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Trends in the Utilization of Telecommunications Satellite Systems

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1 Introduction

"The telecommunications satellite system" is one of the important research and development themes in the frontier fields of the Third Science and Technology Basic Plan[1]. The telecommunications satellite system, which ensures safety and security as well as enabling long-distance and wide-area broadcasting, is one of the typical products of practical space development and has now become an indispensable infrastructure for the construction of ubiquitous networks that integrate communications systems such as terrestrial optical fiber networks and submarine cable systems. Benefits of satellite communications include: provision of an alternative means of communication in the event of a communication blackout due to terrestrial disasters; provision of radio wave-based communications to isolated islands and remote areas where terrestrial infrastructures are not fully developed; swift adaptability in TV broadcasting and support for emergency activities where mobility is required; and utilization in mobile platforms such as aircraft and ships that cannot communicate directly with terrestrial networks. Terrestrial telecommunications infrastructures and telecommunications satellite systems in space are now in a complementary relationship, wherein roles are shared, rather than being in a competitive relationship.

From the viewpoint of scientific and technical development, telecommunications systems that use geostationary satellites are already operating commercially, and the prevailing opinion is that the technology has reached complete maturity so that there remains little room for new technological development. There is also a contrary viewpoint that satellite communications technology has not fully evolved[2]. The technology roadmap for telecommunications satellites prepared by the Japan Aerospace Exploration Agency (JAXA) assumes that after the demonstration of new communication functions, which will be developed based on the Third Science and Technology Basic Plan, the construction of a common platform based on Internet protocol (IP) (including the integration of telephone systems and television broadcasting systems into the Internet) and the creation of more sophisticated satellite television systems using the 21GHz band will be realized by around 2020 as a result of advances in satellite communications technology. It is also expected that further innovation will be facilitated by the advent of conversion from communications based on electromagnetic waves to that based on light quantum communications[3]. European countries and China are planning to conduct experiments on quantum cryptography communications between the earth and manned spacecraft.

This article outlines the present utility of the telecommunications satellite systems from the viewpoint of application and Japan's communications policy. This policy aims at ensuring safety and security and increasing user convenience by utilizing the telecommunications satellite systems to be developed and demonstrated over the period covered by the Third Science and Technology Basic Plan (up to FY 2010). Furthermore, trends in research on quantum space communication, which is still in its infancy, will be described because European countries and China are planning to begin experiments on long-distance quantum cryptography communications on a global scale between manned spacecraft and the earth in the next few years.

2 Effectiveness of telecommunications satellite systems from the viewpoint of application

2-1 Utilization of satellites in basic telecommunications

In Japan, the following commercial geostationary telecommunications satellites are in constant operation: “N-STAR” of Nippon Telegraph and Telephone Corporation (NTT) (transferred to JSAT Corporation in 2000), “B-SAT” of Broadcasting Satellite System Corporation, “JCSAT” of JSAT Corporation[4], and “Superbird” of Space Communications Corporation (SCC)[5]. Thus, the utilization of satellite communications meeting the basic needs of information communications is growing, including bidirectional communications in the transmission of emergency information, delivery of TV programs, correspondence education, symposiums, and other events. The benefits of satellite communications can be clearly seen in direct broadcasting and one-to-many communications rather than in bilateral communications between two points. This means that multi-channel broadcasting using telecommunications satellites is the primary source of profits for satellite communication providers such as JSAT. These Japanese telecommunications satellites have been procured from worldwide sources since Japan agreed with the U.S.A. to abide by the provisions of the Super 301 Clause*1 in 1990.

In Japan, more than 30 satellites produced in the U.S.A. have been launched using European and American launch vehicles. In August 2006, JSAT launched “JCSAT-10” made by Lockheed Martin using an Ariane-5 launch vehicle produced in Europe. The order for “Superbird-7” (Space Communications Corporation), scheduled for launch in 2009, was placed with a Japanese satellite manufacturing company (Mitsubishi Electric Corporation).

The size of the global telecommunications satellite market is about ¥300 billion per annum. In recent years, developing countries in South America and Africa, which lag behind in terms of infrastructures for terrestrial communications, are going to launch, in succession, telecommunications satellites made by the U.S.A., European countries, and China in order to improve their communication infrastructures. This is evidence that telecommunications satellite systems are of even greater benefit in thinly-populated areas. In Japan too, there are thinly-populated areas such as mountain-ringed regions, and the positive use of telecommunications satellite systems will contribute to the efficient elimination of the digital divide.

2-2 Utilization of satellite communications in disasters and emergencies

In order to build robust communications systems that are able to withstand disasters, it is necessary to prepare measures based on the assumption that all the terrestrial communication infrastructures will be adversely affected. Actually, such application research is presently being conducted and products are already available on the market. The following are some examples of communications systems that utilize satellites.

