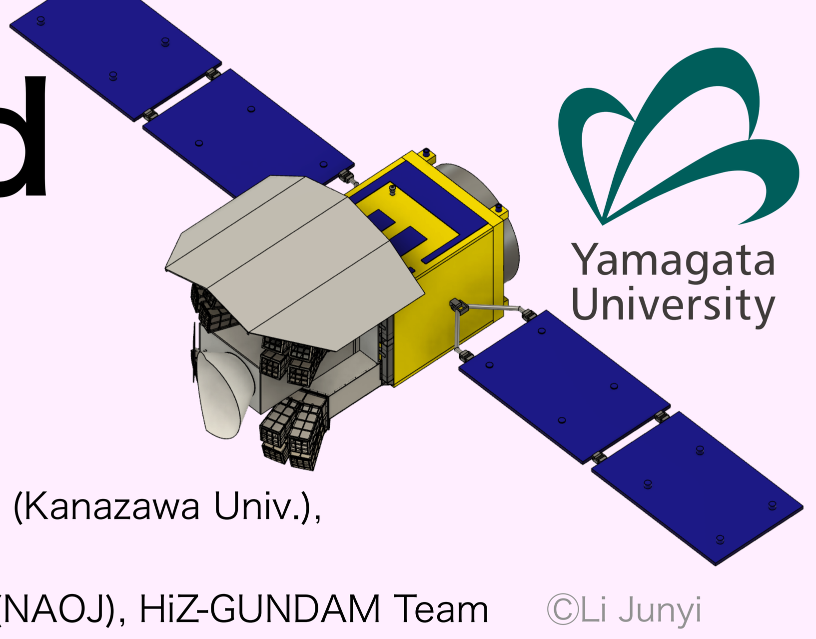
Development of a SpaceWire-Based Dummy Network for HiZ-GUNDAM



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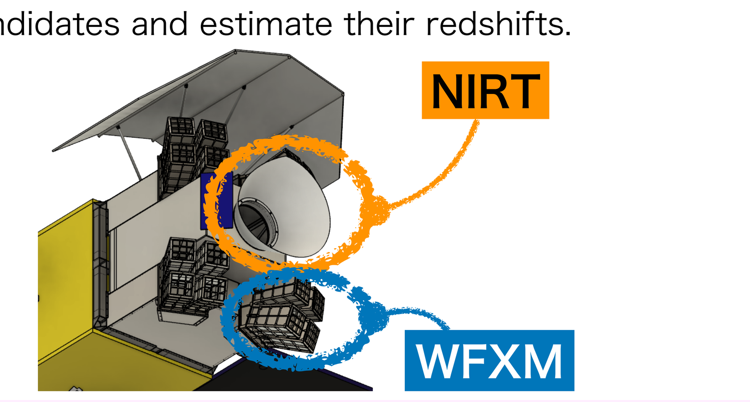
Abstract

