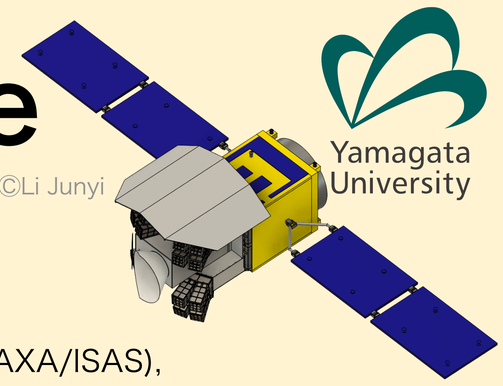
Data Transfer Test due to SpaceWire Network for HiZ-GUNDAM



Yamagata University

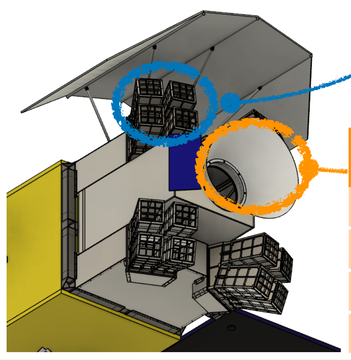
Keito Watanabe
Yamagata Univ.

Shuichi Gunji, Takumi Togashi, Haruaki Niinuma, Natsuki Kurooka (Yamagata Univ.),
Daisuke Yonetoku, Tatsuya Sawano (Kanazawa Univ.), Hiroshi Tomida, Akihiro Doi, Hideo Matsuhara (JAXA/ISAS),
Takanori Sakamoto (Aoyama Gakuin Univ.), Hiroshi Akitaya (Chiba Institute of Technology.), Yusuke Kono (NAOJ), HiZ-GUNDAM Team

Abstract HiZ-GUNDAM is a satellite project aimed at observing high-redshift gamma-ray bursts (GRBs). The satellite will be equipped with wide-field X-ray monitors (EAGLE) and a near-infrared telescope (MONSTER). They are connected to a computer (MPU) that controls the flow of data via a network called SpaceWire. It is necessary to verify through ground test whether data transfer can be correctly achieved for multiple detectors. In particular, it is important to estimate the time it takes for the MPU to collect event data from all 16 EAGLE modules. We created dummy mission equipment by combining the Raspberry Pi microcomputer with the Space Pi developed by Shimafuji Electric Co., Ltd. We then connected multiple units to build a SpaceWire network simulating HiZ-GUNDAM. Using this network equipment, we estimated how long it takes for the MPU to collect data from the EAGLE detectors.

1. HiZ-GUNDAM

HiZ-GUNDAM is a satellite project aimed at observing high-redshift gamma-ray bursts (GRBs). It will carry two instruments: Exploration of Ancient GRBs with Lobster Eye, EAGLE; wide-field X-ray Monitor and Multiband Optical and Near-Infrared Simultaneous Telescope for Efficient Response, MONSTER.



Wide-field X-ray Monitor ; **E**xploration of **A**ncient **G**RBs with **L**obster **E**ye
EAGLE [1]

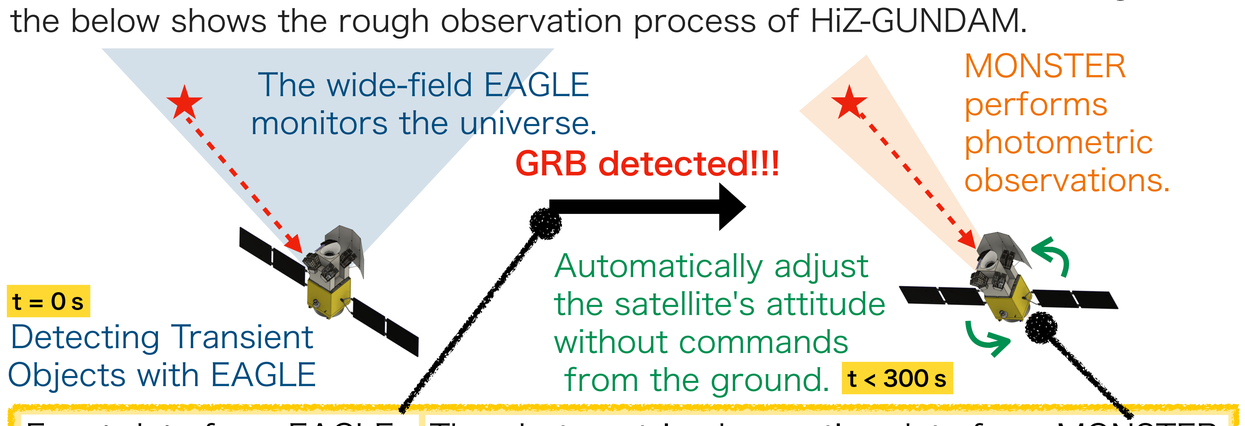
Energy Range	0.4 - 4 keV
Optics	Micro pore optics
Focal Plane Detector	pnCCD
Field of View	0.53 sr in 16modules
Timing Accuracy	100 ms

