DEVELOPMENT OF ENGINEERING TEST SATELLITE Ⅷ

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1. Introduction

NASDA's Engineering Test Satellite (ETS) series aims at developing satellite common base technology and has been carrying out the technology development of various satellites from the ETS-I to ETS-VII, responding to the needs of each period. The ETS-Ⅷ has purposes of achieving the following technology developments necessary for the early 21-st century and conducting experiments and demonstrations:

(1) Technology for 3-ton class spacecraft bus, most advanced in the state of the arts, that can fully support various missions becoming necessary for the space activities in the outset of the 21-st century,
(2) Technology of large deployable reflector, most advanced and largest of its kind.
(3) Mobile satellite communication system (MSS) technology that can provide an audio/data communication with hand-held terminals,
(4) Mobile satellite multimedia broadcasting system (BSS) technology with compact disk-class high quality sound and data transmission,
(5) Base technology of satellite positioning in use of high stability atomic clock.

To verify the above technologies in orbit, the ETS-Ⅷ is scheduled to be launched by the H-IIA rocket from Tanegashima Space Center in 2003 into a geo-stationary orbit of 146 degrees of east longitude.

2. Outline of ETS-Ⅷ

National Space Development Agency of Japan (NASDA), Communications Research Laboratory (CRL), Nippon Telephone and Telegraph Company (NTT), and Advanced Space Communications Research Laboratory (ASC) are cooperating in the development of the ETS-Ⅷ. In-orbit image of the ETS-Ⅷ is shown in Fig. 1, and Table 1 shows its major characteristic.

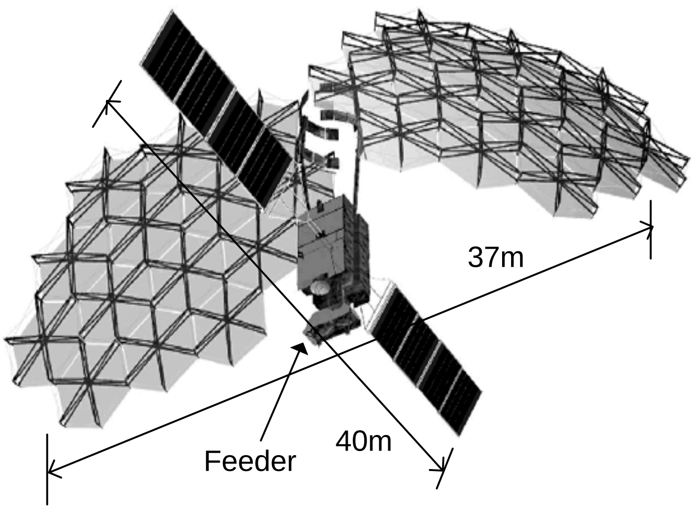

Fig. 1 In-orbit image of ETS-Ⅷ

Table 1 Major characteristic of ETS-Ⅷ

Orbit	Geo-stationary orbit (146° E)
Launch date	2003
Bus size	2.45x2.35x3.8m
Weight (Dry)	2.9 ton
Payload mass	1200 kg
Attitude control	3-axis-stabilized
Design life	10 years (Bus) 3 years (Mission)
Electric power	7.5 kW
Apogee Engine	500N class bi-propellant thruster

2.1 Mission Payload

Fig. 2 shows a configuration of the mission payload for communication and satellite positioning experiments(1). The Mission payload consists of MSS and BSS communication equipment, feederlink equipment, and satellite positioning equipment. The followings are brief description of the mission payload equipment.

