3 Development of Satellite System

3-1 Overview of WINDS Satellite

SATO Tetsuo, NAKAMURA Yasuo, and ARAKI Tsunehiko

The Wideband InterNetworking engineering test and Demonstration Satellite (WINDS) aims at developing and verifying the key technologies for future ultra high speed satellite communications such as: (1) Ka-band multi-beam antenna with high power multi-port amplifier; (2) Ka-band active phased array antenna; and (3) an on-board Asynchronous Transfer Mode switch. It also aims to create and demonstrate new utilizations for satellite communications through various experiments. The development of WINDS has been conducted by JAXA and NICT and WINDS is scheduled to be launched by H-ⅡA launch vehicle in 2007 (fiscal year).

Keywords
Wideband InterNetworking engineering test and Demonstration Satellite (WINDS), Multi-Beam Antenna (MBA), Multi-Port Amplifier (MPA), ATM Baseband Switch subsystem (ABS), Active Phased Array Antenna (APAA)

1 Introduction

The Wideband InterNetworking engineering test and Demonstration Satellite (WINDS) is a research and development satellite for developing and demonstrating leading technologies as listed below. Its aims are to take advantage of wide area, broadcasting, and disaster-resistant characteristics of geostationary satellite communications and to contribute to the establishment of an advanced information and communications network society that will eliminate regional disparities based on complementary utilization with ground communications networks.

(1) Development and demonstration of ultra-high-speed fixed satellite communications technology
- Technologies required for implementing ultra-high-speed communications
– 1.5 Mbps transmission and 155 Mbps reception with a 0.45 m diameter antenna intended for homes
– 1.2 Gbps transmission and reception with a 5 m diameter antenna intended for enterprises
- Technologies required for increasing communications coverage
– Ultra-high-speed communications in wide areas in the Asia/Pacific region
- Construction of communications network systems required to cultivate application fields

(2) Verification of ultra-high-speed fixed satellite communications network functions
- Verification of ultra-high-speed communications network and promotion of application experiments

The technologies related to ultra-high-speed communications and wide area coverage, which WINDS will develop and demonstrate, are expected to be the foundations for future ultra-high-speed satellite communications technologies. Figure 1 illustrates the relevant technological positioning of the missions. Taking advantage of these features, application experiments are planned including backup of the backbone network in the event of disasters and other occasions, implementation of a wideband Internet via small earth stations (and the corresponding elimination of the digital divide on isolated islands and in mountainous areas), prompt securing of a wideband communication network for afflicted areas in natural disasters, and multipoint connection for interactive distance education and multipoint simultaneous content delivery.

Figure 2 shows the configuration of the communications network system provided for the application experiments. The WINDS satellite system is being developed as part of an integrated system together with other component systems that constitute the communications network system: i.e., a combined earth experimental system and tracking and control system. JAXA and NICT are jointly developing the communications network system. Table 1 shows the development tasks assigned to each organization.

2 Satellite system

Table 2 shows the major specifications of WINDS. Figure 3 is a schematic diagram of the satellite in orbit, and Fig. 4 shows the sys-

