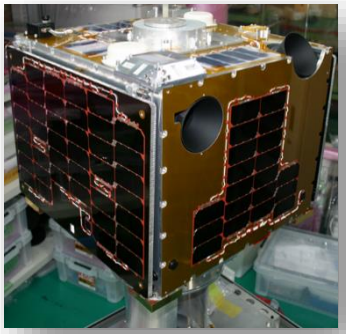
My 20-year journey with micro/nano satellites

Associate Professor, Toshinori Kuwahara
(UNISEC Japan Chairperson)
Department of Aerospace Engineering
Tohoku University

November 14, 2020
UNISEC Global Meeting #3

Self-Introduction



RISESAT (~60kg)

ALE-1 (~70kg)

Toshinori Kuwahara, Dr. –Ing.

1981 Born in Kyushu, Japan

2000 Entering Kyushu University

2005 Master Degree, Kyushu University

2009 Doctor Degree, University of Stuttgart

2010 Assistant Professor, Tohoku University

2015 - Associate Professor, Tohoku University

<u>Research Topics</u>

Space Development and Utilization by means of Microsatellite Technologies.

2017 - Nakashimada Engineering Works, Ltd., Technical Advisor

2017 - ALE Ltd., CTO

2020 - UNISEC Japan, Chairperson

Contents of Presentation

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- CANSAT Development as Bachelor Student (Kyushu University, Japan)
- Microsatellite Development as Master Student (Kyushu University, Japan)
- Microsatellite Development as Doctor Student (University of Stuttgart, Germany)
- Micro-/Nano-satellite R&D as Academic Researcher (Tohoku University, Japan)
  - Scientific satellite missions
  - Space Education and Regional Collaboration
  - Collaboration with Industrial Partners
  - UNISEC Japan and Global
- Future Plan

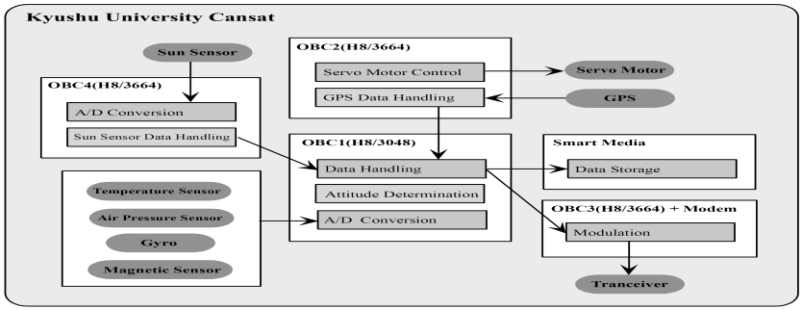
CANSAT Development as Bachelor Student

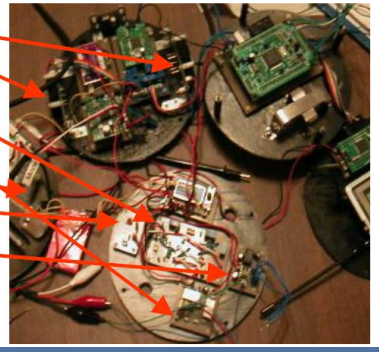
Prof. T. Yasaka

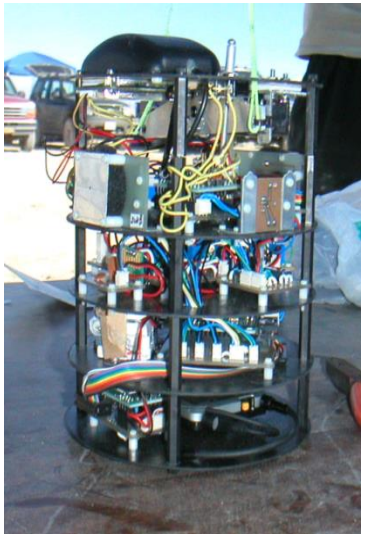
“CanSat2003” - Kyushu University

- CANSAT was the first training for the space system development at the University.
- Best hands-on training for system design, electrical engineering, instrument handling and AIT.
- Experienced a mission failure due to the insufficient structural design, analysis, and verification.

ARLISS 2003
@Nevada







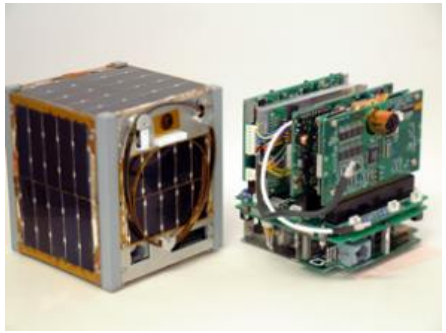
CanSat2003

Parachute was broken and crashed on ground

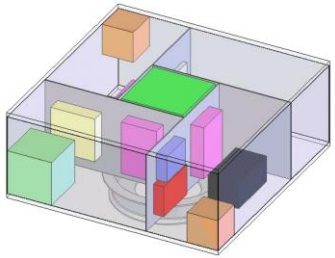
Microsatellite Development as Master Student

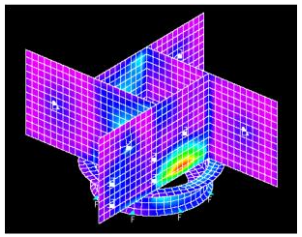
"QTEX" - Kyushu University

- World first CubeSats were developed by Japanese Universities and launched in 2003.
- Unlike other Universities, Kyushu University was focusing on the development of 50-kg-class tethered microsatellite.
- Again, it was the best training for learning satellite design, development, and AIT, as well as various bus system and mission payload technologies.

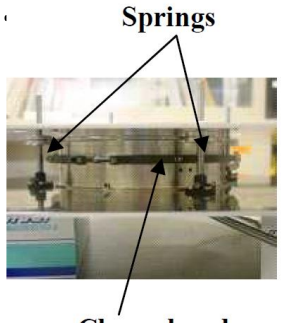


World-first CubeSat X-IV
© University of Tokyo

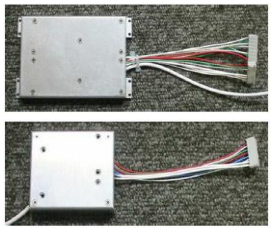




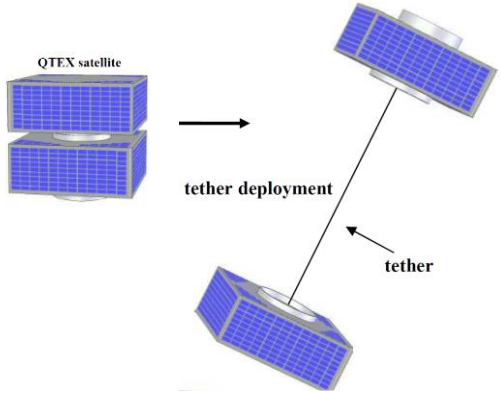
Structure



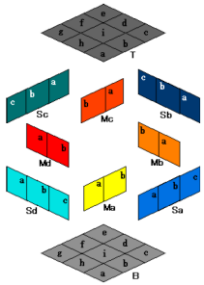
Mechanism



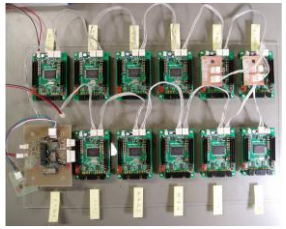
Communication



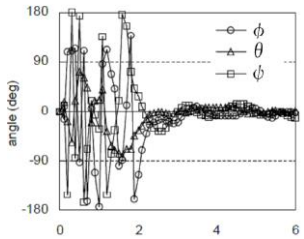
Tethered Satellite QTEX
Kyushu University
(50kg)



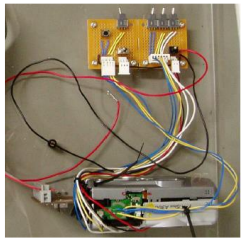
Thermal



C&DH



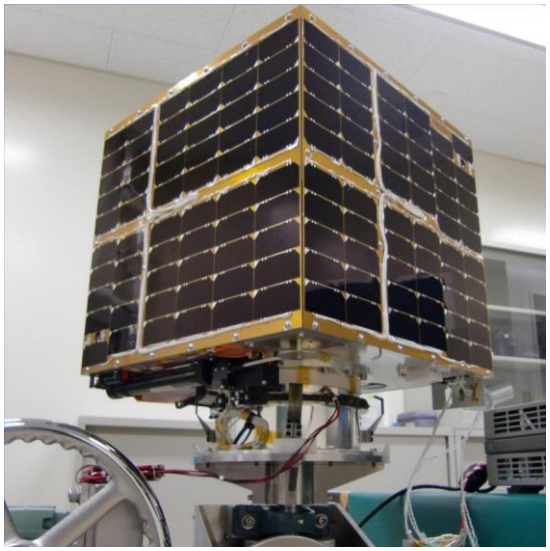
Attitude



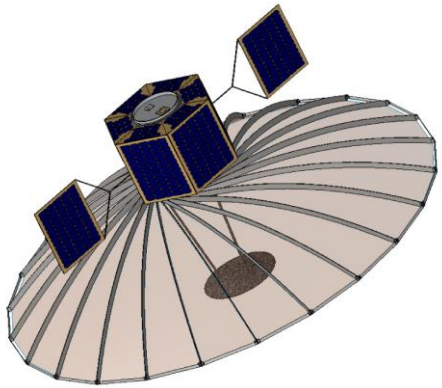
Payload/Camera

iQPS – Spin-off Company

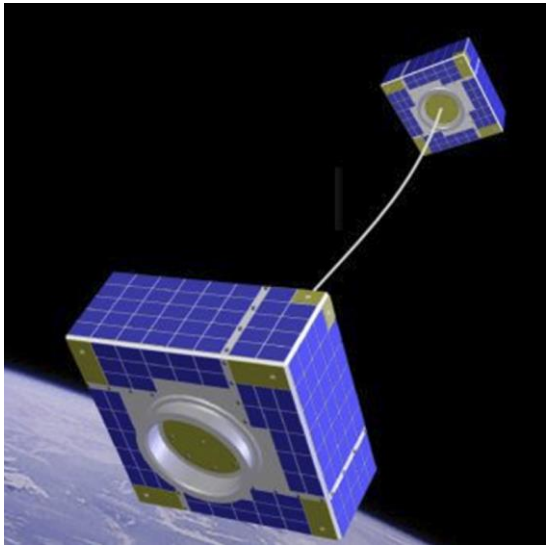
- Microsatellite technology research and development activity of the Kyushu University resulted in the establishment of a spin-off company “iQPS.”
- iQPS is now providing services related with Earth observation micro-satellites, small SAR satellites, and various micro-satellite key technologies such as electrodynamic tether, debris sensors, low-shock non-pyrotechnic separation mechanism, and controllable drag augmentation device.



