Power System Development of the AGU Remote Innovative CubeSat Alert System -2 – ARICA-2

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Abstract

We present the power system development of the 2U CubeSat, AGU Remote Innovative CubeSat Alert system -2(ARICA-2). The main goal of the ARICA-2 project is to demonstrate the real-time alert system of transient astronomical sources using commercial satellite network devices. 1U CubeSat ARICA was launched in November 2021. However, we have not been able to send and receive the data at this point. Therefore, we started developing 2U CubeSat ARICA-2, which is an improved version of ARICA, in April 2022. One of the possible causes of the communication problem of ARICA is the power system, such as a negative power budget or a failure in the installation of the inhibit switches. ARICA-2 is upsized from 1U to 2U to ensure a sufficient power generation and is equipped with improved inhibit switches. The calculation of power consumption and simulation of power supply on orbit have been finished. We confirmed the performance of our Electric Power System (EPS) and the health of the installed batteries. We are currently in the EM development phase with the goal of launching in Japanese fiscal year 2024.

Background

Gamma-ray burst(GRB)

1. The prompt gamma-ray emission: a few milliseconds to a few minutes
2. The afterglow emission: a day to a week
3. Difficult to predict when and where a GRB occurs

▶An observation of a GRB requires a quick alert to the ground for the follow-up observations of an afterglow by various telescopes to understand the nature of a GRB.

Current GRB Alert systems

1. Data relay system by satellites (Swift/Fermi)
   ▶Significant contribution of NASA is needed.
2. Installing multiple ground stations in its orbit (HETE-2/SVOM)
   ▶ Requires a lot of effort for the preparation.

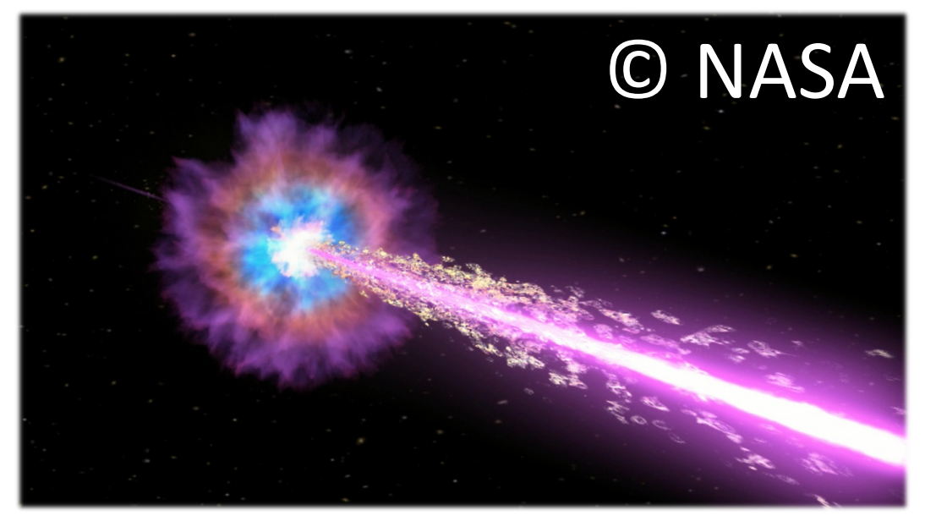
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Fig1. GRB

ARICA(AGU Remote Innovative CubeSat Alert System)

ARICA demonstrates a new GRB alert system with 1U CubeSat using commercial satellite communication services. It was launched by Epsilon-5 as the JAXA's Innovative Satellite Technology Demonstration-2 on November 9. However, no signal has been received from ARICA yet. A possible causes include a broken inhibit switch or a low successful communication probability with commercial communication satellites at the altitude of 560 km.

