6 Plan of Experiments

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Wideband InterNetworking engineering test and Demonstration Satellite was developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). The experimental plan has two categories. One is a fundamental experiment which will be carried out by JAXA and NICT. The other is application experiment which will be conducted by several selected organization. NICT's experiment plan includes evaluating the performances of the onboard equipment, the earth station, fundamental transmission, high speed satellite networking communication, and the network application.

Keywords
Wideband InterNetworking engineering test and Demonstration Satellite, Fundamental experiment, Application experiment

1 Introduction

The Wideband InterNetworking Engineering Test and Demonstration Satellite (WINDS) is part of a satellite system aimed at the establishment of a high-speed satellite communications system using the Ka-band. The purpose of the system is to demonstrate the technologies required to implement a satellite communications network system that can complement a ground communications system and vice versa[1]. Planned Ka-band high-speed satellite communications experiments using WINDS are classified into two categories: fundamental experiments to be carried out by the Japan Aerospace Exploration Agency (JAXA) and the National Institute of Information and Communications Technology (NICT)—the organizations developing the satellite—and application experiments to be carried out by universities and other institutions selected through the solicitation of the Ministry of Internal Affairs and Communications (MIC). This article provides an overview of the plans for the experiments, mainly focusing on the details of the experiments envisioned by NICT. A rough sketch is also provided of the fundamental experiments planned by JAXA and of the application experiments selected by the MIC.

2 Fundamental experiments

The WINDS fundamental experiments are among those performed by the satellite development organizations (JAXA and NICT). JAXA and NICT will cooperate to execute a variety of these experiments testing the WINDS communications network system. The purposes of the experiments are to verify the functions and performance of the developed equipment and to demonstrate the overall effectiveness of the WINDS communications system.

Figure 1 shows the schedule of the WINDS experiments. Following evaluation of initial functions and performance (approximately four months after launch) through approximately seven months after launch, only fundamental experiments will be performed, to ensure stable experimental environments for the application experiments and to

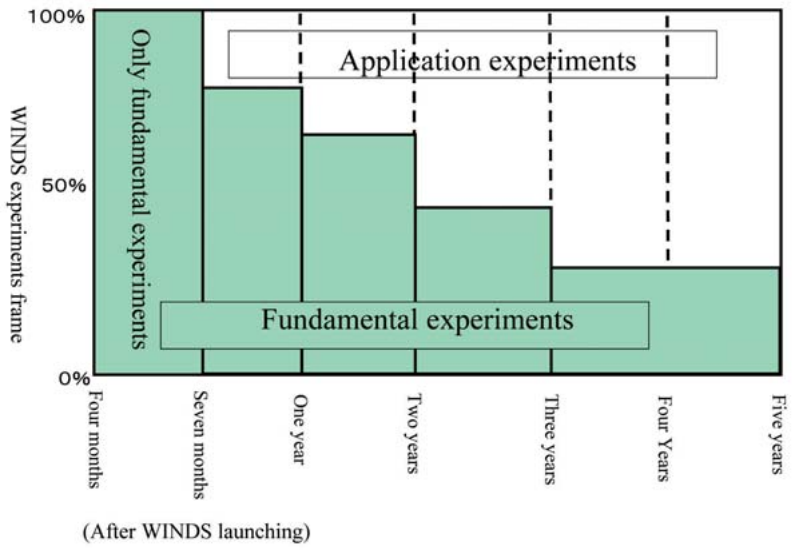

Fig. 1 *Schedule of WINDS experiments*

demonstrate and publicize the effectiveness of the WINDS communications network system. From approximately seven months to two years after launch, fundamental experiments will have priority over application experiments in the schedule of experiments—as stated above, to demonstrate and publicize the effectiveness of the WINDS communications network system. However, we will take care to ensure that as many application experiments as possible will be performed. From two years after launch until the end of the mission, application experiments will have priority over fundamental experiments in terms of the experimental schedule.