Small Satellites



SAR satellites



Electrodynamic Tether

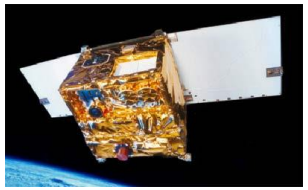
© iQPS

https://i-qps.net/

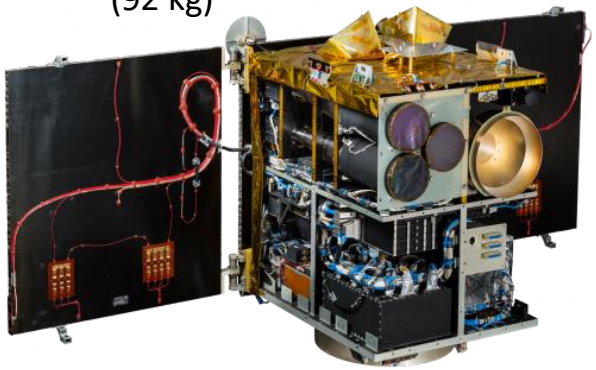
Microsatellite Development as Doctor Student

“FLP” - University of Stuttgart (2005～)

- Moved to University of Stuttgart, Germany, after obtaining the Master of Engineering degree in Japan.
- DLR was successful in launch (2001) and operation of micro-satellite BIRD (Bispectral and Infrared Remote Detection), and delivered operational wildfire-detection information with on-board neuronal network classifier.
- As a doctoral student, engaged in the development of 120-kg-class Earth observation and technology demonstration micro-satellite Flying Laptop, later renamed as FLP.



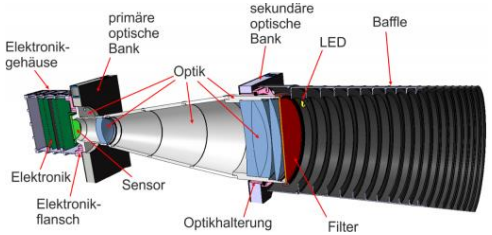
BIRD 1 © DLR
(92 kg)



Microsatellite FLP
© IRS/University of Stuttgart
(~120kg)

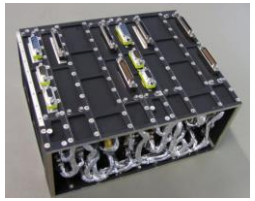
OSIRIS Optical
Com. Terminal

AIS Receiver



Multispectral Camera

GPS



LEON3 OBC

© IRS/University of Stuttgart

https://twitter.com/flying_laptop

During the Doctoral Study, I met with…

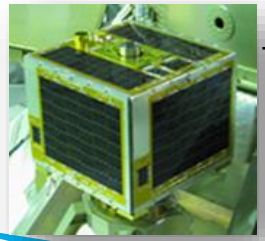
Prof. Tetsuo Yasaka　Prof. Sir Martin Sweeting　Me

I want to be a professor…!

IAC 2007 @ Hyderabad, India

Micro-/Nano-satellite R&D as Academic Researcher

Tohoku University Satellite Missions



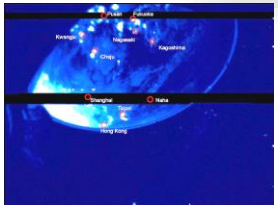
SPRITE-SAT (2009)

RISING-2 (2014)

DIWATA-1 (2016)

S&F Network

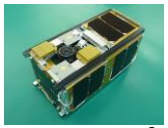
DIWATA-2 (2018)



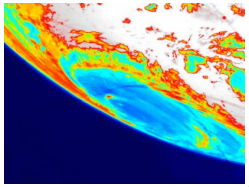
✓Earth Obs.

✓Earth Obs.

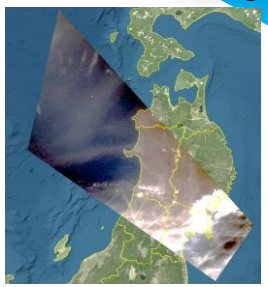
Nano-satellites



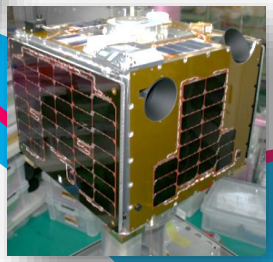
RAIKO (2012)



✓IR Obs.



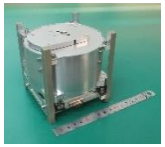
✓Spectrum Obs.



RISESAT (2019)

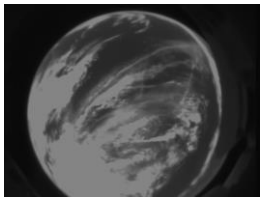
© ALE

ALE-1 (2019)

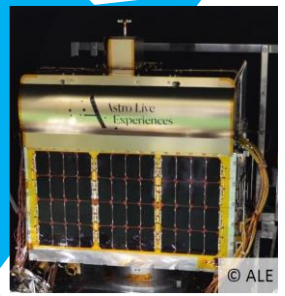


© NEW, Ltd.

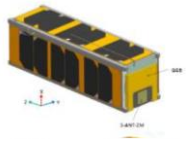
FREEDOM (2017)



✓Wide Obs.



ALE-2 (2019)



IHI-SAT (2019~)

© IHI

R&D Activities

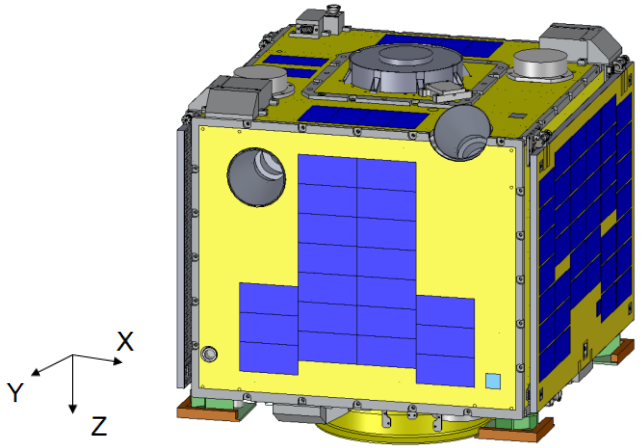
Scientific satellite missions

Scientific Microsatellite RISESAT

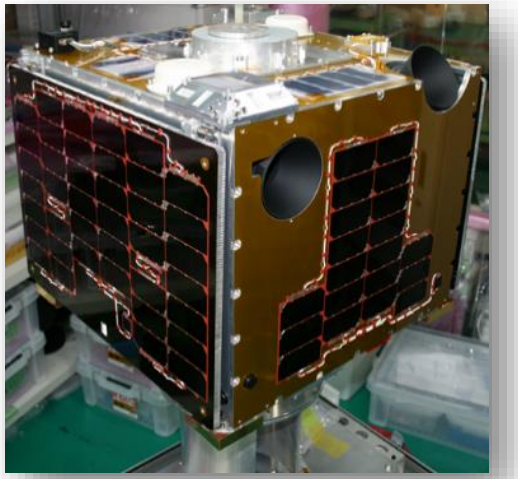
- *Rapid International Scientific Experiment Satellite* -

System Specification

Size and weight	
size	Smaller than W 500 x D 500 x H 500 mm
weight	less than 55 kg
Orbit	
type	Sun Synchronous Orbit
local time	9:00-15:00 (Default LTDN 11:00)
altitute	between 500 – 900 km
inclination	approx. 98 deg
Attitude determination and control	
method	3-axis stabilization
pointing accuracy	< 0.1° (3σ) (Reqs.), < 0.04° (3σ) (Objectives)
pointing stability	6"/s
sensors	star sensor (2), FOG (3-axes), magnetometer (3-axes), GPS receiver (1), course and accurate sun sensors(4π)
actuators	reaction wheels (4) magnetic torquers (3-axes)
Power supply	
solar cells	GaAs multijunction cell 10 series x 5 parallel x 3 panels (Deployanble panels and one body panel) 10 series x 1 parallel + 10 series x 2 parallel
battery unit	9 series x 2 parallel NiMH (3.7Ah, 18V)
max. power generation	> 100 W
max. power consumption	> 50 W
Communication	
command uplink	UHF, 1200bps at Sendai station, Japan
HK downlink	S-Band, 0.1W, 38400pbs – max. 500Kbps main: Sendai station, Japan sub: Fukui Univ. of Tech. station, Japan sub: Kiruna station, Sweden
Mission Data downlink	X-band, max. 2.4Mbps main: Fukui Univ. of Tech. station, Japan sub: Sendai station, Japan



