NEXTAR Standard Platform for Quick Startup of Remote Sensing Operations

HIHARA Hiroki, YOSHIDA Teiji, TANAMACHI Takehiko, KUMASHITA Kyousuke, KOBAYASHI Akihide

Abstract

NEC boasts achievements in the manufacturing and operation of various spacecraft systems, from communications/broadcasting satellites to meteorological satellites, Earth observation satellites, scientific satellites and space stations. With the MUSES-C (HAYABUSA), which has recently returned to the Earth, NEC demonstrated that it possesses the technologies required for the agile operation of spacecraft in lunar and planetary orbits as well as in low Earth orbit (LEO) and geostationary orbits (GEO). The NEXTAR standard platform is the culmination of these achievements and enables public institutions and private businesses to start up remote sensing operations using observation sensors and communications equipment promptly.

Keywords

small satellite, Operationally Responsive Space (ORS), SpaceWire, ubiquitous
solar cell, triple junction, lithium-ion battery

1. Introduction

Since remote sensing operations utilize imaging data of various wavelengths, from the RF region to visible and ultra-violet light, they require a highly reliable satellite that can continue uninterrupted operation even in space, where it is exposed to drastically varying temperatures and high-density radiation.

To start up a remote sensing operation promptly, so as not to miss the best business opportunity, it is necessary to deploy and operate onboard observation sensors quickly into orbit.

The NEXTAR (NEC Next-generation Star) standard platform responds to this need by providing a development framework that can complete system integration in a short time maintaining its high reliability.

This paper describes the subsystems of the standard platform, including the satellite management subsystem, power supply subsystem, solar array paddle subsystem, attitude and orbit control subsystem and structure subsystem/thermal control subsystem.

2. Satellite Management Subsystem

The satellite management subsystem, which is in charge of the data processing of the NEXTAR standard platform, consists of the following components:

- Versatile onboard computer (Space Cube 2)
- Telemetry/command interface module
- SpaceWire router
- Network data recorder
- Standard middleware
- Software development kit

These components are implemented with universality by improving on previous satellite subsystems on the following points:

(1) Radiation-resistant devices

To prevent soft errors caused by space radiation, such as data inversion or latch-up due to excessive current, the main devices, including microprocessors and routers, are manufactured using the SOI (Silicon on Insulator) process, which features excellent radiation resistance. This leads to the error-free operation of the devices in the radiation environment inside the solar system.

(2) High-speed, universal embedded network: SpaceWire

We adopted the SpaceWire RMAP (Remote Memory Access Protocol) standard, which is the embedded network protocol standardized internationally by the EU, USA, Japan and Russia. This is the first international network specification standard for space-born equipments in which Japanese proposals have been incorporated. The protocol demonstration was performed successfully for the first time in the world using the satellite-borne computer described below in low Earth orbit, and the results led to recognition of the contribution of Japanese industries, including NEC, to the establishment of this international standard. [*1]

This standard supports a serial communication rate of up to 400 Mbps with an electrical interface and supports higher rates with an optical interface. The electrical interface manifests this performance using exclusively digital circuitry, without using an analog PLL.

In consequence, the devices for implementing system LSIs equipped with high-speed communication interfaces can be selected with moderate restrictions related to export control from the available devices in the market, such as the ASIC (Application-Specific Integrated Circuit) and FPGA (Field-Programmable Gate Array). This facilitates the overseas deployment of our space system business.

(3) Versatile multi-purpose embedded computer

With previous satellites, it had been a common practice to develop a dedicated embedded computer in each subsystem, such as the data processing subsystem, attitude/orbit control subsystem and mission subsystem, including observation sensors. For the NEXTAR standard platform, we have developed the Space Cube 2, a versatile multi-purpose computer applicable for the control of any subsystem, by reflecting recent improvements in microprocessor performance and advances in LSI integration. **Photo 1** shows an external view of the computer, and **Table** shows its specifications.