(1) Instantaneous emergency alarm system and simultaneous multiple address system

From 2004, a nationwide instantaneous alarm system (J-Alert)[6], by which alerts for earthquakes, seismic surges, volcano eruptions, meteorological disasters, armed attacks, etc. are sent to prefectural governments and city offices from the Japan Meteorological Agency and Cabinet Secretariat via a commercial communications satellite (Superbird) to certain areas, started to operate in 2004. It is expected that coverage will be widened to include more areas in the future. It must be understood that the terrestrial communication cables can be easily damaged at any time by natural disasters such as earthquakes, fires, and lightning strike, floods, or human-generated disasters such as a terrorist attack; therefore, it is an important issue to establish a satellite-based communications system as the core transmission channel.

In addition, Japan should develop a satellite system that enables immediate information transfer to the public regarding disasters and emergency management as an important infrastructure. The necessity for having such satellites is described in JAXA's long-term vision[7] published in March 2005.

(2) Communication on disaster site

It is very important to secure communication infrastructures at disaster sites. After the earthquake that occurred in Indonesia in May 2006, the Japan Ground Self Defense Force, Japanese Red Cross Society, and NPO's provided assistance to victims and contributed to the rescue work at the disaster sites. The communication tools used by these rescue parties depended on the portable terminals of the Iridium satellite system deployed by the U.S.A. rather than on terrestrial communications systems[8]. While the communication channels at the disaster site itself were practically useless due to traffic congestion, the rescue work was conducted smoothly thanks to the communications provided via the Iridium satellites. Sixty-six Iridium satellites in low altitude orbit cover the entire planet. In the area from the Middle East to Africa, portable terminals linked to the Thuraya satellite[9], operated by a company of United Arab Emirates (UAE), are used. Japan is unquestionably behind the rest of the world in establishing communication infrastructures to deal with disasters.

(3) Communication support by emergency helicopters

The ratio of helicopters to total aircraft is very high in Japan and it can be said that the country is a helicopter powerhouse. It is widely recognized that helicopters are effective tools in disaster relief when large-scale earthquakes or landslides have occurred. However, since helicopters are not provided with communication links to arbitrary terrestrial spots, it is difficult for them to transmit photographs and video images they have taken without support from the ground to relay these images. For example, when a disaster relief helicopter is sent to a location outside its base station territory, an information gathering vehicle (Heli-Tele receiving vehicle)[10] follows the helicopter relaying the communications. However, it must be noted that the vehicle may not be able to keep up with the helicopter where a disaster has damaged roads.

In Japan, emergency medical helicopters (Doctor-Heli) are deployed at ten hospitals and the emergency care centers of nine prefectures as of October 2006, and these contribute to the evacuation or rescue of victims. However, it has been pointed out that Japan is behind the rest of the world in this field because the number of emergency medical helicopters is still small compared with European countries and U.S.A. Emergency medical helicopters are equipped with medical devices exclusively for emergency medical care, and emergency medical care specialists and nurses are on board to carry out emergency medical care on the spot and transport victims to hospitals in response to a request from the fire department, etc. Securing frequencies for communication with the ground in the operation of emergency helicopters is an issue that still needs to be resolved. For the operation of such helicopters in an emergency, communication using satellites that provide a broad frequency band would be preferable. Since a helicopter has huge rotor blades turning above the body of the craft, it is necessary to use a communications system that is synchronized with the rotation angle of the rotor so that communication with satellites is enabled through the gaps between the rotors while they are rotating at high speed. There has just been a successful test communication with a geostationary satellite through providing active phased array antenna (APAA) on the both sides of the fuselage.

2-3 Satellite communications in mobile objects

(1) Applications to aircraft and ships

Communication technologies for mobile platforms such as aircraft and ships using communications satellites and operating systems are now being established.

Recent commercial aircraft are equipped with a radome in which a 360-degree antenna is installed so that satellite communication is always available. Although satellite communication using the Ku band often suffers from significant radio wave attenuation during rainfall, commercial planes that fly at high altitudes are not affected by the weather and can receive high-quality radio waves from within satellite's visual range.

Ships are also mobile platforms that cannot use terrestrial lines for communication as in the case of aircraft, and satellite communications have become the primary communication tool, replacing conventional short-wave radio communications while vessels are at sea and are out of sight of land. The main satellite for this purpose is the INMARSAT satellite that uses the L band, and relatively low-cost antennas are installed in the ships. Since the maximum communication speed of the INMARSAT satellite at present is 432 kbps, which is rather low, a high-speed satellite communication service using the Ku band has started operation[11].

