Birds OpenSource Webinar

MicroOrbiter-1 Operation Report

2024/07/31

by MOUMNI Fahd

Agenda

I. Introduction

II. Missions Overview

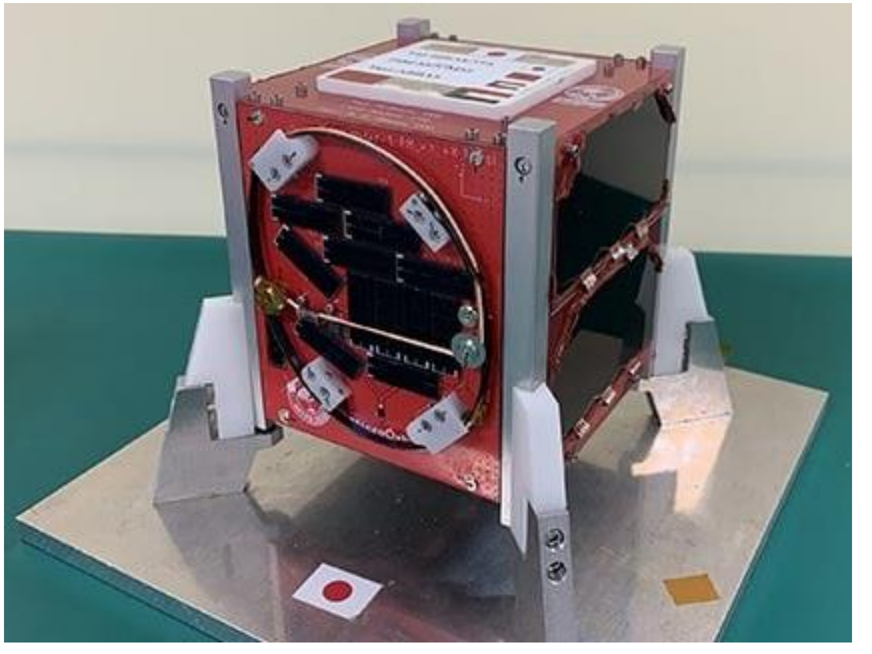
III. Ground Station

IV. Results and Data Analysis

V. Conclusion

I. Introduction

- MicroOrbiter-1 (MO-1) is the jointly developed 1U CubeSat project between MicroOrbiter Inc. and the Kyushu Institute of Technology

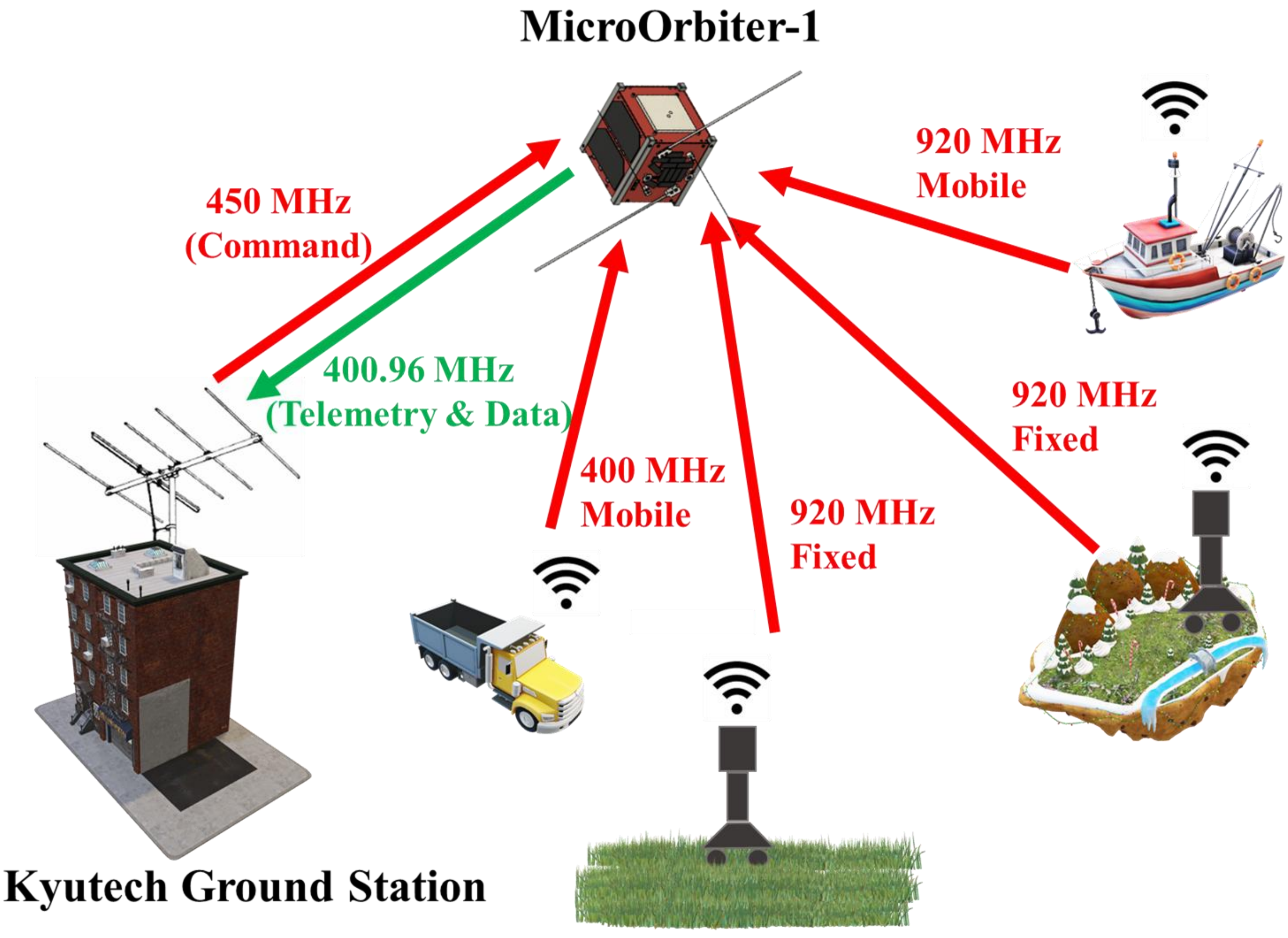


- MO-1 is an IoT (Internet of Things) CubeSat that uses LoRa modulation to allow access to remote areas

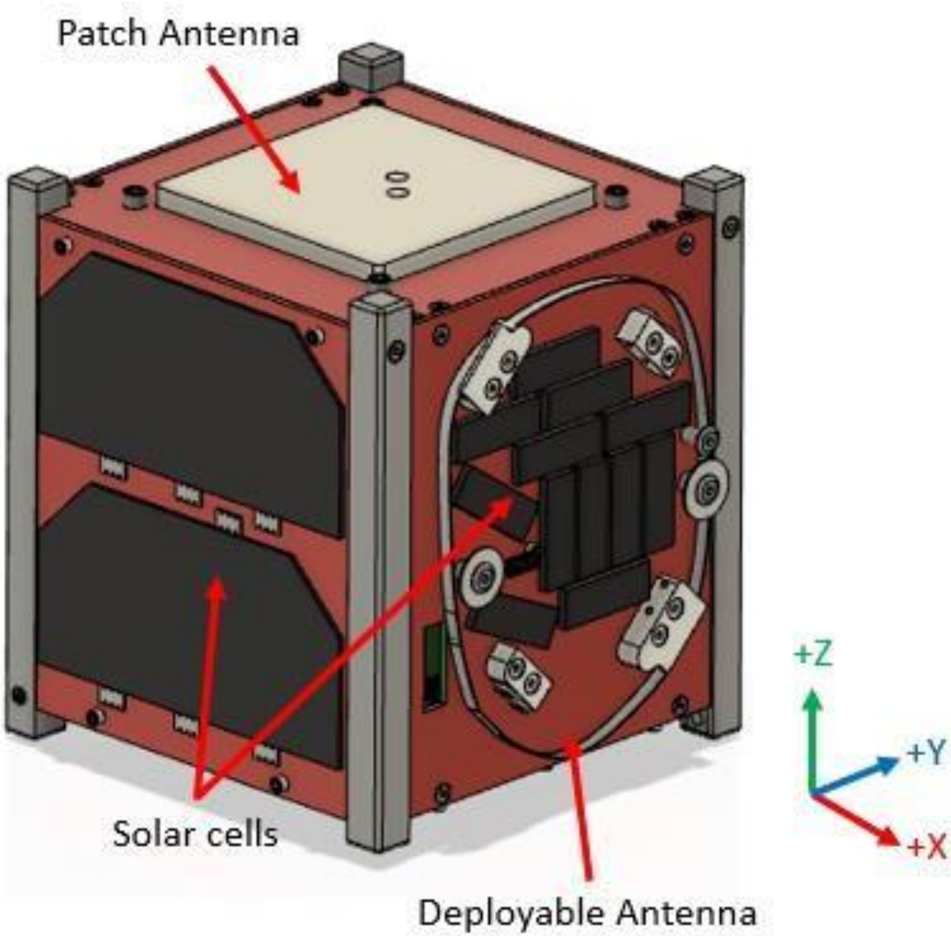
- The satellite was released on April 11th from the ISS

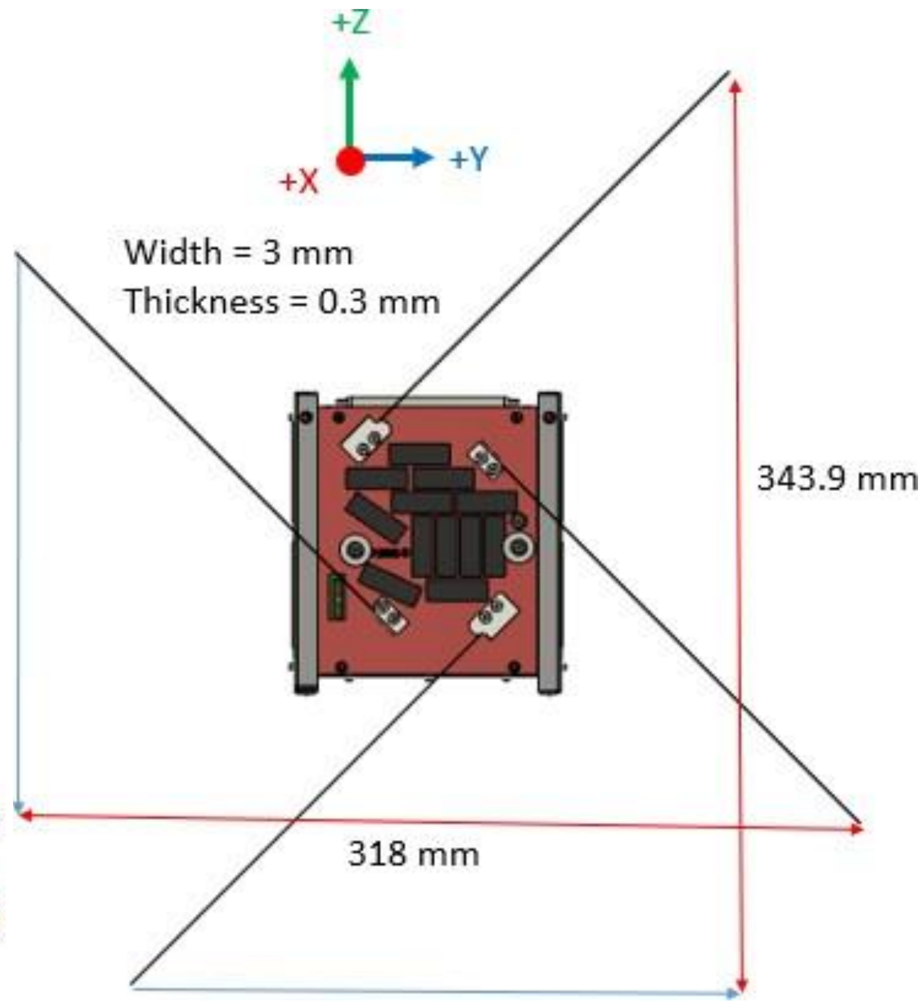
Satellite Release (Pictures by JAXA)

II. Missions Overview

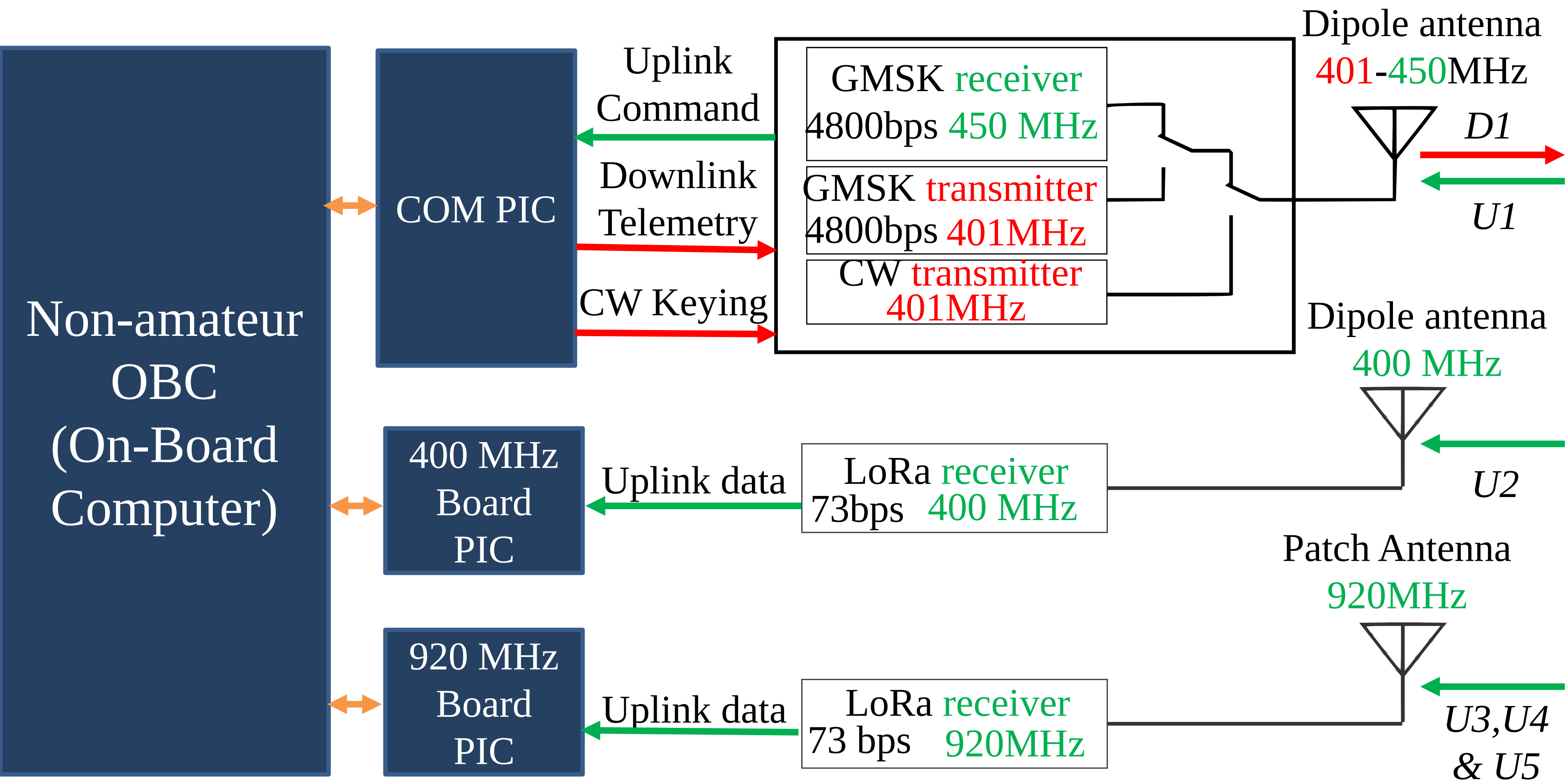


Quick structure Overview





Communications Diagram



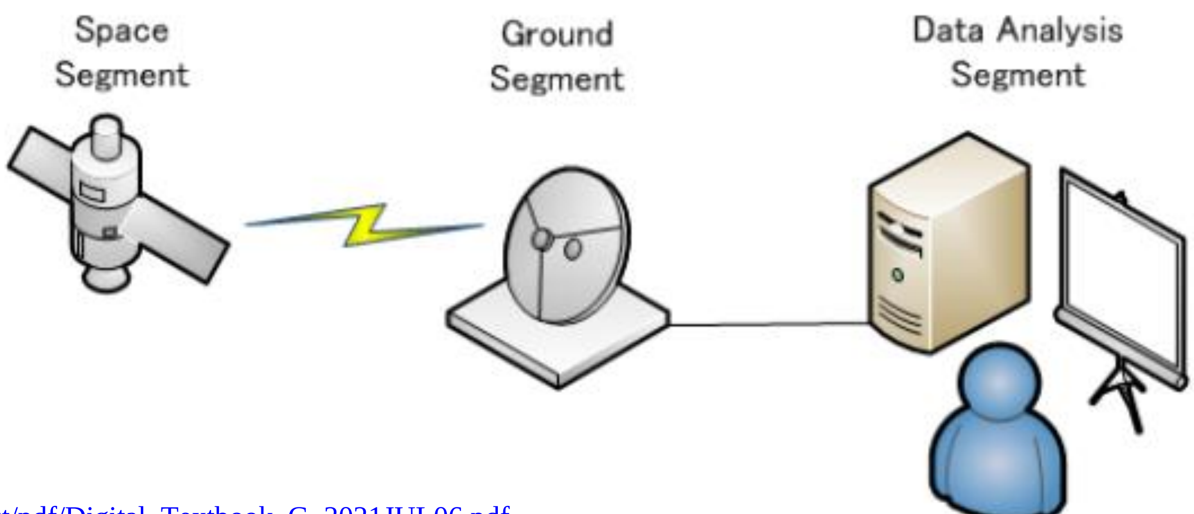
D = Downlink
U = Uplink

COMMS Consideration for Operation

- Achieves Downlink for LoRa Missions + House Keeping Data
- CW Decoded manually with Ground Station Command
- Obtains Reset PIC Data
- CW = 23 sec, RX (Receiving) = 270 sec
- **1 to 2 CWs / pass** (around 10 minutes)
- CW interval changeable if Power is OK