By concentrating our effort for the development of the single type of computer, implementing ASICs extensively and developing basic software, we succeeded in reducing the dimensions to 1/8 those of previous computers, thereby contributing to the size reduction of the satellite bus. This computer was mounted on the SDS-1, JAXA's small demonstration satellite, and completed the in-orbit demonstration without a problem.


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Photo 1 Space Cube 2.

Table Space Cube 2 specifications.

SpaceWire interface	8ch(nominal)
UART interface	2ch
Size(mm)	71(W) × 220.5(D) × 175.5(H)
Weight	1.9kg(nominal)
Power consumption	14W(nominal)

(4) Standard middleware/software design kit

The Space Cube 2 uses a RTOS (Real-Time Operating System) based on TRON as its basic software. The RTOS based on the TRON specification was developed by a collaboration of Japanese industry and universities and comprises about 60% of the RTOSs used in the embedded equipment market. It is low-priced, makes building high-quality applications easy and is blessed with a substantial technical education environment for fostering quality software development engineers.

We packaged our high-reliability technology assets as the standard middleware on the RTOS, achieving integration of the development environment across all subsystems.

The RTOS and standard middleware are integrated into the SDDS/E (SystemDirector Developer's Studio/Embedded) that is provided by NEC as an open platform and are provided as an Eclipse-based embedded software integrated development environment. This development environment is provided exclusively through the NEC portal site based on cloud computing technology in order to ensure version control and configuration control. It also enables business deployment based on joint collaboration with a third-party vendor or enterprise.

The implementation of a standard platform in this way makes it possible to adapt flexibly to the remote sensing target, operation scale, operation mode and system operation period of each operator, to quicken integration and to deliver the spacecraft system to customers promptly in operation on the orbit.

[*1] Joint research with JAXA/ISAS (Japan Aerospace Exploration Agency/the Institute of Space and Astronautical Science) scientists was held to establish scalable network architecture from stand-alone satellite as ASTRO-H, JAXA's upcoming X-ray astronomy observatory, to constellation satellites for which NEC took the lead in the establishment of network specifications and its implementation.

3. Electrical Power Subsystem and Solar Array Paddle Subsystem

For the Electrical Power Subsystem(EPS) and Solar Array Paddle subsystem(SAP), we developed power supply units and SAP that is compatible with use anywhere from low Earth orbit to deep space exploration and which features a reduced number of units, compact size, light weight and low cost.

Electrical power is supplied using the series topology, in which the SAP outputs are connected in series to an APR (Array Power Regulator), which performs step-down regulation. This makes it possible to regulate SAP output voltage, which varies greatly depending on the distance from the sun. We also adopted the battery bus topology, in which the BAT (battery) and other satellite onboard equipments are connected directly to the APR output, so that the SAP output and BAT charging can be controlled by adjusting the APR output alone.

The SAP uses triple-junction high-efficiency solar cells and the BAT uses large (50 Ah capacity) lithium-ion battery cells.

The PCU (Power Control Unit) has a SpaceWire-type data bus interface and achieves high functionality, compact size and light weight by means of high-density packaging (**Fig. 1**).