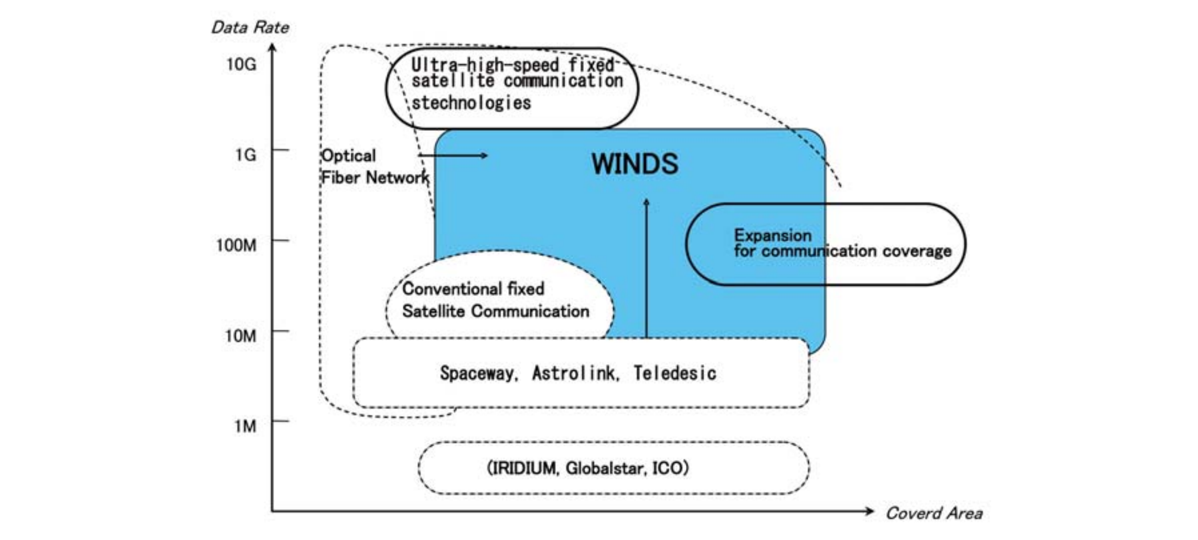

Fig.1 *Positioning of WINDS missions*

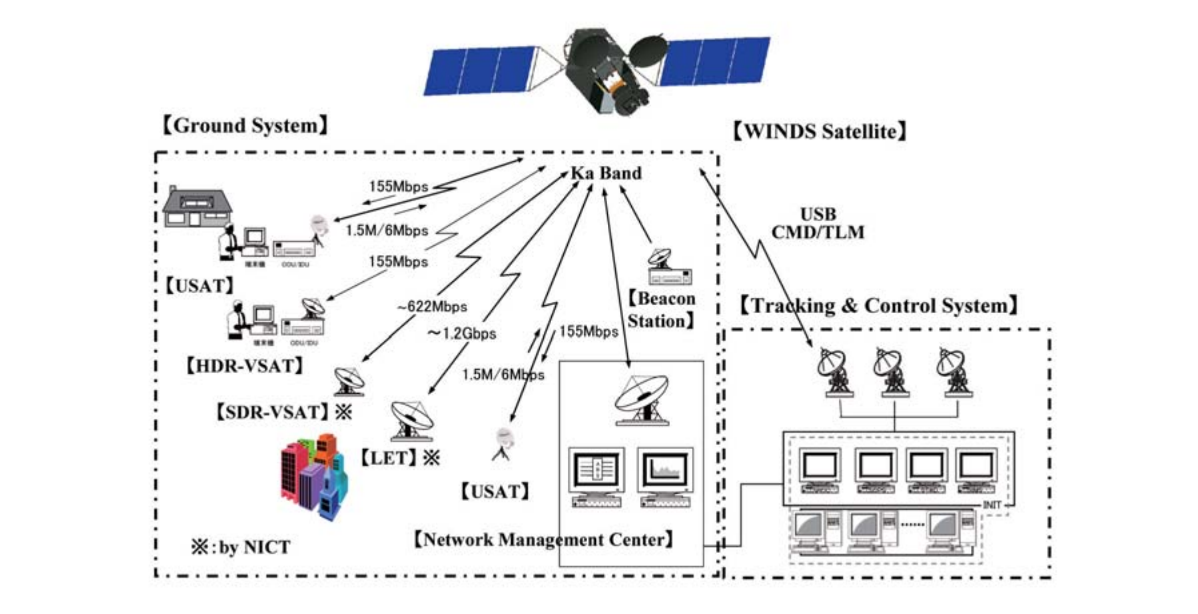

Fig.2 *WINDS communications network system*

Table 1 *Assignment of development tasks for WINDS communications network experimental system*