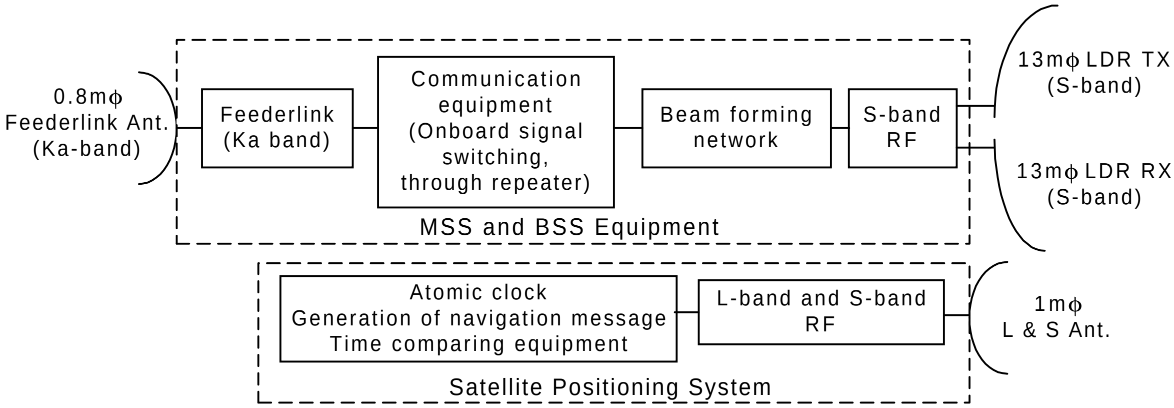

Fig. 2 Configuration of mission payload

(1) Large deployable reflector

Onboard high gain antenna with large reflectors is fundamental technology to realize MSS and BSS using handy terminals. In the ETS-VIII system, two 13m aperture antenna reflectors (TX and RX) are installed to avoid passive inter-modulation effect.

To construct such an antenna, we have developed modular type deployable antenna(2). The antenna reflector consists of fourteen basic modules which shape is hexagonal truncated pyramid. A mechanical size and weight of a reflector are 19.2m x 16.7m and 170 kg including a deployable supporting boom, respectively. Surface accuracy of the reflector is designed to be less than 2.4mm rms. Furthermore, alignment adjustment mechanisms (AAM) are installed in each supporting boom to adjust unexpected beam pointing errors.

(2) Antenna feed system

Phased array feed systems are combined with the large reflectors to create multiple steerable beams for MSS and BSS experiments(3). The 31 solid state amplifiers (10W and 20W class SSPAs) followed by 31 transmit feed elements produce 300W RF power at maximum, and 31 low noise amplifiers are equipped at receiving side for low noise signal reception. Onboard beam forming network controls the amplitude and phase of the signals to/from the feed elements to make desired beam pattern.

(3) Onboard signal switching

Two sets of onboard baseband switching equipment are installed to realize onboard signal routing(4). One is an onboard processor (OBP) which is designed to perform voice channel switching among mobile users or between mobile users and ground network users. The other one is an onboard packet switch (OPS). It has a function of data packet switching among mobile data terminals. Table 2 shows their specifications. These switching equipment enables mobile satellite communications with higher quality and multi-channel capability.

(4) Satellite positioning system

Cesium atomic clock equipment on the ETS-VIII generates an extremely high accurate time signal. High accuracy orbit determination, onboard atomic clock evaluation, navigation and positioning experiments are planed to be conducted to study the basic technique of geostationary-satellite positioning system using the atomic clock(5). Furthermore, a time comparing equipment (TCE) is equipped to conduct precise time comparison between the onboard atomic clock and the ground reference clocks(6). Table 3 shows the specification of the experimental positioning system.

Table 2 Specification of onboard processors

	OBP	OPS
Modulation	35k symbol/sec π/4-QPSK	512k symbol/sec π/4-QPSK
Access method	MC-TDMA (5ch / carrier)	Slotted ALOHA
Information rate	5.6 kbps(Voice)	4k - 32 kbit/packet
Number of channels	500	128 packets /carrier (max)
Satellite EIRP/Carrier and G/T	49 dBW, 13 dB/K	52 dBW, 13 dB/K
Ground terminal EIRP and G/T	9 dBW, -24 dB/K	18 dBW, -21 dB/K

Table 3 Specification of positioning system

Frequency	L band (1595.88 +/- 7.5 MHz), S band (2491.005 +/- 7.5 MHz)
EIRP	38 dBW
Transmit signal	Spread spectrum signal with navigation message (50 bps)
PN code	1.023 Mcps, 1.705 Mcps, 3.41 Mcps, 5.115 Mcps
Objective accuracy	less than 100m (Orbit determination) less than 10nsec (Clock synchronization without TCE) less than 10ps (Clock synchronization with TCE)

2.2 Bus System

The ETS-Ⅷ bus is applying the following new technologies to build a prototype satellite bus for future large advanced satellite systems[7].