Near-infrared Telescope ; **M**ultiband **O**ptical and **N**ear-infrared **S**imultaneous **T**elescope for **E**fficient **R**esponse
MONSTER [2]

Observation Band	0.5 - 2.5 μm
Telescope Type	Offset/athermal Optics
Field of View	12 arcmin × 12 arcmin
Exposure Time	10 min (2min × 5 frames)

2. MPU **M**ission data **P**rocessing **U**nit

Our objective is to disseminate information regarding high-redshift GRBs to the community all over the world quickly as possible. To achieve this, it is important to analyze EAGLE and MONSTER data on the satellite.
The Mission data Processing Unit (MPU), on-board system of the satellite, receives science data from these mission instrument and analyzes them. Also, the MPU would launch some commands to mission instruments. The figure on the below shows the rough observation process of HiZ-GUNDAM.



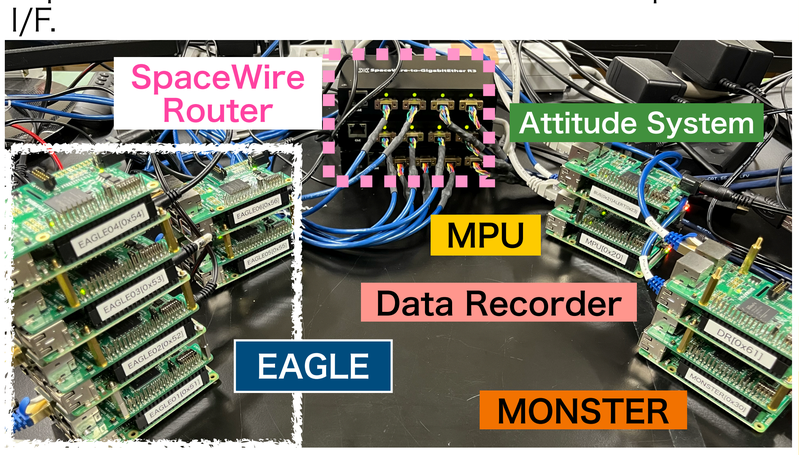
Event data from EAGLE is analyzed to determine whether it is GRB. t < 0.1 s	The photometric observation data from MONSTER is analyzed in order to identify high-redshift GRB candidates. t < 1800 s
Instruction to change position, transmission of ground-based alerts, ⋯etc.	

Onboard Computer
Mission data Processing Unit (MPU)

Our goal is to issue the alert to the ground within 1 hour of detecting a GRB.
It is important to experimentally simulate the feasibility of this observation sequence.

3. SpaceWire Dummy Network

As HiZ-GUNDAM utilizes the satellite-specific communication standard “SpaceWire”, it's necessary to gain knowledge through various experiments. Since the MPU connects to a lot of devices and continuously transfers data, we must consider efficient data acquisition methods. However, as there is no actual MPU, we started to experiment with several emulators with SpaceWire I/F.



A new platform for conducting various tests via SpaceWire is now ready! This system is being used to conduct a number of experiments.

Space Pi

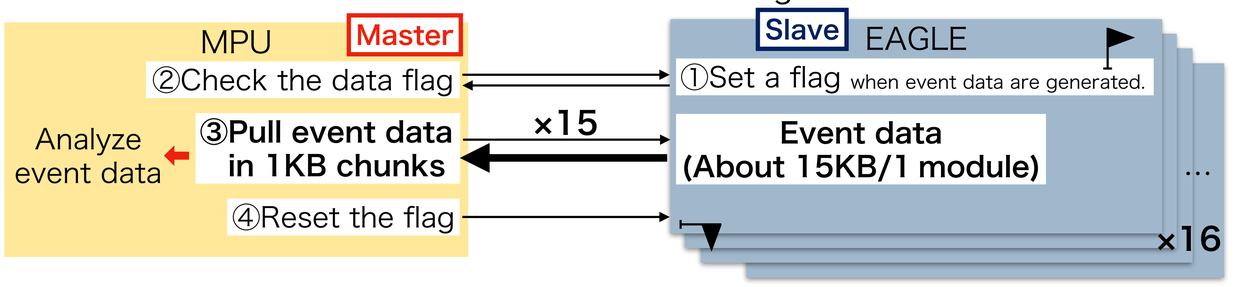
- SpaceWire Communication board.
- It has two SpaceWire ports and Field Programmable Gate Array (FPGA) chip in which SpaceWire circuit is installed.