(2) Telecast via satellites

Video production departments of TV companies value high quality video content, and the ability to rapidly prepare equipment and materials for on-the-spot news coverage of events and accidents and to secure the transmission of images are the major advantages. The technology for TV broadcasting vans used in the field has advanced remarkably in recent years. The Satellite News Gathering (SNG) vehicle has been developed to meet such requirements as reduced preparation time for video recording, improvement of image quality using a high-definition video camera, and provision of enhanced programs. While a certain period of time is normally required to establish a communication channel by adjusting the direction of antenna, the mobile SNG vehicle using advanced antenna technology can establish the channel while traveling to the site,

Relationship between frequency and wavelength of electromagnetic wave

Both radio waves and light that are used in communication are forms of electromagnetic waves and have the following relationship: wavelength × frequency = speed of light (about 300,000 km/s). The wavelengths of radio waves are considerably longer than those of light. Radio waves having a wavelength between about 1 cm and 1 m are called microwaves, which are further divided by frequency into L band, C band, etc. The K band is further divided into the Ka band, which has higher frequency, and the Ku band, which has lower frequency. The direct broadcasting satellite that transmits TV programs to household audiences uses the Ku band.

Light — Radio wave

Wavelength	100nm	1μm	10μm	100μm	1mm	10mm	100mm	1m	10m	100m
Designation	Visible/ near-infrared	Short wavelength, infrared	Intermediate to far- infrared			EHF	SHF	UHF	VHF	HF
Frequency band					300 - 3000 GHz	30 - 300 GHz	3 - 30 GHz	300 - 3000 MHz	30 - 300 MHz	3 - 30 MHz

Band	Ka, Ku	X	C	S	L
Frequency band	10.9 - 36 GHz	6.2 - 10.9 GHz	3.9 - 6.2 GHz	1.55 - 3.9 GHz	0.39 - 1.55 GHz
Major applications	Satellite communications and broadcasting	Earth observation	Satellite communications	Weather satellite	Cellular phone

significantly reducing the time lost between the arrival at the site and the start of transmission. In addition, the telecast station on the mobile SNG vehicle can broadcast while traveling, which the conventional geostationary telecast station was incapable of doing. This enables, for example, the televising of marathons. Furthermore, telecast vehicles have rapidly become more sophisticated with the down-sizing of satellite communication devices, making it possible to edit videos on the SNG vehicle and easier to find a space for parking due to the down-sizing of the SNG vehicle itself. When the quasi-zenith satellite system is established, further improvements in terms of flexibility of parking, simplification of antennas, cost and size of the equipment are expected.

3 Objectives of the telecommunications satellite systems in the Third Science and Technology Basic Plan

The Third Science and Technology Basic Plan sets out the research and development themes and goals for three items: "Wideband InterNetworking engineering test and Demonstration Satellite (WINDS)," "Engineering Test Satellite VIII (ETS-VIII)," and "Research and development of advanced satellite communications technologies" based on the successful realization and demonstration of the former two items.

3-1 Engineering Test Satellite VIII (ETS-VIII)

JAXA has scheduled the launch of the Engineering Test Satellite VIII (ETS-VIII)[12] in FY 2006 to demonstrate satellite communications technology that enables direct communication between portable terminals and satellites. JAXA will take the lead in the development of the satellite bus, a large deployable antenna, and a high-accuracy reference clock, while the development of the main communication devices will be carried out by the National Institute of Information and Communications Technology (NICT) and Nippon Telegraph and Telephone Corporation (NTT).

As shown in Figure 1, ETS-VIII deploys two huge antennae of 19 m×17 m to allow high-speed communication with mobile objects using the S band. It is expected that the size of the ground station for satellite communication will be significantly reduced to be little larger than a cellular phone. The weight of the satellite in geostationary orbit is about three tons, the largest of Japan's geostationary satellites. The dimensions of the satellite are: the length of solar panel is 40 m in the deploying direction and the length of antenna in the deploying direction is also 40 m. Among the elemental technologies of the satellite, the development of the large antenna is the most difficult problem, and experiments on deployment are being carried out as preliminary tests using partial models mounted on the second stage of the Ariane launch vehicle. Although the first experiment failed, the payload for the second deployment test (LDREX-2) was successfully launched using the Ariane 5 ECA launch vehicle on October 14, 2006. The objectives of these experiments are to demonstrate that the direction can be freely set using the phased array antenna and to demonstrate that the portable phones

