promoted practical space projects such as pico/nano/micro satellite development at the university level globally since its establishment in 2013. More and more non-spacefaring countries and universities have joined the activities and are providing valuable information and education on the increasingly important topic of orbital debris mitigation. Since the Earth orbital environment is a limited resource future small satellite space missions will require coordination and careful understanding of debris mitigation issues in order to ensure long-term sustainability of these activities. Thus, UNISEC-Global organized debris mitigation competitions in 2016 and 2017. However, debris issues were found to be complex and a handbook was identified as a valuable means to provide guidance to UNISEC-Global members.
In response to this challenge, the International Academy of Astronautics (IAA) formulated a study group to assemble advice and practical steps that can be taken to help new and more experienced developers of microsatellites (and smaller) understand their obligations, international guidelines, standards, and national laws related to ensuring they sustainably develop their small satellite missions. The group includes key experts and interest groups, and the outputs will be captured in a handbook which will be made openly available. UNISEC-Global is assisting in its formulation and will play a leading role disseminating the information through the university network worldwide.

Biography

Rei Kawashima

Dr. J.-C. Liou is the Rei Kawashima has contributed to micro/nano/pico satellite for education and business applications through her leadership role in UNISEC - the University Space Engineering Consortium that she co-founded in 2002. She has been appointed as the Secretary General of UNISEC-Global, an international organization that was established in 2013 and obtained the permanent observer status of United Nations' Committee on the Peaceful Uses of Outer Space (UNCOPUOS). She organizes training programs and technology competitions to facilitate university's participation in space projects worldwide and especially in developing countries.

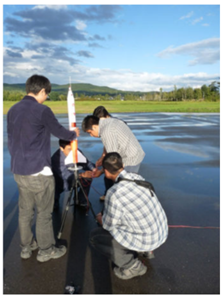


Outline

- Background
- Overview
- Contents of the Handbook
- Trade Study
- Summary

Background – UNISEC activities

- University Space Engineering Consortium (UNISEC) 2002 Japan
  - Facilitate Practical Space Activities – build, launch, operate your satellite!
- UNISEC-Global 2013
  - By the end of 2020, let's create a world where university students can participate in practical space projects in more than 100 countries
- UNCOPUOS Permanent Observer 2017
  - New vision 2030-All
- More and more new countries/universities are joining the activities and need to provide correct information on debris issues to prevent their satellites from becoming debris and to increase awareness.



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Debris Mitigation Competition(DMC)

Debris Mitigation Competition

- **Objective:** To facilitate the sharing of innovative solutions for debris mitigation and developing effective deorbit devices that can be demonstrated and validated with Micro/Nano-Satellites. It is also expected to increase awareness of debris problems among satellite developers and university students.
- **Conducted:** 2016 and 2017

Overview of IAA-Study Group (IAA-SG 4.23)

- **Title of Study**：Post Mission Disposal for Micro and Smaller Satellites – Concept and Trade Studies
- **Members: 65 members from 18 countries**
- **Chairs:** Darren McKnight (USA), Toshiya Hanada (Japan), Alex da Silva Curie (UK), and Peter Martinez (South Africa)
  - **Secretary:** Rei Kawashima (Japan)
  - **Experts** : IAA members and non IAA members
- **Goal:** Provide framework for a practical implementation to assure compliance with Space Debris Mitigation guidelines for micro and smaller satellites.
- **Target Communities**: Universities, micro/nano/pico-satellite manufacturers, and new spacefaring entities
- **Outcome:** A Handbook for Post-Mission Disposal of Satellites Less Than 100Kg
  - UNISEC-Global will help disseminate information and ensure the handbook will be used.

Study Group Meeting at IAC2018 (Bremen)

