KiboCUBE Academy

Live Session #2-1

Launch and Operation of CubeSats

Tohoku University

Department of Aerospace Engineering

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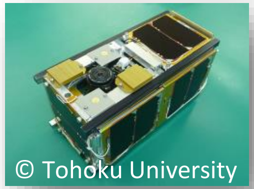
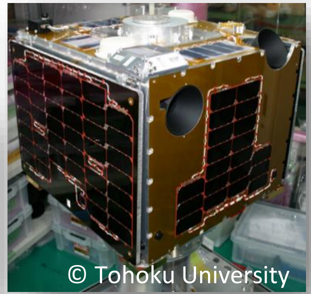
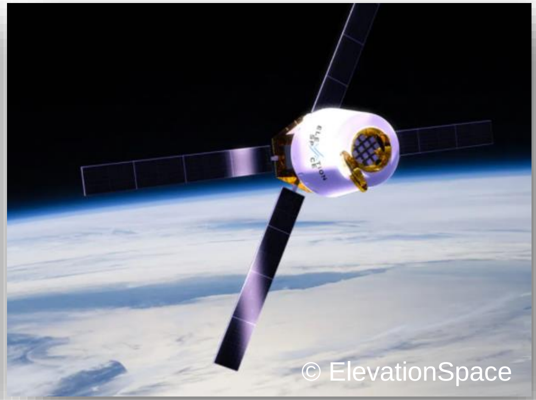
This lecture is NOT specifically about KiboCUBE and covers GENERAL engineering topics of space development and utilization for CubeSats.
The specific information and requirements for applying to KiboCUBE can be found at:
https://www.unoosa.org/oosa/en/ourwork/psa/hsti/kibocube.html

Lecturer Introduction







Toshinori Kuwahara, Dr. –Ing.

Position:

2015 - Associate Professor, Department of Aerospace Engineering, Tohoku University
2017 - Technical Advisor, Nakashimada Engineering Works, Ltd.
2017 - Technical Advisor, ALE Co., Ltd.
2020 - Chairperson, University Space Engineering Consortium Japan (UNISEC)
2021 - Co-founder/CTO, ElevationSpace Inc.

Research Topics:

Space Development, Utilization, and Exploration by Small Spacecraft Technologies

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1. Introduction to Small Satellites

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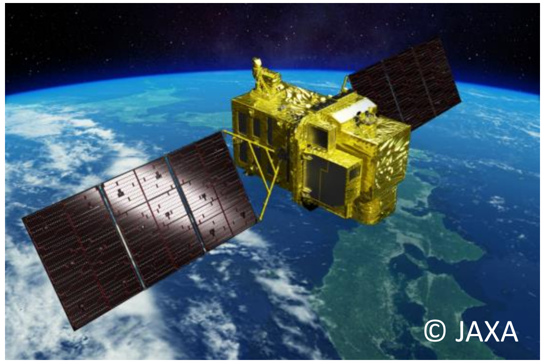
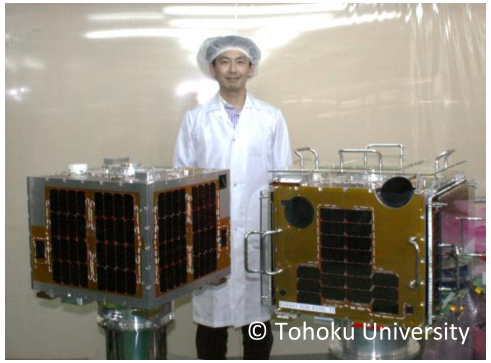
1.1. Characteristics of Small Space Systems

Comparison between large and small satellites:

Large Satellite



Small Satellite



Large Satellite		Small Satellite
Large	Mass	**Small**
High	Cost	**Low**
Long	Development Time	**Short**