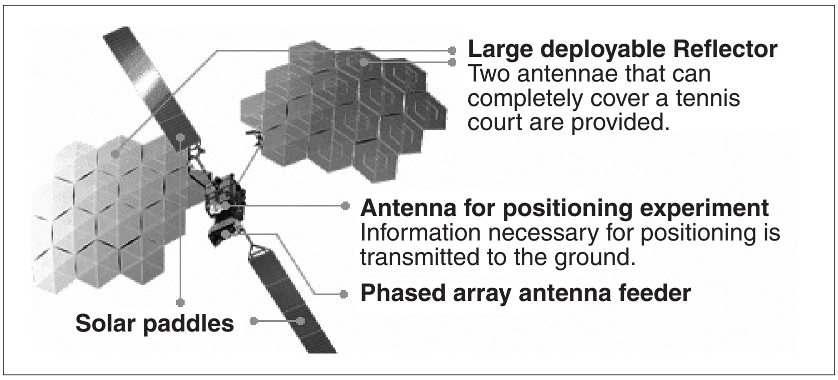

Figure 1 : Structure of engineering test satellite VIII

Illustrated by JAXA

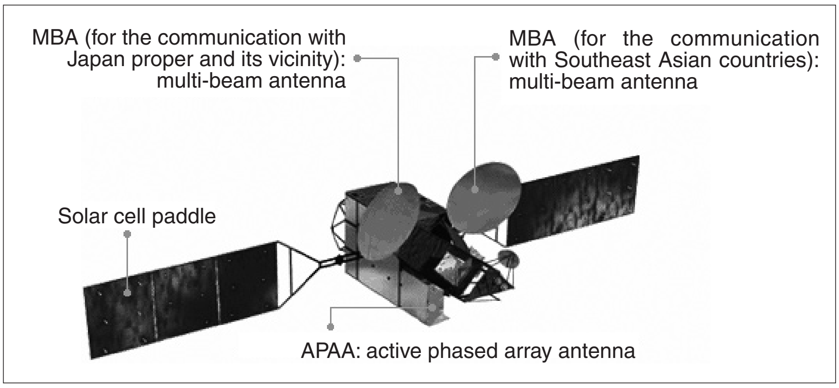

Figure 2 : Structure of ultrahigh-speed Internet satellite (WINDS)

Illustrated by JAXA

and packet exchange are adequately performed using multibeam. If it can be shown that direct communication between the satellite and cellular phones is possible, as has been demonstrated by the Thuraya satellite, the purpose of the experiment, to show the feasibility of the new satellite communications technology, will have been achieved. It is also planned to carry out positioning tests using GPS by transmitting time information from the high-accuracy reference clock. These experiments are another step toward the Japanese version of the GPS technology.

3-2 Wideband InterNetworking engineering test and Demonstration Satellite (WINDS)

JAXA has scheduled the launch of the ultrahigh-speed Internet satellite (WINDS: Wideband InterNetworking engineering test and Demonstration Satellite)[13], as depicted in Figure 2, in FY 2007. Features of the technology include: (i) flexible control of orientation using active phased array antenna (APAA); (ii) high-speed information exchange using a switching router (155 Mbps × 3 channels) mounted on the satellite; (iii) output control in response to weather conditions using variable output Ka band communication; and (iv) mesh-type network that enables connection between users with a single hop.

The communication speed of WINDS depends on the type of ground antenna. The download speed is 155 Mbps for a household ultra small aperture terminal (USAT) with a dish diameter of 45 cm, and both upload and download speeds are 155 and 622 Mbps for very small aperture terminals (VSAT) with a dish diameter of 1.2 and 2.4 m, respectively. Ultrahigh-speed satellite communication at 1.2 Gbps is possible for a large ground station with a dish diameter of 5 m for business use. This is yet to be realized.

WINDS's antenna system covers Japan, neighboring areas, and Southeast Asian countries including the major cities in these regions. Furthermore, Australia, New Zealand, and Hawaii are covered by the beam scanning of the active phased array antenna. Although the amount of data that can be transmitted using the Ka band is very large, the signal is significantly attenuated when it rains. In rainy regions, output is boosted using an output-variable high power multi-port amplifier (MPA) thereby ameliorating any rain attenuation effects.

By achieving these technical objectives, the digital divide will be bridged using satellite communications. It also means that the Internet can be spread to those regions where a terrestrial network is impractical.

Typical annual leasing fees for repeaters of commercial communications satellites amount to several hundreds of millions of yen. Regarding communication applications using WINDS, the Ministry of Internal Affairs and Communications will invite public submissions. If a proposal is accepted, the applicant will be entitled to prepare a ground station that suits the purpose of the experiment and use the high-performance repeater free of charge. By accepting requests from both domestic companies and Southeast Asian and Pacific nations, Japan will contribute to international cooperation.

3-3 Research and development of advanced satellite communications technology

In the period covering the implementation of the Third Science and Technology Basic Plan, the Ministry of Internal Affairs and Communications is planning to develop and demonstrate technologies that can be used to create robust communication tools applicable to natural disasters, eliminate the digital divide, and facilitate the introduction of the satellite Internet by making use of communication equipment mounted on ETS-VIII and WINDS.

