University of Tokyo's History on Micro/nano/pico-satellites (2010 – 2019)

- Practical Applications -

Nano-JASMINE

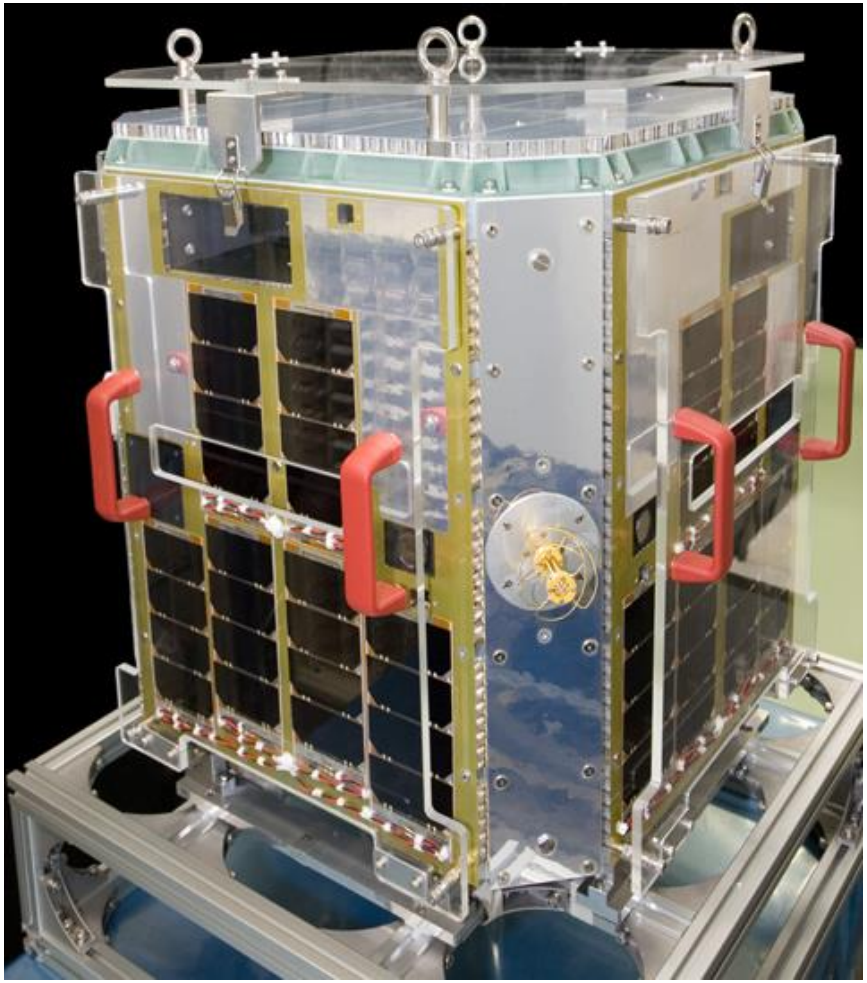
Intelligent Space Systems Laboratory
University of Tokyo
ISSL

Mission: Astrometry (Getting precise 3D map of stars and their movements)
Developer: University of Tokyo, National Astronomical Observatory of Japan, Shinshu University, Kyoto University
Launch: TBD

Size	50 [cm-cubic]
Weight	37 [kg]
Attitude control	3-axis stabilization with Star, Sun, Magnet sensor, FOG, RW, Magnetic torquers
OBC	FPGA
Communication	S-band 100 [kbps]
Mission life	2 [year]

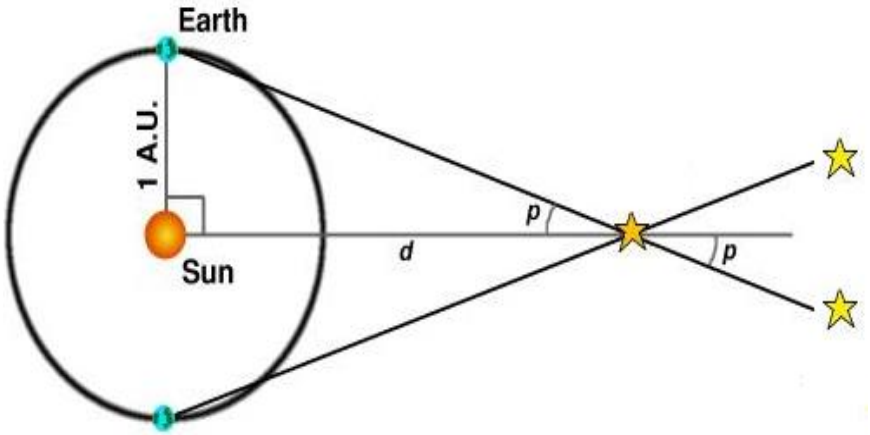
Special features:

-Attitude Stability	0.8 arcsec for 8.8 sec
-Thermal Stability	< 0.1K (at -50 degree)
-Map Accuracy	Compatible with “Hipparcos” Satellite (‘89)
-Telescope	two CCDs with TDI



NJ's "Astrometry" Mission

- **Mission**
  - **Estimate 3 Dimensional positions of stars and their movement ("Astrometry")**
  - **Pre-cursor for "JASMINE" series**



Star position determination by

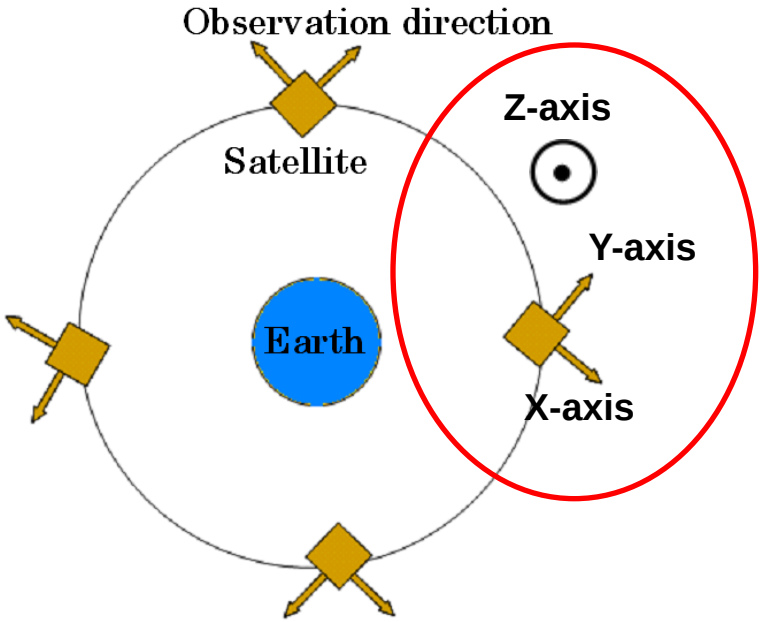
Annual Parallax

- **Attitude stabilization**
  0.8 arcsec / 8.8s
- **Temperature stability**
  – 50℃, ±0.1℃

- Long exposure time required.

- Separation angle between two telescopes should be kept constant.

Star Observation using TDI



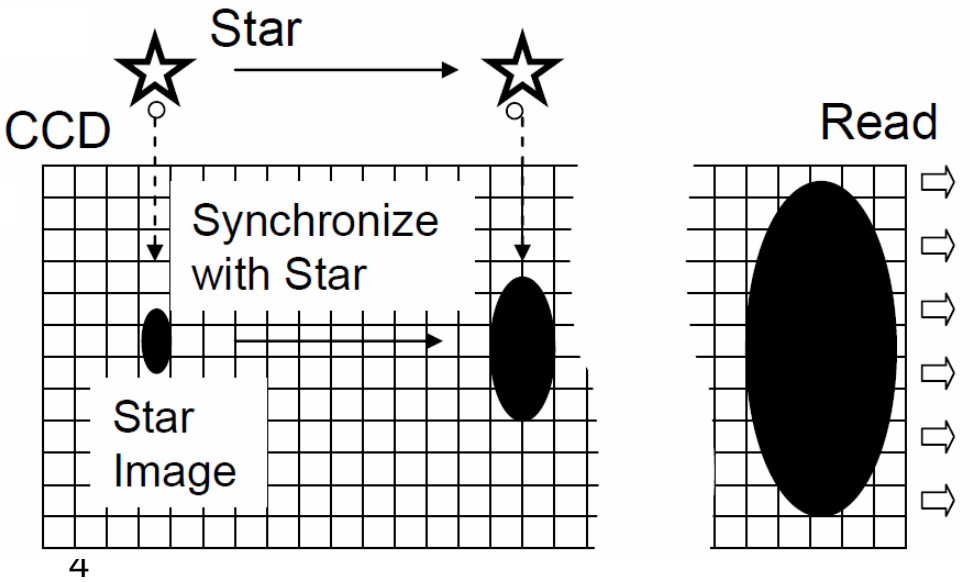
Time Delayed Integration (TDI) using special CCD sensor

Spin rate is synchronized to capacity transfer speed on CCD to get long exposure time

