Development of the ASNARO, an Advanced Space System

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Abstract

The ASNARO is a small earth observation and imaging satellite under development by NEC as a consignment contract together with: the Japanese Ministry of Economy, Trade and Industry (METI), the Institute for Unmanned Space Experiment Free Flyer (USEF) and the New Energy and Industrial Technology Development Organization (NEDO). It is not simply an engineering test satellite but aims at supplying subsequent models for the needs of future overseas markets. It is supported by some of our latest technologies in introducing standardization and miniaturization and it is being developed accordingly as a small, high-performance, low-priced satellite featuring high market competitiveness.

Keywords

earth observation satellite, size reduction, standardization
price reduction, deployment in the global market

1. Background

NEC Space Systems Division is developing the ASNARO (Advanced Satellite with New system Architecture for Observation) under a consignment contract with the Japanese METI USEF and NEDO. It introduces an advanced space system concept by reducing the sizes of satellites.

NEC has already manufactured many small satellites (around 500 kg) in the S&T field such as the HAYABUSA, MUSES-C, and the AKATSUKI, PLANET-C satellites, but the mainstream commercial market for earth observation/communication satellites deployed globally is for the development of large satellites of high performances and with multiple function capabilities (weighing a few tones) such as DAICHI, ALOS and KIZUNA, WINDS. The European and U.S. satellites occupy almost 100% of the share in the commercial satellite market and we are likely to encounter a high bar for new entries, even with our very attractive advanced technology and track record of reliability. However, in the small satellites field, the demand for small models at affordable prices is rapidly rising in the Asian, African and South American countries.

Based on such a market background, the ASNARO has been developed as a small earth observation satellite featuring low price, short delivery term and high market competitiveness by introducing and advancing various recent technological innovations. These include the innovative "miniaturization" technology for small scientific satellites. Such advances are helping to provide the "multi-functionality" and "high performance" of large satellites while maintaining the features of small satellites such as "light weight," "low price" and "short delivery term."

In addition, while previously satellites had been developed from the beginning so that the entire satellite system was optimized according to the needs of a specific mission, the development method has been reviewed and changed from that of a whole satellite system to an architecture that standardizes components used in common (bus module). This policy has favored component adoption by other satellites, even when the mission is quite different. For example, the ASNARO has a high-resolution optical sensor but the interface between the bus module and mission module is standardized. When an observation satellite using a radar sensor is to be developed, it can be implemented in a short delivery term and at a low price because the design makes it possible to minimize the modification of the bus module according to the requirements specific to the mission module.

This paper describes the ASNARO project and our strategy for satellite size reduction and standardization by taking the development of the NEXTAR small standard bus as an example.

2. Outline of ASNARO

The ASNARO is a small earth observation satellite with a total weight of below 500 kg that orbits the earth at a low altitude of about 500 km. The mission objective of the ASNARO is the optical observation of the ground surface using a high-resolution optical sensor. This satellite is being developed to target a ground sampling distance (GSD) of below 0.5 meter, which is equivalent to that of the resolution of the 1-2 ton class of the commercial optical earth imaging and observation satellites of overseas manufacturers.

The ASNARO is scheduled to be launched in 2012 and to operate for 3 years or more (Target 5 years), while utilizing ground station support from inside as well as outside Japan. The ASNARO is essentially composed of the bus and mission modules. The bus module is being developed as the NEC, NEXTAR small standard bus, and the mission module is being developed as three subsystems. These are: 1. the optical sensor subsystem that carries the camera for imaging the ground surface, 2. the mission control subsystem that controls the camera, communications equipment and satellite attitude and saves the captured images and 3. the direct transmission subsystem that transmits the image data to the ground by tracking the ground stations. **Fig. 1** shows an external view of the ASNARO and **Table 1** lists its system specifications.