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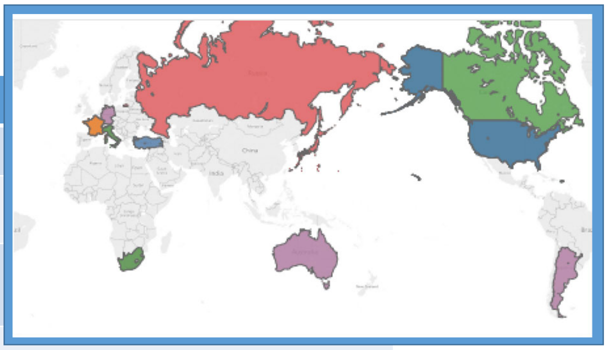
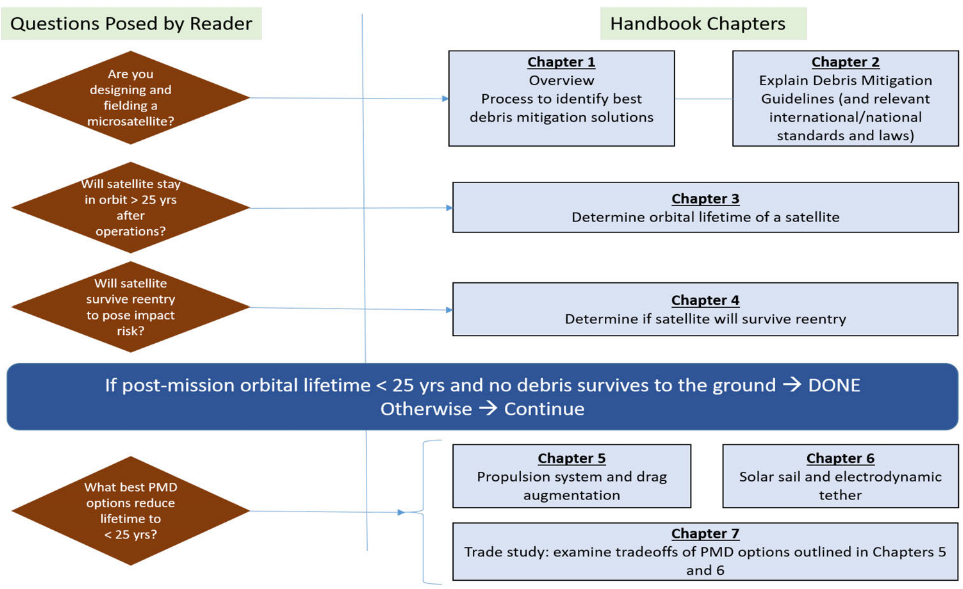
An International Effort



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) Livio Gratton (Argentina), Klaus Schilling (Germany), Roberto Opromolla (Italy), Christophe Bonnal (France), Vera Pinto Gomes (Portugal), Rene Laufer (Germany), and many others

Logical Plan

“Compliant, Complete, Coherent, Compelling”



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.

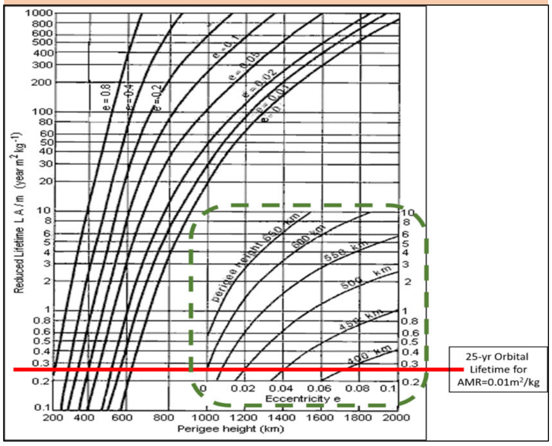
  3. Ensure that all objects left on-orbit are reentered or moved to an acceptable graveyard orbit within 25 years after their operational life with a probability of 90%.

  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

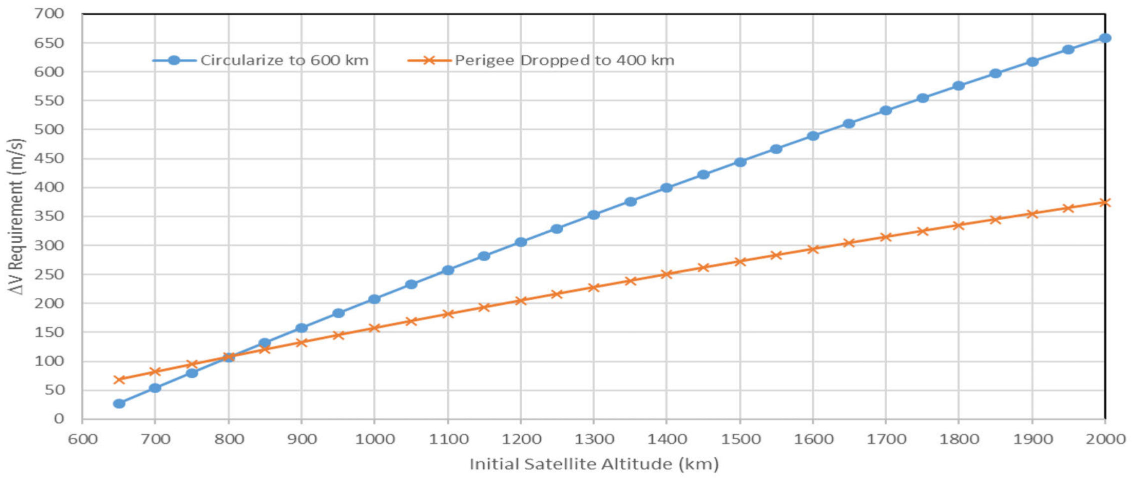
- STELA
  - ✓**S**emi-analytic **T**ool for **E**nd of **L**ife **A**nalysis
  - ✓Designed by *CNES* to support the *French Space Operations Act*
  - ✓STELA is available for download
    - https://logiciels.cnes.fr/en/content/stela
- Provides more flexibility in dealing with varying spacecraft orientations,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