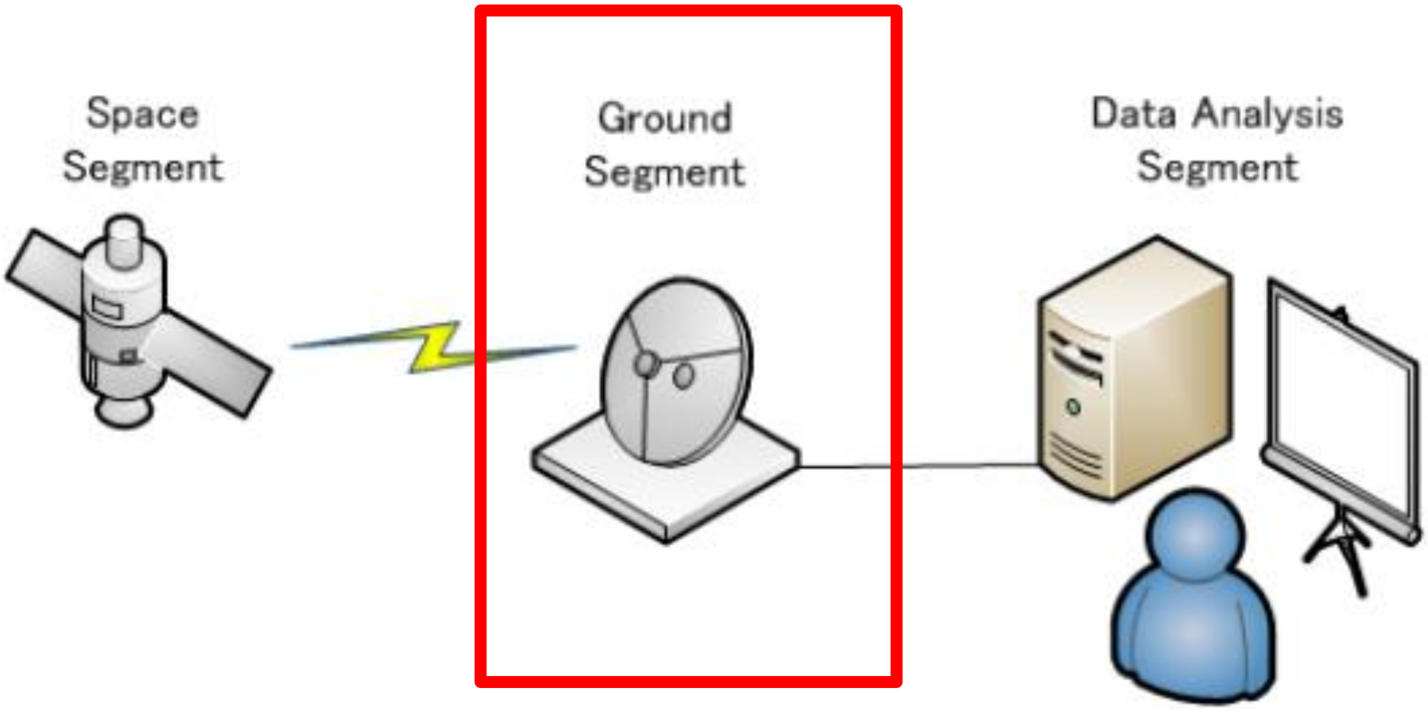
Importance of the daily operations

- Our only way of communication with the satellite.
- The value of the satellite is the data in space
- The more frequent the data, the more accurate, especially when special phenomena happen
- You never know when your satellite can stop working
- More data = More understanding



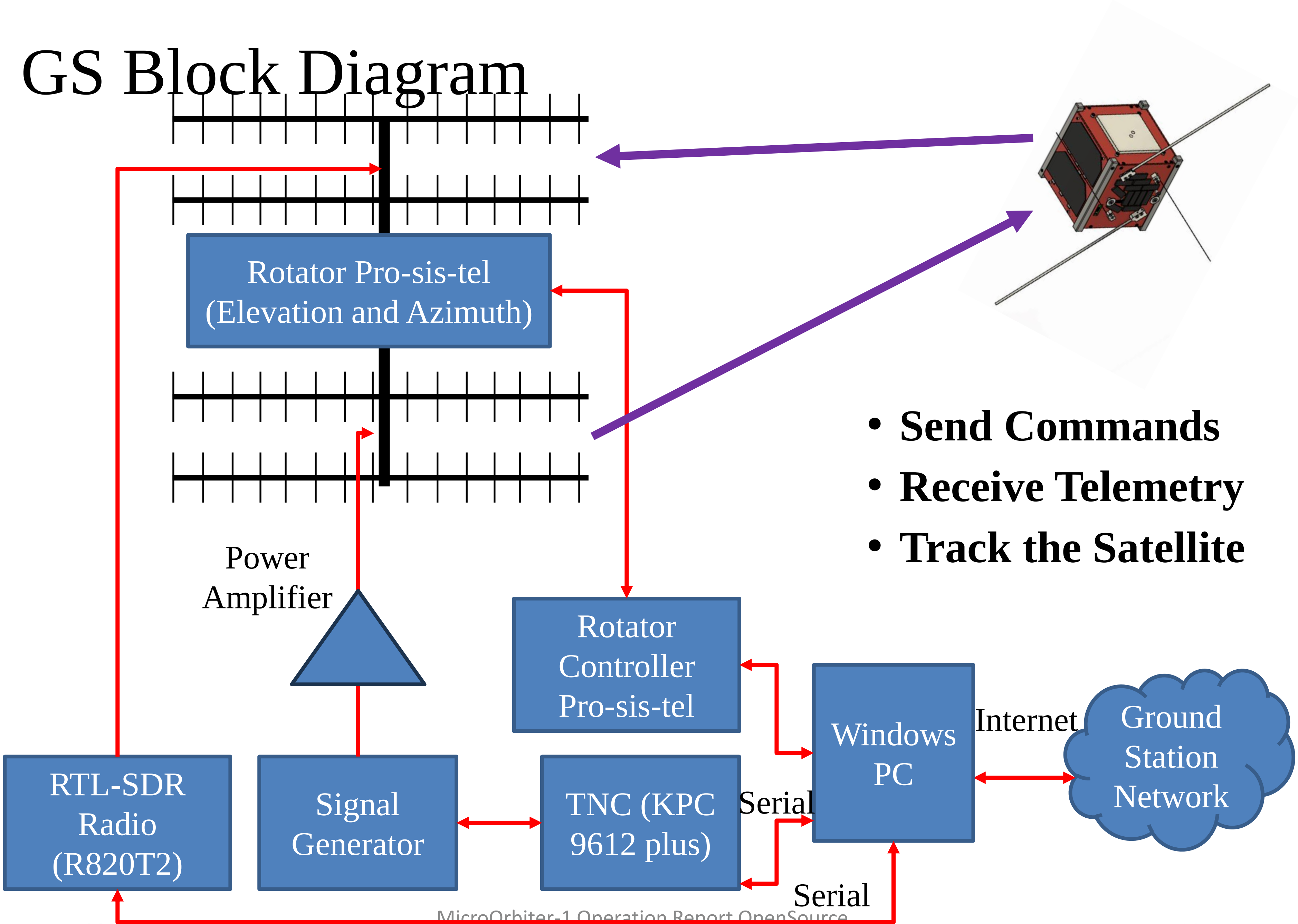
https://birds-project.com/mext/pdf/Digital_Textbook_G_2021JUL06.pdf

III. Ground Station



https://birds-project.com/mext/pdf/Digital_Textbook_G_2021JUL06.pdf

GS Block Diagram



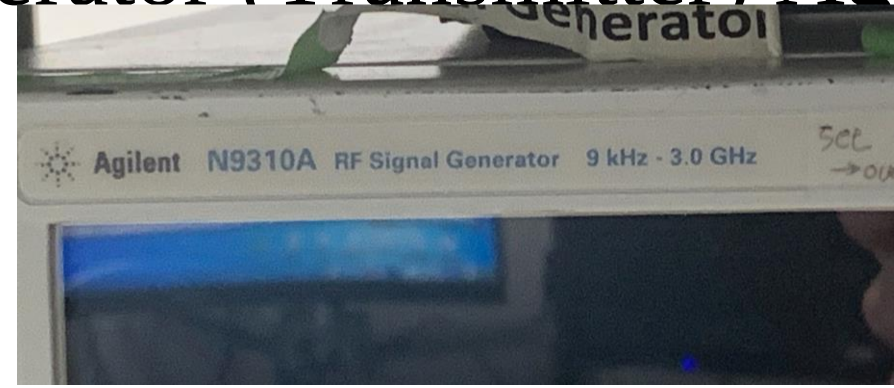
- **Send Commands**
- **Receive Telemetry**
- **Track the Satellite**

Ground Station Antenna

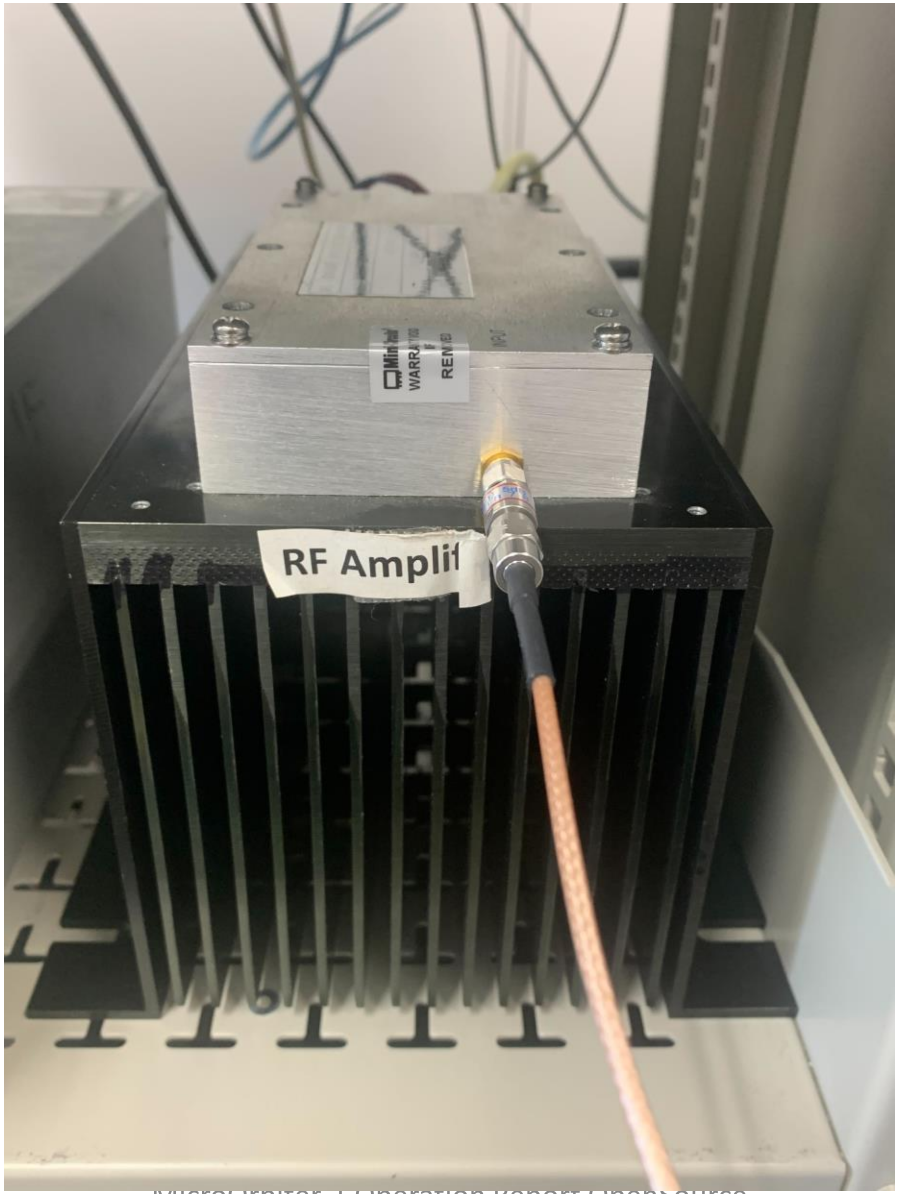
Rotator controller Pro-sis-tel (Elevation and Azimuth)

TNC (KPC 9612 plus)

Signal Generator (Transmitter) Agilent N9310A



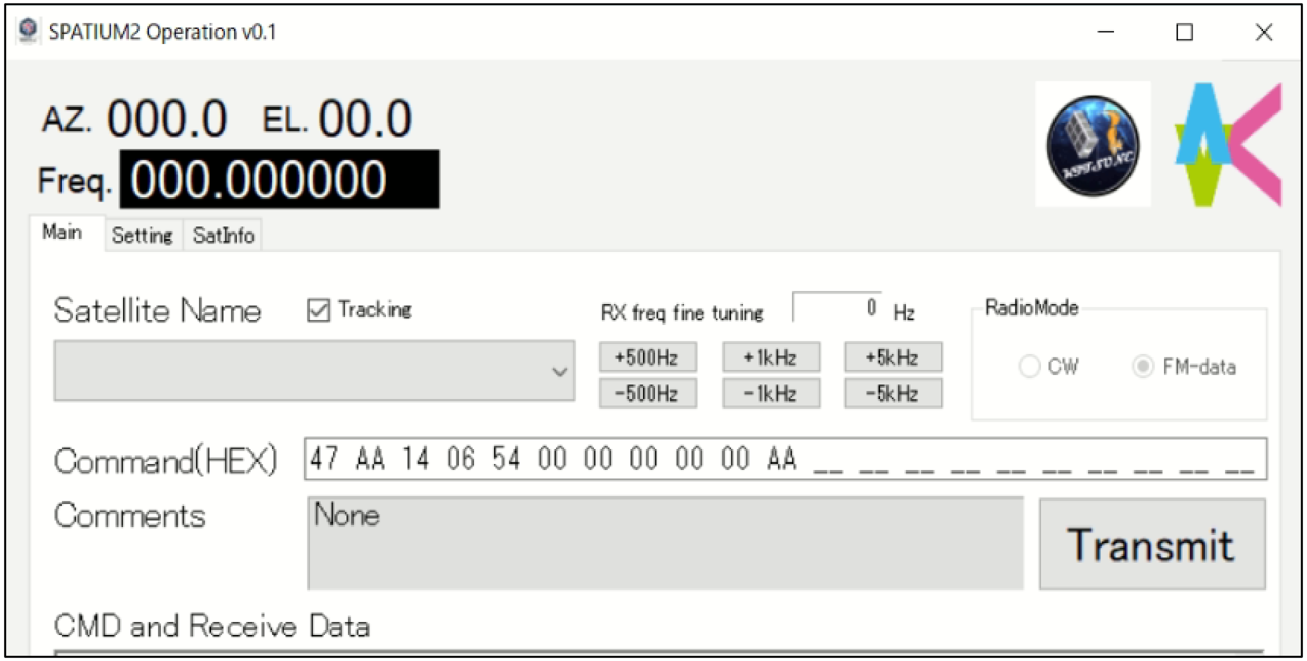
Power Amplifier



RTL-SDR Radio (R820T2)

Windows PC

MicroOrbiter-1 GS Software



1. Uplink realized by inserting a command and clicking on the "Transmit" button
2. Downlink realized when the same software can decode the response from the satellite

Commands and responses are in HEX so conversion is performed on downlinked packets to understand the received data (a locally developed software is used for that purpose)

