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# Flight Model Development of the AGU Remote Innovative CubeSat Alert system - ARICA

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**ABSTRACT**

We present the flight model development of the 1U CubeSat, AGU Remote Innovative CubeSat Alert system (ARICA), which is scheduled to be launched in the Japanese fiscal year 2021 as the JAXA Innovative Satellite Technology Demonstration-2 project. The main goal of ARICA is to demonstrate the real-time alert system of the transient astronomical sources using commercial satellite network devices. The development of the flight components has been finished in April 2021. The thermal vacuum test was conducted at the end of April 2021. The vibration and shock tests were performed in May 2021. We are currently in the final stage of the development of ARICA to be ready for launch.

## INTRODUCTION

AGU Remote Innovative CubeSat Alert system (ARICA) is the 1U CubeSat project to demonstrate the alert system of the astronomical transient sources. ARICA will be launched as a part of the JAXA Innovative Satellite Technology Demonstration-2 in the Japanese fiscal year 2021. (1) Our goal is to develop and demonstrate the alert system using two commercial satellite network devices for a future space mission.

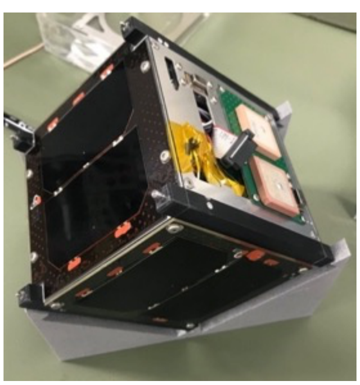

**Figure 1: ARICA**

### *Background*

Among the astronomical transient sources, we want to detect gamma-ray bursts (GRBs). GRBs have two characteristics. First, the duration of the prompt gamma-ray emission of a GRB is very short. It only lasts from a few milliseconds to a few minutes. On the other hand, the afterglow emission follows for a day to a week between radio and an X-ray band. Second, GRBs are not possible to predict when and where they occur. Therefore, the observations of GRBs require a quick alert to the ground for the follow-up observations of afterglows by various telescopes to understand the nature of GRBs. (2)

In the current GRB alert system, NASA's data relay satellite system or an installation of a large number of ground stations throughout the orbit has been adapted. (3,4) However, it is difficult to use the NASA's system for a project with a limited contribution from NASA. It also requires a large number of efforts to prepare many ground stations. Therefore, we will develop a new GRB alert system using a commercial satellite communication service and demonstrate its capability using the CubeSat.

***Features of ARICA***

ARICA is equipped with two types of commercial satellite network devices. One is Short Burst Data (SBD) using the Iridium satellite, and the other is Eyestar-S3 (Eyestar) using the Globalstar satellite. Both devices have been used in space, but it is unclear whether they can be used as real-time communication capabilities as a new GRB alert system between ground and space. Thanks to the standardization of CubeSats, we focus on the development of the mission component and shorten the development period by purchasing the flight satellite bus components from AAC-Clyde Space.

***Mission Description***

There are the following four mission goals in ARICA to demonstrate in orbit.

① The data from the gamma-ray detector are processed by the FPGA to automatically identify a burst. If it is determined to be a burst, the alert will be issued and downlinked to the ground. The delay time of the alert will be measured. The goal is to alert the burst information to the ground within a minute.

② The satellite's housekeeping data are sent regularly to the ground to check the success rate of the data receiving from the orbit. And their delay time is also measured. Our goal is to receive the housekeeping data regularly for more than 70% of the operation time.

③ We will confirm the in-orbit performance of the GAGG scintillator used for the first time in space. The GAGG scintillator is used as the gamma-ray detector part. We can measure the tolerance to the radiation for 6 months and make sure there is no significant degradation in its performance.

④ We check for a quick command uplink to the satellite. We ensure that a command uplink to the satellite within 10 minutes is possible anywhere in orbit.