Development task	JAXA	NICT
WINDS communication network system	①System integration ②Development of communication protocol	①Support of system integration ②Support of communication protocol development
Satellite system	①System integration ②Development of bus subsystem ③Development of Mission system ・MBA/MPA ・APAA ・IFS ・NITR	①Development of Mission subsystem ・ABS
Ground System	①Development of mission management center, Beacon station, High Data Rate (HDR)-VSAT, USAT	①Development of LET(Large Earth Terminal), Super High Data Rate(SDR) - VSAT
Tracking & control system	①Development of Tracking & control system	N/A
Launch/Operation	①Launch operation ②Satellite operation ③Initial operation	①Support of initial operation

tem configuration. When developing WINDS, we considered the severe restrictions on the development period and minimized development risks by reducing the development of new technology to the requisite minimum for accomplishing the mission. The equipment newly developed for WINDS are as follows.

- Ka-band high-power multi-beam antenna (MBA)/multi-port amplifier (MPA)
  – Ka-band high-power antenna technology with regional rain-attenuation compensation function
- Ka-band Active Phased Array Antenna (APAA)
  – Electronic beam-steering technology that enables wide coverage and flexible radiation to an arbitrary location
- ATM baseband switch (Asynchronous Transfer Mode baseband switch: ABS)
  – ON-board high-speed line connection technology

Figure 5 shows the placement of the

Table 2 *Major specifications of WINDS*

Launch Schedule	JFY 2007 (Feb, 2008)
Mission Life	5 years
Location	143 deg E
Dimensions	3 m × 2 m × 8 m Paddle Width: 21.6 m
Mass	4,850 kg (Lift off)
Electric Power	> 5,200W (EOL, Summer Solstice)
Consumption Power	8,000W (EOL, Summer Solstice, AJT) *supplied by PDL + BAT* 4,000W (Eclipse)
Attitude Control	Zero-Momentum 3-Axis control ±0.05deg(R/P)、±0.15deg(Y)

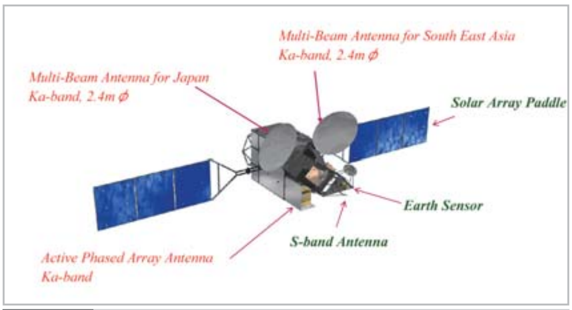

Fig.3 *External appearance of WINDS in orbit*

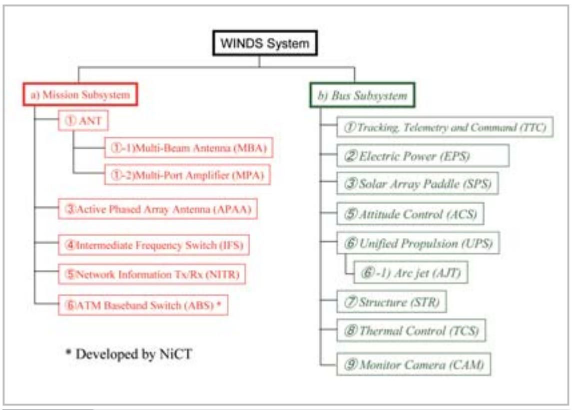

Fig.4 *System configuration of WINDS*

WINDS onboard equipment with respect to these newly developed equipment. WINDS has the mission and the bus equipment in separate structure modules (i.e., places equipment with the same function or equipment for the same system in the same region) to improve efficiency in the satellite assembly and system tests.

We have now completed assembly of the WINDS flight model and began ground tests for the satellite system at the Tsukuba Space Center in January 2007. This testing is scheduled for completion in around October 2007. As an example of the test configuration for the flight model, Fig. 6 indicates the setup conditions for the system RF emission test. Figure 7 shows the WINDS development schedule.