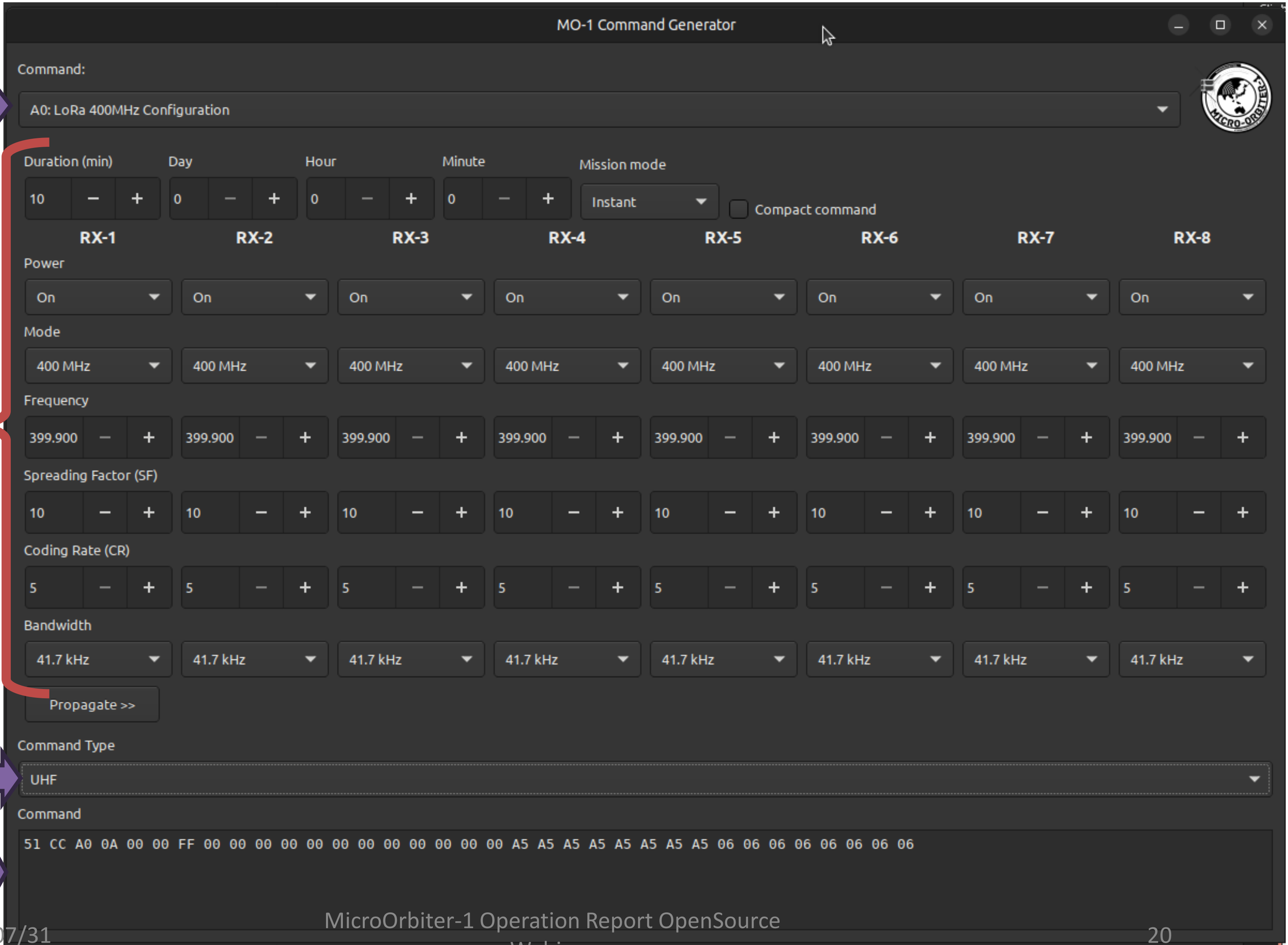
MicroOrbiter-1 GS Command Generator

Command selection

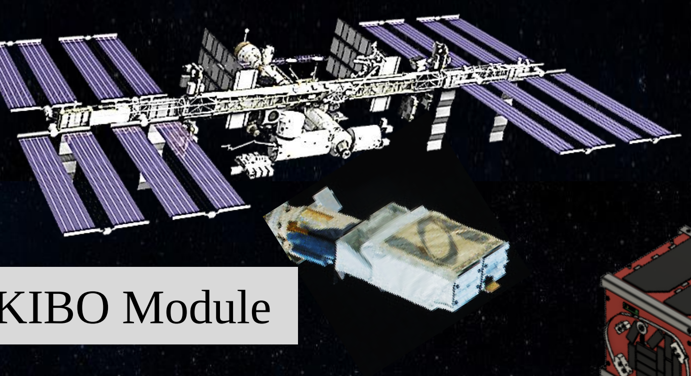
Adjustable parameters

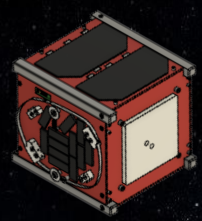
Command type (32 bytes, 4 x 8 bytes, …)

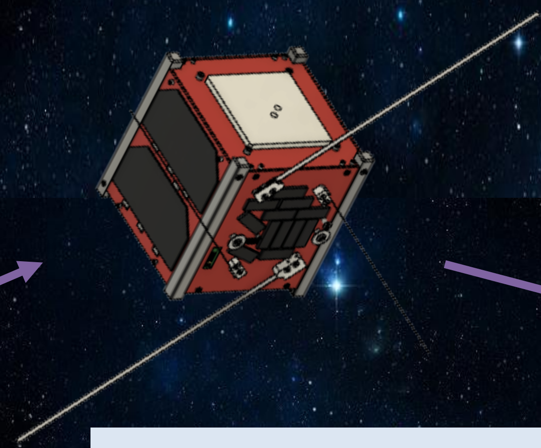
Generated command

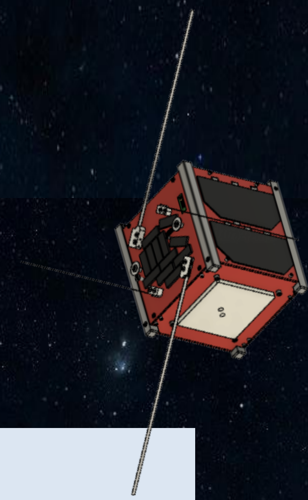


Deployment Overview









MicroOrbiter-1 Deployment (**t = 0**)

- **Release** of Deployment **switches**
- **Charging** starts (EPS **ON**)
- Turning **ON** (OBC **ON**)
- **Telemetry** is collected
- Attitude **stabilization** (detumbling)

(MAIN BUS)

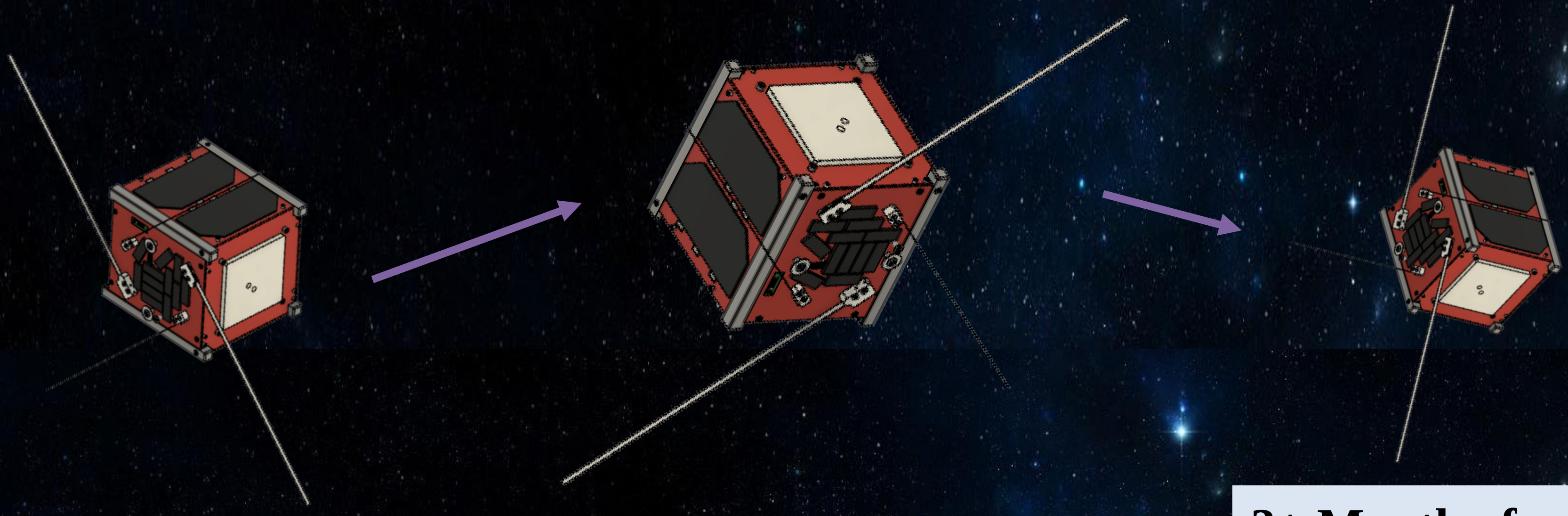
t = 31.0 min

UHF board = **ON**

CW transmission **starts**

Dipole **antennas deployment**

Operation Timeline



Week 1-2 (Initial Operation)

- Satellite Overall Health Monitoring :

1. EPS
2. OBC
3. COMMS
4. Antenna Deployment
5. Start LoRa missions if EPS OK

Week 2+ (Stable Status)

- Satellite Overall Health Monitoring
- 920 LoRa Mission performance
- 400 LoRa Mission performance

3+ Month of operation

- Satellite Overall Health Monitoring
- Continuous optimization of operations to achieve the success criteria

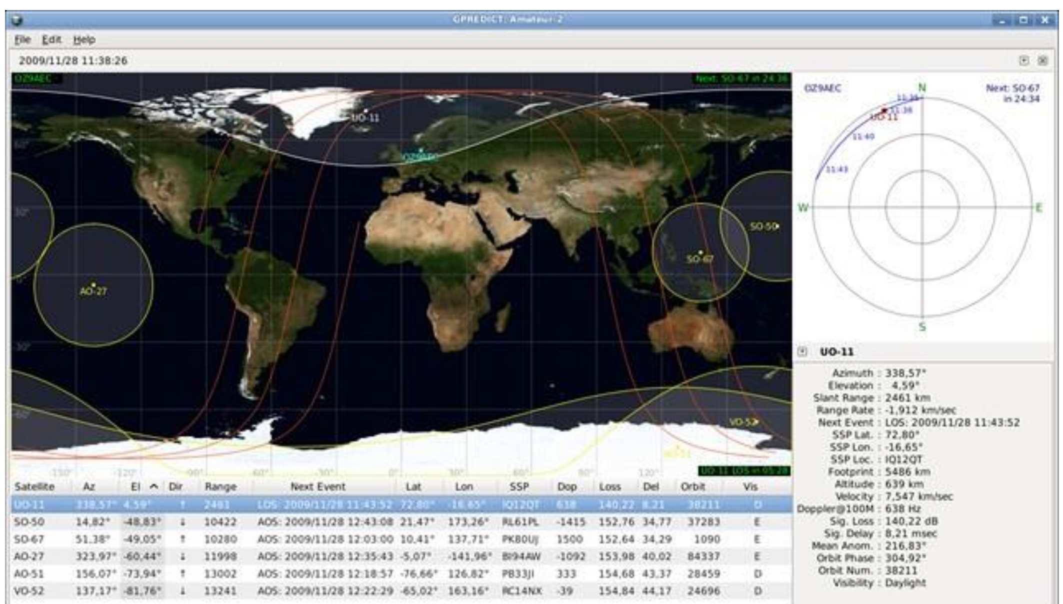
Mission Execution

Mission	Human Resource	Task List	Execution Frequency
LoRa Mission	Full Team	1. Sensory data downlink 2. Uploading data to database	• Once every day • Elevations ≥ 40°
Housekeeping	Full Team	1. Telemetry Downlink 2. Weekly summary 3. Archiving	Every day

Telemetry data Analysis and Mission Scheduling

- As Telemetry Data is received, the trajectory of the satellite and ground passes can be predicted :

1. For Each Predicted Pass, the elevation angle is calculated
2. In function of the elevation angle, the highest angles should be selected for the daily passes (≥ 8°)

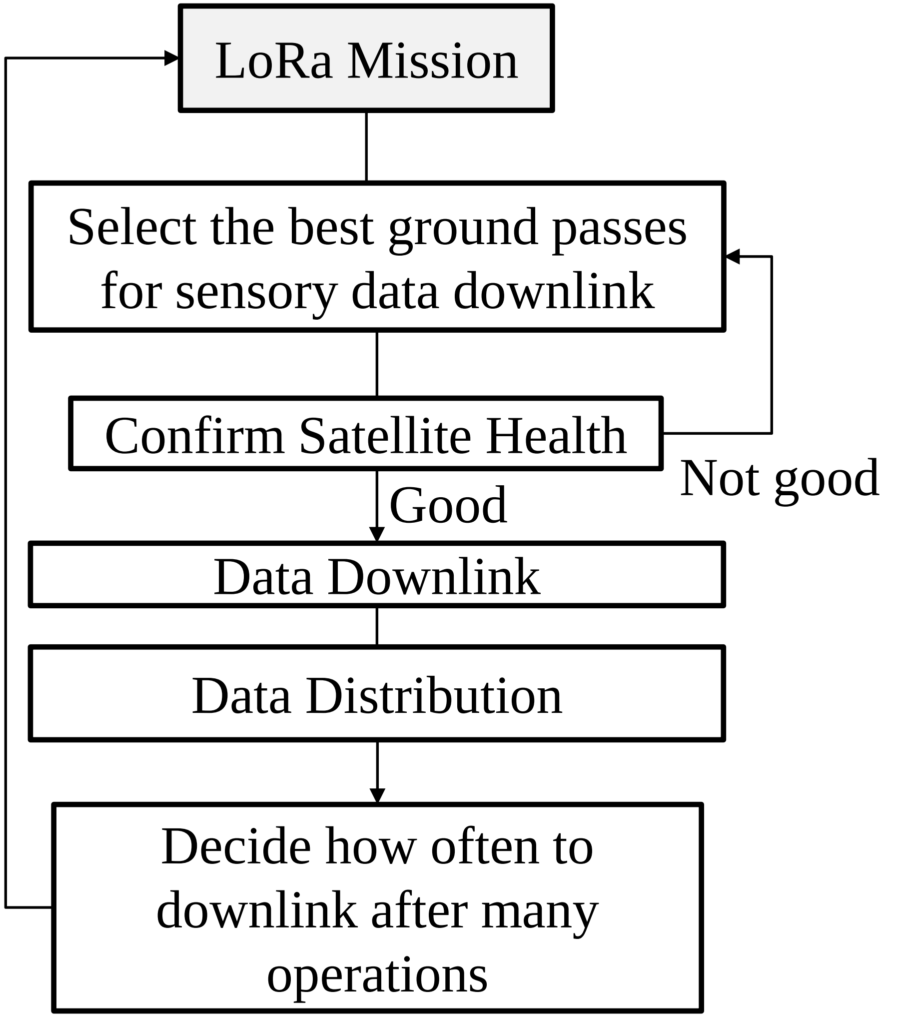


http://gpredict.oz9aec.net/

Operation Weekly Plan

	Weekly Plan						
	1	2	3	4	5	6	7
Non-Amateur GS	920 LoRa ON	920 LoRa ON	920 LoRa ON	920 LoRa ON	920 LoRa ON	920 LoRa ON	Next Week Planning 920 LoRa ON
	House Keeping data and Telemetry downlink (UHF COMMS)						