Launch configuration

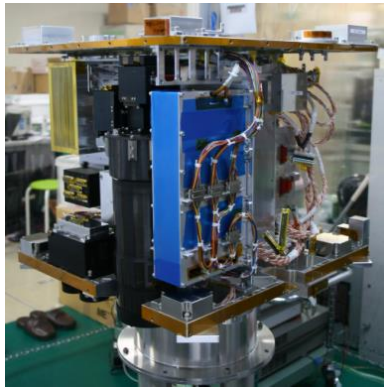


Flight Model

RISESAT Payload Instruments

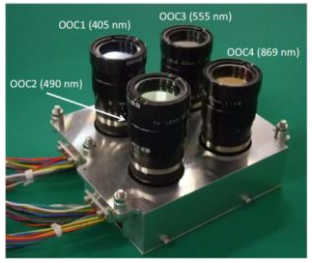
Camera Instruments

High Precision Telescope
- HPT
(Taiwan(NCU))



Meteor counter
- DOTCam
(Taiwan(NCKU))

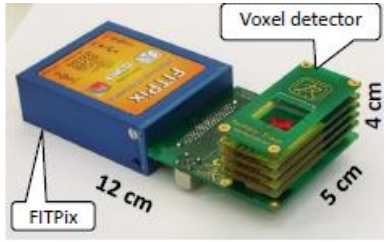
Ocean Observation Camera
- OOC
(Hokkaido University)

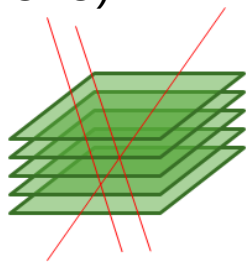


Micro Monitor Camera
- MMC
(Tokyo Univ. of Science)

Sensor Instruments

TIMEPIX – Particle counter
(Czech, IEAP CTU)





Technology Demonstration

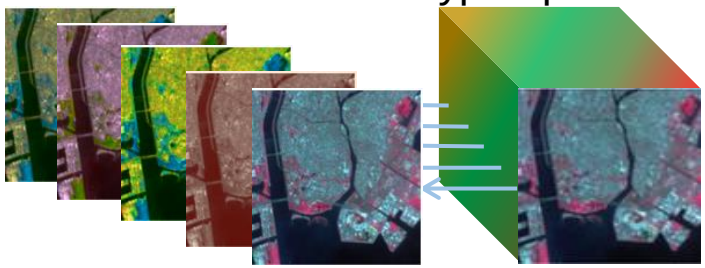
Laser Communication Transmitter
VSOTA (NICT, Japan)

High-resolution Multispectral Observation

Unique Application

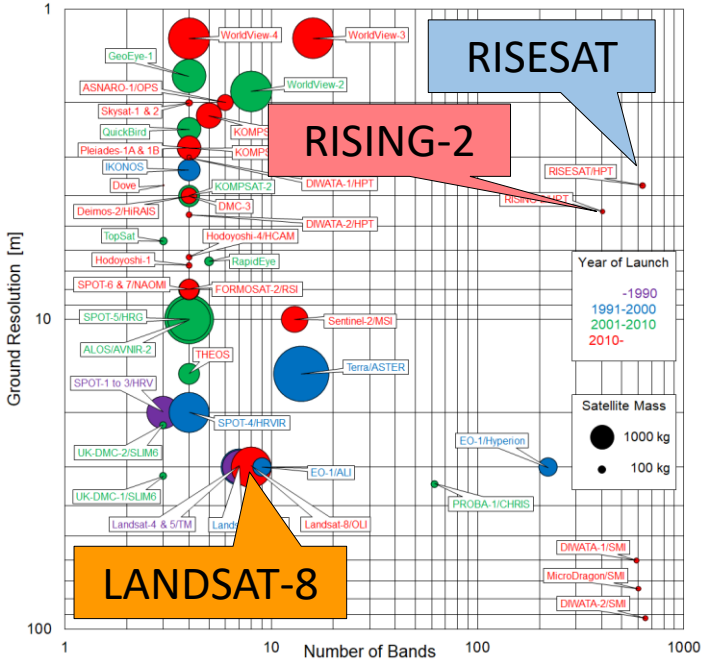
HPT: High-Precision Telescope

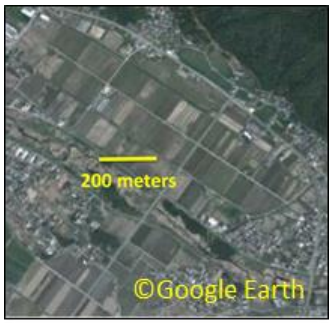
Hyperspectral

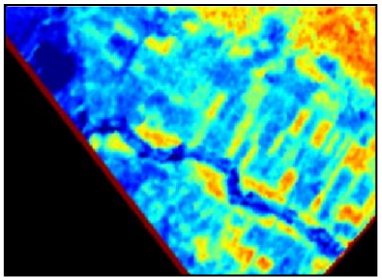


LCTF: Utilize Liquid Cristal Tunable Filters
（420～1050 nm）
Selective Observation depending on observation targets
GSD: 5 m @600km

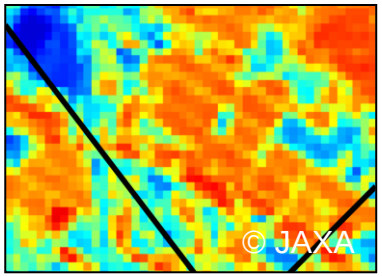
GSD –Number of Bands







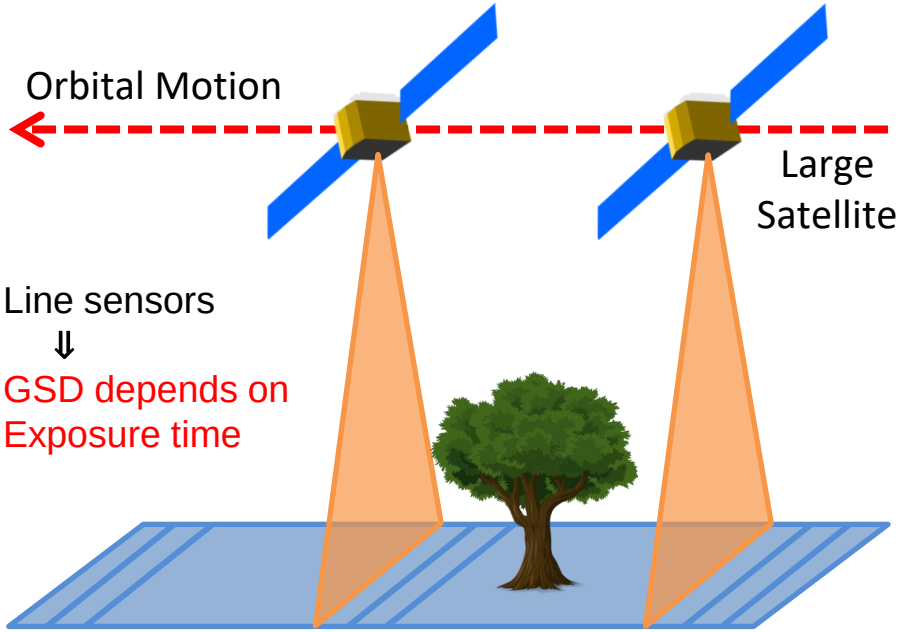
RISING-2 HPT (5 m/pixel)
© Hokkaido University



LANDSAT-8 (30 m/pixel)

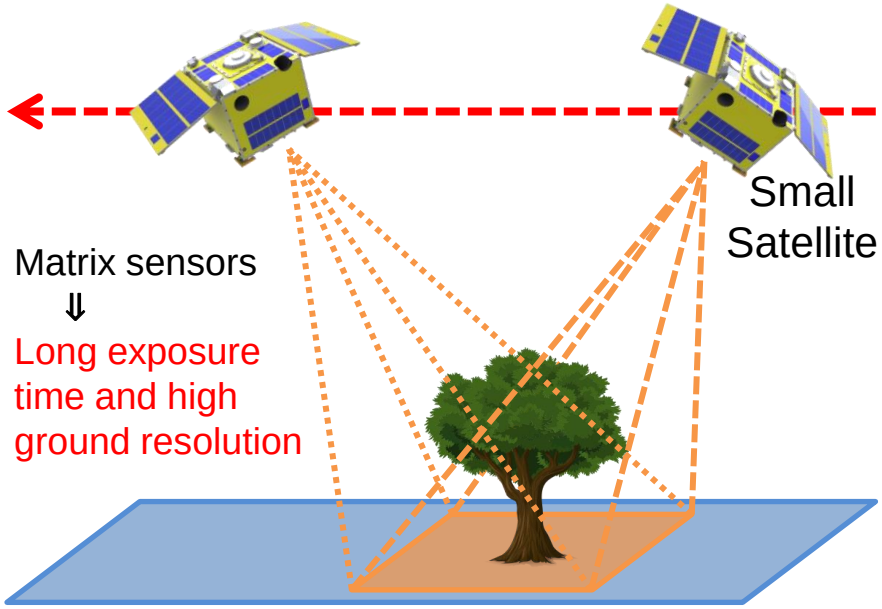
Advanced Attitude Control System

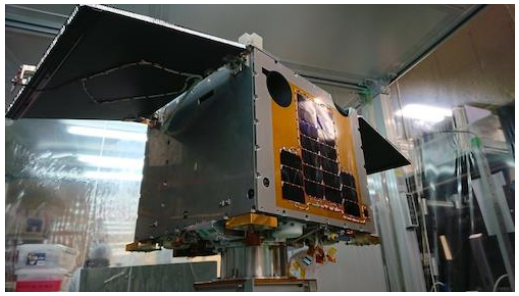
Push Broom : Attitude stabilization



LANDSAT-8 (2,780kg)