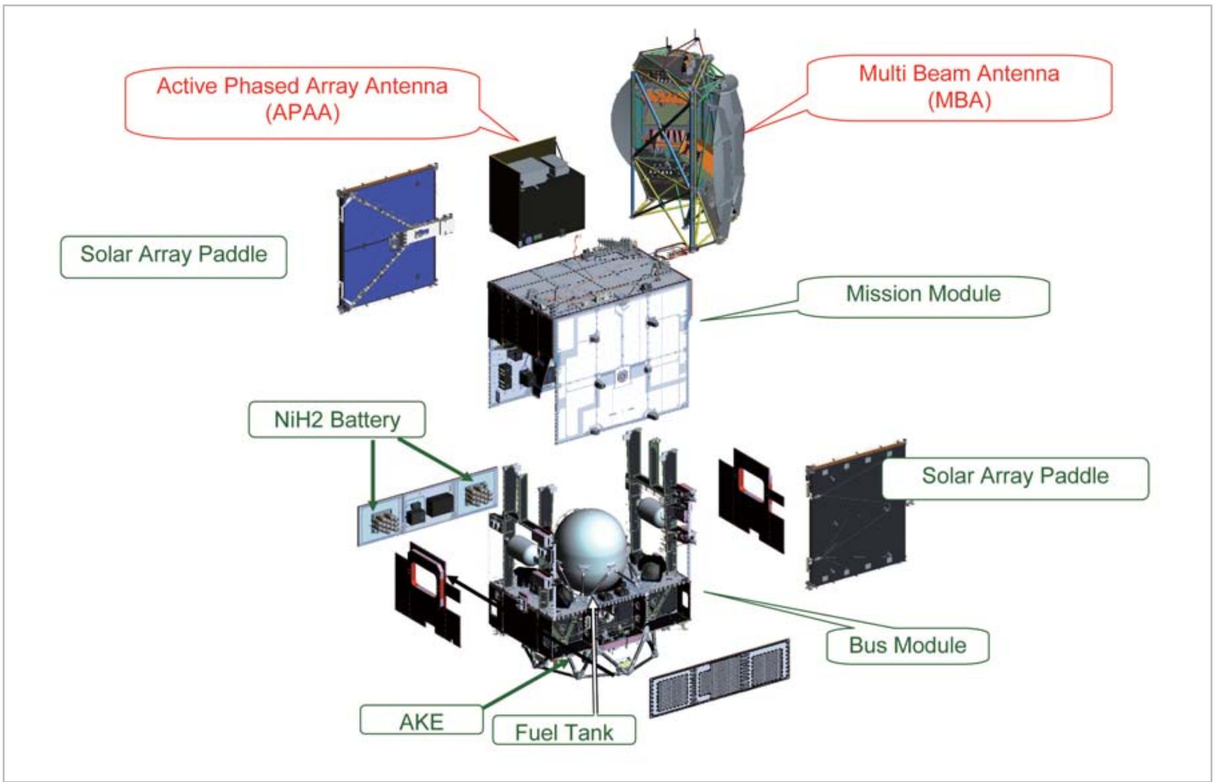

Fig.5 *Structure of WINDS*

Fig.6 *RF emission test setup*

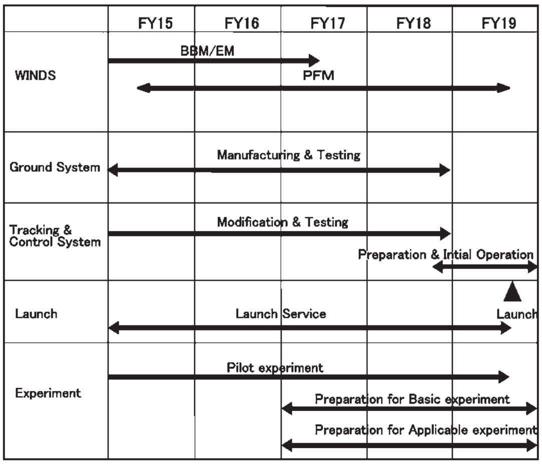

Fig.7 *WINDS development schedule*

3 Bus system

The WINDS bus system is based on JAXA's continual design technologies. Its features include a Telemetry Tracking and Command subsystem adopting the 1553 B data-bus communication method in compliance with USB/CCSDS, an Electrical Power Subsystem based on the 50 V stabilized single-bus method, and a high-power Solar Array Paddle Subsystem. Figure 8 is a functional diagram of the WINDS bus system.

3.1 Telemetry Tracking and Command subsystem (TTC)

The Telemetry Tracking and Command subsystem (TTC) consists of the RF unit, which provides RF functionality from the S-band antenna to the S-band transmitter and receiver, and the DH unit, which performs data handling in the baseband. The TTC uses the packet-based interface method in compliance with the CCSDS guideline and the integrated satellite data-bus method. The major functions of the TTC system are as follows.

- Command signal reception and distribution control function
- Telemetry collection and editing function
- Light load mode function
- Satellite time control and delivery function
- Ranging signal relay function
- Battery control function

The RF and DH units use equipment with development records in DRTS, ALOS, SELENE, or other satellites. Specifically in WINDS, some of the battery control functions (such as undervoltage control and overheating control) among the software functions of the DH unit were newly added.

3.2 Electrical Power Subsystem (EPS)

The Electrical Power Subsystem (EPS) uses the 50 V stabilized single-bus method. The EPS converts power to the 50 V stabilized power source from the Solar Array Paddle in the sunshine and from the battery in shade and supplies this power to the onboard equipment. Here, during north-south station keeping, which uses a DC arc-jet thruster, the Solar Array Paddle alone cannot supply the power required, so battery power is used to cover the shortfall. WINDS is equipped with two sets of nickel hydrogen batteries (97AH). The major functions of the EPS are as follows.

- Power supply function
- Power storage function
- Explosive ignition power control function