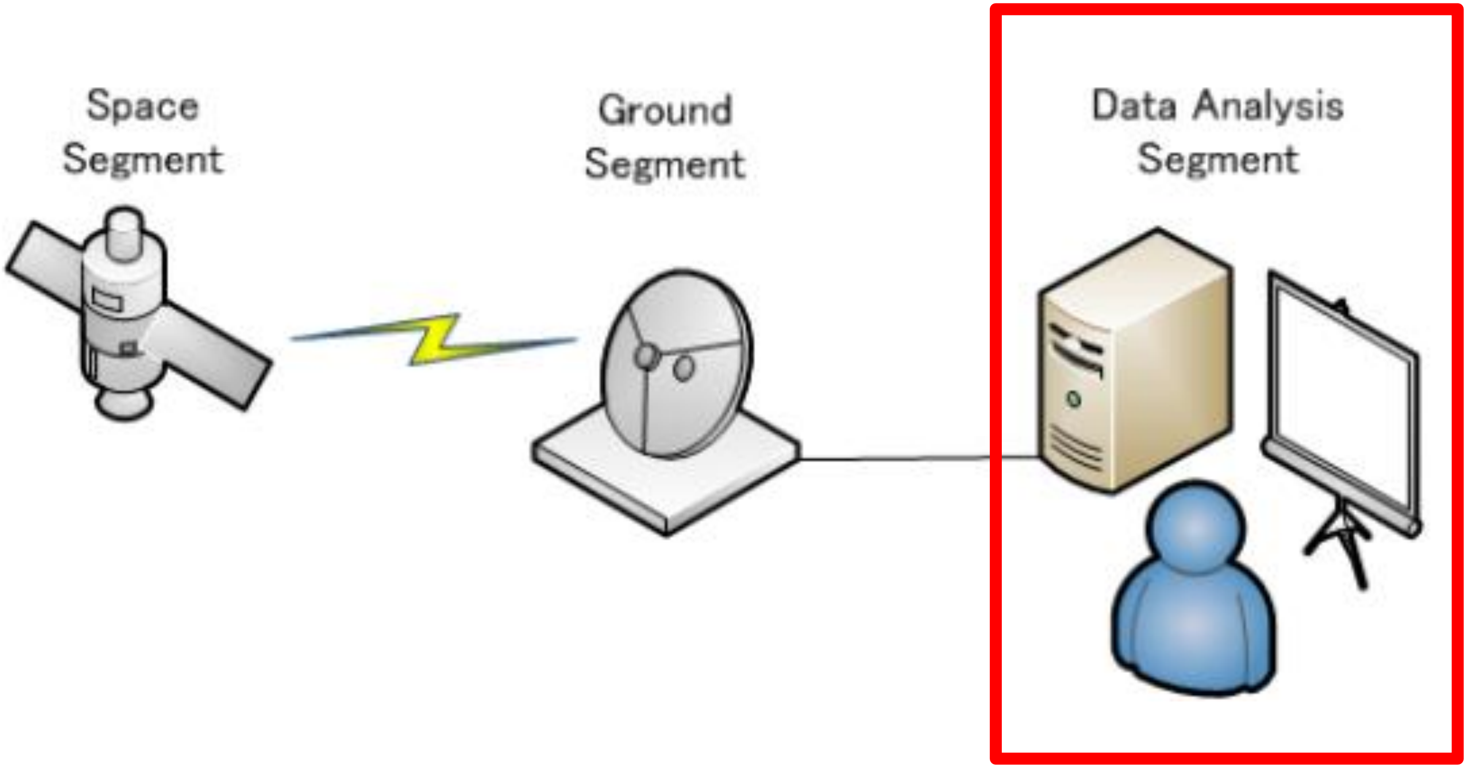
Operation Monthly Plan



Overall Mission Plan

1. Communication Team announces the ground passes time, elevation angle and communication window time
2. Along with EPS consideration, LoRa mission team selects the mission targets, the ground passes for scheduled command uplink and downlink
3. Each LoRa mission should be enabled independently initially and can be done simultaneously if power budget allows.
4. If satellite housekeeping data suggests to change the main mission operation plan, coordination must be properly conducted within the team (**Ex : Update of power budget from space data**)

IV. Results and Data Analysis



https://birds-project.com/mext/pdf/Digital_Textbook_G_2021JUL06.pdf

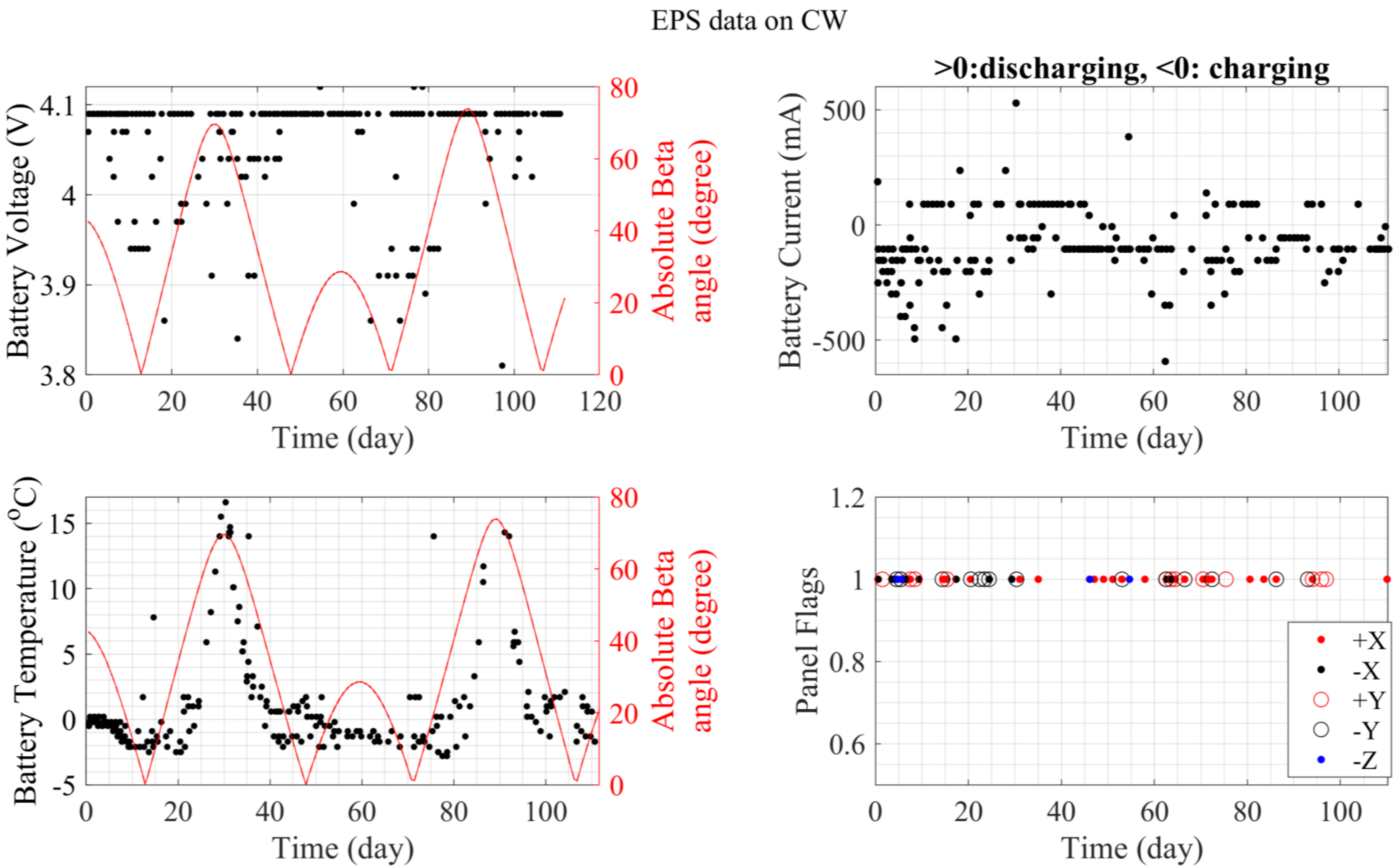
First of each

First CW beacon	6:30 12 Apr 2024 JST
First CMD Uplink (UL) Success	7:11 14 Apr 2024 JST
First HK Data Packets (20/20)	14:26 16 Apr 2024 JST
First 100 Packets in one shot (126/200)	19:24 3 Jun 2024 JST
First LoRa 920 UL Success (11 packets)	19:35 12 May 2024 JST
First LoRa 920 packets DL (8 packets)	1:51 15 May 2024 JST
First TLE Store & Forward Mission Full Success	13:19 25 Jul 2024 JST
First LoRa 920 Packets from Indonesia	10:20 3 Jul 2024 JST
First LoRa 920 packets from the US	6:07 21 Jul 2024 JST
Highest number of HK packets in one shot (183/200)	2:40 11 Jul 2024 JST

Summary

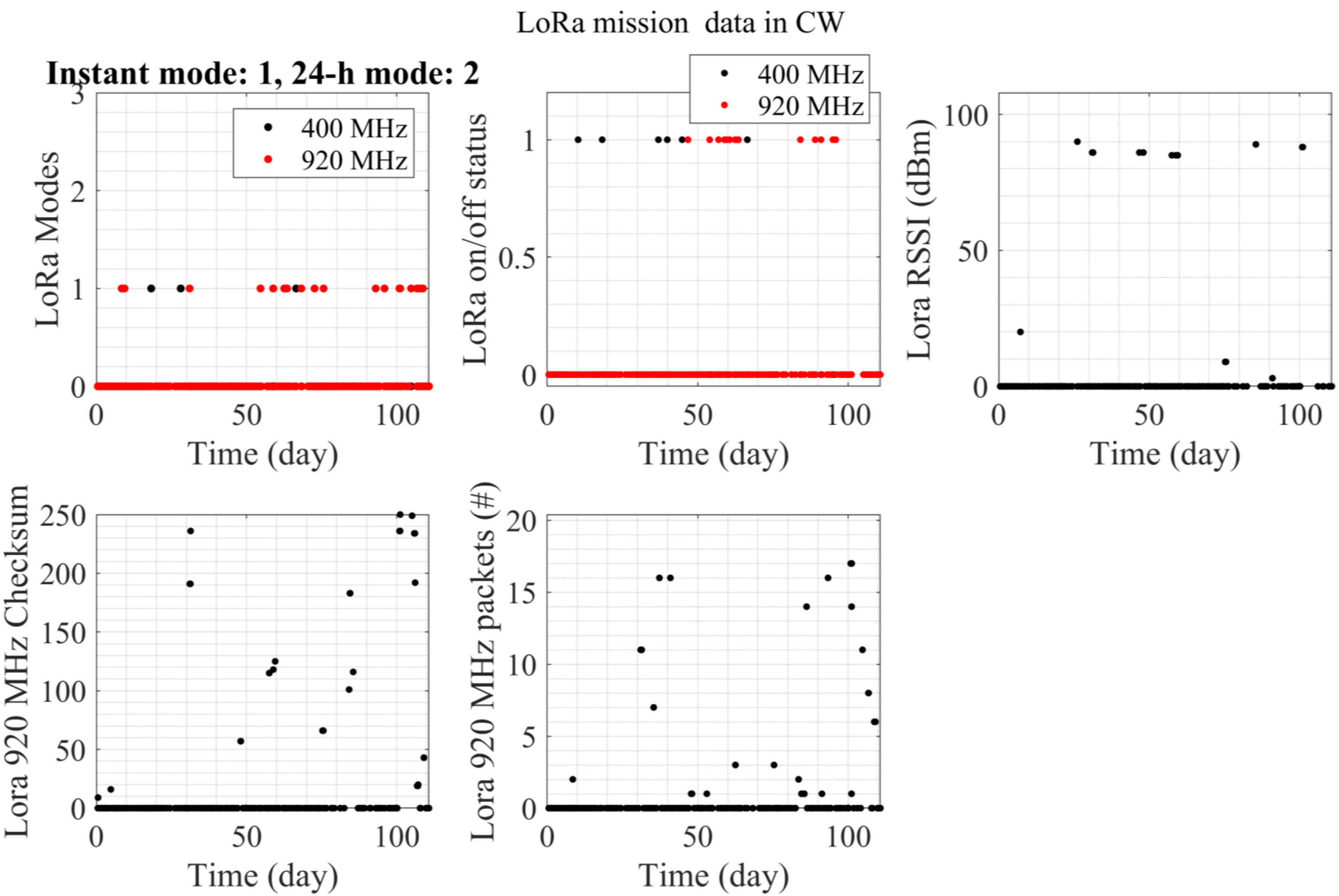
Passes	362
Decoded CW messages	511
HK Data Packets	13975
LoRa 920 Data Packets	189
LoRa 400 Data Packets	0