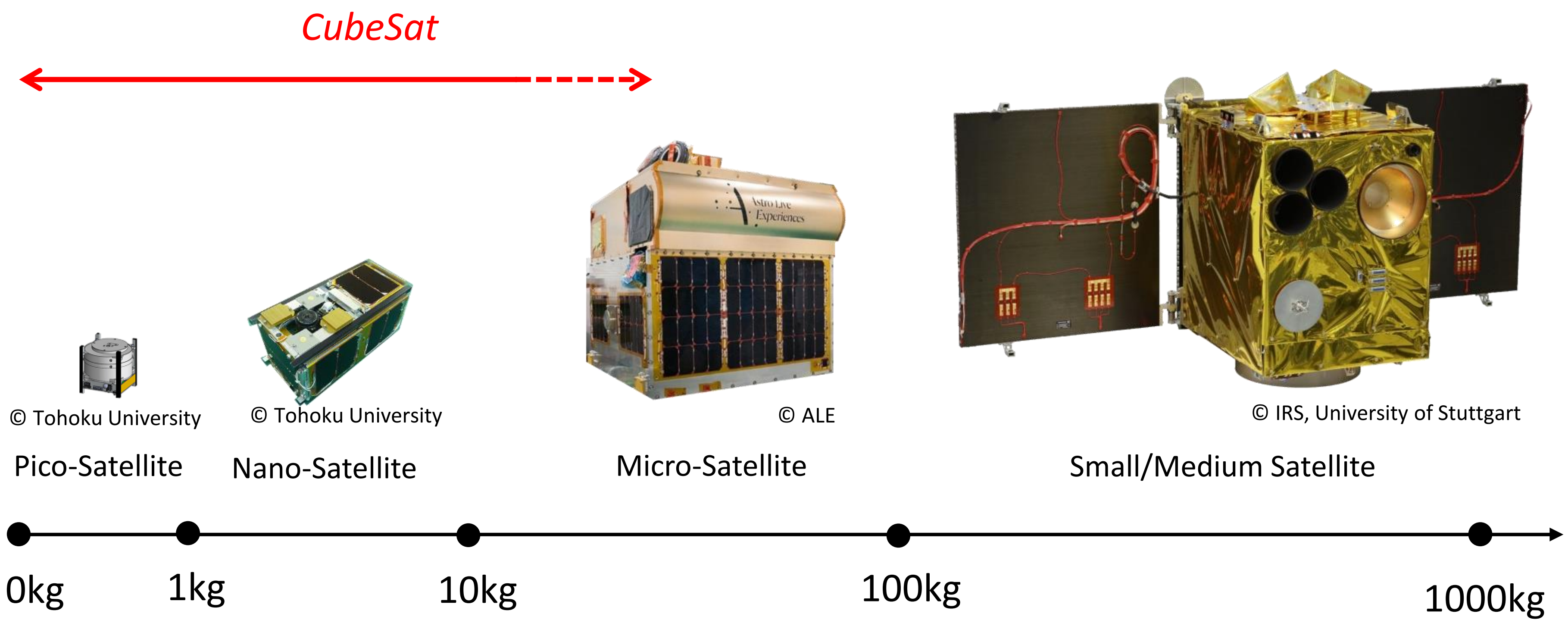
- Dedicated launch
- Need high-reliability, low-risk
- High-performance,
  Low observation frequency

- Small mass = Frequent launch opportunities
- Low cost = Can try challenging missions, realize large constellations/networks (frequent observations)
- Rapid Development = Can utilize brand new technologies
- Suitable platform for space education and rapid technology demonstration

1. Introduction to Small Satellites

1.2. Mass Categories

Small, Micro, Nano, and Pico-satellites.



1.3. Advanced Applications of CubeSats

There are a wide range of applications for CubeSats.

Earth Observation

- Optical observation
- SAR (Synthetic Aperture Radar)
- Radio signal analysis
- Weather observation measurement

Communication

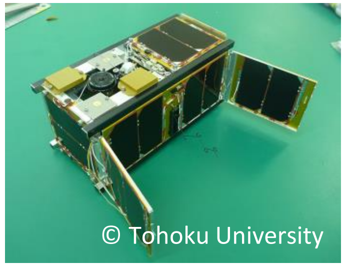
- Data relay
- M2M (Machine-to-Machine) communication
- AIS (Automatic Identification System)
- High-speed laser communication

New technologies

- GNSS signal occultation measurement
- Space robotics
- Electrodynamic Tether
- Re-entry and return capsule