2.1 Experiments by National Institute of Information and Communications Technology (NICT)

Table 1 shows the details of the fundamental experiments planned by NICT. These experiments are classified into categories A, B, C, D, and E below. JAXA classifies its fundamental experiments as those designed to verify the performance of the developed equipment (Category 1) and those aimed at demonstrating the effectiveness of the system (Category 2). Among the NICT experiments, Experiments A, B, and C, which concern basic performance, correspond to JAXA's Category 1 Fundamental Experiments, while Experiments D and E, which concern applications, correspond to JAXA's Category 2 Fundamental Experiments.

A: Experiments to verify performance of onboard equipment (corresponding to Category 1 Fundamental Experiments)

These fundamental experiments are designed to verify the functions and performance of the communication mission equipment aboard WINDS. These experiments are performed regularly after satellite launch in order to evaluate the operational status of each of the onboard equipment and any changes over time.

B: Experiments to verify performance of earth stations (corresponding to Category 1 Fundamental Experiments)

These experiments entail the acquisition of data relating to the functions and performance of each earth station used in the experiments. The data acquired here are used as basic data in the evaluation of the experimental system.

C: Fundamental transmission experiments (corresponding to Category 1 Fundamental Experiments)

In these experiments, fundamental transmission characteristics of the experimental

Table 1 *Details of NICT's fundamental experiments*

No.	Experiments item	Comments
Category A	Experiments to verify performance of onboard equipment	
N-A-01	Level diagram verification experiment	
N-A-02	Frequency characteristics verification experiment	
N-A-03	APAA performance evaluation	Joint with J1-B01
N-A-04	Regenerative transponder function verification experiment	Joint with J1-A01 and J1-A03
Category B	Experiments to verify performance of earth station	
Category C	Fundamental transmission experiments	
N-C-01	TDMA synchronization experiment	
N-C-02	Rain attenuation compensation experiment	Partially joint with J1-A02
N-C-03	Bend pipe mode transmission characteristics experiment	
N-C-04	Regenerative mode transmission characteristics experiment	
N-C-05	ABS congestion experiment	
N-C-06	1.2Gbps transmission experiment	
Category D	High speed satellite network experiments	
N-D-01	Star network experiment	Joint with J1-A04
N-D-02	Mesh network experiment	Joint with J1-A04
N-D-03	Protocol evaluation experiment	
N-D-04	Dynamic demand assignment experiment	
N-D-05	SHV transmission experiment	
Category E	Network-Application experiments	
N-E-01	Connection experiment with ground networks	
N-E-02	Medical ICT satellite communications experiment	

satellite communication links are evaluated. The experiments involve evaluation of link quality characteristics and multi-connection methods within various communication methods in each communication mode (bent-pipe or regenerative mode).

D: High-speed satellite network experiments (corresponding to Category 2 Fundamental Experiments)

In these experiments a high-speed satellite network is established using each communication mode (bent-pipe or regenerative), followed by evaluation of the performance of the protocols, networking, and applications.

E: Network application experiments (corresponding to Category 2 Fundamental Experiments)

These include joint experiments within Japan and in the Asia/Pacific region, as well as other international joint experiments with nations in North America and Europe.

2.1.1 Experiments for verifying performance of onboard equipment

(1) Level diagram verification experiment

If a transponder setting is not tested in the initial check and if it is then considered necessary to check this setting, the transponder modes and routes are switched and the level diagrams of the communication signals are measured for each case; results are then compared with design values and the results of ground tests. The results of these transponder tests will then be reflected in link design for future communication experiments.

(2) Frequency characteristics verification experiment

If a transponder setting is not tested in the initial checkout and if it is then considered necessary to check this setting, the transponder modes and routes are switched and the amplitude-frequency characteristics, phase-frequency characteristics, and group delay characteristics are measured. These data are used to analyze bit error rate (BER), for example.

2.1.2 Experiments for verifying performance of earth stations

With respect to the earth stations built by NICT—namely, the Kashima 5-m antenna Large Earth Station (LET) and the Vehicle-mounted 2.4-m-Antenna Super-High Data-Rate/Very Small Aperture Terminal (SDR-VSAT)—a range of performance verification experiments are performed, including tests of wideband frequency characteristics, level diagrams, transmitter and receiver input and output characteristics, and loopback BER characteristics.