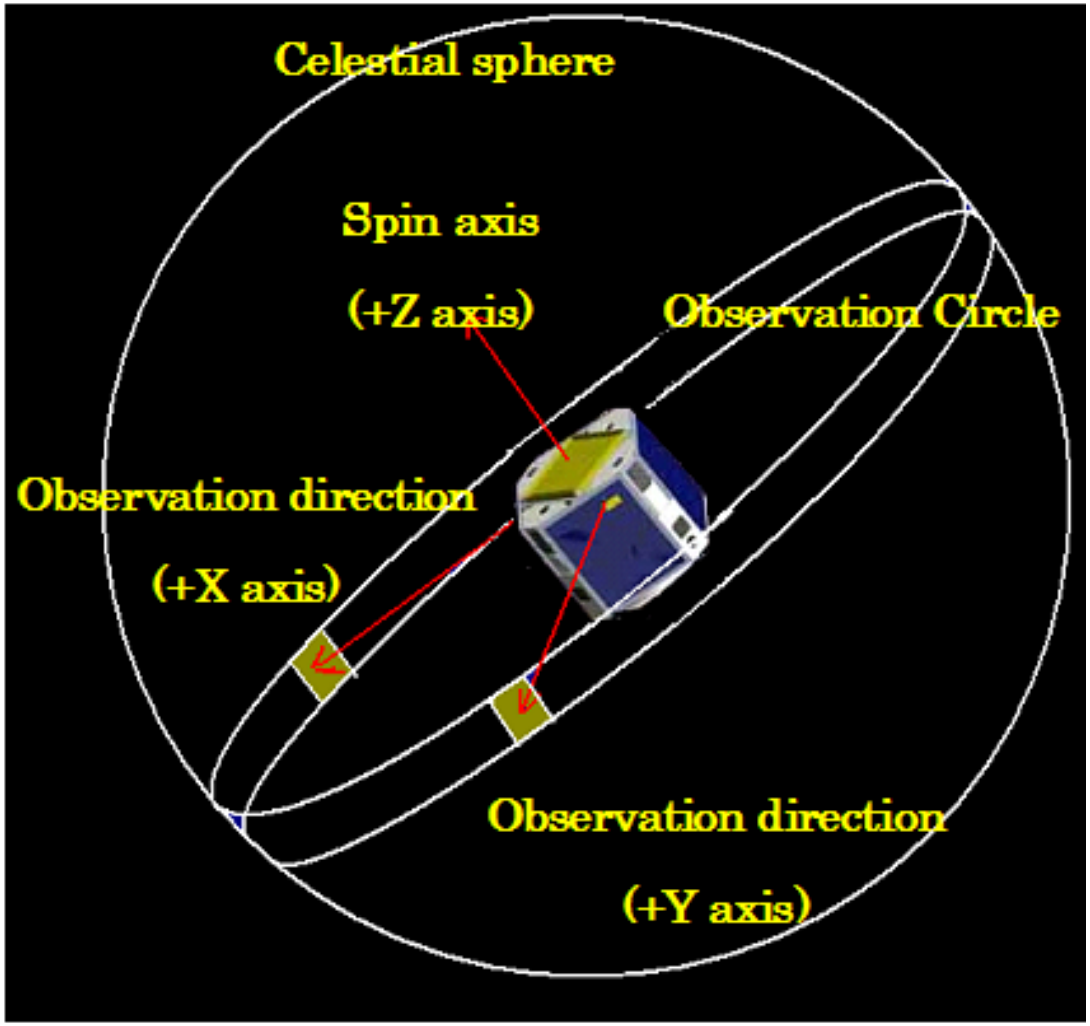
X, Y->Observation direction

Z-> Spin axis in orbital period

4 x 10^{-7} rad/sec level stability is required



Stability Requirements for the AOCS



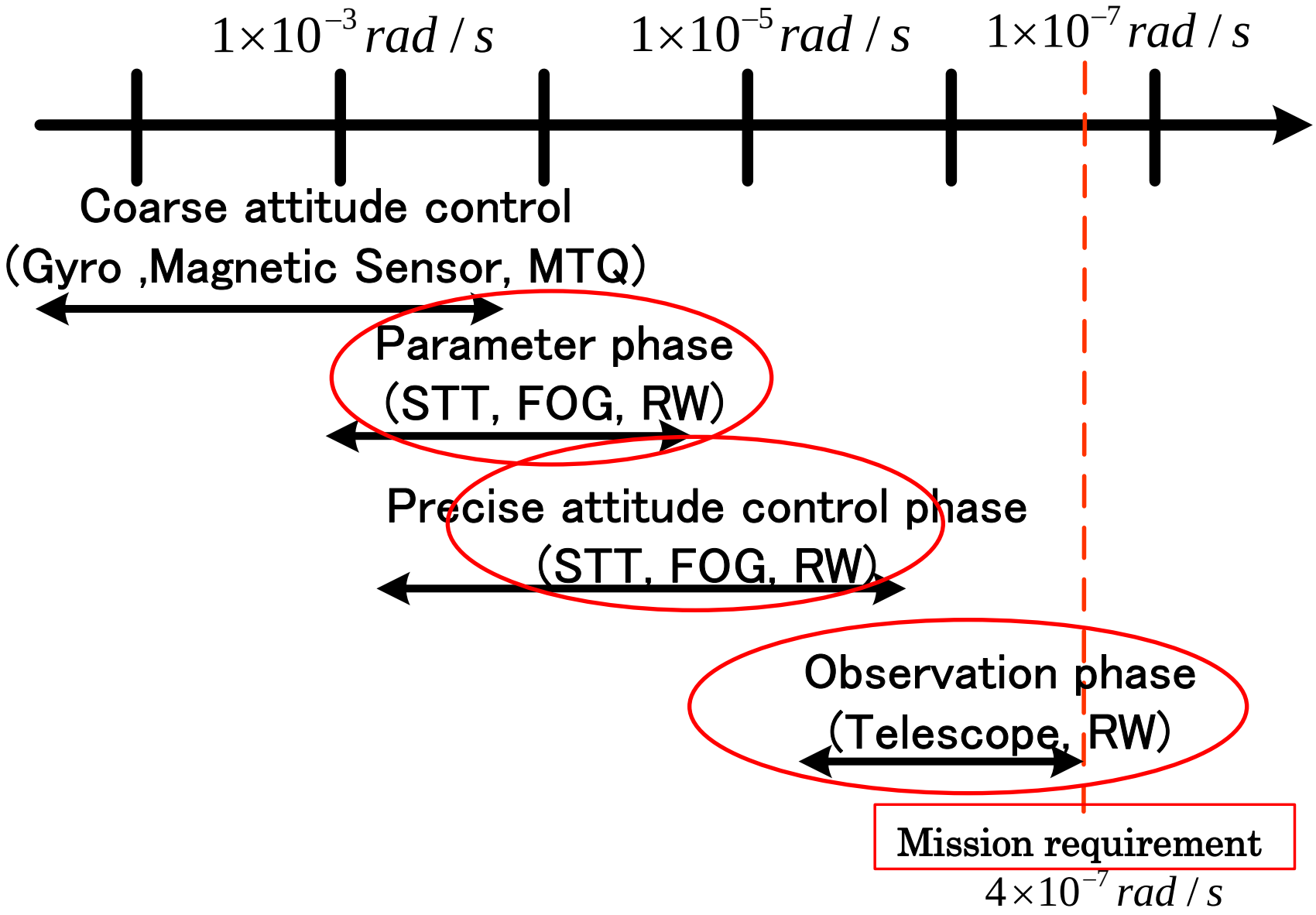
-> Z axis (Spin axis)

$$\omega_z = 1\times10^{-3} \pm 4\times10^{-7}\, rad/s$$

->X, Y axes

$$|\omega_x|, |\omega_y| < 2\times10^{-6}\, rad/s$$

Strategy to Achieve High Attitude Stability



Hodoyoshi PJ (“First Program,” 2010-2014)

Low cost supply chain network

Hodoyoshi-reliability

Satellites, components, infrastructure with high competitiveness

New Paradigm of Space Development and Utilization

Low-cost, Quick, Practical level

Human Resource Training

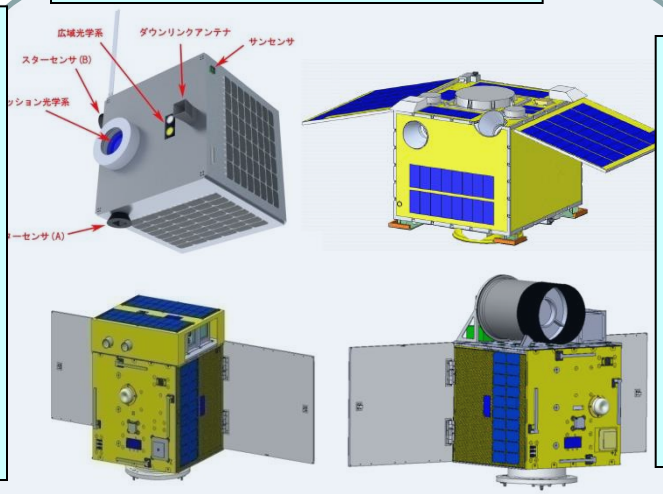
Development Process

Miniature components

Advanced components

Optical system, Image processing

Tech. Demonstration



Four satellite development

Infrastructure

Promotion

Ground Station

Ground Testing

[Standa-rdization]

Personal use
Novel missions
Foreign Customers

Novel Missions Demo.

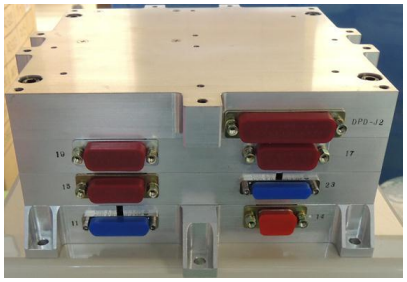
Mission creation

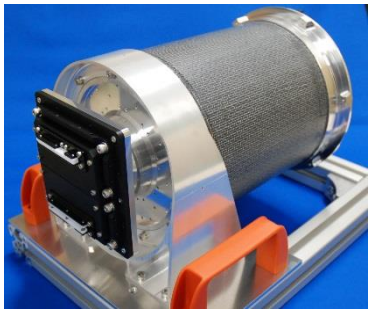
Space science mission

New utilizations
New Players

Components Developed in Hodoyoshi-PJ

- Radiation-hardened SOI-SoC onboard computer
- Software architecture (SDK, HILS, etc.)
- Optical camera with 2.5 - 200m GSD
- Li-Ion battery and power control unit
- Low-shock lock/release & deployable mechanism
- High speed and versatile data handling unit
- High speed, low power RF transmitter （>500Mbps)
- Electric propulsion system (Ion thruster)
- Attitude control system for micro/nano-satellite
  - Fiber optical gyro, Reaction wheel, CMG, etc.
- Debris mitigation device (deployable membrane)
- Optical communication system (with NICT)

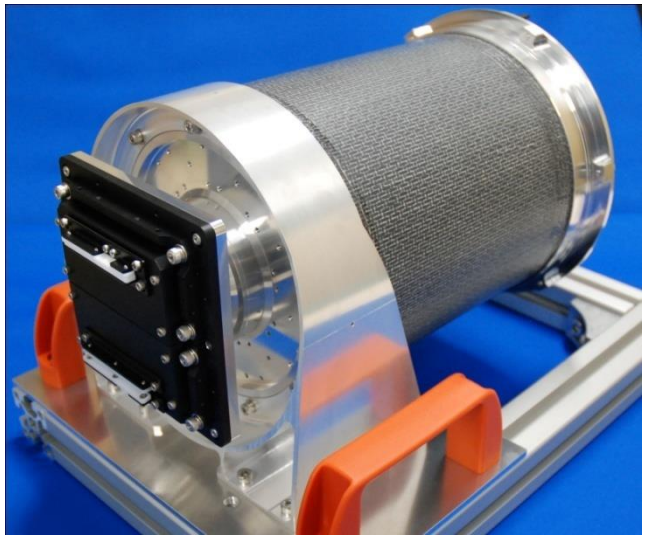




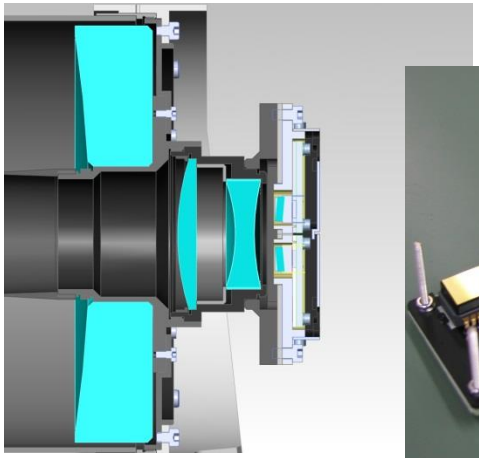
All components for micro-sat can now be purchased in Japan

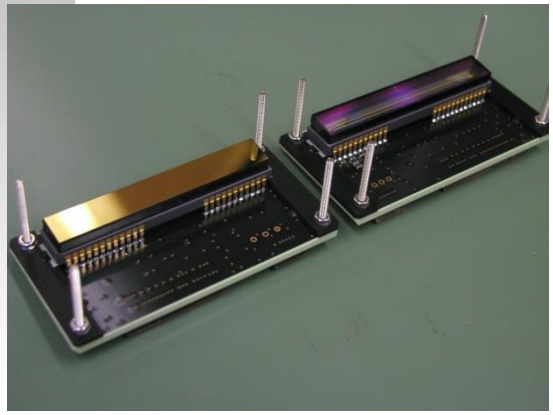
High Resolution Camera for Hodoyoshi-4

- ✓ Aperture: 15cm, weight: 3.5kg GSD: 5m suitable for micro-sat
- ✓ 4 bands: R,G,B, NIR
- ✓ Scalable design extension for 2.5m GSD advanced camera



5m GSD@500km





Scan system	Push-bloom type
GSD	5m/pixel (at 500km)
Swath	20km
Spectral band	<u>4bands</u> B1: 450nm-520nm (Blue) B2: 520nm-600nm (Green) B3: 630nm-690nm (Red) B4: 730nm-900nm (NIR)
Quantization	12bits
Mass	< 9kg