Science

- Astronomy
- Bioscience experiment
- Moon, Asteroids, Planets, and Deep Space Exploration.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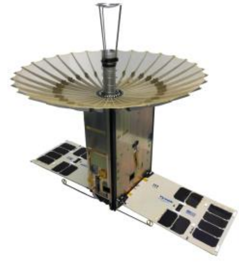
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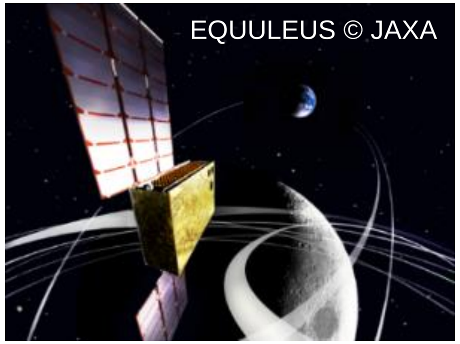
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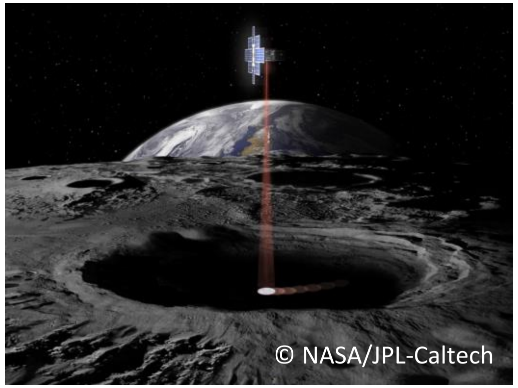
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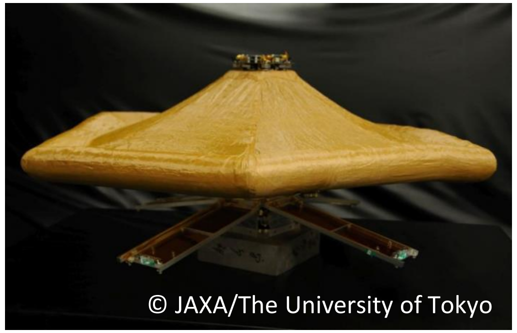
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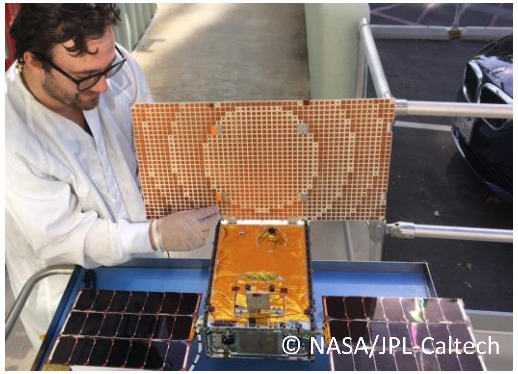
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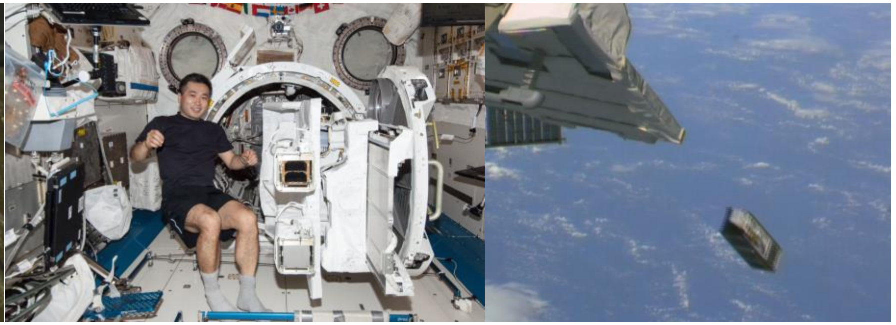
2. Launch Opportunities for CubeSats

