Guidance Control Computer for Launch Vehicle

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Abstract

The H-IIA/H-IIB are the main launch vehicles domestically developed in Japan. With 14 consecutive successful launches among a total of 20 attempts, they have now acquired international reliance and are improving their competitiveness. NEC is involved in this project with the guidance control computer (GCC). As part of development for dealing with component depletion, NEC is developing a new GCC featuring high speed, high performance, compact size and light weight by adopting a new MPU. This paper introduces the circumstances of the development of past computers for launch vehicle together with the features, functions and performance of the new GCC and the efforts NEC will make with regard to computer systems for launch vehicle in the future.

Keywords

guidance control computer (GCC), common computer module, HR5000
inertial guidance computer (IGC), on-board software (OBS), TOPPERS/HRP

1. Introduction

The GCC plays the role of the brain in the autonomous control of the launch vehicle. It inputs data from flight critical sensors and calculates navigation, guidance and control commands by using On-board software (OBS). The results are transmitted to the vehicle through individual control equipment so that the vehicle flies along the scheduled route to launch the payload, such as a satellite, accurately into the designated orbit. The GCC for launch vehicle is needed to achieve the critical mission: "uninterrupted, sure functioning without malfunctioning even under the vibrations, shock and temperature environment during launch as well as in the radiation environment in space."

At NEC, we are developing the new GCC for the H-IIA/H-IIB. It adopts a new MPU, maintains high reliability as defined above and features higher speed, more compact size and lighter weight than before. It adopts a modular structure compatible with a backplane compliant to the PCI standard to enable the flexible addition of modules for functional extension and redundancy in the future. In particular, the new MPU board is being developed as a common computer module to be used in all the launch vehicles to be developed in the near future. Its development testing is conducted under very stringent environmental conditions so that it can be used in equipment other than the GCC, such as the inertial sensor, as well as in the Epsilon launch vehicle.

2. Circumstances of the Development of the GCC for Launch Vehicle

2.1 The role of the GCC

The H-IIA features autonomous flight without receiving guidance control commands from the ground equipment. Namely, it continues flight by detecting its own position, acceleration and attitude using the electronic equipment and software on board and performing auto-correction to advance the designated flight route correctly.

Fig. 1 shows the configuration of the avionics of the H-IIA. The GCC is located at the center of this system and inputs the data from the inertial measurement unit (IMU), which incorporates gyros and accelerometers. Based on these input data, the GCC computes position, velocity and attitude using the on-board software (OBS), transmits the required control commands to the engine and gas jet systems according to guidance control algorithms and also outputs event commands such as the separation command. In addition, it also edits and encodes the telemetry data that is output for ground monitoring.

As shown in Fig. 1, a GCC is mounted in each of the two stages of the launch vehicle. Each GCC is in charge of the control of its stage under the initiative of GCC2, mounted in the second stage. One of the major features of the guidance control system of the H-IIA is that the GCCs are interconnected through a data bus. This design contributes to improve-

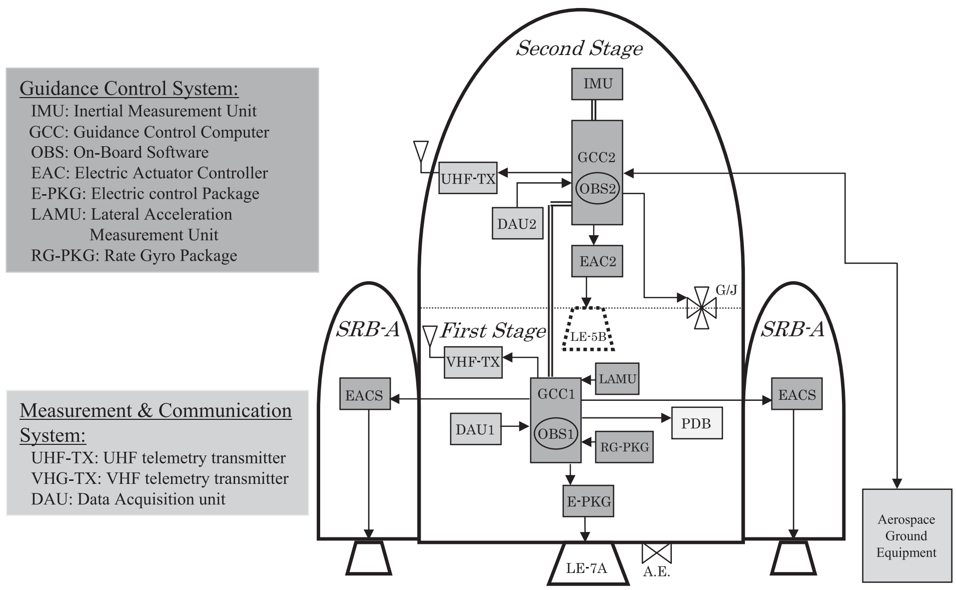

Fig. 1 Configuration of the avionics system of the H-IIA launch vehicle.

ments in control capability, assembly/maintenance/inspection efficiencies and the overall reliability of the launch vehicle thanks to the reduction of signals sent across stages.