Target Pointing : Active agile attitude control

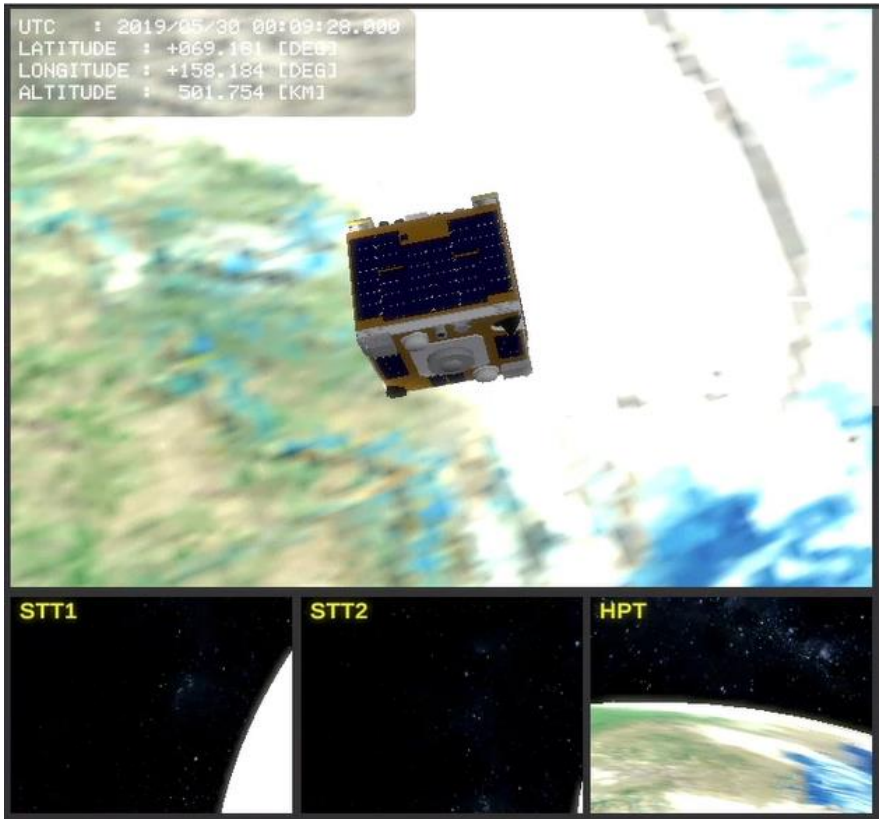




RISESAT (59kg)

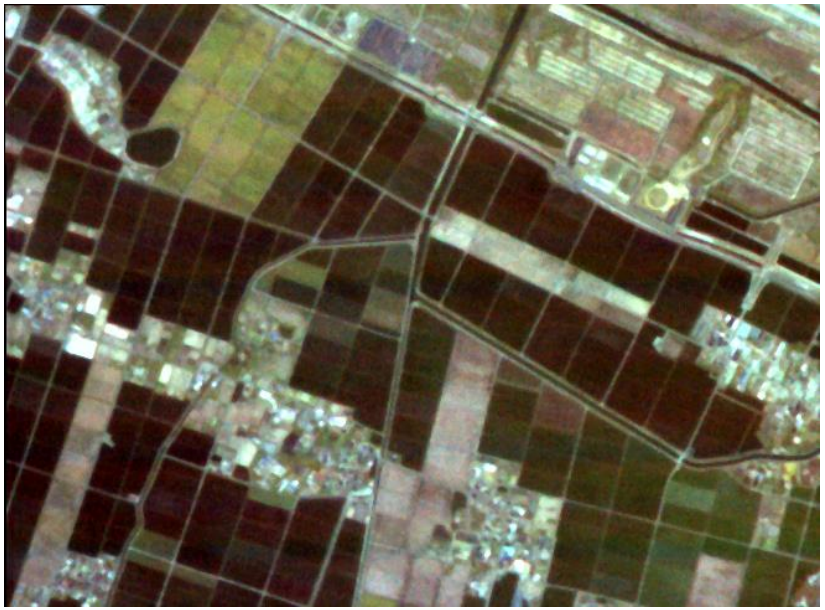
Orbit Demonstration Results

Multispectral Observation



2019/05/30 00:09:28 ~ 00:19:02 UTC

- 実際の姿勢制御ログ(1Hz)からCGを生成
- 約50倍速再生
- 地表の状態は当時とは異なる



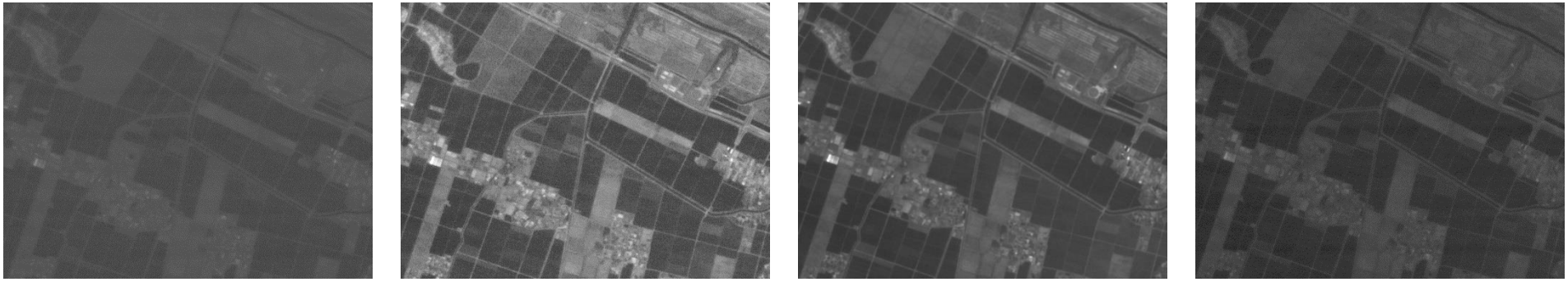
First Light
Sendai (2019/5/30), True Color Composite

- 可視･近赤外8バンド観測
  - 443, 490, 555, 670, 710, 765, 869, 910 nm
- 前半: 粗姿勢決定系を使用したため揺れる
- 中盤: STT利用のため姿勢を慣性空間固定
- 後半: FOG角速度を積分しつつ追従制御

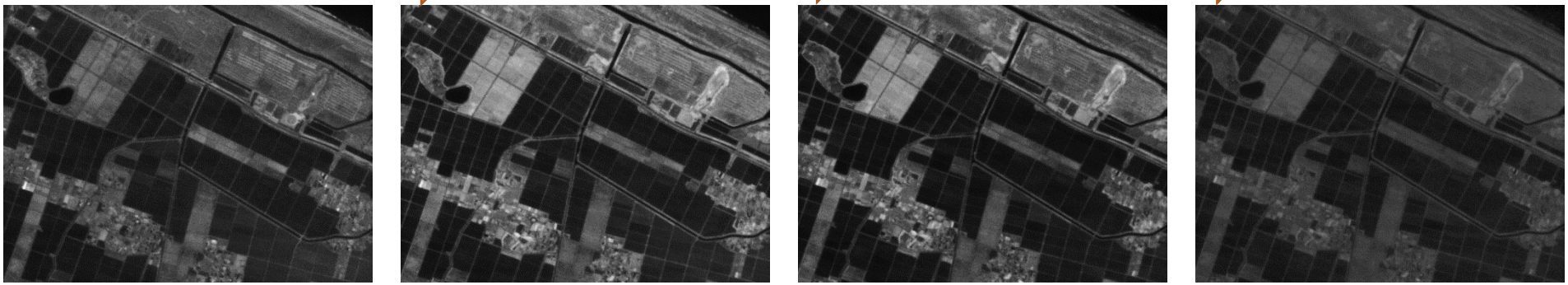
Example of Multispectral Image Acquisition Sequence