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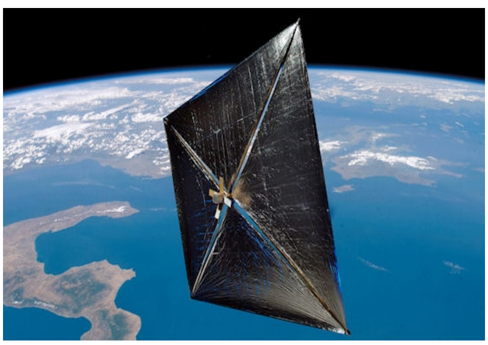
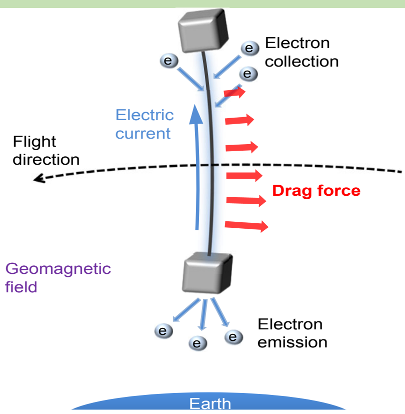
Reduce Lifetime by Non-Drag Forces

- 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

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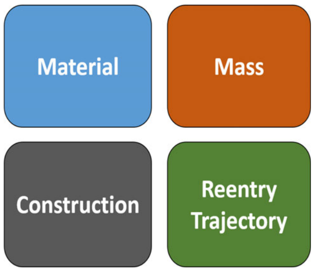
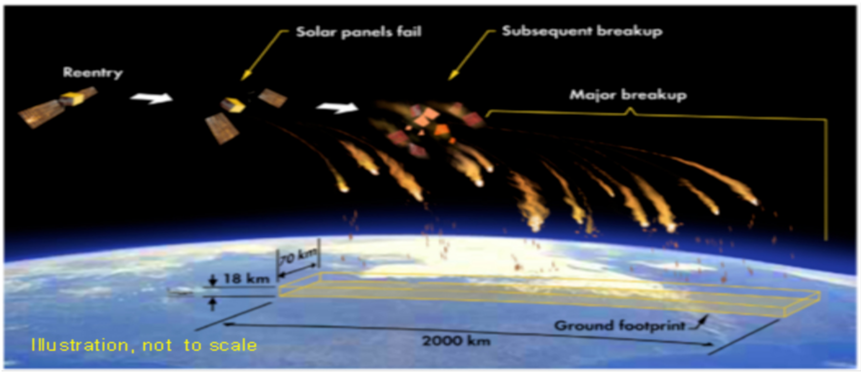
Reentry Survival

- 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





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?

- PMD strategy depends on:
  - mission orbit and requirements,
  - satellite capabilities and physical characteristics such as size, weight, and power,
  - operational paradigms,
  - cost, size, weight, and power of PMD options,
  - technical maturity of PMD options,
  - operational complexity of PMD options,
  - vulnerability of the PMD options to space environmental effects, to include orbital debris.
- Tradeoff process has four major steps
  1. Select three spacecraft/orbit scenarios
  2. Determine lifetime without PMD
  3. Apply four PMD options and discuss implementation realities
  4. Calculate integrated collision risk

Summary

- This handbook 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 March 2019 to be followed by IAA official review.**
- **4th draft is available for your review up to Dec 15, 2018.**