2.1.3 Fundamental transmission experiments

(1) TDMA synchronization experiment

Based on Time Division Multiple Access (TDMA) assignment information, this experiment verifies that beam-scanning synchronization and burst synchronization are operating normally, in addition to evaluation of synchronization performance. The Tsukuba Network Management Center (NMC) transmits a bent-pipe Reference Burst (RB) (155 Mbps), which is then received by the Kashima LET. The Kashima LET generates and transmits a High-rate Reference Burst (HRB) (622 Mbps) in synchronization with the bent-pipe RB, for reception by the SDR-VSAT. Synchronization performance is then evaluated both for the Kashima LET and the SDR-VSAT.

(2) Bent-pipe mode transmission characteristics experiment

With the system operating in bent-pipe mode, this experiment acquires the burst synchronization characteristics of the communication signals as well as basic transmission characteristics, including bit error rate (BER). The BER is measured at 622 Mbps[2][3]. The characteristics are measured using modems that can provide transmission methods incorporating a variety of transmission rates and error-correction codes.

(3) Regenerative mode transmission characteristics experiment[4]

With the system operating in regenerative mode, this experiment acquires the uplink and downlink transmission characteristics, including the BER and connection delay characteristics involved in signal processing. The experiment is also planned to measure and evaluate downlink BER and other quantities. The uplink characteristics are evaluated in terms of the cell disposal rate.

(4) ABS congestion experiment

This experiment involves the acquisition of data on the behavior of the onboard switch in conditions of congestion. The experiment focuses signals transmitted by multiple beams to a specific beam in order to cause congestion, followed by observation of the behavior of the ABS (ATM-based Baseband Switching) subsystem under the given conditions.

(5) 1.2-Gbps transmission experiment

Single-wave 1.2-Gbps transmission experiments are performed in bent-pipe mode, and the resultant characteristics are evaluated in terms of various indices, including the BER.

2.1.4 High-speed satellite network experiments

(1) Protocol evaluation experiment

In this experiment, the characteristics of the upper layer protocol (i.e., TCP/IP throughput) are evaluated in a star or mesh network configuration. Using various TCP accelerators and other equipment, the experiment measures TCP/IP throughput and evaluates the effects of these accelerators and equipment.

(2) Dynamic demand assign experiment (TBD)

By changing the communication control software in the NMC and the onboard equipment setting software, this experiment performs dynamic demand assignment. Instead of planned assignment of equipment in advance,

in these experiments slots are dynamically assigned in response to association requests from users.

(3) SHV transmission experiment

This experiment involves Super Hi-vision (SHV) transmission, technology under development by NHK as a medium for wideband transmission experiments. Data rates range from 150 Mbps to 600 Mbps. The experiment uses the baseband system developed by NHK Science & Technical Research Laboratories, including the modem.

2.1.5 Network application experiments

(1) Connection experiment with ground networks

The satellite network system is connected to ground networks, including the Japan Gigabit Network (JGN) at the Kashima Space Research Center; combined transmission experiments are then performed using the satellite network and the ground networks. Using the NICT high-speed burst modem, the WINDS satellite network is connected to the JGN for high-speed transmission experiments.

(2) Medical ICT satellite communications experiment

In our aging society, it is becoming increasingly important to construct a safe and secure medical assurance system. This medical ICT system, designed to make use of satellite communications, is aimed at more efficient and more advanced treatment and health-care systems by combining the Body Area Network (BAN), involving the collection of various biosignals, with satellite communications.

2.2 Joint or simultaneous experiments with Japan Aerospace Exploration Agency (JAXA)

2.2.1 Experiments for verifying performance of onboard equipment

(1) APAA performance evaluation

To verify age-related deterioration and the soundness of the Ka-band Active Phased Array Antenna (APAA), this experiment checks the APAA elements using the Rotating Element Electric Field Vector (REV) method [5]. The NMC transmits unmodulated continuous waves, and the NMC receives the response of the APAA elements. By evaluating the level variation in the acquired data, the experiment verifies the soundness of each APAA element. The Kashima earth station also receives the signals and uses the received data for reference in experimental evaluation.