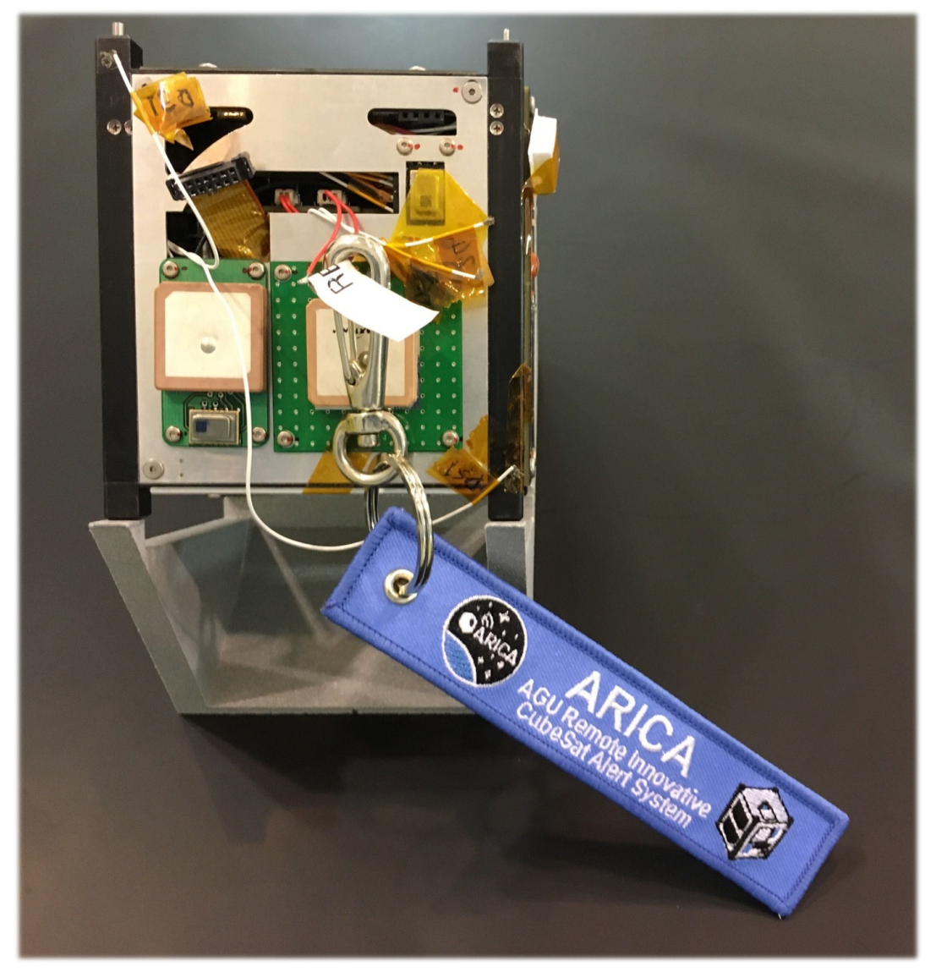

Fig2. Overview of ARICA


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Fig3. Launch of Epsilon-5 rocket

ARICA-2 Project

Based on the current situation of ARICA, we started developing our second satellite, ARICA-2, last year. This project demonstrates the new GRB alert system using two different commercial satellite communication devices, SBD and STX-3. ARICA-2 is equipped with the UHF transceiver as the redundant radio system in case of failure of a commercial satellite communication. ARICA-2 has three-axis attitude control with three magnetic torquers to direct the antennas toward the direction of commercial communication satellites. We use the space-qualified EPS, 30Wh battery, SAP, and 2U CubeSat structure of AAC Clyde Space. The command & data handling (C&DH) system is controlled by the Sony's board computer, Spresense. ARICA-2 is equipped with the three-axis gyro sensor, the three-axis magnetic sensor, and the sun sensor for the attitude determination.

