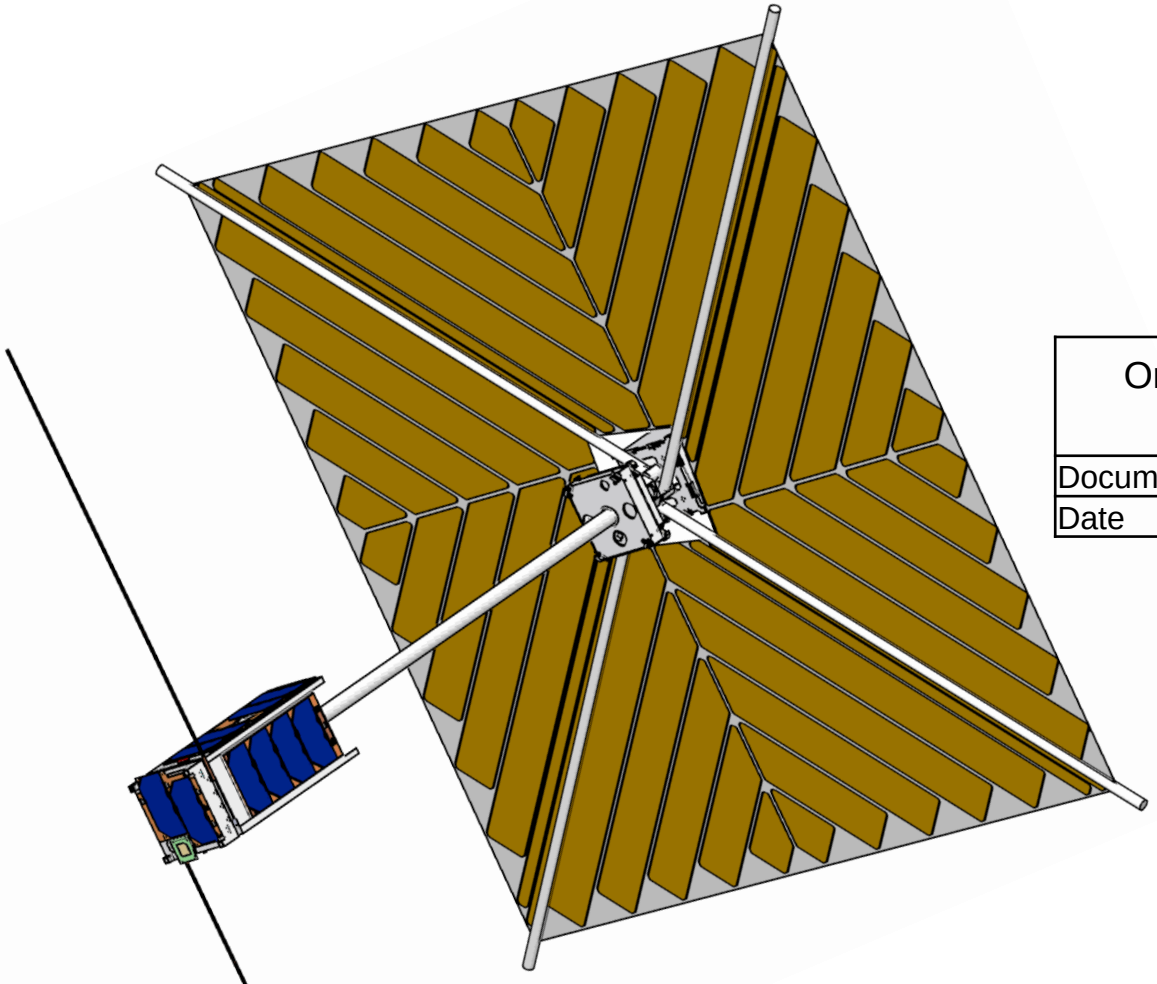
OrigamiSat-1

Launch/operation report（As of Sept. 2019）



OrigamiSat-1 Launch/operation report （As of Sept. 2019）			
Document #	OP-S1-0124	Version #	Ver. 1.0
Date	2019/09/18		

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Summary and contents

Summary: **3U CubeSat OrigamiSat-1 / FO-98 (JS1YAX)** was launched into the prescribed orbit (500km altitude Sun-synchronous orbit) on Jan. 18, 2019 at 10:57JST by the Epsilon-4 rocket. **Just after the successful launch, the satellite and the ground station successfully established uplink/downlink communication.**
However,
- After 6.5 days of operation (CW/FM downlink, FM uplink), CW downlink from the satellite stopped.
- After the signal loss, 5.8GHz downlink mission was tried, but no response was heard until Jun. 1, 2019.
- Between Jun. 3 and Jul. 24, membrane deployment commands were sent, but no significant change in satellite altitude was observed. This implies that the membrane has not been deployed.

This document reports the situation of satellite operation after the launch, basically for amateur radio operators, who sent a significant amount of on-orbit data.

Contents:

1. Satellite Overview

3 missions [Mission 1～3] / System configuration /
System diagram / Mission sequence / Development team

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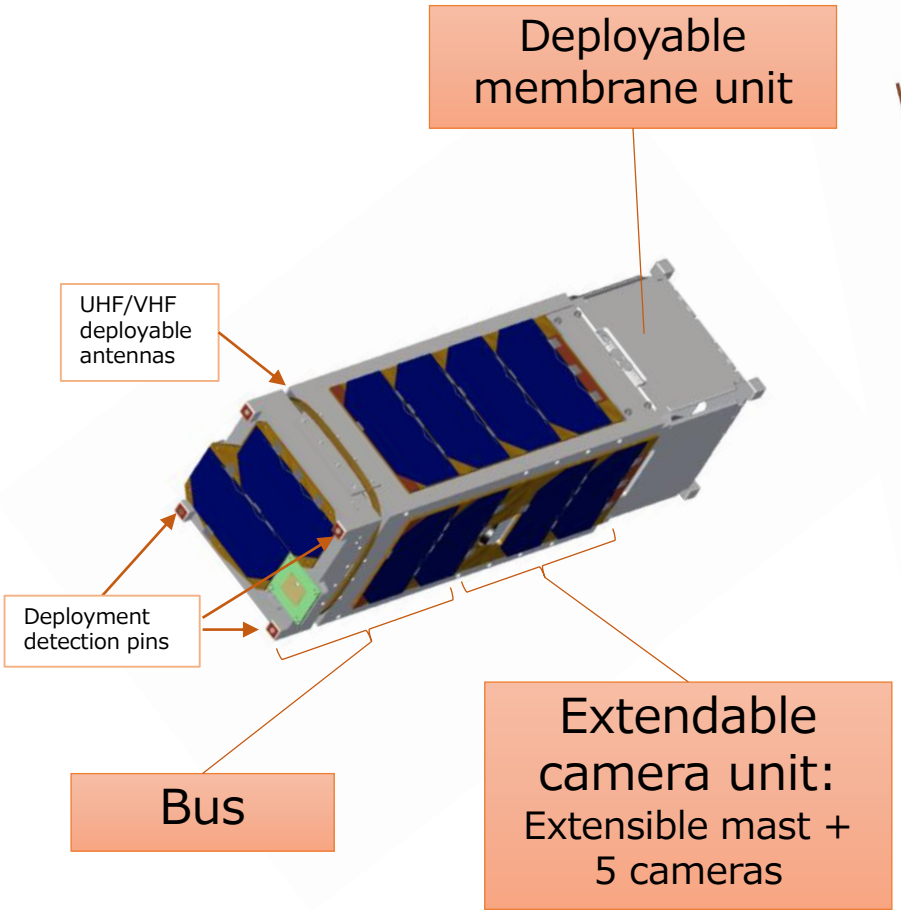
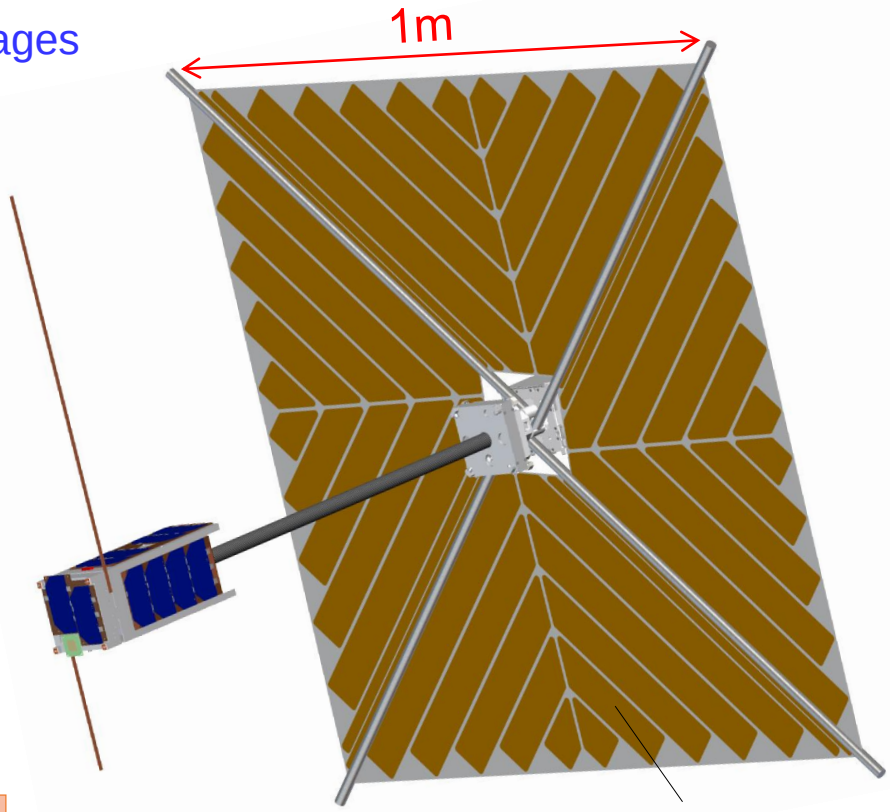
3U CubeSat OrigamiSat-1 / FO-98

X: 100 × Y: 100 × Z: 340.5 mm

4.1 kg

Implementing 3 missions, described in next pages





Deployed configuration

[Mission 1] Deployment of multi-functional membrane **EM model**

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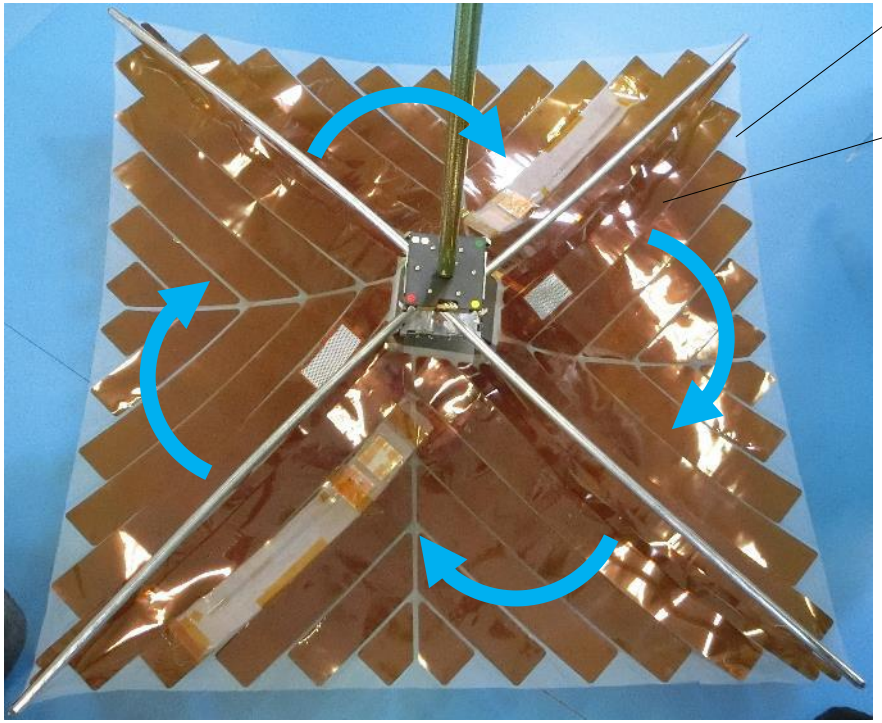
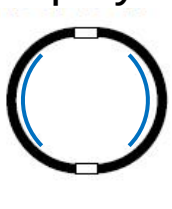
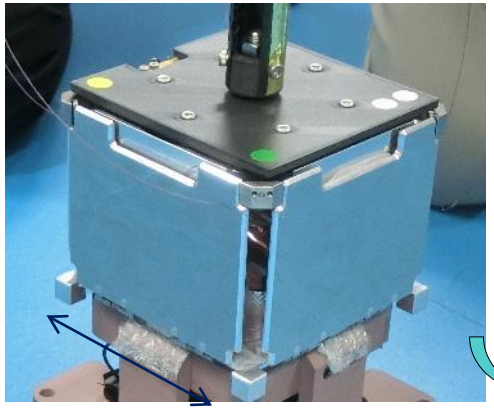


82μm-thick Polyester plain-woven fabric

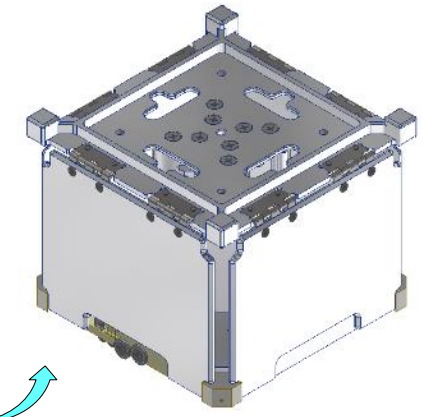
75μm-thick Polyimide film (Dummy for thin-film solar cells etc.)