## SATELLITE DESIGN

ARICA consists of four boards, solar array panels (SAPs) and an electric power system (EPS) /battery, and two panels. It is necessary to store parts in the limited space of 1U (10 cm x 10 cm x 10 cm), and it is also important to develop a board on which communication devices and detectors are mounted. Therefore, we manufacture parts other than SAPs, an EPS/battery, and a 1U structure purchased from AAC-Clyde Space. The components and the internal design of ARICA are shown in Figure 2. Figure 3 shows the system diagram of ARICA.

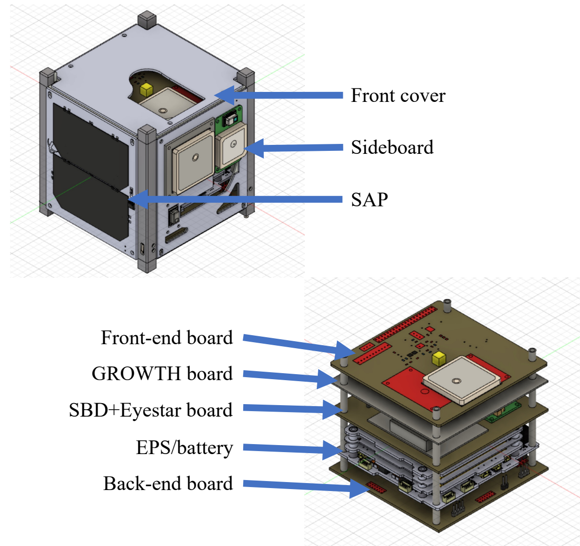


**Figure 2: ARICA internal board design**

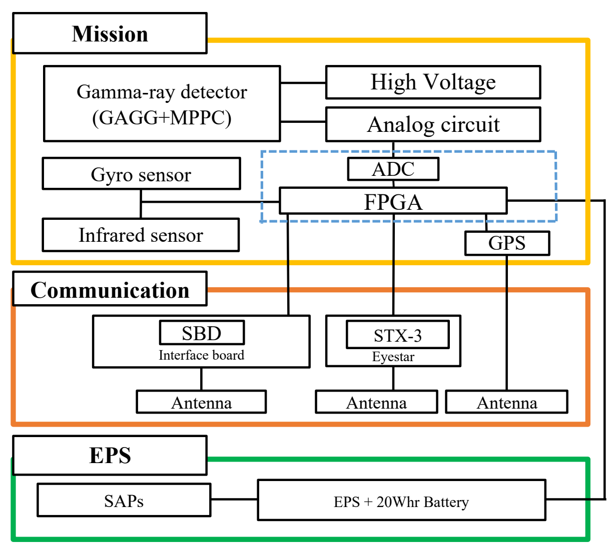


**Figure 3: System diagram of ARICA**

① Front cover plate

It is a 1.6 mm thick aluminum plate (A6061 T6) with a hole at the part of the GPS antenna and a detector (Figure 4).