Infrastructure

Launch Opportunity

H-IIA
Epsiron
DNEPR
ROCKOT
PSLV
Space-X

Ground Station

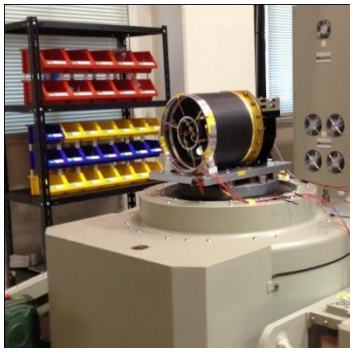
- C/X , UHF/S –band antenna, comm system
- Kyushu Univ.（2.4m）、Taiki-cho (3.8m)
- Ground station network, remote control

Test facility is concentrated at Kyushu-tech University

Prof. Cho of Kyushu Inst.of Tech

One Stop Test Facility and Test Innovation

Test Standard（ISO）

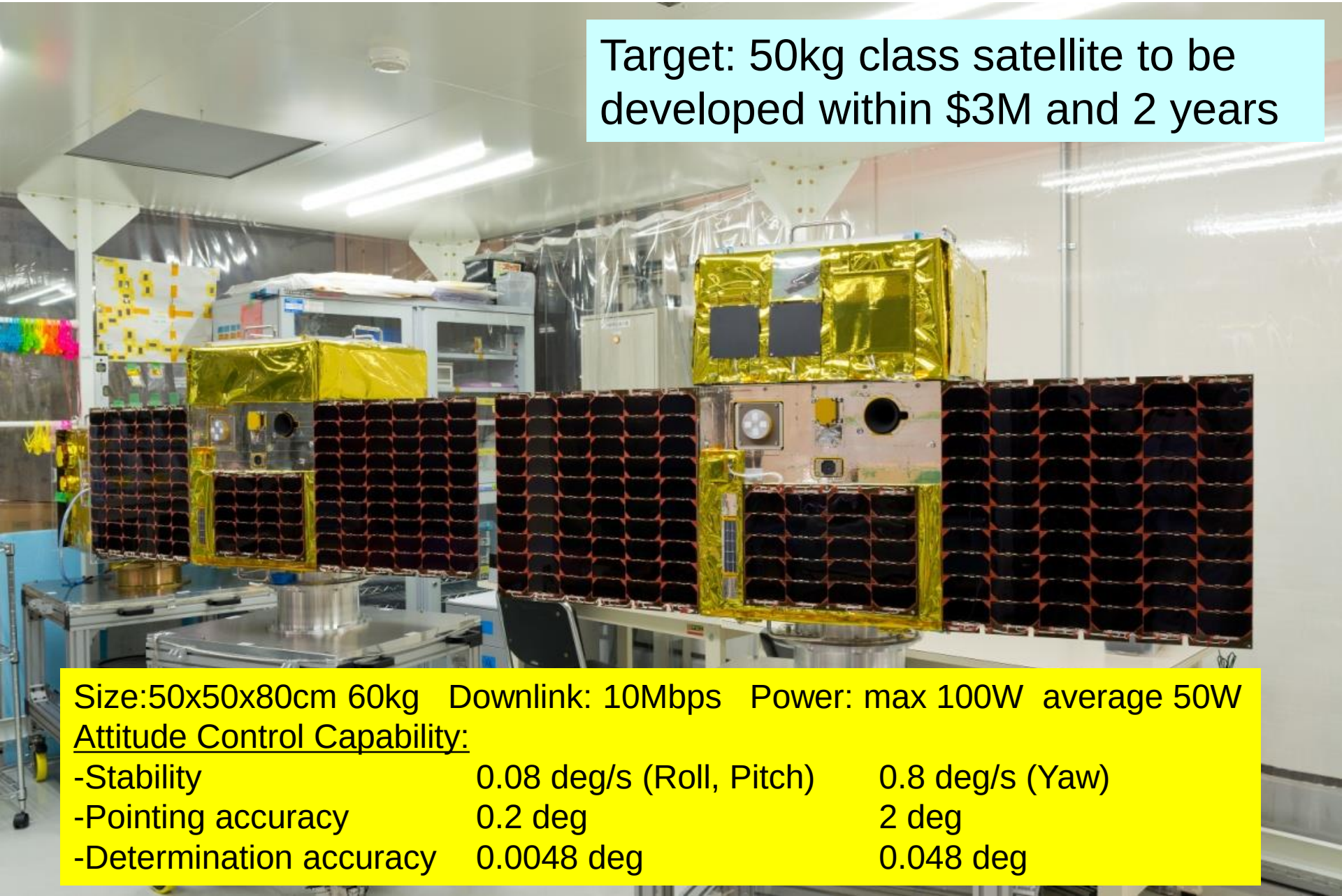


Leak test

SEU/SEL Radiation Test

Standard Workshop

Hodoyoshi-3 (left) and Hodoyoshi-4 before Shipment (April, 2014)



Target: 50kg class satellite to be developed within $3M and 2 years

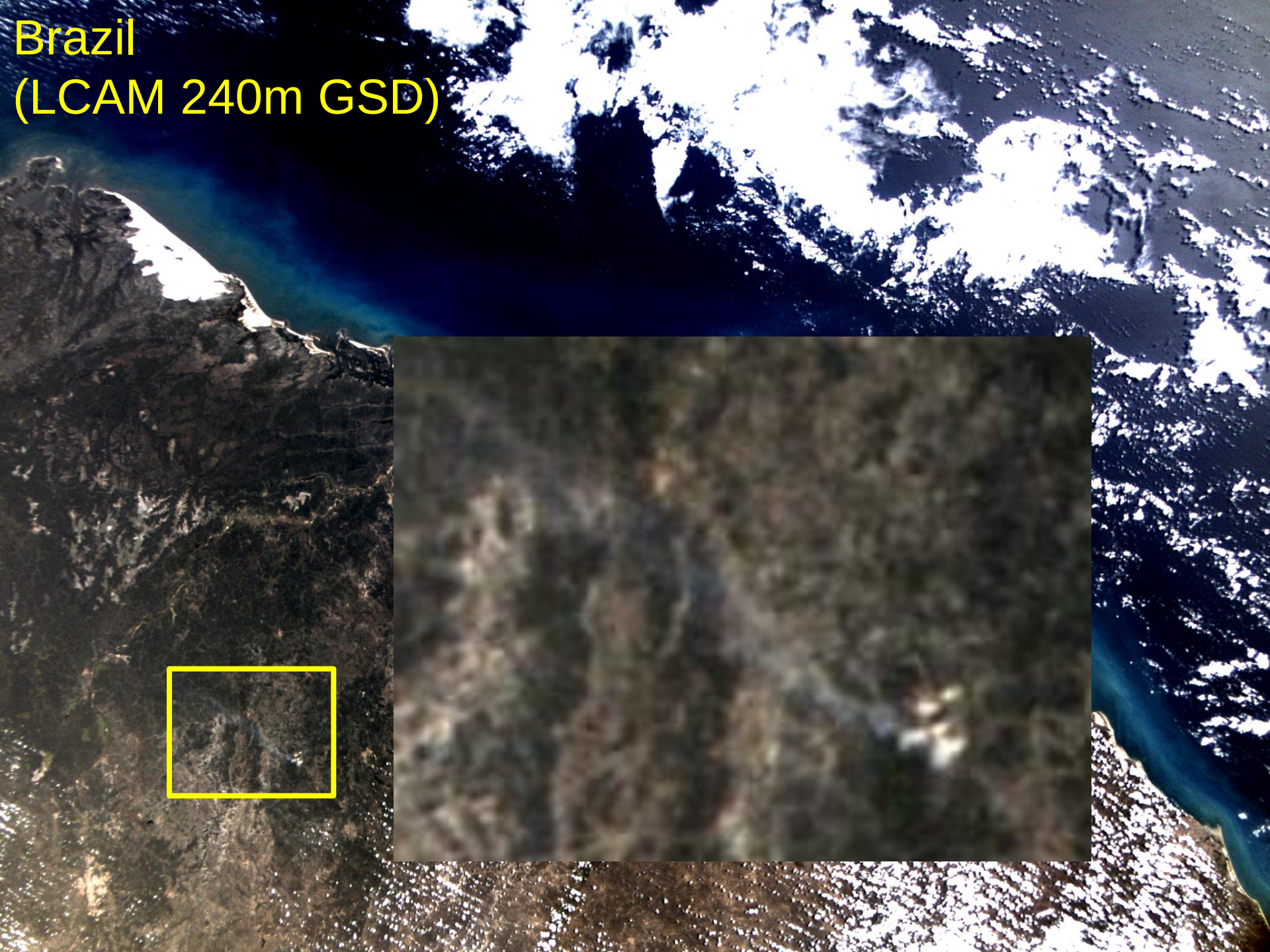
Size:50x50x80cm 60kg Downlink: 10Mbps Power: max 100W average 50W

Attitude Control Capability:

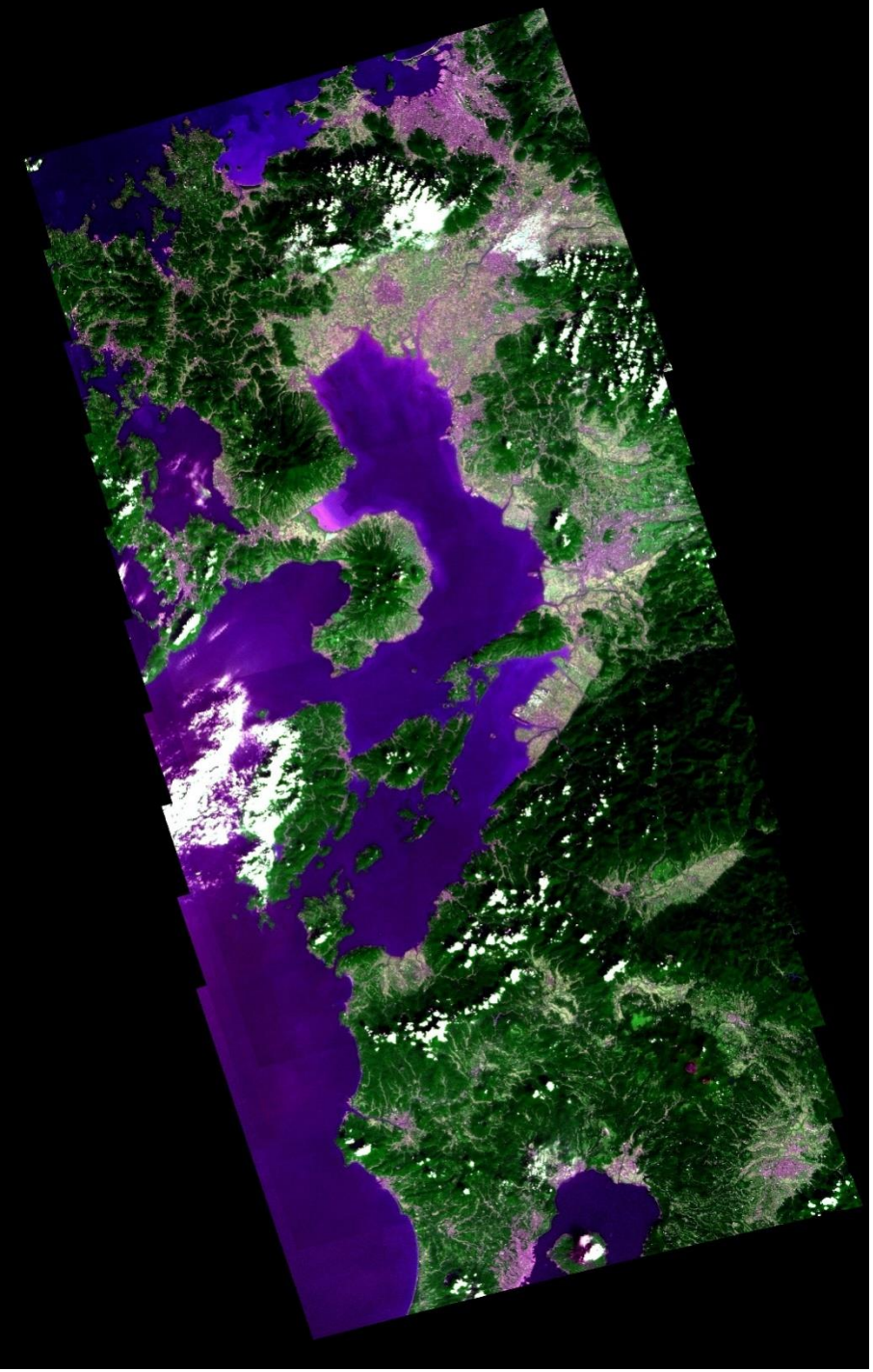
-Stability	0.08 deg/s (Roll, Pitch)	0.8 deg/s (Yaw)
-Pointing accuracy	0.2 deg	2 deg
-Determination accuracy	0.0048 deg	0.048 deg