4 sequential image acquisition in two separate LCTF channels

VIS 443 nm → 0.5 s → 490 nm → 0.5 s → 555 nm → 0.5 s → 670 nm



NIR 710 nm → 0.5 s → 765 nm → 0.5 s → 869 nm → 0.5 s → 910 nm

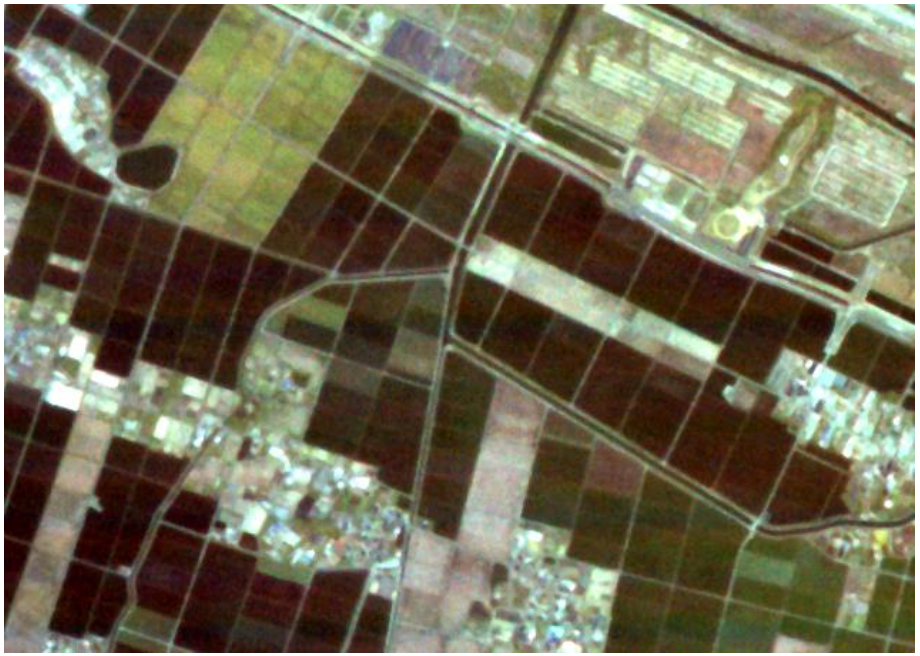


GSD: 3.7m, Exposure Time: 30 msec

“First Light” Scenes of RISESAT HPT

Target: Sendai, Japan

RISESAT HPT (true color)



N

500 m

<u>True color</u>
R: 670 nm (Red)
G: 555 nm (Green)
B: 490 nm (Blue)

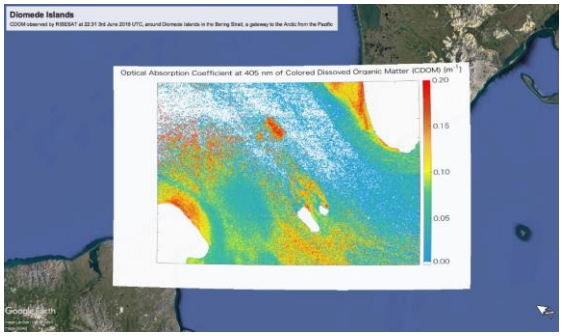
RISESAT HPT (false color)

<u>False color</u>
R: 869 nm (NIR)
G: 670 nm (Red)
B: 555 nm (Green)

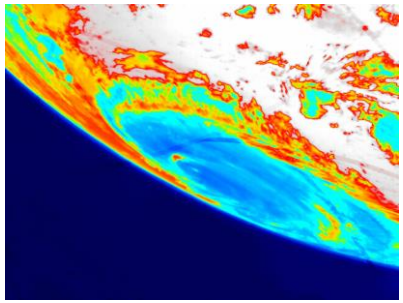
Our Scope of Scientific Missions

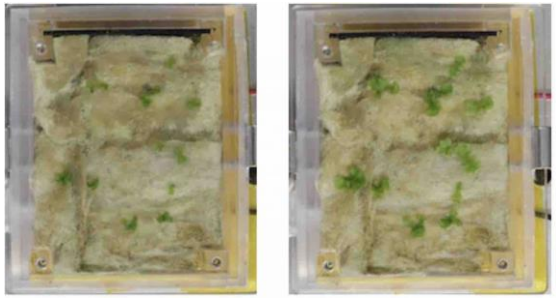
Scientific Missions

- Multi-spectral Earth Observations
  - Agriculture
  - Forestry
  - Fishery
- Four-band Global Ocean Observation
- Space Radiation In-situ Measurement with RIMEPIX Detectors
- Lightning Event Observation
- Meteorological Phenomenon Observation
- Earth Upper Atmosphere Aeronomy
- Atmospheric Scintillation Observation (Optical Com.)
- Debris Observation
- Space Bioscience Experiment



Bering Strait


Typhoon / Cumulonimbus Cloud

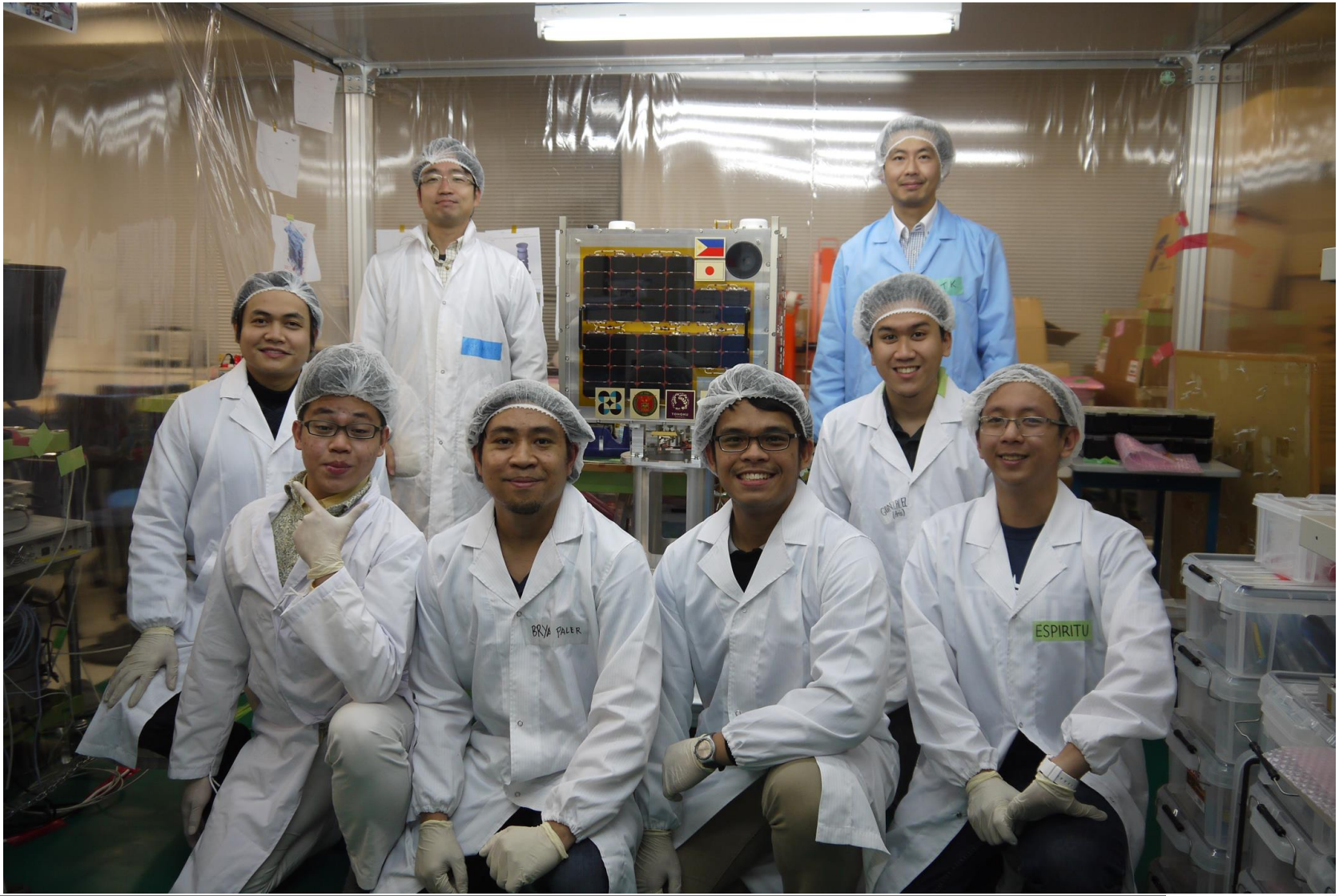

© Tohoku University

R&D Activities

Space Education and Regional Collaboration

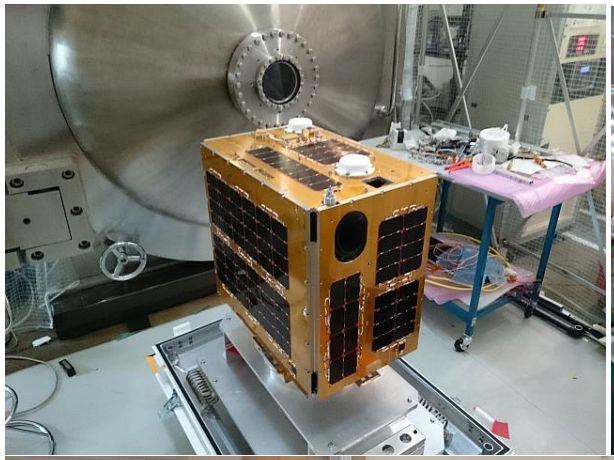
Space Education through Collaborative Researches

