2 Overview of the Engineering Test Satellite VIII (ETS-VIII) Project

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The Engineering Test Satellite VIII (ETS-VIII) project started from a conceptual design for a mobile satellite communications and broadcasting system produced by the Ministry of Post and Telecommunications in 1992. The aim of this project is to develop fundamental technologies for mobile satellite handheld phone services and digital sound broadcasting services using the S-band frequency. To develop the required technology in Japan, the Japan Aerospace Exploration Agency (JAXA), the Communications Research Laboratory (CRL), and other organizations have collaborated to develop a large satellite bus, large scale deployable reflectors, a phased array antenna feed system, onboard signal switching equipment for voice and data communications, a high-accuracy positioning system, and so on. The development of the onboard components is almost complete and a ground test of the satellite system is being conducted at JAXA's Tukuba Space Center in preparation for launching the satellite in 2004. This report presents an overview of the history of the ETS-VIII project, the organizational structure, and the in-orbit experiments.

Keywords

Engineering Test Satellite VIII, AMobile satellite communication, Mobile satellite broadcasting, Development of fundamental technology, S-band frequency

1 Introduction

The development of the current Engineering Test Satellite VIII (ETS-VIII) is one part of a Japanese satellite development project designed to develop the fundamental technologies for next-generation mobile satellite communications and satellite positioning systems. Specifically, the goals of this project are to develop the following new technologies, in-orbit tests, and experiments [1]-[3].

- Bus technology for a three-ton-class large geostationary satellite bus
- Large-scale satellite-borne deployable reflector
- Mobile satellite communications using small ground stations such as handheld terminals
- Fundamental technologies for satellite positioning systems

Bus technology for a three-ton-class large satellite will prove essential in any next-generation communications system designed to meet increasing demands for higher-capacity communication. This technology is also expected to serve a range of further applica-

1 Formed in January, 2001, through the consolidation of the former Ministry of Posts and Telecommunications, the former Management and Coordination Agency, and the former Ministry of Home Affairs. The Ministry of Public Management, Home Affairs, Posts and Telecommunications referred to in this paper is equivalent to the former Ministry of Posts and Telecommunications.

2 Formed in January, 2001, from the former Ministry of Education, the former Science and Technology Agency, and other bodies. The Ministry of Education, Culture, Sports, Science and Technology referred to in this paper is equivalent to the former Science and Technology Agency.

3 Organization formed in October, 2003, from the former National Space Development Agency of Japan, the former Institute of Space and Astronautical Science, and the former National Aerospace Laboratory of Japan. JAXA, as referred to in this paper, is equivalent to the former National Space Development Agency of Japan.

4 R&D Corporation funded by the Japan Key Technology Center and private companies. Completed its mission in March, 2001.

tions in the establishment of an overall space infrastructure. At the same time, the large-scale onboard deployable reflector will prove essential in establishing a satellite-based small-terminal mobile phone system. The technology used to develop this antenna will in turn be applicable to future large orbital structures, such as a geostationary platform.

Currently a great deal of attention has been focused on new forms of next-generation mobile satellite communications. If we are to realize these new communication services, we must first develop multi-beam onboard antennas and design a communications switch for onboard satellite deployment. Efforts such as these to develop fundamental satellite positioning technologies will not only enhance and supplement existing systems but will also lead to the development of new, original systems. Fig.1 illustrates some of the services made possible through the technological developments associated with the ETS-VIII.

This satellite development initiative is a joint project of the Communications Research Laboratory (CRL), the Japan Aerospace Exploration Agency (JAXA)[3], the Advanced Space Communications Research Laboratory (ASC)[4], and Nippon Telegraph and Telephone Corporation (NTT), with the central support of the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT)[1] and the Ministry of Education, Culture, Sports, Science and Technology (MEXT)[2]. These groups have worked diligently to develop the satellite, onboard systems, and required ground-station facilities, aiming to launch the ETS-VIII in 2004 (using the H-IIA rocket at the JAXA Tanegashima Space Center).