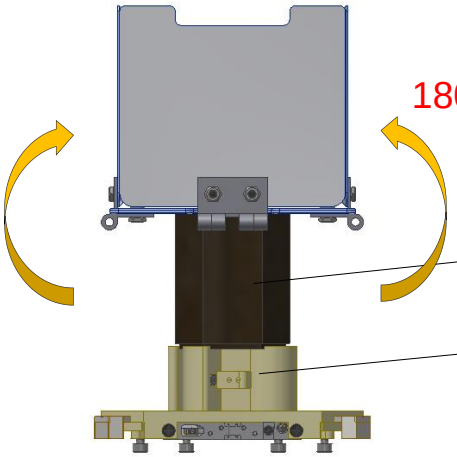


Tubular CFRP boom
(2 metallic convex tapes are installed)



Flipped





[Mission 1] Deployment of multi-functional membrane FM model

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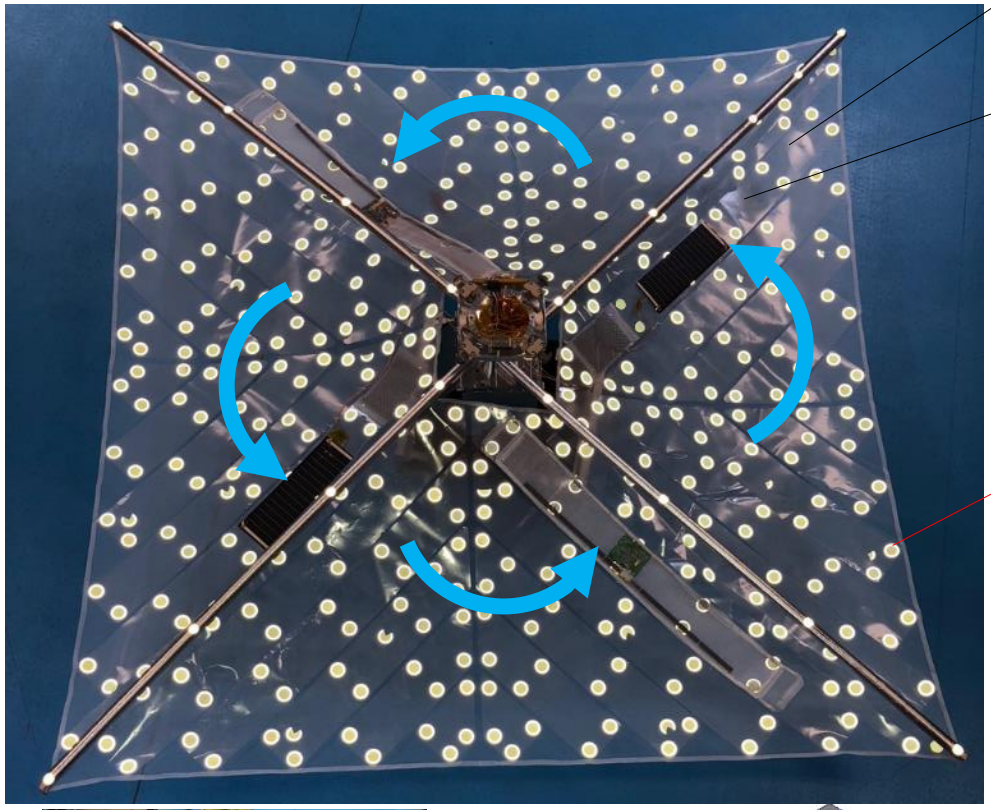
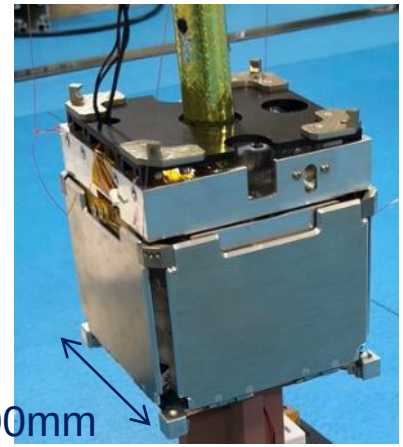


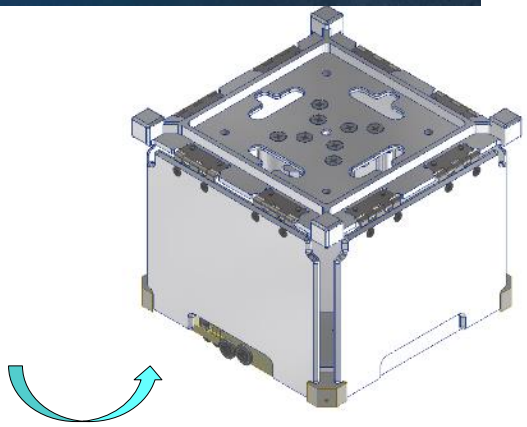
82μm-thick Polyester plain-woven fabric

50μm-thick Superio-UT film (Dummy for thin-film solar cells etc.)
- Transparent film is used to reduce the shadowing effect on the satellite bus.
- Following actual devices are attached: **CIGS thin-film solar cells**, **On-membrane SMA antenna**, **Sphere solar cells**.

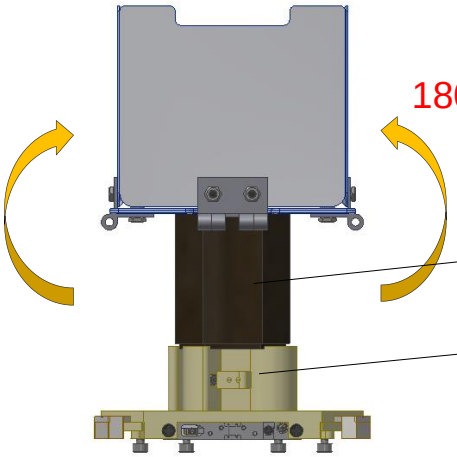
Retro-reflective markers are attached throughout the membrane for shape and deployment motion measurement



100mm



Flipped



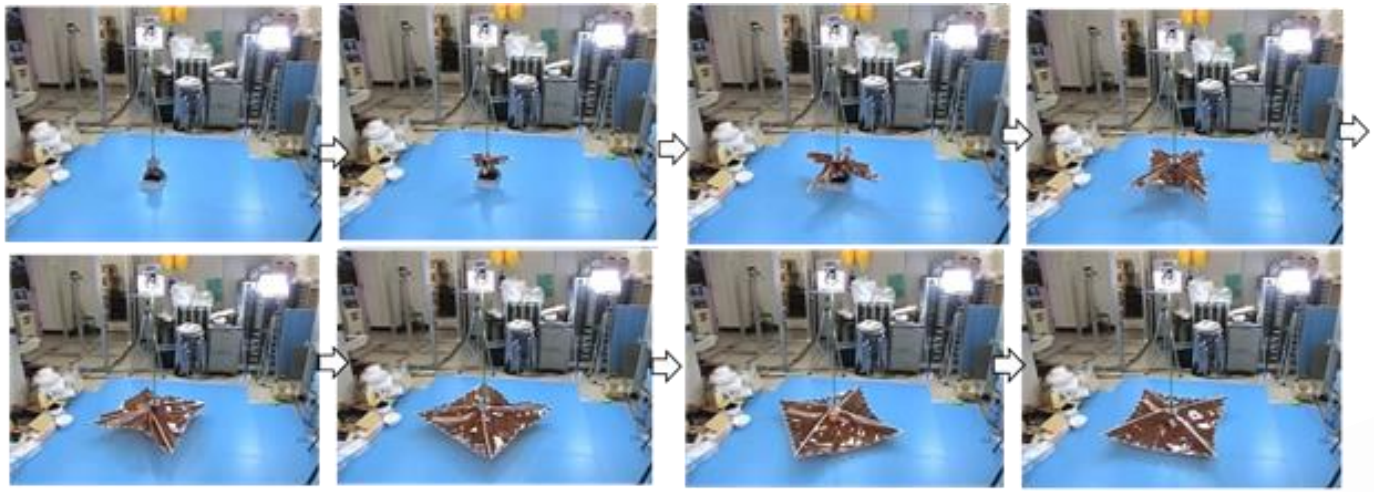
180 deg deployment

Hub for membrane

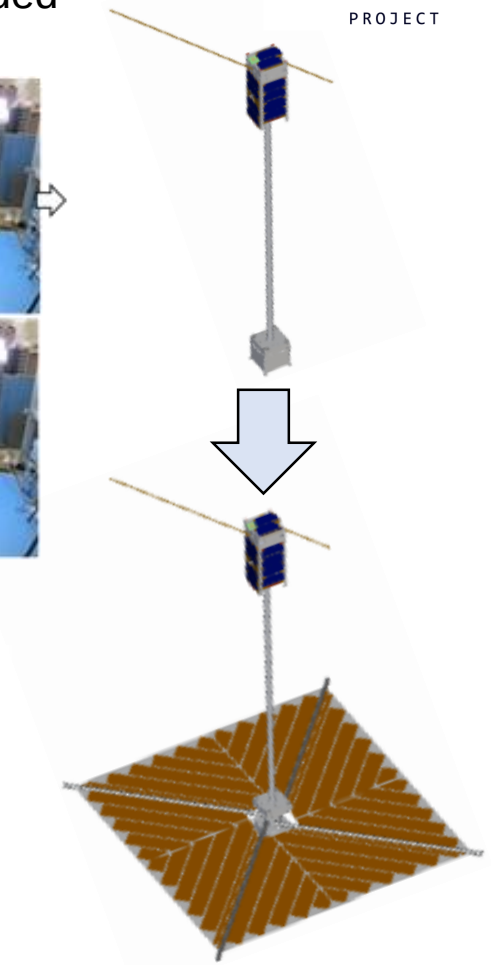
Hub for CFRP booms

Ground deployment test with extendable mast

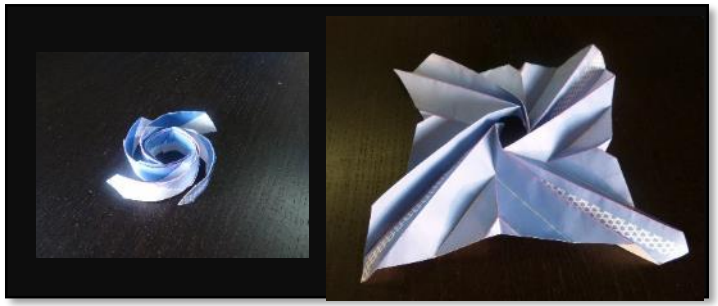
- Four membrane corners (four membrane boom tips) are suspended from ceiling

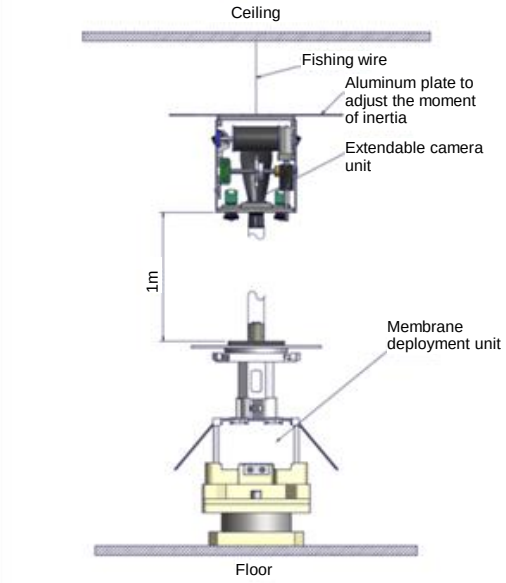


(Apr. 2017, at Hiroshi Furuya Lab, Tokyo Tech)



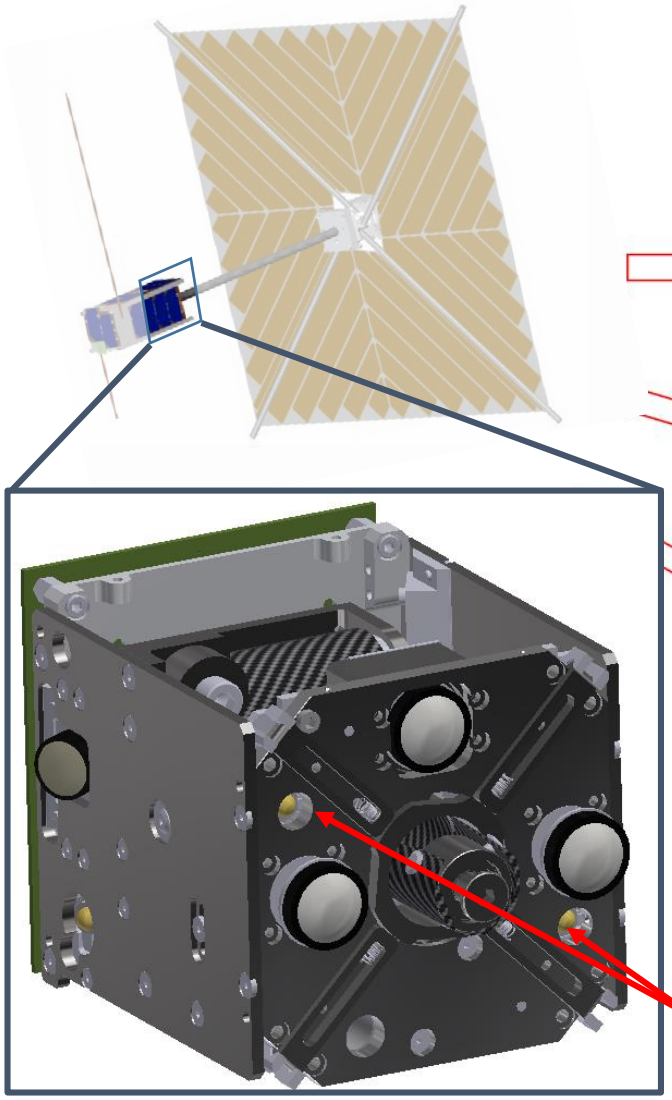
Ref: Folding pattern demonstration using Origami