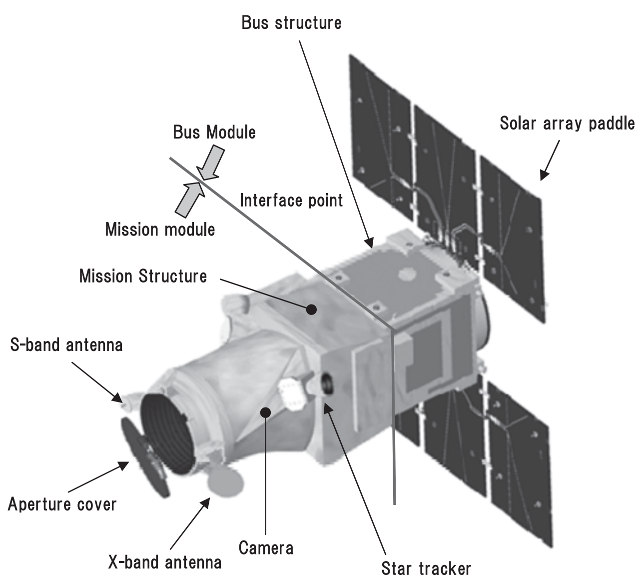

Fig. 1 External view of ASNARO.

Table 1 ASNARO system specifications.

Item	Detail
Mission - Optical sensor - Data storage - Data transmission	 Panchromatic/multi-spectrum sensor. Resolution: ≤0.5 meter (Pan, altitude 504 km) Swath: 10 km ≥120 GB X-band, 16-phase QAM, approx. 800 Mbps
Image capturing range	Inside the cone in ±45° from nadir.
Agility	45°/45 sec. (Ave. 1°/sec.)
Launch	FY2012 (scheduled). Compatible with major launch vehicles including the Epsilon rocket and H-IIA of Japan as well as foreign commercial rocket, such as Dnepr and Rockot.
Orbit	Sun-synchronous sub-recurrent orbit (Altitude 504 km). Orbit inclination angle: 97.4° Local sun time at descending node: 11:00
Ground stations	Commercial ground stations and mobile stations in Japan, plus overseas stations
Operating period	≥3 years (Target 5 years)
Weight	■ Bus: 250 kg (excl. propellant) ■ Mission: 200 kg (max. weight) ■ Propellant: 45 kg (max. weight) <TOTAL>: 495 kg
Power	Generated power: 1,300 W (3 years after) Mission supply power: 400 W

3. Strategy for Size Reduction and Standardization using the NEXTAR Small Standard Bus

The ASNARO uses the NEC NEXTAR small standard bus being developed based on the scientific satellite design concept of JAXA and ISAS (Institute of Space and Astronautical Science). This bus is designed so that the bus and mission module of the satellite are mutually independent: structurally, thermally and electrically. The interface condition between the mission and bus module is standardized so that the bus module is compatible with several missions without a need for a design change. **Fig. 2** shows the view of the NEXTAR bus.

Fig. 3 shows examples of the application of the NEXTAR standard bus: (a) is an optical sensor satellite carrying the high-resolution optical camera adopted by the ASNARO, (b) is a satellite carrying a synthetic aperture radar (SAR) sensor based on radar technology and is capable of observation of the ground surface on a cloudy day or at night, which is impossible with the optical sensor, (c) is a case of carrying a hyper-spectral sensor that is capable of observation by separating the observed light into a very large number of wavelengths, and

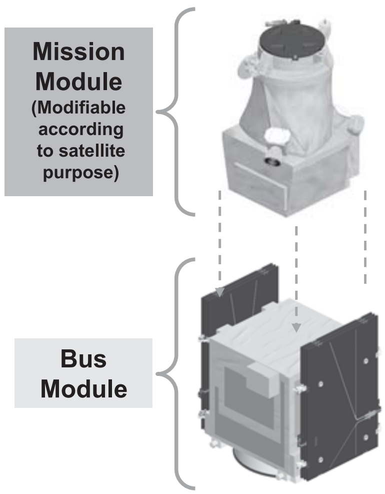

Fig. 2 View of NEXTAR standard bus.

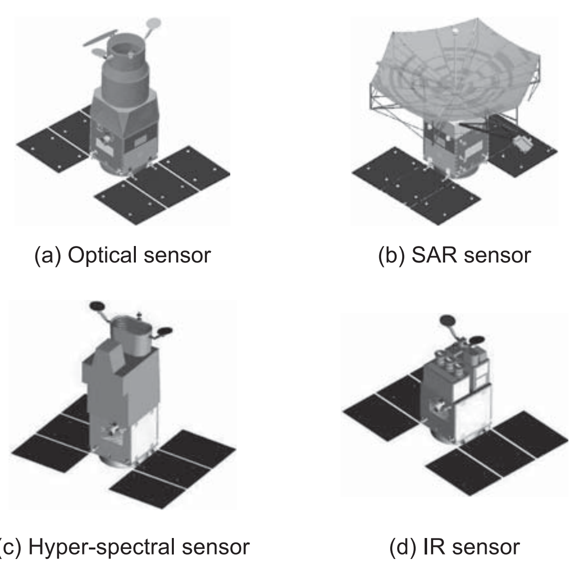

Fig. 3 Examples of observation satellites using standard buses.