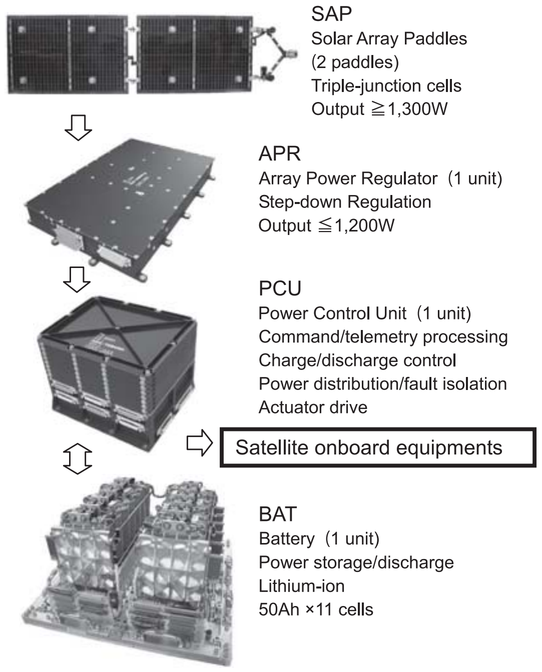


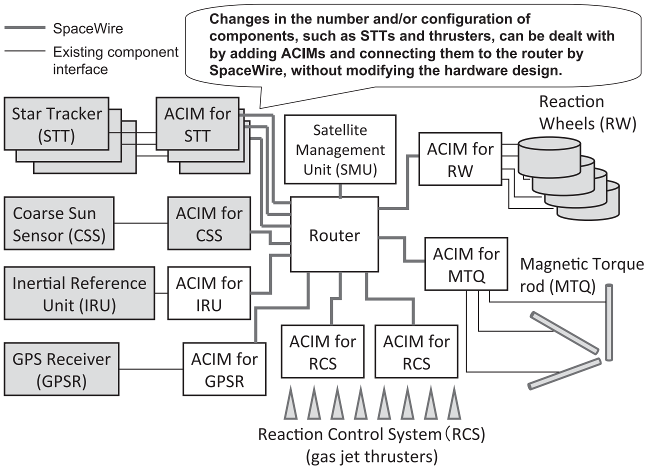
Fig. 1 Electrical Power Subsystem/Solar Array Paddle subsystem.

4. Attitude and Orbit Control Subsystem

The AOCS (Attitude and Orbit Control Subsystem) determines attitude and orbit position based on information from sensors detecting satellite attitude and location and controls attitude and orbit by driving actuators. Since the functions, specifications and configuration of devices such as sensors and actuators are variable between satellites, the functional and performance requirements for the AOCS are highly dependent on each satellite's mission requirements. Consequently, the AOCE (Attitude and Orbit Control Electronics), which is the computer handling the integrated control of these devices, is difficult to produce by repetitive manufacturing, making it necessary to develop and verify this subsystem independently for each project.

We introduced SpaceWire technology in the AOCS and succeeded in implementing a "standard platform AOCS," which is a standardization of hardware and software at the module level that makes it possible to cope with any mission requirement using a catalogue menu selection method.

(1) The interfaces of the AOCE are implemented as individual interface modules (ACIMs). ACIMs can be combined according to the equipment configuration of each satellite, so the AOCE can be produced by repetitive manufacturing. SpaceWire connections between ACIMs and the AOCE make design changes due to additions or modifications unnecessary. The AOCE itself is implemented using a universal computer (SMU: Satellite Management Unit) of



Changes in the number and/or configuration of components, such as STTs and thrusters, can be dealt with by adding ACIMs and connecting them to the router by SpaceWire, without modifying the hardware design.

Fig. 2 Variable AOCE configuration based on SpaceWire ACIM connections.

the same type as that used in the data processing subsystem (**Fig. 2**).

(2) When changing sensors and actuators according to mission requirements, different types from the same manufacturer are always selected in order to maintain the same interface and enable the common use of ACIMs and embedded software.

(3) The embedded attitude control software uses common control modes in consideration for use in the standard satellites and derived satellites expected in the future (5 types). Functions are modularized to enable repetitive manufacturing of the software.

5. Structure Subsystem and Thermal Control Subsystem

The structure subsystem forms the basic structure of the satellite and supports or installs all equipment. Its function is to maintain the mechanical environments of equipment within the specified ranges.