2. Launch Opportunities for CubeSats

2.1. KiboCUBE Launch Opportunity

- “KiboCUBE” provides deployment opportunities from the ISS Kibo module.
- The possible launch vehicle can be one of the transfer vehicles to the ISS:
  - HTV: H-II Transfer Vehicle
  - SpX Dragon: SpaceX Dragon
  - Orbital Cygnus
- The launch environment is different in each vehicle.
- CubeSats are installed in the satellite deployment POD (J-SSOD: Japanese Experiment Module (JEM) Small Satellite Orbital Deployer) and stowed inside the Cargo Transfer Bag (CTB) with soft packing material.
- Vibration conditions are very mild relative to those encountered during a direct launch.
- Frequent launch opportunities are provided, up to 4 times per year.
- Adopting an approximate orbital altitude of 400 km ensures the CubeSats re-enter the atmosphere after their mission lifetime without becoming space debris.

CubeSat Transfer to the ISS © JAXA



Deployment from the ISS © JAXA

3. CubeSat Operation and Debris Mitigation

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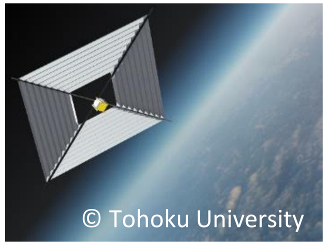
3.1. Operational Phase of CubeSat deployed from ISS

- Operational phase of the CubeSat to be deployed from the ISS can be categorized into several phases as follows.

Launch Phase	Preparation Phase	Early Operation Phase	Mission Phase	Disposal Phase
CubeSat is launched and delivered to the ISS.	**CubeSat is stored in the ISS and prepared for deployment into orbit.**	**CubeSat is deployed from ISS, communication link is established, and initial inspection is conducted.**	**CubeSat conducts its missions.**	**CubeSat is set to disposal mode and waits until the re-entry into Earth's atmosphere.**

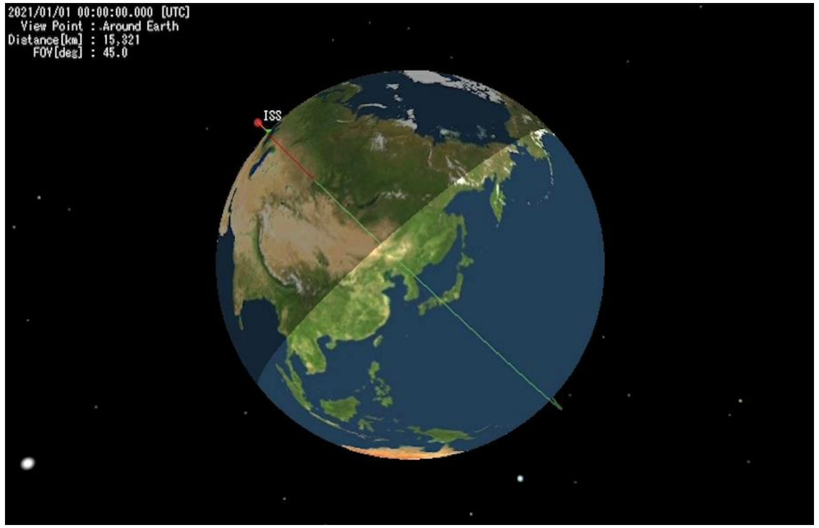


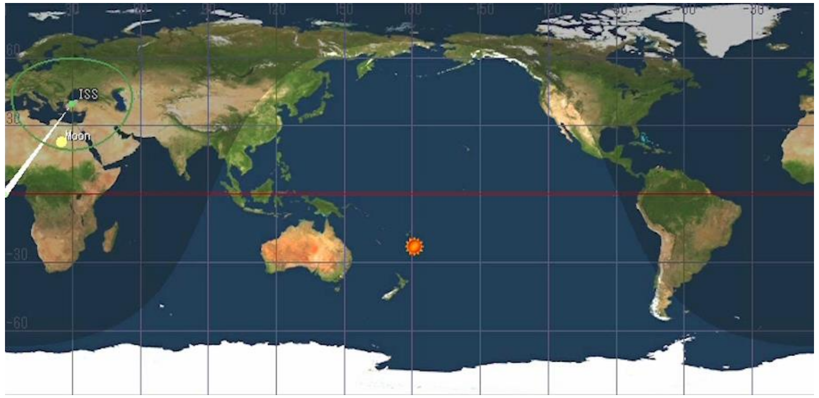
3. CubeSat Operation and Debris Mitigation