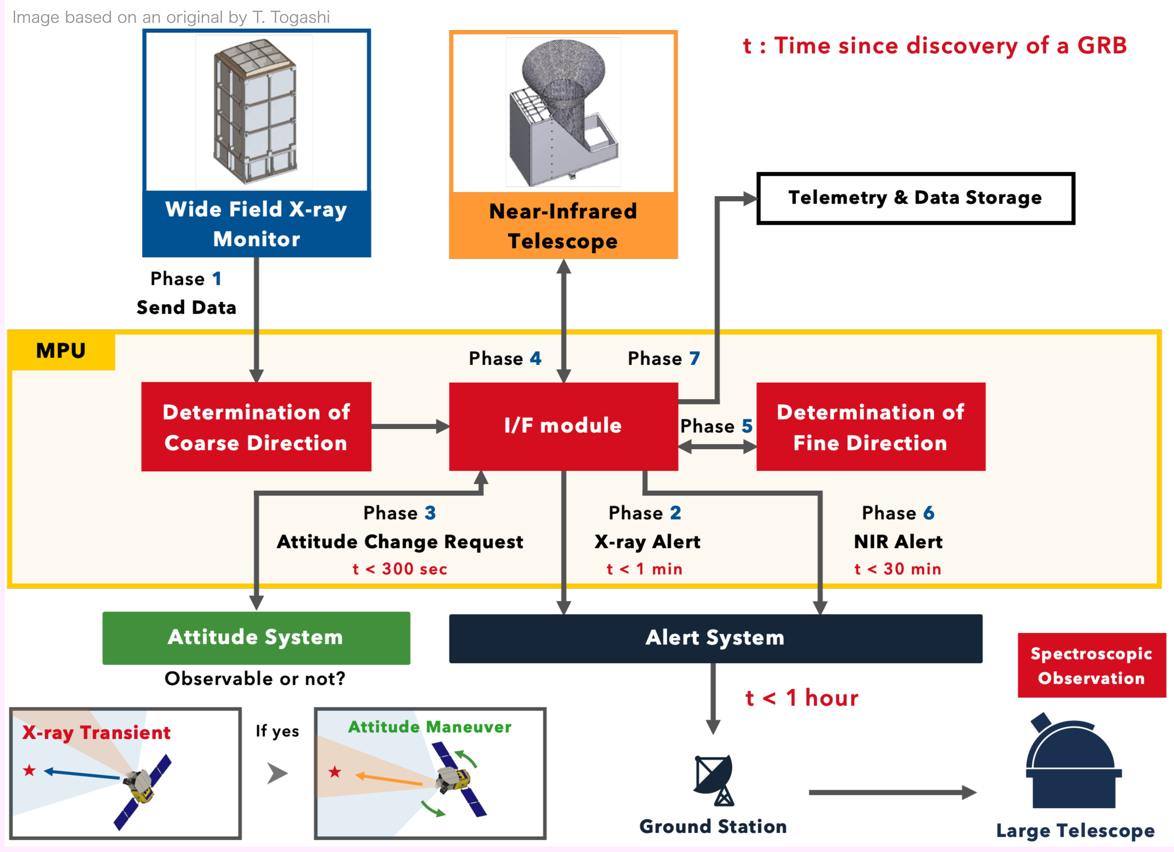
HiZ-GUNDAM is a satellite project aimed at observing high-redshift gamma-ray bursts (GRBs). The satellite will be equipped with wide-field X-ray monitors and a near-infrared telescope. The Mission Processing Unit (MPU) receives and processes instrument data via a SpaceWire network. However, since there are no real devices yet, we have developed several dummy modules that communicate via SpaceWire. Using these dummy modules connected via SpaceWire, we tested basic sequence for detection of the GRB. Moreover to synchronize each clock of these modules, we also carried out the broadcast test using the protocol on SpW called Time Code.

1. HiZ-GUNDAM

HiZ-GUNDAM is a satellite project aimed at observing high-redshift gamma-ray bursts (GRBs). It will carry two instruments: a Wide-Field X-ray Monitor (WFXM) with a field of view of ~0.65sr, which will detect transients in the 0.4-4.0 keV range and localize them with several arcmin accuracy, and a 0.3 m class Near-infrared Telescope (NIRT), which will perform follow-up observations simultaneously in 5 bands (covering 0.5-2.5 um) to detect optical afterglow candidates and estimate their redshifts.



2. MPU Mission data Processing Unit



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 WFXM and NIRT data on the satellite. The Mission 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 instrument. The figure on the left shows the rough observation process of HiZ-GUNDAM.

SCOPE Main Tasks of MPU

Related contributions

- Judge whether the transient event is a GRB or not using data from WFXM — **Phase 1** — Togashi's Talk (19th 16:45-)
- Analyze photometric observation data from NIRT — **Phase 5** — Niinuma's Poster
- Store data in on-board storage — **Phase 7**
- **Give commands to mission equipment** — **I/F module**
- **Communicate with almost all equipment using SpaceWire**

} **My Research**

Our goal is to issue the alert to the ground within **1 hour** of detecting a GRB. To achieve this goal, we are optimizing software and considering efficient network topologies.

3. SpaceWire

SpaceWire is a communication standard designed specifically for space use. This is used for communication within the HiZ-GUNDAM satellite. SpaceWire has the following features.

1. Easily Networking

As a lot of mission equipment are connected to the HiZ-GUNDAM, the network systems must be extremely flexible and scalable. SpaceWire satisfies these requirements..

