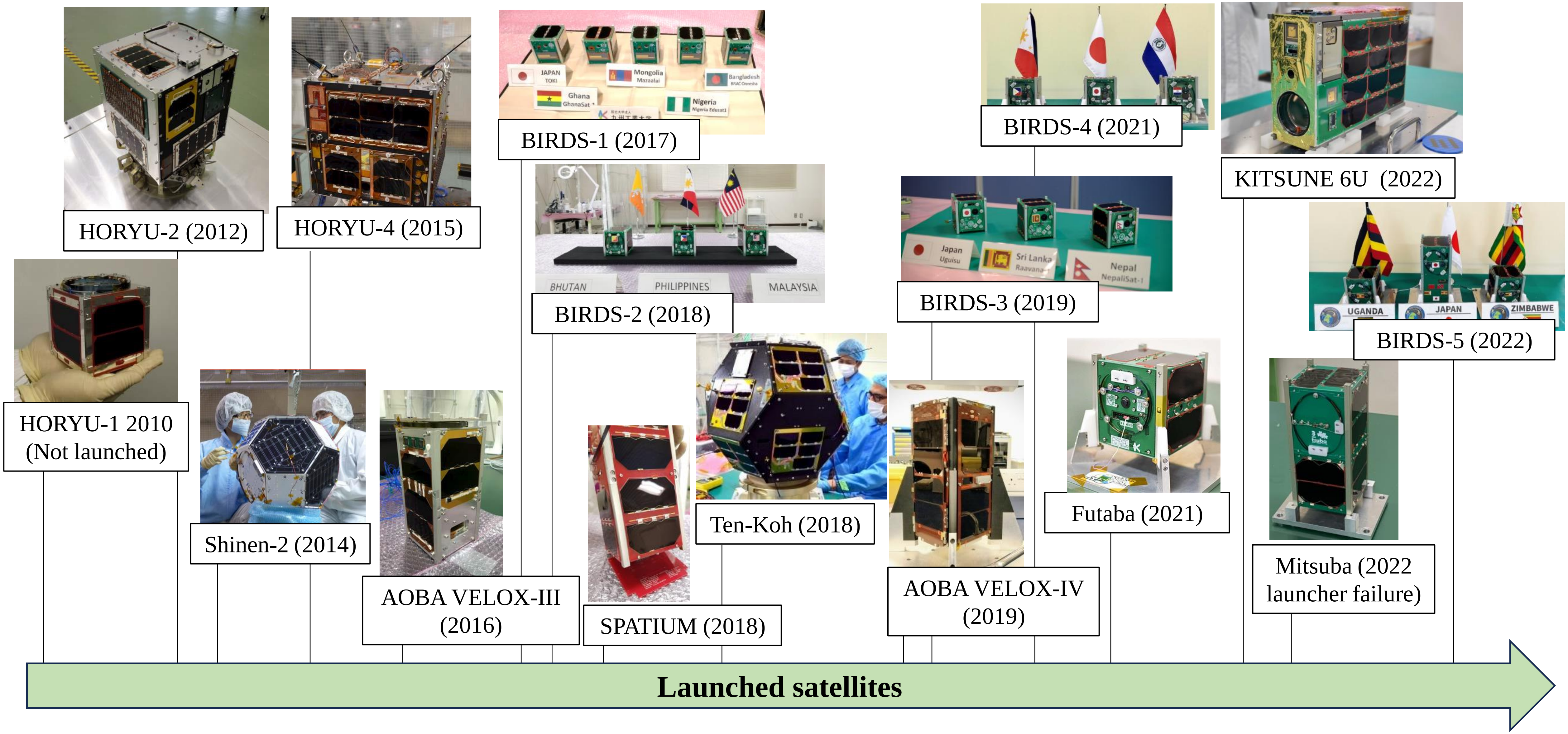
Development and Operational Insights from the CURTIS CubeSat

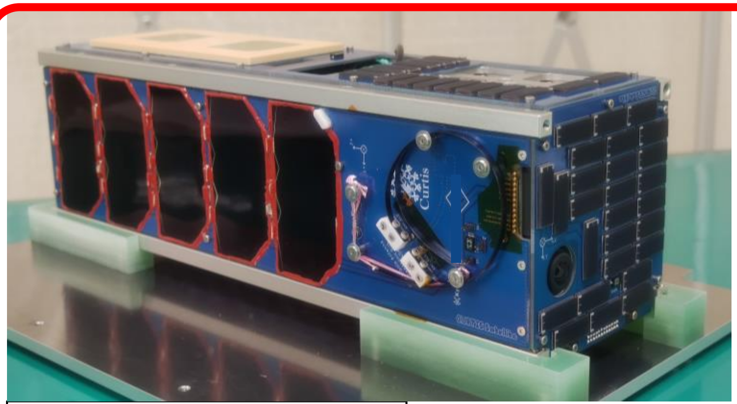
Rodrigo Cordova, Ph.D

2024/10/09

Brief introduction of Kyutech satellite projects

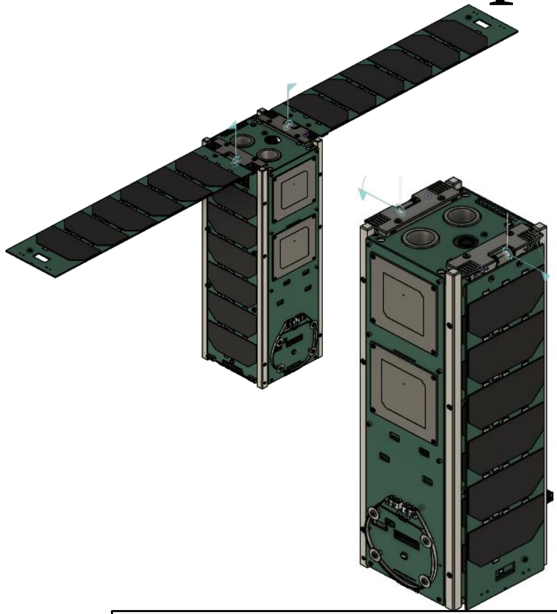


Brief introduction of Kyutech satellite projects



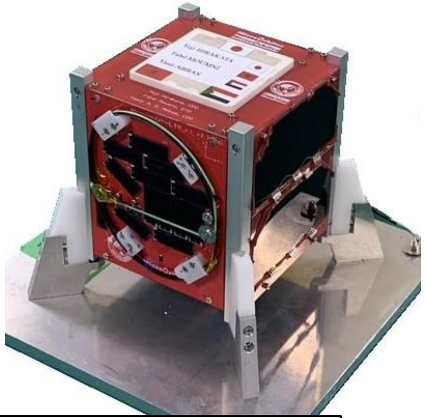
CURTIS (2024)

BIRDS-X (2025)

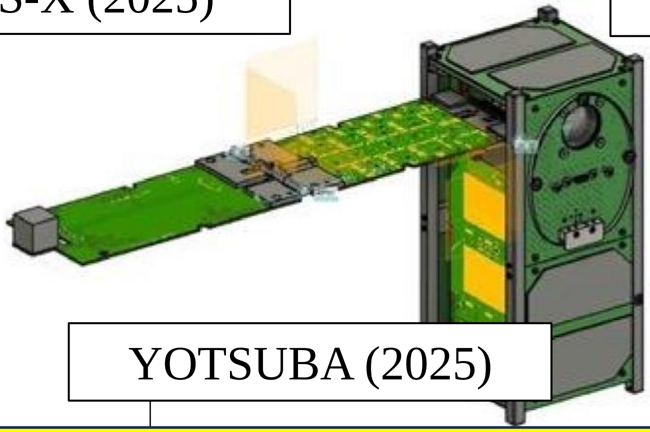


LEOPARD (2025)

VERTECS (2025)



MicroOrbiter-1 (2024)



YOTSUBA (2025)

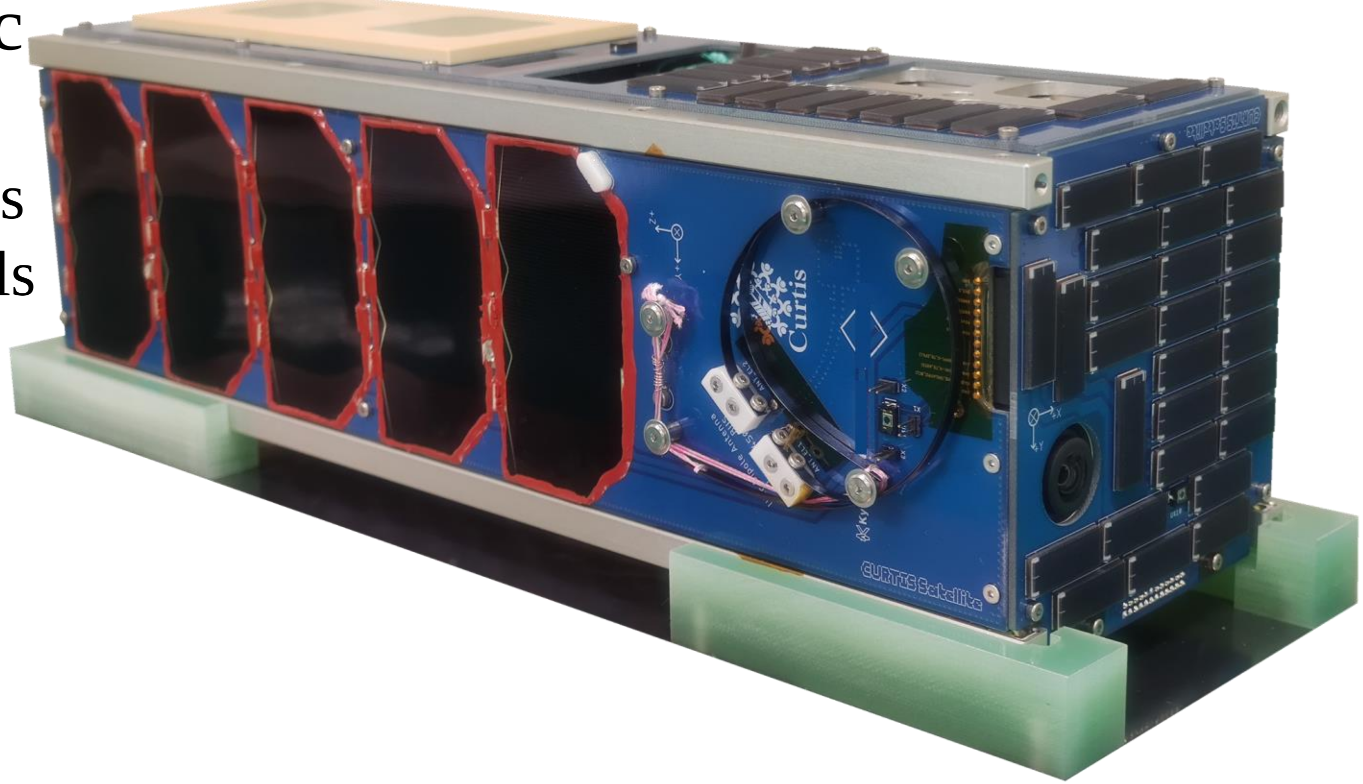
Operations finished

To be launched

CURTIS overview

CURTIS project:

- Technology demonstration satellite of payloads developed by Panasonic
- Missions:
  - In-orbit thermal exchange experiments using surface-coated graphite materials for their use in space applications,
  - Demonstration a highly integrated BUS comprised of an OBC, EPS, and UHF transceiver in a single board
  - Mid-resolution imaging by an in-vehicle analog camera
- Deployed into ISS orbit



CURTIS overview

CURTIS project

Satellite development

Kyutech

Satellite BUS:
Structure
OBC
EPS
Transceivers (UHF/S-band)
Thermal payload control board
Access boards

Satellite integration

Panasonic

Satellite payloads:
In-vechicle camera payload
Thermal mission payload
Panasonic bus

Satellite components:
S-band patch antenna
Camera payload control board
Panasonic access board
Batteries
Thermal insulation materials

Frequency coordination

Panasonic/Infostellar

Launch coordination

Kyutech/Panasonic

MBA/JAXA

Environmental test

Kyutech

Thermal vacuum test
Vibration test
EMC test

Panasonic

EMC test
Radiation test

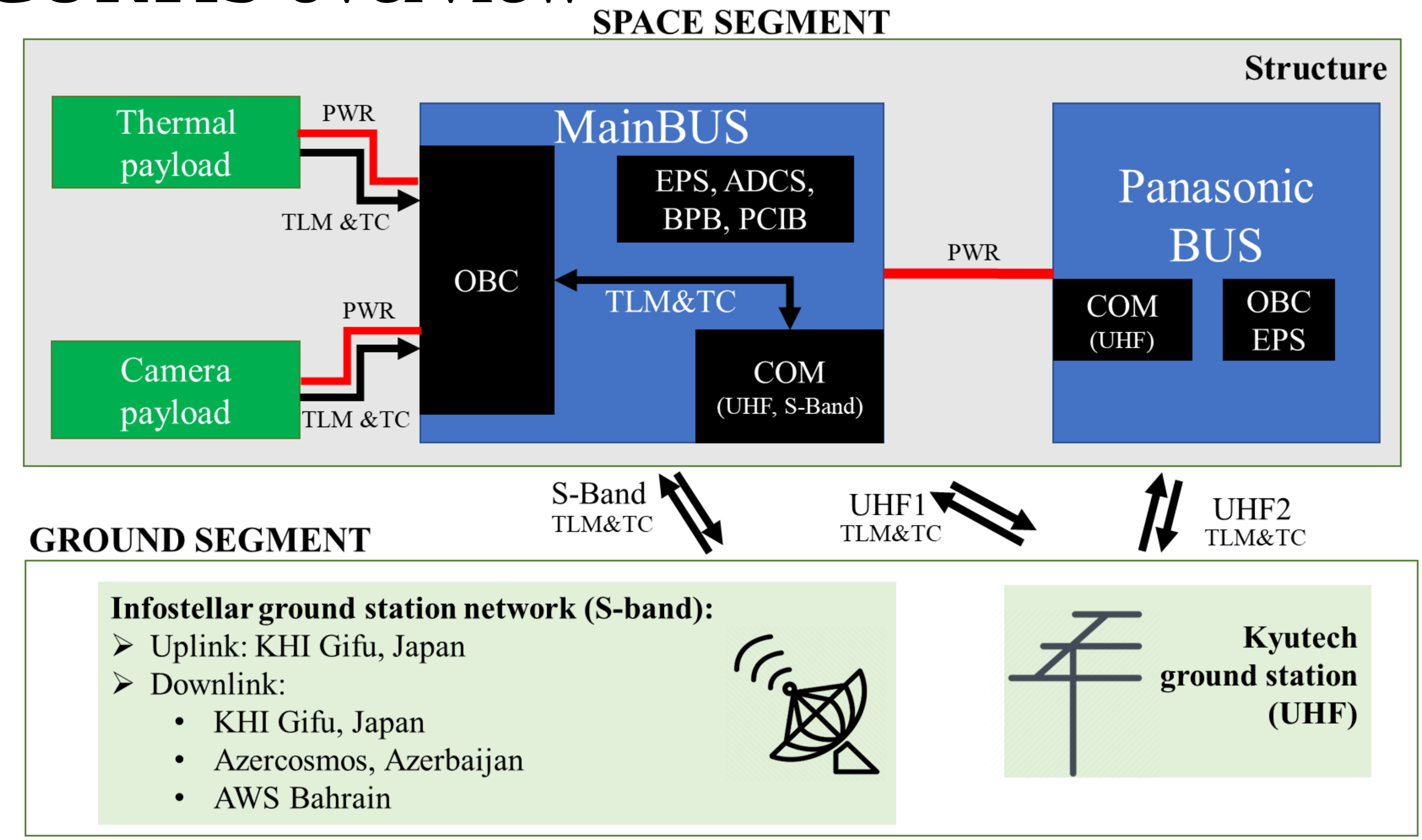
Operations

Kyutech/Panasonic

UHF Ground station
- GS software
- GS equipment

Infostellar S-band Ground station network
- Compatibility coordination
- GS software

