AGU Remote Innovative CubeSat Alert System

~ Evaluate a real-time gamma-ray bursts alert using the commercial satellite networks ~

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ABSTRACT

We demonstrate the real-time alert system of the transient astronomical sources such as cosmic gamma-ray bursts (GRBs) using two commercial satellite network devices. One is the Iridium's Short Burst Data (SBD) and the other is the Globalstar's STX-3. Although these satellite communication devices have been used in the space environment, it still needs to verify whether the network can be used as a GRB alert system. We are currently developing a 1U CubeSat called AGU Remote Innovative CubeSat Alert system (ARICA) which contains both SBD and STX-3 to demonstrate the real-time GRB alert system. The ARICA has been selected as the JAXA Innovative Satellite Technology Demonstration-2 and scheduled to be launched in the Japanese fiscal year 2021.

ARICA Mission

◎Gamma-ray Bursts (GRB) observations

Gamma-ray bursts (GRBs) are extremely energetic explosions that have been observed in distant galaxies and the brightest electromagnetic events known to occur in the universe. GRBs have two characteristics:

- The short prompt emission (ms~min) & afterglow emission (day~week)
- Difficult to predict when & where they occur

These features requires a quick alert to the ground for the follow-up observations of afterglows by various telescopes to understand GRBs.

The successful examples of the alert systems are *HETE-II* & *Swift*. These satellites made the breakthrough in GRBs observations. However, these systems are difficult to introduce for a small project.

■ *HETE-II*
- Send the data to 15 ground stations
- Ground observers receive the data within seconds

⇒ Require the manpower to install many ground stations

■ *Swift*
- Self follow-up observations by onboard telescopes
- Use the data relay satellites (TDRSS) developed by NASA to alert to the ground in few seconds

⇒ Difficult to use for a non-NASA project

To overcome these issues, we propose the new GRB alert system using commercial satellite networks. The project is named AGU Remote Innovative CubeSat Alert system (ARICA) which is 1U CubeSat mission. ARICA will be launched as a part of The JAXA Innovative Satellite Technology Demonstration-2.

Demonstrate Commercial Networks

We focus on the two commercial satellite networks taking into account the cost and the capacity as a new GRB alert system.

◎Iridium Satellite network

- Worldwide duplex and data communication
- Telemetry & command data through the satellites, the ground station, and the internet

■SBD9603N (Iridium Communication Inc.)
- Size/weight: 60x45x17mm/20g (including the interface board)
- Uplink/Downlink size: 270/340 bytes
- Data are transferred as an e-mail attachment to the user

【SBD9603N】

【Iridium Satellite Communication】

◎Globalstar Satellite Network

- Simplex/Duplex voice and data communication
- The data through the satellites, the 24 ground stations around the world, and the internet

■Eyestar-S3 (NearSpace Launch Inc.)
- Size/weight: 55x26x15mm/22g
- Downlink size: 34 bytes (simplex)
- The data are easily obtained from the web server

【Eyestar-S3】

【Globalstar Satellite Communication】

Gamma-ray Detector

The gamma-ray detector in ARICA is composed by Multi Pixel Photon Counter (MPPC) and Gadolinium Aluminium Gallium Garnet (Ce) (GAGG(Ce)) crystals.

◎GAGG

- Large light output
- Good sensitivity in the hard X-ray band
- 6mm cube crystal (EPIC Crystal Co., Ltd.)

Scintillator	GAGG(Ce)	BGO*	NaI*
Amount of lights	50000 photon/MeV	8000 photon/MeV	45000 photon/MeV
Emission wavelength	540 nm	480 nm	415 nm

(※BGO&NaI are often used as gamma-ray detector)

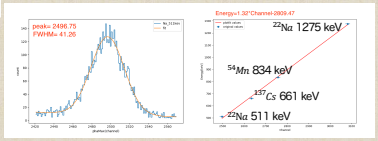
◎MPPC

- A multi-pixel Geiger-mode Avalanche Photodiode (APD) called SiPM
- Small volume & low voltage (~50V) comparatively
- 6mm squared MPPC is used for the FM (S13360-6050CS, Hamamatsu Photonics Inc.)