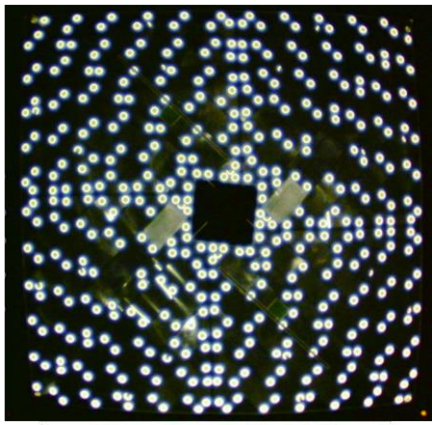


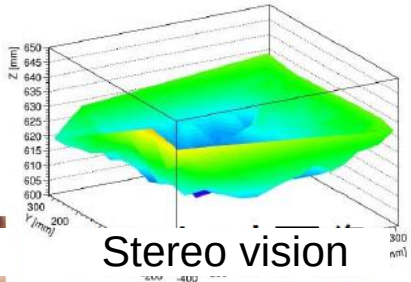
[Mission 2] On-orbit measurement of deployable structures using cameras

- ✓ **Measurement of**
  1. **Deployment dynamics**
  2. **Deployed shape**



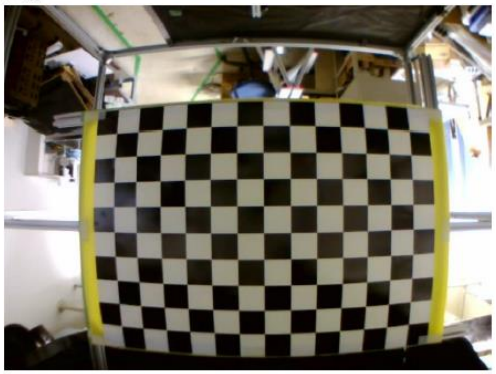
Photos





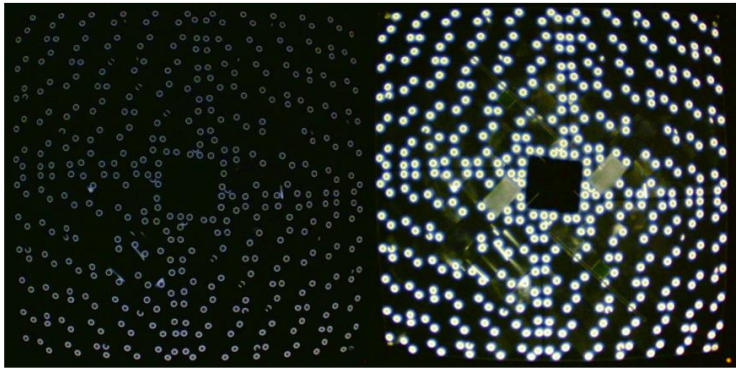
Movie

Stereo vision



White LED: Light source for camera shooting

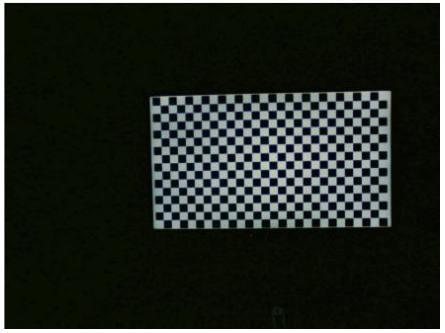
Estimation of out-of-plane shape by stereo vision

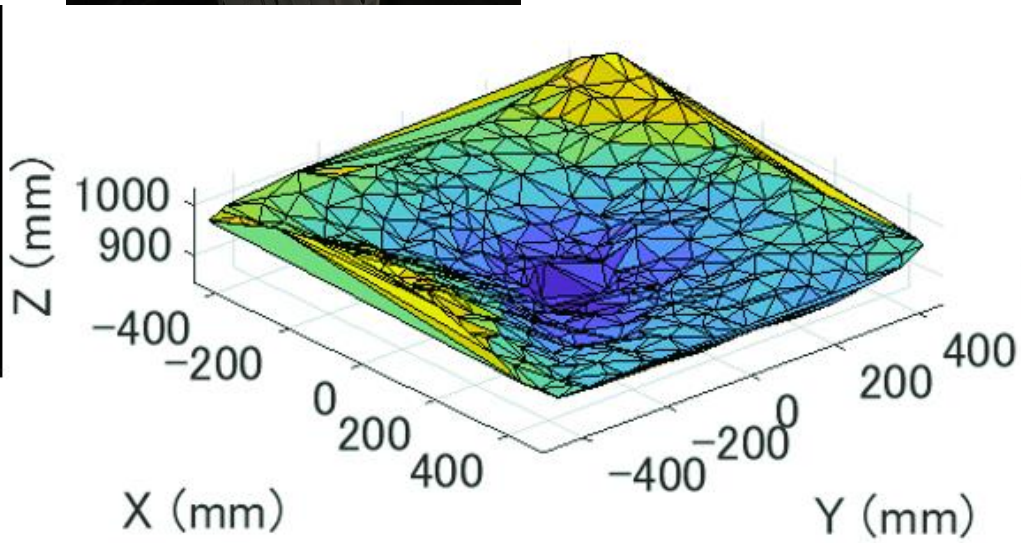


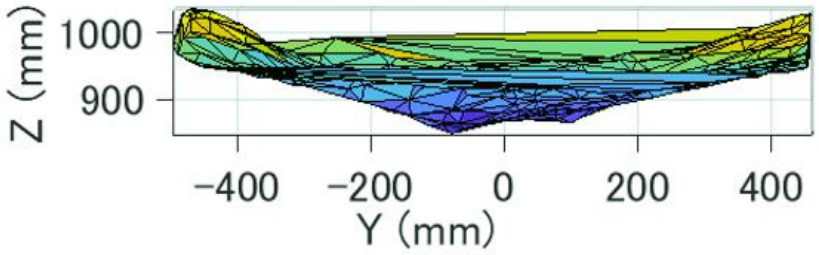
2592 × 1944
325KB

Accuracy evaluation using checker board (1m distance)

Lens distortion correction	Standard deviation
Without correction	4.8 mm
With correction	4.0 mm

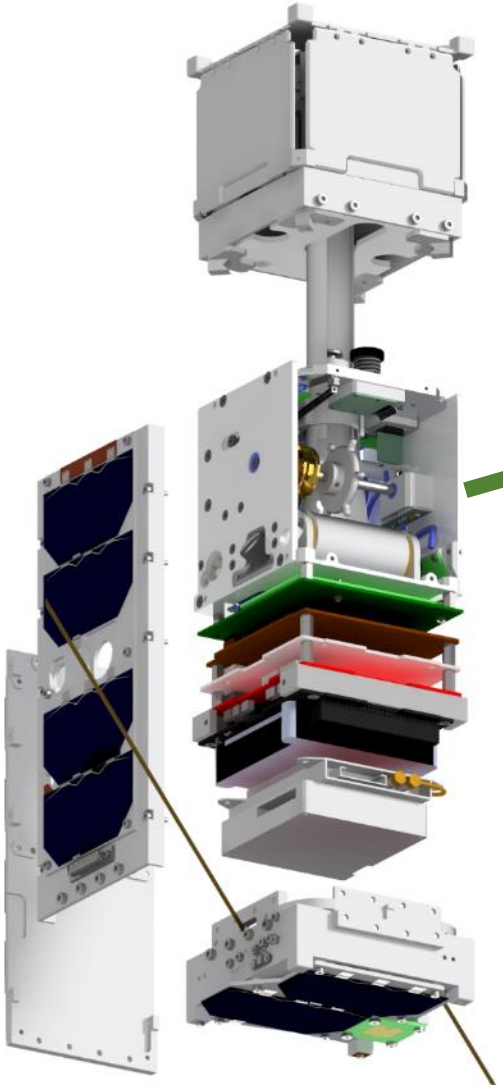






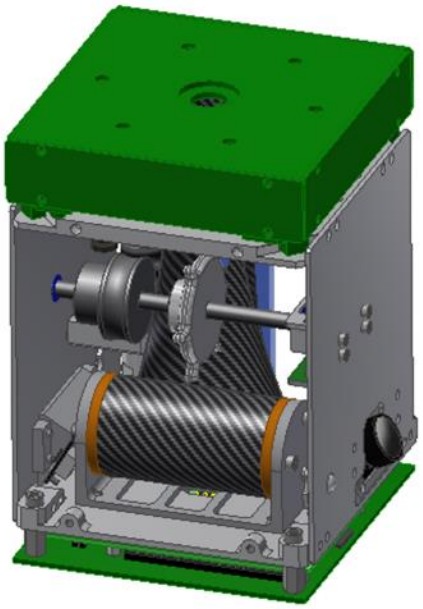
✓ 100mm deformation is successfully detected

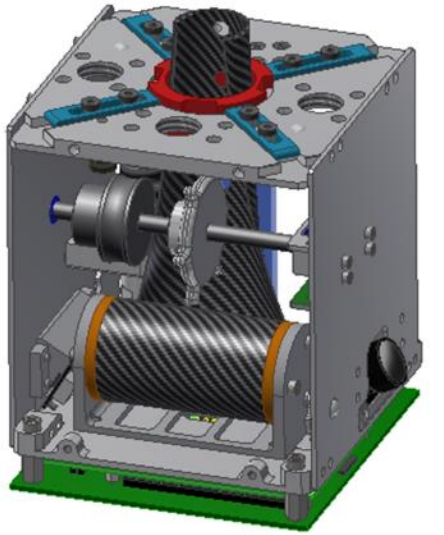
Extendable camera unit: **Launch lock mechanism** and **Mast extension mechanism**



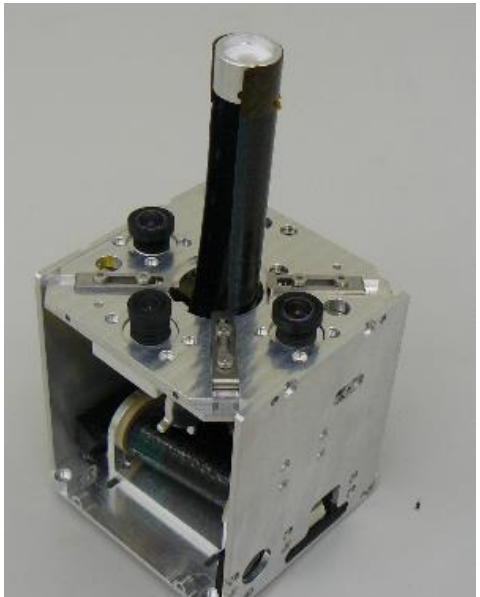
Bottom part of membrane deployment unit

Extendable camera unit





Membrane deployment unit is hidden



Movie shooting during membrane deployment

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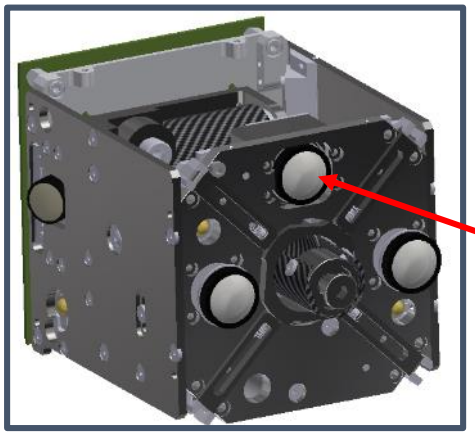
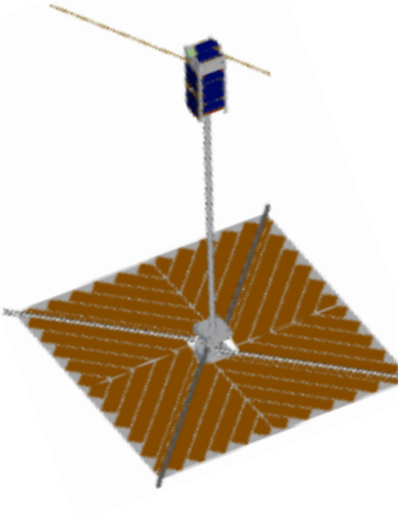
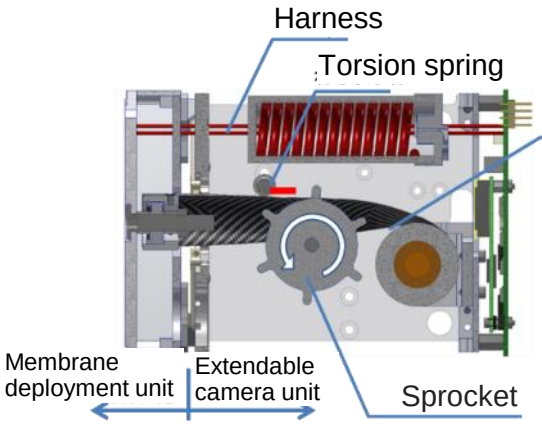
- ✓ 320x240, 80fps movie

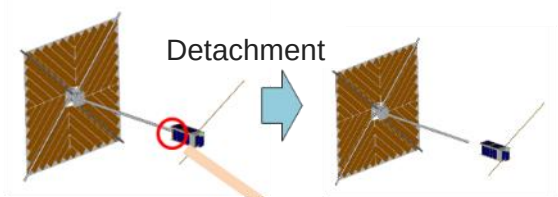


Movie camera



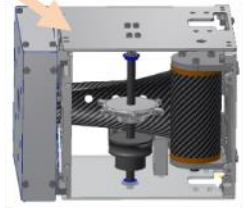
Detachment mechanism for extendable mast

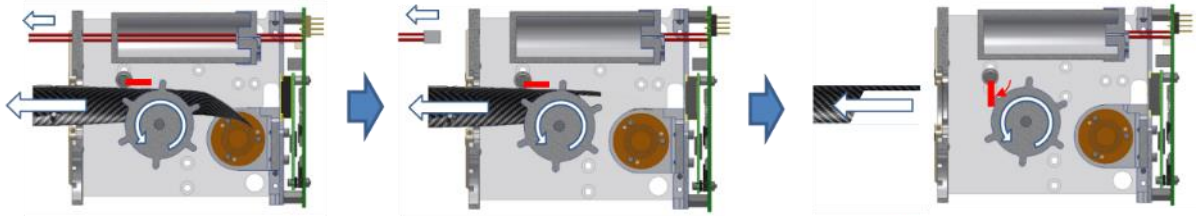




Sprocket rotates, and deploys mast.