CURTIS overview



CURTIS overview

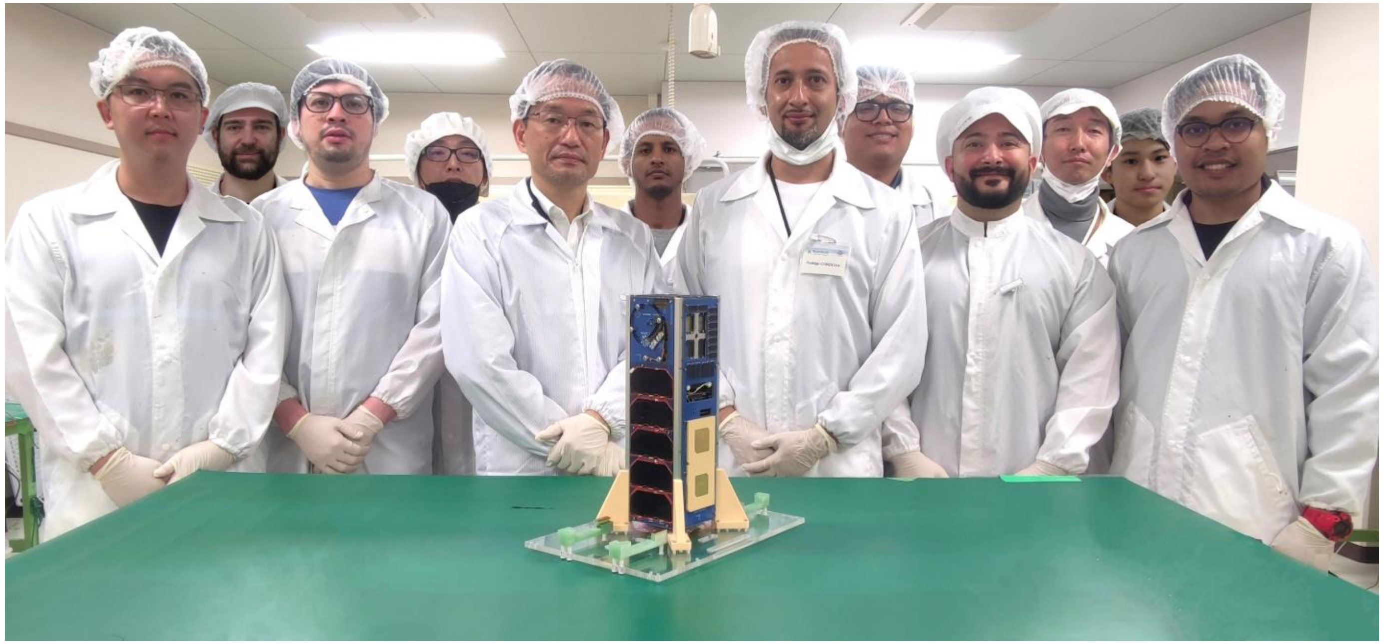
Kyutech team:

Academic staff

- Management and system engineering
- OBC
- ADCS
- Environmental test
- Safety review and launch coordination

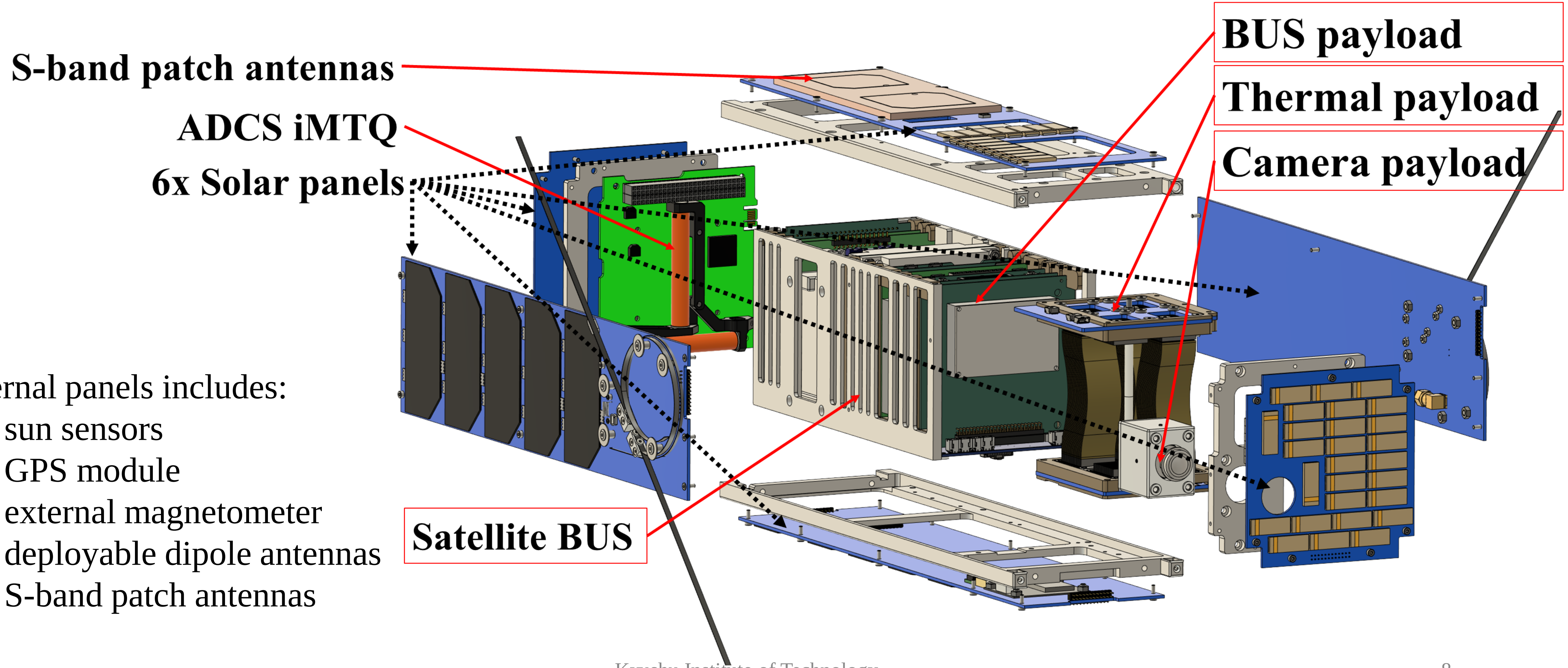
Students

- B4 students
- Graduate students
- Mentors



CURTIS overview

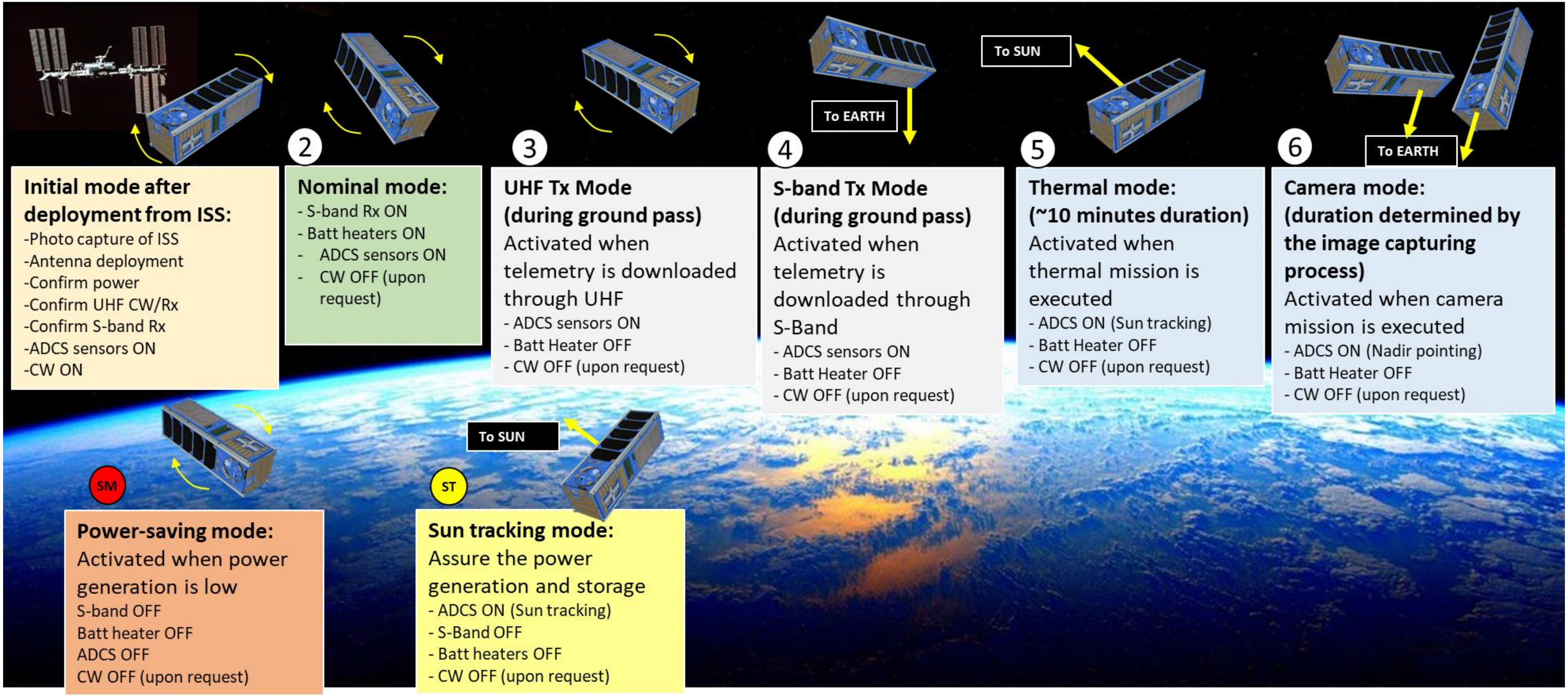
Satellite BUS and external panels



External panels includes:

- 6 sun sensors
- 1 GPS module
- 1 external magnetometer
- 2 deployable dipole antennas
- 2 S-band patch antennas

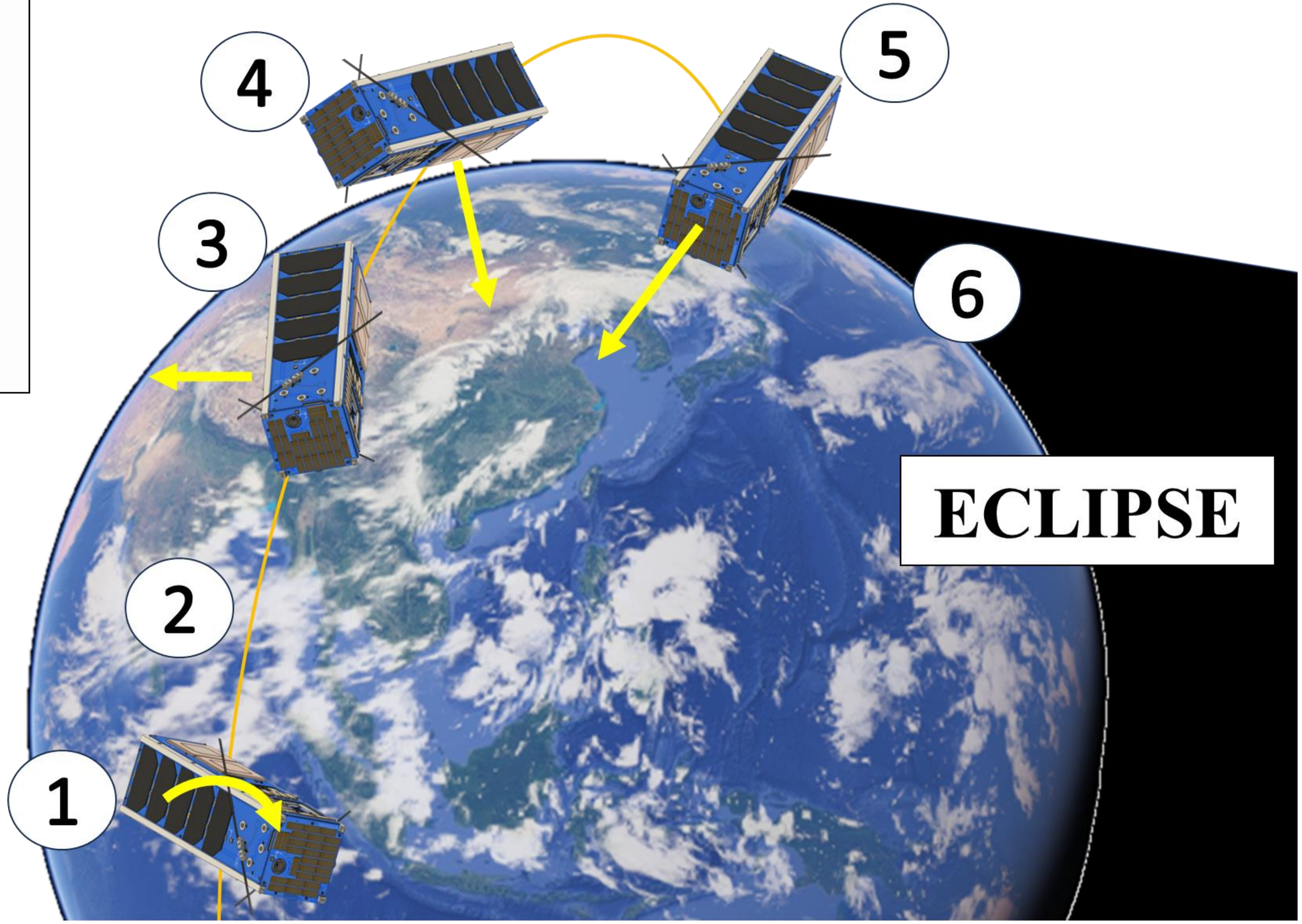
Concept of operations and missions



Concept of operations and missions

1. **Tumbling**
2. **Detumbling**
3. **Sun tracking**
4. **Nadir – S-band**
5. **Nadir - Camera**
6. **Thermal (eclipse)**

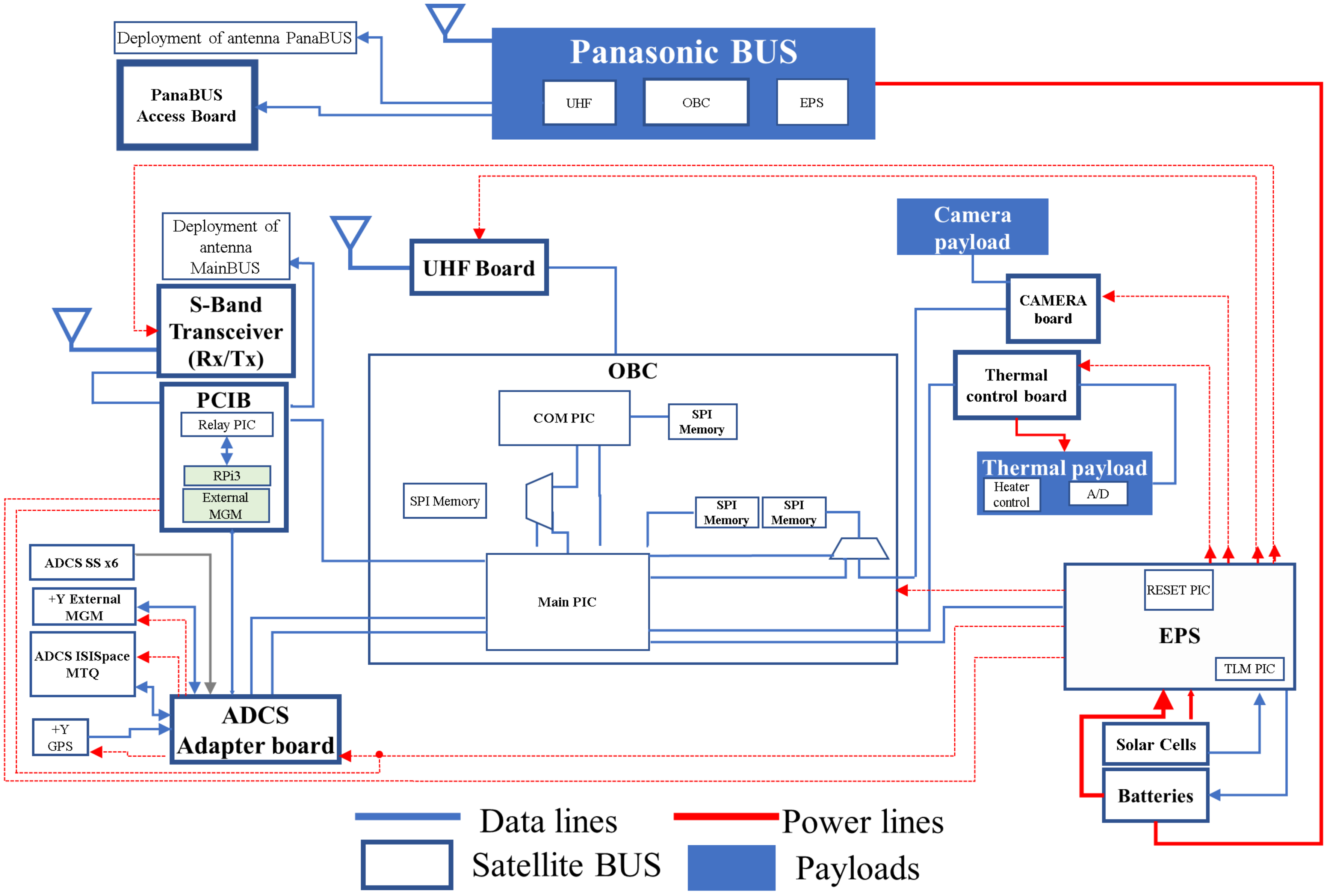
SUN PHASE



Satellite system architecture

Simplified system architecture of CURTIS:

- Kyutech BUS is adapted for CURTIS missions
- Back-plane board serves as an interface board among subsystems
- Dedicated control boards operate the payloads

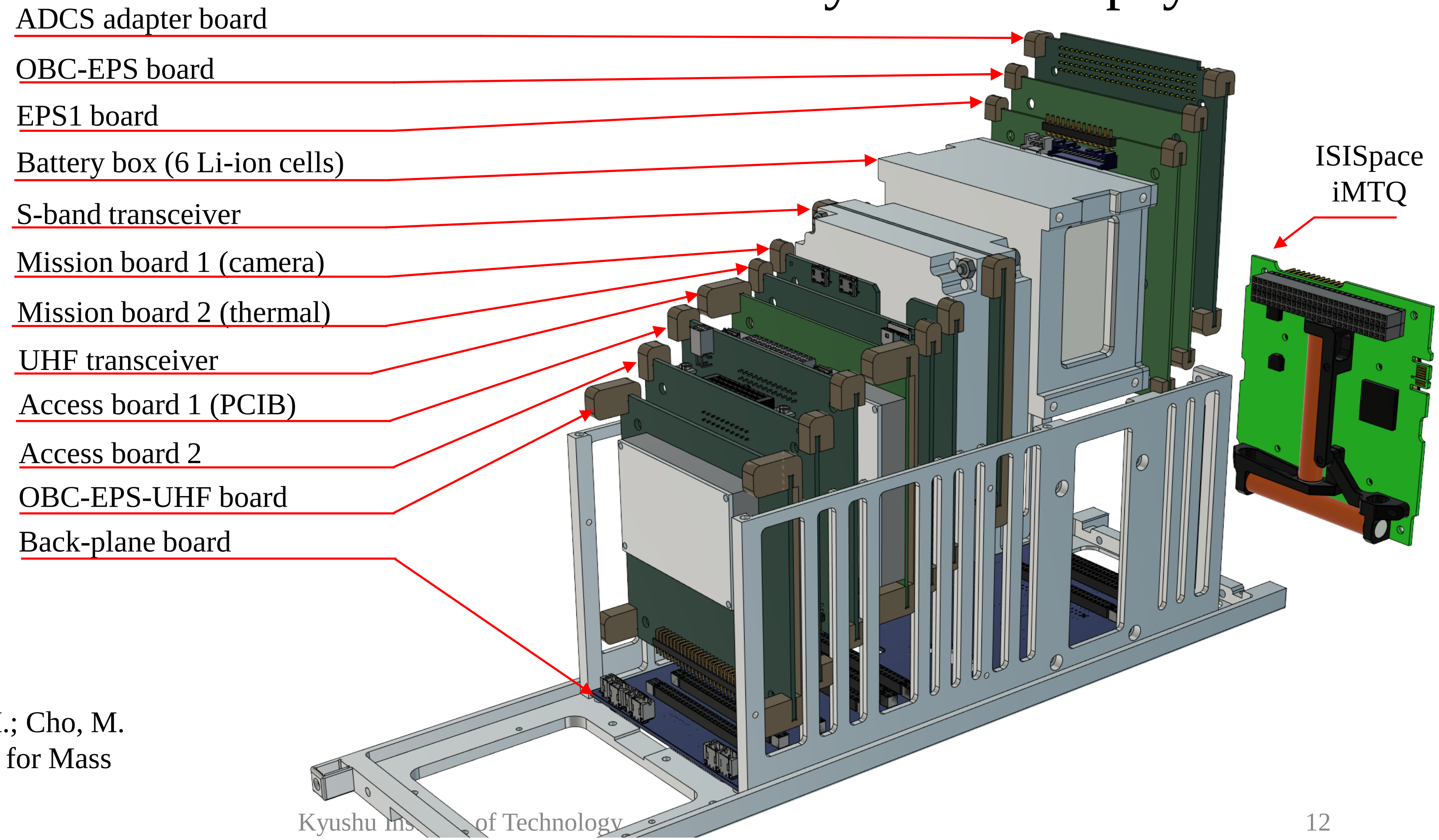


Satellite BUS - Structure

- ✓ Slot type structure designed to “insert” the subsystems at their assigned slot
- ✓ Back-plane board served as the interface of the subsystems and payloads

Features:

- The subsystems are inserted using a set of spacers
- Spaces between subsystems are standardized, except for oversized components



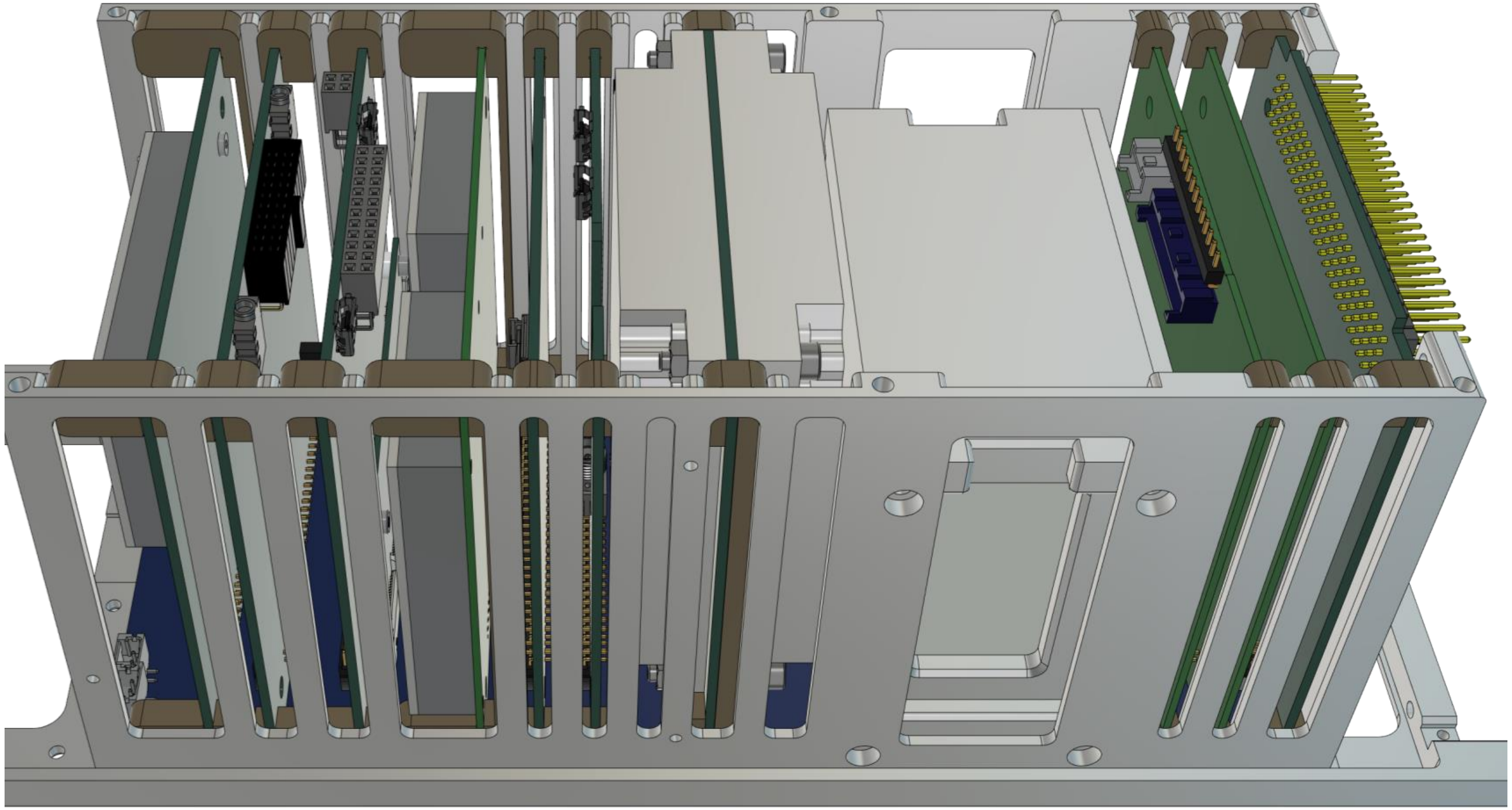
Areda, E.E.; Cordova-Alarcon, J.R.; Masui, H.; Cho, M. Development of Innovative CubeSat Platform for Mass Production. Appl. Sci. 2022, 12, 9087. https://doi.org/10.3390/app12189087

Satellite BUS - Structure

- ✓ Mass producible design approach
- ✓ Simplified assembly procedure

Key parameters:

- Tolerances management
  - BPB-subsystem
  - Subsystem-slot
  - Slot-spacer
- Standardization of the PCB design
- Harness management



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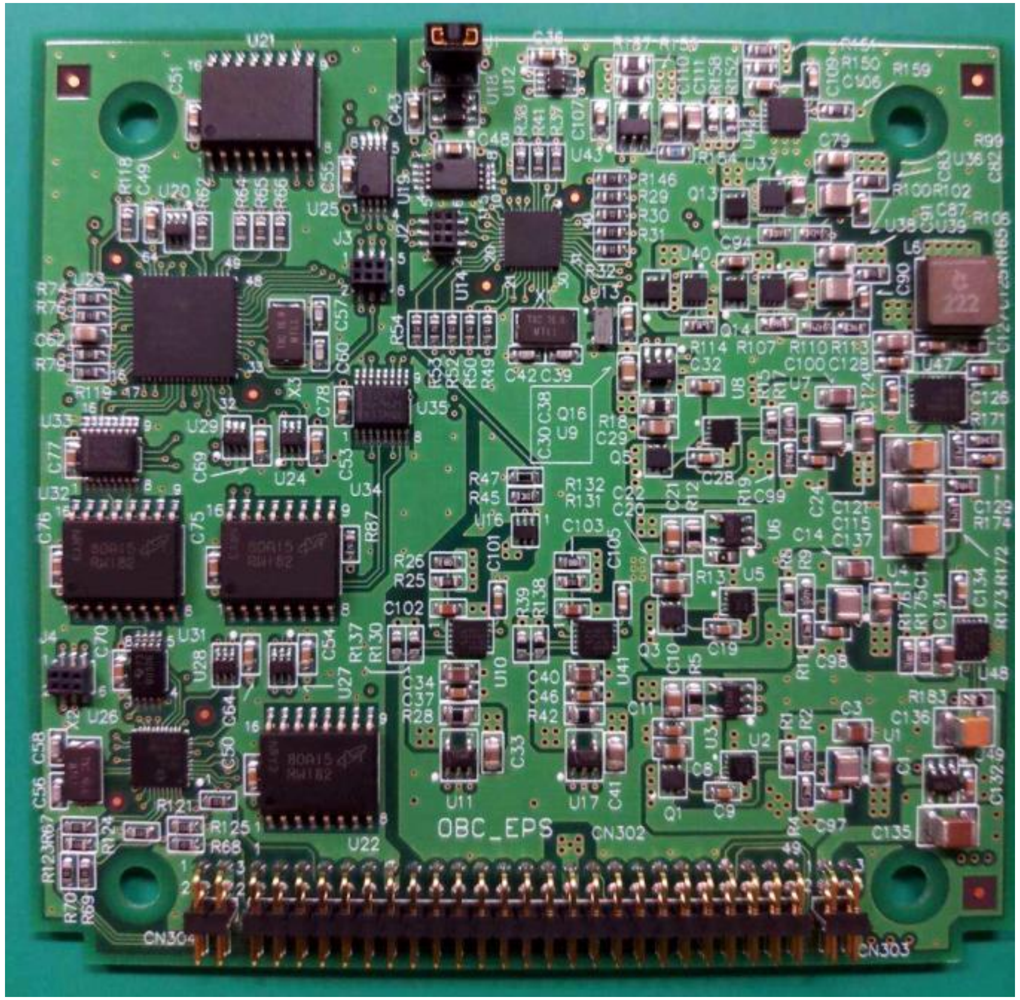
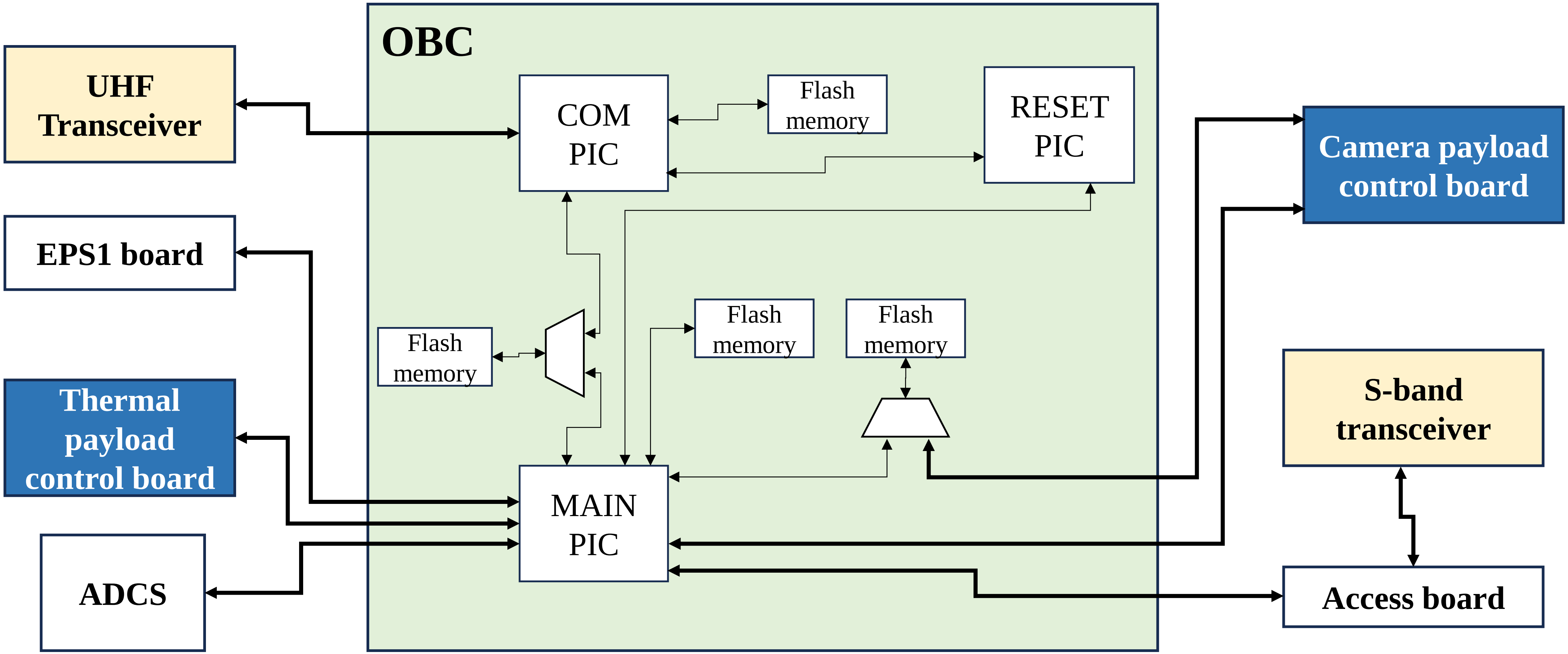
Satellite BUS – OBC/EPS board

- ✓ Flight heritage from BIRDS and KITSUNE satellite projects
- ✓ Execute commands from Ground Station through UHF and S-band transceivers.
- ✓ Execute mission using scheduled commands with tunable parameters.
- ✓ Manage and transmit Housekeeping data and Mission data.