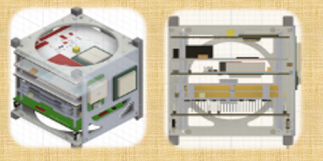
◎Evaluation of the detector

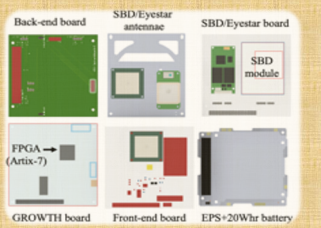
We assembled the detector for evaluation. The result shows:

- The energy resolution of ^{22}Na (511 keV) ⇒ 7.4% ± 1.3%
- The linearity is also in the acceptable level.



【The spectrum of ^{22}Na (511 keV) 】 【The linearity between channel and energy】





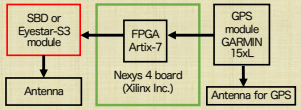
【CAD images for ARICA components】

Communication

We performed a ground testing of SBD and Eyestar-S3 module with FPGA and GPS.

- We sent the GPS data through SBD or Eyestar-S3
- FPGA handled the data and operated the modules
- We evaluated:
  - The success rate of getting messages
  - The average delay time between sending command and getting the message

⇒These are important parameter for a GRBs alert system



【The setup of ground testing for SBD/Eyestar-S3】

■SBD9603N
- The success rate: 97%
- The average delay time: 12 seconds (between command execution and receive e-mail)

⇒These are acceptable in our mission.
⇒However, we need to test with the new GPS & antenna of the flight model. (GPS: Hyperon, antenna: Maxtena)

■Eyestar-S3
- The success rate: 36%
- The average delay time: 7 seconds (between command and reflection of web server)

⇒The low success rate caused by the less sensitive antenna on the ground. The 36% success means more than 90% in space according to NSL.

ARICA Instruments & EPS

◎Components

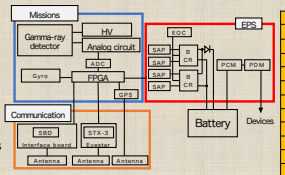
ARICA consists of five boards inside and six panels. (shown in 【CAD images for ARICA components】)

- Front-end board: gamma-ray detector, GPS module
- GROWTH board (Shimafuji Electric Inc.): FPGA, ADC
- SBD/Eyestar-S3 board
- EPS +20Whr battery (AAC-Clyde Space Inc.)
- Back-end board: gyro sensor (BOSCH Sensortec Inc.)
- 1U structure: FM of AAC-Clyde Space Inc.

The top side is exposed to space. Three sides and bottom side are attached with solar array panels. One side contains the antennae of SBD&Eyestar-S3 and the RBF pins.

◎EPS (Clyde Space 3rd Generation EPS)

- Connects to the solar panels via independent BCRs
- BCRs supply charge to the battery through PCMs&PDMs
- TTC nodes are made using I²C interface
- PDMs (switchable): 12V x2, 5Vx 3, 3.3V x3 ⇒Eyestar, gyro, HV
  Non switchable buses: 12/5/3.3V x2 ⇒FPGA, SBD



【The schematic diagram of ARICA】

【Power & mass of components】

Component	Mass (g)	Power (W)
Front-end board	42	3.6*
GROWTH board	61	
Back-end board	28	< 0.1
SBD module	41	0.8
Eyestar module	40	1.6
SBD/Eyestar board	27	< 0.1
GPS + antenna	21	0.2
CS 1U structure	136	
CS EPS battery	275	0.2
CS Solar arrays	42 (126)	
Detector	6	(included in *)
Total	803	6.4

Data Design & ARICA's Operation

◎Data Design

Our communication devices (SBD, Eyestar) have the limits in size of the message. ⇒ we have to select and design the data

The current design includes...
- Output voltages & currents of EPS buses
- GPS potential & time information
- Counts in four energy bands of the detector
- Gyro 3-axis information
- Electric power generation of solar panels

Based on the current design, the size of data are...
- SBD: 72 bytes (/340 bytes)
- Eyestar-S3: 32 bytes (/34 bytes)

◎Operation of ARICA

ARICA has two operation modes:

- HK mode
  - During no trigger signal, generate the HK data & send the data every min.
- GRB mode
  - Generate the burst data & send the data every sec for a minute

These mode switches are operated by the FPGA.