(2) Regenerative transponder function verification experiment

In regenerative mode, this experiment confirms that a call is connected and that routes are selected normally based on the calling information. The experiment also confirms the functions of the intra-beam ABS multi-cast and the inter-beam ABS multicast (i.e., interline copying and inter-area copying) and confirms normal operation of the ABS.

2.2.2 Fundamental transmission experiments

• Rain-attenuation compensation experiment [6]

This experiment is intended to acquire data to be applied to Category 2 Fundamental Experiments as well as to application experiments. In this experiment, WINDS compensation for attenuation due to rain is evaluated for satisfactory performance, with assessment of the conditions and effects of such compensation, including its effects on the fundamental parameter settings of the NMC. Using the network information link, this experiment measures the amount of rain attenuation, followed by compensation through control of satellite transmission power and evaluation of the control parameters and the applied algorithm.

(i) Assigns power to multiple areas and confirms that power is distributed as expected.

(ii) Sets up a fully-guaranteed station in an area, checks that the “best-effort” earth stations operate as expected, and evaluates the effects of rain-attenuation compensation.

(iii) Locates stations at the center and edge of a single beam and confirms the effects of rain-attenuation compensation.

(iv) Locates the USAT and the HDR-VSAT

in a single beam and confirms the effects of rain-attenuation compensation.

(v) Compares the WINDS standard rain attenuation compensation method with other methods, to be followed by evaluation of the standard method.

2.2.3 High-speed satellite network experiments[7]

(1) Star network experiment

Through the construction of a star network, this experiment is designed to confirm network operation. In addition, connection delay characteristics and transmission characteristics are evaluated for each of the ATM service classes: Constant Bit Rate (CBR) and Unspecified Bit Rate (UBR).

(2) Mesh network experiment

Through the construction of a mesh network, this experiment aims at confirming network operation. In addition, connection delay characteristics and transmission characteristics are evaluated for both of the ATM service classes: CBR and UBR.

2.3 Experiments by JAXA

Tables 2 and 3 show the details of the fundamental experiments carried out by JAXA. These experiments are classified into two categories: those confirming the performance of the developed equipment (Category 1 Fundamental Experiments) and those demonstrating the effectiveness of the WINDS communications network system (Category 2 Fundamental Experiments).

Category 1 Fundamental Experiments include the joint experimental items described in **2.2**, experiments relating to operations in special circumstances (including natural disasters) to confirm that the system can handle responses to disasters and abnormal events, and performance evaluation experiments for the Multi-Port Amplifier (MPA) and Multi Beam Antenna (MBA), equipment installed aboard WINDS.

Category 2 Fundamental Experiments include multi-cast experiments such as e-learning, distribution of data observed by the Advanced Land Observing Satellite (ALOS), image-distribution experiments (including high-definition transmission), and experiments aimed at bridging the digital divide on isolated islands. These experiments also assess emergency communication transmission in simulated disaster areas to verify the effectiveness of the satellite communication under these extreme conditions.

Table 2 *Details of Category 1 Fundamental Experiments carried out by JAXA*

No.	Experiments item	Comments
WINDS network experiments system fundamental performance evaluation experiments		
J1-A01	Slot allocation experiment	
J1-A02	Rain attenuation compensation experiment	
J1-A03	ABS multicast experiment	
J1-A04	Network construction experiments by multi-terminal	
J1-A05	Experiment for special circumstances like disaster etc.	
WINDS on-board equipments performance evaluation experiment		
J1-B01	APAA performance evaluation	Common with N-A-03
J1-B02	MPA performance evaluation	
J1-B03	MBA performance evaluation	

The experiments of J-A01to J-A04," indicate joint experiment of NICT and JAXA.