3.2. Orbit of International Space Station (ISS)

- Orbit of ISS:
  - Orbit altitude: ≃ 400km*
  - Inclination: ≃ 51.6 deg
  - Orbital period: ≃ 91 min

  * Orbit altitude changes for about ±20km
- CubeSats deployed from the ISS stay in almost the same orbit as the ISS.
- Slight differences in initial relative velocity and different mechanical characteristics, such as mass and shape (and hence, ballistic coefficient), make the CubeSats separate from each other into different orbits.
- ISS orbit covers the ground surface of regions with lower latitude (between ± 51.6 deg).
- ISS rotates around the Earth about 16 times a day, while the Earth rotates about 22.5 deg during the 1 orbital period of the ISS.





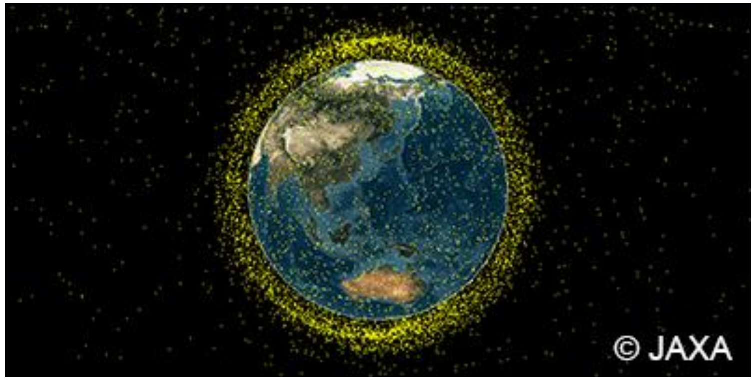
Spheresoft

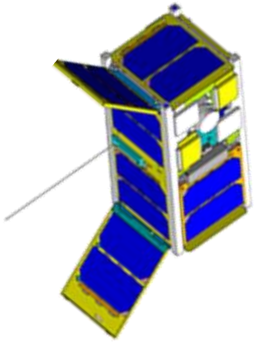
3.3. Space Debris Mitigation Methods

- There are two major debris mitigation and prevention methods.

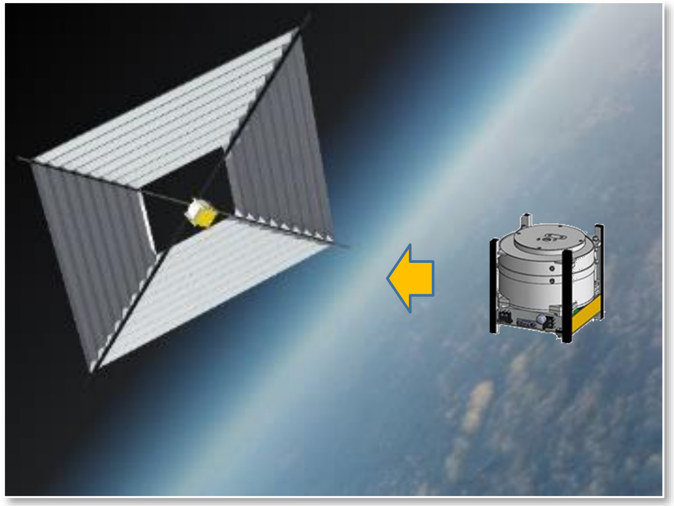
- PMD: Post Mission Disposal
  - Spacecraft terminating their operational phase in LEO (Low Earth Orbit) region should be de-orbited with an expected residual orbital lifetime of 25 years or shorter.
  - Projection area of the spacecraft in the velocity direction needs to be large enough to catch sufficient atmospheric drag for re-entry.

- ADR: Active Debris Removal
  - Debris-removing spacecraft actively approaches and removes non-cooperative space debris.





2U CubeSat RAIKO
Natural De-orbit by Design



1U CubeSat FREEDOM
Utilization of Active De-orbit Devices
to Increase Atmospheric Drag

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Thank you very much.

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