After launch, project members will conduct in-orbit tests of the satellite-borne systems and basic mobile satellite communication and positioning experiments. In addition, domestic/overseas universities, research insti-

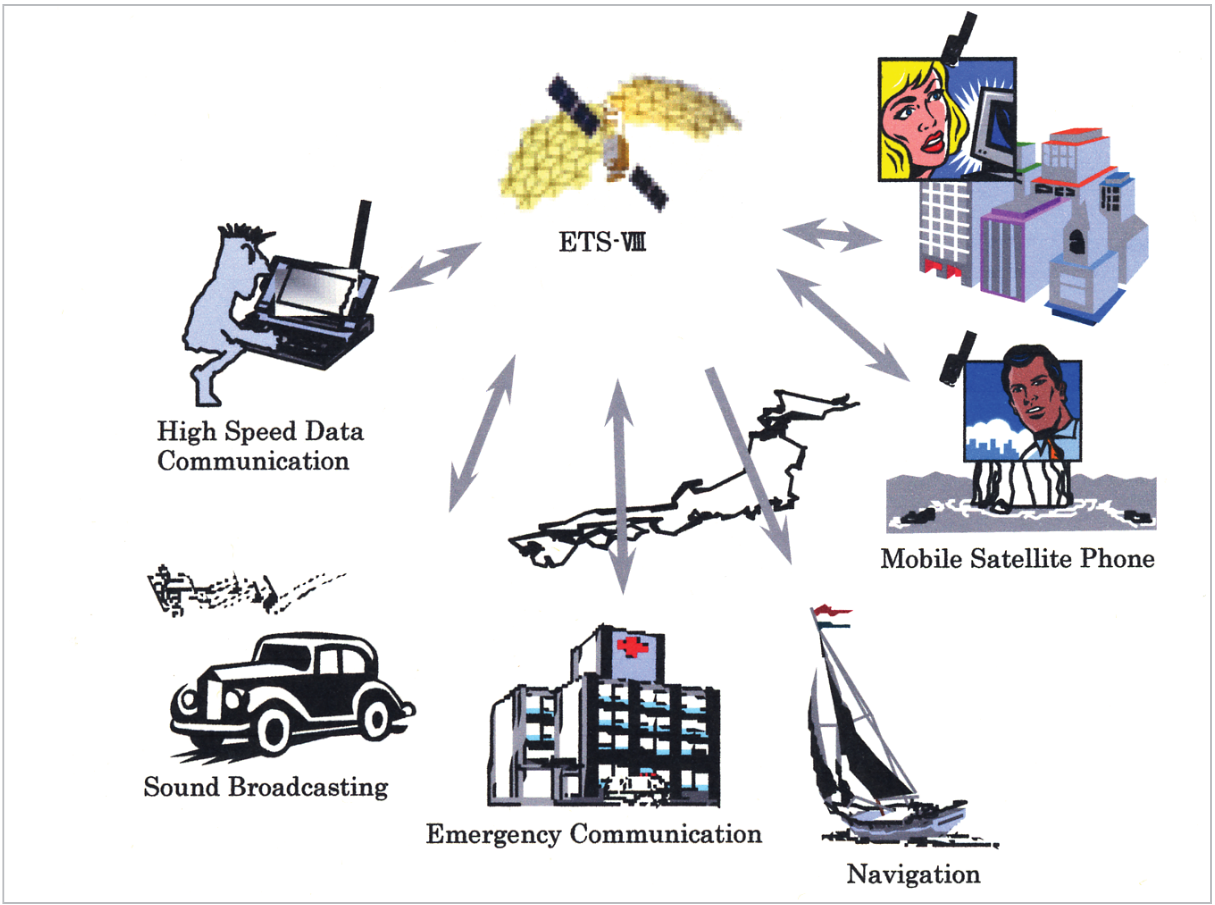


Fig.1 Services image

tutes, and enterprises plan to conduct experiments in a variety of satellite communication applications. The national institutes will thus serve as a central entity facilitating high-risk technological development and orbital field testing for a wide range of organizations. These collective efforts will, it is hoped, contribute to the space exploration activities of tomorrow's more technology-oriented Japan. This report describes the background and outlines the schedule of this new satellite project.