2.2 History, Functions and Performance of On-board Computers for Launch Vehicle

The history of Japanese practical satellite launch vehicles began with the N-launch vehicles. However, most of the N-launch vehicles were manufactured by introducing technologies from the United States and their on-board computers were operated as complete black boxes made in the USA.

It was in the 1970s that the long-cherished wish of Japanese engineers, the domestic development of practical satellite launch vehicles, was started based on the operation technologies cultivated with the N-launch vehicles, achieving a domestication ratio of 100% with the H-II, after the development of H-I. Engineers also succeeded in improving functions and reducing costs with the H-IIA developed after it.

In this process, the challenge of the domestic production of the on-board computer for launch vehicle was started in 1977, aiming at mounting in the H-I. In this history, we at NEC have been in charge of all of the Japanese on-board computers for launch vehicle from the first N-I to the present.

Table shows outlines of functions and performance specifications of on-board computers used with H-I, H-II and H-IIA.

The current GCC (in the current H-IIA/H-IIB) has improved its functions and performance specifications drastically from the IGC used with H-I and H-II. Its significant features are the addition of various interface functions and the enrichment of the self-diagnostic function. Its computing function block uses the space-spec version of V70 as its microprocessor. The V70 is a 32-bit MPU by NEC and belongs to the same generation as the Intel 80386. Although simple comparison is not possible due to differences in computing specifications, it can be said that the processing performance of the current GCC is more than six times better than that of the IGC of the H-II.

The new GCC to succeed the current GCC will adopt the HR5000, the latest 64-bit space-use microprocessor developed by JAXA. Its processing performance is more than ten times better than that of the current GCC.

3. Technical Features of the New GCC

The new GCC for the H-IIA/H-IIB uses the same external interface specifications as the current GCC but incorporates the following new features:

1) Development of a common computer module adopting the latest space-use MPU (HR5000)

2) Adoption of a modular structure compliant to the PCI standard

Table Functions and performance of on-board computers for launch vehicle

Item	IGC for H-I	IGC for H-II	Current GCC for H-II A/B	New GCC for H-II A/B
Main functions	- Computing function - Interface function among digital equipment	- Computing function - Interface function among digital equipment	- Computing function - Interface function among digital equipment - Interface function with vehicle equipment - Measurement communication control function	- Computing function - Interface function among digital equipment - Interface function with vehicle equipment - Measurement communication control function
Microprocessor	Bit-slice type microprocessor	Bit-slice type microprocessor	32-bit microprocessor V70	64-bit microprocessor HR5000
Word length	16 bits	16 bits	32 bits	64 bits
Operation speed	0.26 MIPS (H-I usage mix)	0.34 MIPS (H-II usage mix)	2 MIPS (Dhrystone)	29 MIPS (Dhrystone)
Arithmetic	Fix-point	Fix-point	Floating-point	Floating-point
Operating System	None	None	Real-Time OS (RX616)	Real-Time OS (TOPPERS/HRP)
Memory capacity	RAM: 32 Kbyte	RAM: 64 Kbyte	RAM: 2 Mbyte ROM: 128 Kbyte	RAM: 4 Mbyte ROM: 2 Mbyte
Interface function (excluding power source interface)	- 4 types (Digital circuits) - Provided only among units	- 3 types (Digital circuits) - Provided only among units	- 11 types (Analog and discrete circuits) - Interface function among equipment - Interface function with vehicle equipment	- 11 types (Analog and discrete circuits) - Interface function among equipment - Interface function with vehicle equipment
Size	300 × 450 × 180 (mm)	296 × 370 × 205 (mm)	270 × 360 × 220 (mm)	230 × 343 × 273 (mm)
Weight	16 kg	14 kg	21 kg	14 kg
Power consum ption (Nominal)	60 W	45 W	52 W	50 W

3.1 Development of the Common Computer Module

We have developed the common computer module by setting as many universal specifications as possible so that they can be applied commonly to the processors of electronic equipment for launch vehicle in the future. In particular, we set very stringent specifications on the thermomechanical environment and EMC conditions.

Photo 1 shows an external view of the common computer module. It is a very compact board with a size meeting the 3U cPCI standard. In consideration for its use in high-reliability avionics systems in the future, we are also examining extending the board to improve reliability by providing redundancy.