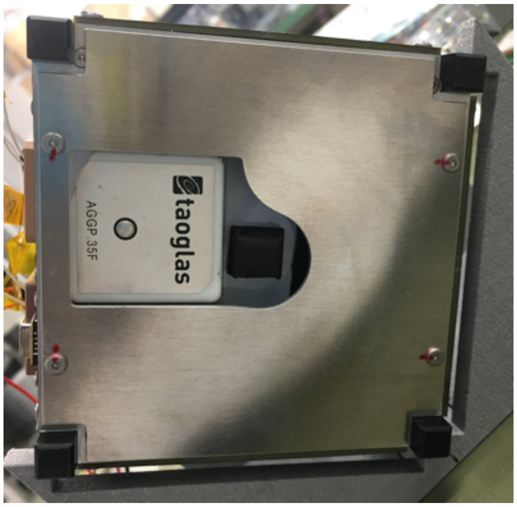


**Figure 4: Front cover**

② Front-end board

This board is equipped with a GPS module (HT-GNSS200; Hyperion technologies), an antenna (AP.35A; Taoglas) and a gamma-ray detector (Figure 5). 1.5 mm think lead tiles are pasted on the back of the board. This is to shield the radiation to the FPGA under the front-end board. The detector part uses 6 $mm^3$ GAGG crystal (EPIC Crystal) and an MPPC (S13360-6050CS; Hamamatsu Photonics). The GAGG crystal is wrapped with Teflon as a reflector, and then, covered by a black light-shielding tape (CP-743; Shurtape). The performance of the gamma-ray detector was presented in Watanabe et al. 2020. (5)

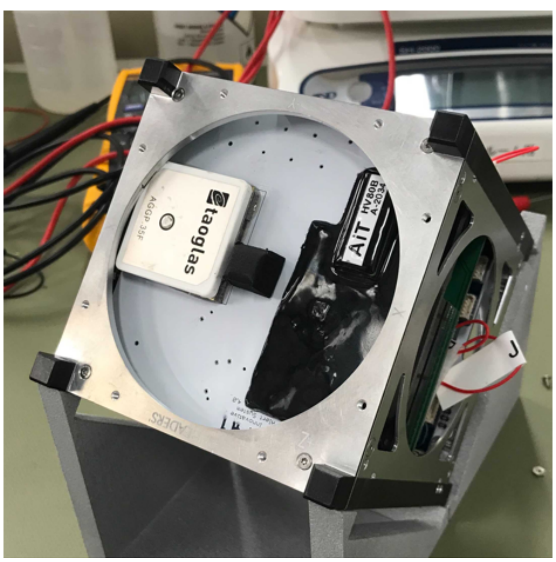


**Figure 5: Front-end board**

③ GROWTH board

This board controls the entire satellite system (Figure 6). The board was originally developed for thundercloud gamma-ray detection (Shimafuji Electric). We modified the location of the fixing holes to match the PC/104 standard used in the 1U structure. The FPGA is Artix-7 (Xilinx Inc.) and implemented it on the board. Using this FPGA and ADC, the analog information of the detector is converted to a digital value. Furthermore, the data from the gyro sensor and the EPS are obtained and sent to each communication device.

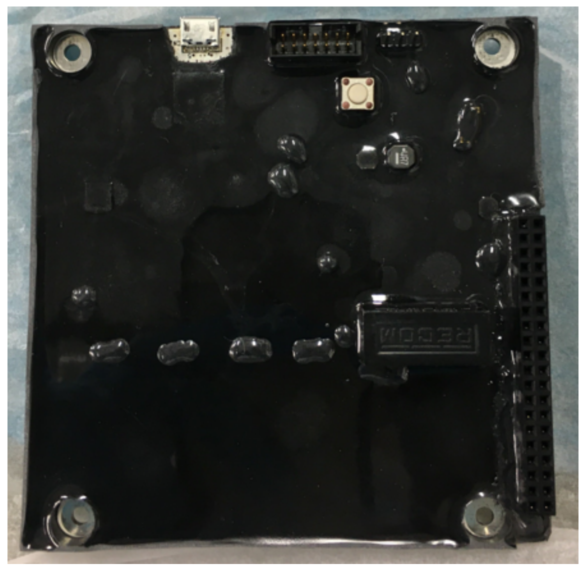

**Figure 6: GROWTH board (after potting process)**

④ SBD+Eyestar board

This is a board on which two satellite communication devices are mounted (Figure 7). The antennae of each device are connected to the sideboard plate.

The SBD's UART communication is 3.3V, while the Eyestar's UART communication is 5V. Also, the connector that can be connected to the FPGA of the GROWTH board can only be used up to 3.3V. Therefore, the voltage of the UART communication part of Eyestar is converted into 3.3 V using CD40109BE (Texas Instruments).