In the design phase, a single failure point

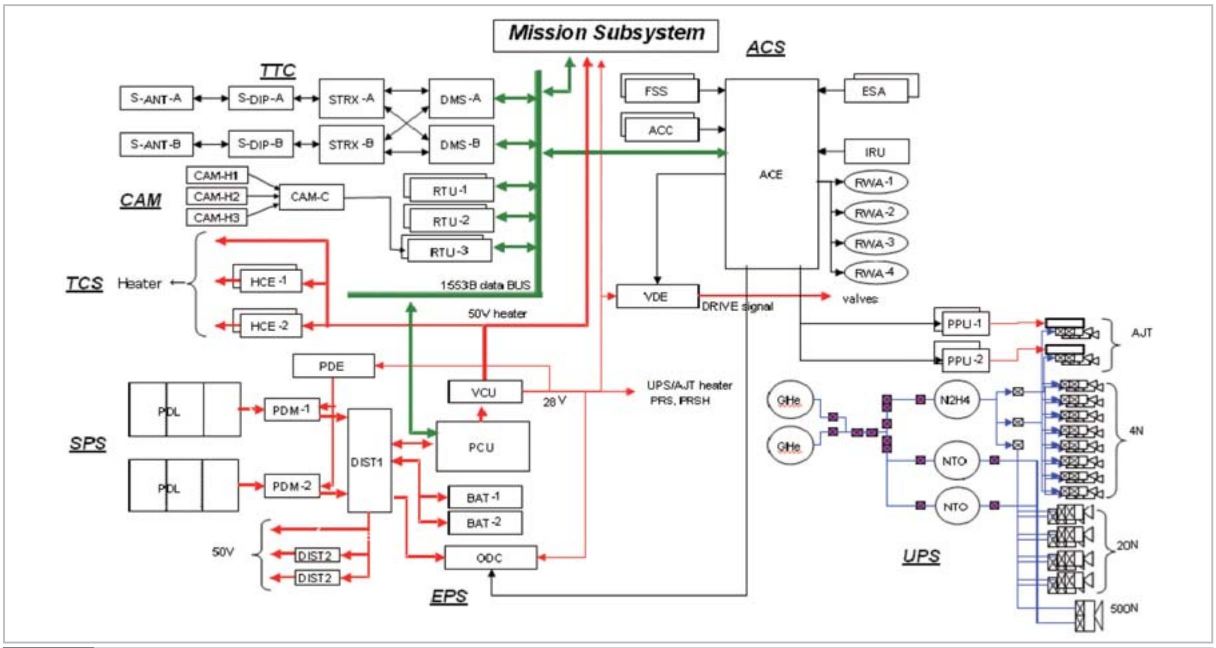

Fig.8 Functional diagram of the WINDS bus system

on the power bus line was evaluated for not only the electrical, but thermal, structural, and packaging aspects to avoiding a catastrophic failure of the power supply system by short-circuiting, improving reliability as a result.

3.3 Solar array Paddle Subsystem (SPS)

The Solar Array Paddle Subsystem (SPS) converts solar energy to electrical energy and supplies power to the satellite. The SPS has a rigid Solar Array Paddle that can generate 5.2 kW or more (up to the EOL summer solstice) with two wings. Figure 9 shows the external appearance (photograph) of the Solar Array Paddle. The major functions of the SPS system are as follows.

- Power generation and supply
- Holding and releasing of Solar Array Paddle
- Solar Array Paddle drive function

The Solar Array Paddle, the main component of the SPS, is a high-power Solar Array Paddle that uses highly efficient triple-junction solar cells produced in Japan [Power conversion efficiency: 27 % (nominal)]. The dimensions of a single wing are 9.8 m × 2.3 m. Adopting the triple-junction cells has successfully reduced overall weight. In the development of the Solar Array Paddle, the thermal structural characteristics in the combination of the new triple-junction cells and the solar cell panels were evaluated and reflected in the design.