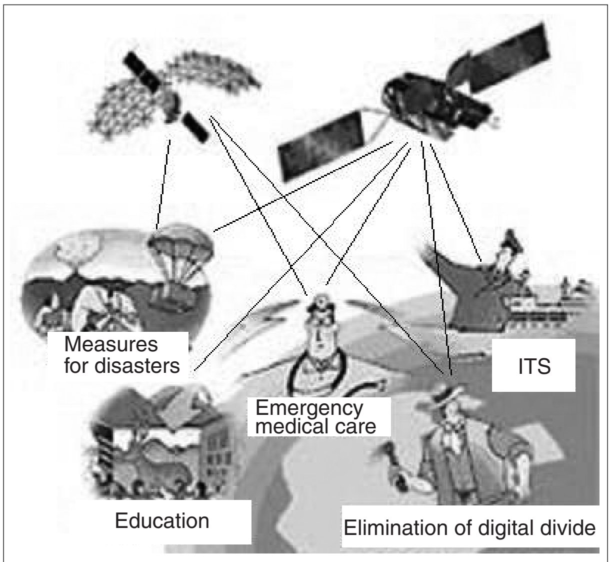

Figure 3 : Schematic representation of new satellite communication through ETS-VIII and WINDS

Illustrated by JAXA

Furthermore, diversified basic satellite technologies that can be used in the event of natural disasters and in crisis management will be developed in addition to those for mobile object satellite communication using portable terminals. One example is the development of a repeater that can be used for high-capacity core networks in normal times as well as being used for a large number of low-capacity user circuits when disasters occur. Thus, by FY 2010, it is planned to develop the fundamental technologies required for building a system that secures the transmission of information using satellites in a large-scale disaster so that the safety and security of the public can be ensured. Figure 3 is a schematic representation of advanced satellite communication.

4 Experimental results of Optical Inter-orbit Communications Engineering Test Satellite (OICETS) and future issues

In Japan, JAXA has taken on the challenge of developing a new technology for optical intersatellite communication, and achieved satisfactory results that are better than had been expected. Optical Inter-orbit Communications Engineering Test Satellite (OICETS: “Kirari”) was launched by ISC Kosmotras (Ukraine, Russia) using a Dnepr launch vehicle in August 2005. The major objectives of the test had been reached by March 2006 and further demonstration

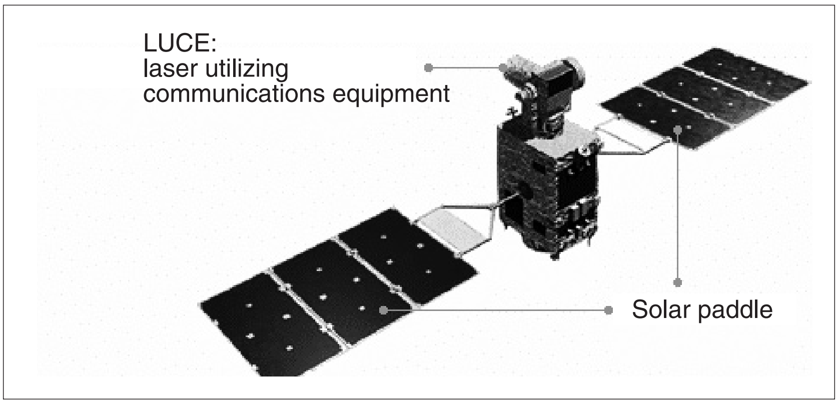

Figure 4 : Structure of Optical Inter-orbit Communications Engineering Test Satellite “Kirari”

Illustrated by JAXA

experiments are being conducted aiming at attaining better than planned results[14]. OICETS conducted a successful demonstration of optical communications between a geostationary satellite and a low earth orbit satellite, a world first. The counterpart in the experiment was the European geostationary communications satellite, Advanced Relay and TEchnology MISsion (ARTEMIS). The communication distance was about 40 thousand km and bidirectional communication was successfully achieved with a relative displacement speed of several kilometers per second and a laser beam spread angle of 5 microradians.

In the communication test with the ground carried out by the National Institute of Information and Communications Technology (NICT) in March 2006 as part of the communication tests using OICETS, errors of transmission from the satellite to the ground (downlink) were fewer than expected. Accordingly, the results were better than the targeted values in terms of reducing the effects of atmospheric fluctuations. However, line isolation occurred during the test due to the generation of clouds.

Since the speed of optical communication is much faster than that of microwaves currently used for the satellite communications, it may become possible to realize space communication networks in the order of gigabits (Gbps) or terabits (Tbps). One of the weak points of optical communications is that optical beams are significantly attenuated by clouds and vapor existing in the communication atmosphere. In communication between satellites, however, since the effects of the atmosphere can be almost ignored, high-capacity high-speed communication is enabled. Furthermore, intersatellite optical communication allows a remarkable reduction in the size of antennas, which confers the advantage that the attitude is not affected by the motion of antenna while in operation. Communication technologies using radio waves almost reached maturity and the future development of satellite communications technologies will be focused on the improvement of optical communication technologies. Among the forms of communications between the earth and space, many of which are susceptible to atmospheric fluctuations, optical communications are expected to be effective in relay systems that connect ground stations in low rainfall desert areas, aircraft flying at high altitudes, and stratospheric platforms (airships).