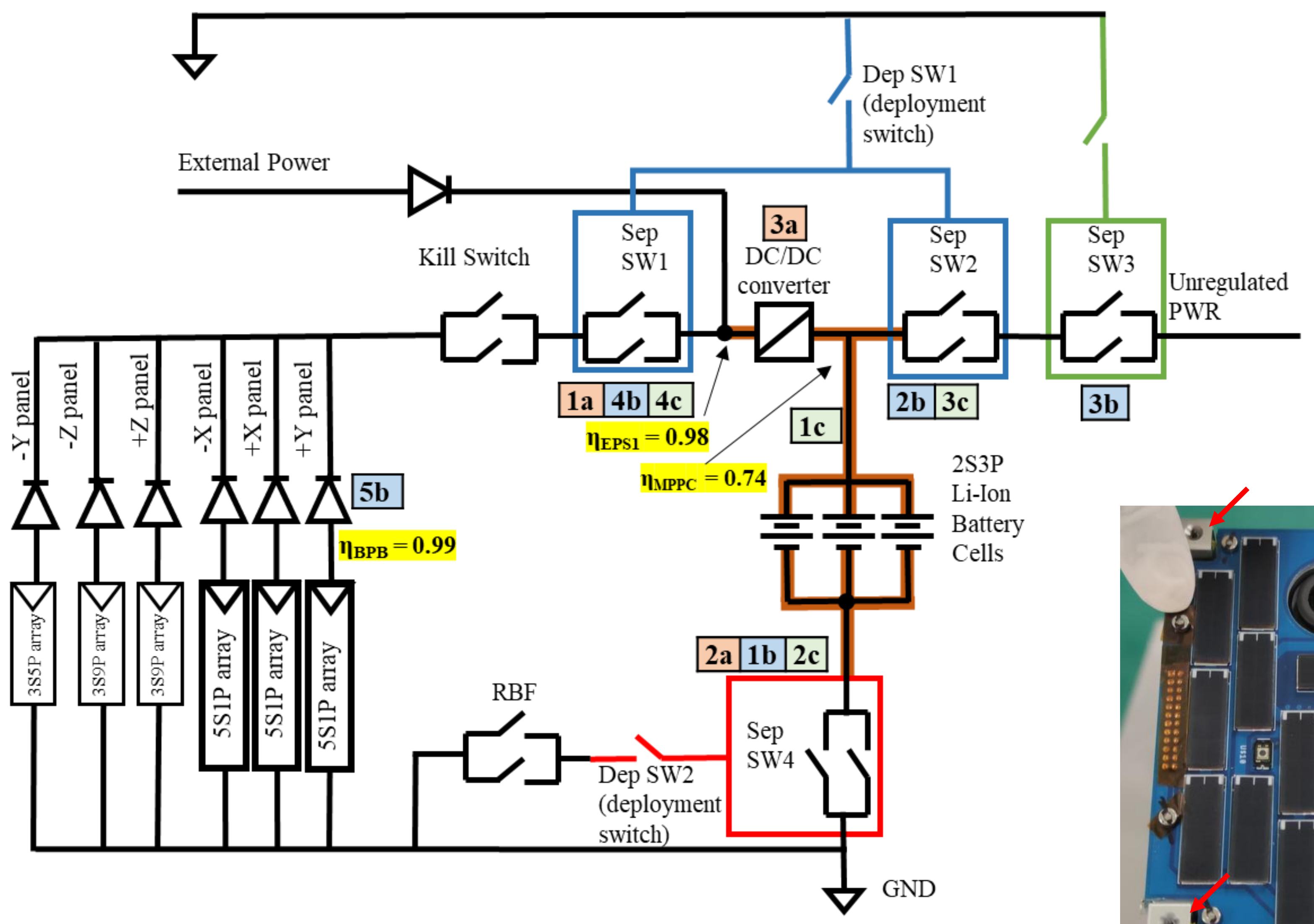
Microcontroller	Part No.	Function
Com PIC	PIC16F1789	Interface with the UHF transceiver.
Reset PIC	PIC16F1789	Fault recovery, HK data collection from EPS power lines.
Main PIC	PIC18F67J94	Mission control, data handling, command scheduling.



Satellite BUS – OBC/EPS board

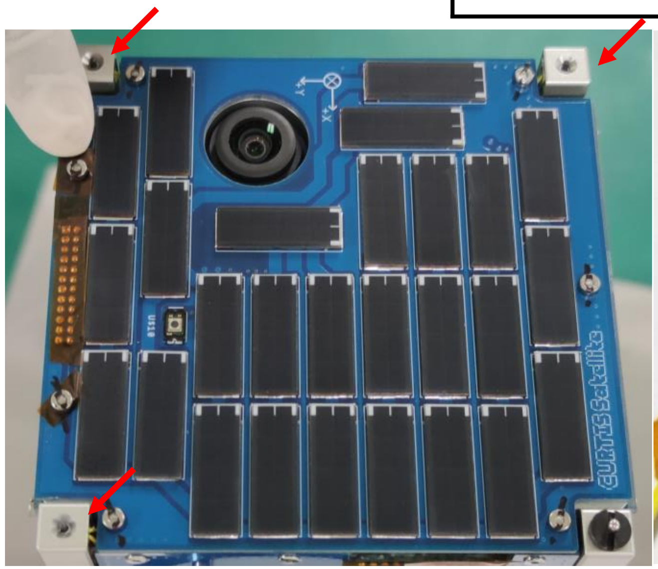


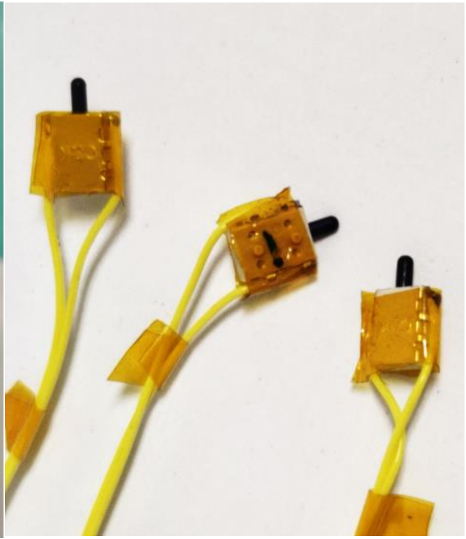
Satellite BUS – EPS Subsystem



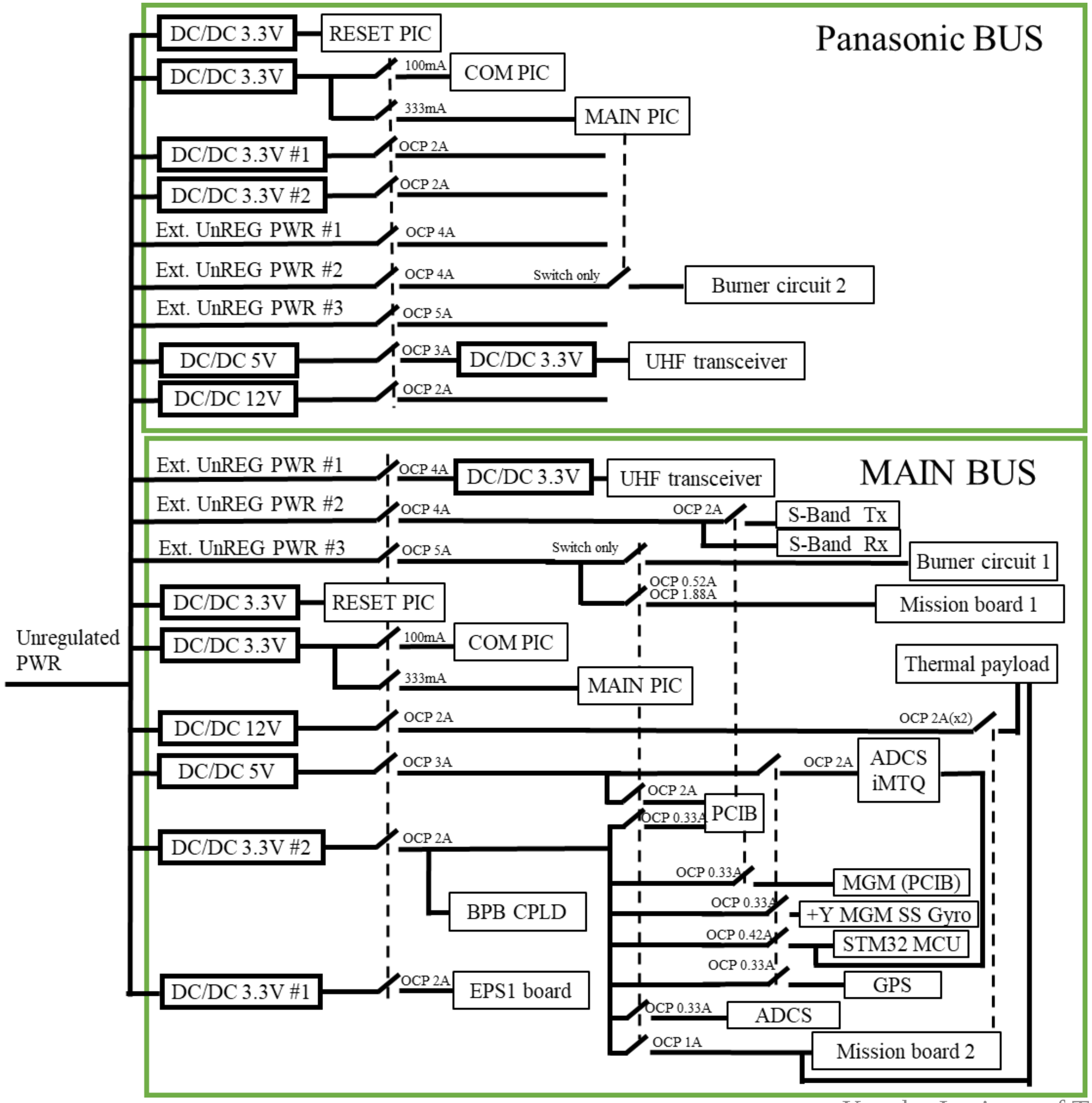
Inhibits

Type of Inhibit	Sign	Location
Overcharge	1a	Sep Sw1
	2a	Sep Sw4
	3a	DC/DC converter
Over-discharge	1b	Sep Sw4
	2b	Sep Sw2
	3b	Sep Sw3
	4b	Sep Sw1
	5b	Diodes
External short	1c	Double Insulator
	2c	Sep Sw4
	3c	Sep Sw2
	4c	Sep Sw1





Satellite BUS – EPS Subsystem



PanaBUS board is powered by the raw power line from the battery

OCP circuits were added at the power lines of each device of the satellite to increase the robustness of the power lines

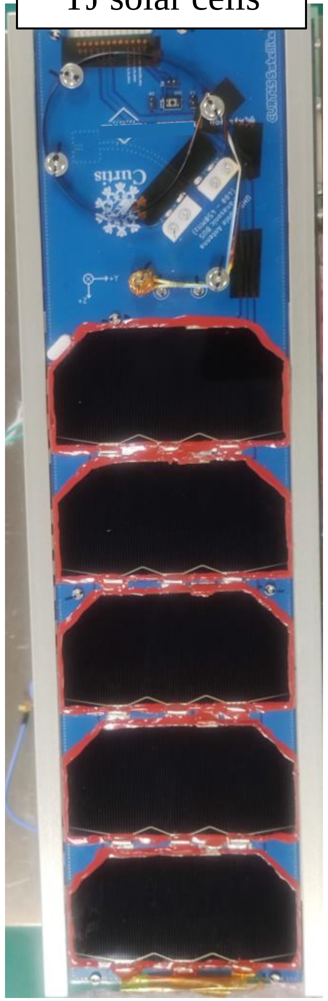
Satellite BUS – EPS Subsystem

Solar cell parameters	
Triple Junction (TJ) Solar Cell assembly 3G30A	
V max power per cell [V]	2.409
I max power per cell [A]	0.503
efficiency	0.293
area [m2]	0.003018

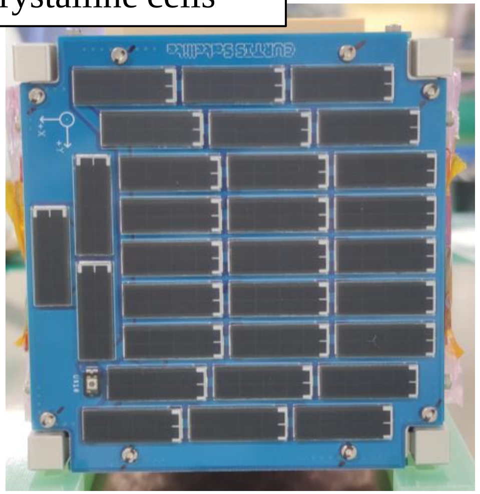
Solar cell parameters	
Monocrystalline (MC) Solar Cell IXOLARTM	
V max power per cell [V]	4.46
I max power per cell [A]	0.0059
efficiency	0.17
area [m2]	0.000122

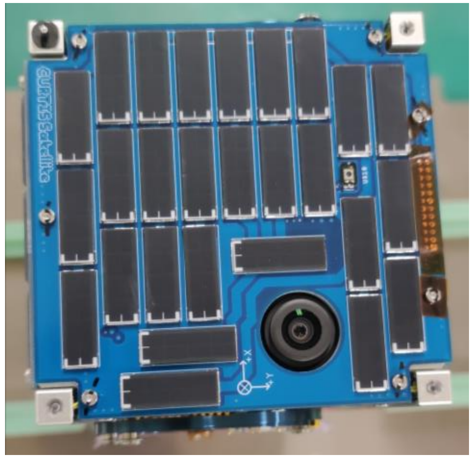
Panel	No. of Cells	Connection	Max. Voltage [V]	Max. Current [A]
+X	5 (TJ solar cells)	5S1P	12.1	0.5
-X	5 (TJ solar cells)	5S1P	12.1	0.5
+Y	5 (TJ solar cells)	5S1P	12.1	0.63
-Y	15 (MC cells)	3S5P	13.4	0.031
+Z	30 (MC cells)	3S10P	13.4	0.063
-Z	27 (MC cells)	3S9P	13.4	0.057

TJ solar cells

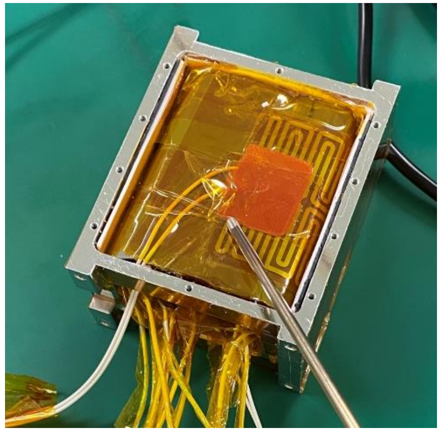


Monocrystalline cells



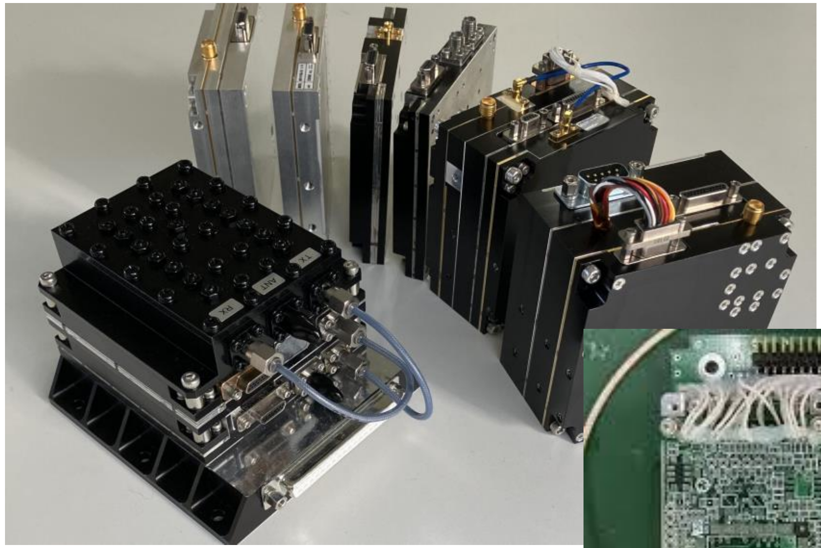


Batteries parameters	
Capacity per cell [mAh]	3350
Voltage avg. per cell [V]	3.6
weight per cell [g]	49.5
size per cell [mm]	18.3x65.3
configuration	2s3p
Voltage total	7.2
Total capacity [mAh]	10050
Energy capacity [Wh]	72.36