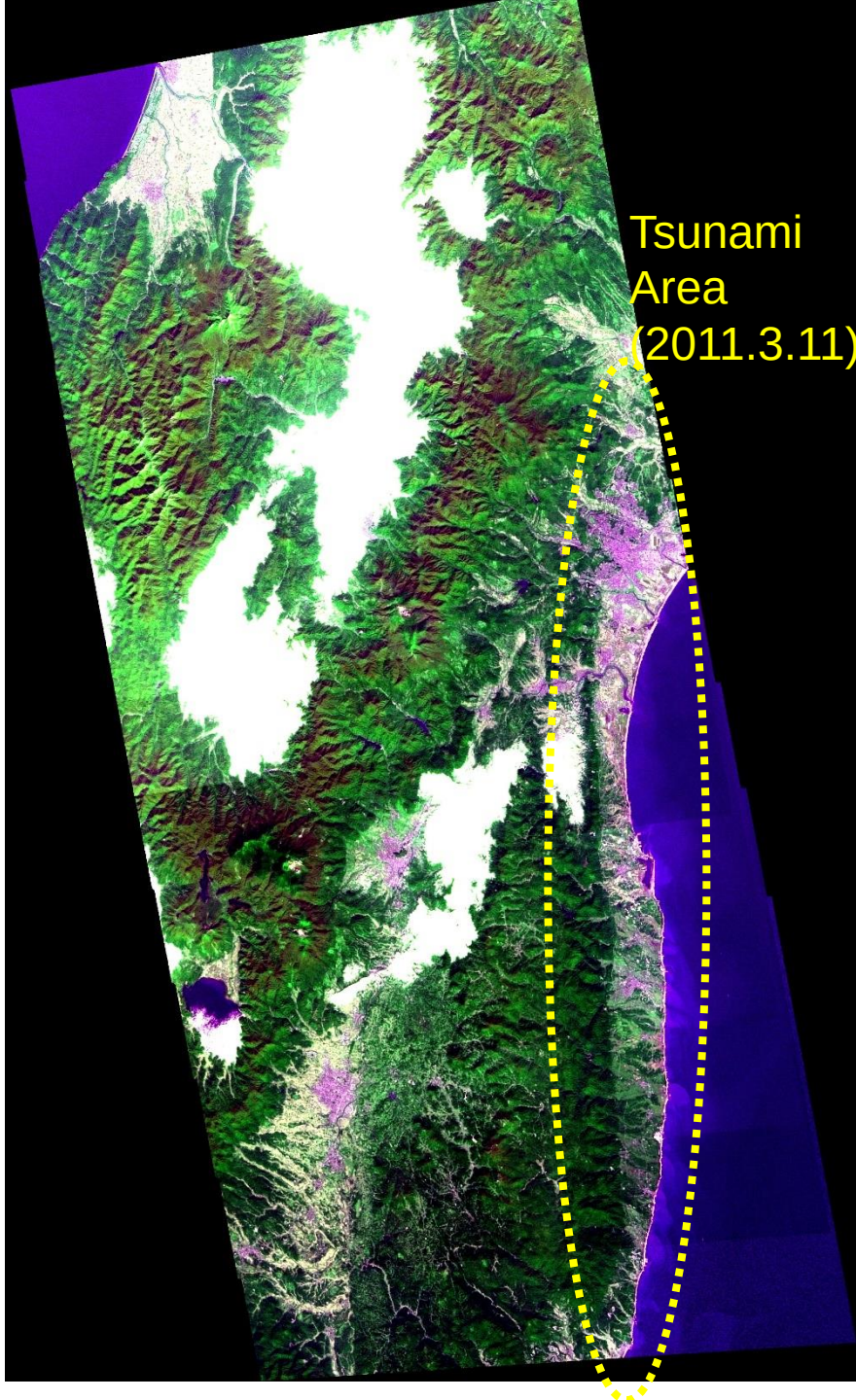
Implementation to Dnepr at Yasny 2014/6/10

Wide Angle Camera


Brazil
(LCAM 240m GSD)


Sri Lanka
(LCAM 240m GSD)




Tsunami
Area
(2011.3.11)

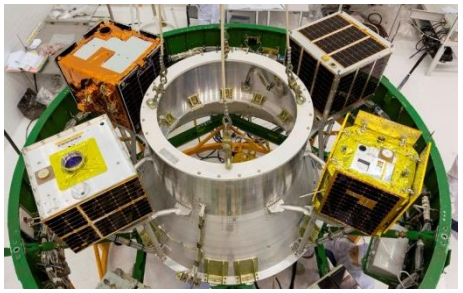

Chiba
（6m GSD)


Oyster Growing Floating Tables
Hiroshima
（6m GSD）

HODOYOSHI-1

Mission: Earth Remote Sensing (6.7m GSD, 4 bands: RGB & NIR)
Developer: AXELSPACE, University of Tokyo, NESTRA
Launch: DNEPR launch on November 6, 2014

Size	about 50 [cm-cubic]
Weight	60 [kg]
OBC	FPGA
Communication	UHF, X (10-20 Mbps)
Average power	50 W
Attitude control	3-axis stabilization with STT, SAS, Magnetometer, Gyros, RW, Magnetic torquers
- stability	0.1 deg/sec
- pointing accuracy	5 arcmin
- determination	10 arcsec
Optical sensor:	15kg, 6.7m GSD (500km alt.)
- Focal length	740mm (F# 7)
- Swath	27.8 x max 179km (500km alt.)
- Bands(SNR)	B(57), G(74), R(80), NIR



Optical Camera (6.7m@500km)
developed by Genesia Corporation

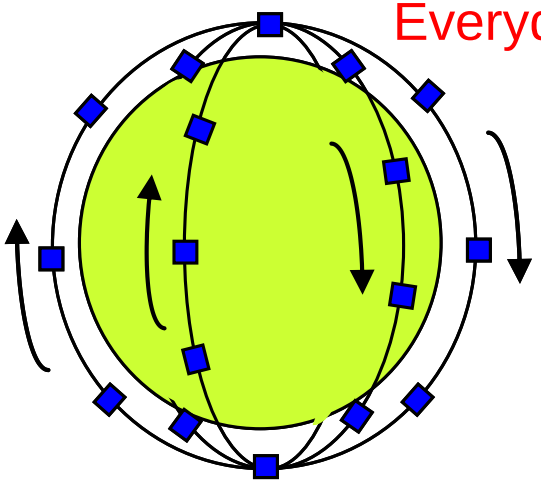

Dubai (6.7mGSD)
©AXELSPACE


New Zealand
©AXELSPACE

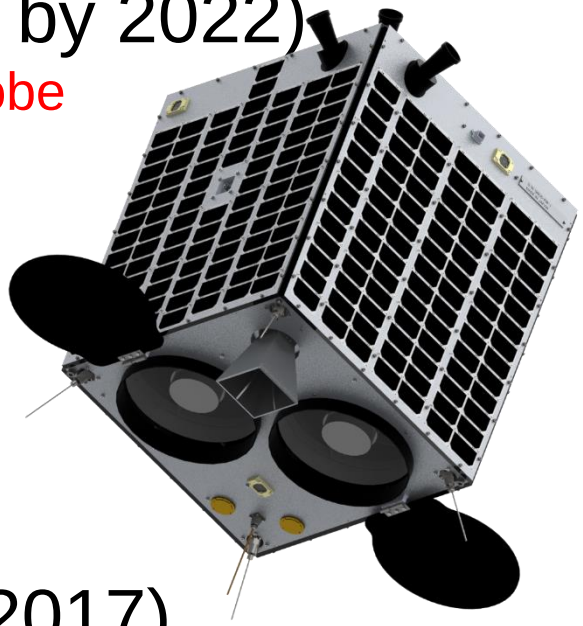
Future Plan of AXELSPACE

- GRUS（launch in 2018, 30 satellites by 2022）

Everyday coverage of the whole globe



2.5m resolution images

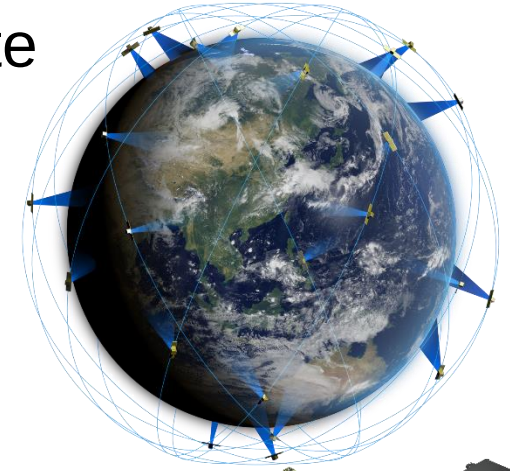


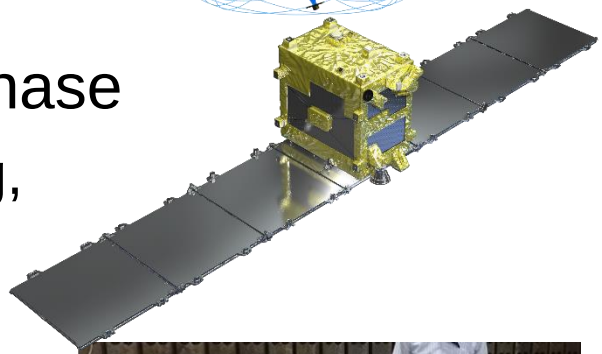
- WNISAT-1R (launched in summer 2017)

- Glacier Observation of arctic ocean
- GNSS-R reflection experiment
- Laser communication experiment

Small SAR Satellite Constellation

- Small SAR(Synthetic Aperture Radar) satellite constellation for frequent and persistent information gathering from Earth
- Six satellite constellation until 2021, 20 sats are the goal to achieve daily to hourly revisit
- The launch of the first demo satellite will be in late 2019 and now in EM development phase
  - Demo satellite: 3m ground resolution, 140kg, 0.7m cubic size, designed based on Hodoyoshi outcomes
- The mission part is developed in ImPACT (Impulsing Paradigm Change through Disruptive Technologies) program, funded by Cabinet Office, Government of Japan



