Overview and Status of AGU Remote Innovative Cubesat Alert System-2 on 2023

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ABSTRACT

We present the overview of the 2U CubeSat, AGU Remote Innovative Cubesat Alert system - 2 (ARICA-2). ARICA-2 was selected as a feasibility study phase of the JAXA-Small Satellite Rush Program (JAXA-SMASH) and the JAXA Innovative Satellite Technology Demonstration-4 project in 2022. The main goal of ARICA-2 is to demonstrate the real-time alert system of transient astronomical sources, such as gamma-ray bursts, using commercial satellite network services. The first 1U CubeSat ARICA, which had the same mission goal as ARICA-2, was successfully launched in 2021 by the JAXA's Epsilon rocket No.5. However, communication with ARICA has yet to be established due to severe hardware issues. Therefore, ARICA-2 is the re-challenging mission of ARICA. ARICA-2 has several different features compared to ARICA. First, a transceiver using amateur radio frequency is added to the commercial satellite network devices to communicate directly from the ground. Second, ARICA-2 uses Sony's low-power board Spresense as an onboard computer. Third, the attitude control system using magnetorquer is installed to establish better communication with the commercial network satellites. Fourth, the size of a gamma-ray detector is 70 mm x 70 mm x 10 mm, which is larger by a factor of 200 in volume compared to ARICA, to enhance the detection rate of gamma-ray bursts. We plan to develop the engineering model (EM) in 2023 and perform thermal vacuum and vibration tests on the EM. We report the current status and a prospect of ARICA-2.

Introduction

Gamma-ray bursts (GRBs) are energetic explosions in distant galaxies and the brightest electromagnetic events known to occur in the universe. There are two origins for GRBs. The long GRBs, which have a duration of longer than two seconds, are the emission from a relativistic jet produced by the death of a massive star colliding into a neutron star or a black hole. A subclass of GRBs, called short GRBs, with a duration of fewer than two seconds, is associated with the merger of binary neutron stars or a neutron star and a black hole binary. The recent observation suggests a short GRB is the electromagnetic counterpart of a gravitational wave source.[1]

The crucial step to identifying the nature of GRBs is to alert their detections immediately to the community. The alert enables scientists to follow up on GRBs via various telescopes to obtain detailed information. *HETE-2*[2] and *Swift*[3] are successful examples of the alert system. These satellites made breakthroughs in GRB observations thanks to the alert system. *HETE-2*, with an inclination angle of 2 degrees, installed 15 ground stations along the equator to receive the alert messages in real time. On the other hand, *Swift* uses NASA's TDRSS to alert the detection of GRBs. However, both systems are difficult for a small project to introduce because of the manpower needed to install and maintain many ground stations or permission to use TDRSS for a non-NASA project.

ARICA-2

AGU Remote Innovative Cubesat Alert system - 2 (ARICA-2) is a CubeSat project to demonstrate the alert system using commercial satellite networks. The alert message from ARICA-2 transmits through the satellite networks such as Iridium and Globalstar to the ground in real-time (figure 1). Our first 1 U project, ARICA, was successfully launched in 2021 as the JAXA Innovative Satellite Technology Demonstration-2 project. However, due to some serious hardware issues, we are not able to establish communication with ARICA. ARICA-2 is a re-challenge mission that started its development in the Japanese fiscal year 2022. The full success criteria of ARICA-2 are the following:

- establishment of the downlink via commercial satellite networks for more than 30% of its orbit,
- establishment of the uplink via commercial satellite networks for more than 30% of its orbit,
- the capability to send real-time data with less than 10 minutes delay, and
- the capability of alerting a GRB event within a minute.

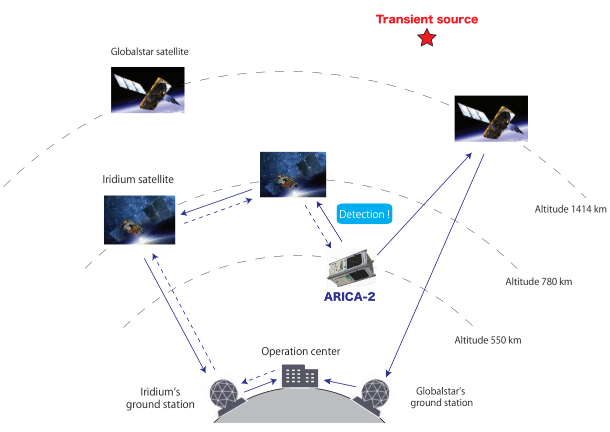

Figure 1: The alert system of ARICA-2.

ARICA-2 is 2U cubesat (figure 2). The components are divided into six parts: a communication part, a gamma-ray detector part, an onboard computer (OBC) part, a power management part, an attitude control part, and a camera part. Figure 3 shows the block diagram of the overall system of ARICA-2.