When sprocket keeps rotating and unreels all the mast, mast is detached.



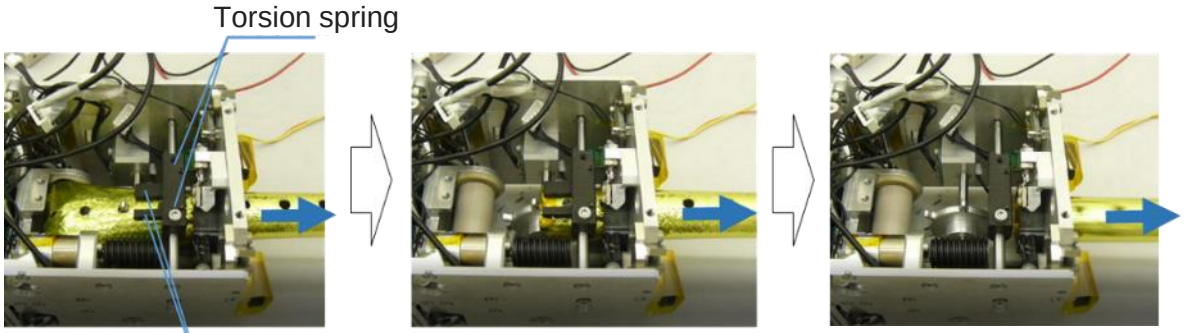


Mast deployment (Harness is pulled together

Harness is detached by cutting fishing wire using nichrome

Torsion spring pushes the mast root edge

Mast detachment



A part pushes mast root edge

The part rotates, and keeps pushing the mast outside

[Mission 3] Amateur radio communication

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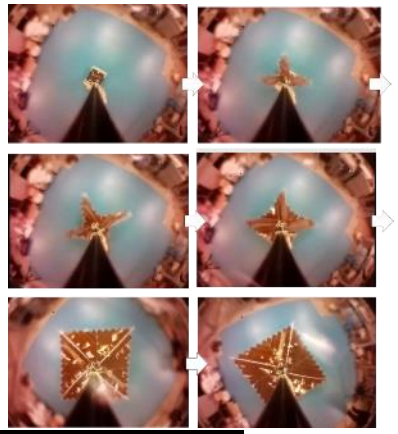


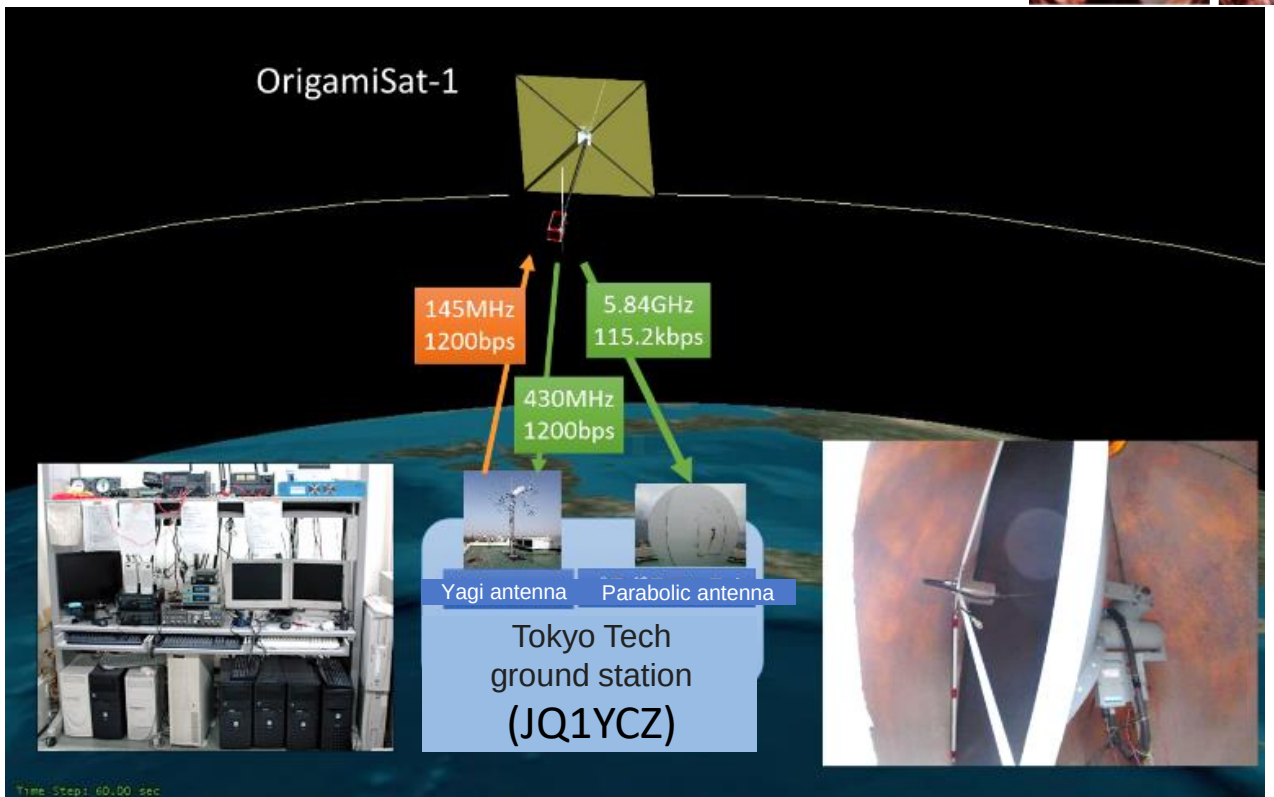
(1) Use of VHF/UHF-band: Command and telemetry

✓ Collaboration with amateur radio operators' community.

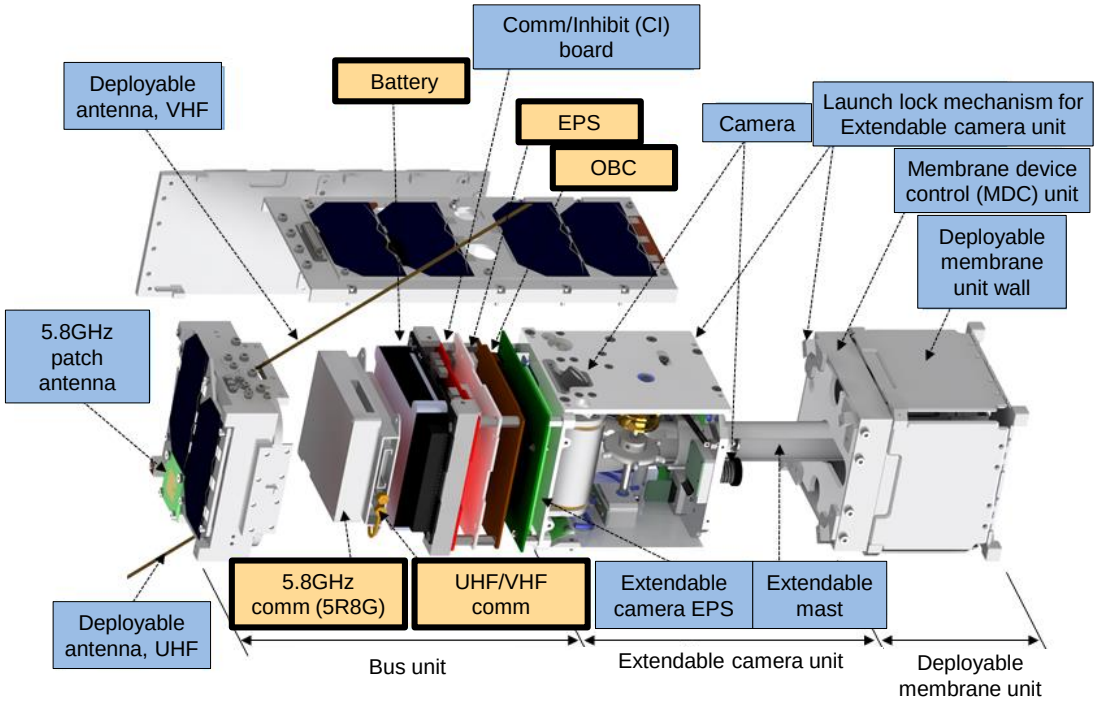
(2) Use of 5.84GHz: Mission data downlink

✓ Aims at training of new satellite communication system developed by FITSAT-1 (Niwaka) developed by Fukukoka Institute of Technology (Released from ISS in 2012).

Satellite's call sign:
JS1YAX



System configuration (1/2)

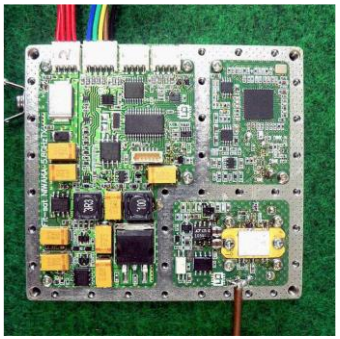


NTX (FMCW) 430MHz,
NRX (FM) 145MHz
Nishi-musen 301A

OBC
GomSpace
NanoMind

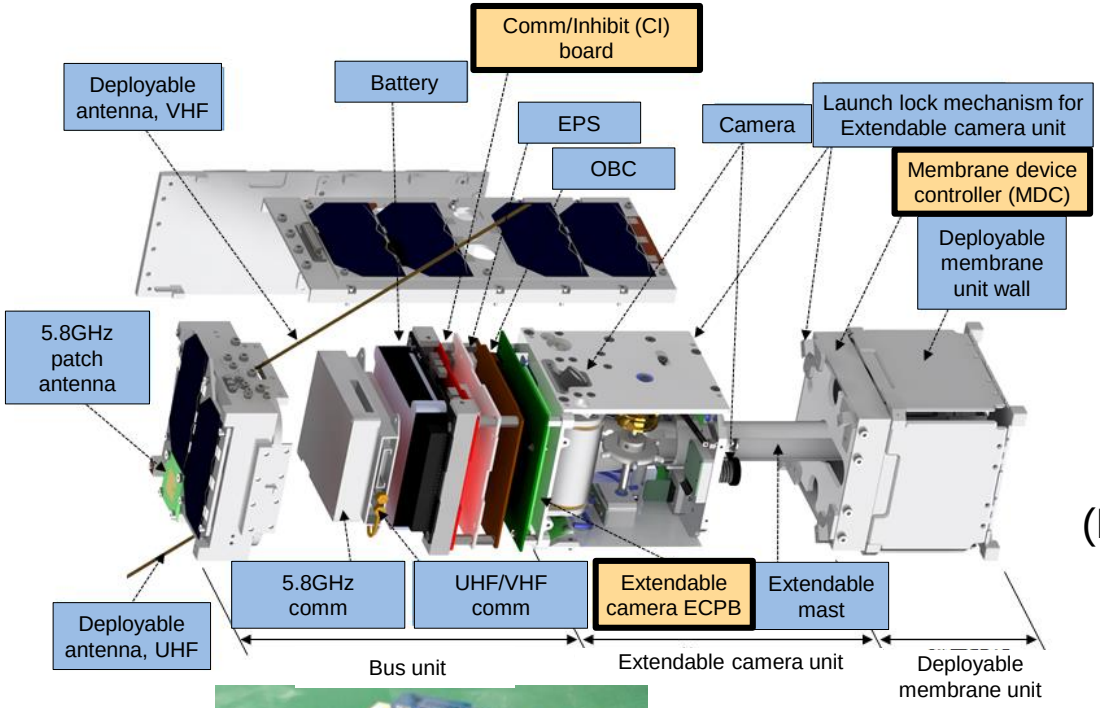
EPS
Clyde Space 3rd
Generation EPS

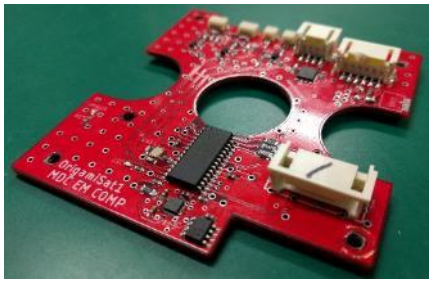
BAT
Clyde Space
3G Battery



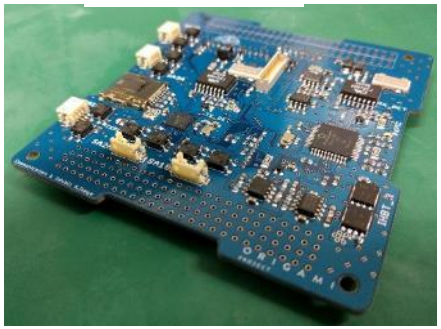
5R8G
TX 5.84GHz
Logical Product LPTX5840-1
(Same component with
FITSAT-1)