2 Background and organization of satellite development

With the launch of the Engineering Test Satellite V in 1987, the MPHPT, MEXT, CRL, JAXA, NTT, and others initiated a program to develop the fundamental technology for an integrated mobile satellite communication system that would span maritime, aeronautical, and land mobile communications. Encouraged by the success of this program, in 1996 the NTT group launched the N-STAR, providing Japan with its first domestic commercial mobile satellite communication service. Specifically, the N-STAR inaugurated 2.5-GHz / 2.6-GHz (S-band) commercial ship and automobile satellite telephone services for the Japanese land mass and neighboring seas.

Four years earlier (in 1992), the Ministry of Posts and Telecommunications (now the MPHPT) had begun work on the conceptual design of an R&D satellite for next-generation mobile satellite communications/broadcasting systems. At first, the goal was to develop a next-generation communications/broadcasting R&D satellite equipped with a large deployable reflector that would enable S-band frequency mobile satellite digital sound broadcasting. The goal was revised in 1993, however, to a more ambitious conceptual design: a mobile satellite communications/broadcasting system equipped with two large deployable reflectors allowing mobile satellite communications using compact ground stations as small as hand-held terminals. Work on this conceptual design indicated that development of such a system would indeed be possible, leading to the approval of the project by the 1994 Space Activity Committee. Specifically, the Committee authorized the development of mission systems through joint work between the MPHPT and the CRL, while JAXA was to pursue research on a next-generation field-testing system.

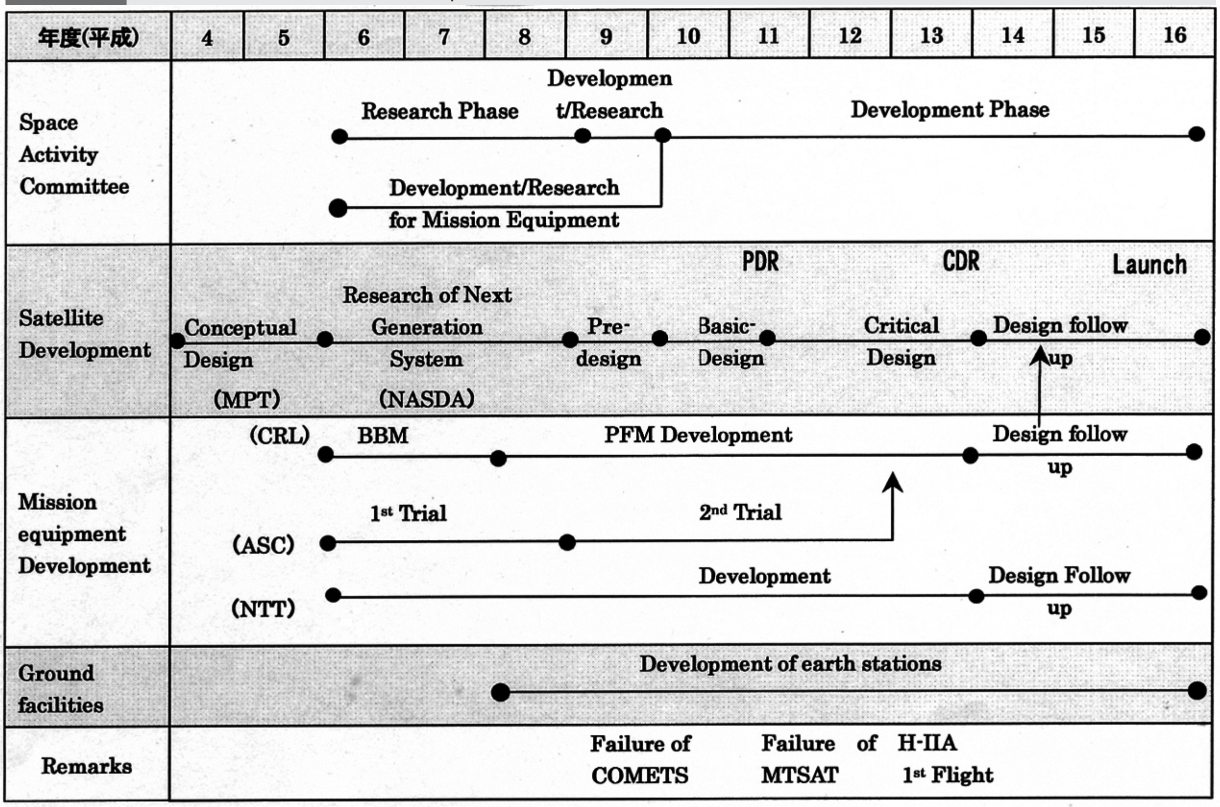
In March 1994, the Advanced Space Communications Research Laboratory (ASC), a research corporation funded in part by the Japan Key Technology Center and in part by the private sector, was established to pursue research and development of mission systems in collaboration with the CRL.