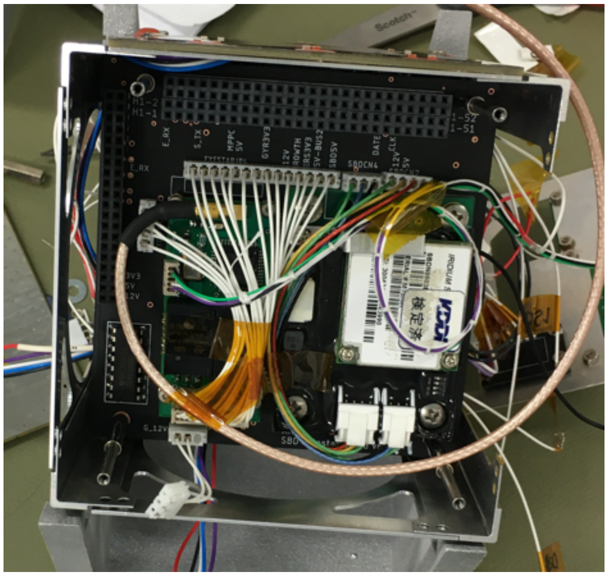

**Figure 7: SBD-Eyestar board**

⑤ EPS/battery, SAPs

The EPS/battery (01-02689 (25-02451 + 01-02682)), SAPs (25-02869, 25-02867), and the 1U CubeSat structure (01-02233) are the flight products of AAC-Clyde Space Inc (Figure 8 and 9). The battery is 20Whr. There are three SAPs on the side (25-02869) and one on the bottom (25-02867).

**Figure 8: EPS/battery**

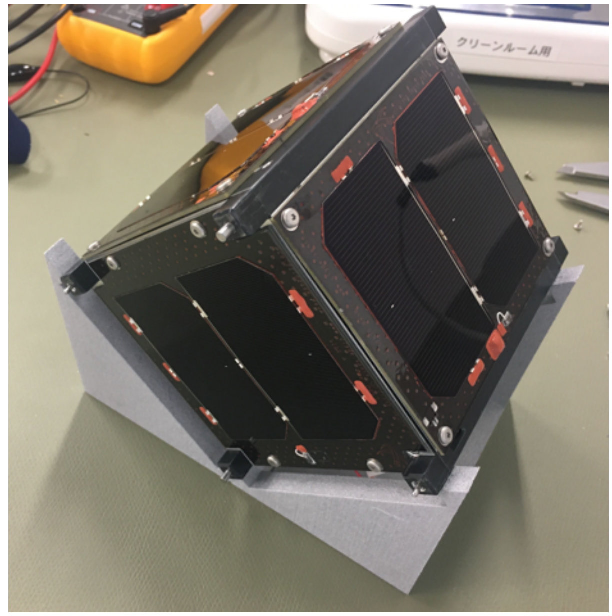

**Figure 9: SAPs**

⑥ Back-end board

This board is equipped with a gyro sensor and a connector of the infrared sensor (Figure 10). There are also external connection ports so that we can connect to a battery charging port, RBF, or communication devices.

The gyro sensor uses BMX055 (BOSCH Sensortec Inc., Figure 11) and is installed to obtain attitude information. We are using the mounted board of Akizuki Denshi. The infrared sensor uses AMG8834 (Panasonic, Figure 12), and the mounted board is made by taking into account the design of the sideboard plate. This sensor is used to judge whether the plane of the sensor is facing the earth or not. Using the output of the sensor, we will be able not to transmit the radio signal when the antennae are facing toward the earth (one of the required protections for radio astronomy).