(d) is a case of carrying an IR sensor that observes IR rays generated from sources of heat.

Standardization of the bus enables common use and mass-production of on-board equipment to be applied on different satellites. It also permits to manufacture and stock the on-board equipment before manufacturing satellites. In addition, standardization of the manufacturing test procedure also enables significant reductions in cost and lead-time.

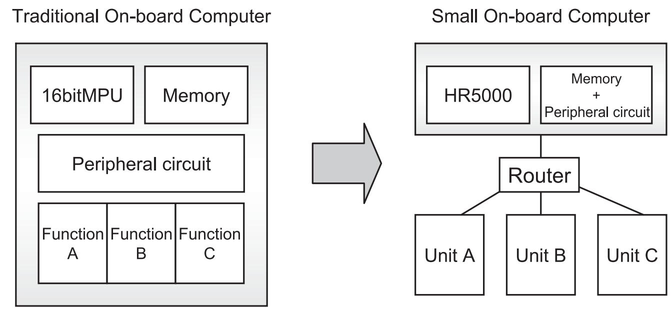

Fig. 4 Use of SpaceWire networking technology.

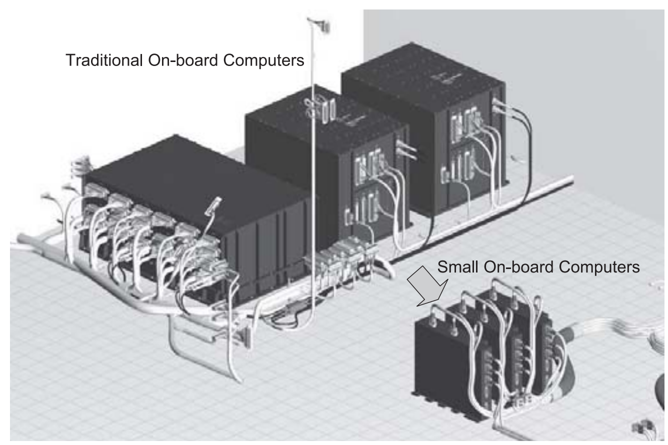

Fig. 5 Use of a compact satellite-born computer in NEXTAR.

An example of the introduction of standardization technology applied to the NEXTAR is the standardization of the data control inside the satellite by adopting the SpaceWire RMAP (Remote Memory Access Protocol), which is an embedded network standard formulated by international standardization under the leadership of the EU, the USA, Japan and Russia. The CPU boards of computers equipped on traditional satellites as well as other functions such as the data control, attitude control and mission control functions have been developed individually according to the mission requirements of each satellite. With the NEXTAR, this method has been changed to use a standardized computer that implements the functions required of the bus for the entire network (**Fig. 4**).

As a result, the previous method of implementing the data control, attitude control and mission control using three different computers is now enabled with the use of a small common computer "SpaceCube2," which contributes significantly to a reduction in the size and price of satellites (**Fig. 5**).

4. Strategy for Size Reduction of the Mission Module of ASNARO

The equipment of the mission module of the ASNARO includes the high-resolution optical sensor, data recorder and the X-band transmission system, etc. The optical image captured from an altitude of 504 km is converted into a digital signal and stored in a 120 GB capacity (at the end of life) flash memory data recorder without compression. The stored image data is modulated via 16QAM modulation system and the frequency is converted into X-band (8-GHz band). It is eventually transmitted to the ground station at a high 800-Mbps data rate via a directional X-band antenna equipped with a two-axis gimbal.

As shown in **Table 2** , the ASNARO introduces various new technologies for a small satellite of about 500 kg in order to implement a performance equivalent to that of a satellite weighing a few tones.

Table 2 Performance comparison between the ASNARO and commercial satellites of other countries.