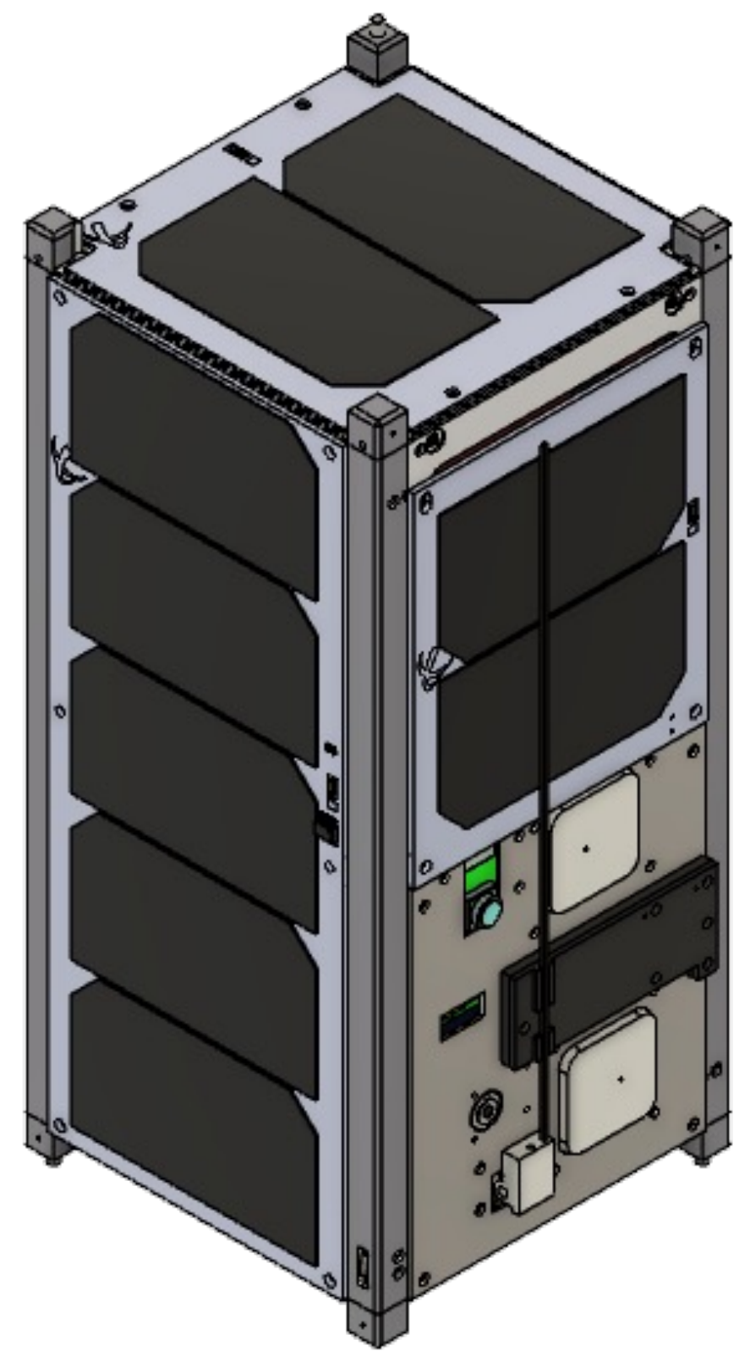

Fig4. Overview of ARICA-2

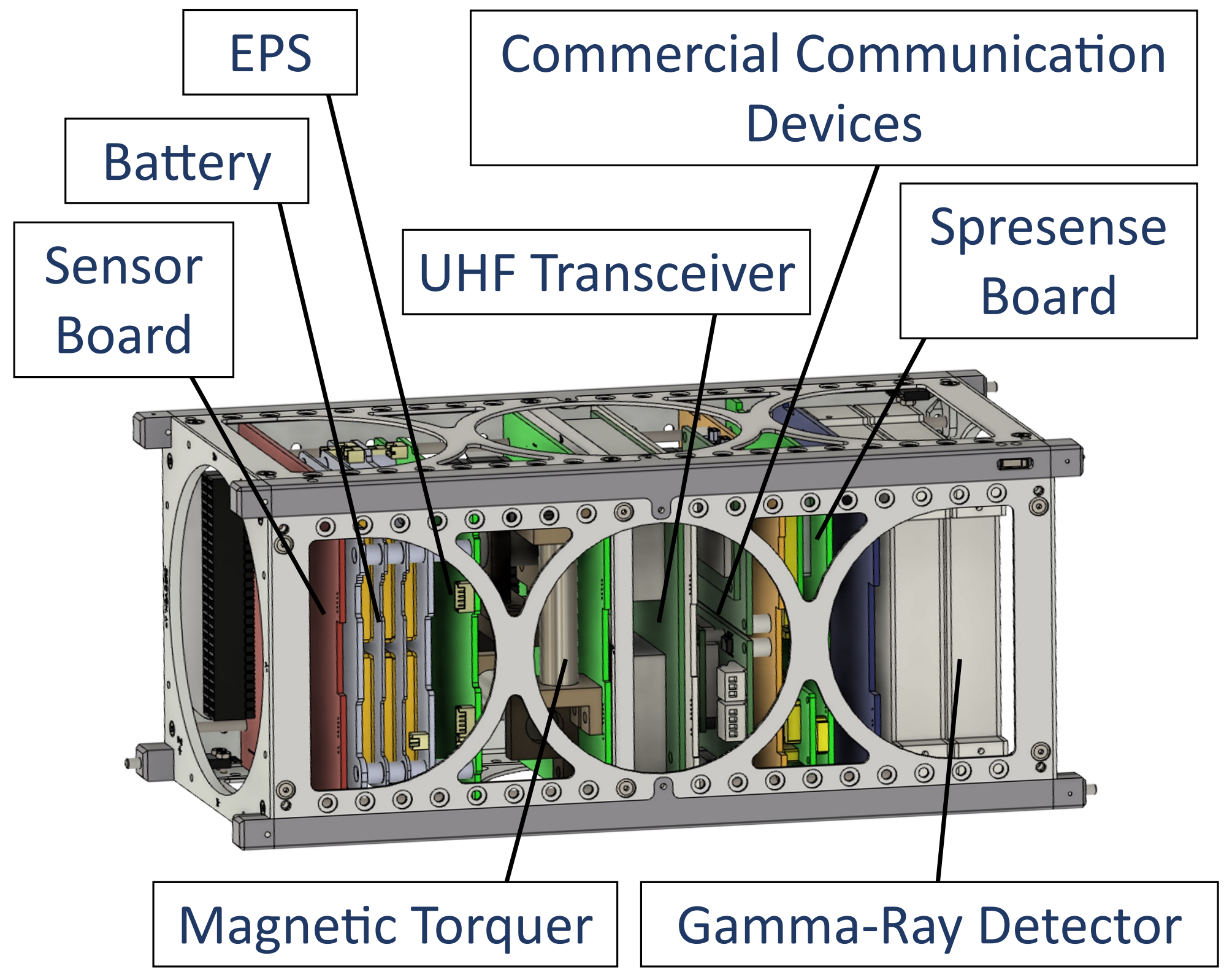

Fig5. Components of ARICA-2

Power Management

ARICA-2 uses the 3rd Generation EPS, the 30Wh Standalone Battery, the Side 1U SAP, the Side 2U SAP, and the End 1U SAP of AAC Clyde Space. The Battery can stack to the EPS board via 104 pins connector. ARICA-2 controls the operation of the EPS and monitors the status with I²C serial bus by our designed interface board attaching two Spresense boards.