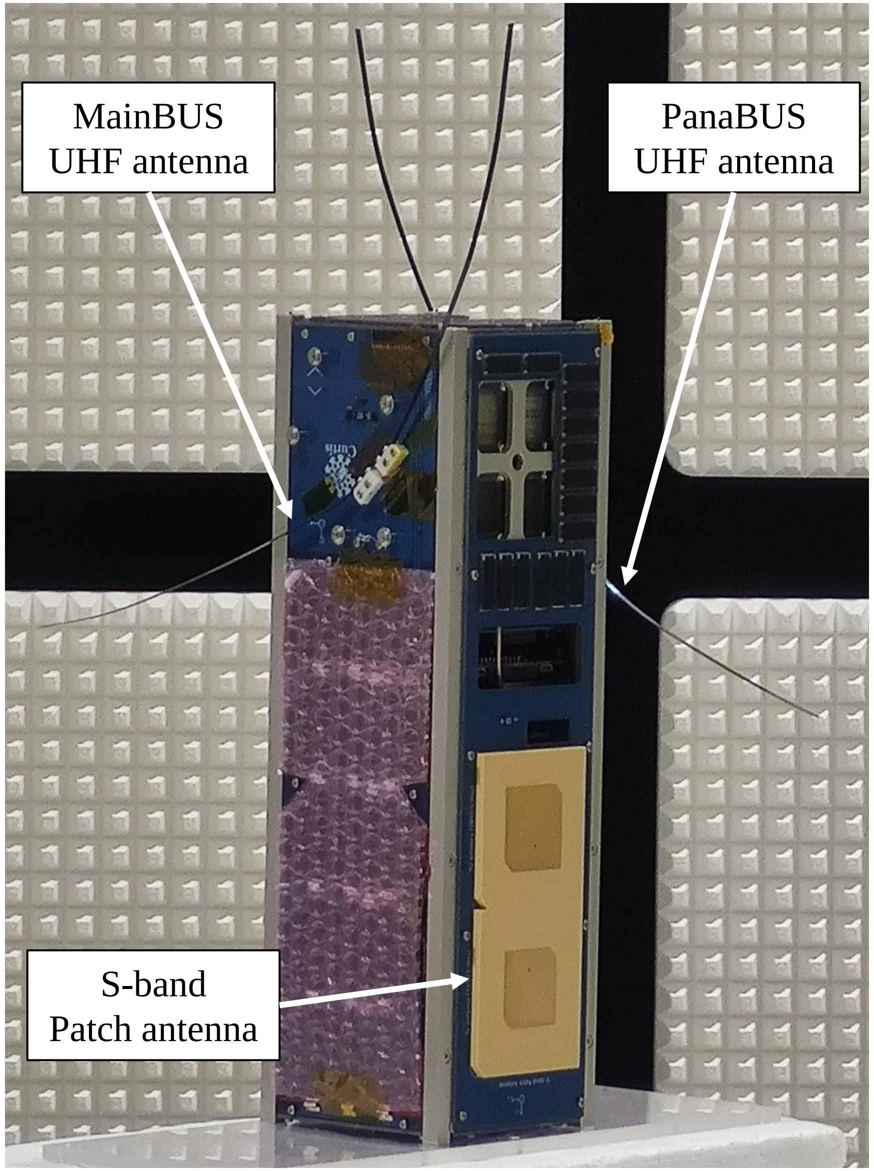
Satellite BUS – COM Subsystem

Specifications	
UHF	UHF transmitter: 400.96MHz, 4800bps UHF receiver: 450.00MHz, 4800bps 1 UHF dipole antenna
S-band	S-band transmitter: 2276MHz, 64kbps S-band receiver: 2096MHz, 4kbps Dual S-band patch antenna



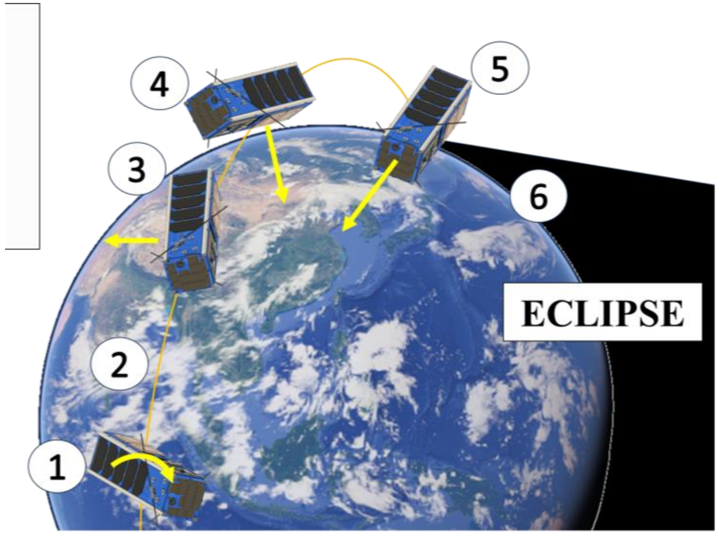
https://addnics.co.jp/

UHF dipole antenna – Folded

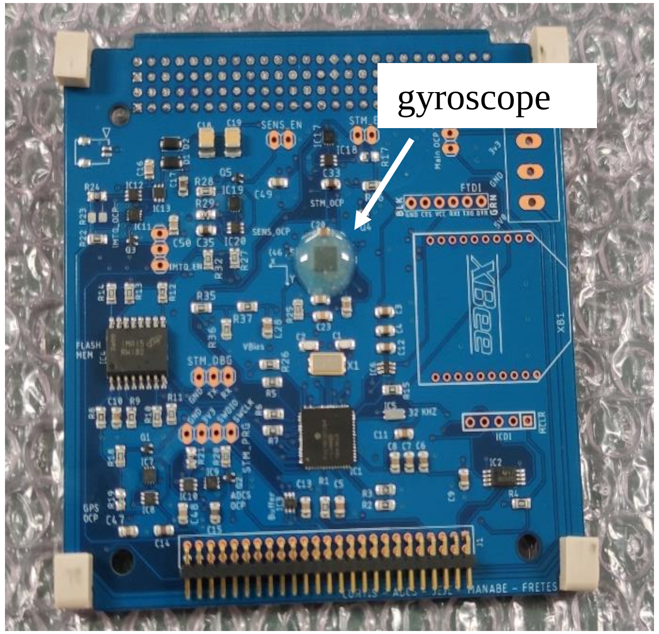


Satellite BUS – ADCS Subsystem

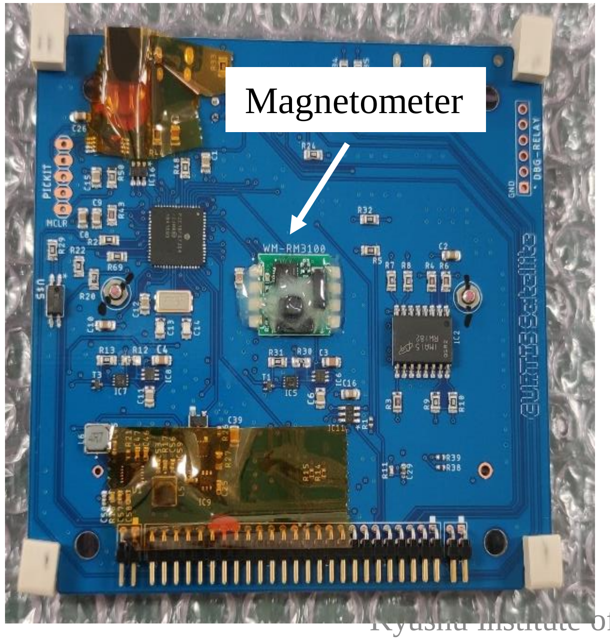
Specifications	
Actuator	ISISpace iMTQ (3 magnetic torquers, 1 magnetometer and a control board)
ADCS hardware	ADCS adapter board: (1 PIC MCU, 1 STM32 MCU, 1 gyroscope) 2 external magnetometers 6 coarse sun sensors 1 GPS module
Attitude control modes	Attitude/orbit acquisition, Detumbling, Sun tracking, Nadir pointing (S-band comms), Nadir pointing (Camera)



ADCS adapter board

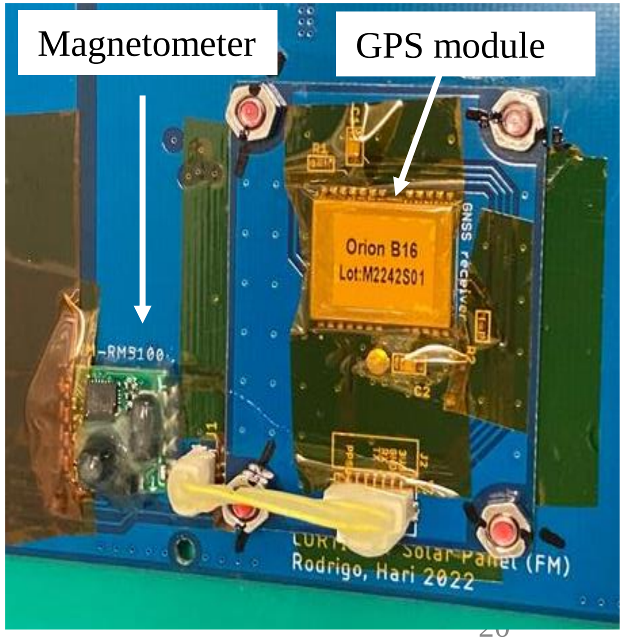


PCIB



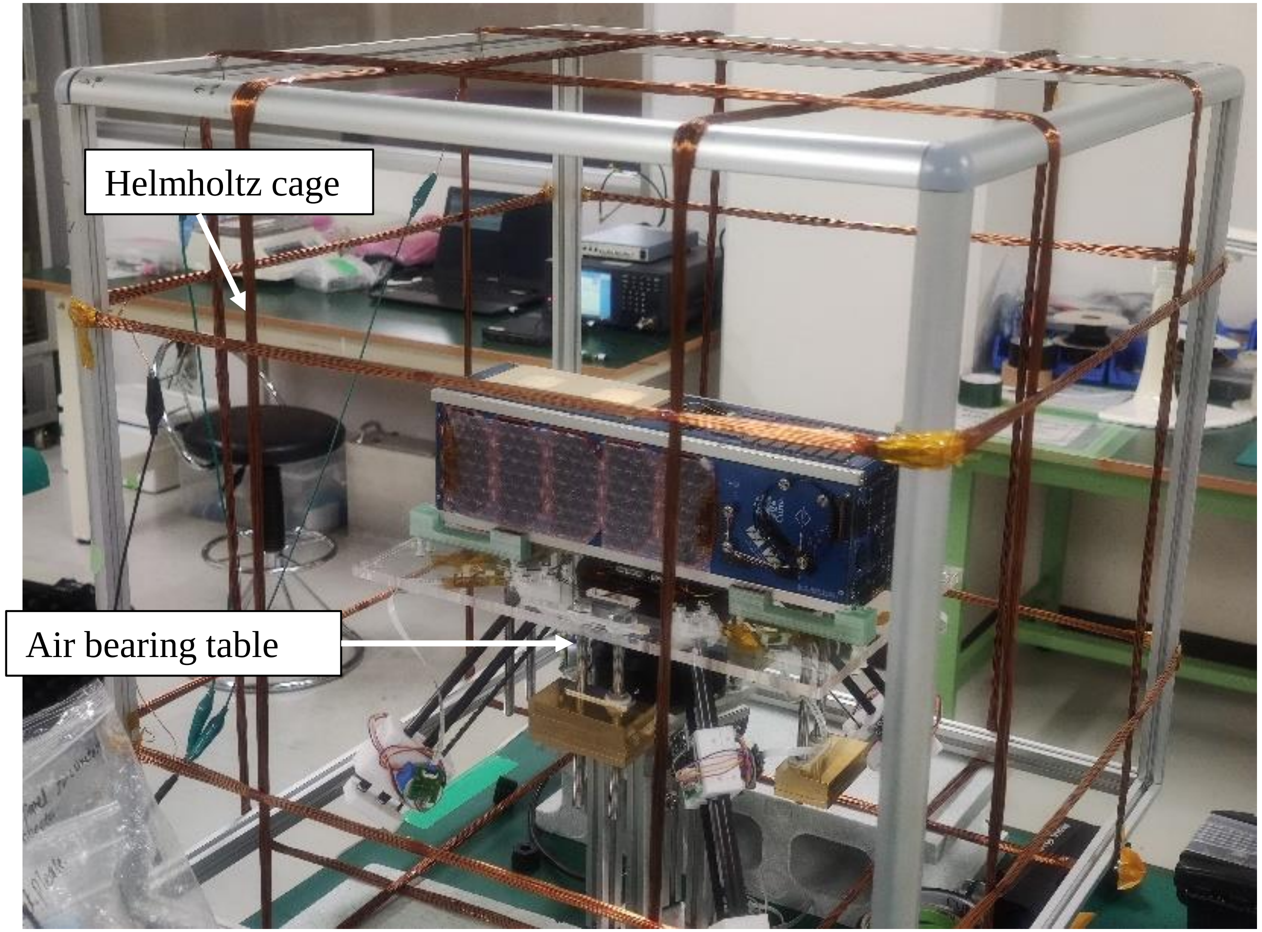
IMTQ

+Y Panel (GPS, magnetometer)



Satellite BUS – ADCS Subsystem

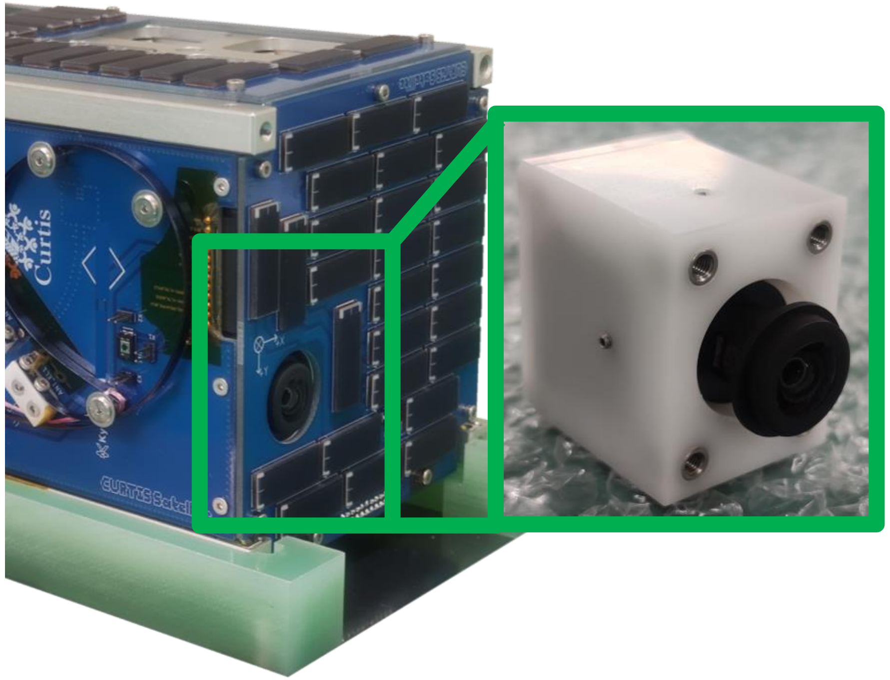
Calibration of sensors and hardware-in-the-loop test in Kyutech facilities