5 Future satellite communications technologies

5-1 Prospects for the development of telecommunications satellite systems in the period up to 2020

JAXA established the Future Applications of Satellites Subcommittee from 2003 to 2004 as part of the Satellite Application Promotion Committee, and published a report entitled “Toward the Development of New Telecommunications Satellite Systems”[15]. This report describes the vision for the future based on the expected results of technical developments achieved by about 2010 using the mobile communications made possible by ETS-VIII and the ultra-high speed internet of WINDS. It is foreseen that the size of repeaters will be significantly reduced while capacity will be increased by about 2020. The systems are to be integrated into the Internet, meaning that the networks of common platforms based on the Internet protocol (IP) will play a core role. Regarding the satellite broadcasting system, the transition to the next-generation broadcasting system that uses the 21 GHz band is a matter requiring attention. As to data relay, the Data Relay Technology Satellite (DRTS: “Kodama”) relays a large amount of data collected by the earth observation satellites. In the future, it is expected that optical communications will be used for intersatellite communications based on the results of OICETS. Figure 5 shows the roadmap for the development of the telecommunications satellite system described in the report. A detailed roadmap was also introduced in the report, “Political Importance and Future Approach of Space Development in the Communications, Broadcasting and Positioning Fields” submitted by the Space Communications Policy Division of the Ministry

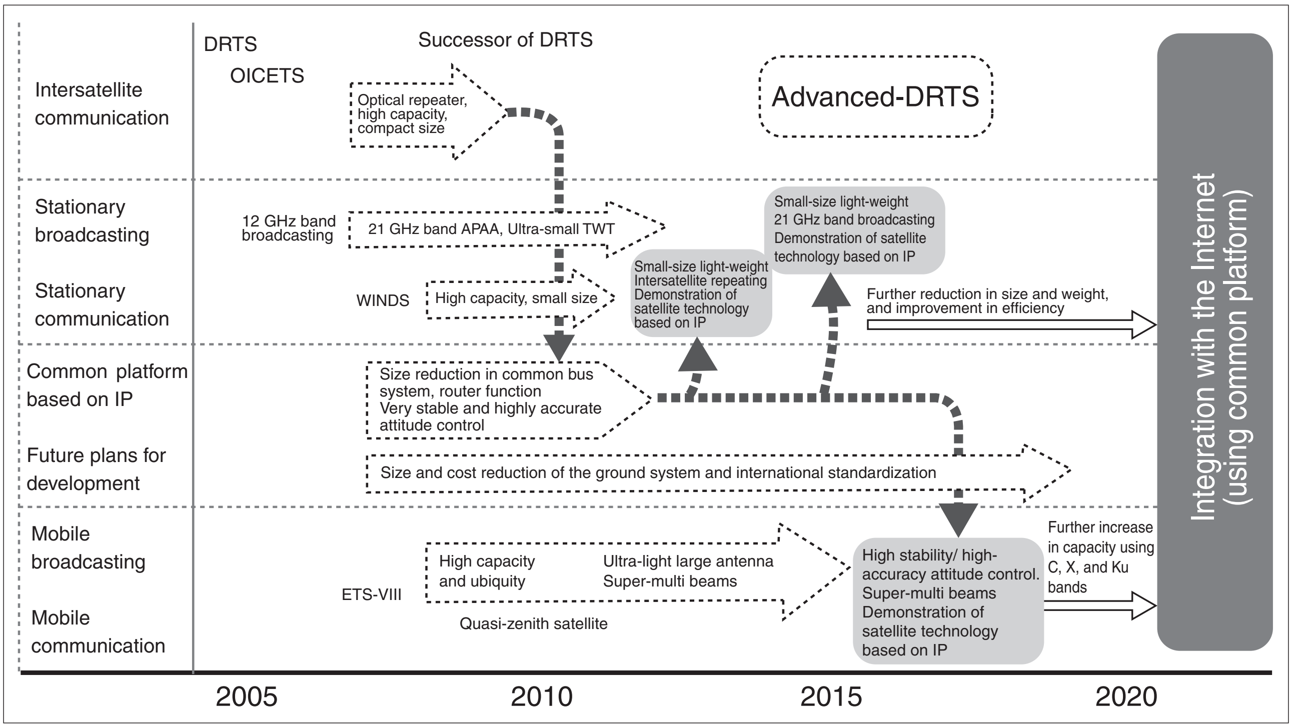

Figure 5 : Roadmap for the development of economical telecommunications satellite system consistent with ground systems

Source: Toward the Development of New Telecommunications Satellite Systems (JAXA)

of Internal Affairs and Communications to the Space Activities Commission on August 25, 2006[16].