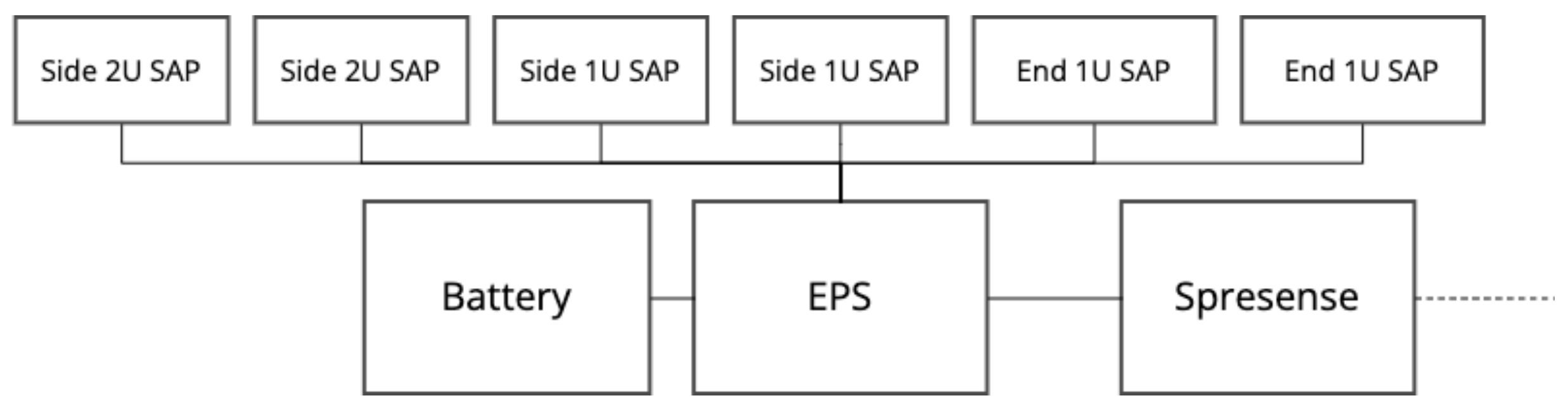

Fig6. Block diagram of Power Management

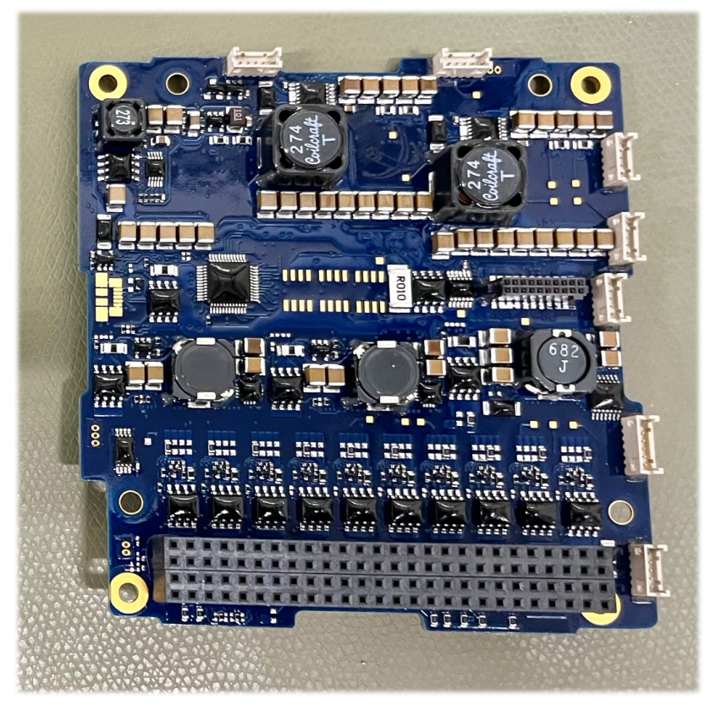

Fig7. EPS

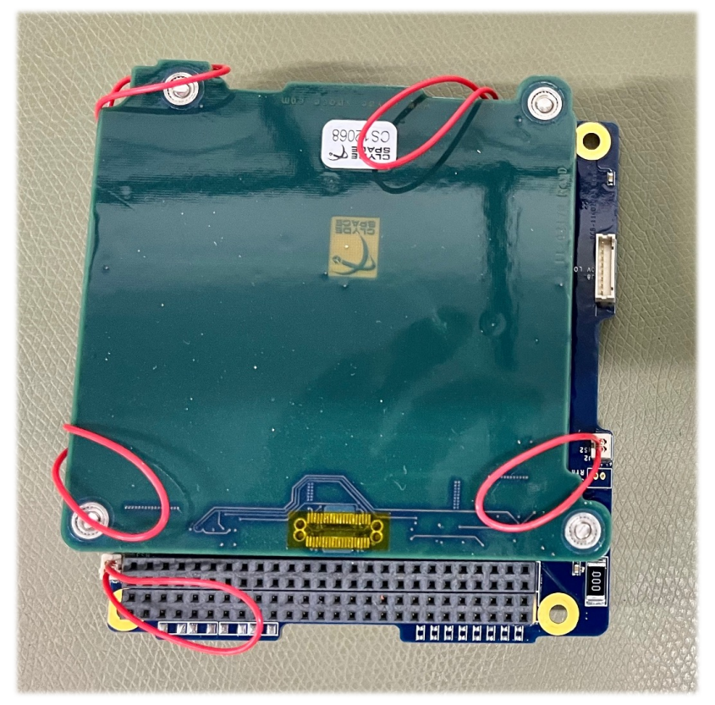

Fig8. 30Wh Battery

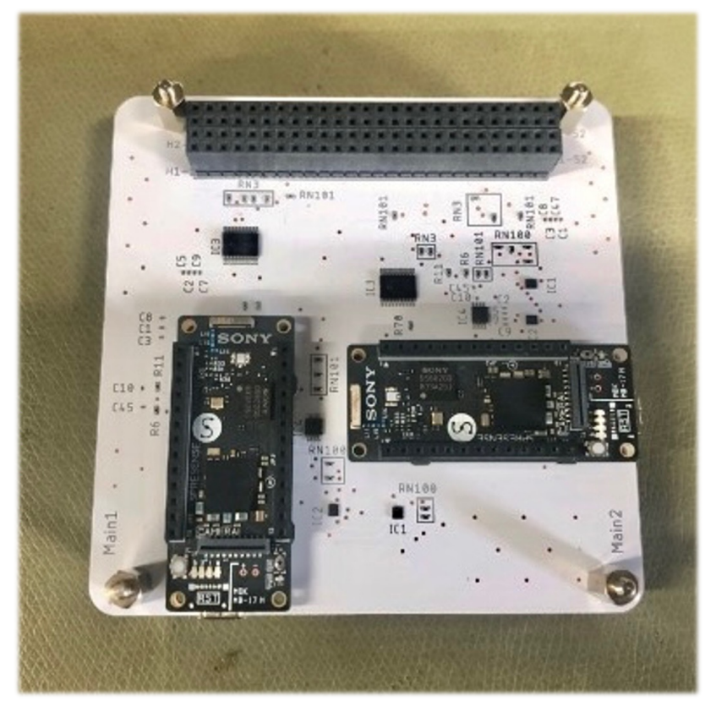

Fig9. Spresense Board

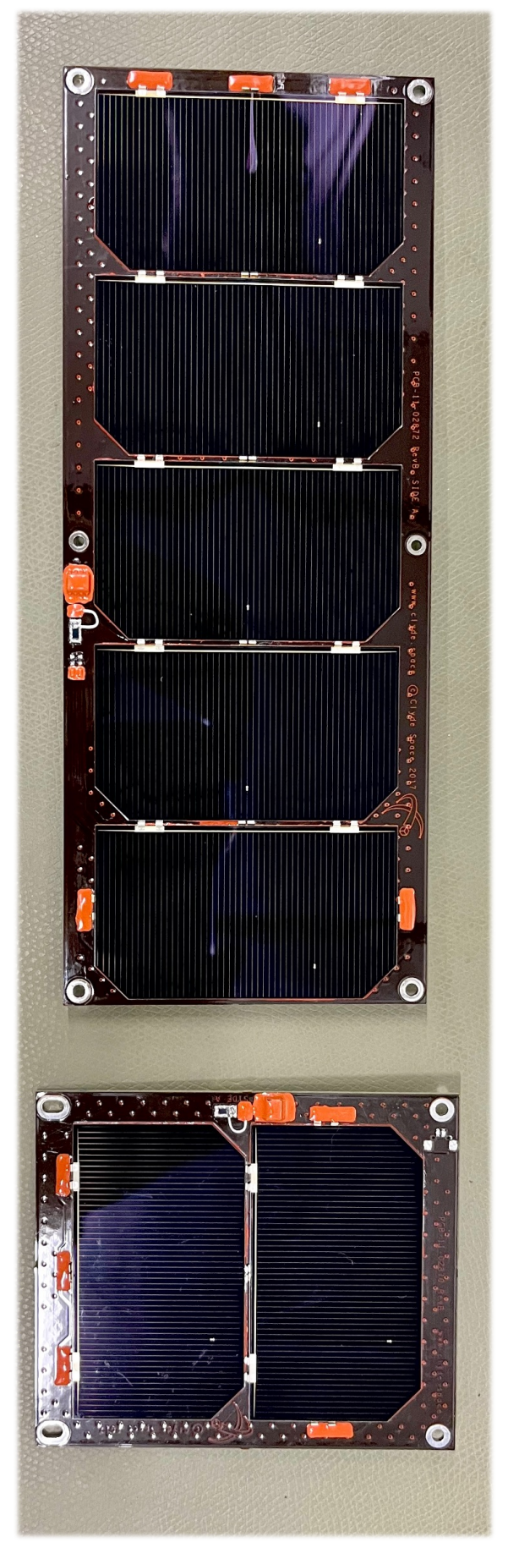

Fig10. SAP

Power Supply Simulation

We analyzed the estimated power supply in orbit using the simulation software, the CubeSat Toolbox for MATLAB®(Princeton Satellite Systems). This software supports setting SAP and battery parameters, modeling a CubeSat, computing trajectory etc. Our setup condition is in Tab1, and the simulation result is in Tab2. The Normal Operation Mode is to direct the panel with patch antennas attached toward commercial communication satellites, and the Power Saving Operation Mode is to direct the Side 2U SAP toward the sun.

Tab1. Simulation Setup Condition

No.	Parameter		
1	Solar Cell Efficiency	28.4	%
2	Power Conversion Efficiency	85.0	%
3	Altitude	560	km
4	Orbital Inclination	97.6	deg
5	Total Simulation Time	12.0	h
6	Eclipse Time (worst case)	4.5	h

Tab2. Simulation Result

No.	Operation	Power Input per orbit
1	Normal Operation Mode	4.1 Wh
2	Power Saving Operation Mode	4.7 Wh