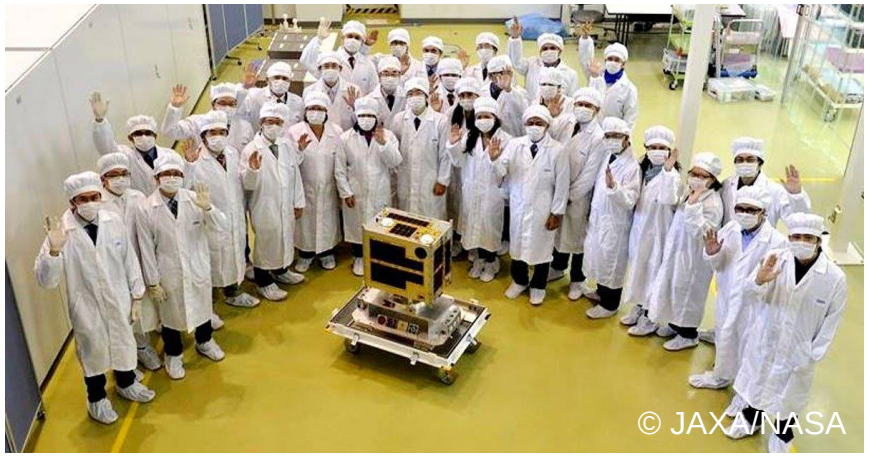
Philippines' Example – DIWATA Projects

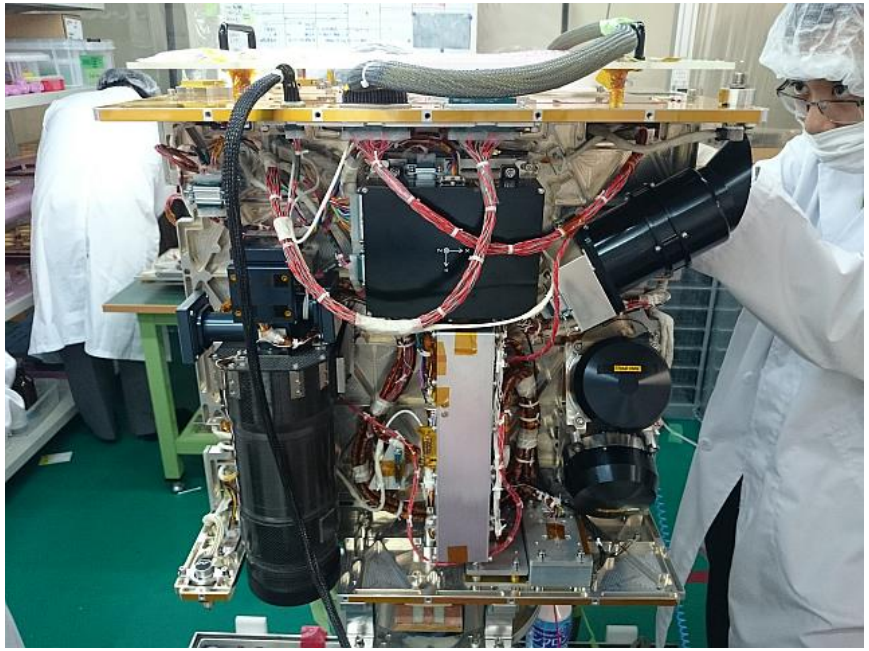


Micro-satellite DIWATA-1 Project

World-first 50-kg-class Micro-satellite deployed from the ISS



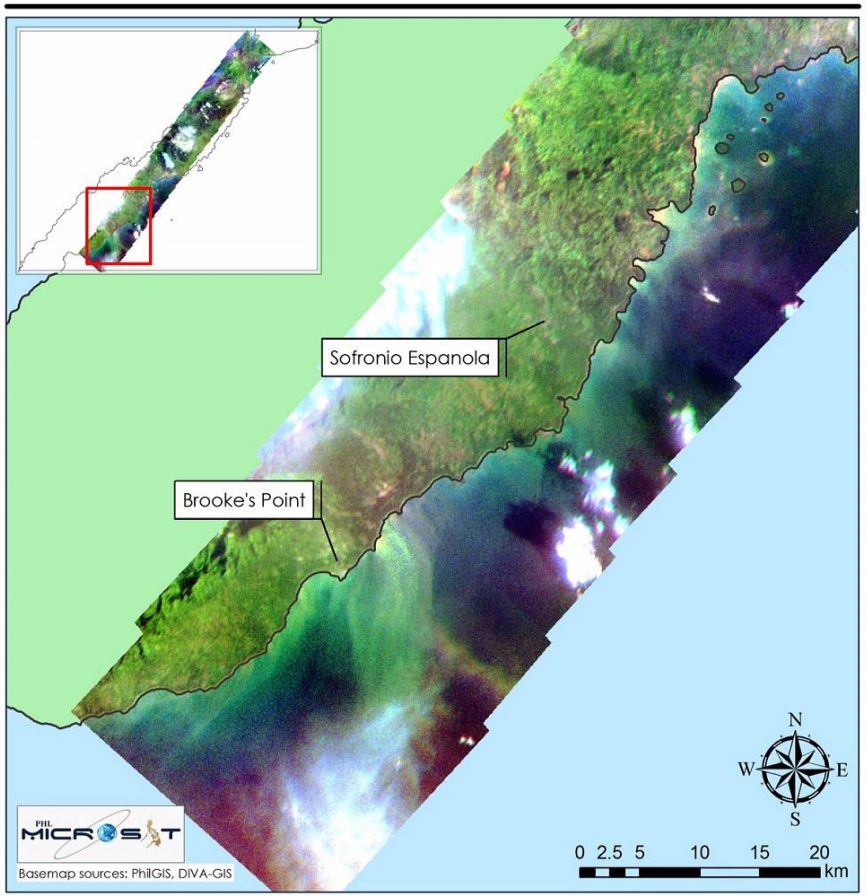


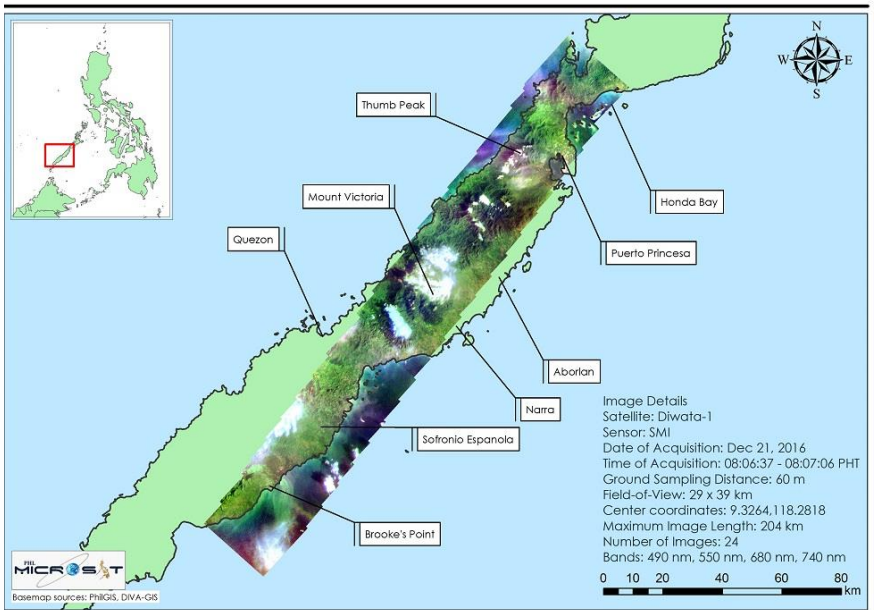


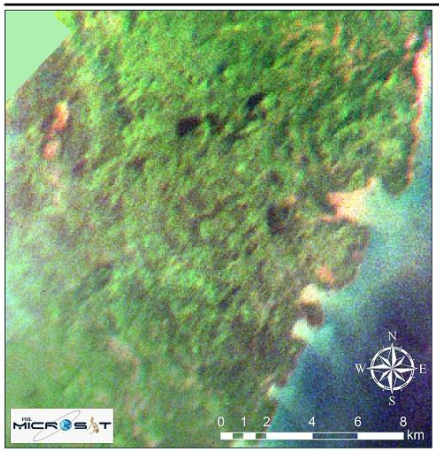
Micro-satellite DIWATA-1 Project

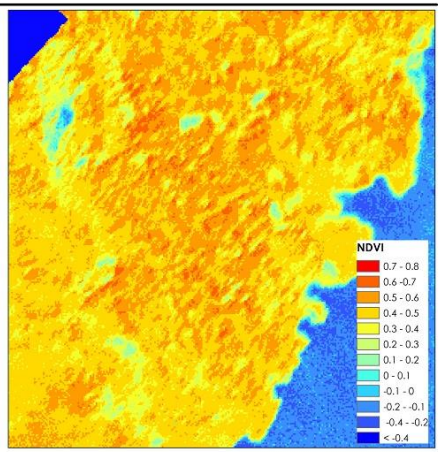
Deployment from the ISS

DIWATA-1 Multi-spectral Images









Space-borne Multi-spectral Imager (SMI)
Palawan, Philippines - Dec. 21, 2016

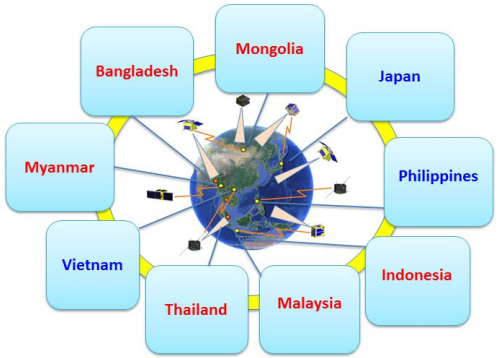
http://newsbytes.ph/2017/03/06/photos-diwata-1-micro-satellite-captures-images-of-silted-palawan-areas/

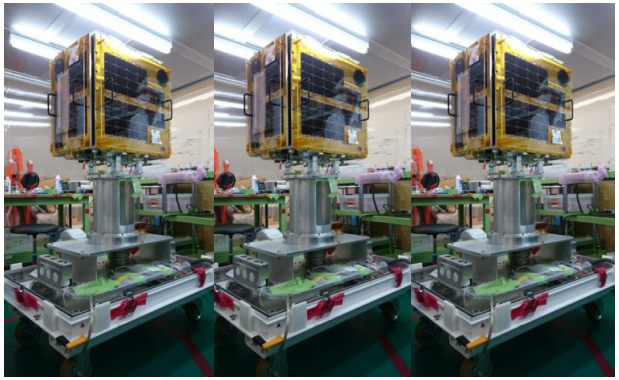
International Collaboration

Asian Micro-satellite Consortium

- International collaboration for establishing micro-satellite constellation for multi-spectral observation with collaborative operation and data sharing .
- More than ten Asian countries are being involved.