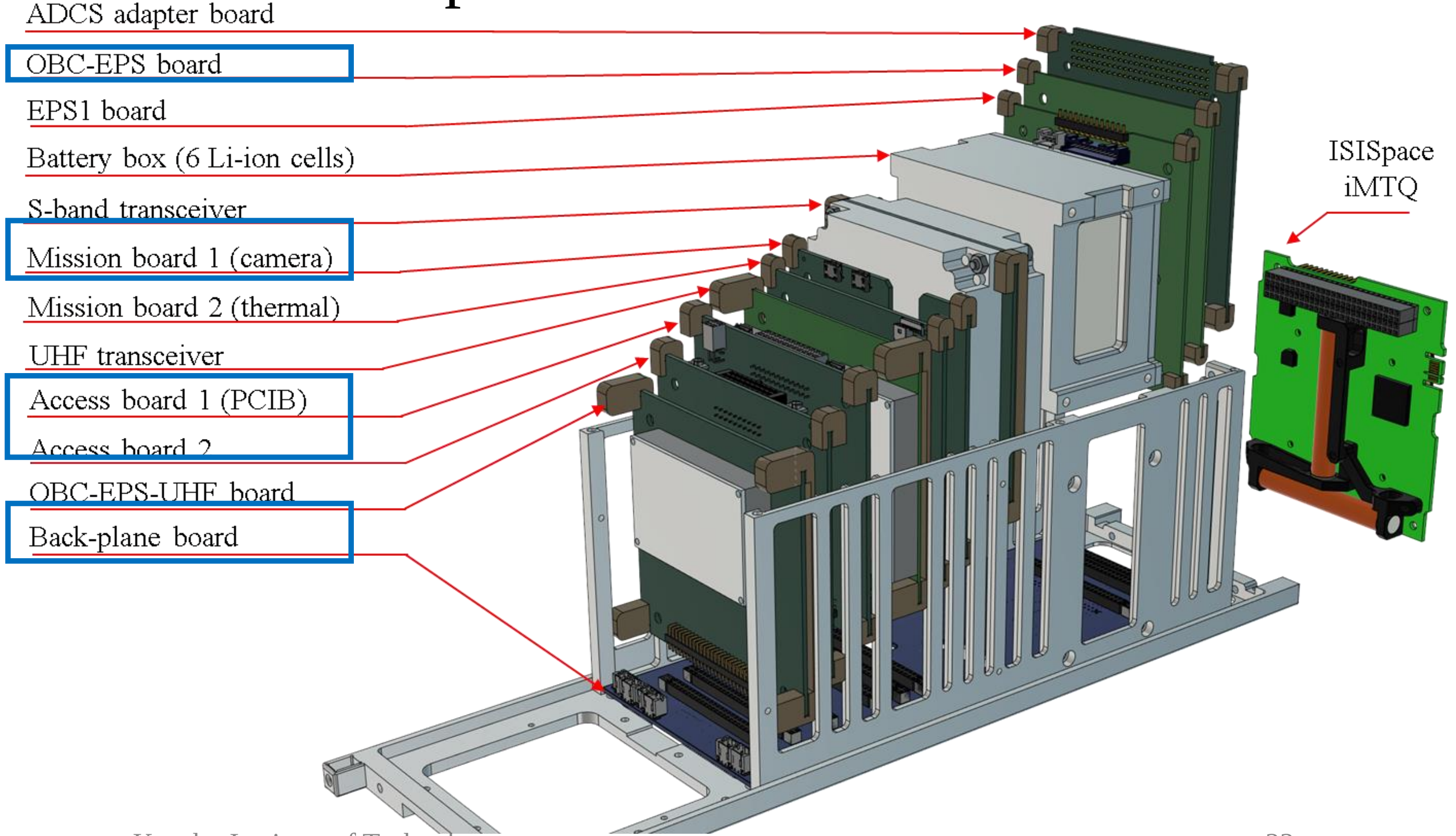


Satellite payloads

CURTIS missions:

- Earth imagery using an in-vehicle camera module
- CMOS sensor with a resolution of 2.6Mpix and camera lens field of view angle of 62.5deg.





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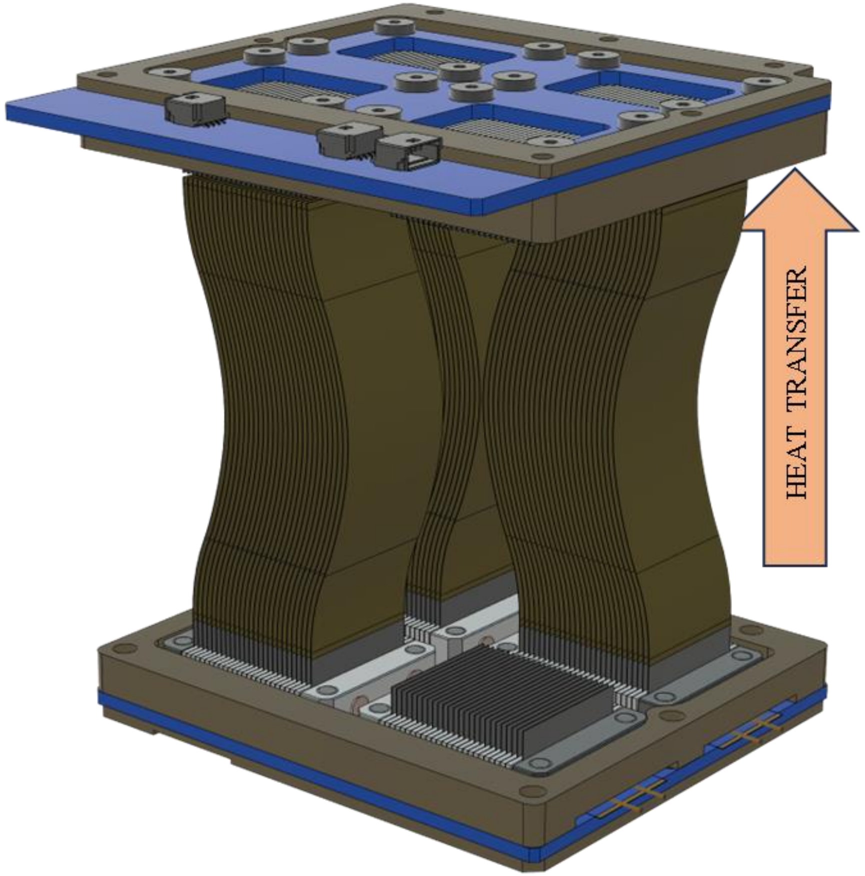
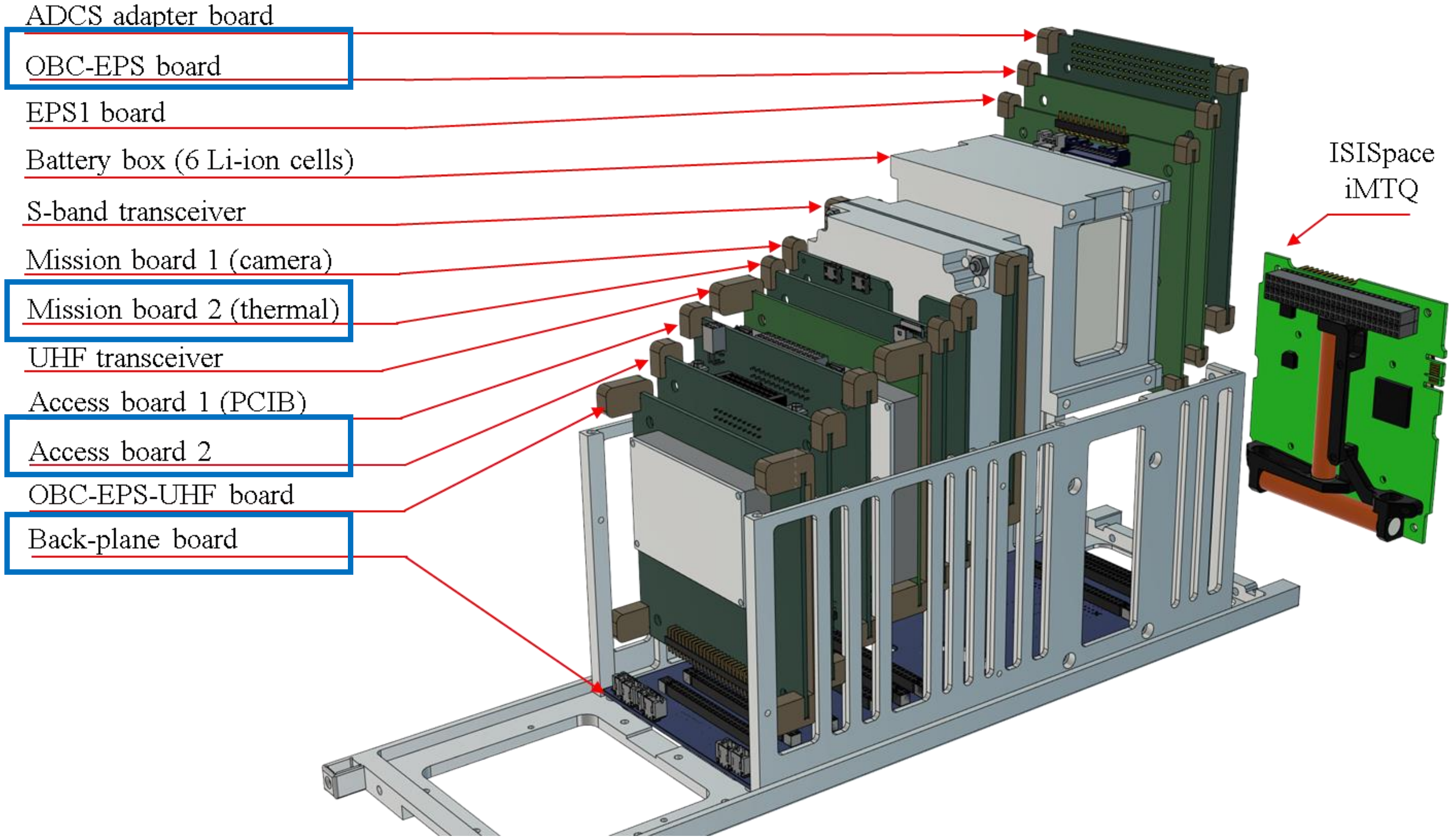
Satellite payloads

CURTIS missions:

- Thermal conductivity experiments of surface-coated graphite materials





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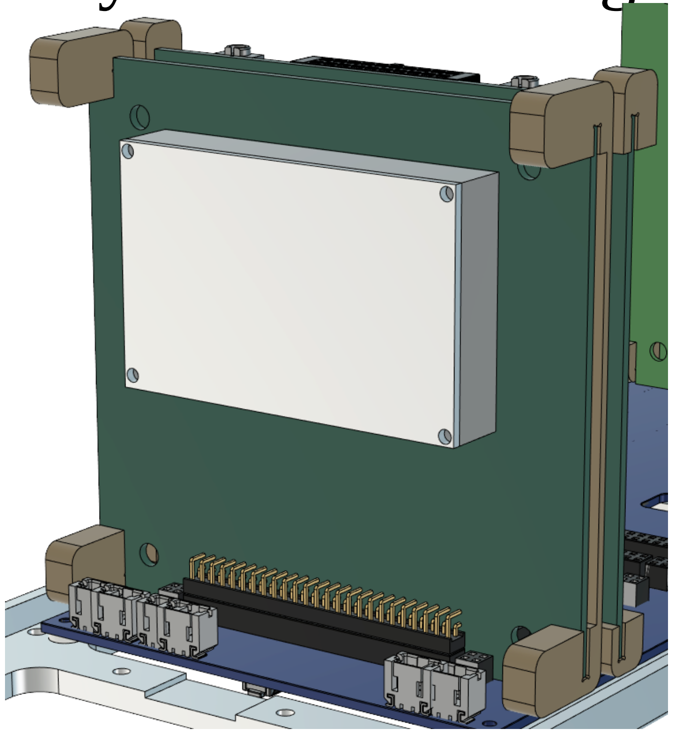
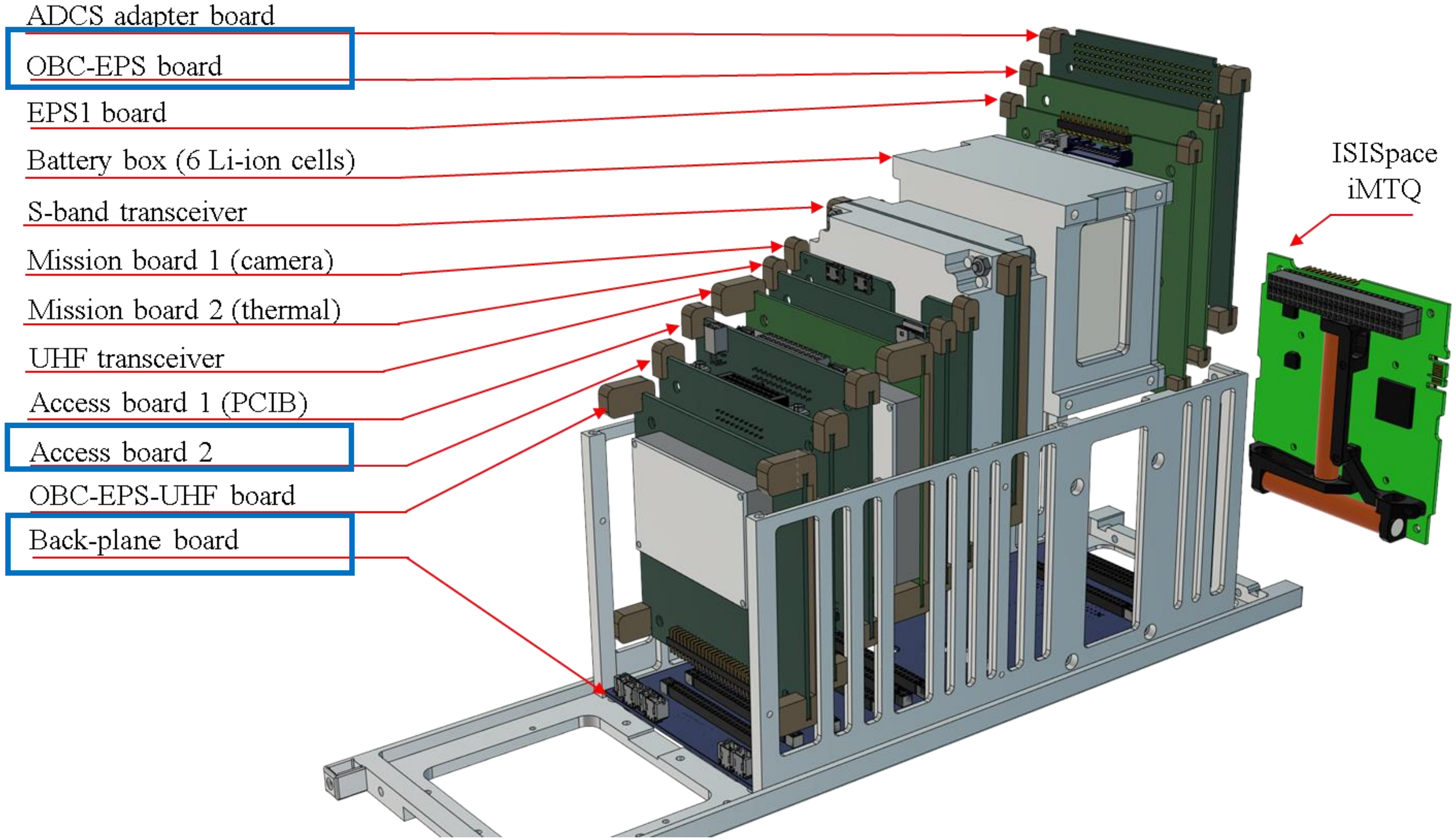
Satellite payloads

CURTIS missions:

- Demonstration of a highly integrated OBC-EPS-UHF board based on Kyutech BUS design





https://digitalcommons.usu.edu/smallsat/2023/all2023/198/

Project lifetime – Lean development

Kick-off meeting (Apr ‘21)

MDR meeting (October ‘21)

CDR meeting (Apr ‘22)

Delays in the project

FRR meeting (Aug ‘23)

Delivery (Dec ‘23)

Launch (Mar ‘24)

Design, manufacture and test of the engineering model

FM manufacture, integration and environmental test

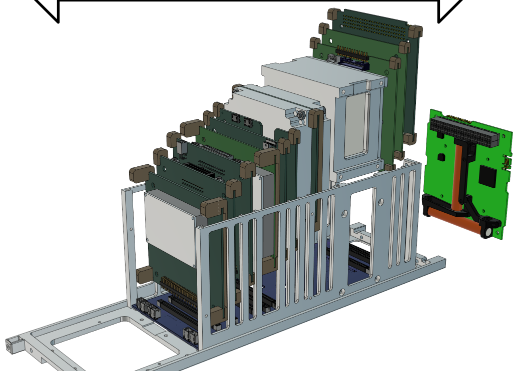
Integration of FM satellite (Apr ‘23)