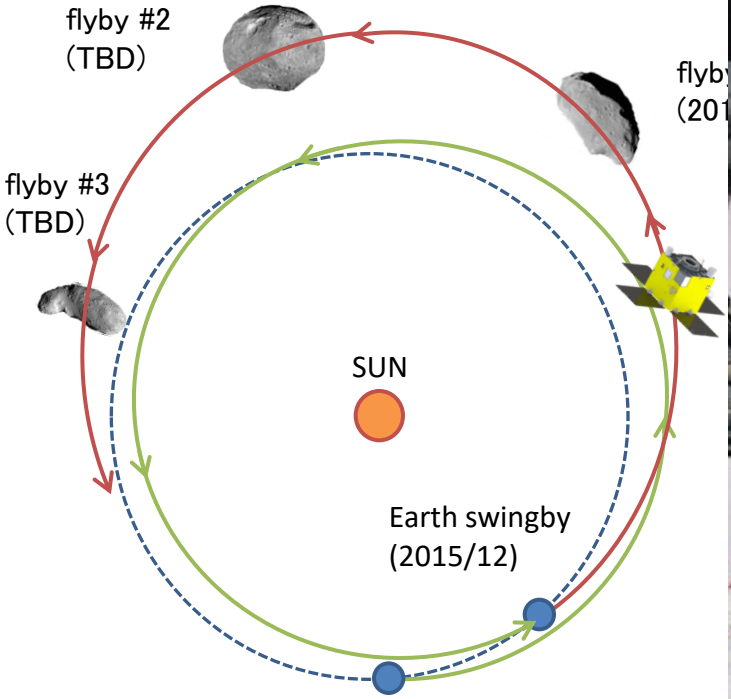


Synspective

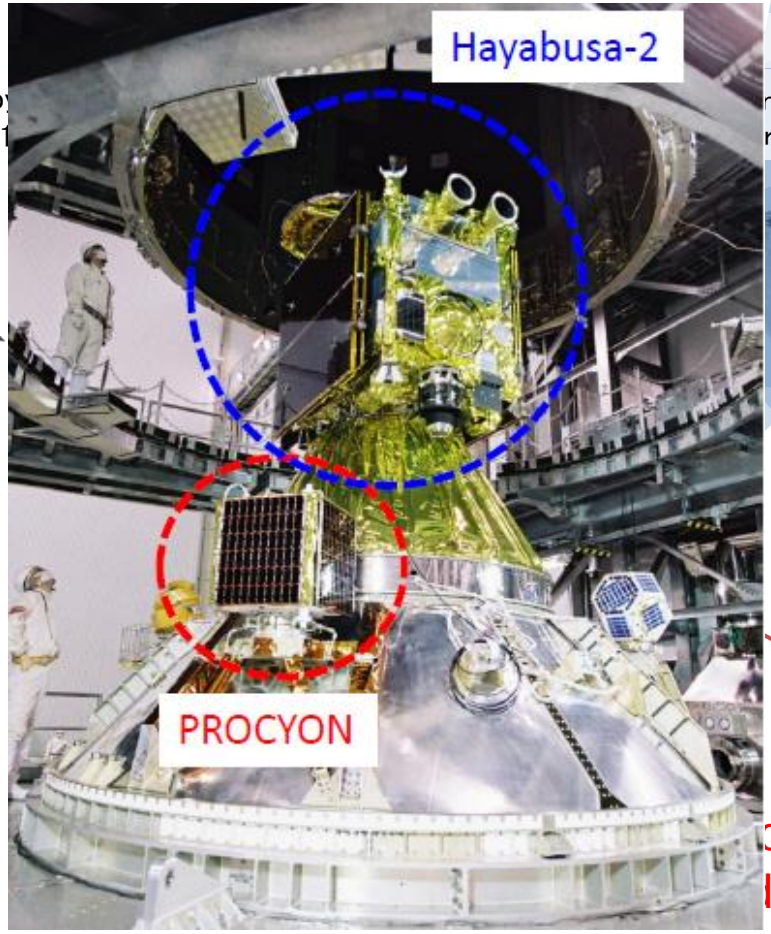
50kg-class deep space probe "PROCYON"

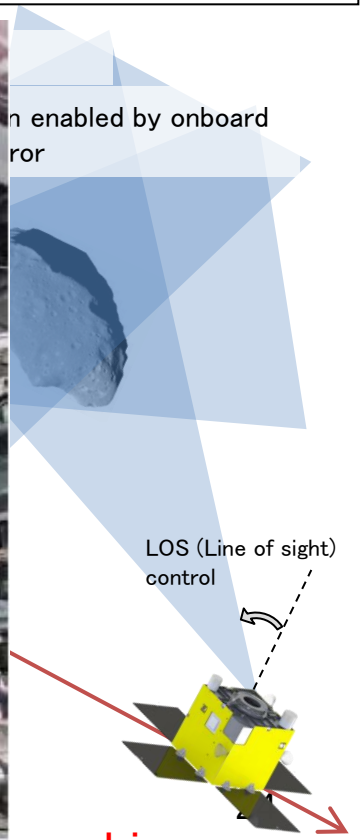
(PROCYON: PRoximate Object Close flYby with Optical Navigation)

Developer: **Univ. of Tokyo and JAXA** (Japan Aerospace Exploration Agency)
Launch: H2A rocket (together with Hayabusa-2 asteroid explorer, 2014 Dec.)
Mission: Demo. of 50kg deep space exploration bus system (nominal mission)
Asteroid flyby observation (advanced mission)



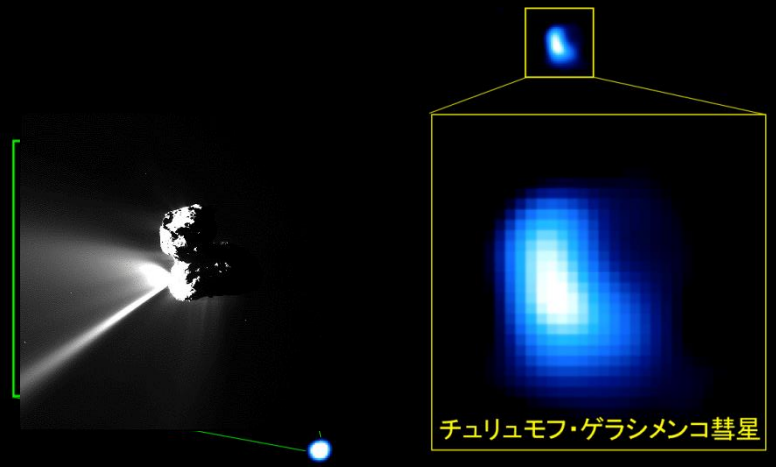
Launched (2014/12, together with Hayabusa-2 asteroid explorer)



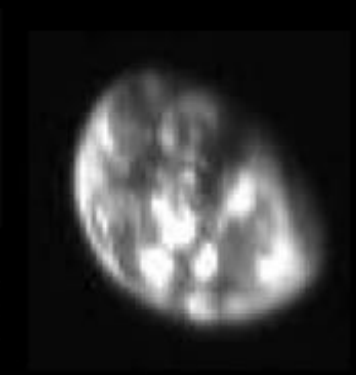


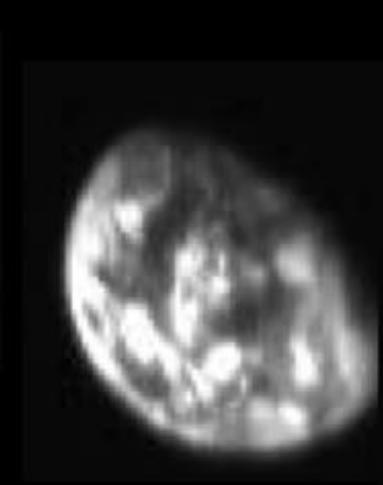
n enabled by onboard
ror

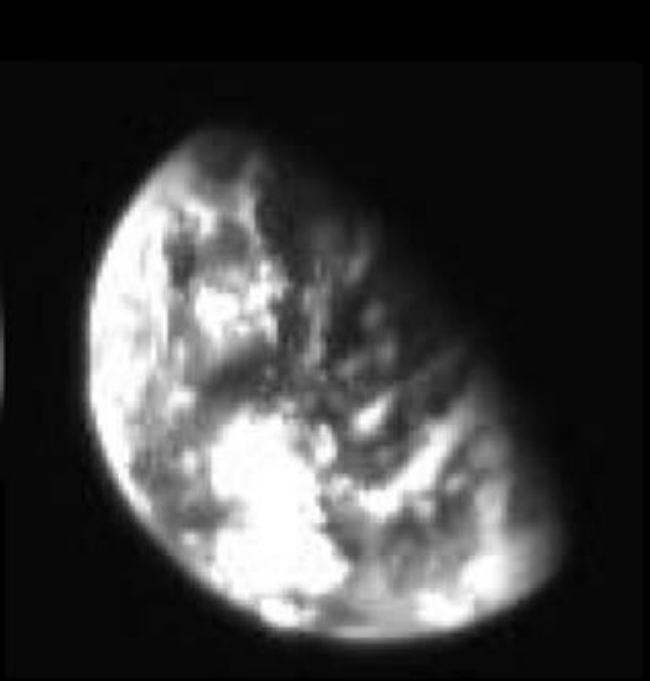
oyoshi compo.
l within 1.2 years



Hydrogen emission around 67P/Churyumov–Gerasimenko comet was observed on Sep. 13, 2015. This comet is the destination of the European Space Agency's Rosetta mission.







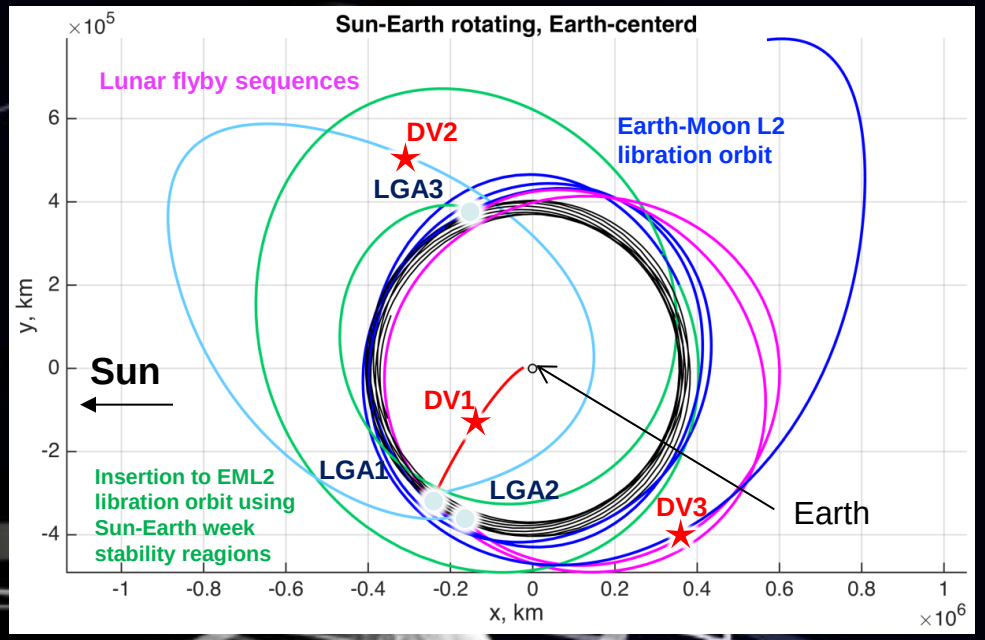
Obtained technologies

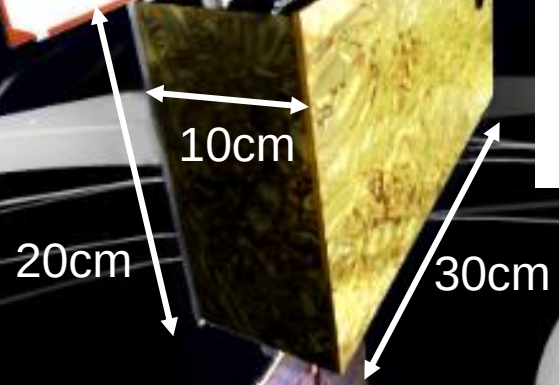
- Deep space navigation (100km @ 3σ)
- Long range communication using transponder (60M km by GaN based >30%)
- Attitude control in deep space environment (stability < 0.01deg)