Asian Micro-satellite Consortium



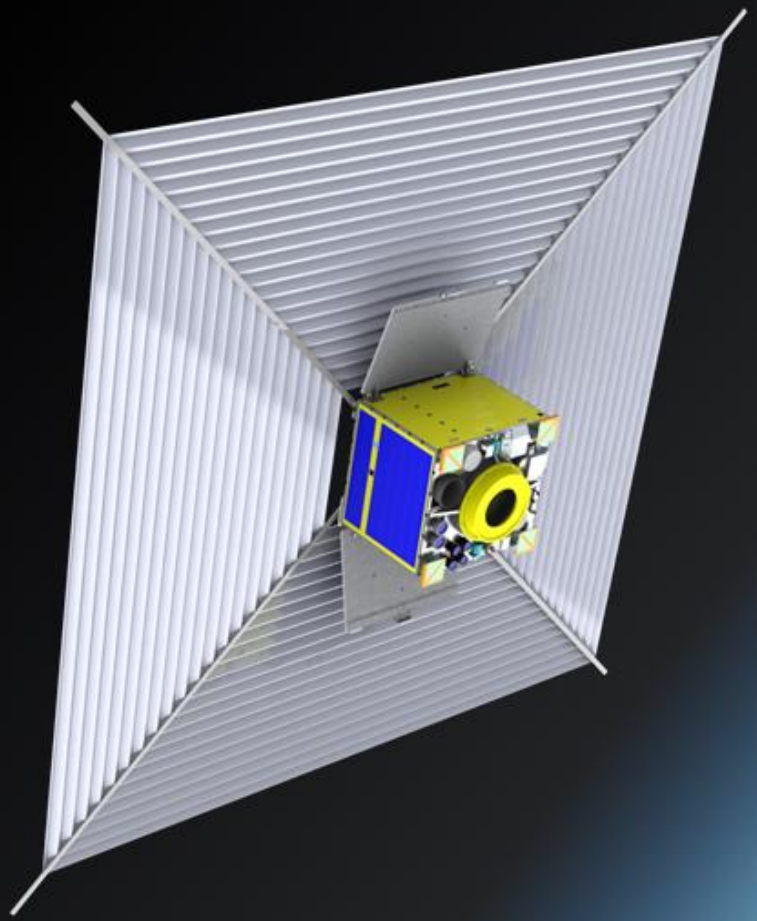


R&D Activities

Collaboration with Industrial Partners

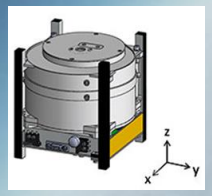
Space Debris: Post Mission Disposal

De-orbit Sail – Nakashimada Engineering Works, Ltd.

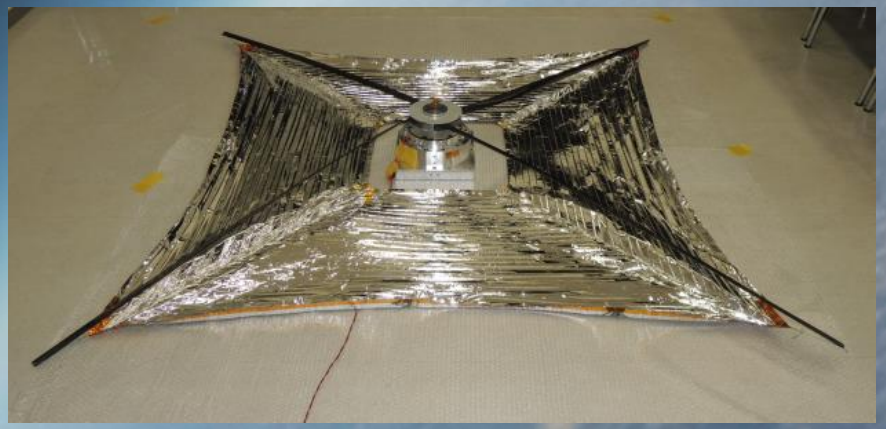


RISESAT (Jan. 2019)

De-orbit Mechanism (DOM®)
for sustainable space utilization



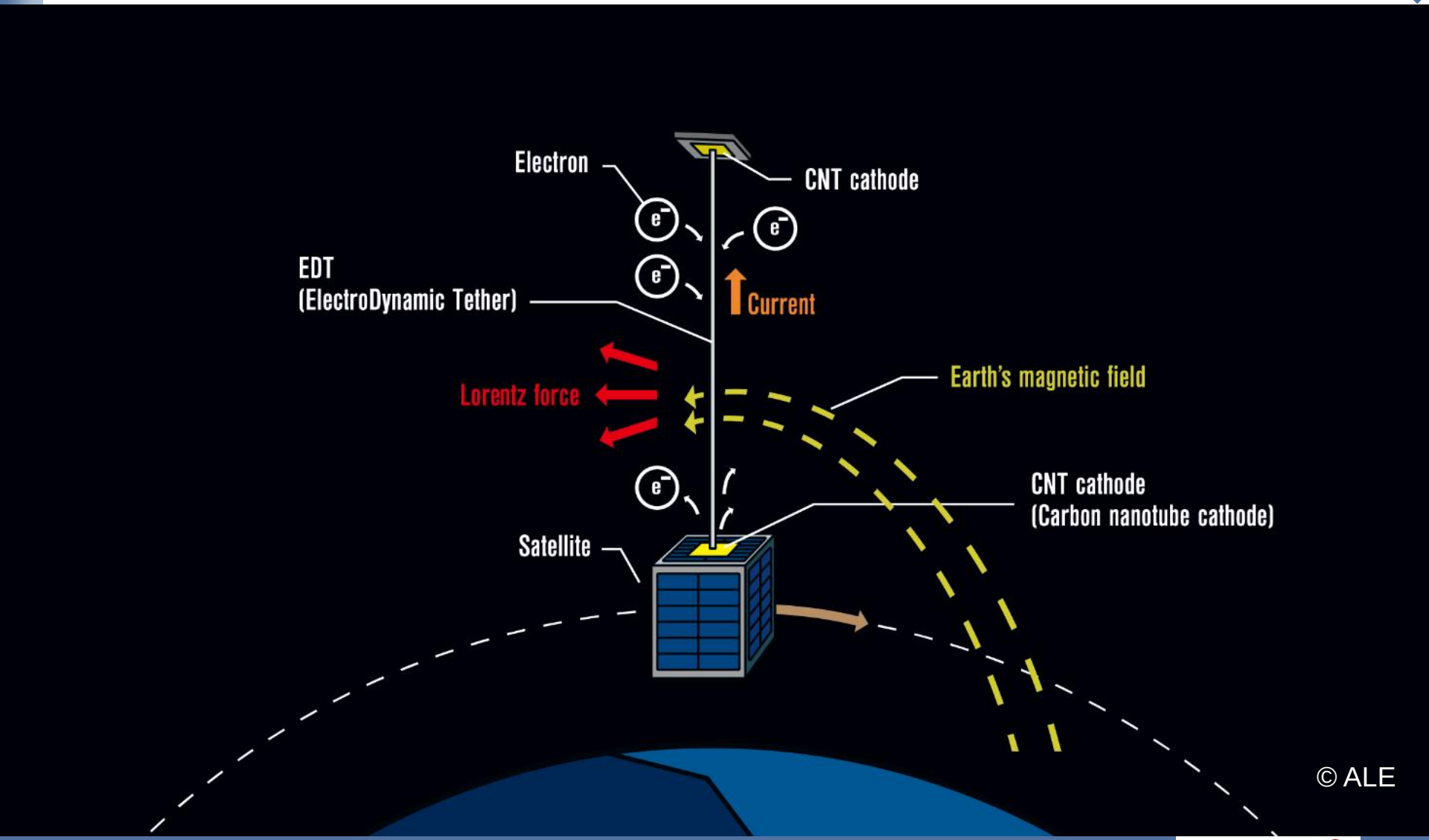
FREEDOM (Jan. 2017)