Definition of the missions, team and schedule

Verification of the mechanical and system interfaces

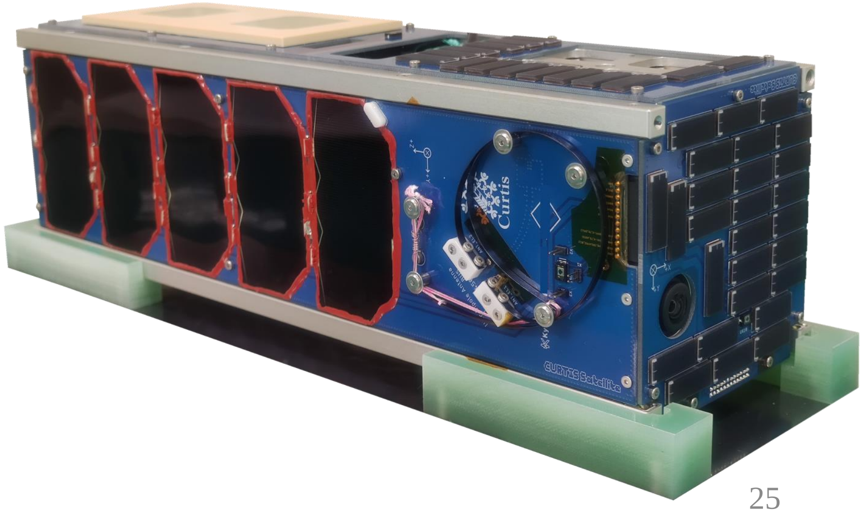
Definition of system architecture based on Kyutech BUS and flight heritage components

Design and test of the slot-type based structure



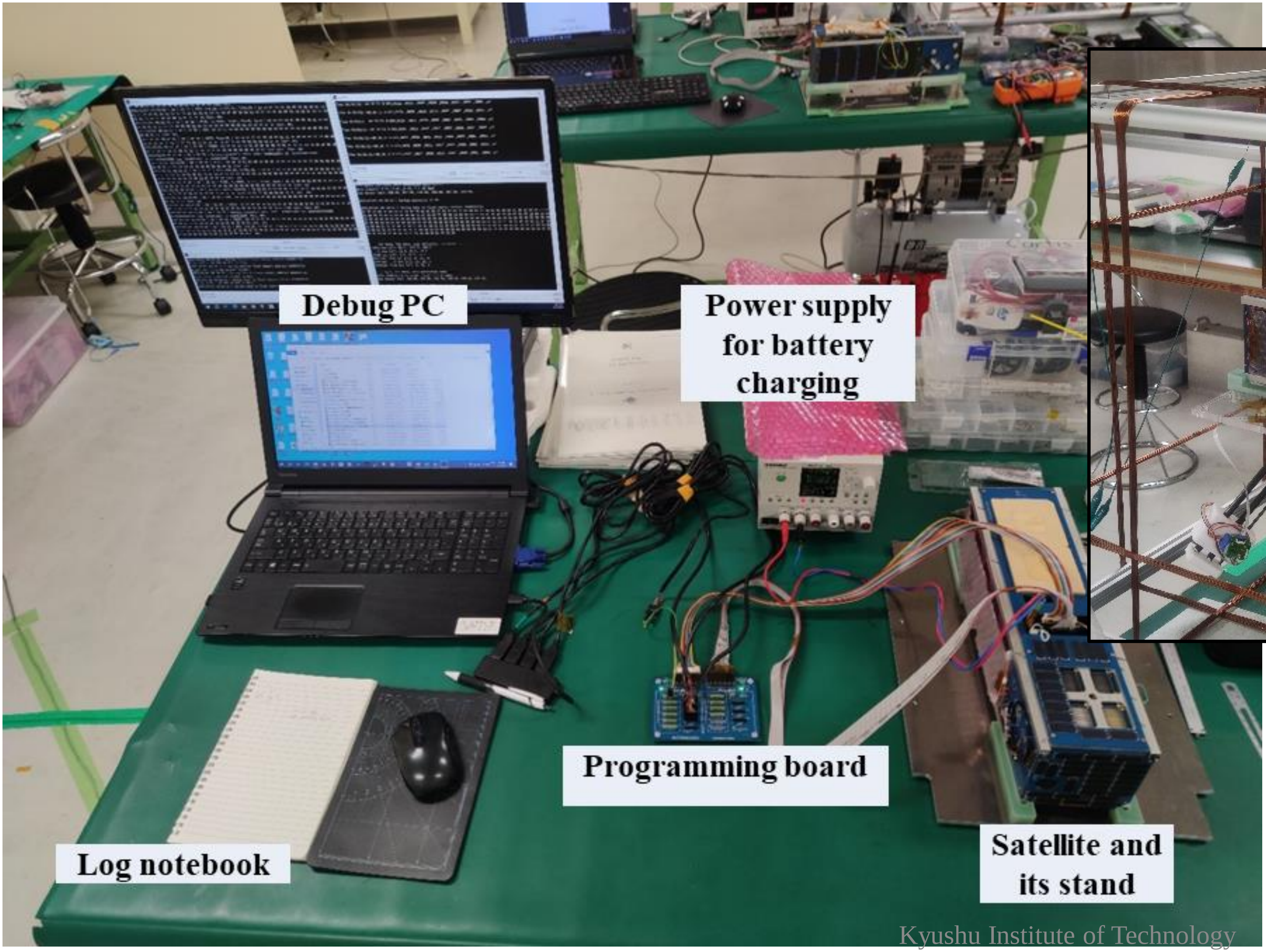
Verification of operations of the BUS and payloads

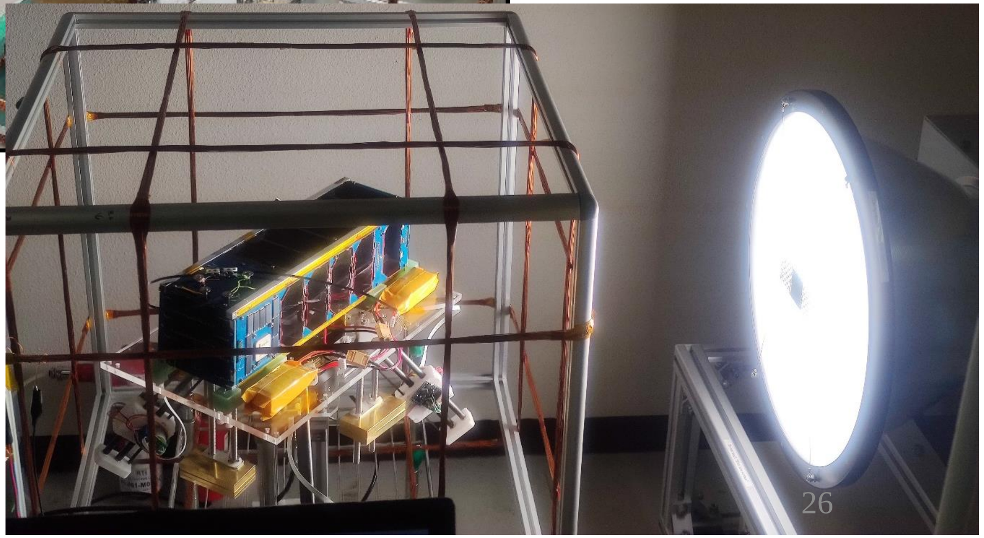
Preparations of the GS operations



Identification of issues and solutions implemented in FM

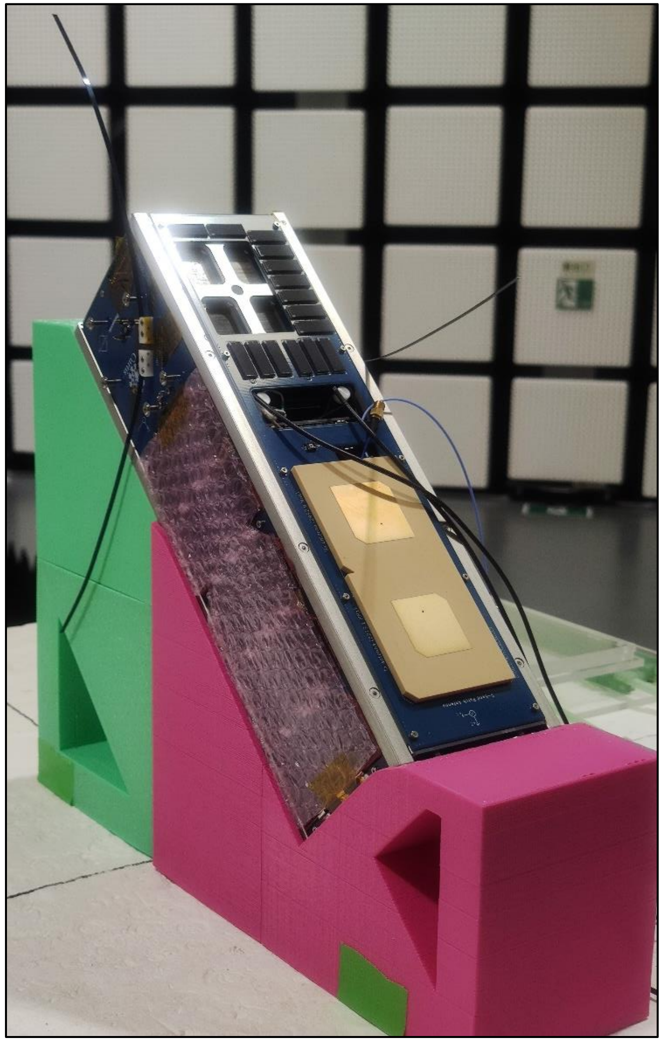
Project lifetime – Lean development



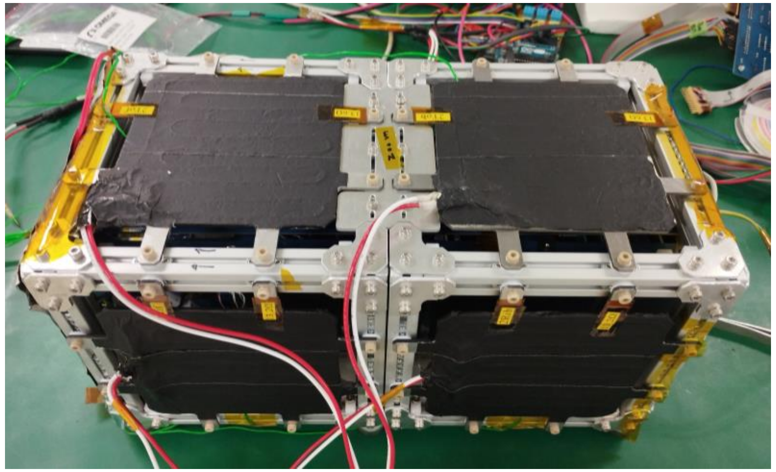


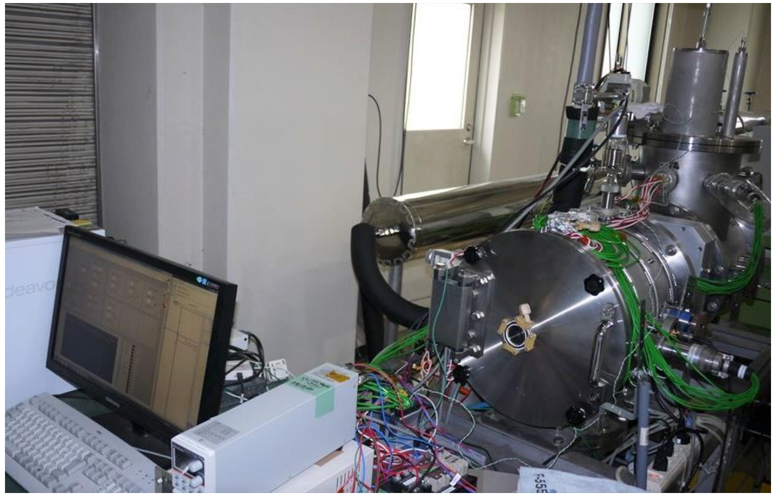
Project lifetime – Environmental tests

EMC test picture

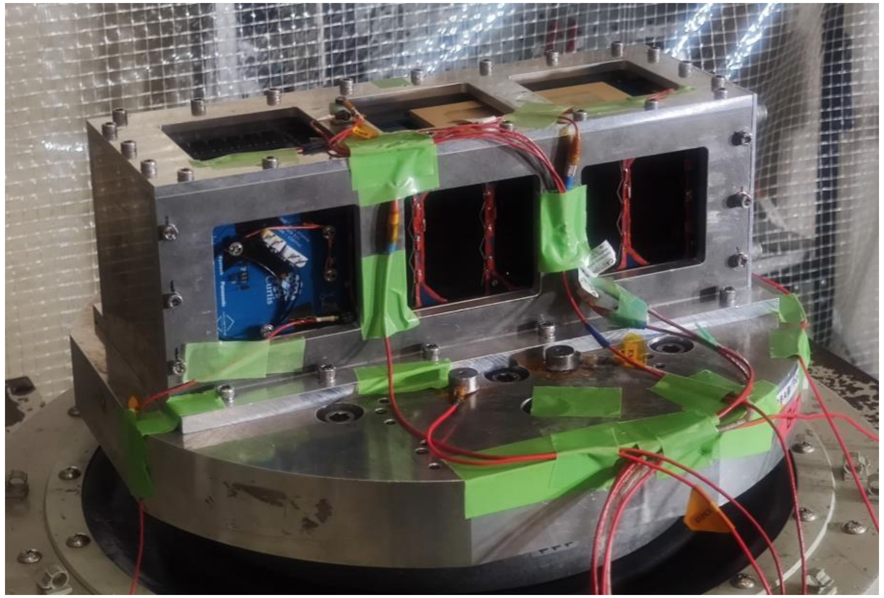


TVT test picture

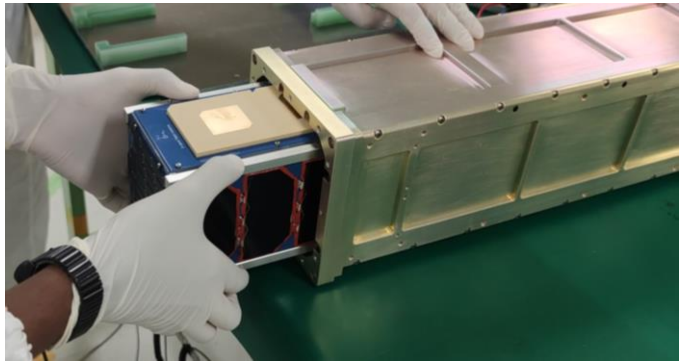




Vibration test picture



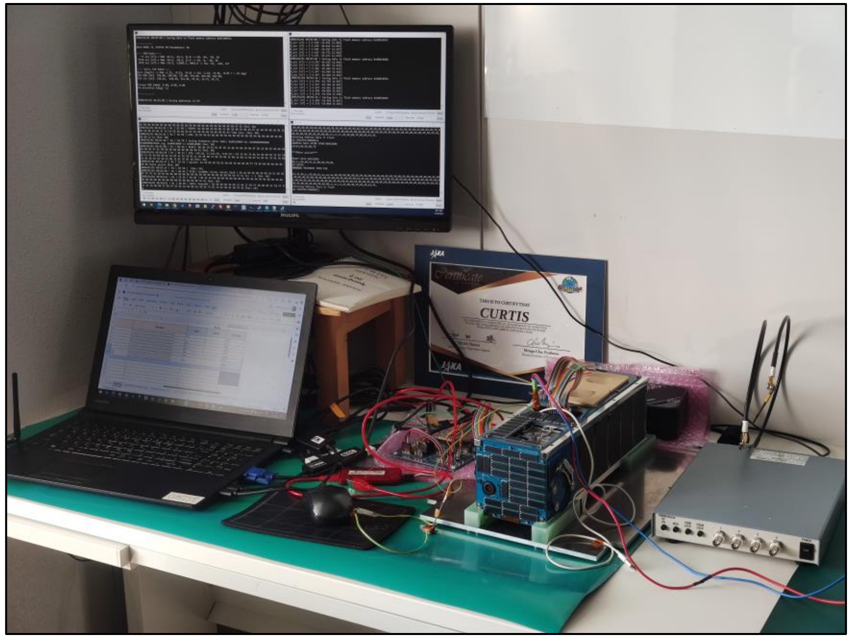
Fit-check test



Release from ISS

Ground station and UHF operations

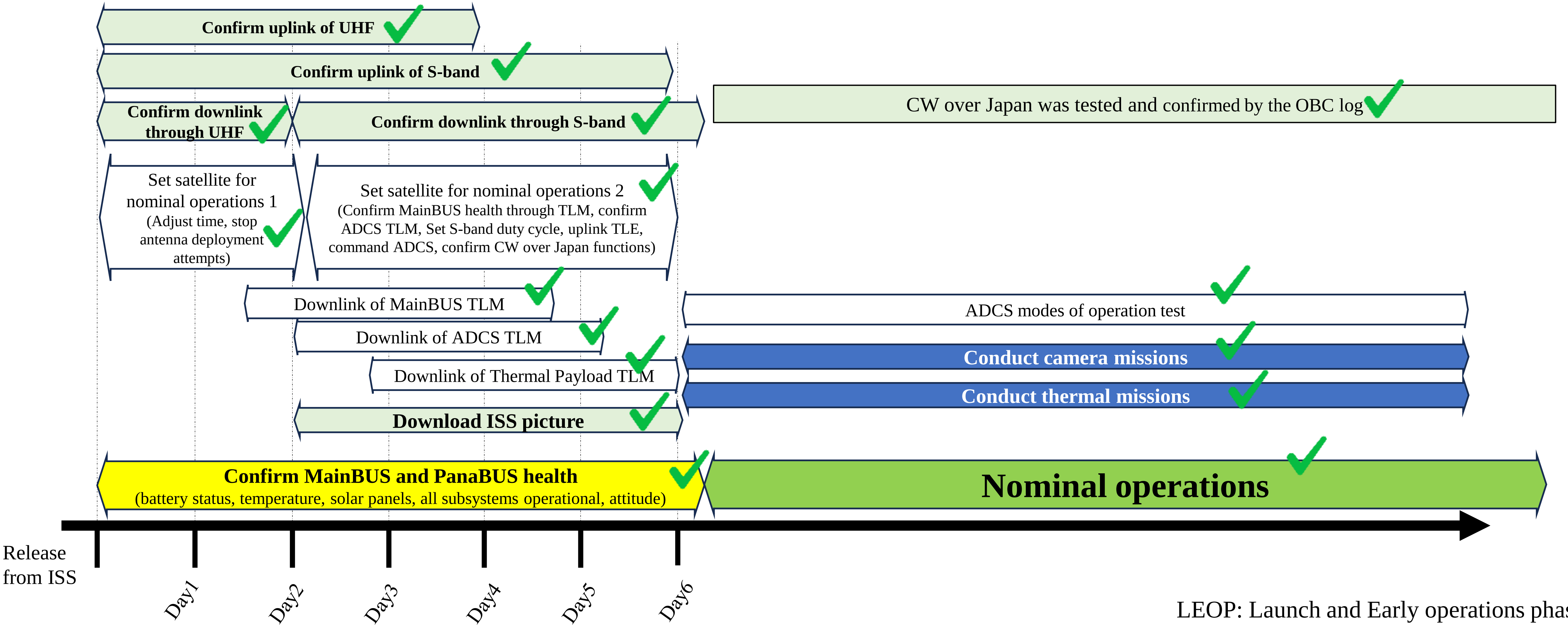
The EM satellite was used as testbed for mission planning, debugging and testing of commands