13 CubeSat (6U) will be launched by NASA SLS in 2020

EQUULEUS

EQUilibriUm Lunar-Earth point 6U Spacecraft

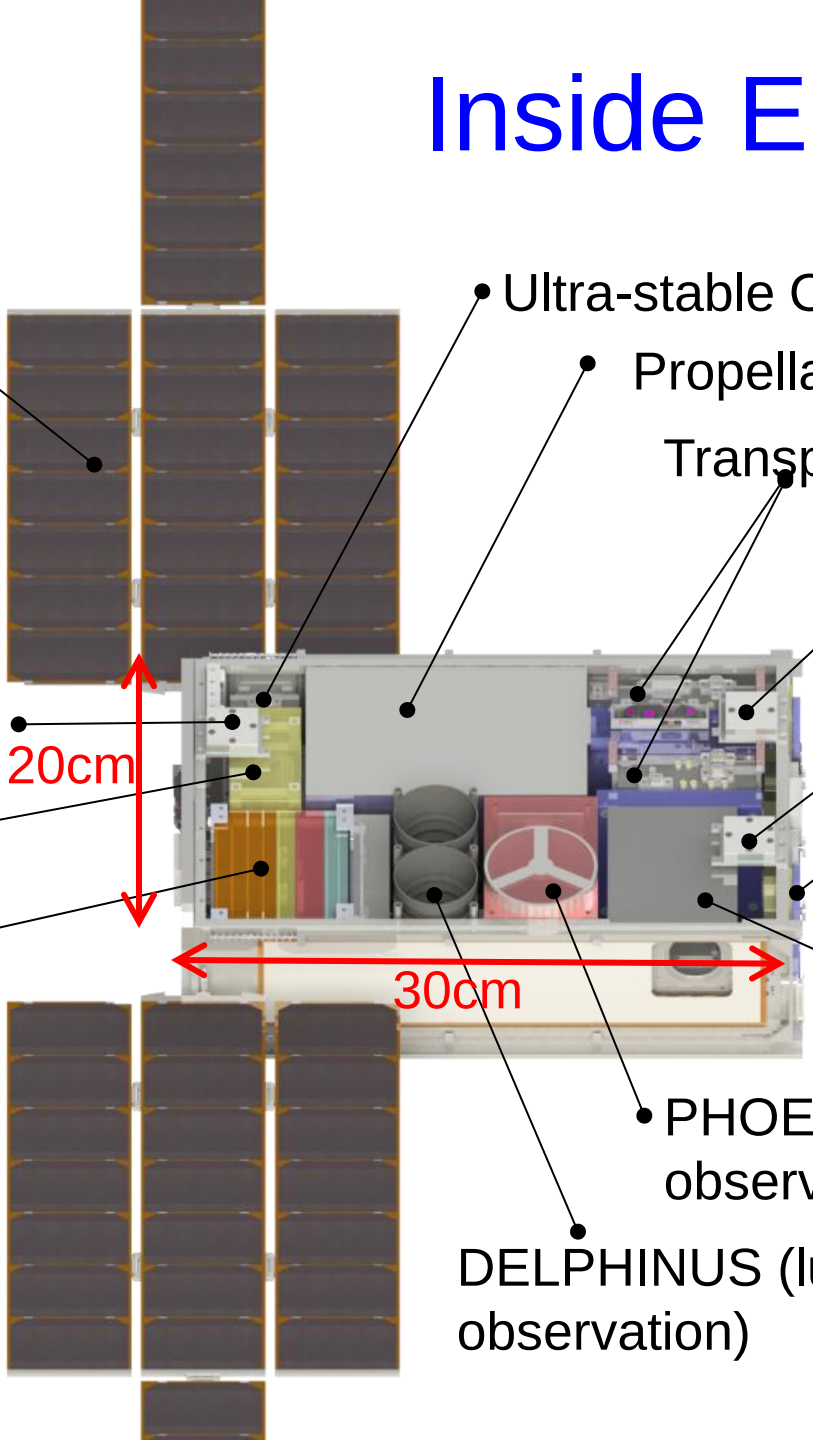




Mission to Earth Moon Lagrange Point

Intelligent Space Systems Laboratory, 2016/08/01

Inside EQUULEUS



Solar Array Paddles with gimbal

Ultra-stable Oscillator

Propellant (water) Tank

Transponder

X-Band MGA

X-Band LGA

X-Band LGA

Battery

Water resistojet thrusters

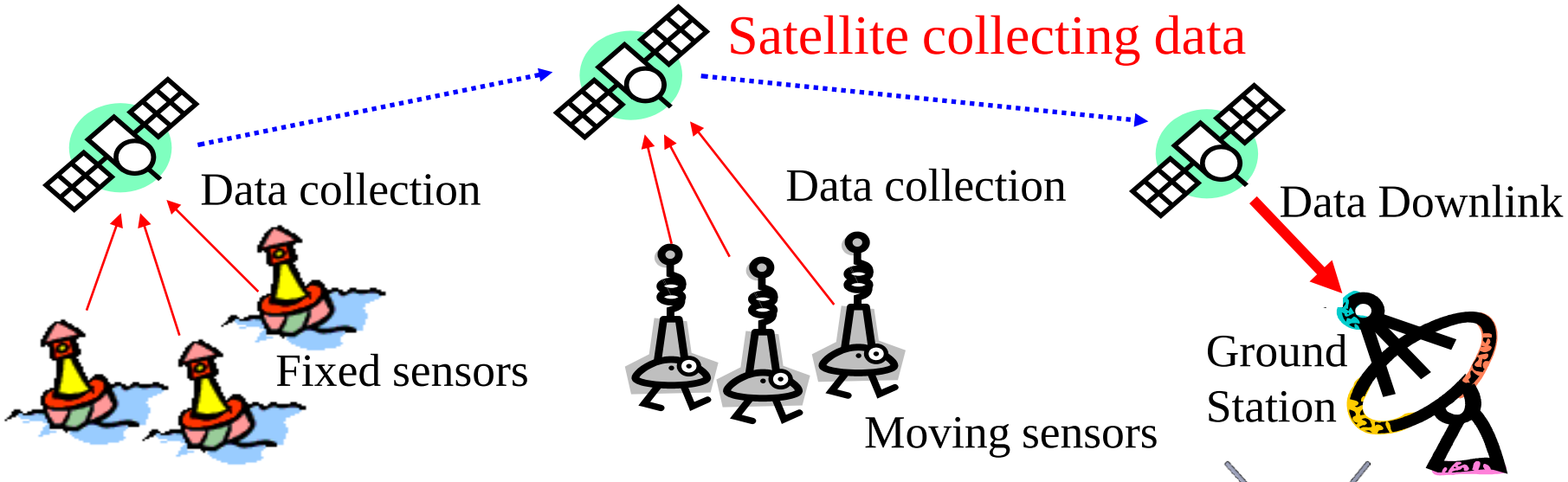
CDH & EPS

Attitude control unit

PHOENIX (plasma-sphere observation)

DELPHINUS (lunar impact flashes observation)

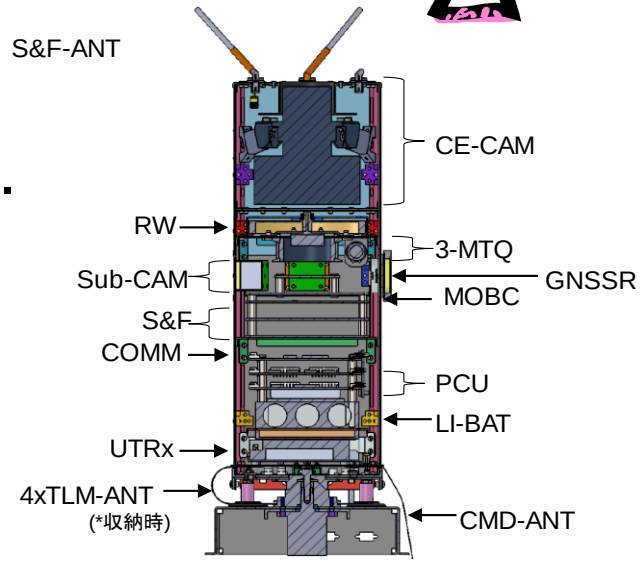
“Store & Forward” collects ground information



Application areas: disaster prediction, water level monitoring, soil moisture, PH…..

Key Issue: **How to send data with very low RF power to the satellite ?**

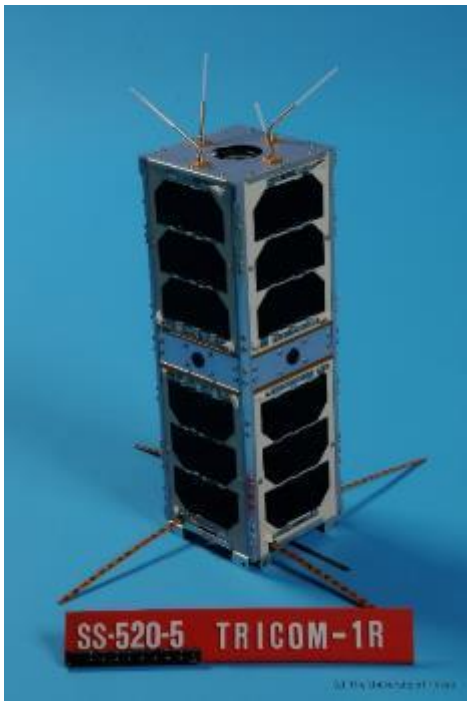
20mW RF power, low data rate (300bps) transmission is now possible.