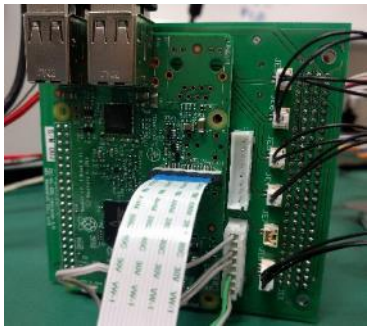
System configuration (2/2)





MDC
(Membrane Devices Controller)
On-membrane missions

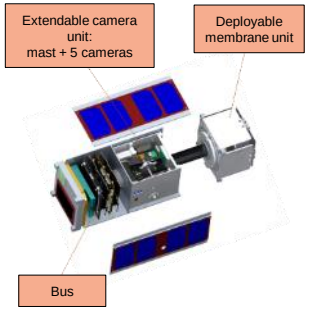




CI board (Communication & Inhibit control Board)
Modem for FM comm, **Power inhibit**
COBC (Comm micro-computer)
(COBC consists of **two PIC** micro-computers:
RX COBC and TX COBC)

ECPB (Extensive Camera Power Board)
+Raspbery Pi
Power control for
Extendable camera unit
+Camera shooting

OrigamiSat-1 system diagram



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OrigamiSat-1 System -: Data Line -: Power Line

BUS Unit
Separation Switches
RBF pin (Hardware lock)
SAP +x
Battery 30Whr
Heater
Thermister #5
5V
Clyde Space 3G EPS
Battery Charge Regulator
RBF pin
I²C
Power Control Unit
Bus 3.3V
Micro SD
OBC Nanomind A712D
Thermister #7
UART
CAN
I²C
RX Ctrl
3.3V
REG
12V
Bus 3.3V
EEPROM
Multiplexer
Thermister #6
UART
I²C
6DOF IMU
PIC16LF877A (RX)
Timer SA555
PIC16F886 (TX)
5V
TX Ctrl
Bus 5V
AX.25
PLL Signal
Modem(RX)
Modem(TX)
SW 5V
5.83GHz Radio Unit (TX)
AD Converter
145MHz Radio Unit (RX)
435MHz Radio Unit (TX)
SW3.3V
Thermister #1
Thermister #3
Thermister #4
Thermister #2
Antenna Lock (Melting Wire)
Nd Magnet

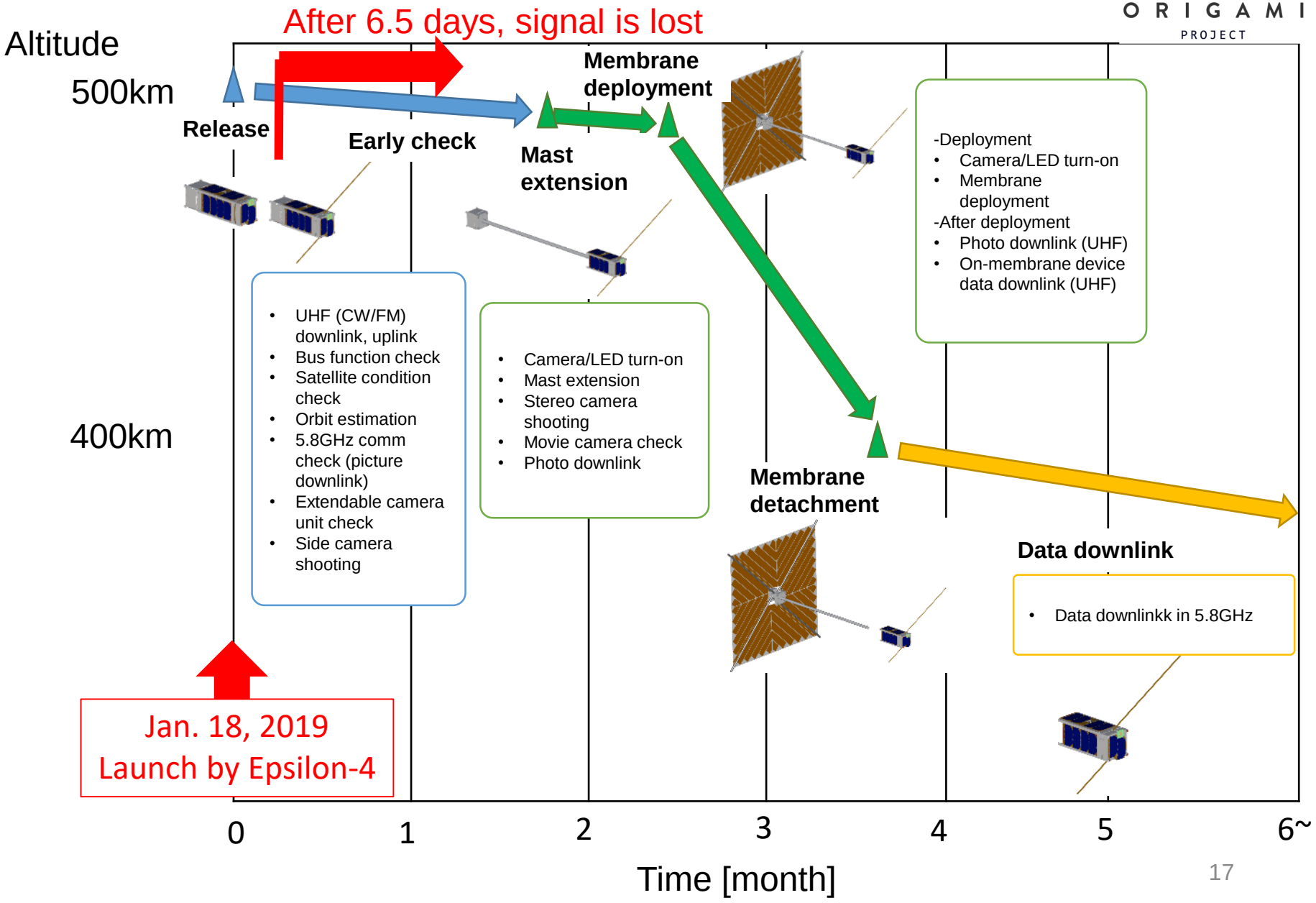
Extendable Camera Unit
LED1
LED2
CAM5
CAM4
CAM1
LED3
CAM2
LED4
CAM3
SW 5V
SW 5V
SW 12V
SW 3.3V
SW3.3V
Power Control Unit
Connector
UART
Extendable Camera Unit Controller
Raspberry Pi
Micro SD
Encoder
Mast Motor
CAN
Launch Lock Mechanism

Extendable Mast

Control Unit for On-membrane Devices
Ir LED
6DOF IMU
PIC 18F25K80
Memory

Deployable Membrane Unit
LED
Spherical Solar Cell
Thin-film Solar Array Cell
Thermistor
Launch Lock (Melting Wire)
Deployable Membrane
SMA Antenna (430MHz RX)
ADC
comparator
Detector

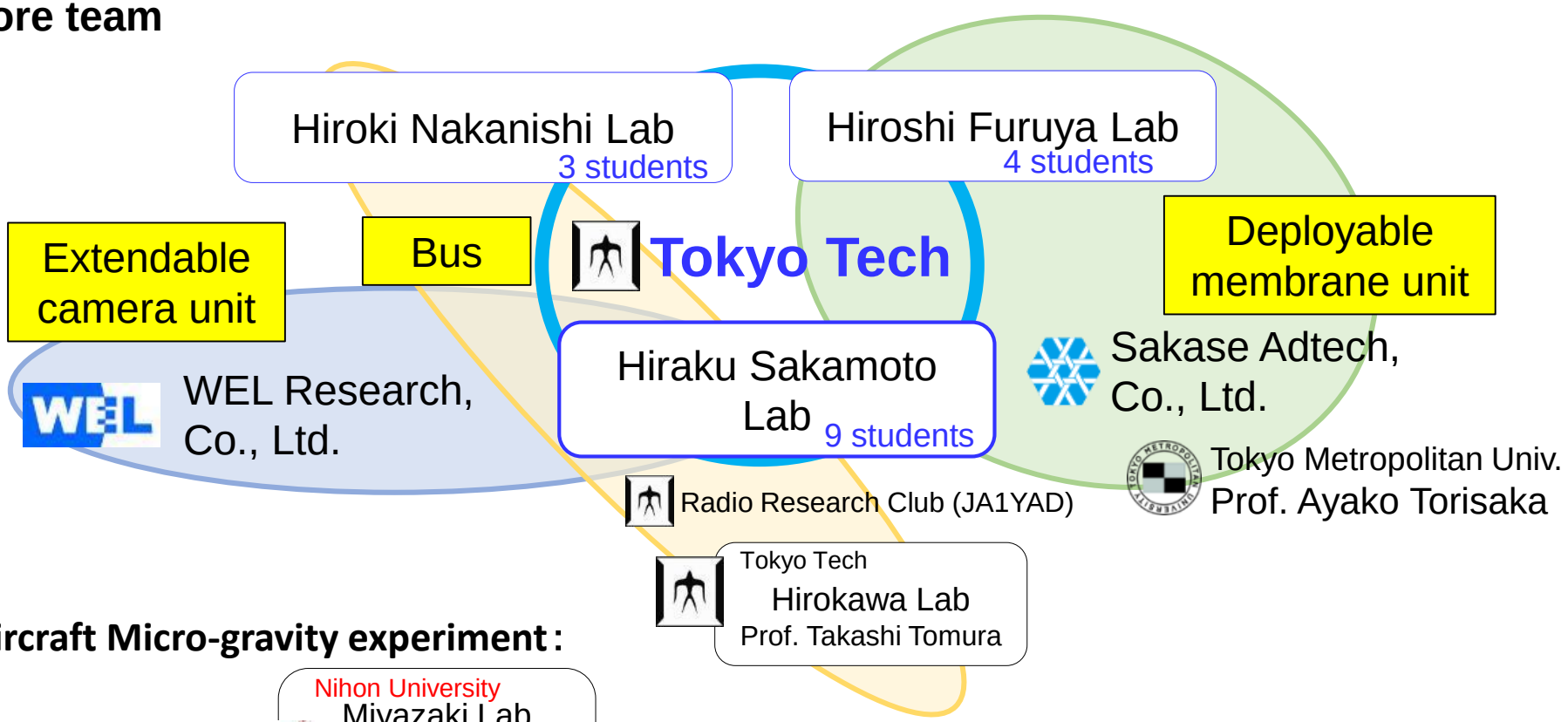
OrigamiSat-1 mission sequence and launch result



OrigamiSat-1 development team

Principal Investigator	H. Sakamoto (Associate Professor, Tokyo Tech)
Project Manager	H. Nakanishi (Associate Professor, Tokyo Tech)
Student Project Manager	K. Ikeya (Graduate student, Tokyo Tech)

Core team

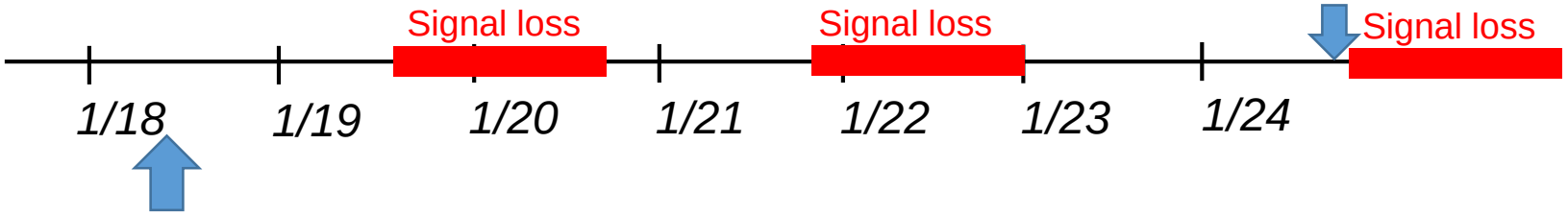


Aircraft Micro-gravity experiment :

Nihon University
Miyazaki Lab
Prof. Masahiko Yamazaki

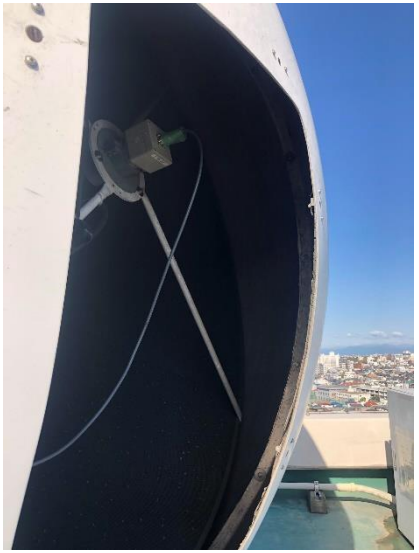
2. Sequence of events after launch

Event sequence after launch (1/2)



- ✓ After release from rocket, on Jan. 18, 2019 at 11:22JST, an amateur radio operator received CW (continuous wave) signal from satellite. CW HK (house keeping) data were successfully obtained.
- ✓ On the same day, command uplink was successfully executed from Tokyo Tech ground station. After this success, HK data downlink operations were repeated in CW as well as in FM (frequency modulation).
- ✓ There were 2 periods (both about 24 hours) of signal losses on Jan. 19 and 21.
- ✓ On Jan. 24, downlink signal was stopped again, and has not restarted yet.
- ✓ In the ground experiment, a system bug was found in power mode transition function in the satellite. This explains two 1-day signal losses. However, this error should be recovered by satellite's automatic reset.
- ✓ The reason of the current signal loss, longer than 1 day, has not been identified yet.