3.2 Adoption of a Modular Structure Compliant to the PCI Standard

The new GCC must respond flexibly to system changes such as the addition/modification of interfaces. As the first step toward implementing the next generation launch vehicle avionics equipment, the new GCC uses a backplane that is compliant to the PCI standard so that modules can be added or changed

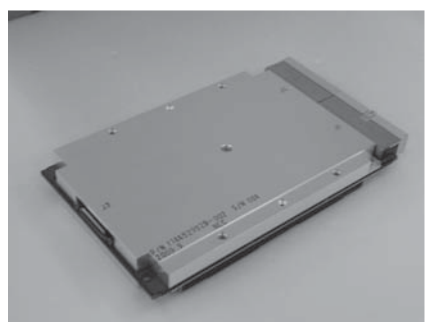

Photo 1 External view of the common computer module (EM).

as required. Modules are connected to the backplane when they are inserted into the module slots on the front of the GCC. **Photo 2** shows an external view of the new GCC.

Function modules available for the new GCC include telemetry editing, analog input/output, discrete signal input/output and data bus interface function modules. These modules can be combined in multiple variations according to system requirements so that the GCC is compatible with launch vehicles other than the H-IIA/H-IIB, such as the Epsilon. Even when a new interface function is requested in the future, the

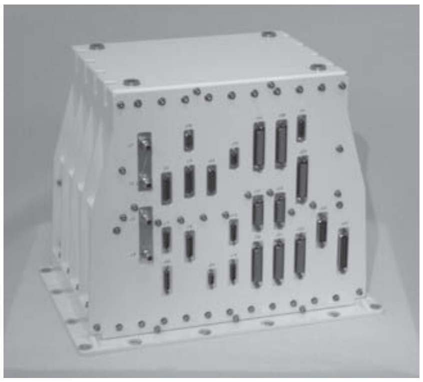

Photo 2 External view of the new GCC (EM).

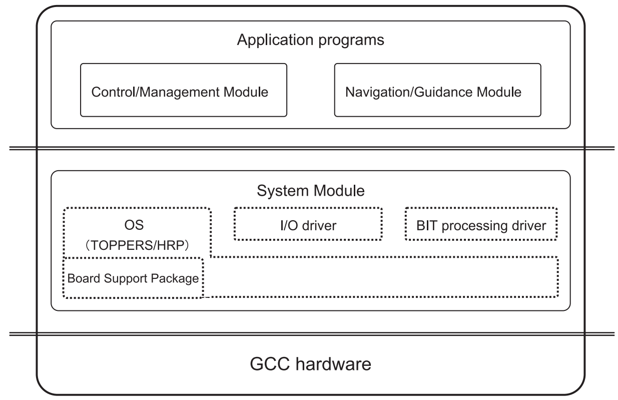

Fig. 2 Configuration of the on-board software of the new GCC.

new GCC can handle it flexibly by additionally developing a corresponding function module.

4. On-board Software

We have also modified and developed the on-board software of the GCC following the development of the new GCC. **Fig. 2** shows the configuration of the on-board software of the new GCC. The on-board software of the H-IIA is composed of system module, navigation/guidance module and control/management module.

The system module, of which NEC is in charge, acts as an intermediary between GCC hardware and application programs so that application programs do not have to access GCC hardware directly.

The system module consists of a real-time OS, I/O drivers corresponding to the GCC's interfaces and a test program (BIT: Built-In Test) for detecting GCC hardware failures. The OS is TOPPERS/HRP (High Reliable Profile), a high-reliability real-time OS of the μITRON specification developed by JAXA for the HR5000 space-use MPU.

On-board software is verified first through individual verifications of software functions, then through on-board verification with GCC hardware and finally through system testing combining all guidance control hardware and software. Off-nominal cases that cannot be produced in actual hardware are verified in full-software simulation testing simulating the hardware with software.

It is planned that the system module will be extended with new functions, such as redundancy management and network control functions, for use in launch vehicle avionics systems with higher reliability to be developed in the future.

5. Conclusion

In the above, we described the history of on-board computers for launch vehicle and introduced a new GCC and common computer module under development.

The new GCC will complete development by the beginning of FY2011 and will then be put to use as the successor to the current GCC. The new GCC is also planned to be used as the base for the GCC for the Epsilon, with the modification of some interface specifications. The common computer module will be incorporated in the IMU (Inertial Measurement Unit) as well as in the GCC.

In the future, Japanese development of key technologies for launch vehicle will be advanced toward the next generation, featuring higher reliability.

At NEC, we are determined to continue the development of new technologies aiming at implementing higher-reliability avionics systems for the next major launch vehicle, based on our expertise in the development of on-board equipment up to the present, as well as on the upcoming results of the development of the common computer module and the new GCC.

*TRON is an abbreviation of "The Real-time Operating system Nucleus."
*ITRON is an abbreviation of "Industrial TRON."

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Vol.6 No.1 Space Systems

Vol.6 No.1
April, 2011

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