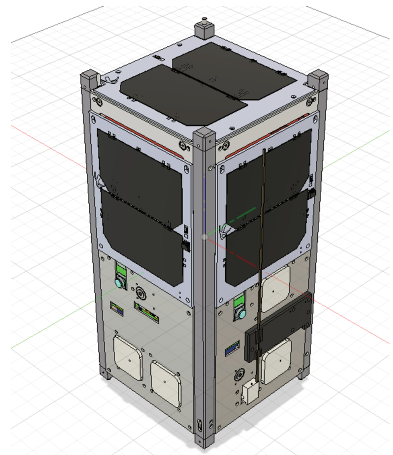

Figure 2: Overview of ARICA-2.

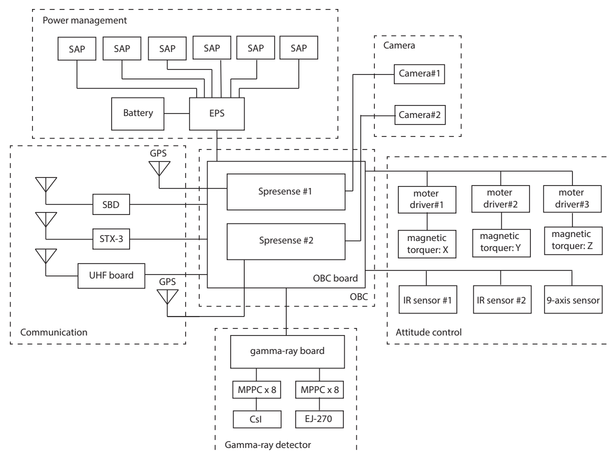

Figure 3: Block diagram of ARICA-2.

ARICA-2 was selected as a feasibility study phase of the JAXA-Small Satellite Rush Program (JAXA-SMASH) and the JAXA Innovative Satellite Technology Demonstration-4 project in 2022. We are targeting a launch in the Japanese fiscal year of 2024.

Communication

As the communication device for the Iridium satellite network, we use Short Burst Data (SBD) 9603N. The interface board of SBD is I9603-IF-01-TL by Embedded Technology Inc. The patch antenna is TAOGLAS IP.1621.25.4.A.02. We designed the interface board and mounted STX-3 for the Globalstar satellite network. The patch antenna is TAOGLAS SP.1615.25.4.A.02. SBD can establish bidirectional communication, whereas STX-3 is a one-way communication device.

ARICA-2 also equipped the UHF transceiver to enable direct communication to the ground. The transceiver, ADD1397B by Addnics Inc., has been flown on various small satellites and uses an amateur frequency of 435 MHz. ADD1397B can emit a CW beacon signal, downlink, and uplink the data in 4800 bps.

Gamma-ray detector

The gamma-ray detector of ARICA-2 is composed of two layers of scintillator crystals. The top layer is CsI(Tl) in a size of 7 cm $\times$ 7 cm and 1 cm thick. The second layer is a plastic scintillator of EJ-270 in the same size as CsI(Tl) crystal. CsI(Tl) crystal is widely used in space experiments to observe GRBs. EJ-270 works not only as a rejection of particle events but also as a neutron detector from a solar flare, which is a secondary science objective. Scintillation lights from both crystals are collected by the 8-10 chips of Hamamatsu's MPPC S14160-6050HS array. The readout board is designed and manufactured by TAC Inc. based on the experience of the gamma-ray detector to observe a gamma-ray from a thundercloud.[4]

OBC

The OBC is Spresense, low-power, and six-core microcontroller board by Sony [1]. The Spresense demonstrated the usage of the space environment in the JAXA Innovative Satellite Technology Demonstration-2 project. We assigned each task of ARICA-2 to an individual core to establish a parallel process and reduce the risk of a single-point failure. ARICA-2 equipped two Spresense boards for redundancy. We developed the OBC board to mount two Spresense boards and establish connections to various devices.

Power management

The EPS, 30 Whr battery and solar panels are flight-proven components of AAC-Clyde Space Inc.

Attitude control

Three-axis magnetorquers control the attitude of ARICA-2. We designed and developed the torquers with PB Permalloy as the core material. A motor driver, DRV-8830, controls the current to the torquers. A Sun sensor is D6T-32L-01A by Omron Inc. D6T-32L-01A is an infrared sensor with 64 $\times$ 64 pixels. According to our experiment, this infrared sensor can locate the Sun with $\sim 1^\circ$ accuracy. A gyro sensor and a magnetic sensor are ICM-20948.

[1] https://developer.sony.com/develop/spresense/

Camera

Although the camera part is not the main mission, we have two Spresense's camera boards attached to ARICA-2 as the extra success mission. The Spresense's camera board, CXD5602PWBCAM1, is 5.11M pixel cameras with a size of 24 mm $\times$ 25 mm. Our plan is to catch beautiful view of aurora from space.

Structure

The 2U structure is also flight-proven components of AAC-Clyde Space Inc. The structure also contains inhibit switches and separation springs.

Schedule

We will complete the development of the breadboard model (BBM) of each component by July 2023. After the internal review, we will start manufacturing the engineering model (EM) in August and September 2023. The construction of the EM will be on October 2023. After the completion of the EM, various environmental tests, including thermal vacuum and vibration tests, will follow. The flight model (FM) development will start in February and May 2024 after the final internal review.

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