2. High Communication Speeds

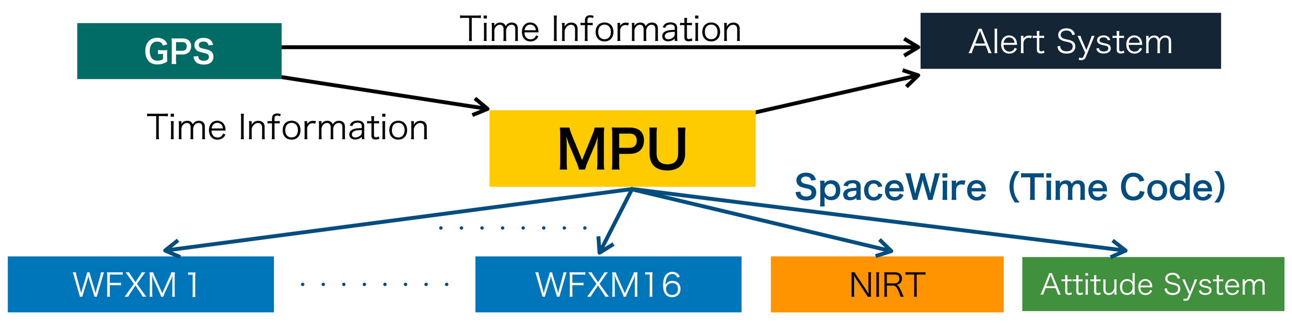
NIRT and WFXM send several Mbytes of data to the MPU in a short period of time. Since the maximum data transfer rate of SpaceWire is 400 Mbps, there are no problems.

3. Time Synchronization for Each Modules

In order to synchronize the time on each mission device, the SpaceWire has a dedicated protocol called "Time Code".

SCOPE Distribution of time information on HiZ-GUNDAM

The satellite will be equipped with GPS to add time information to GRB data. The time accuracy of the HiZ-GUNDAM requires a few tens of milliseconds. The following diagram indicates the concept of time information distribution.



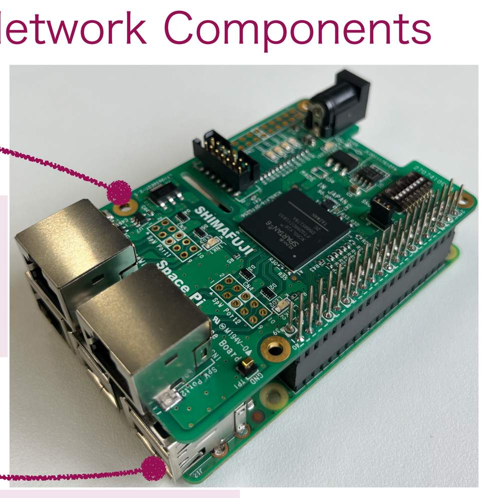
It is important to investigate whether time synchronization can be achieved using Time Code with many mission equipment connected.

4. Dummy Network for HiZ-GUNDAM

It is necessary to gain knowledge of communication procedures based on SpaceWire standards and the usefulness of Time Code. However, as there is no actual MPU, we started to experiment with a pseudo-computer with SpaceWire I/F.

SCOPE Dummy Network Components

Space Pi



- SpaceWire Communication board
- It has two SpaceWire ports and Field Programmable Gate Array (FPGA) chip in which SpaceWire circuit is installed.
- Communication speed is 50 Mbps.

Raspberry Pi 3B

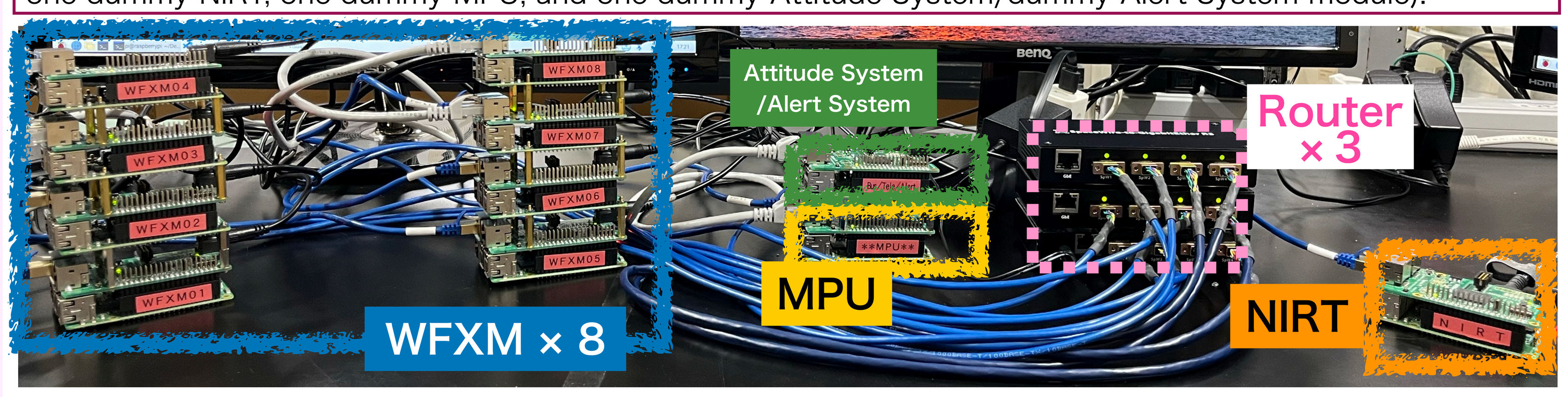
- A single-board computer
- It includes Quad-core 1.2GHz Broadcom BCM2837 64bit CPU and 1GB of RAM.
- 40-pin extended GPIO