5-2 Transition to quantum communications

Although not referred to in the roadmap shown in Figure 5, it is possible that quantum communications will begin to replace communications based on electromagnetic waves and light waves. The development of quantum communications has just started worldwide and the path to practical use would seem to be quite a long one, but steady progress in basic research is being made by the government and private companies in Japan. The Third Science and Technology Basic Plan of Japan has adopted the “realization of quantum communications technology that enables high capacity and confidentiality in information communications by 2030” as an important research and development theme in the information and communications field. While quantum communications technology includes large-scale, complex application systems such as quantum computers and quantum teleportation, quantum cryptography (quantum key distribution) communication is the smallest-scale and most rudimentary application of the technology. The outstanding feature of quantum cryptography communication is that should quantum signals be stolen during transmission, the state of quanta changes instantaneously, becoming meaningless data and, at the same time, it is detected by the transmitter that the data have been stolen. This is why quantum communication is the safest communications system.

Quantum communications technology utilizes such properties as quantum entanglement (quantum correlation) and quantum superposition and it is quite different from conventional technologies that utilize electromagnetic waves and light waves. As explained in the next chapter, there is a trend overseas to conduct basic experiments in this field making use of outer space.

The eighth Delphi survey made by National Institute of Science and Technology Policy (NISTEP) in the period from 2003 to 2005 took up the theme that “quantum communications technology enables high-capacity communications with planetary exploration satellites at a speed that is a million times faster than that of current optical communications." This theme is seen at the sub-domain of planetary exploration in the frontier field. This technology is expected to be realized when quantum communications technology is fully developed for terrestrial communication. The response to the Delphi questionnaire showed that quantum communications will most probably be technically realized around 2018 and put to practical use around 2028.

6 Trends in countries aiming at conducting quantum communications tests in space

Quantum communications technology is making the transition from indoor tests to field tests, and there is global competition over the longer communication distances that can be achieved. In Japan, field tests of quantum cryptography communication using optical fibers about 100 km long have been conducted[17]. The best result that has been achieved was: 1,000 bps on the transmitting side and 10 bps on the receiving side at a distance of 100 km. Since the loss is large when optical fibers are used, the bit rate is about one hundredth for a distance of 100 km, and it is very difficult to enable long distance communications without using relays. Japan's current target is to obtain a bit rate of 100 kbps over 100 km.

Another approach to quantum communications is the open space propagation method that utilizes the straight path of light propagation. When the light propagates in open space on the ground, it is very difficult for the light to reach the objective point (receiving point) because of the curvature of the earth and, in addition, the light is attenuated or deflected by the atmosphere. A promising method to solve this problem is to set the route through outer space via a satellite. The U.S.A., European countries, and China are conducting research aiming at quantum communications between satellites and the ground.

(1) Open space propagation tests on the ground in the U.S.A.

In the U.S.A., a research group at Los Alamos National Laboratory succeeded in a test of quantum communications over 10 km by open space propagation (a method that does not use optical fibers). This is regarded as a remarkable success and could lead to high-speed quantum communications using outer space because the distance used in the tests was equivalent to the optical depth between satellites and the ground that amounts to several hundreds kilometers[18].

(2) European experimental plan for quantum communications using the International Space Station

Europe is conducting long-distance field tests of quantum cryptography communications using open space propagation on the ground. Professor Zeilinger of the University of Vienna (Austria) and his group performed open space propagation experiments to test the entanglement of quanta using optical ground stations (OGS) of the European Space Agency (ESA) in the open space between La Palma Island and Tenerife Island (both are part of the Spanish Canary Islands), which are 144 km apart[19]. To verify the results of the ground experiments over a longer distance, the group is planning a quantum cryptography communications mission called "SPACEQUEST" in outer space. A transmitter will be installed on the International Space Station and experiments on quantum communications in space over a distance of more than 1,600 km between the Space Station and the ground will be conducted[20]. This project has received high praise from ESA. It is scheduled to launch the equipment containing two optical terminals made by Contraves of Switzerland around 2011 at latest.

(3) Chinese plan for quantum communications tests using manned spacecraft

In China in 2005, Professor JianWei Pan of the University of Science and Technology of China succeeded in a test of quantum entanglement cryptography communication over a distance of 13 km using the open space propagation method, a distance which is presently the world record[21]. Following this, quantum communications test equipment is to be mounted on the manned spacecraft, "Shenzhou," scheduled for launch in 2008, and it is planned to conduct a quantum communications test over a distance of several hundreds kilometers. It should be noted that China may become the pioneer in long-distance communication using manned spacecraft on its own ahead of the U.S.A. and Europe. China's main objective is to develop a system capable of achieving communications between two points on the ground via satellites as in the case of present satellite communications. It is supposed that China is trying to realize high-capacity secure communications by replacing conventional microwave communications with quantum communications.