	ASNARO	WorldView-2	GeoEye-1
Launch year, External view	2012(Scheduled) 	2009 	2008 
Developing country	Japan	U.S.A.	U.S.A.
Orbit	504km Sun synchronous	770km Sun synchronous	684km Sun synchronous
Mission Life	3years	7.25years	7years
Satellite mass	<500kg	2,800 kg	2,000 kg
Ground sampling distance (GSD) Swath	< 0.5m(Pa) <2m(Mu) 10km	0.46m(Pa) 1.84m(Mu) 15.8km	0.41m(Pa) 1.65m(Mu) 14.4km
Data rate	832Mbps	800Mbps	740Mbps

* Pa: Panchromatic (monochrome image) / Mu: Multiband (color image)

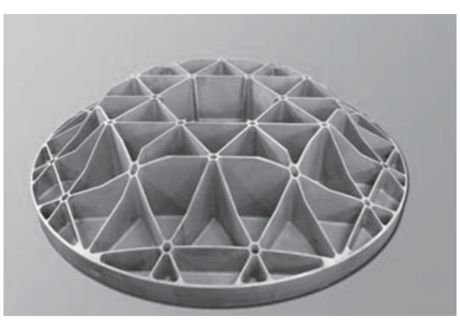

Photo Primary mirror of ASNARO made from NTSIC material.

(1) Use of the NTSIC Mirror

Optical observation satellites have traditionally used glass as the material for the primary mirror of the camera (telescope) but the ASNARO adopts a high-strength, reaction-sintered, silicon carbide (NTSIC, developed jointly by NEC TOSHIBA Space Systems, Ltd. and Toshiba Corporation). This material is obtained by improving silicon carbide (SiC) and features lighter weight, higher strength and lower thermal distortion than the glass material (**Photo**). NTSIC features a higher strength than the ordinary SiC material and has a dense and no pores on the surface.

(2) Use of flash memory

The mainstream memory used hitherto in the data recorder for storing the observation data of traditional optical observation satellites has been the SD-RAM that features high-speed processing and high reliability. On the other hand, the ASNARO adopts a flash memory that features lower heat dissipation, lower power consumption, lower price, same size and larger capacity than the SD-RAM in order to reduce the size, weight and price of the data recorder.

(3) Use of the 16QAM system

Traditionally, optical observation satellites used to use the modulation system called QPSK for transmitting observation data. This system can transmit 2 bits of information per symbol and the rate is limited to around 400 Mbps due to the restriction of the 8-GHz frequency band used.

Therefore, larger satellites had to have two sets of 400 Mbps communication equipment, including antennas, in order to transmit data at 800 Mbps.

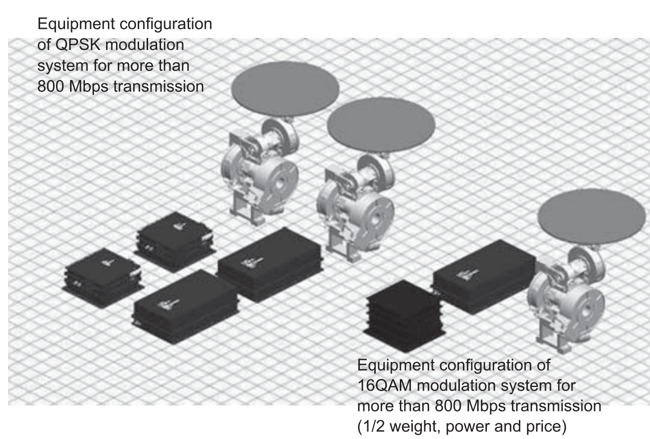

Fig. 6 Equipment configuration of the data transmission system of the ASNARO.

Currently, the ASNARO adopts a 16QAM system that can transmit 4 bits, which is twice that of the QPSK, per symbol. It can thereby achieve the same 800-Mbps transmission as larger satellites using a single set of communication equipment and as a consequence enable reductions in the size, weight and price of the satellite (**Fig. 6**).

5. Conclusion

One of the purposes of developing ASNARO is in order to manufacture a satellite that can compete with the satellites of other countries in the global market. This paper summarizes the development of the ASNARO satellite and discusses the miniaturization and standardization technologies used to achieve optimum performance and low price. The ASNARO satellite system is being manufactured and tested while targeting a launch date before the end of FY2012. At NEC, we aim to reliably develop the ASNARO, which is attracting worldwide attention, and to promote activities aimed at obtaining subsequent orders and exporting the product to overseas countries.

We are also developing a space solution package using the ASNARO and NEXTAR standard bus as core products. As the package will include ground stations (satellite control stations and data reception stations) and TT (Technical Transfer for users, including education and technology support,) we will also standardize and prepare menus for these systems so that we can provide customers with solutions to meet their needs for shorter delivery terms and lower costs.

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