2024/ 6 NEW MODEL

SpaceWire-to-GigabitEther R3

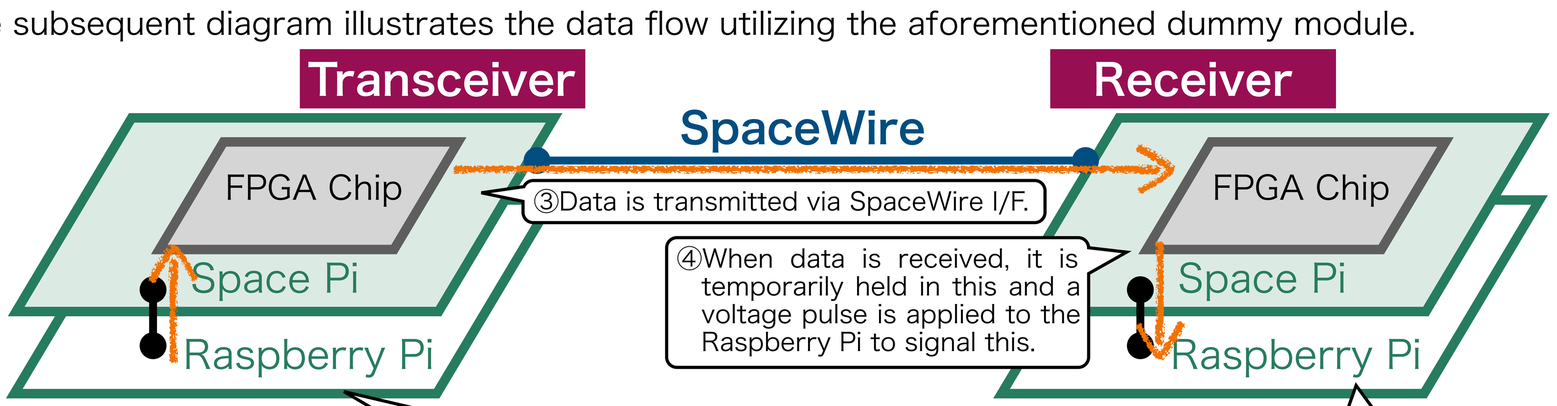
This is a SpaceWire physical router that relays SpaceWire data to multiple mission modules. Four modules can be connected to this router to relay data.
This includes the new ability to deliver Time Code (Time Code Master).

To simulate communication between HiZ-GUNDAM hardware components and to gain knowledge about SpaceWire, we constructed a dummy network consisting of 11 dummy modules (8 dummy-WFXM modules, one dummy-NIRT, one dummy-MPU, and one dummy-Attitude System/dummy-Alert System module).



SCOPE How dummy modules work?

The subsequent diagram illustrates the data flow utilizing the aforementioned dummy module.



①Software is installed on the Raspberry Pi that imitates each device, creating data based on SpaceWire.
②Once the data is ready, the address assigned to each mission device is specified and the data is passed to the FPGA. SPI communication is used at this time.

⑤When triggered by a voltage pulse, data is read out from the FPGA.

Each Raspberry Pi is running the following simple software, which is programmed in C and still under development. All of these contain programs that create SpaceWire data.

Dummy MPU
- Send commands to each mission equipment
- Control which mission equipment requests data
- Analyze WFXM and NIRT data (tentative)

Dummy NIRT
- Upon received of a command to commence observation from the MPU, a notification is transmitted to it
- Transmits photometric data when data is requested by the MPU (tentative, about several Mbytes)

Dummy WFXM
- Create pseudo-histogram data (tentative, about 1400 bytes)
- Upon received of a command from the MPU, the device transmits the data it has accumulated