(4) Start of space quantum communications in Japan

In Japan, NICT is conducting research on space quantum communications. In addition to the experiments on optical communication technology in outer space between OICETS and the ground, NICT is carrying out basic research on quantum communications. This may include field tests for high-capacity (terabit class), global-scale, long-distance quantum communications in the open space between outer space and ground by combining space robot technology, which is a Japan's specialty, and quantum communications technology, into which research is just beginning. In order for Japan, which does not have its own manned spacecraft, to lead the world in this field, it is necessary to demonstrate space quantum communications over longer distances using communication test satellites such as OICETS. With the future advances that will be made in quantum communications technology, it is expected that more attention will be focused on space quantum communications, which is still in its infancy.

7 Conclusion — The optimal form of technical development and applications of the telecommunications satellite systems —

Although satellite communications technology seems to have reached maturity, ETS-VIII and WINDS, in accordance with the Third Science and Technology Basic Plan, are expected to generate new communication technologies that represent a departure from conventional commercial satellite communications. It is important to fully incorporate such new technologies into our daily life when they are developed, and, to accomplish this goal, the following need to be prepared including infrastructure development and improving the handling skills of users.

(1) Utilization of satellite communications in times of disasters and emergencies

Although catastrophic disasters have occurred frequently recently, no serious problems have affected communication networks, and the weaknesses of terrestrial communication networks seem to have been overlooked. However, catastrophic disasters, whether natural or human, accompanied by the destruction of communication infrastructures can occur at any time. Furthermore, even if communication channels are not destroyed, line connections are often disrupted due to communication congestion. Space infrastructures can overcome the weaknesses of terrestrial infrastructures, such as communication blackouts and traffic congestion, at times of disasters. Therefore, Japan should establish a "satellite that enables immediate information transfer to the public regarding disasters and emergency management" as one of the most important infrastructures. It goes without saying that software relating to how to communicate what information and practical procedures for reliable implementation of measures are important. Communication routes in the event of disasters must be established and training and exercises including the operation of emergency power sources should be periodically conducted so that the positive effects of the nationwide instantaneous alert system (J-Alert) using satellite communications as the core system are maximized. It is desirable that not only employees of local governments but also local senior engineers participate in the training and exercises.

(2) Continuous utilization of telecommunications satellite systems for improved convenience

In order to improve the convenience of mobile communications and provide ubiquitous Internet connection, it is necessary to continue to provide the communication functions of ETS-VIII and WINDS, which are now going to be operated on an experimental basis. Although permanent satellite systems must be procured globally because of the Super 301 Clause, this fact is not necessarily a barrier to the promotion of technical development in Japan. Japan should propose specifications for satellites required to serve the national interest and security including world class functions that have been developed in Japan. This would improve the chances that satellites equipped with devices and equipment developed in Japan are selected in the course global procurement. To bring about this situation, it is necessary to establish a system in which technical development, production, and operation are continuously being fostered.

(3) Promotion of research on future technologies based on satellite communications technology

Japan must decide on what direction technical development should take in satellite communications systems after the targets of the Third Science and Technology Basic Plan has been achieved. In addition to the modification of technologies such as improving the capacity and accuracy of communications using electromagnetic waves and integration with the Internet, utilization of outer space as a research area for quantum communications technology is one possible future theme of research. Before quantum communications technology becomes widely applied in society, much research and development work including the development of new photonic elements and transmission systems must be conducted. Therefore, this is one direction that Japan should take in promoting research on space quantum communications that use space propagation over long distances (ranging from several thousands to several tens of thousands kilometers) based on the satellite communications technologies developed by Japan.

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Glossary

*1 Super 301 Clause: Super 301 Clause is one of the provisions in the Omnibus Trade and Competitiveness Act (1988) that allows sanctions to be imposed on foreign countries. Its purpose is to strengthen Article 301 of the Trade Act, and stipulates that when unfair trade practices or trade barriers are suspected, the Office of the United States Trade Representative (USTR) will negotiate to improve the situation. If the situation does not change, retaliatory sanctions may be imposed on the relevant country. The Japanese government was asked to procure telecommunications satellites from global sources, and the Japanese government has procured all of its geostationary telecommunications satellites from the U.S.A. since then.

Abbreviations

- *ESA:* European Space Agency
- *ETS:* Engineering Test Satellite
- *JAXA:* Japan Aerospace Exploration Agency
- *LDREX:* Large Deployable Reflector Small-sized Partial Model
- *NICT:* National Institute of Information and Communications Technology
- *OICETS:* Optical Inter-orbit Communications Engineering Test Satellite
- *WINDS:* Wideband InterNetworking engineering test and Demonstration Satellite

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