Later, a "Symposium on a Next-Generation R&D Satellite" [renamed the "Symposium on the Engineering Test Satellite VIII (ETS-VIII)"] was convened by the MPHPT, MEXT, CRL, JAXA, NTT, and the ASC. Participants in the symposium investigated issues related to a number of system elements, including the large-scale geostationary satellite bus, the large deployable reflector, and onboard mission systems.

In FY1997, the Space Activity Committee approved the framework of the ETS-VIII development program, and JAXA provided a preliminary design for the satellite. JAXA and the CRL then proposed a high-precision time standard and time-comparison system as elements of the overall onboard system, with the newly stated goal of establishing the fundamental technology for future satellite positioning in addition to the R&D for mobile satellite communication systems. In FY1998, the entire satellite development project was officially approved and full-scale development of the satellite began. In April 1999, the satellite system was subject to a preliminary design review (PDR), followed in November 2001 by a critical design review (CDR), after which the project entered the current stage of design followup. Fig.2 shows the development organization, and Table 1 shows the development schedule.

In the initial stages of conceptual design, the ETS-VIII was to be launched in 2000 or

Table 1 *Schedule of ETS-VIII development*



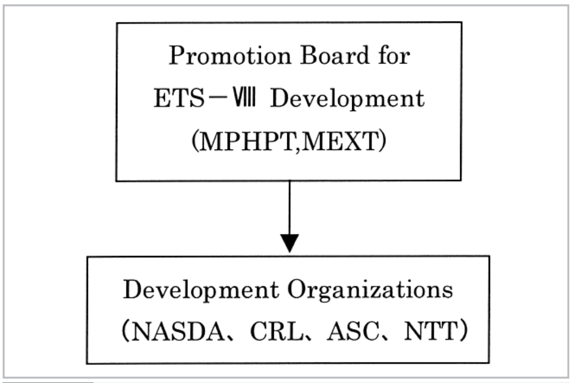


Fig.2 *Organization structure for satellite development*

2001. This was postponed to 2002 when the Space Activity Committee approved the R&D project. This date has been further postponed to 2004 due to the unsuccessful launch of the Communications and Broadcasting Engineering Test Satellite (COMETS) into geostationary orbit in 1998 and to delays in development of the H-IIA rocket, delays attributable to the failed launch of the multifunctional transport satellite (MTSAT) in 1999.