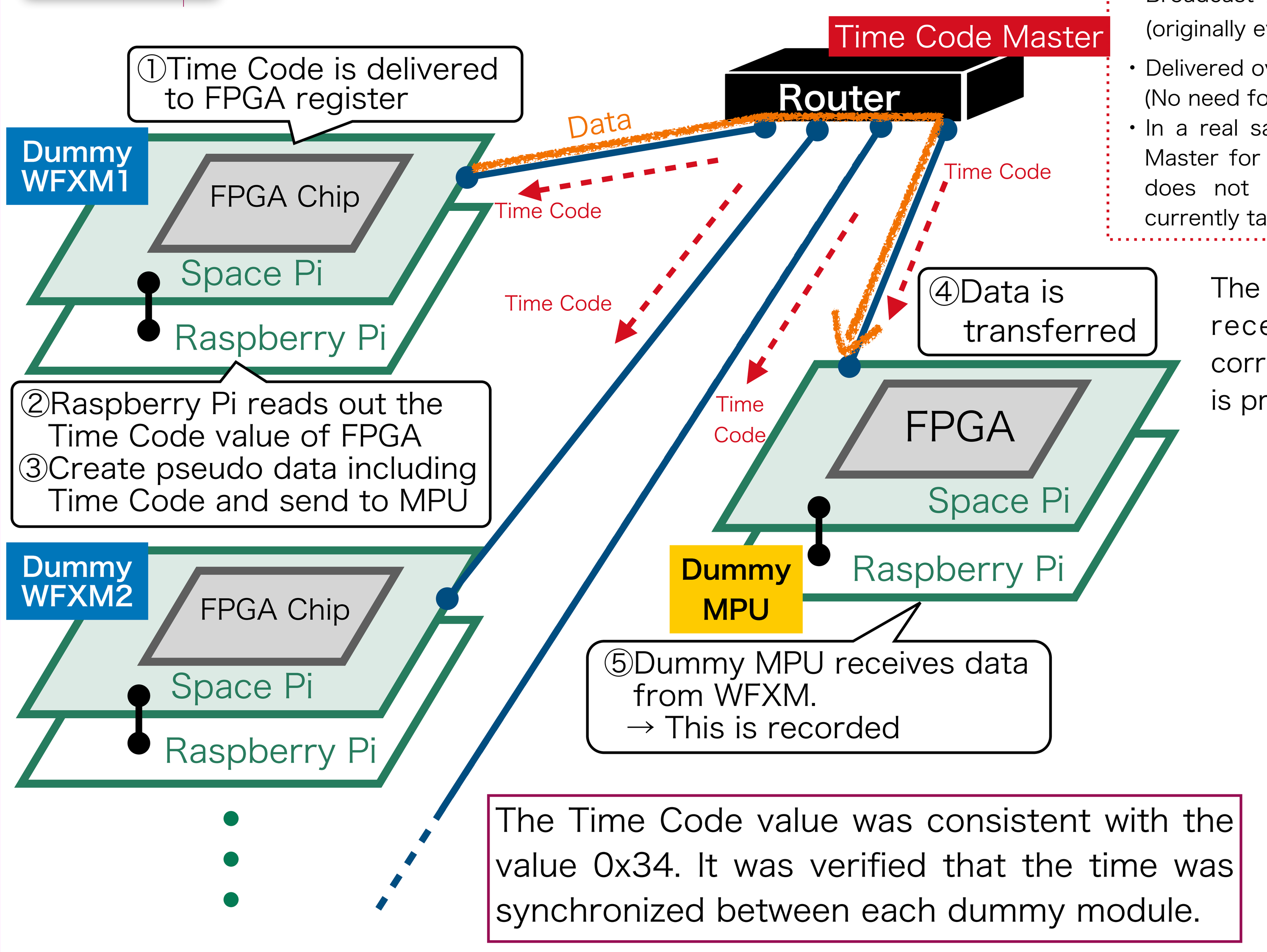
Dummy Attitude System / Alert System
- Notify the MPU that the attitude change has started and that is complete when a command is received from the MPU
- Receive alert information from the MPU

5. Time Code Synchronize Test

As the time code could be broadcast from the new router, it was distributed to the entire dummy network to ascertain whether the time is synchronized. The test was conducted using a total of eight WFXM modules and an MPU.