Table 3 *Details of Category 2 Fundamental Experiments carried out by JAXA*

No.	Experiments item
「Satellite network technology demonstration experiments」 and 「network application experiments」	
J2-01	Multicast experiment
J2-02	Multicast experiment (receiving only earth station)
J2-03	E learning experiment
J2-04	Sentinel Asia
J2-05	ALOS observation data distribution experiment
J2-06	ALOS quick look data distribution experiment
J2-07	Hi-vision transmission experiments by using the portable HDR-VSAT
J2-08	Transmission experiments by using the portable VSAT and USAT
J2-09	Hi-vision transmission experiments by using VSAT
J2-10	Emergency communication transmission experiment
J2-11	Isolated island model - digital divide solution experiment
J2-12	Ship communication experiments
J2-13	Deep see dolling vessel CHIKYU communication experiment

3 Application experiments

The various application experiments are performed by organizations selected through a solicitation of experimental applications.

From February 1, 2007 through March 30, 2007, the Ministry of Internal Affairs and Communications solicited the submission of application experiments related to the WINDS satellite to be launched in fiscal 2007, aiming at the establishment of ultra-high-speed fixed satellite communication technologies. As a result, 53 proposals were gathered. Based on results of deliberation at the Satellite Application Experiment Promotion Conference (Chair: Prof. Fumio Takahata, Waseda University) held on May 30, 2007, the MIC adopted all proposals. Table 4 shows the number of proponents of the experiments categorized by country. Table 5 shows the number of experiments categorized by the field of application experiments[8].

On July 26, 2007, the WINDS Application Experiment Consortium was established. The Consortium is now promoting specific studies to assist in the planning of the application

Table 4 *Number of proponents of experiments categorized by country*

Total	Japan	Thailand	Indonesia	Malaysia	Philippines	Singapore	China	Others
53(*)	26	11	3	3	2	2	1	5

(*) International joint experiment (joint experiment with another country) is 30.

Table 5 *Number of experiments categorized by field of application (some duplication for cross-category experimental projects)*

Total	Propagation	Disaster prevention	Medical treatment	Education	Others
61	14	8	6	18	15

experiments.

4 Conclusions

This article describes the planning of experiments for high-speed satellite communication experiments using WINDS, focusing on the fundamental experiments planned by NICT. Given that he design lifetime of the satellite is five years, and given that the fundamental and application experiments cover a wide range of topics, we need to coordinate planning with the relevant organizations and perform the experiments efficiently.

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References

1 M. Shimada, T. Kuroda, Y. Ogawa, R. Suzuki, T. Takahashi,T. Toriumi, I. Hosoda, and Y. Ohshima, "Overview of Satellite Communications System for WINDS", 50th Space Science and Technology Conference 3D02, 2006-11.

2 T. Takahashi, Y. Hashimoto, N. Yoshimura, R. Suzuki, T. Kuroda, Y. Ogawa, T. Ogawa, and I. Hosoda, "Development of High-Data-Rate Burst Modem for WINDS", 25th AIAA International Communications Satellite Systems Conference, AIAA 2007-3159, Seoul Korea, Apr 2007.

3 Y. Hashimoto, T. Takahashi, N. Yoshimura, R. Suzuki, G. Richard, and D. Mike, "The Development of the High-Speed Network for the WINDS", 50th Space Science and Technology Conference 3D10, 2006-11.

4 N. Yoshimura, Y. Hashimoto, T. Takahashi, R. Suzuki, H. Katagiri, T. Kumagai, and M. i Yoneda, "Development of On-board Baseband Switch for WINDS", 50th Space Science and Technology Conference 3D07, 2006-11.

5 S. Mano, and T.Katagi "A method for measuring amplitude and phase of each radiating element of a phased array antenna", IEICE Trans. vol.J65-B no. 5 pp. 555-560 May 1982.

6 K. Suzuki, M. Shimada, M. Yokoyama, T. Hasegawa, H. Miyoshi, Y. Tsuneoka, T. Shimokawara, and H. Ootomo, "A compensation control for downlink rain attenuation in WINDS and simulation results", 50th Space Science and Technology Conference 3D12, 2006-11.

7 M. Yokoyama, M. Shimada, T. Kuroda, Y. Ogawa, R. Suzuki, Y. Hashimoto, N. Yoshimura, T. Takahashi, S. Nakazato, T. Okui, and Y. Ohshima, "Network Control of the WINDS Communications System", 50th Space Science and Technology Conference 3D11, 2006-11.

8 http://www.soumu.go.jp/s-news/2007/070604_4.html.

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