Event sequence after launch (2/2)



Tokyo Tech
JQ1YCZ
5.8GHz antenna

©N1JEZ

Vermont, USA
N1JEZ 5.8GHz antenna

- ✓ Between May 7 and Jun. 1, 2019, 5.8GHz downlink experiments were carried out using two amateur ground stations at Tokyo Tech and Vermont, USA. But no signal was heard from satellite.
- ✓ **Membrane deployment commands** were sent from Tokyo Tech ground station. When membrane is deployed, the orbital altitude will rapidly drop. Between Jun. 3 and Jul. 24, 2019, the commands were sent. However, TLE (orbit information published by CSpOC) has not evidenced any significant change in altitude. Thus, we conclude that the membrane has not been deployed yet.

Membrane deployment operation（From 2019/6/3 to 7/24）

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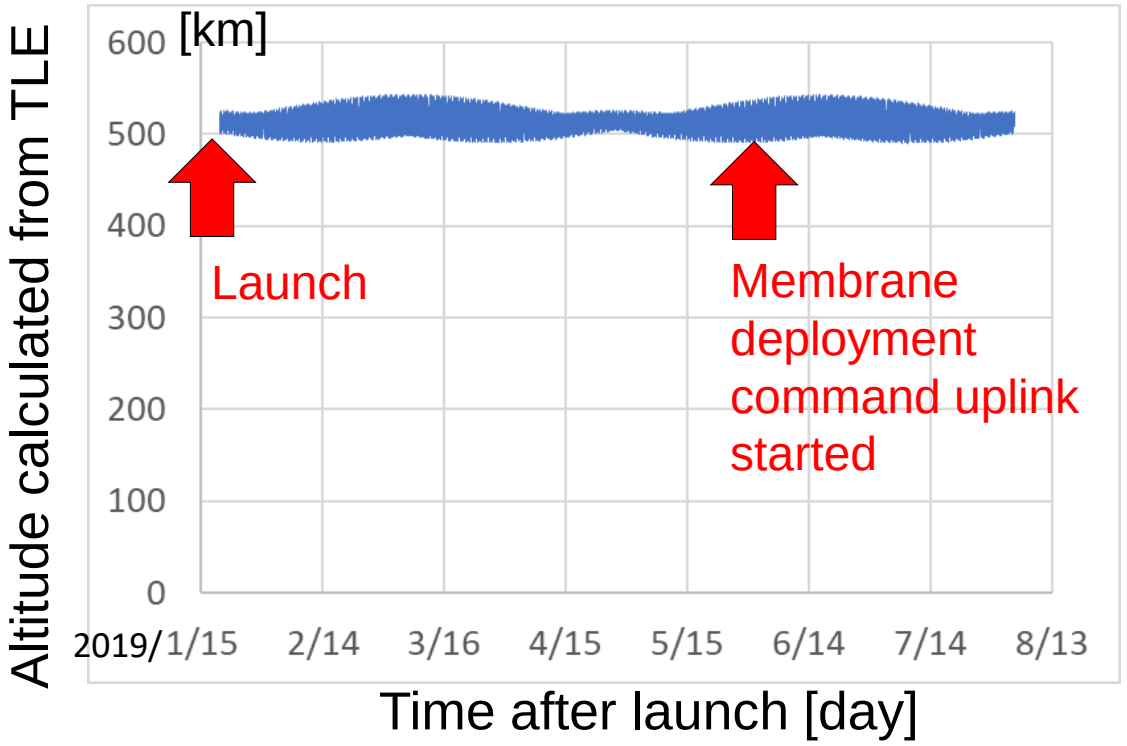
- ✓ Two kinds of membrane deployment commands were sent.
  - ➢ Main: through EPS
  - ➢ Sub: through membrane device controller
- ✓ Altitude does not show any significant change.



3. On-Orbit data

OrigamiSat-1 / FO-98 (JS1YAX) is an amateur radio communication satellite. Its telemetry data were obtained by many Ham operators all over the world. The next pages show the satellite's HK (house keeping) data obtained for 6.5 days of operation after launch.

Reference:
Reception report website http://www.origami.titech.ac.jp/archives/722

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On-orbit data: Temperature

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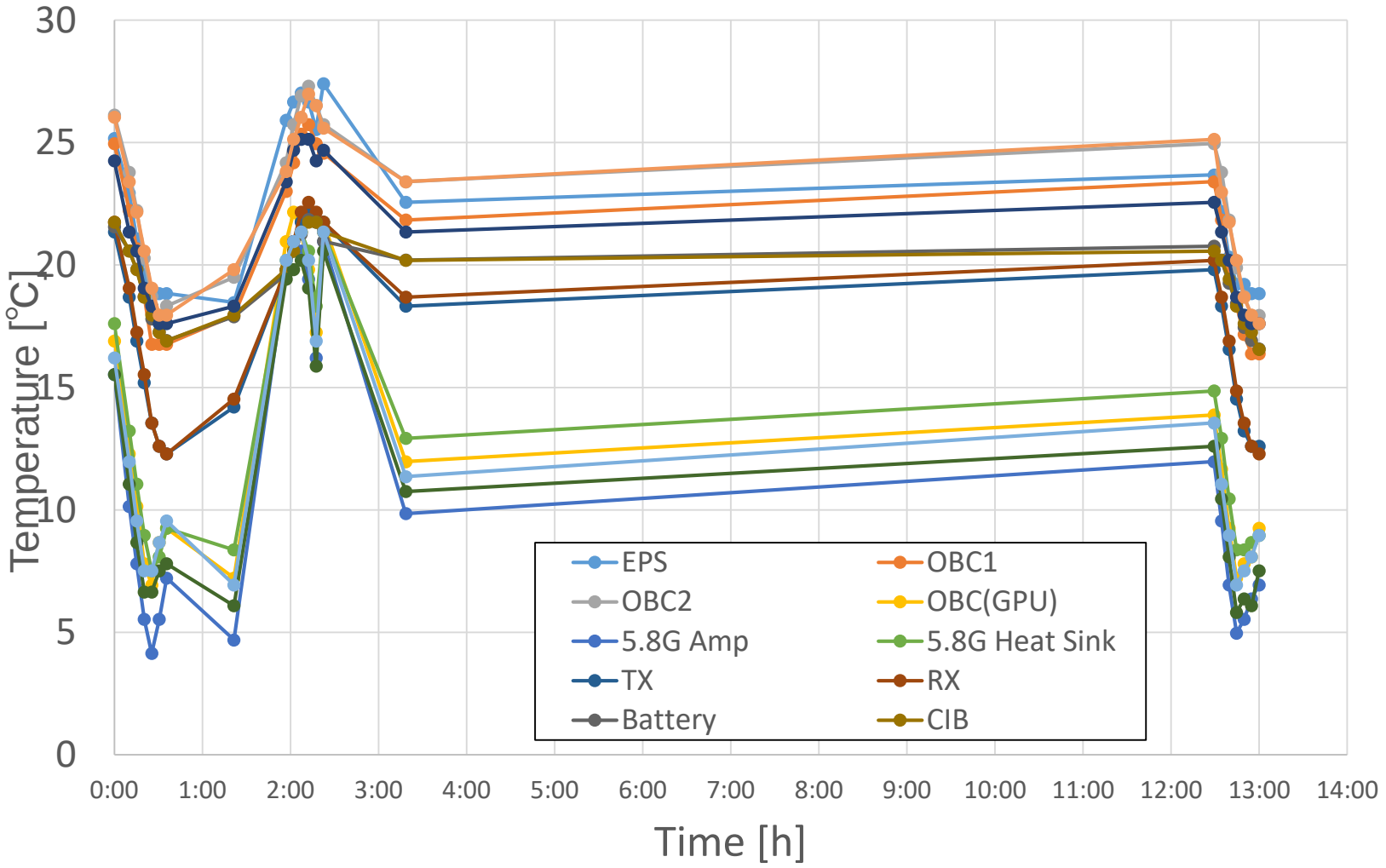
- All components remains between 5 and 30 deg. Celsius.



Temperature（1/21 - 1/22 For about 12 hours）

On-orbit data: Angular velocities

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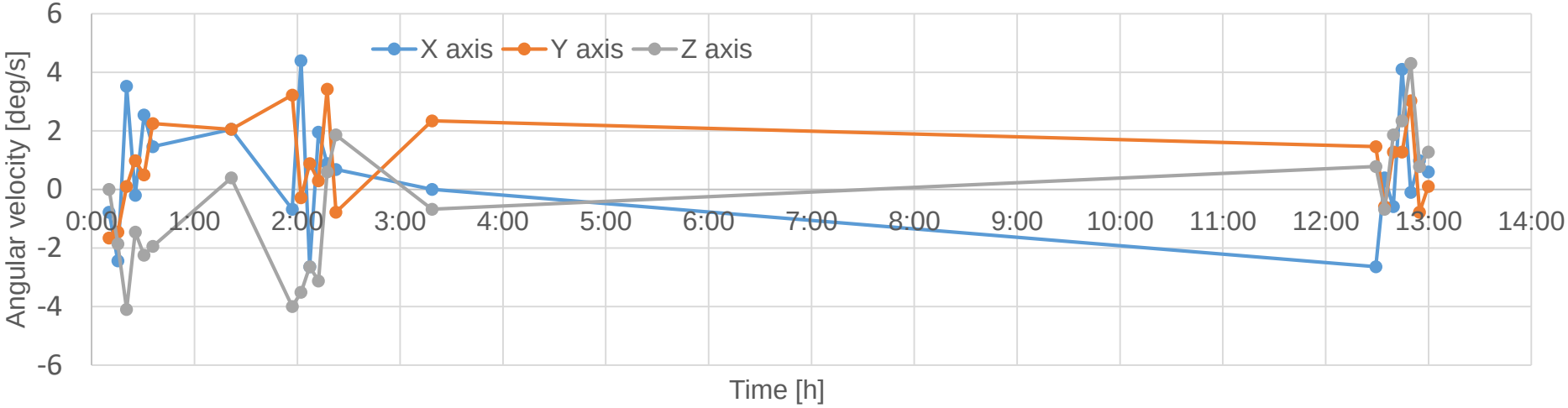
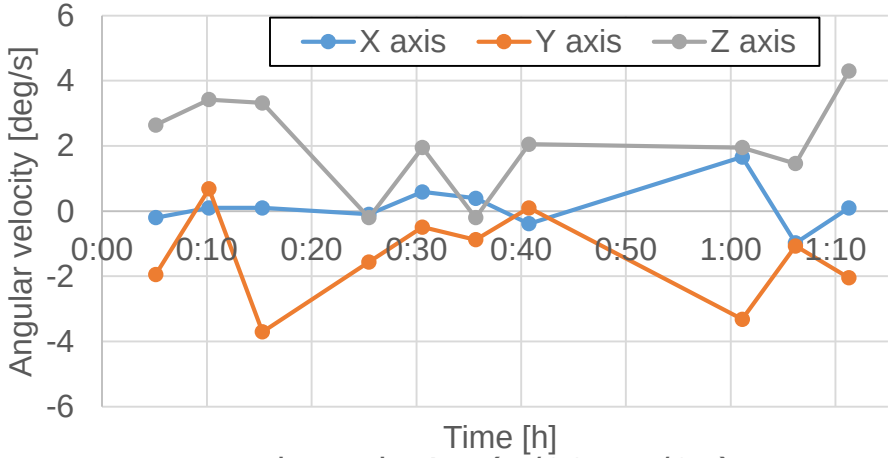
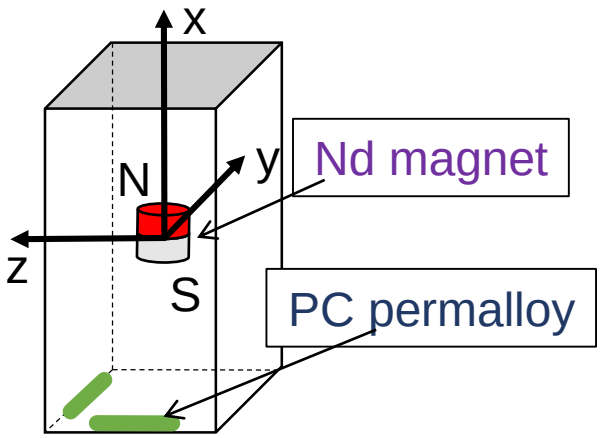
- HK data shows slow tumbling in 3 - 4 deg/s.
- No significant change in spin rate between Jan. 21 and 24.