UHF ground station setup

Preliminary operation results

From LEOP to Nominal operations



LEOP: Launch and Early operations phase

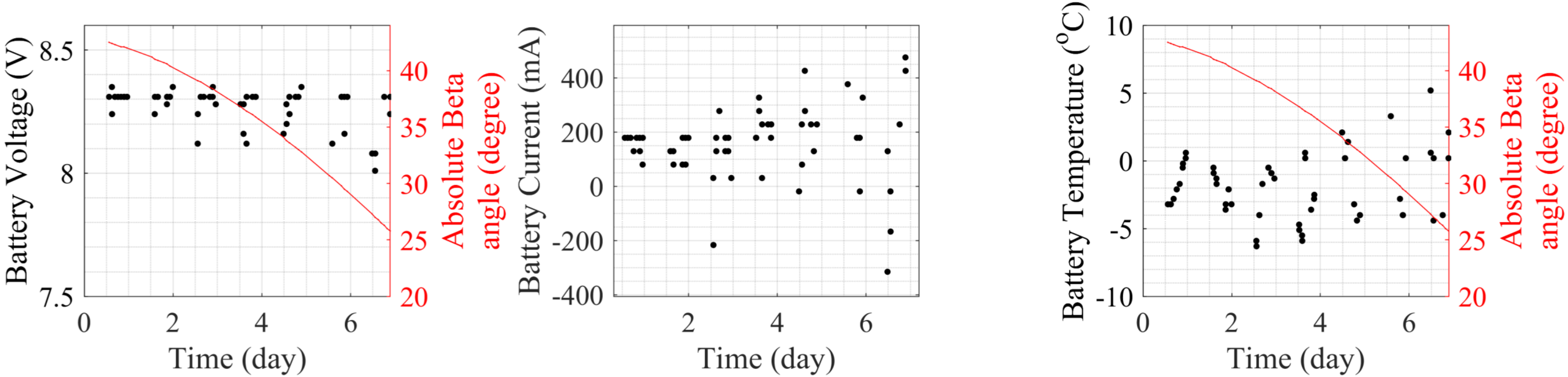
Preliminary operation results

Battery status after deployment into orbit:

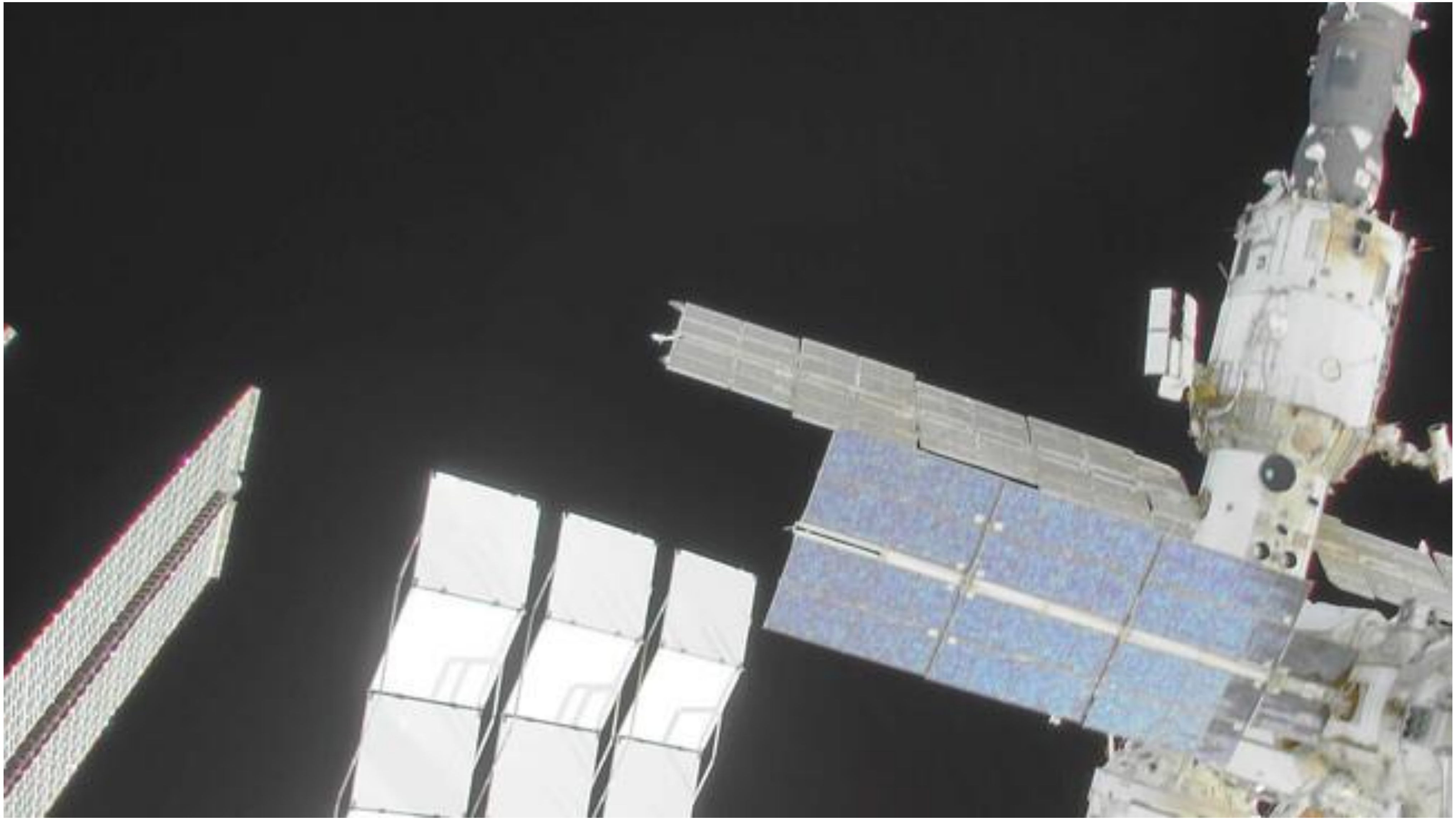
- Battery voltages and current information were nominal
- Temperature of the battery and the satellite is cold generally
- Power generation were confirmed.

From CW message, we confirmed that all subsystems were operational

CW #1 data



Preliminary operation results

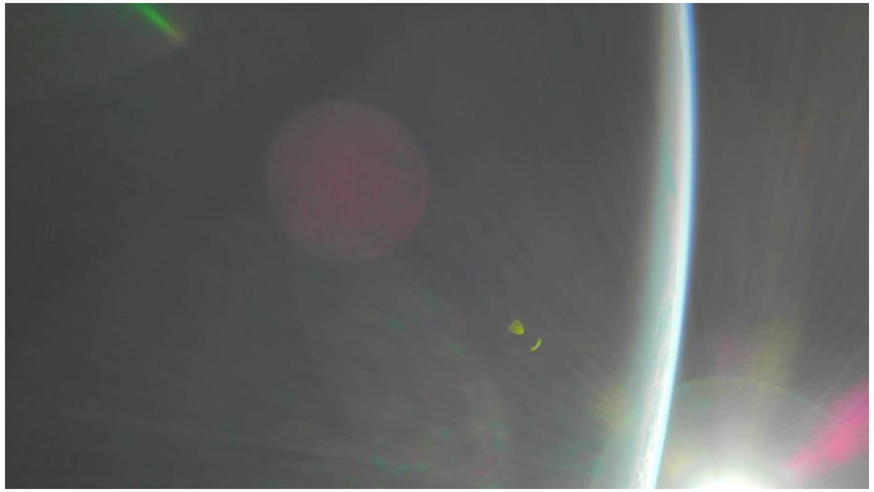


Picture taken at 12 seconds after the release from ISS
- S-band downlink

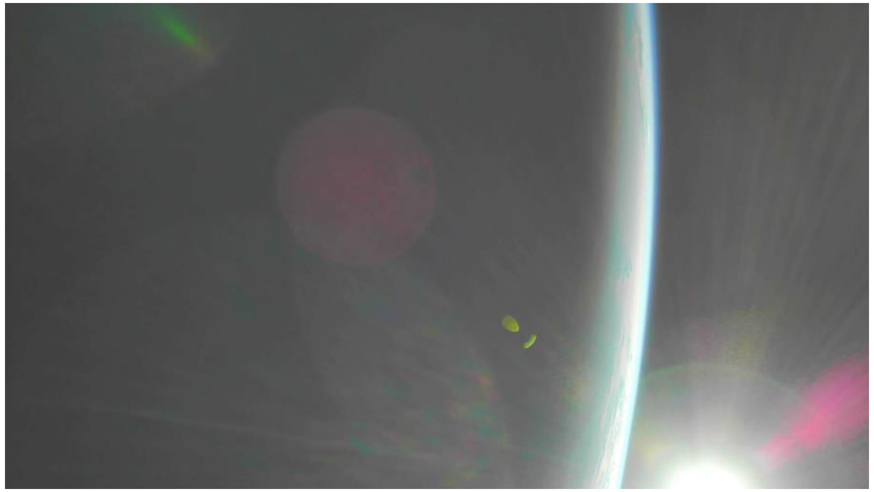
Preliminary operation results

Pictures taken during Nadir pointing maneuvers (patch antenna facing towards Earth)

Patch antenna side



Patch antenna side



Patch antenna side

Patch antenna side

Preliminary operation results

Picture taken over Kansai region, Japan

Lessons learned – Teamwork

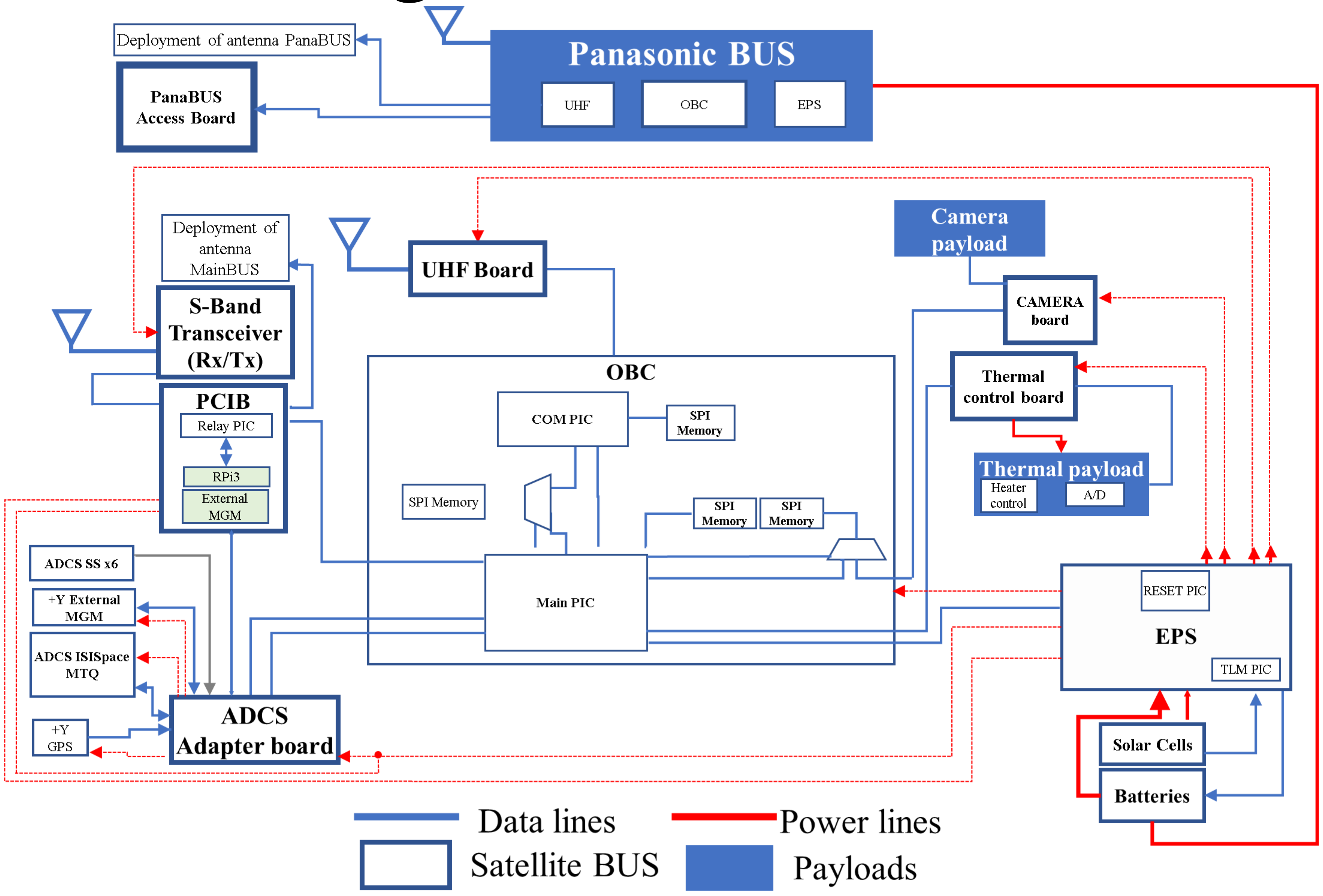
- Understand the system architecture of the satellite is a must
- Understand mechanical interfaces is essential to ensure the correct design of electronic boards
- Understand electrical interfaces is essential to ensure correct operation of the subsystems and avoid any short circuits
- Understand the overall schedule of the project
- Keep the workplace organized

Lessons learned – Integration and test

System architecture serves as a reference to:

-**Verify** the interfaces of the satellite

- **Complete** all the functional tests to ensure the operations of the payloads **<u>during all the project lifetime</u>**



Lessons learned – Integration and test

- Slot-type based was very useful during the test of individual subsystems since they can be easily removed from the satellite
- Mechanical tolerances were important to keep when fabricating the spacers for the subsystems
- Fully functional EM was essential during the development and test of the FM.
- Extensive test is essential for the development of an FM:
  - Extensive functional tests
  - Long duration test to find any software bug
  - End-to-end test to understand the operations of the satellite

Thank you!

Rodrigo Cordova, Ph.D.

Laboratory of Lean Satellite Enterprises and In-Orbit Experiments (LaSEINE)
Kyushu Institute of Technology
cordova.rodrigo207@mail.kyutech.jp