The ETS-VIII is scheduled to be launched by the H-IIA into geostationary orbit at 146 degrees east longitude. The original ETS-VIII program included a digital sound broadcasting experiment utilizing the through repeater mode. However, acquisition of the appropriate license to operate a wireless station has proven problematic due the likely review of the use of the 2,535 to 2,540-MHz satellite sound broadcasting band promoted by the MPHPT. Additionally, securing of a license has been slowed by the incompatibility between the proposed spread-spectrum technology standard and the OFDM method to be employed by the ETS-VIII (in conformity with standards established by the EU). To address these issues, separate experiments are scheduled to assess OFDM multicasting in the communication band.

3 Development themes and responsibility

The success of the ETS-VIII will depend on the development of a number of important elements: a large geostationary satellite bus, a large deployable reflector system (including a feeder unit), mobile communications mission systems, and a high-precision time standard system. Development of the foregoing may be outlined as follows.

(1) Large geostationary satellite bus

The technology behind the three-ton-class large geostationary satellite bus is an essential element in the infrastructure of an expanding range of space communications/broadcasting systems. This next-generation satellite bus technology includes modularization of the satellite body to facilitate satellite integration, autonomous control via onboard computer, development of a 7-kW high-power generation and 100-V bus power supply, and installation of an ion engine that will provide north-south orbital control throughout its long service life.

(2) Large deployable reflector system

The large deployable reflector system consists of an onboard high-gain antenna that will be essential to any mobile satellite communications/broadcasting system using compact ground stations such as mobile terminals. Development in this area is primarily focused on an S-band frequency large deployable reflector (with an electric aperture of 13 m) that consists of 14 mesh reflector modules and a phased array feeder designed to generate multiple beams; this feeder will incorporate a group of solid-state amplifiers which synthesize and produce 400-W (max.) high-output power in space, a beam-forming network (BFN) allowing emission of various types of beams in any direction over Japan and the vicinity, and a lightweight feed element offering reduced cross-coupling between elements.

(3) Communication mission systems

A multi-beam satellite communications system requires an onboard switch to reduce delay in the satellite propagation path by connecting any given two beams with a single hop. In regenerative repeating, such a switch is also used to increase channel margin by separating uplink noise from downlink noise. Thus our goal in the ETS-VIII project is to develop a 1,000-channel onboard switch for satellite voice communications and a high-data-rate onboard packet switch for mobile terminals. In addition, we will develop an S-band converter equipment that can be configured flexibly to work as an experimental transponder and a Ka-band feeder link unit with low phase noise performance.

(4) High-precision time standard/comparison equipment

The ETS-VIII will feature a high-precision time standard system (with an atomic clock and a signal generator transmitting a GPS-compatible signal) and a high-precision time comparison system, the first such systems to be deployed in Japan. These systems will permit in-orbit operation of the atomic clock, high-precision orbital determination, and precise ground-satellite time comparison, and the technologies behind these operations will together form the foundation of future Japanese satellite positioning systems.

(5) Upgrading ground stations

We plan to upgrade the Ka-band feeder link station (base station), develop the S-band reference station, create ground terminals compatible with the onboard switch, design vehicle-borne and other mobile stations, and establish a range of additional ground-station facilities for both experimental and practical use.

In order to ensure that these systems are developed efficiently, the ETS-VIII Liaison Committee has appointed a responsible organization from either the CRL, JAXA, ASC, or NTT for each mission. Table 2 shows the major development themes and its responsible organization.

In August 1999, JAXA, the CRL, the ASC, and NTT entered into the “Agreement on the Development, Launch, and Operation of Mobile Communications/Broadcasting Experimental Instruments and High-Precision Time Experimental Instruments for the Engineering Test Satellite VIII,” in order to facilitate cooperation among these groups. Additionally, “Interface Coordination Meetings” have been held at regular intervals to deal with various issues related to the exchange of ideas among the relevant institutes, propose solutions to