Satellite's angular velocity (1/20 - 1/21 For about 12 hours)



Angular velocity (1/23 - 1/24)



On-orbit data: Battery voltage (long term)

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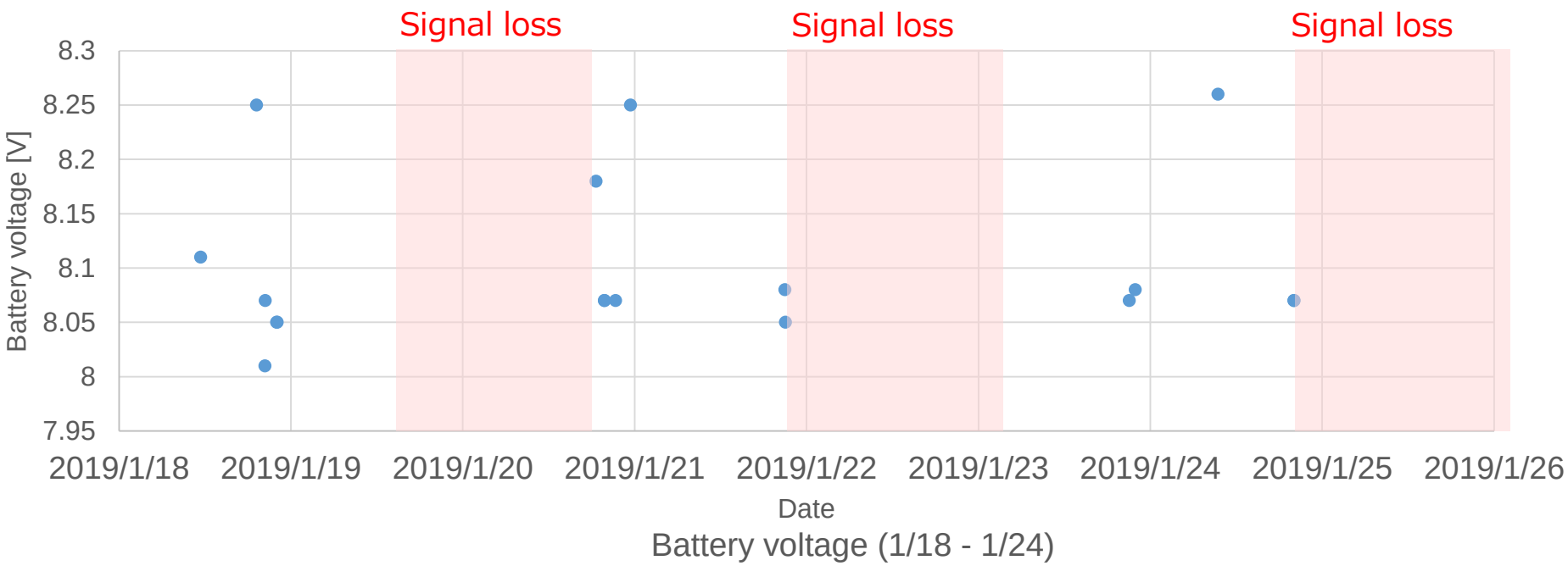
- 8.0 - 8.25 V were kept (successful charge and discharge).



On-orbit data: HK data in one orbit period

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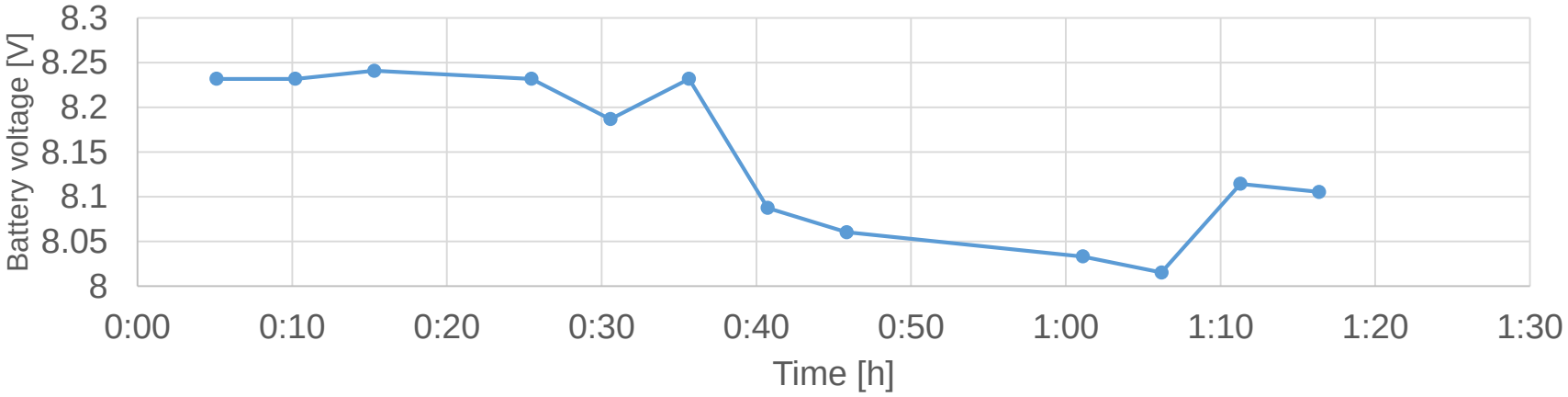
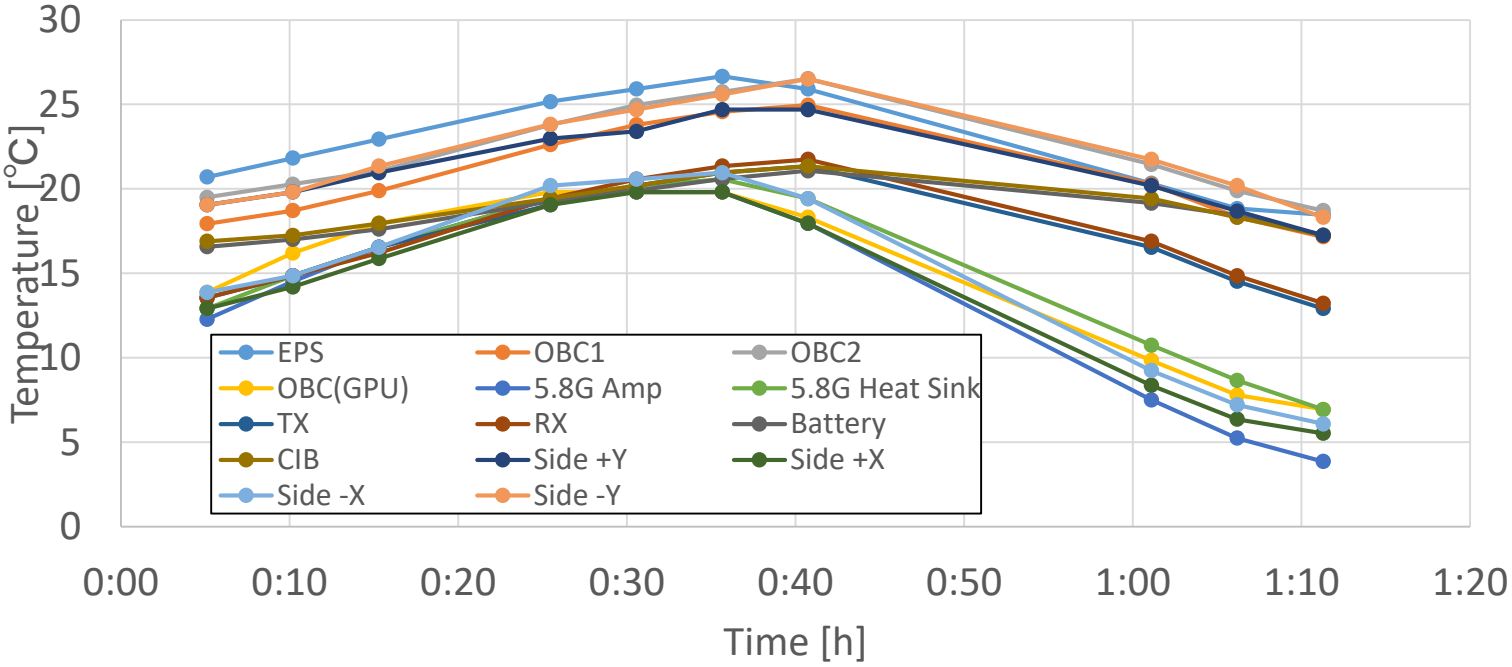
1/23 – 24, for about 70 minutes (no time stamps were obtained)





4. System bugs found after launch

Ground experiments after launch showed two bugs in CI board.
Currently, the relation of these bugs to on-orbit anomaly has been investigated.

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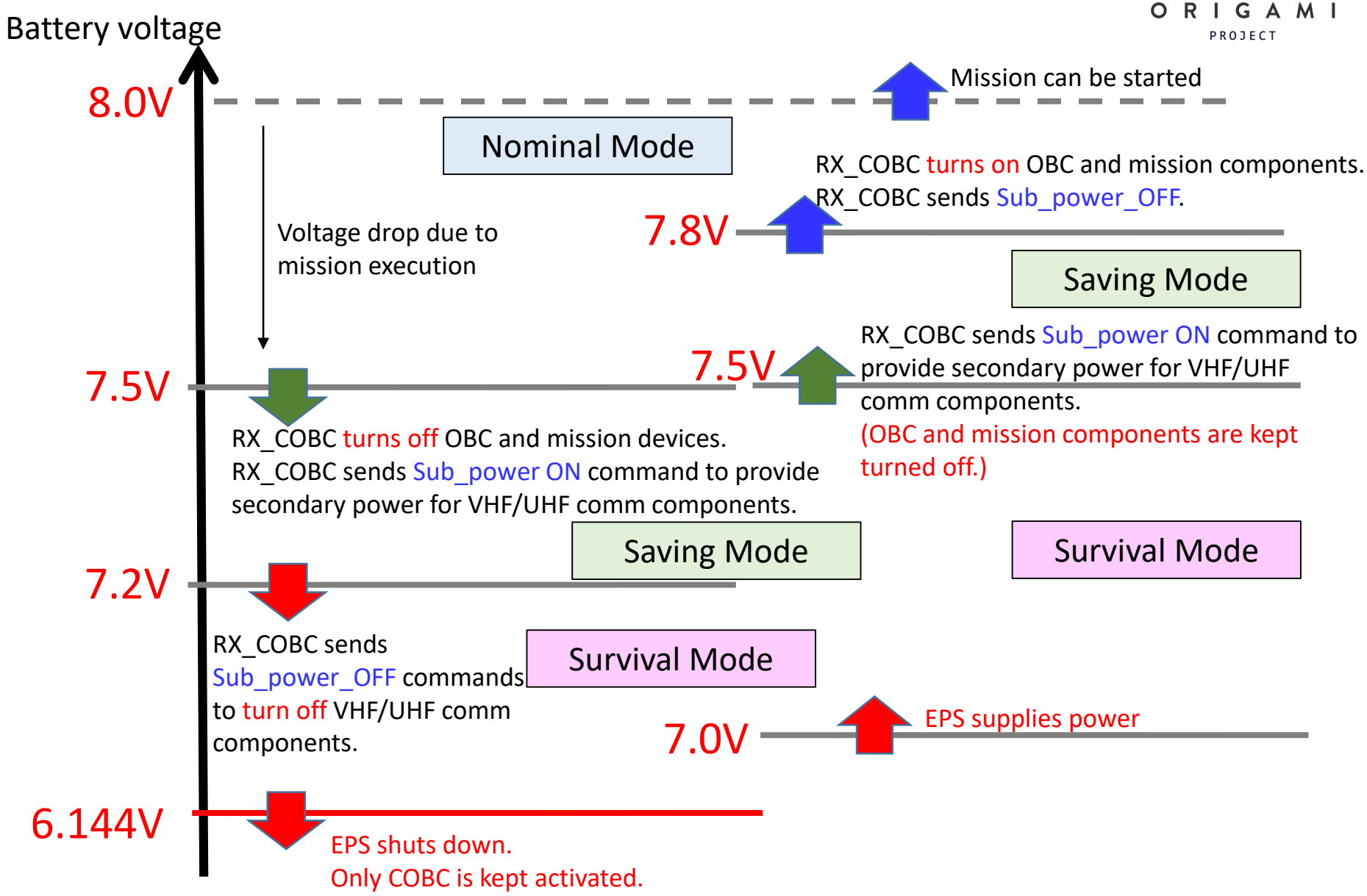
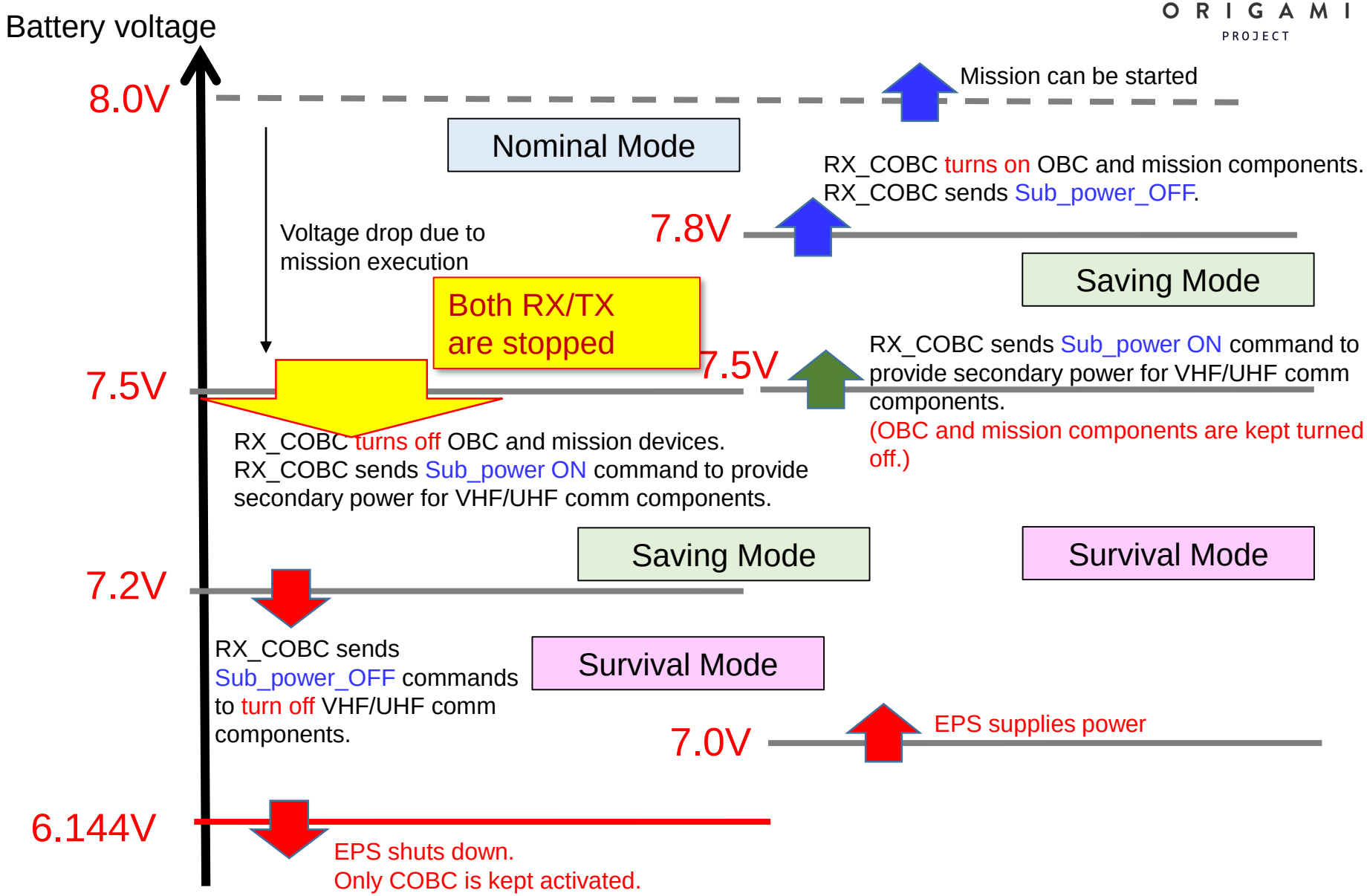
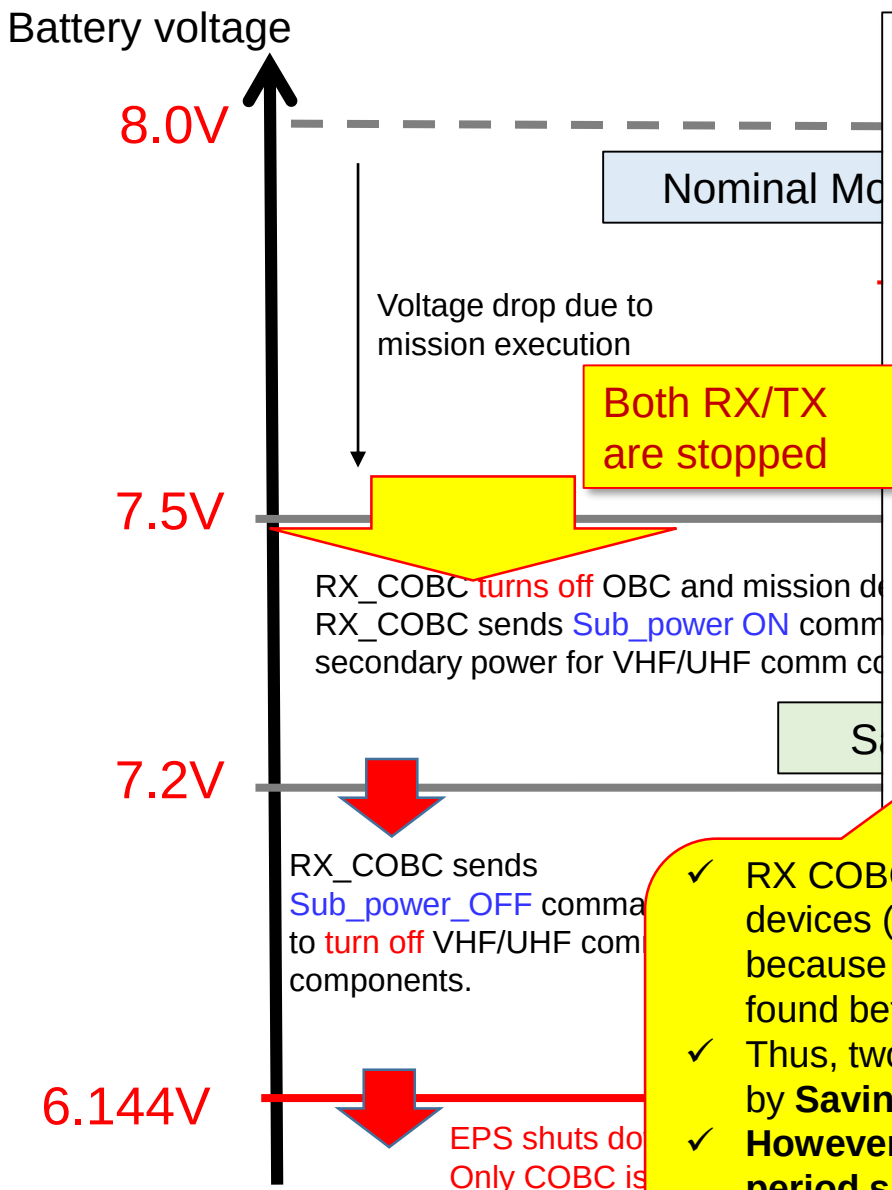
Satellite's power mode transition (RX COBC changes the modes)