EPS Data from CW messages

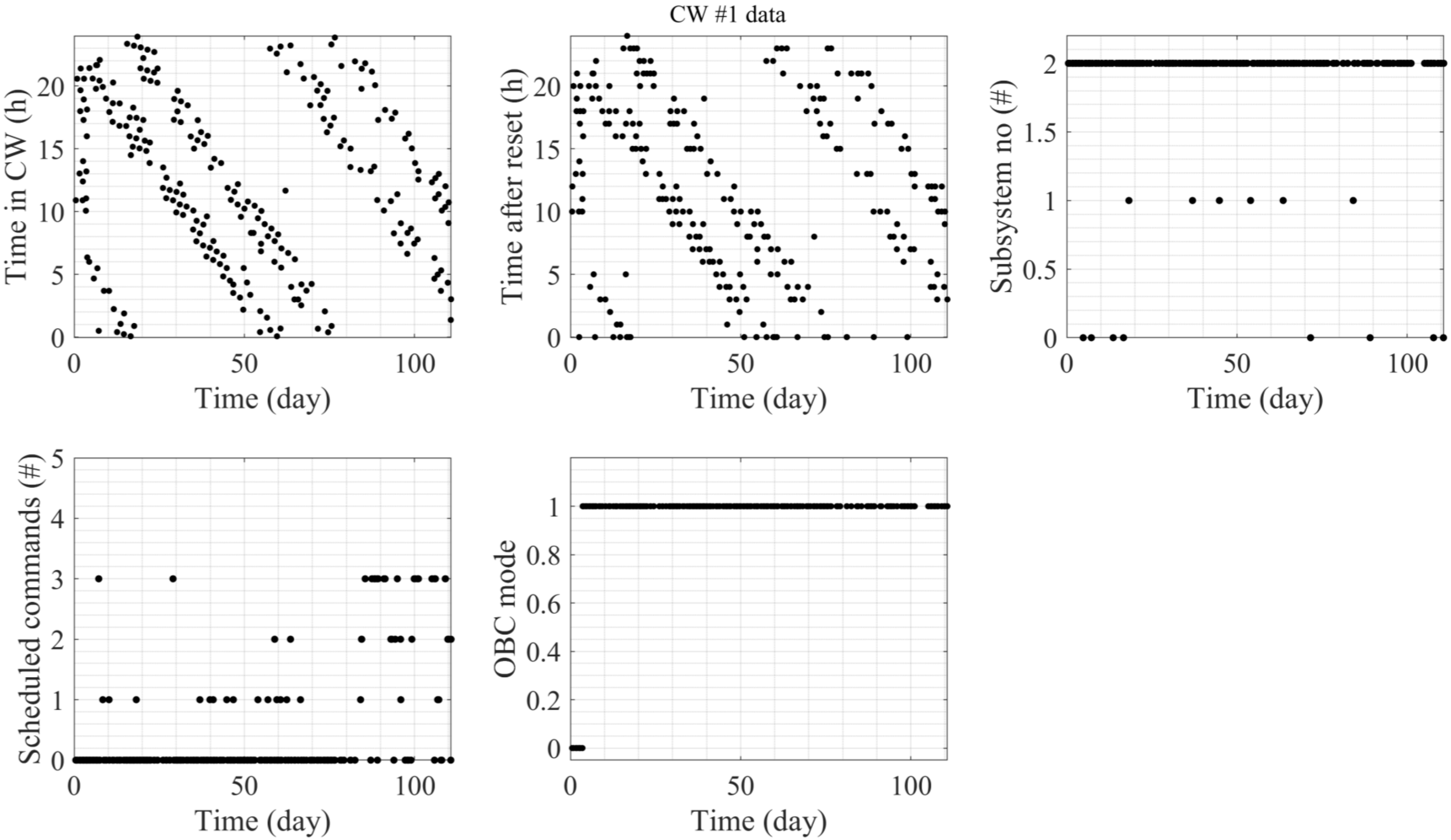


Credit : Dr. Necmi Orger

LoRa Data from CW messages

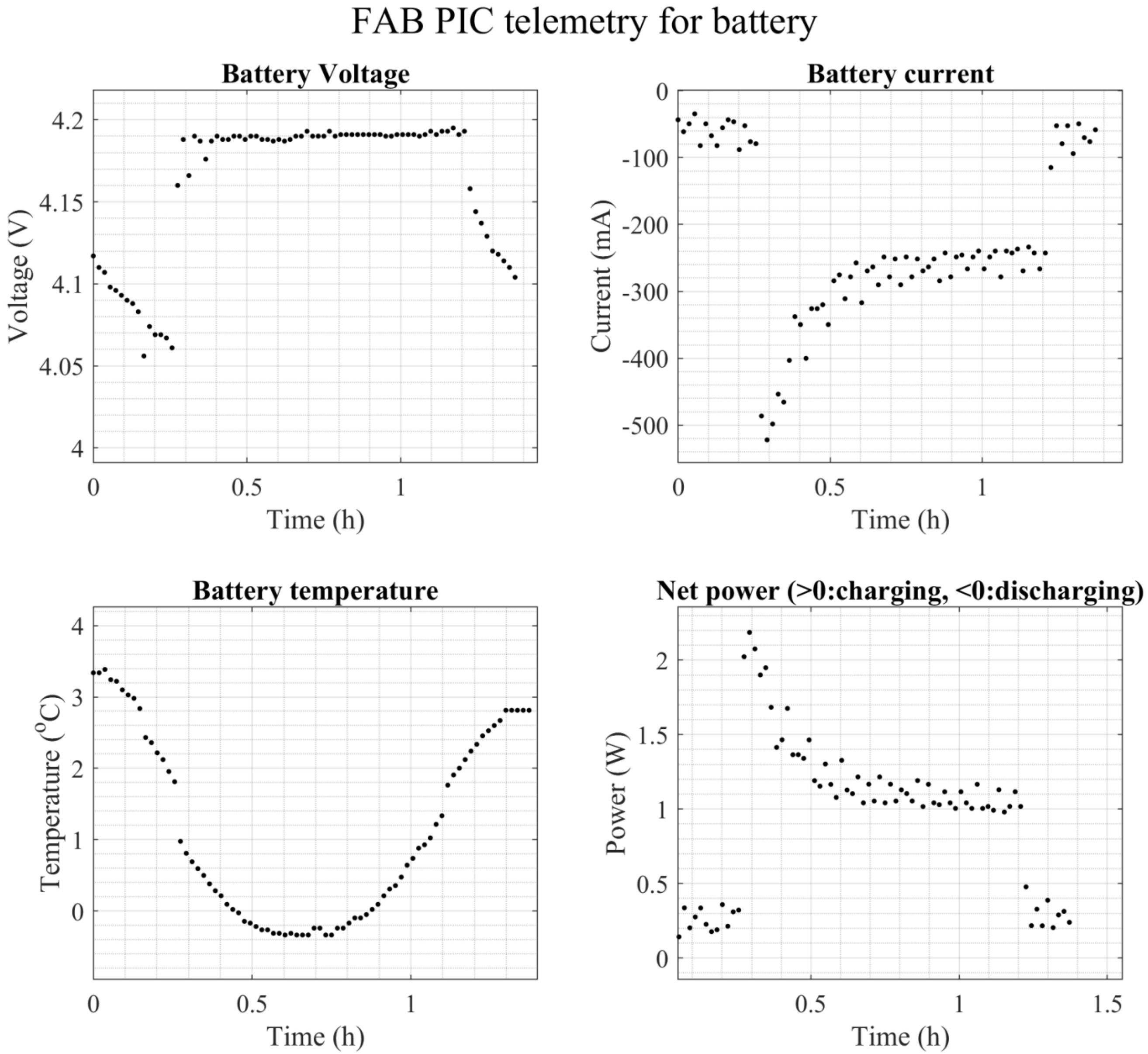


OBC Data from CW messages



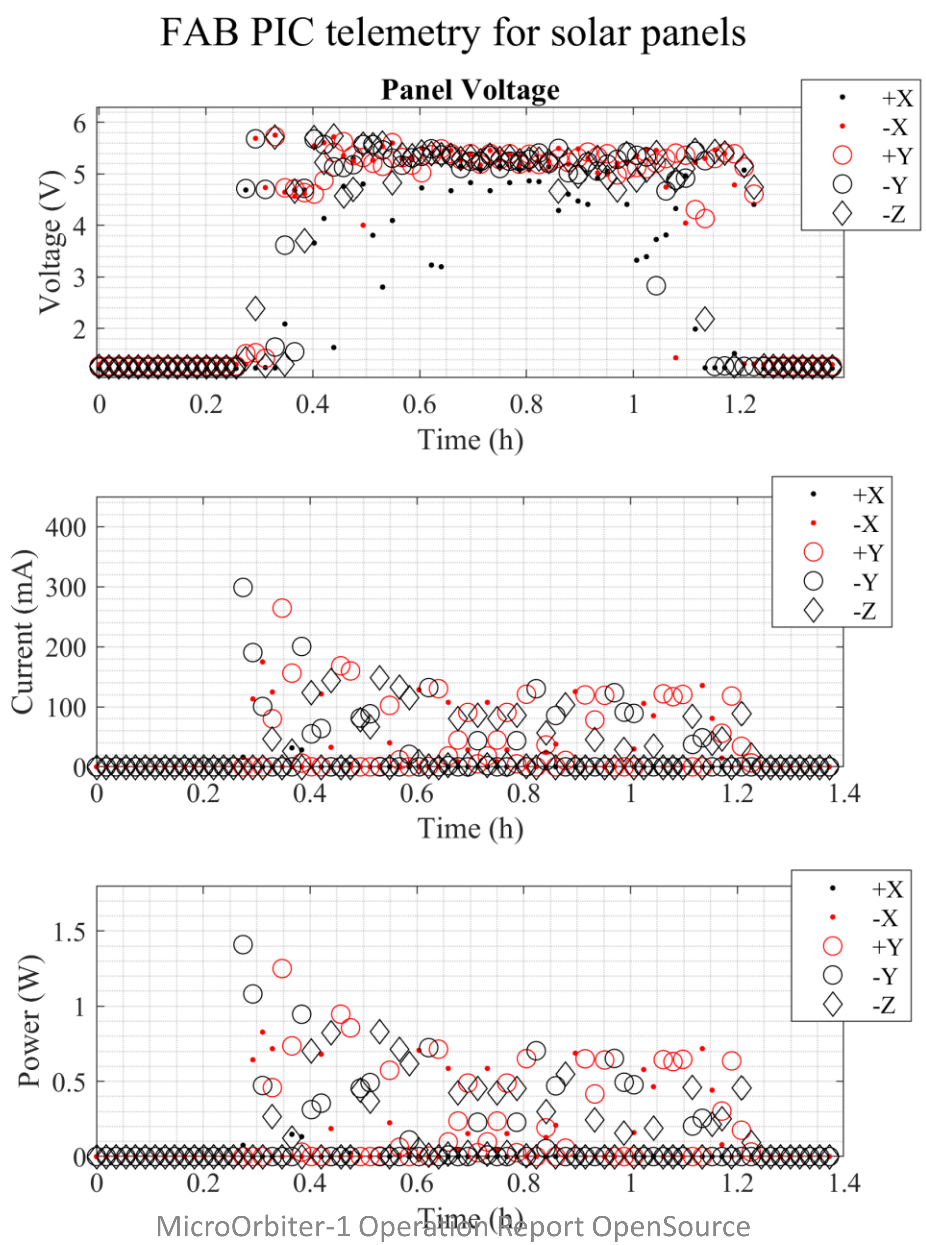
Credit : Dr. Necmi Orger

Battery HK Data sample plots for 1 orbit



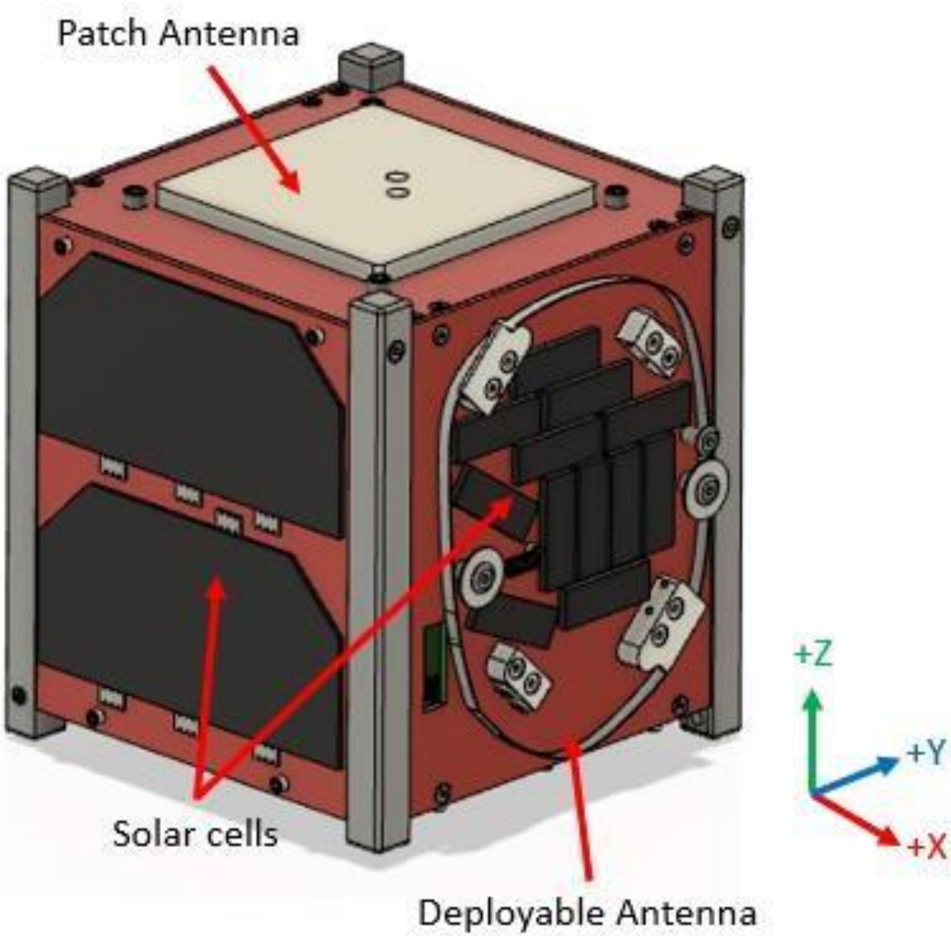
Credit : Dr. Necmi Orger

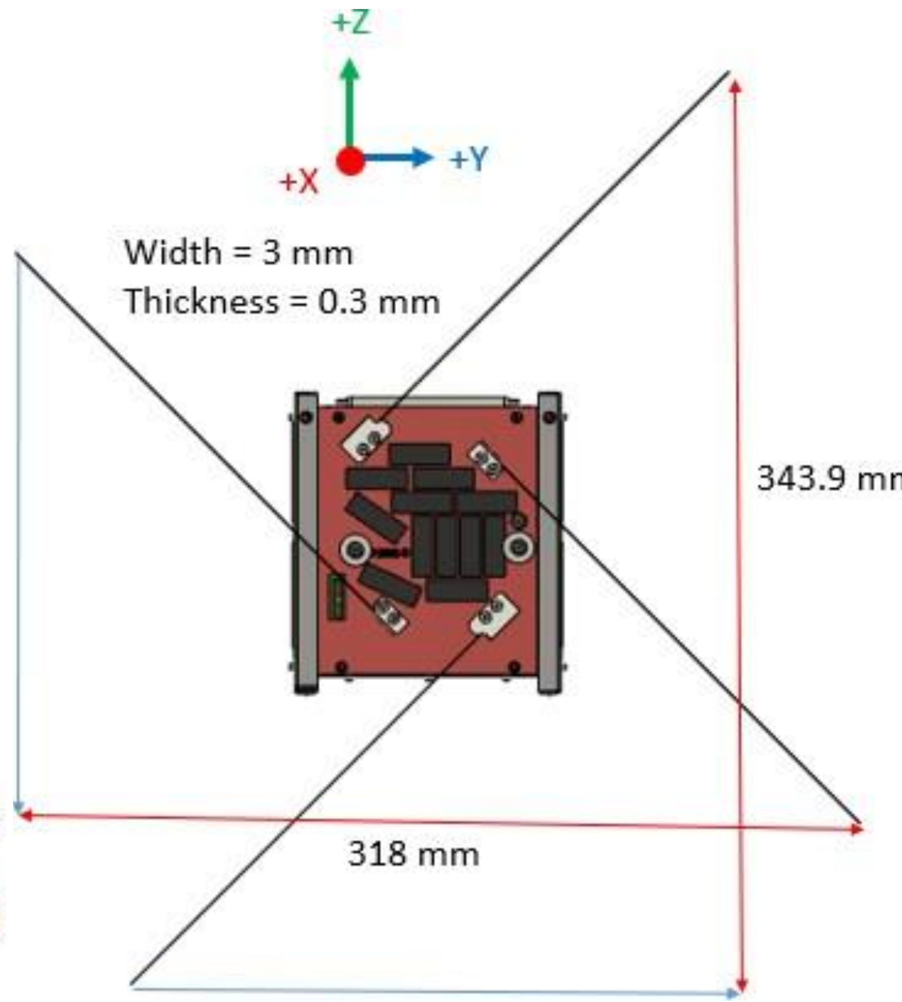
Panels HK Data sample plots for 1 orbit



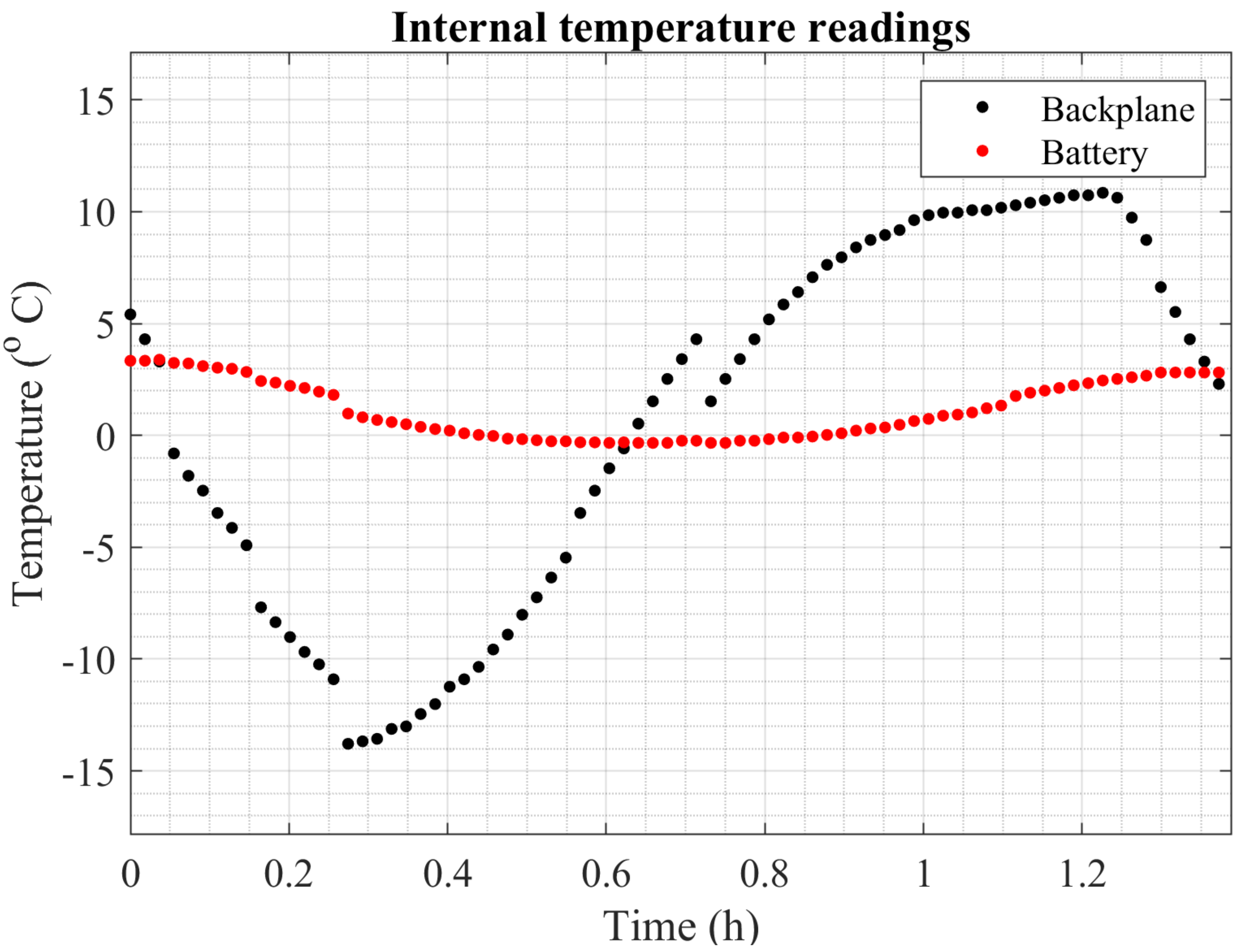
Credit : Dr. Necmi Orger

Quick structure Overview



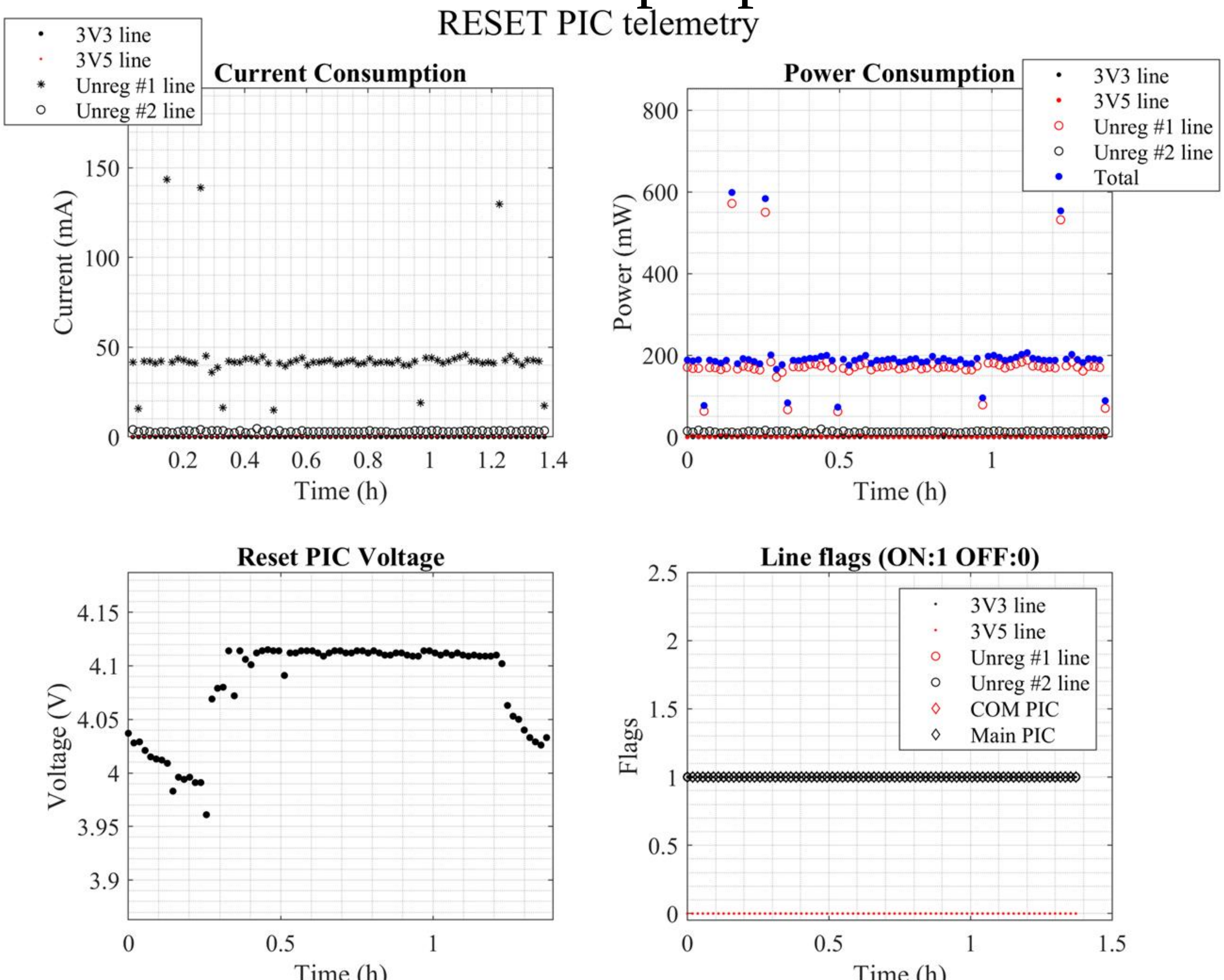


Internal Temperature HK Data sample plots for 1 orbit



Credit : Dr. Necmi Orger

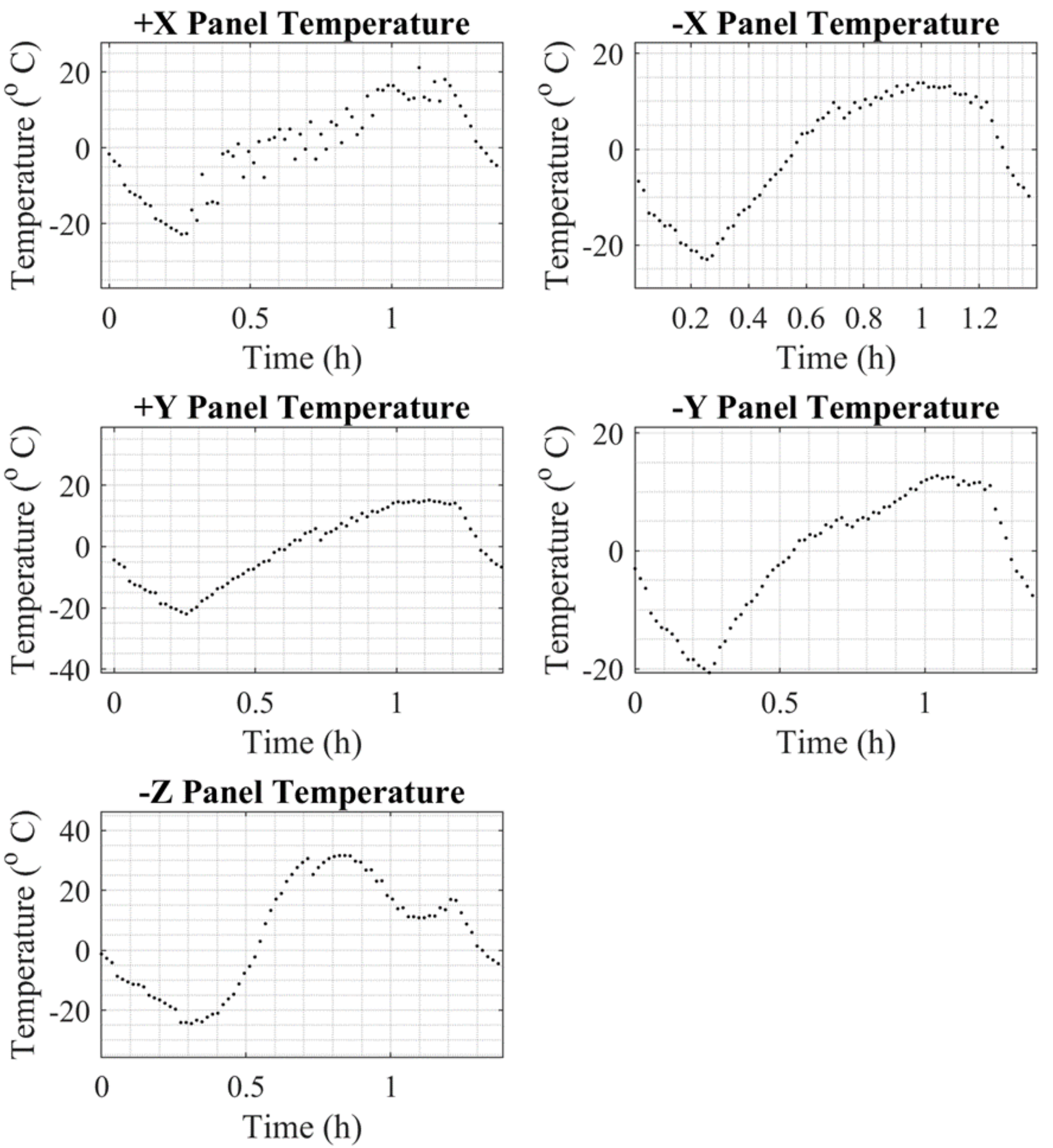
Reset PIC HK Data sample plots for 1 orbit



Credit : Dr. Necmi Orger