http://www.nakashimada.co.jp/aerospace_dom2.html

Space Debris: Post Mission Disposal

Electrodynamic Tether – ALE Co., Ltd. / JAXA

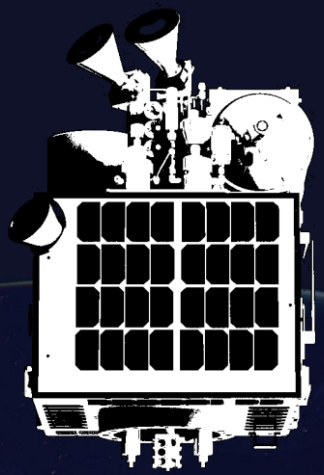


Space Entertainment

Artificial Shooting Star

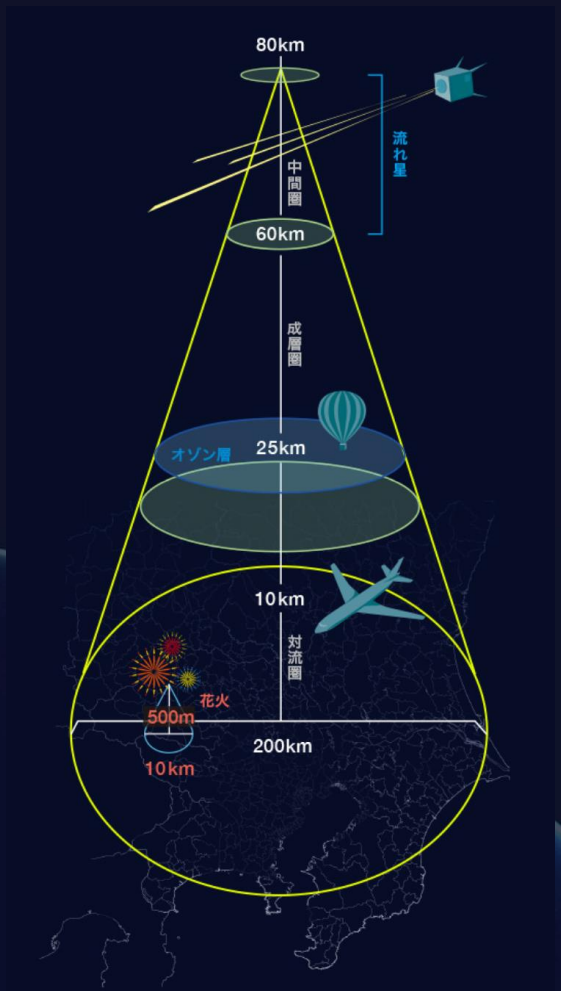
ALE Project

- Artificial Meteor



ALE

https://star-ale.com/

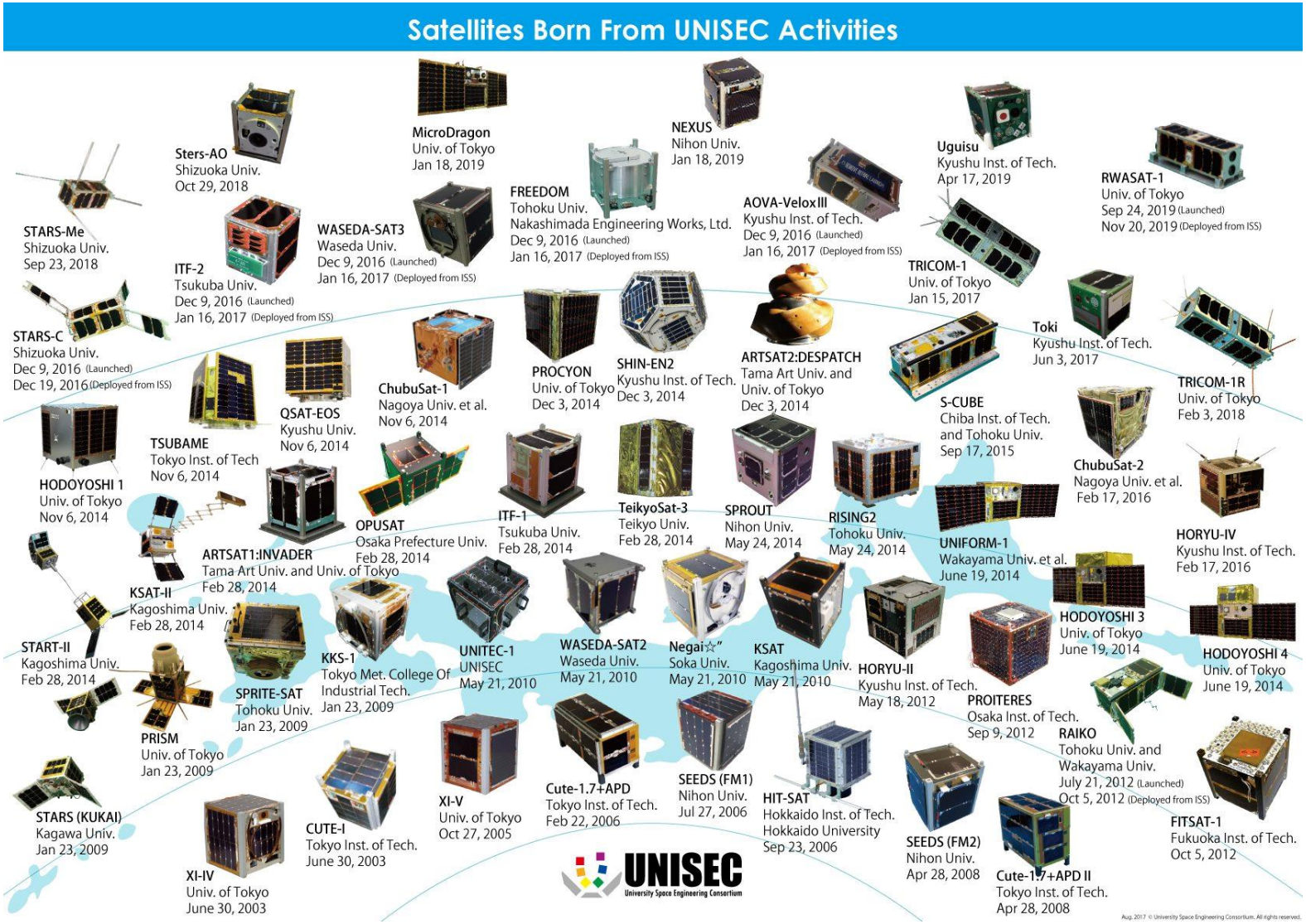


R&D Activities

UNISEC Japan and Global

UNISEC Japan Starts Playing a Role in Mission Assurance

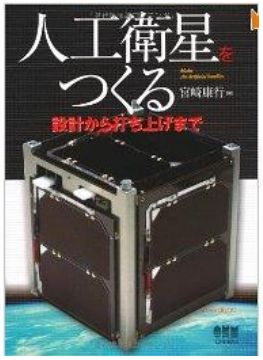
- UNISEC Academy -



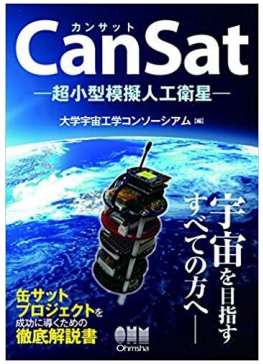
Accumulate Best Practices and Encourage Competitions

「上がれ！空き缶衛星」
川島レイ（2004年 新潮社）

「マイクロサット開発入門」
東北大学超小型衛星開発チーム（著）
吉田 和哉（監修）
（2011年、東北大学出版会）



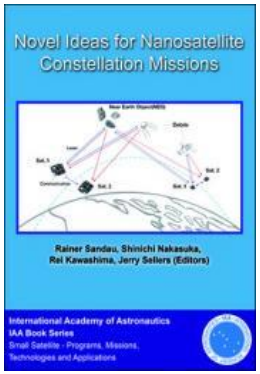
「人工衛星をつくる
ー設計から打ち上げまでー」
宮崎 康行（2011年、オーム社）
（日本大学理工学部 航空宇宙工学科 教授）



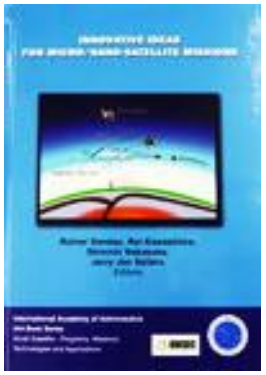
「CanSat−超小型模擬人工衛星」 大学宇宙工学コンソーシアム著
（2014年、オーム社）

「上がれ！空き缶衛星−20年後のメッセージ集録」
川島レイ（2020年 Kindle版）

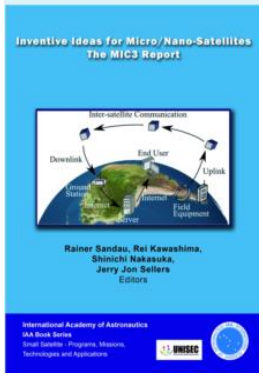
「キューブサット物語
川島レイ（2005年 エクスナレッジ）



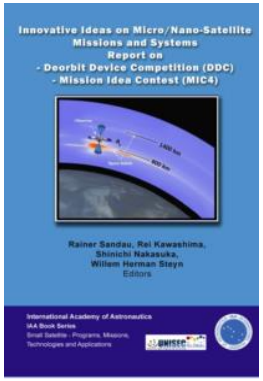
「Novel Ideas for Nanosatellite Constellation Missions」
（2012年、IAA出版）



『Innovative Ideas for Micro/Nano-Satellite Missions』（2013年、IAA Book Series）



INVENTIVE IDEAS FOR MICRO/NANO-SATELLITE THE MIC3 REPORT
(2015年 IAA出版）



INNOVATIVE IDEAS ON MICRO NANO-SATELLITE
（(2017年、IAA出版）

Future Plan

Personal Objectives

- Broaden the scope of research including the Moon, planet, and deep space exploration.
- Improve the technology level of domestic CubeSats and Micro-satellites to and improve the success rate of academic space missions, as well as to enhance NewSpace businesses.
- Provide international space educations and share practical experiences to turn out top space engineers for the world'd future space development, utilization, and exploration.

UNISEC Japan Vision

1. Setting new frontier development goals and promoting the practical development, utilization, and exploration of space
2. Enhancing cooperation in space engineering technologies
3. Assuring the level of space technology

http://unisec.jp/unisecen/presidenten.html

Thank you very much.