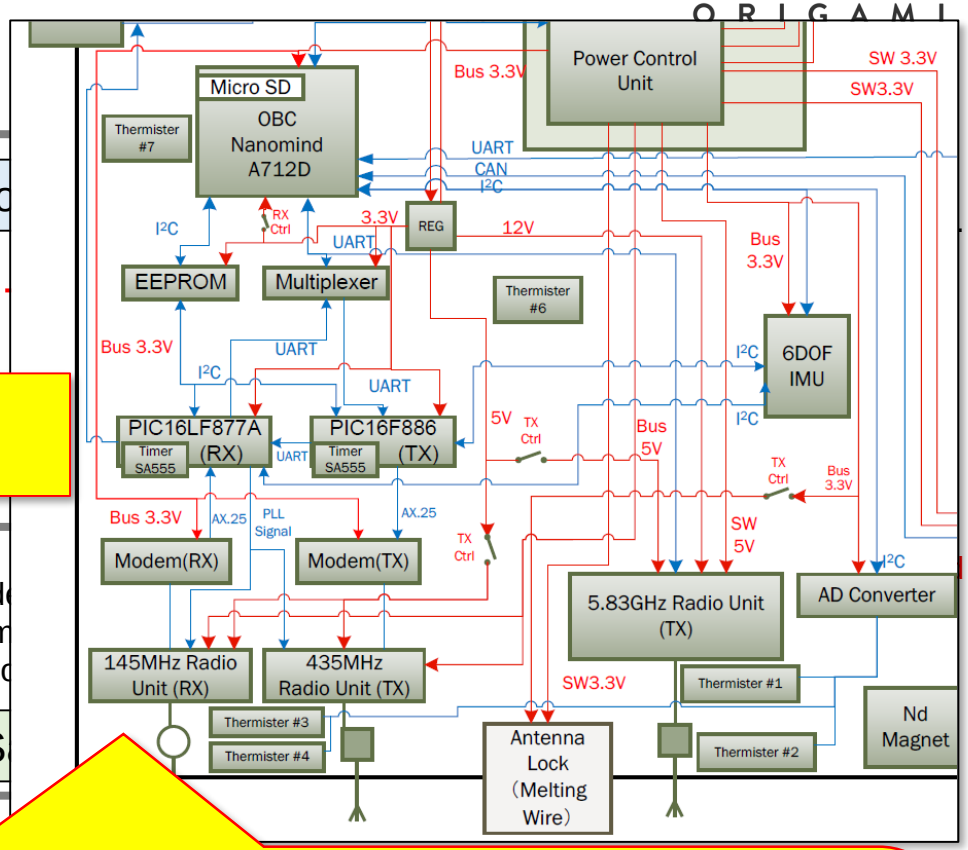


System bug found after launch (1)



System bug found after launch (1)





- ✓ RX COBC (PIC) sends initial setting commands to Comm devices (NRX/NTX). But the commands may not be received because of **too short delay** in program. This bug was not found before launch.
- ✓ Thus, two signal losses (about 24 hrs) were possibly caused by **Saving Mode**.
- ✓ **However, if it has over 7.8V, automatic reset in every 1-day period should recover transmission.** The reason of current signal loss has been unclear.

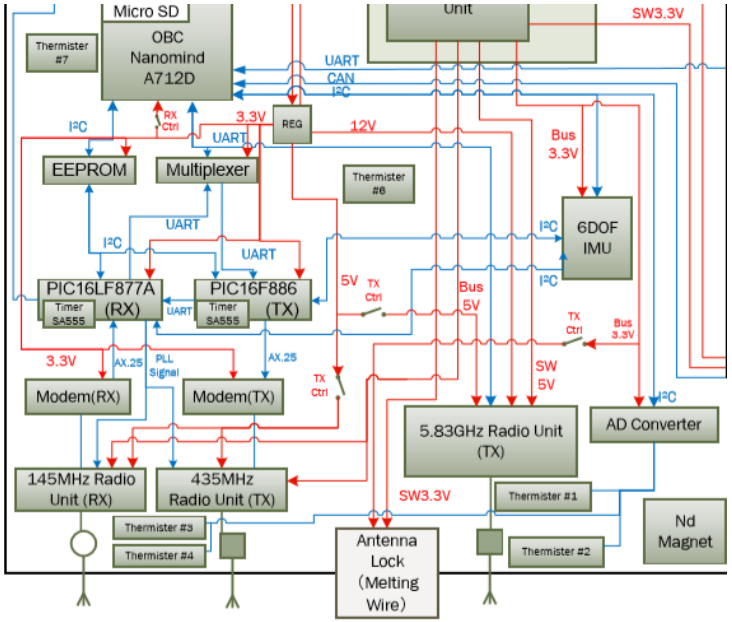
System bug found after launch (2)

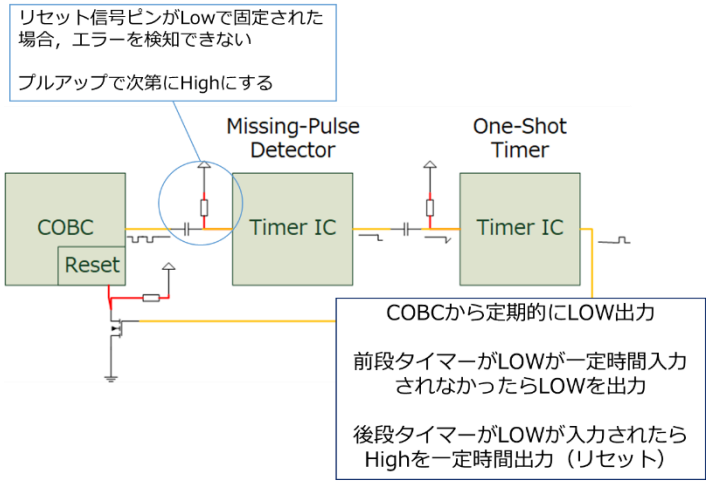
I2C collision for EEPROM from TX COBC, RX COBC, and OBC

In OrigamiSat-1, TX COBC, RX COBC, and OBC share data in same EEPROM using I2C protocol.

In ground experiments using Engineering Model (EM), the access rate from TX COBC, RX COBC, and OBC to EEPROM have been increased.

- Then, there is failure mode that both RX COBC and TX COBC continuously repeat resets.
- The reason of this failure mode and possibility to occur this in orbit are currently investigated on ground. (This bug will cause satellite's signal loss for a long time.)





Watch dog timers for COBC

5. Operation plan

Operation plan (after Sep. 2019)

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- Currently, telemetry from the satellite has been stopped, possibly caused by an anomaly in COBC on CI board.

  But, the COBC reset caused by WDT system or battery voltage drop may recover CW transmission, making possible to resume all the missions.

- **Thus, the following operations are continued to wait for recovery of OrigamiSat-1.**

i. **Once in a month operation:** To succeed the ground-station operation procedure, (i) send membrane deployment command to satellite and receive a response,.
ii. **Once in two month operation:** To verify the Tokyo Tech ground station system, (ii) Receive telemetries from other CubeSat. (iii) Send commands to OrigamiSat-1 and receive them using the satellite's EM RX on ground.
iii. **Once in four month operation:** To succeed the operation procedure, (iv) send commands to activate 5.8GHz TX, and receive the signal using parabolic antenna.

Summary of this report

ORIGAMI PROJECT

- 3U CubeSat OrigamiSat-1/FO-98 has been developed to conduct three missions: [1] Deployment of multi-functional membrane, [2] On-orbit measurement of deployable structures using cameras, and [3] Amateur radio communication. It has been successfully sent to prescribed orbit (500km-altitude Sun Synchronous Orbit) on Jan. 18, 2019.
- For 6.5days after launch, satellite's housekeeping data were obtained. However, the signal from satellite has been lost, and uplink commands have not been responded (no membrane deployment has been conducted).
- Occasional operations are to be conducted to maintain the ground station functions for preparing possible satellite's recovery.

Acknowledgement:
The project team really appreciate Japan Aerospace Exploration Agency (JAXA) who launched the satellite and provided significant technical support, amateur radio operators who received satellite's telemetries, and all others who supported the project.