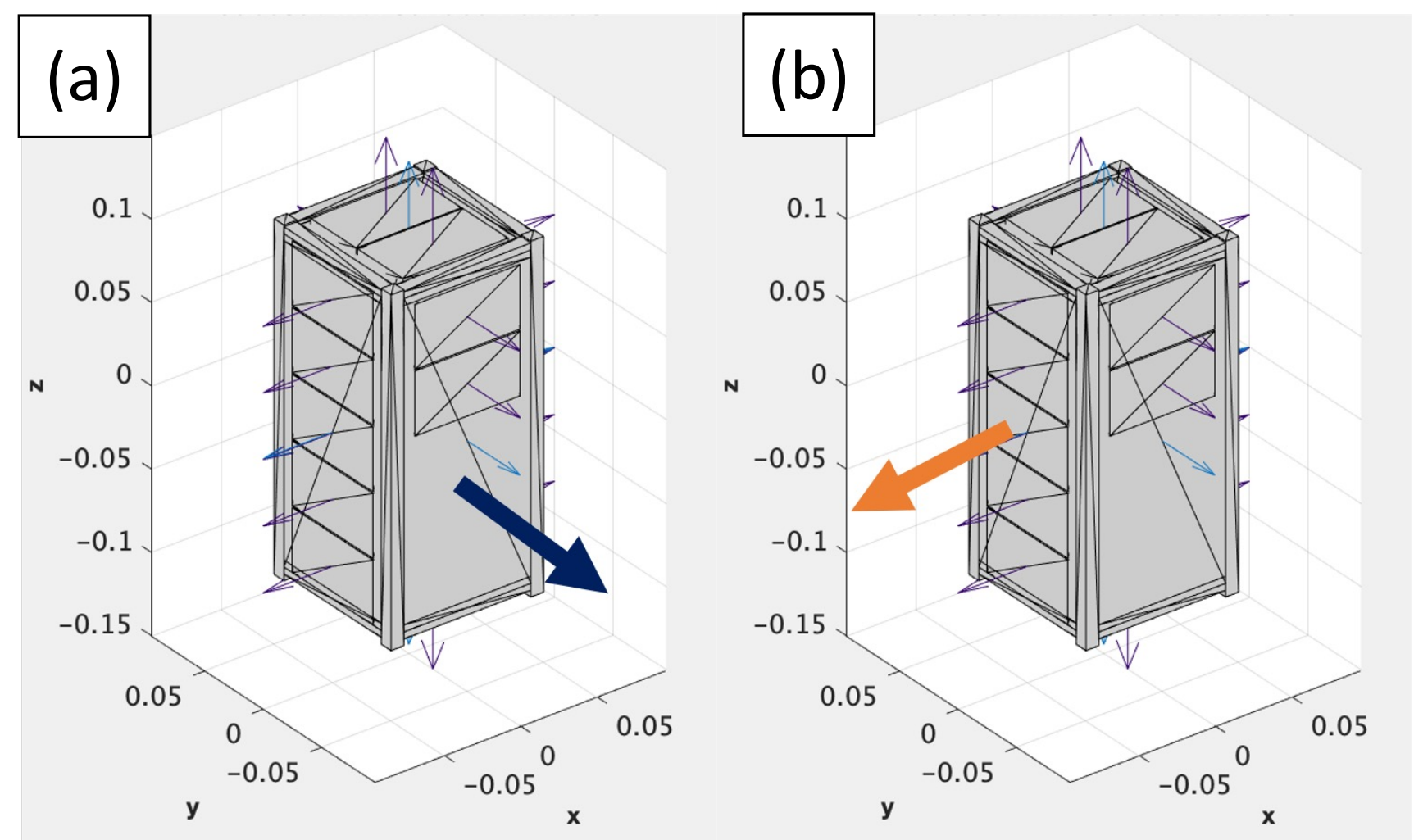

Fig11. (a)Normal Operation Mode: The space direction vector is indicated by the blue arrow. (b)Power Saving Operation Mode: The sun direction vector is indicated by the orange arrow.

Power Consumption and Power Budget Calculation

We listed the power consumption of each component and calculated the power budget of ARICA-2 in orbit. As you can see from Tab3, Power Saving Operation Mode has a +1.9 Wh power budget, while Normal Operation Mode has a -0.4 Wh power budget. Although this result provides an issue in a nominal operation, the power consumption of some components are still unknown. Therefore, we should investigate the power consumption of the uncertain components, and also reconsider the satellite operation.

Tab3. Power Consumption

No.	Component	Power Consumption
1	SBD (One TX per min)	0.26 W
2	STX-3 (One TX per min)	0.04 W
3	UHF Transceiver (GMSK TX)	0.80 W
4	UHF Transceiver (CW TX/COM RX)	0.20 W
5	Magnetic Torquer	0.42 W
6	Gyro and Magnetic Sensor	0.01 W
7	Sun Sensor	0.10 W
8	Spresense Board	0.50 W
9	Gamma-Ray Detector	1.00 W
10	EPS	0.20 W

Tab4. Power Budget

No.	Operation	Power Input per orbit	Power Output per orbit	Power Budget
1	Normal Operation Mode	4.1 Wh	4.5 Wh	- 0.4 Wh
2	Power Saving Operation Mode	4.7 Wh	2.8 Wh	+ 1.9 Wh

Conclusion

Summary

ARICA-2 demonstrates a real-time alert system for GRBs using commercial satellite networks and updated various parts from our previous satellite, ARICA. We estimated the power budget of ARICA-2, and the budget is -0.4 Wh in a currently assume nominal operation.

Future Work

1. Designing the ARICA-2 power management software system.
2. Investigation of the details of ARICA-2 power consumption.
3. Determination of the ARICA-2 nominal operation taking into account the power budget.