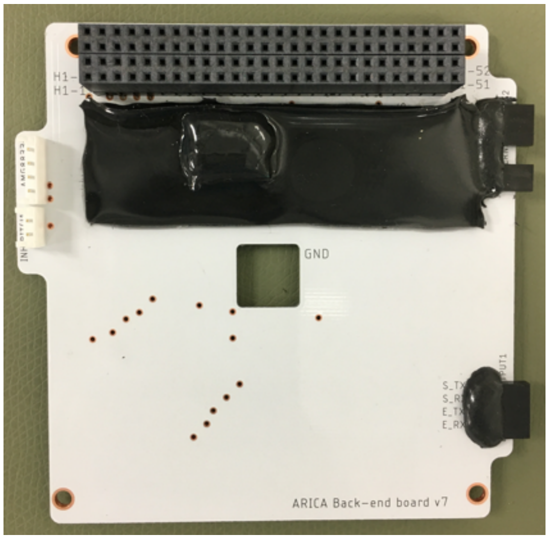


Figure 10: Back-end board (after potting process)

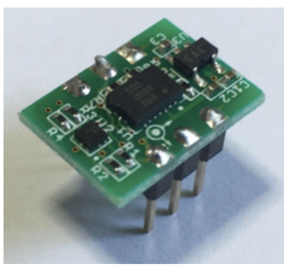

Figure 11: Gyro sensor (BMX055)

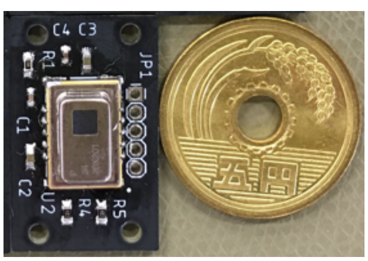


Figure 12: Infrared sensor (AMG8834)

⑦ Sideboard plate

This board is equipped with an infrared sensor and antennas for two communication devices (Figure 13). The antenna for the SBD is Maxtena (MPA-D254-1621). Eyestar uses the attached patch antenna.

The material of the sideboard is aluminum with 0.9 mm thickness.

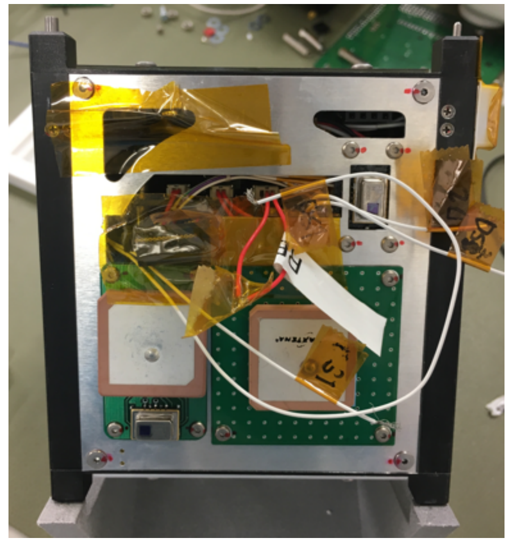

Figure 13: Sideboard

***Power and mass***

The total power consumption of ARICA is 6.7 W. The total weight of ARICA is 1076 g. The performance of power consumption and mass of each component were presented in Watanabe et al. 2020. (5)

## TESTS

In this spring, we conducted a thermal vacuum test and a vibration test, which are necessary tests before launching ARICA.

***Thermal vacuum test***

From April 27th to 30th, a thermal vacuum test was conducted at the Institute of Space and Astronautical Science. The purpose of this test is to see if ARICA can operate in an environment close to outer space.

ARICA was placed on the seat and put inside a thermal vacuum chamber (Figure 14). While monitoring the temperature of the ARICA itself and the chamber, the HK data were transmitted from the spacecraft.