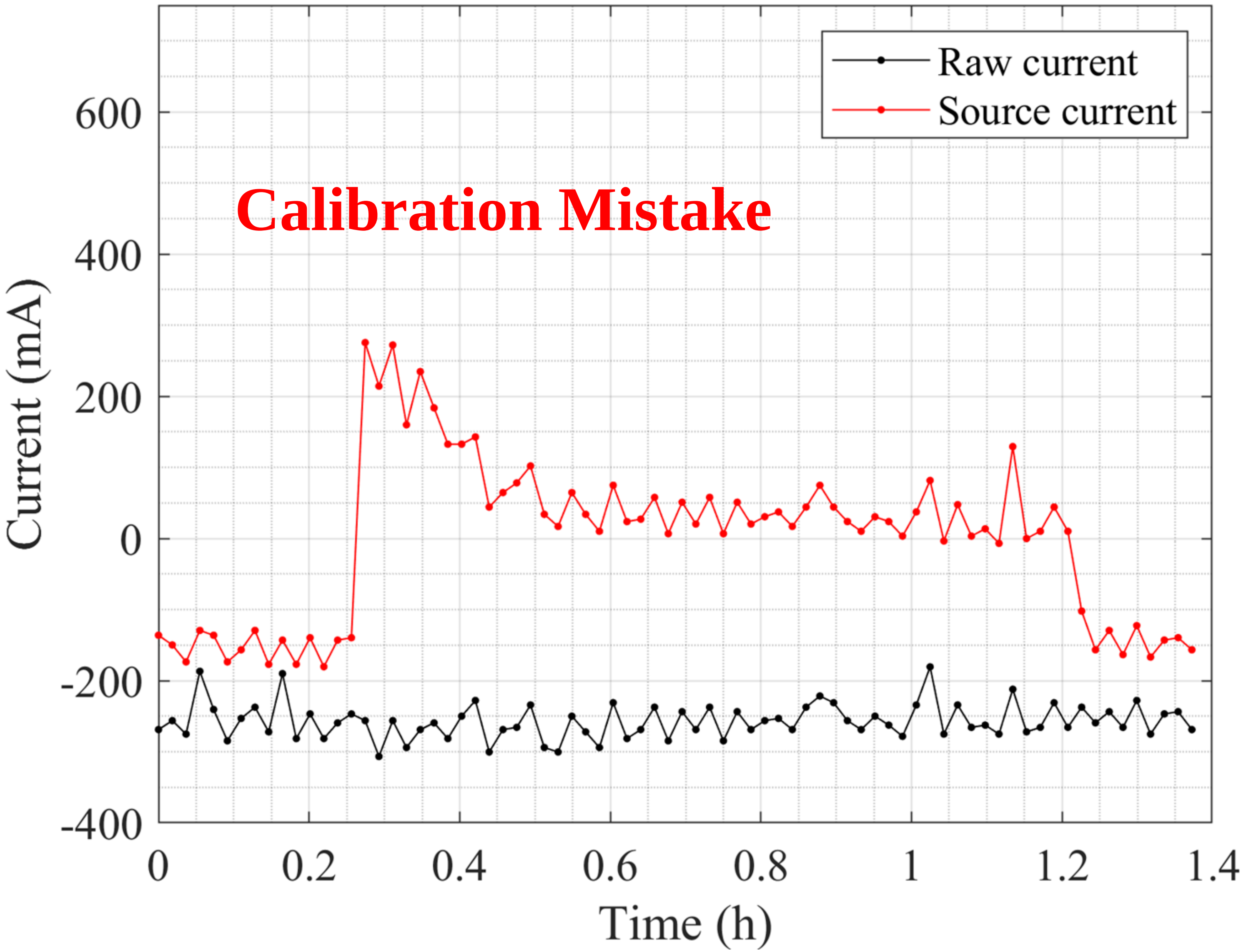
Panel Temperature HK Data sample plots for 1 orbit

FAB PIC panel temperature



Credit : Dr. Necmi Orger

Raw and Source Currents HK Data sample plots for 1 orbit

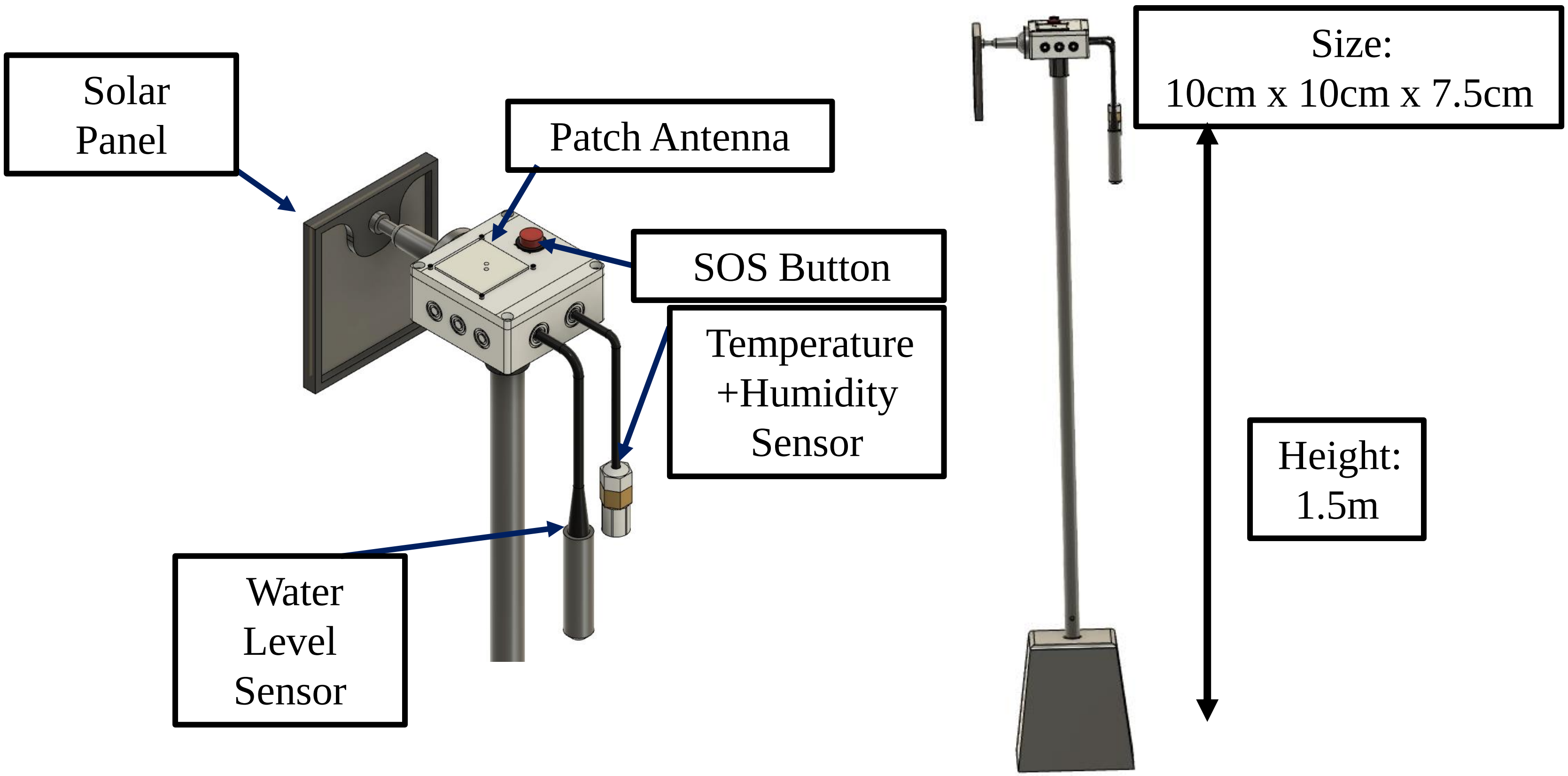


Credit : Dr. Necmi Orger

LoRa Mission Results for Japan Operations

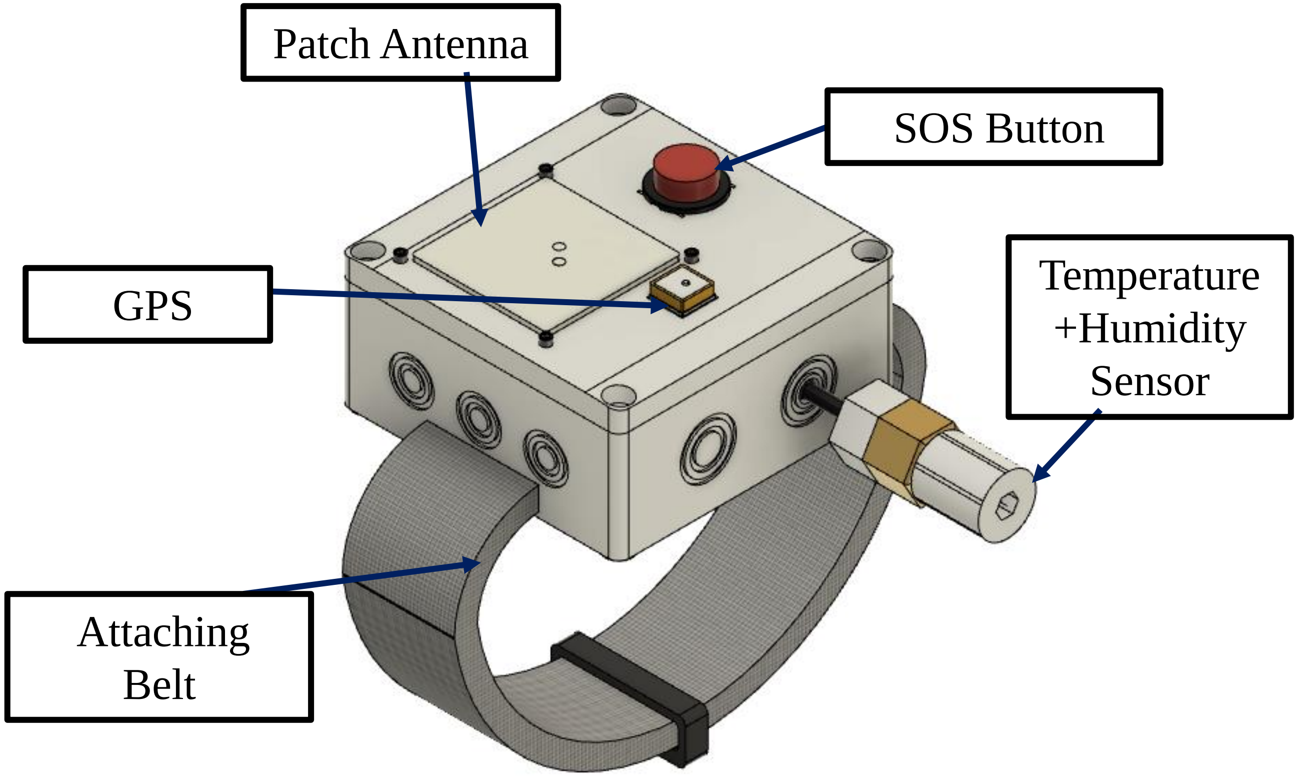
Mission	Duration	Antenna Gain	TX Power set in GST Board	Pointing	Elevation in degrees	Results
920	10 min	11 dBi (arrow)	0.25 W	Manual	71	First 11 packets (50% error)
		11 dBi (arrow)	0.25 W	Manual	56.16/ 58.29 / 69.85 / 73.27	5 packets (50% error)
		2 dBi (patch)	0.25 W	Automatic	84.57 / 89	2 packets (50% error)
		2 dBi (patch)	0.25 W	Manual	71/ 73 /83	-
400		9.2 dBi (arrow)	0.25 W	Manual / Automatic	71 /65	-
		20 dBi (Yagi)	0.25 W	Automatic	71	-