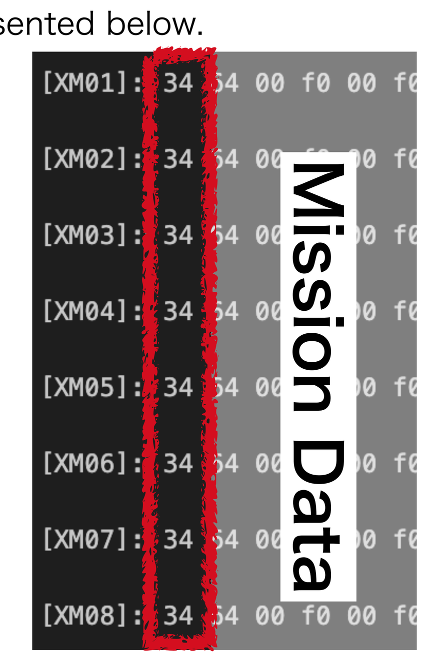
SCOPE Time Code Broadcast and Data Transfer

- Time Code is expressed as a 6-bit number.
- Broadcast Time Code every second (originally every $\frac{1}{64}$ sec)
- Delivered over SpaceWire data signal lines (No need for time-specific cables)
- In a real satellite, the MPU plays a role of the Master for Time Code, but this dummy module does not work as a master, so the router currently takes that role.



The Time Code value was consistent with the value 0x34. It was verified that the time was synchronized between each dummy module.

The portion of the WFXM data received by the MPU that corresponds to the time code is presented below.

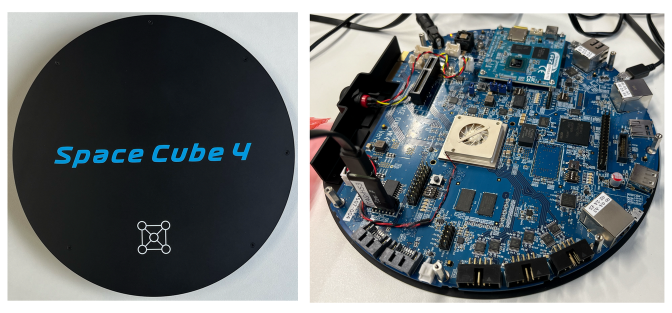


6. Future Work

Current issues

It is challenging for SpacePi and Raspberry Pi to read the Time Code with immediate and precise accuracy due to the fact that they are linked by SPI communication, which is a distinct standard from SpaceWire.

Future Work

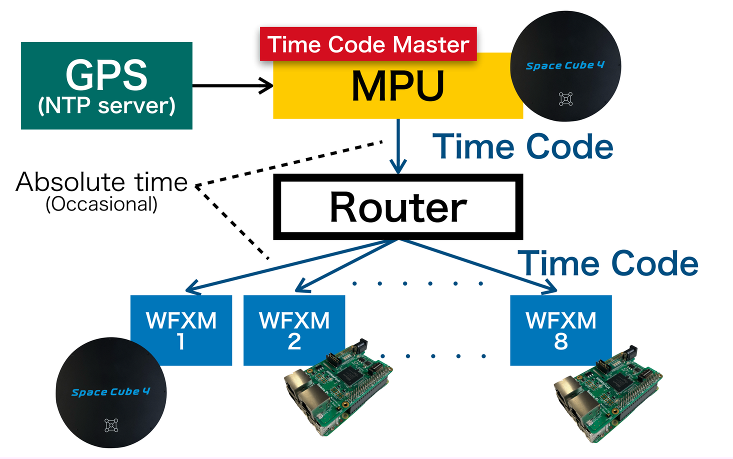


Two computers for ground test of spacecraft, called "SpaceCube MK4", have recently been delivered.

Each device will be assigned an MPU and a WFXM, and the delivery of GPS absolute time and Time Code should provide an indication of the degree of accuracy of the time synchronization. Subsequently, a series of communication tests will be conducted utilizing this apparatus.

SCOPE Conceptual diagram of future experimental set-up

In the near future, we plan to conduct time-critical tests with the following setup.



Reference

[1] Takumi Togashi, "Development of the software algorithm for detection of gamma-ray bursts for HiZ-GUNDAM mission", SPIE Astronomical Telescopes + Instrumentation,June 16-21, 2024 at Yokohama
[2] Steve Parkes, "SpaceWire User's Guide", STAR-Dundee (2012)
[3] Ryuji Sato, "Development of an onboard software system for the High Redshift Gamma-ray Burst Observation Satellite (HiZ-GUNDAM)", Yamagata Univ Master's thesis (unpublished)
[4] SHIMAFUJI ELECTRIC INCORPORATED, "SpacePi," 5 Nov 2024, http://www.shimafuji.co.jp/en/products/960
[5] Raspberry Pi, "Raspberry Pi 3 model B," 5 Nov 2024, https://www.raspberrypi.com/products/raspberry-pi-3-model-b/