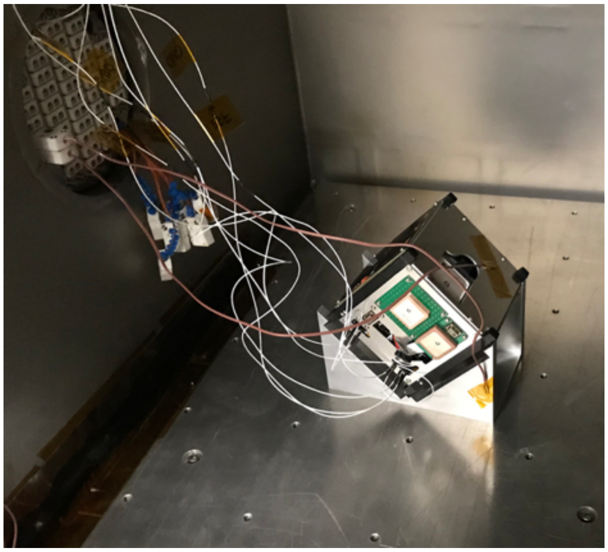

**Figure 14: ARICA inside the thermal vacuum chamber**

After reaching a vacuum state, HK data were acquired at the room temperature (before and after the thermal cycle) and also the temperature at 50 degrees Celsius and -30 degrees Celsius.

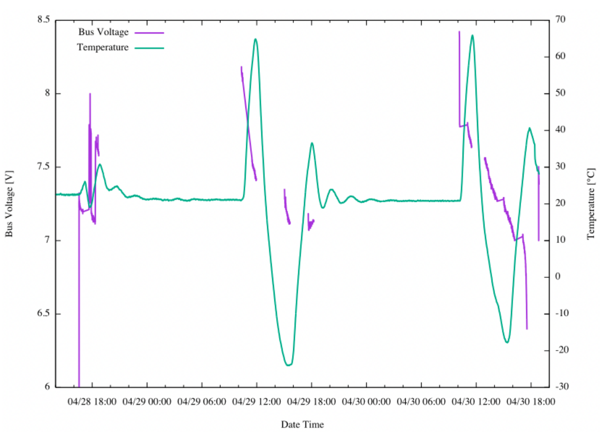


**Figure 15: Temporal variations of the bus voltage (purple) and the temperature inside the chamber (green) during the thermal vacuum test**

Figure 15 shows the bus voltage value and temperature profile that can be obtained from the satellite HK data during the test. You can see that the voltage value can be obtained normally even if the temperature changes. Through this test, we were able to confirm that the satellite functions normally even under temperature changes and a vacuum environment.

### *Vibration and Shock test*

From May 24th to 26th, we conducted a vibration and shock test at Kyushu Institute of Technology. The purpose of this test is to make sure that the satellite can withstand the vibrations that occur when the rocket launches without any failure. These tests were conducted using two types of containers developed by Kyushu Institute of Technology and JAXA.

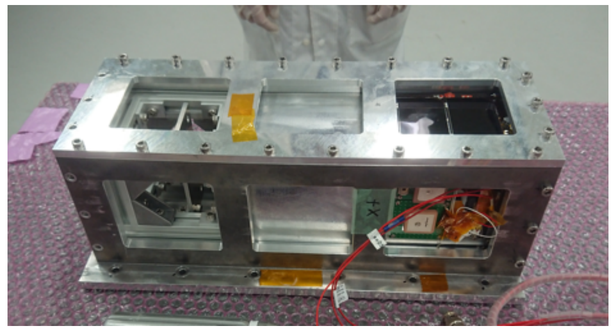

**Figure 16: ARICA inside the container of Kyushu Institute of Technology**

After these tests, the attached screws were not loosed or broken, and there was no problem in the basic function of the satellite before and after the tests.

## CONCLUSION AND FUTURE WORK

We are constructing 1U CubeSat ARICA to demonstrate a real-time alert system for transient astronomical sources such as GRBs using commercial satellite networks. As part of JAXA Innovative Technology Demonstration-2, we will proceed with final preparations for launch in 2021.

## REFERENCES


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5. T. Watanabe *et al*., "ARICA: Demonstration of a Real-time Gamma-Ray Bursts Alert System using the Commercial Satellite Networks", 34th Annual AIAA/USU Conference on Small Satellites, SSC20-P2-21, 2020.