MO-1 Ground Sensor Terminals (1/3)



920 MHz Fixed Ground Sensor Terminal

MO-1 Ground Sensor Terminals (2/3)

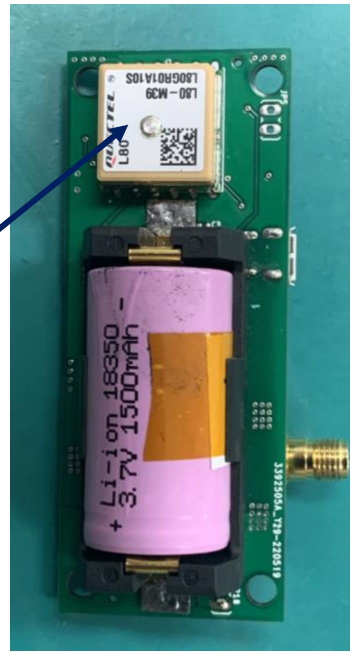


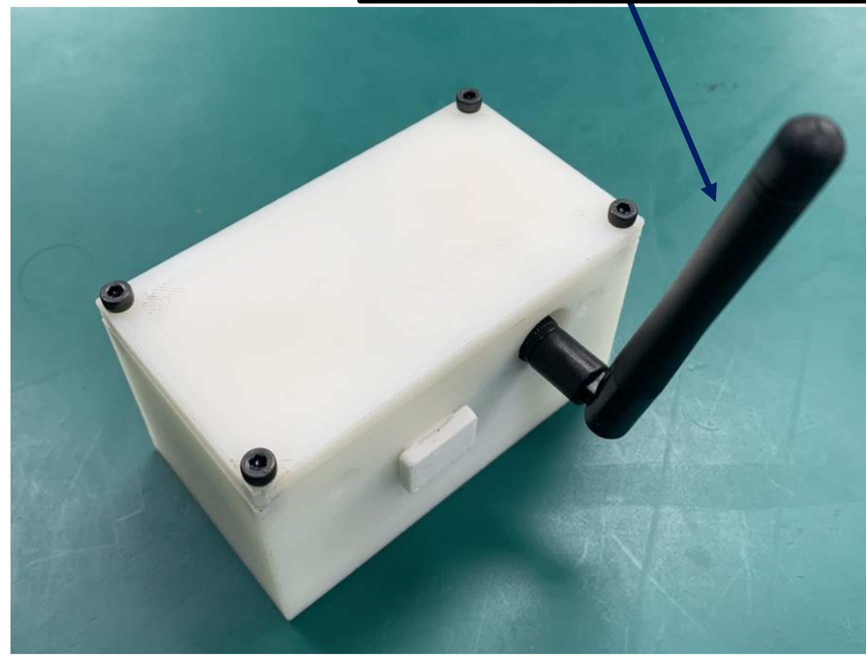
920 MHz Mobile Ground Sensor Terminal

MO-1 Ground Sensor Terminals (3/3)

Monopole Antenna

GPS





400 MHz Mobile Ground Sensor Terminal

400 MHz mission : Not achieved yet

Possible Issue	Suggestion	Results
GS signal decoding	Use an LNA / Reduce the bandwidth in the SDR	Empty packets
Background noise	Try frequently at different times	Empty packets
Satellite temperature	Try when satellite temperature is above 5 deg	At 10 deg and still empty packets
Command sequence is wrong (Copy memory sector)	Try with EM	EM is okay with the sequence applied
Antenna gain is not enough	Try with a high gain antenna	Tried with 20 dBi antenna with proper tracking – empty packets
Antenna tracking is not good	Use the automatic tracking GST / Retry with Yotsuba GS	Empty packets
Command is not being executed	Check the power consuption	Power consumption confirmed for both LoRa missions
Uplink frequency is shifted	Configure the satellite receivers to different frequencies around 400 MHz	Empty packets / Retry + Long Range Test
The chip is not adapted	Try uplinks at 433 MHz	To be done

920 MHz mission : Achieved

- Main Challenge: GSTs are unreliable (low success rate)
- Exploration of Partnerships
- Experiment makes us think about link budget + ADCS

Packets from Japan (0.25 W)	17
Packets from Indonesia (8W)	42
Packets from US (3W)	130

About LoRa missions and power budget

- To try coverage of more regions per orbit, larger durations to run missions were applied
- Dummy packets were received during the experiment

Largest duration for 920 MHz (136.5 mWh)	6 h
Largest duration for 400 MHz (163.3 mWh)	3 h

Long Range Test best results for 920 MHz

Transmission Settings	Effective path attenuation (dB) = 108 + ATT	Receiver Sensitivity (dBm)*	Ideal Sensitivity (dBm)
SF = 9 BW = 41.7 kHz Data rate = 586 bps	135 dB (27dB)	-138 dBm	-134 dBm
SF = 12 BW = 31.25 kHz Data rate = 73 bps	137 dB (29dB)	**-140 dBm**	-143dBm
SF = 12 BW = 41.7kHz Data rate = 98 bps	137 dB (29dB)	**-140 dBm**	-142 dBm

Actual Best Configuration :
SF= 7 (Smallest Spreading Factor)
BW = 125 kHz (Largest Bandwidth)
CR = 5

Results for 920 MHz with partners

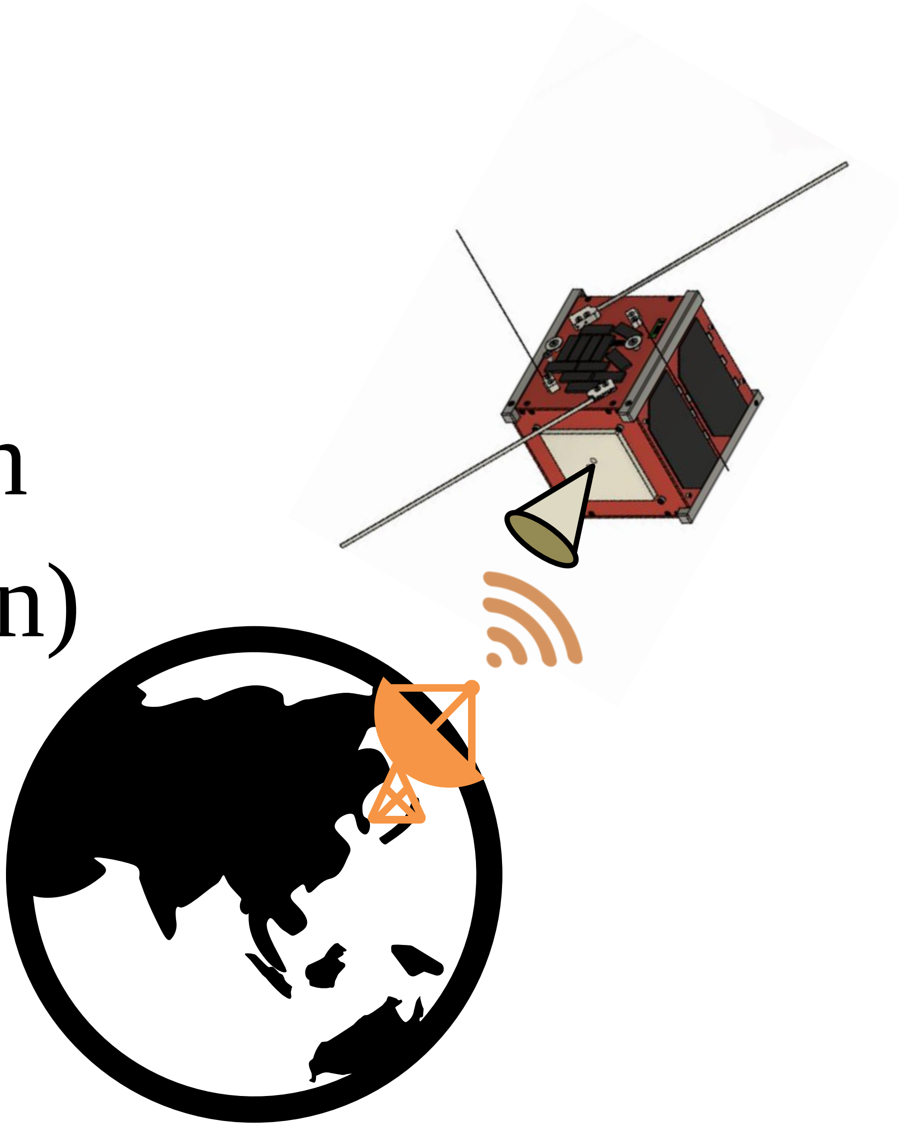
Day	Configuration (4 Frequencies)	Results
8 July	SF7 BW125 CR5	3 packets
9 July	SF8 BW125 CR5	0
10 July	SF9 BW125 CR5	0
11 July	SF9 and SF10 BW125 CR5	0
12 July	SF10 and SF11 BW125 CR5	0
13 July	SF11 BW125 CR5	0
14 July	SF7 BW125 CR5	3 packets
15 July	SF11 BW125 CR5	0
16 July	SF10 BW125 CR5	0

Actual Best Configuration :
SF= 7 (Smallest Spreading Factor)
BW = 125 kHz (Largest Bandwidth)
CR = 5

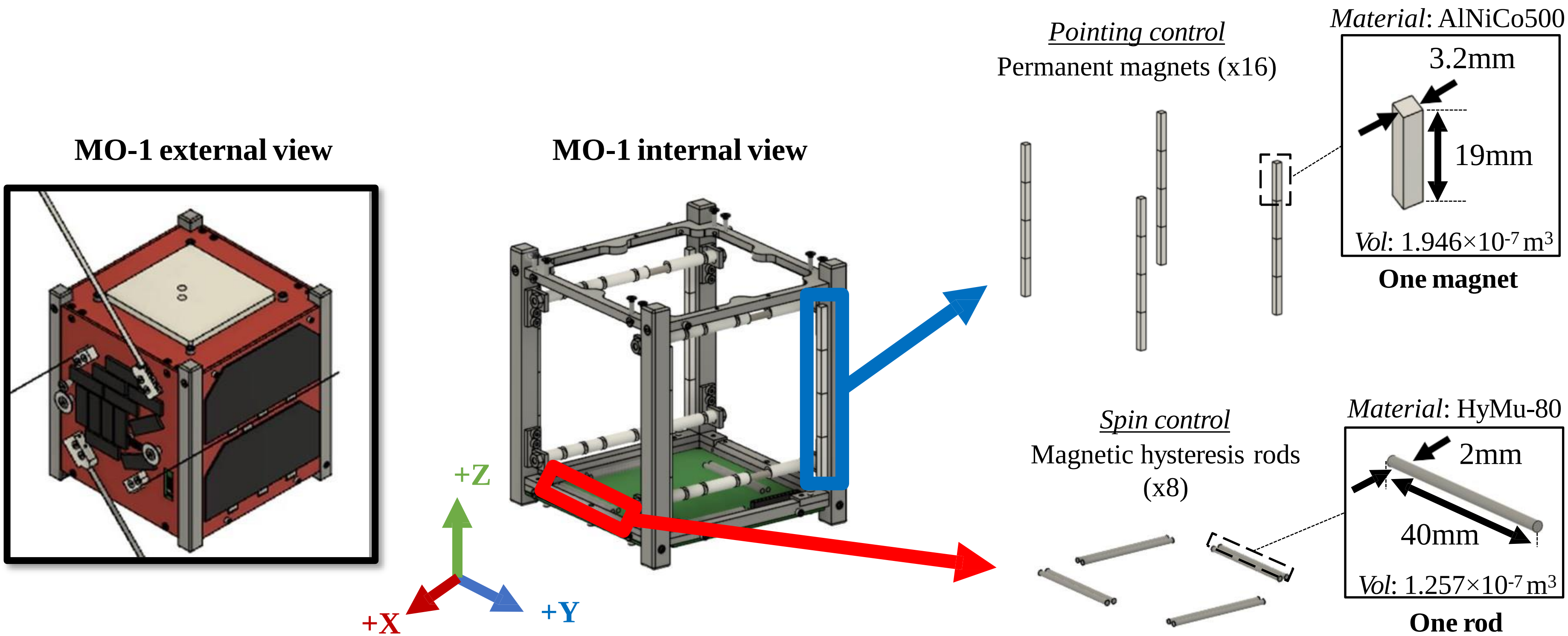
ADCS Talk

- **Patch Antenna** must **face** the **GST** on Earth

(Northward Orientation)



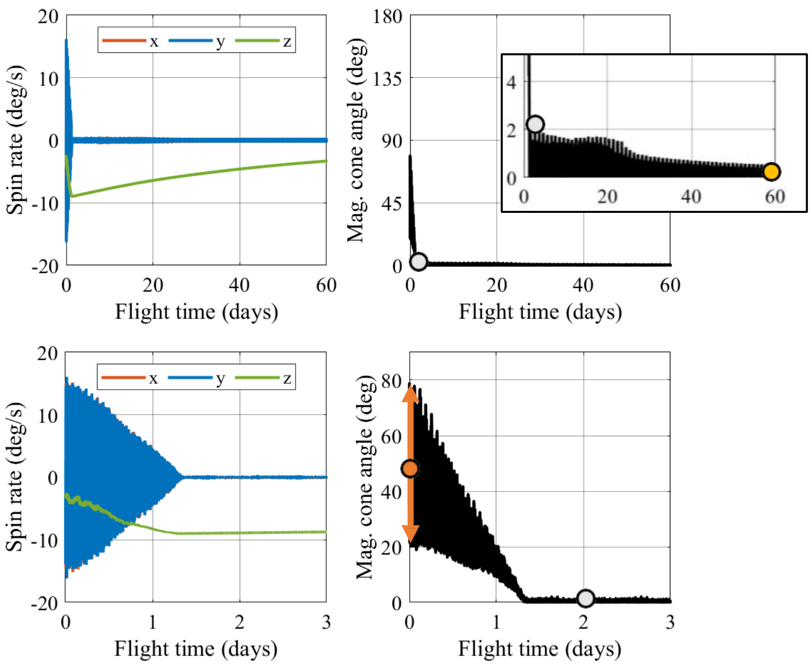
Passive magnetic ACS



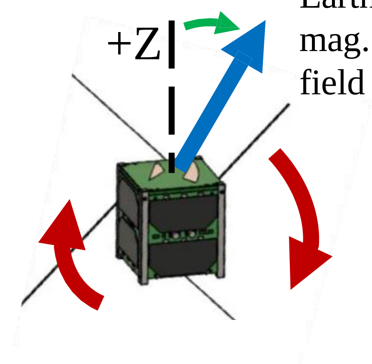
Key points: Fully passive system. No attitude determination: just control.