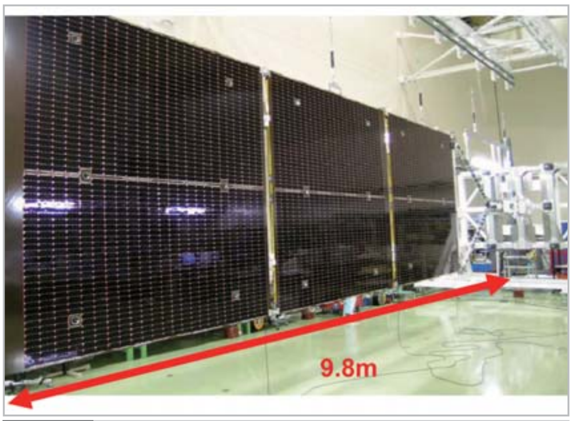

Fig.9 *Solar Array Paddle for Proto Flight Model (PFM)*

3.4 Attitude Control Subsystem (ACS)

The Attitude Control Subsystem (ACS) consists of a Reaction Wheel Assembly (RWA), an Earth Sensor Assembly (ESA), a Fine Sun Sensor (FSS), an Inertial Reference Unit (IRU), Attitude Control Electronics (ACE), and Attitude Control Flight Software (ACFS). The main functions of the ACS system are as follows:

- Initial acquisition function
  - After the satellite is released, the following procedures automatically take place as the initial acquisition sequence: automatic construction of the ACS components, paddle deployment signal transmission, and solar acquisition
- Attitude control in transfer orbit
  - Sun-oriented cruising control is performed
- Attitude control in Apogee Engine Firing (AEF)
  - As part of the AEF sequence, AEF three-axis stabilized attitude control, gyro drift calibration, AEF attitude setting, ullage settling, and AEF control (three-axis control) are performed
- Attitude and trajectory control in drift/geostationary orbits
  - The following stationary controls are implemented: wheel control, unloading, east-west station keeping maneuver (4 N thruster control), and north-south station keeping maneuver (specifically, arc-jet thruster control)
- Paddle drive control
- Propulsion Subsystem component control (valve opening and closing)