Table 2 *Development themes for ETS-VIII*

Items	Main Themes	Organization
Large scale geo-stationary satellite bus		
• 3 ton class satellite bus and total integration	· Module structure、Autonomous satellite control、7 kW class solar power generation、100V power supply bus、Long life Ion engine, etc.	NASDA
Large scale deployable antenna system		
• Reflector	· 14 module, 13m in diameter	NASDA
• Phased array feed system	· Phased array control system design	ASC
• Feed Element	· Light weight, low cross coupling element	CRL、ASC
• High power amp.	· 400W combined in space by SSPA	ASC
• Beam forming network	· Steerable beam, Multi beam, high isolation for frequency reuse	CRL、NTT
Communication and broadcasting mission equipment		
• Feeder-link equipment	· Low noise amp. in Ka-band, low phase noise, Common oscillator for up- and down-link	NASDA
• Onboard signal Processing equipment	· Onboard signal exchange for 1000ch class voice communications	ASC
• Onboard packet switching equipment	· High speed data communication for mobile users	CRL
• S-band Frequency Converter	· switching for various routing configuration	ASC
High accuracy time reference and compare equipment		
• High accuracy time reference equipment	·Operation technique of atomic clock, High accuracy orbit determination	NASDA
• High accuracy time comparison equipment	· Time comparison between ground and satellite clock	CRL
Ground facilities		
• Ka-band Feeder-link earth station	· Base station for experiments, Frequency compensation technique in Ka-band	CRL
• S-band reference earth station for mobile communication experiments	· Reference station for mobile communication experiments	CRL
• Portable earth stations	·Antennas for mobile & portable stations, small size portable earth stations, mobile stations, communication terminals	CRL、NASDA
• Telemetry and Command facilities	·Telemetry and Command facility for CCSDS、User friendly Telemetry and command system for mission equipment	NASDA、CRL
• Ground facility for time reference experiments	· High accuracy orbit determination, operation of onboard atomic clock	NASDA
• Ground facility for time comparison experiments	· High accuracy time comparison experiments	CRL

technological problems, and establish interface conditions for the devices in question.

After the ASC closed its R&D mission in February 2001, the CRL assumed responsibility for the systems the former group had developed, with some revisions of its own to selected systems. In November 2002, all of the systems developed by the CRL, the ASC, and NTT were handed over to JAXA for installation in the satellite and the ground test before launch.

4 Schedule for experiments

The goals of ETS-VIII experimentation are roughly classified as follows.

(1) Evaluation of in-orbit performance of large geostationary satellite bus and onboard systems

We will create projections of the in-orbit performance of the developed systems to examine design validity, potential problems, and operability of practical future systems. In so doing we must evaluate satellite performance at appropriate intervals over a long period of time, from initial checkout immediately after launch through the end of the satellite's service life. Verification items will include the basic properties of the satellite bus (e.g., changes over time in generated power, performance of orbital and attitude maintenance, and onboard battery performance), basic performance of the large deployable reflector (including antenna pattern characteristics, accuracy of beam directivity, vibrations of the flexible structure, and thermal deformation), changes over time in the RF devices, and basic performance of the onboard switch.

(2) Basic communications experiments to establish a next-generation mobile communications technology

We will evaluate the signal quality provided by the mobile satellite communications system via the onboard switch, connectivity between multiple beams, propagation characteristics, and communications performance of ground stations and terminals under various conditions (during walking, high-speed movement, interference, etc.). Through such experimentation, we will establish a fundamental technology for next-generation mobile satellite communications technology, examine its usefulness, and identify problems to be solved prior to commercialization.

(3) Experiments to establish the fundamental technology of a future positioning system

Japan has never before installed an atomic clock aboard a satellite. We are therefore working to develop the basic operational techniques for such an atomic clock and to establish application technologies for high-precision orbital determination and time comparison. These efforts will, we believe, contribute to the realization of a future satellite-based positioning system.

(4) Demonstrations and application experiments

Through demonstrations of basic mobile satellite communications using the onboard switch and multiple beams, we will promote the usefulness of the next-generation mobile satellite communications system, as we investigate and promote a variety of mobile communication applications through application experiments in cooperation with universities, research institutes, and private enterprises.