(1) Bus structure

The ETS-Ⅷ employs light-weight structure, seeking to realize about 40% payload weight ratio (conventionally 30%) as an indicator of satellite bus technology. At the same time, the ETS-Ⅷ makes its structure modular for shortening the development schedule and allowing concurrent work to the integration. An antenna tower is mounted on the earth panel to implement the antenna feed systems, earth and sun sensor assemblies, and so on.

(2) Power supply

Two wing solar paddles (18.7m x 2.5m for one wing size) on which high-efficiency silicon cells are mounted on the panels supply the electric power of 7.5 kW. Satellite bus voltage is designed as 100V to reduce power line loss.

(3) Thermal control

Utilization of heat pipes connecting between north and south panels of the bus expands effective radiation surface against high heat flux generated from the increased capacity of electrical power. Furthermore, an experimental deployable heat radiator is planned to be tested in-orbit for future advanced thermal control system.

(4) TT&C

The TT&C system transmits, receives, and relays telemetry, command and ranging signals, using unified S band, and processes satellite data. Data transmission is done by packets in accordance with the advice from the Consultative Committee for Space Data System(CCSDS). The main data bus interface is based on MIL-STD-1553B, a world standard. Remote interface modules(RIM) is also available for heritage components.

(5) Attitude and orbit control

The ETS-Ⅷ is subject to more various disturbances than existing NASDA satellites because of large-scale flexible structures, i.e., large deployable antennas and solar paddles. The attitude and orbit control system (AOCS) employs a combined logic of gain and phase controls formulated to keep these large-scale flexible structures free from any troublesome fluctuations. As a result, attitude control accuracy is kept to be less than $\pm 0.05°$ in roll, $\pm 0.05°$ in pitch, and $\pm 0.15°$ in yaw.

N-S and E-W station keeping are performed by 22mN ion engines and 22N thrusters, respectively. The attitude during N-S station keeping is stabilized by reaction wheels since disturbance torque caused by ion engine firing is small. The attitude during E-W station keeping is stabilized by three axis-attitude control thrusters because large disturbance torque is generated by station keeping thruster firing.

The spacecraft computer (SC) has autonomous fault tolerant logic, fault detection, isolation and reconfiguration (FDIR) function, and rewriting capability of attitude control software so as to control the attitude flexibly.

3. Development Schedule

We have completed the preliminary design review (PDR) and started critical design phase at this moment. The critical design phase is scheduled to complete at the end of 2000, and a proto-flight model is build up until the end of 2002. Fig. 3 shows a development schedule.

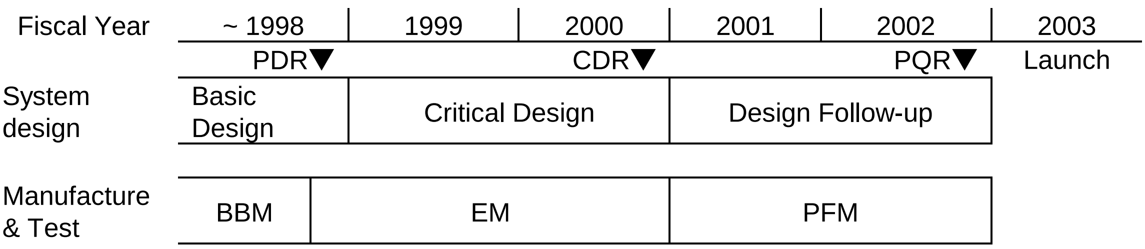

Fig. 3. Development schedule of ETS-Ⅷ

4. Conclusions

We described the outline of the ETS-Ⅷ system. The ETS-Ⅷ is the first three ton class satellite in Japan, and various new technologies are applied for future advanced satellite bus, mobile satellite communications, sound broadcasting, and satellite positioning systems. We expect that these new technologies will contribute to develop new satellite applications in the early 21-st century.

Acknowledgment

The authors would like to thank Shinichi Hama of the Communications Research Laboratory, Shigetoshi Yoshimoto of Advanced Space Communications Research Laboratory, and many people involved in this project.

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