The ACE is based on the design of the OICETS/ISAS scientific satellite (two 16 bit MPUs with standby redundancy configuration) and was adopted in consideration of mass, power consumption, and development schedule. Based on the results of stationary disturbance analysis, WINDS uses an 18 Nms class RWA (four skew configuration).

3.5 Unified Propulsion Subsystem (UPS)

The Unified Propulsion Subsystem (UPS) is a dual-mode system; pressure-regulated and blowdown. The UPS consists of a bipropellant Apogee Kick Engine (AKE) that uses nitrogen tetraoxide (NTO) as the oxidant and hydrazine (N_2H_4) as fuel, and a monopropellant thruster that uses N_2H_4 as the propellant (20 N thruster, 4 N thruster, and DC arc-jet thruster). Figure 10 shows the results of the UPS system firing tests (EM). The major functions of the UPS system are as follows.

- Generation of thrust force for geostationary orbit injection
  - Ullage settling
  - Generation of thrust force for drift orbit injection
  - Three-axis attitude control in AEF
- Generation of control torque and thrust force in geostationary orbit
  - Generation of control torque in geostationary orbit
  - Generation of thrust force for east-west station keeping maneuver
  - Generation of thrust force for north-south station keeping maneuver
  - Wheel unloading
  - Generation of thrust force for deorbiting
- Propellant depletion detection function
  - Detection of propellant depletion in the final stages of AEF
- Propellant ejection function
  - Oxidant ejection function (oxidant ejection after AEF is completed)
  - Fuel ejection function (hydrazine ejection when the antenna operation is stopped)

For the thruster for north-south station keeping maneuver, a DC arc-jet thruster was adopted with a past record in DRTS because part of the equipment constituting the ion engine is no longer available. As a result, the mass of the satellite system increased, but the mass distribution was modified and the balance of the entire system was maintained.

3.6 Structural System (STR)

The Structural System (STR) is based on the panel-support method, with a past record in the COMETS, SELENE, and other satellites. The UPS consists of two structural modules (the mission section and the bus section) and fasteners that connect the two modules. Using a module satellite structure, we improved operability in satellite assembly and system tests. Figure 11 shows the external appearance of the STR. The major functions of the STR are as follows.

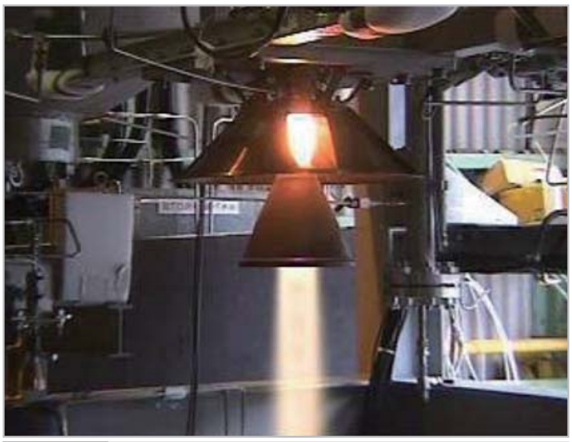

Fig.10 AKE firing test (EM)

- STR supports or stores all other subsystem equipment including MBA, APAA, Solar Array Paddle, and Unified Propulsion Subsystem
- Throughout the mission period on the ground, at launch, and in orbit, STR maintains the conditions for the onboard equipment within the specified range under the environments imposed on the satellite

3.7 Thermal Control Subsystem (TCS)

The Thermal Control Subsystem (TCS) consists of passive thermal control by OSR (Optical Solar Reflector) and MLI (Multilayer Insulator) and active thermal control by heaters and heat pipes. The system has the following functions.