Fig.3 illustrates the organizational structure behind this orbital testing. The Promotion Board for Satellite Application Experiments is hosted by the Space Communications Policy Division of the MPHPT, and its members are drawn from universities, research institutes, and various industry organizations. It organizes the basic and application experiments, and evaluations of the ETS-VIII and of an ultra-high speed Internet satellite, among others. Basic experiments to be conducted by the satellite development organizations, and application experiments performed by the Application Experiment Council participated in by universities, research institutes, and private enterprises will first be subject to approval by the Promotion Board. In addition, the Board will hold a liaison meeting to allow the various groups to schedule basic and application experiments.

In experiments using the ETS-VIII, the satellite development organizations—the CRL, JAXA, and NTT—will carry out basic experiments (1) to (3), while members of external organizations forming the Application Experiment Council will carry out the application experiments described in (4). Twenty-two such application experiments were pro-

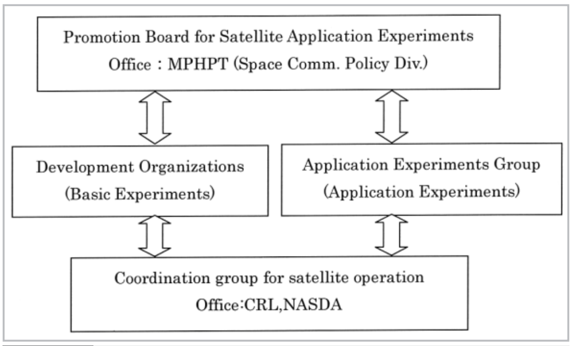


Fig.3 *Organization structure for promoting experiments*

posed from October to December, 2002 by domestic and overseas universities, research institutes, and private enterprises in response to a call for public participation by the Promotion Board for Satellite Application Experiments.

5 Conclusions

As described earlier, the development of ETS-VIII took place over six years, from the 1992 conceptual design through approval by the Space Activity Committee, and already five years have passed since the initiation of full-scale development. Although this satellite project represented a cutting-edge undertaking when first planned, subsequently a number of foreign countries have commercialized satellite-based cell-phone systems, some involving LEO satellites (beginning in the U.S. with the Iridium in 1998 and the Globalstar in 2000) and some employing a geostationary satellite and a large deployable reflector (Garuda of Indonesia in 2000, Thuraya of the United Arab Emirates in 2001). Additionally, due to the delay in rocket development due to the failures of the H-IIA, some ETS-VIII technologies can no longer be viewed as innovative.

Nevertheless, a number of innovative elements remain unique to the current project: the large deployable reflector of module structure designed for next-generation mobile satellite communications, multi-beam technology capable of directing two or more beams to different directions simultaneously, an onboard switch for voice communications based on regenerative repeating, a packet switch for high-speed data communications, and a high-precision time comparison system enabling novel applications of the onboard atomic clock. Moreover, establishment of a three-ton-class large geostationary satellite bus and the development of techniques for in-orbit operations of the atomic clock are expected to play an important role in the creation of an infrastructure for future satellite communications, broadcasting applications, and positioning systems. Further, a variety of additional technologies have emerged through the development of the ETS-VIII, including those relating to ground station facilities (such as mobile stations and terminals) and to a number of onboard systems. These technologies are expected to contribute greatly to future satellite development in the industrial sector.

Development of the ETS-VIII is now approaching the final stages in preparation for the 2004 launch, with subsequent in-orbit experimentation after launch expected to produce significant results. It is clear that the progress made thus far is the result of tremendous efforts on the part of those involved in the project from the start—in industry, academia, and in the government—to tackle the challenges posed by this ambitious undertaking.

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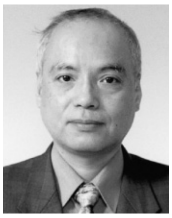

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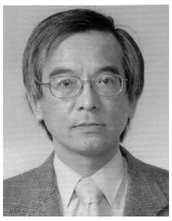

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Frequency Standard, especially on Precise Time Transfer