Raspberry Pi 3B

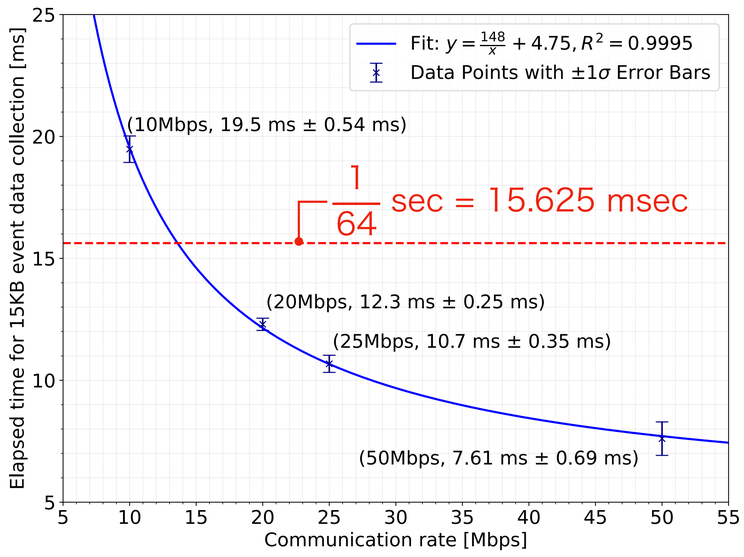
- A single-board computer.
- Software is installed on the Raspberry Pi that imitates each device, creating data based on SpaceWire.

4. Data Transfer Test & Estimation

The MPU is required to process all 16 modules within one second, whilst conducting individual analyses of event data from each module to determine a GRB. This is because it must rapidly determine whether an X-ray burst is a GRB, and, when triggered, adjust the satellite's attitude and direct MONSTER towards the GRB within 300 seconds. The flow when the MPU collects event data from each EAGLE detector is shown in the figure below.

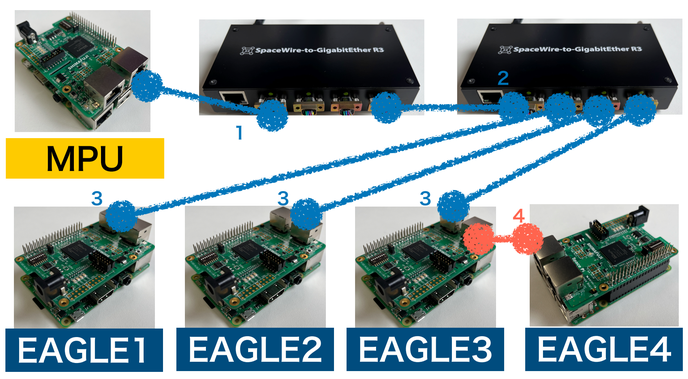


It is unclear whether data from each EAGLE detector can be acquired within one second. The estimated size of EAGLE event data are 15 KB per module. Although, based on past satellite examples, the MPU is expected to collect 1KB per transaction. Moreover, during actual operations, communication timing via SpaceWire is planned to be controlled according to 64 Hz “time slot”. Since modules are assigned to transmit data per time slot, transmission and reception operations must be completed within this timeframe. Also, the communication rate is undefined. Therefore, utilizing a dummy network emulator, the communication time was estimated whilst varying the communication rate.



The graph on the left shows the elapsed time for data collection by one module. It shows that the required time decreases in inverse proportion to the set communication rate.
It also indicates that a communication rate of at least around 20 Mbps is required for one module to complete data transfer within a single time slot.

Also, an experiment was conducted to evaluate the impact of changing the number of relay points in SpaceWire on the elapsed time. In this experiment, EAGLE modules were connected to the MPU as shown in the figure on the right, and the number of relay points was increased by adding one intermediate node for comparison. The results are shown in the table on the right. Adding one more relay point won’t significantly affect the total transmission time.



3 path	4 path
17.76 ms ± 0.57 ms	17.95 ms ± 0.40 ms

5. Summary

- HiZ-GUNDAM is a satellite project aimed at observing GRBs.
- The HiZ-GUNDAM satellite carries two detectors, EAGLE and MONSTER, as well as an onboard computer called the MPU.
- A dummy network based on SpaceWire was developed to experimentally simulate that observation sequence.
- It was determined that an appropriate communication rate should be set at approximately 20 Mbps.
- Notwithstanding the satellite-specific constraints, an estimation was made that the MPU takes less than one second to collect data from 16 modules of EAGLE.

References

[1] D. Yonetoku, A. Doi, T. Mihara, et al., “Concept of high-z gamma-ray bursts unraveling the dark ages and extreme space-time mission—HiZ-GUNDAM,” Journal of Astronomical Telescopes, Instruments, and Systems 11(4), 044002 (2025).
[2] K. Tsumura, H. Matsuhara, K. S. Kawabata, et al., “Concept of the MONSTER onboard the HiZ-GUNDAM satellite,” Journal of Astronomical Telescopes, Instruments, and Systems (2025).

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