- TCS provides thermal control to maintain the temperature of the satellite and onboard equipment (expect APAA, MBA, and the Solar Array Paddle, which have independent built-in thermal control functions) within the allowed temperature range in all operation stages and modes from launch through the end of the mission in orbit
- TCS provides the heater-control function to maintain the temperature of the battery, earth sensor, propellant tubes, and DC arc-jet thruster propellant valve within the allowed temperature range

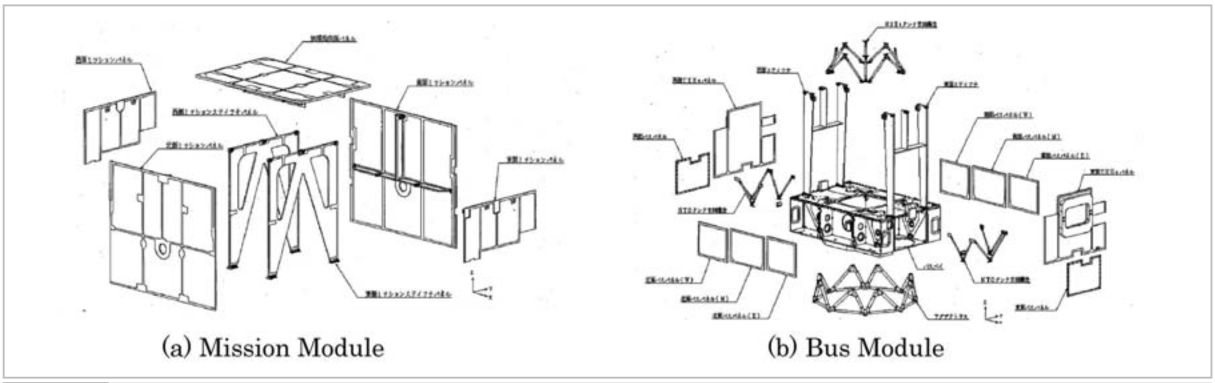

Fig. 11 Structure module configuration

3.8 Monitor camera (CAM)

WINDS is equipped with three monitor cameras to make it possible to check the deployment conditions of the Solar Array Paddle and the MBA Primary Mirror with still color images. The image data acquired are compressed and transmitted to the earth via a TTC link. Figure 12 shows the CAM mounting positions.

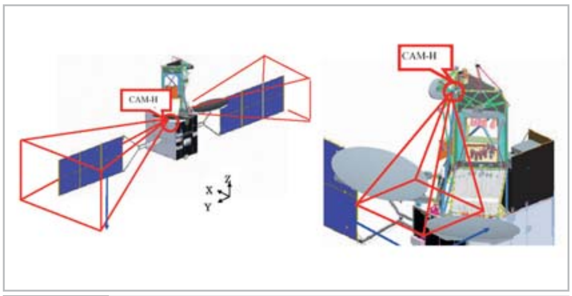

Fig. 12 Placement of CAM

4 WINDS mission system

In addition to the newly developed equipment (MBA, MPA, ABS and APAA), the WINDS mission system consists of an Intermediate Frequency Switch (IFS) and a Network Information Transmitter and Receiver (NITR). The mission system is described in articles to follow this one.

5 Conclusions

This article presents an overview of the WINDS satellite system. Today, WINDS is in the final stage of development. After ground tests of the satellite system, the satellite will be transported to the Tanegashima Space Center and will be launched in January or February 2008.

SATO Tetsuo

WINDS Project Team, Office of Space Applications, Japan Aerospace Exploration Agency (JAXA)

NAKAMURA Yasuo

Deputy Project Manager, WINDS Project Team, Office of Space Applications, Japan Aerospace Exploration Agency (JAXA)

ARAKI Tsunehiko

WINDS Project Team, Office of Space Applications, Japan Aerospace Exploration Agency (JAXA)