3kg TRICOM-1R

Launch of TRICOM-1R by SS-520-5

- Launched on 3/2/2018 by the world smallest orbital rocket by JAXA/ISAS
- S&F and camera experiments successful
  - **8mW transmission from RWANDA succeeded**
- Plan to develop low cost/quick development version to support foreign countries



MOU to develop 3U CubeSat to be launched in mid-2019

News from Africa (09/05/2018)

Smart Africa, Rwanda Sign Deal With Tokyo University For Satellite Technology

Taarifa
We Give You The Facts, You Connect The Dots

International Contributions and Collaborations

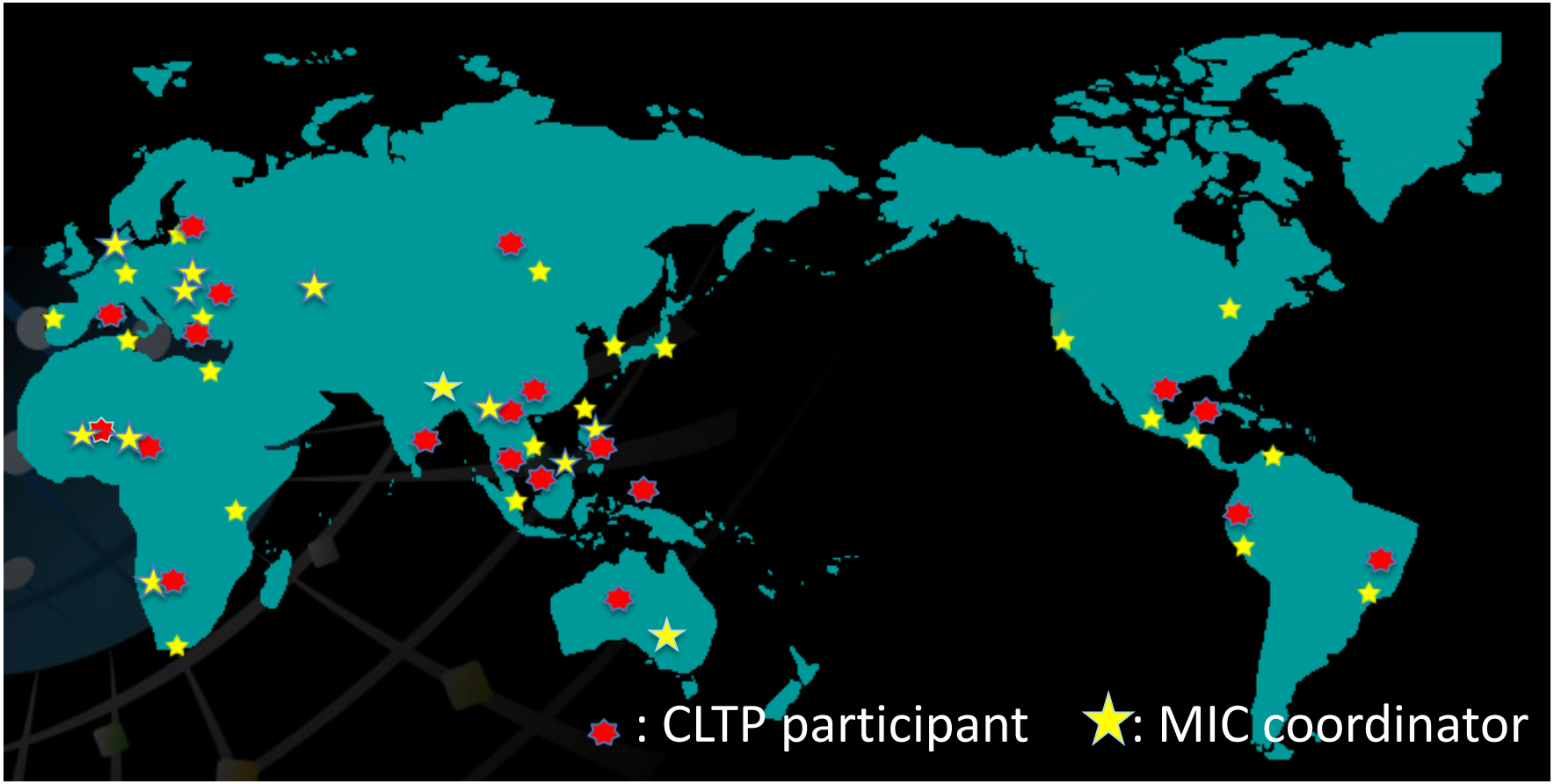
International Collaboration and Contribution

Nano-satellite Symposium has been held every year.

(Next symposium: at ISTS in Fukui, June 2019)

Our Global Network through MIC and CLTP

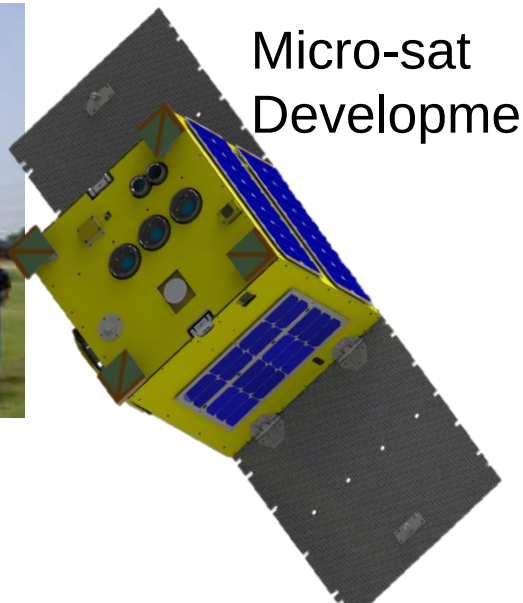
(MIC:33, CLTP: 32 nations) 38 countries in total



Space Engineering Education Support

- E-learning
"World Space School" in satellite technologies and its utilizations
- Hands-on training

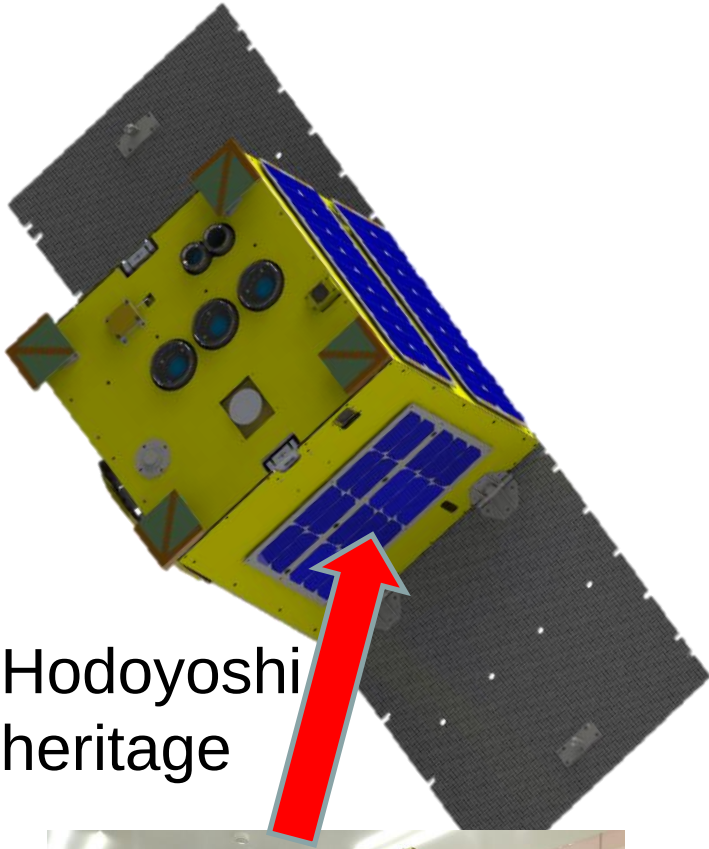
CanSat Education Training



Micro-sat Development

“MicroDragon” for Vietnam

Size	approx. 0.5 m ×0.5 m × 0.5 m (stowed) approx. 1.4 m (SAP deloployed)
Mass	approx. 50 kg
Orbit (Planned)	SSO 500 km LTDN 9:30
ADCS	Three-axis Earth Pointing
EPS	Solar Cells 2x Solar Array Paddles (SAPs) + 5x Body Mount Cells
	Generation 100 W (max) Consumption 50 W (avg) Bus Voltage 28V (unreg) + 5V (reg) Battery 5.8AH Li-ion
COM	S-band 4kbps （CMD） S-band 4/32/64kbps（TLM） X-band 10Mbps（Mission）

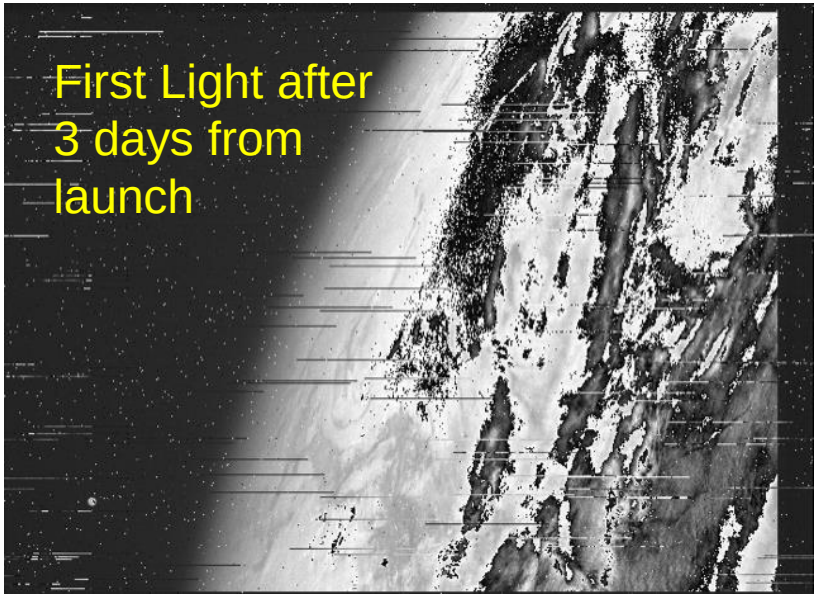


Hodoyoshi heritage

Vietnam first 50kg class satellite (self-made)

MicroDragon Successful Launch（1/18)

Epsilon Rocket
(7 satellites launch)



CLTP (CanSat education) History & Participants

1 month course “CanSat Leaders Training Program”

64 participants
from 32 countries

CLTP1 (Wakayama Univ. in Feb-March, 2011)
12 from 10 countries, namely Algeria, Australia, Egypt, Guatemala, Mexico, Nigeria, Peru, Sri Lanka, Turkey (3), Vietnam.

CLTP2 (Nihon Univ. in Nov-Dec, 2011)
10 from 10 countries, namely Indonesia, Malaysia, Nigeria, Vietnam, Ghana, Peru, Singapore, Mongolia, Thailand, Turkey.

CLTP3 (Tokyo Metropolitan Univ. in July-August, 2012)
10 from 9 countries, namely Egypt (2), Nigeria, Namibia, Turkey, Lithuania, Mongolia, Israel, Philippines, Brazil.

CLTP4 (Keio Univ. in July-August, 2013)
9 from 6 countries, namely Mexico(4), Angola, Mongolia, Philippines, Bangladesh, Japan.

CLTP5 (Hokkaido Univ. in Sept 8-19, 2014)
7 from 5 countries, namely Korea (2), Peru, Mongolia, Mexico (2), Egypt.

CLTP6 (Hokkaido Univ. in August 24-Sept 3, 2015)
8 from 8 countries, namely Bangladesh, Egypt, Mexico, New Zealand, Angola, Turkey, Tunisia, Austria

CLTP7 (Hokkaido Univ. in Sept 21-Oct 1, 2016)
8 from 7 countries, namely Egypt, Peru, Mongolia, Nepal, Myanmar, Serbia, Dominica Republic

UNISEC supported student projects !!