Simulated orbit-attitude dynamics

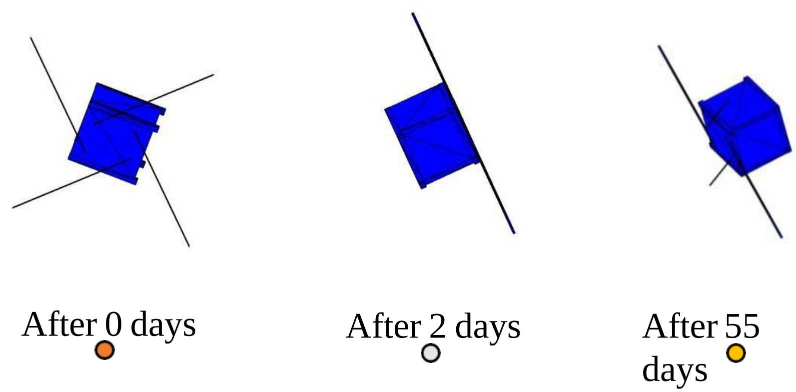
Spin rates and pointing angle



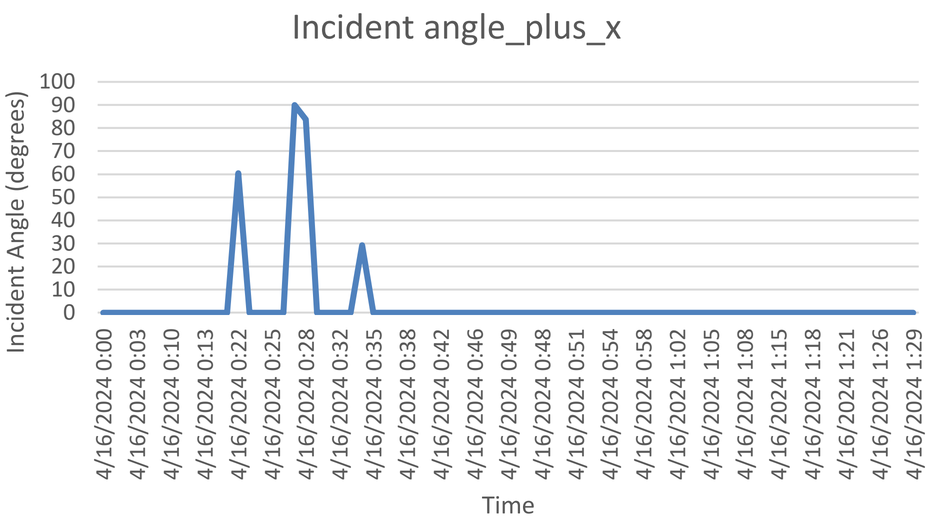
-Alignment with magnetic field within 2 days.
- Pointing error < 2°.
-Steady state spin rate is around 2-3°/s after 2 months.

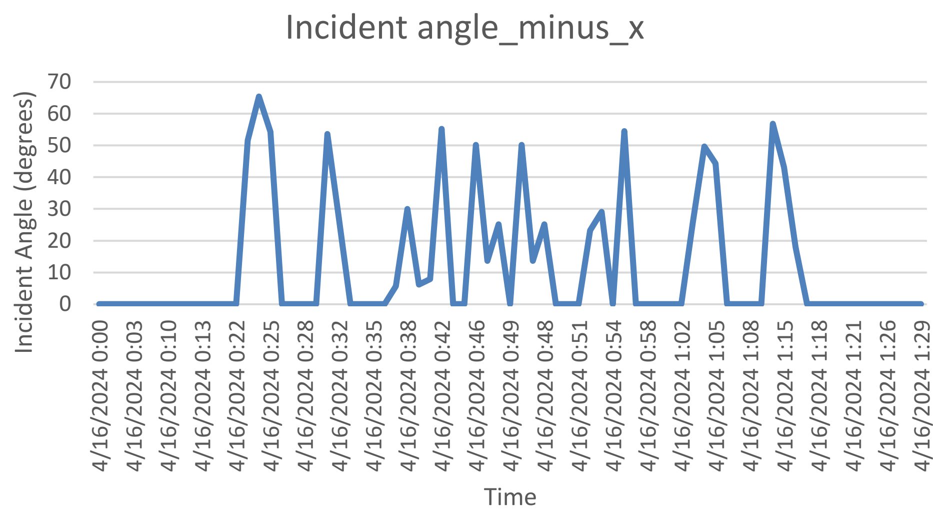


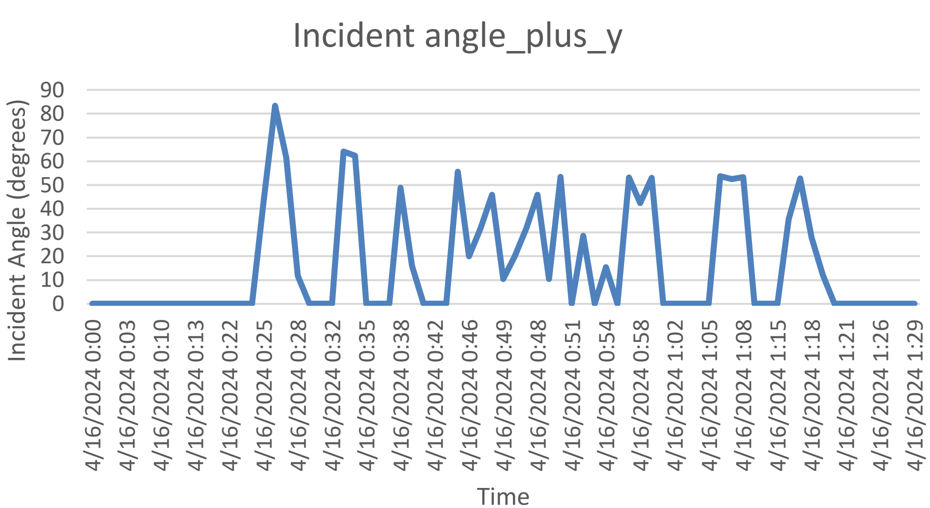
Attitude motion

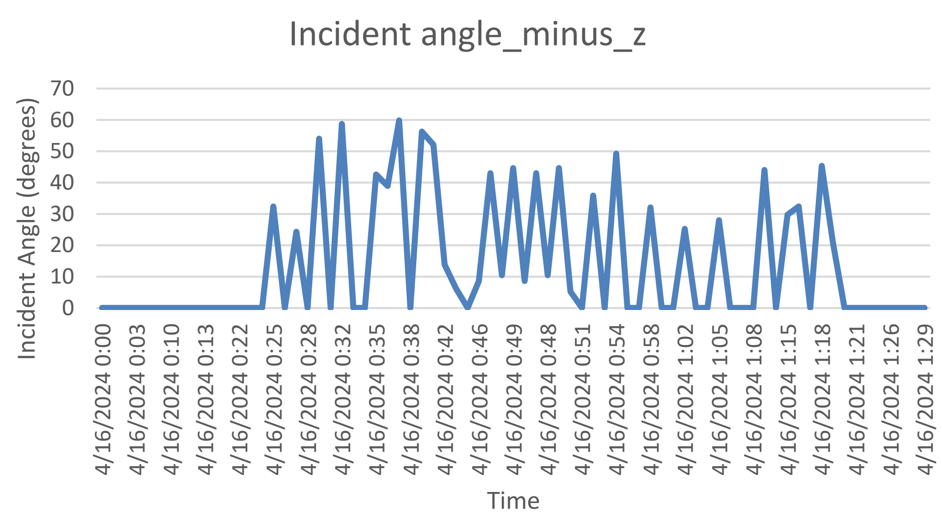


1 Orbit in April

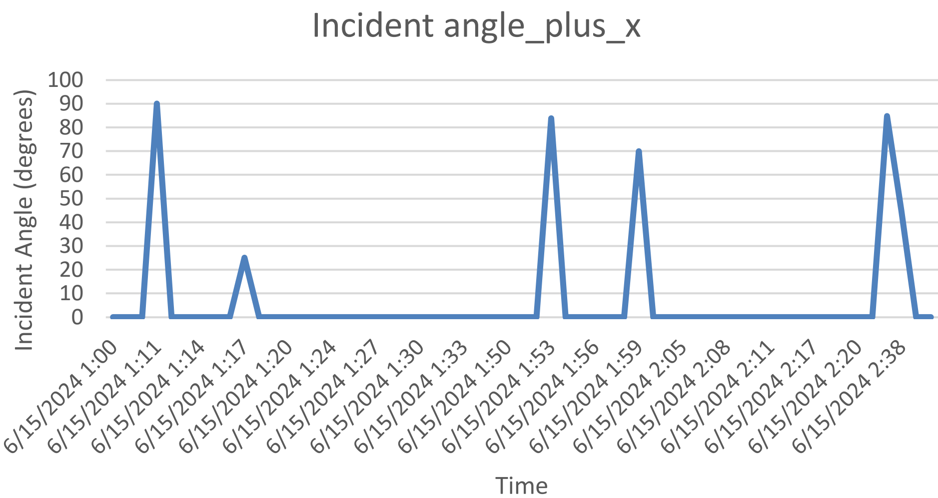


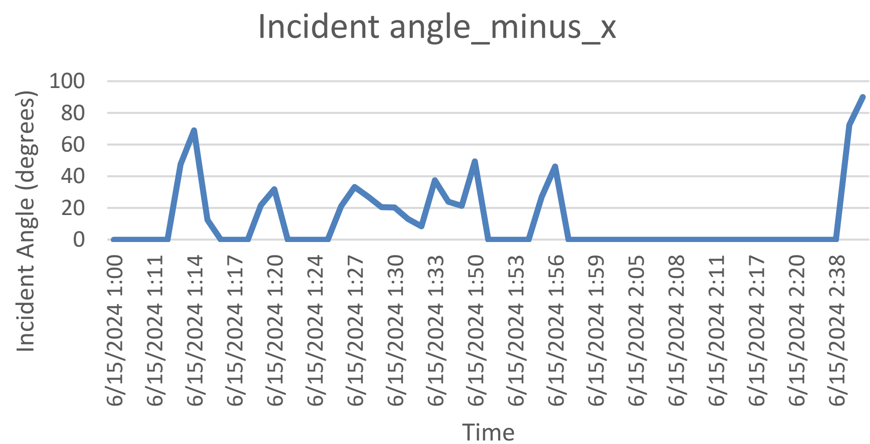


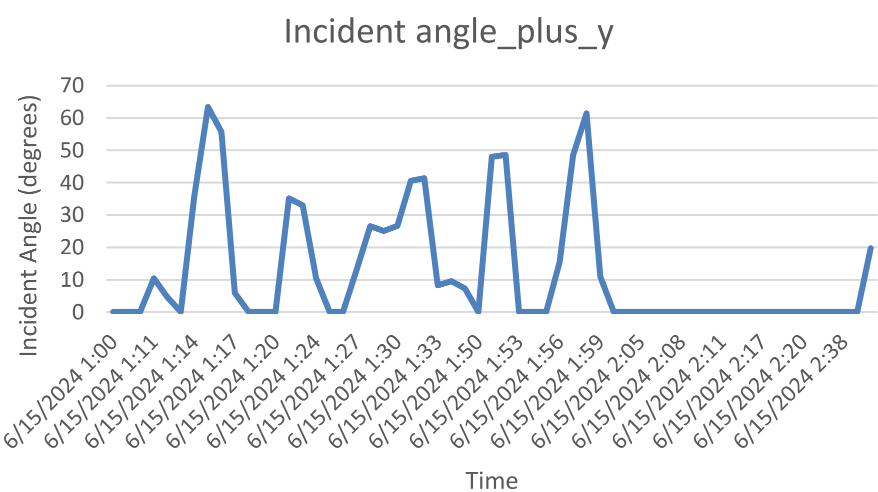


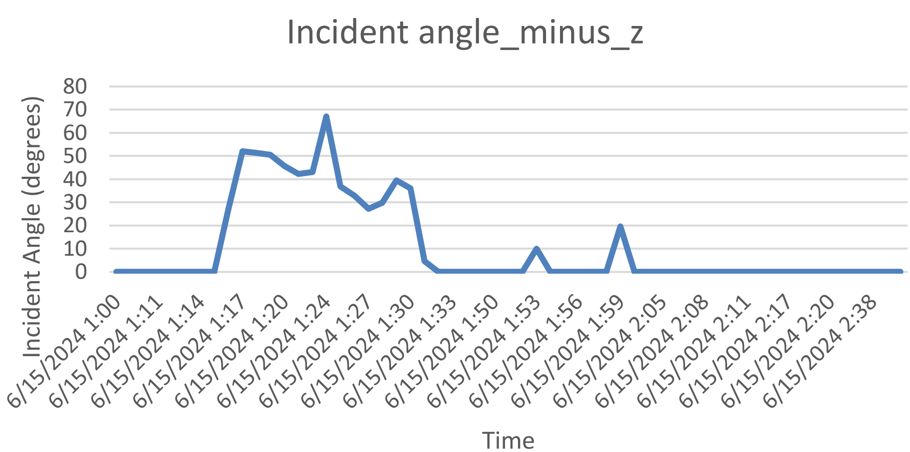


1 Orbit in June

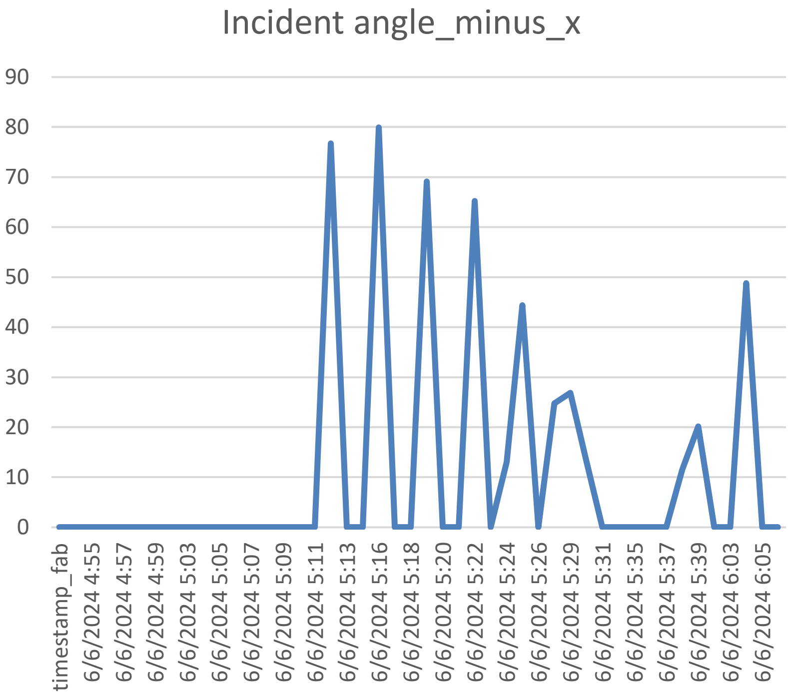


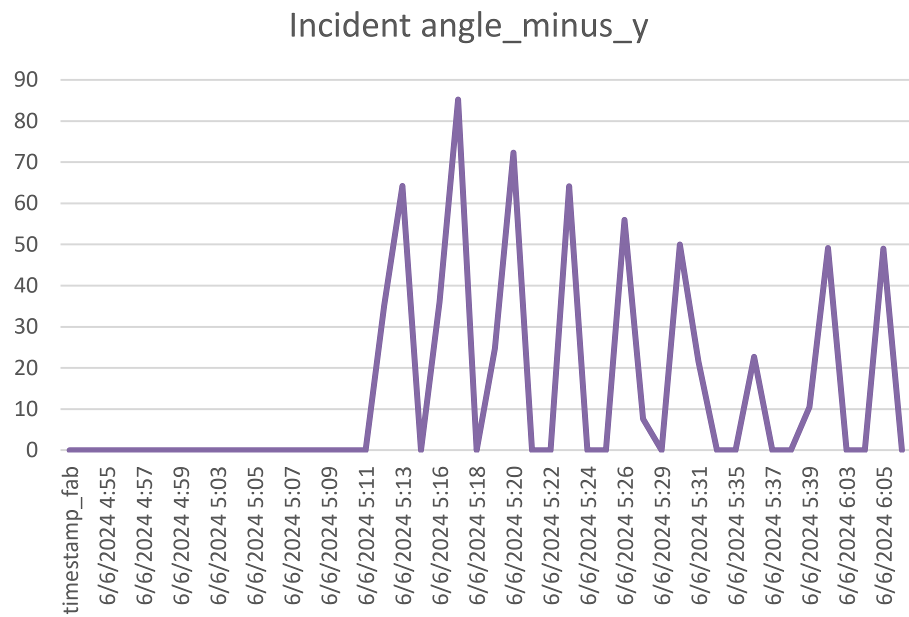


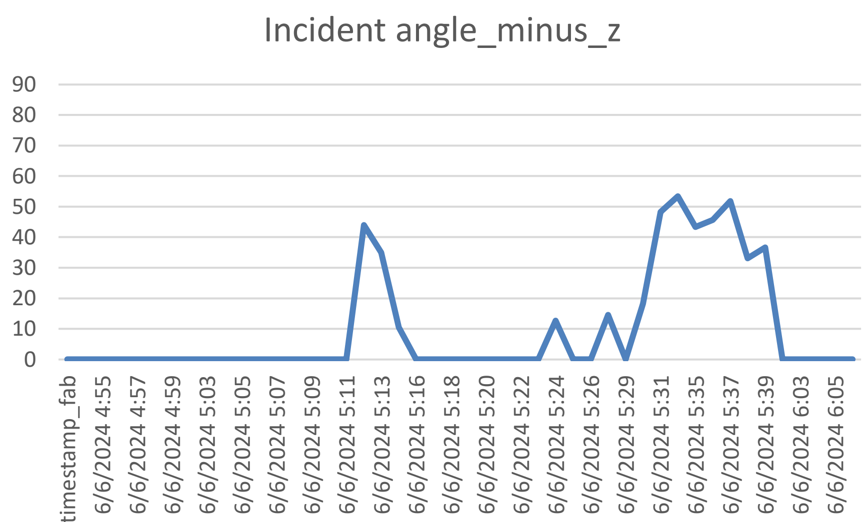




Equator study in sunlight







Conclusion

Thank you for your attention

Many thanks to all the team members