NEC has already developed a small standard bus structure for a satellite which weight at launch is in the 500-kg class and a midsize standard bus structure for a satellite which weight at launch is in the 2-ton class. The small standard bus structure is adopted by the ASNARO (Advanced Satellite with New system ARchitecture for Observation) project of the Japanese Ministry of Economy, Trade and Industry (METI) and the SPRINT-A (Small scientific satellite Platform for Rapid INvestigation and Test - A) project of JAXA, while the midsize standard bus structure is adopted by JAXA's GCOM (Global Change Observation Mission) project. These small and midsize standard bus structures are constitute a standard platform/structure subsystem by complying with multiple launch vehicles, including overseas ones, and by equipping with a standard interface enabling the installation of various observation instruments. In addition, at present, we are commissioned by JAXA to conduct a study on weight reduction in the bus systems of geostationary observation satellites and are tackling drastic weight reduction in the structure subsystem. NEC will provide easier-to-use structure subsystems by taking advantage of the result of this study in the future.

The thermal control subsystem controls and maintains the temperature of satellite-borne equipment even when the satellite is exposed to extremely high or low temperature environments in space. The temperature environment in space is greatly variable between low Earth orbit and geostationary orbit and is even more severe in orbits around distant planets. We do not deal only with orbits around the Earth but also have experience developing thermal control subsystems for planetary exploration spacecraft such as the MUSES-C (HAYABUSA) and PLANET-C (AKATSUKI), for which thermal control is more difficult than for earth orbiters.

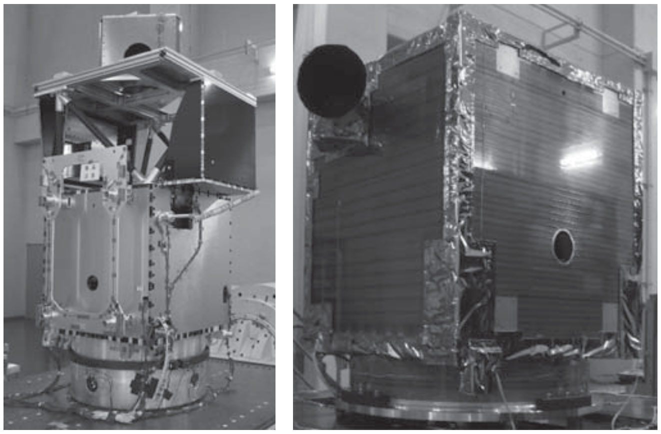


Photo 2 ASNARO vibration testing (Left) and thermal testing (Right).

NEC also applies the thermal control technology cultivated for the planetary exploration spacecraft mentioned above to the thermal control subsystems of small and midsize standard bus structures so that they can adapt flexibly to various orbits, attitudes and missions. The thermal control technology has already been adopted by small and midsize satellites such as the SPRINT-A and GCOM, and the SPRINT-A has completed thermal model testing to verify its thermal design. In the future, too, NEC is determined to offer thermal control technology that can respond to a variety of mission requirements (**Photo 2**).

6. Conclusion

The NEXTAR standard platform is an application development platform that makes it possible to start up remote sensing operations using 100-kg to 2-ton class satellites and to deploy business operations stably for long periods thanks to high reliability.

In closing this paper, we would like to express our gratitude toward JAXA, METI, NEDO (New Energy and Industrial Technology Development Organization) and USEF (Insti-

tute for Unmanned Space Experiment Free Flyer Foundation) for their kind guidance.

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*SpaceCube is a trademark or a registered trademark of the Japan Aerospace Exploration Agency (JAXA) and Shimafuji Electric Incorporated.

*TRON is an abbreviation for "The Real-time Operating system Nucleus."

*Eclipse is a trademark or a registered trademark of Eclipse Foundation.

Authors' Profiles

HIHARA Hiroki
Engineering Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

YOSHIDA Teiji
Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

TANAMACHI Takehiko
Senior Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

KUMASHITA Kyousuke
Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

KOBAYASHI Akihide
Manager
Space Engineering Division
NEC TOSHIBA Space Systems, Ltd.

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Ground Systems Supporting Satellite Operations
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Satellite Transponder Equipment in Active Worldwide Use

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Development of a Radiation-Hardened POL DC/DC Converter for Space Applications
Qualification Situation and Future Deployment of PWBs for Space Development Use

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Vol.6 No.1

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Special Issue TOP