(UNIversity Space Engineering Consortium)

- Founded in 2002, became NPO in 2003
- 72 laboratories from 50 universities
- 892 students, 259 individual/company members
- UNISEC Missions:
  - Education and human resource training for space development/utilization
  - Innovative space technology “seeds” development
- Activities to be Supported:
  - Joint experiment, joint development, joint education, etc.
  - Workshop, symposium, technology exchange, etc.
  - Consultation on legal matters (frequency, export law, etc.)
  - Finding “rivals” within the community !
  - “UNISEC Lecture Series”

UNISEC
University Space Engineering Consortium

http://www.unisec.jp

University Satellites in Japan

44 university satellites launched in 2003-2017

From CanSat to CubeSat, Nano-Satellite

From Educational purpose to Practical application

“UNISEC-Global” activities

40+ regions/countries are interested to start UNISEC in their countries: South Africa, Angola, Namibia, Egypt, Ghana, Kenya, Nigeria, Tunisia, Bangladesh, Korea, Mongolia, the Philippines, Singapore, Taiwan, Thailand, Turkey, Australia, Indonesia, Saudi Arabia, Canada, USA, Guatemala, Mexico, Peru, Brazil, Bulgaria, Italy, Samara (Russia), Switzerland, Germany, Slovenia, Lithuania and Japan.

14 Local Chapters and 1 Association of Local Chapters have been acknowledged. (red part)

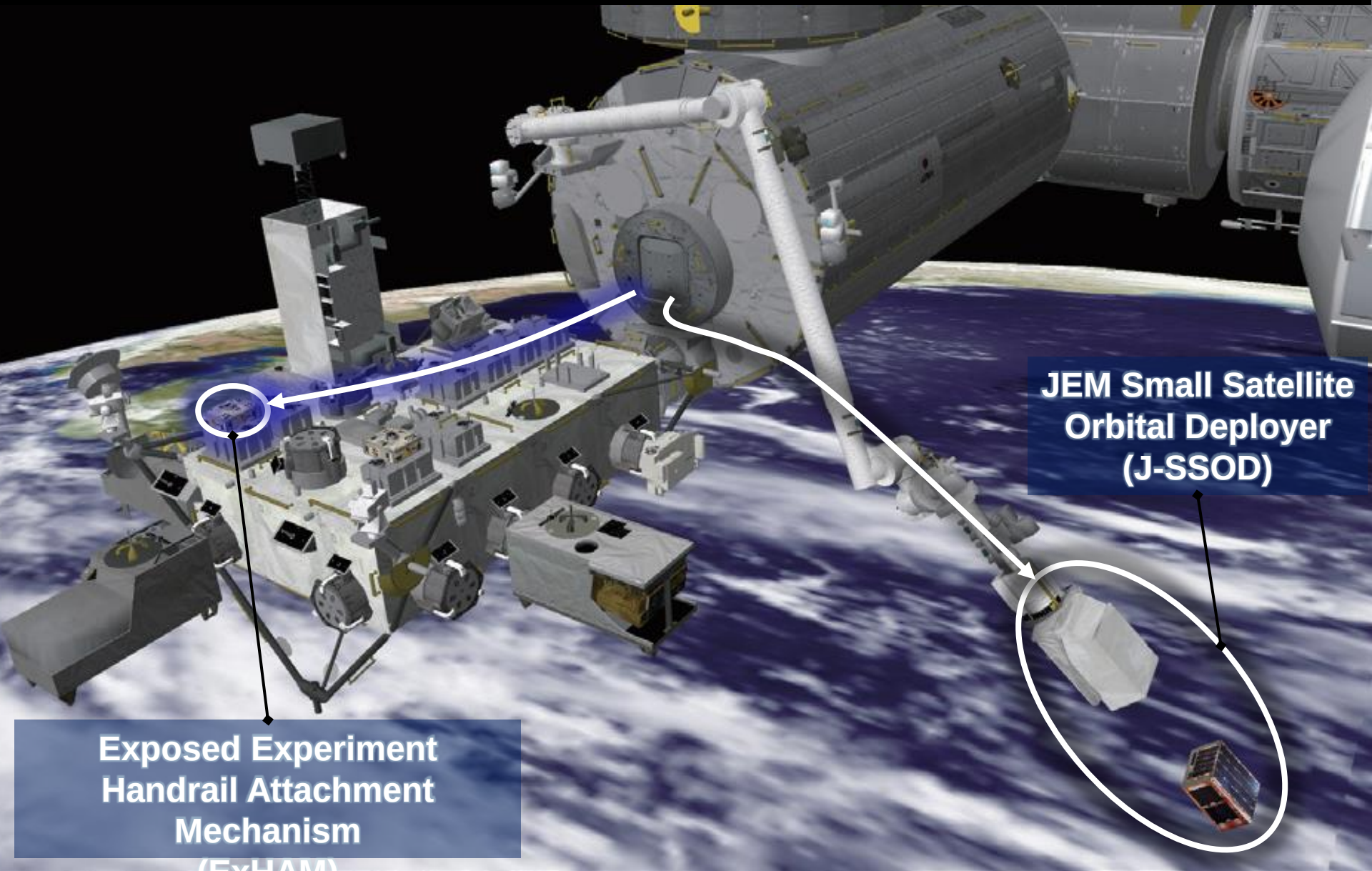
UNISEC-GLOBAL meeting will be held in France in November 2018

Japanese University Satellite Launch

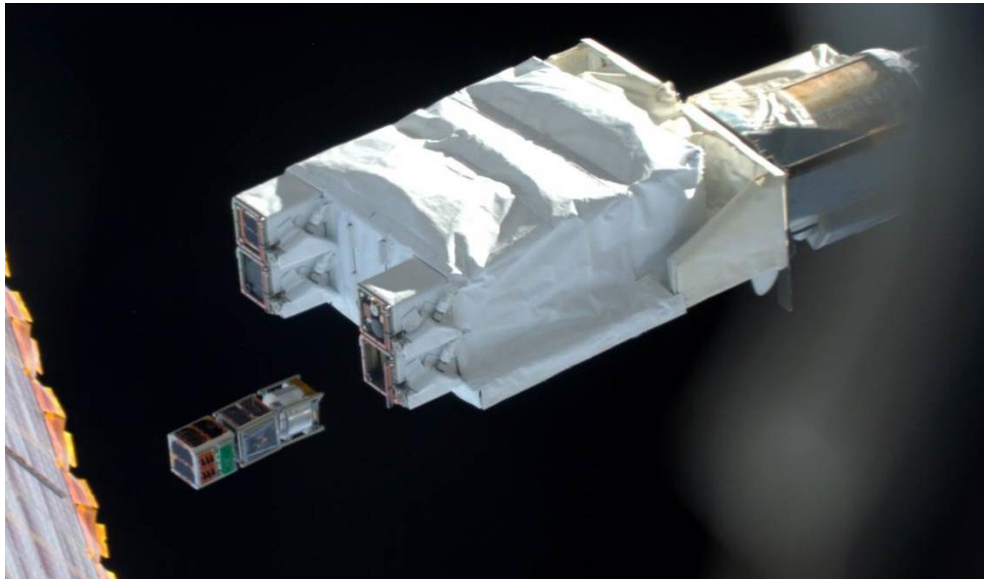
- Foreign Rockets: 12
  - ROCKOT（Russia） 2 (2003)
  - COSMOS（Russia） 1 (2005)
  - PSLV（India） 3 (2008, 2012)
  - DNEPR (Russia) 6 (2014)
- Japanese Rockets and ISS: 36
  - M-V 2 （2006）
  - H-IIA 19 （2009～）
  - HTV⇒ISS deployment 15 （2012～）

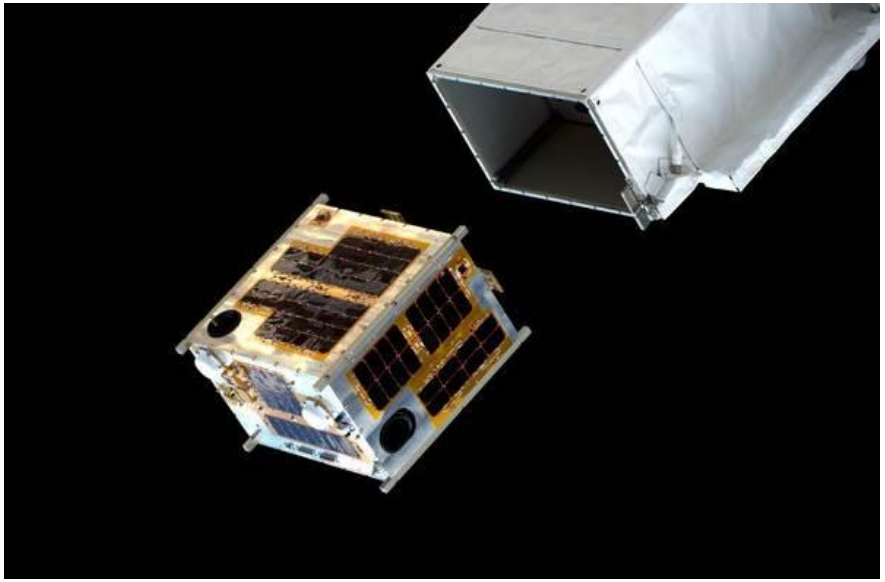
Free or Low Cost Launch Provided by JAXA

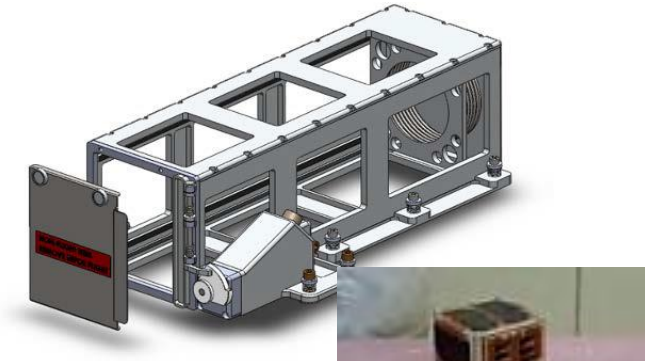
Launch (deployment) from ISS with Kibo Unique Exposed Facility

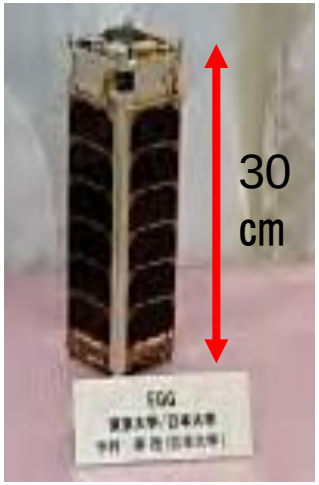


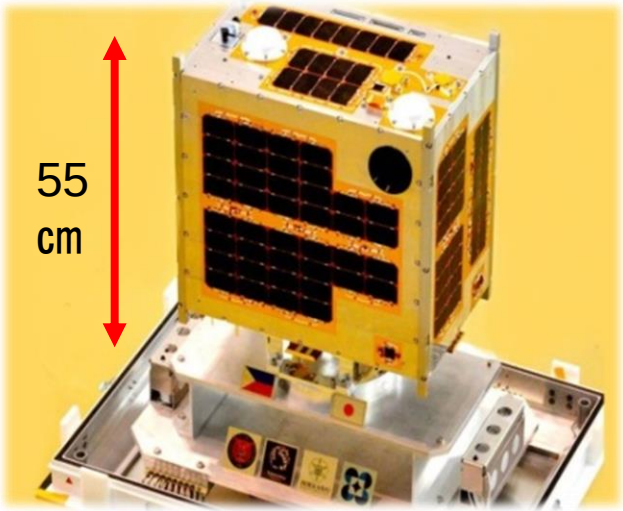
Deployment Capability











Summary

- Micro/nano/pico satellites (<100kg) are making a big “Game Change”
- Constellation of affordable remote sensing satellites (around 50kg, costing 3-5M$) can take images of Earth with high frequency
- 3kg size very low cost (around 300,000$) S&F satellites can be used for collecting ground sensor data **without ground infrastructure**
- Development of these satellites can be used for **education** for space and other areas as well