

Japan's Earth Observation Satellite Development Plan  
and Data Utilization Strategy

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## 1. Introduction

“Ohsumi,” the first satellite in Japan, was launched in February 1970 together with the dreams of the nation. Space development in Japan has subsequently proceeded steadily, contributing to the evolution of science and enhancing the convenience of national life. This aspect will never change.

The importance of ensuring the safety and security of society through wide-area environment monitoring and real-time understanding of the damage from disasters has increased rapidly in recent years. At the same time, obtaining information regarding land vegetation and ocean condition will enable more efficient and effective implementation of production activities, including agriculture and fisheries. Thus, the wide-range and continuous observing system is indispensable for social and economic development and for environmental preservation of Japan. Its implementation as part of the social infrastructure is crucial.

Taking a global view of present conditions reveals that mankind is facing serious problems that may threaten its existence, such as global warming and widespread environmental destruction. Abnormal weather conditions and water shortages in various countries may cause a security problem in Japan which relies on overseas resources for much of its food supply. The Earth observation system will play an important role in predicting these problems on a global scale and will prevent or reduce the influences of such problems. It is therefore important for Japan to make positive efforts to develop this system, not only to fulfill our duties in international society but to firmly establish a base for Japan’s future existence.

On the other hand, measures taken by Japan toward a comprehensive observation system integrating satellites and ground observation networks, and efforts to develop and operate user-friendly observation and data utilization systems have been insufficient. Therefore, the Earth observation system is not yet an integral part of the social infrastructure.

These circumstances exist not only in Japan but everywhere in the world. International society has recognized the necessity of enhanced efforts toward a comprehensive Earth observation system and has taken a large step toward establishing the system.

The urgent necessity of coordinated observations of the Earth system was emphasized at the World Summit on Sustainable Development (WSSD) held in Johannesburg in September 2002.

Reinforcement of international cooperation for global Earth observations was advocated at the G8 Evian Summit in June 2003. Japan expressed its willingness to positively contribute to forming an international cooperation framework for global Earth observations by proposing to hold a ministerial meeting in Tokyo. It was agreed at the 1<sup>st</sup> Earth Observation Summit held in Washington, DC, in July 2003 that nations will cooperate to establish a comprehensive, coordinated, and sustained Earth observation system.

The framework for a 10-year implementation plan to build up GEOSS (Global Earth observation System of Systems) was agreed upon at the 2<sup>nd</sup> Earth Observation Summit held in Tokyo in April 2004. The GEOSS 10-year implementation plan was approved at the 3<sup>rd</sup> Earth Observation Summit held in Brussels in February 2005. In response, each country now starts to implement GEOSS.

Based on such international activities, the Council for Science and Technology Policy in Japan issued the “Earth observation Promotion Strategy” in December 2004 to clearly state the Japan’s basic policy in Earth observation and important issues to be strategically resolved.

In addition, the Council for Science and Technology has collaterally proceeded with deliberations of important policies for establishing the Third Science and Technology Basic Plan. The Council indicated in their report that it is necessary to carefully select and promote “important technologies that are the basis for sustainable development of the nation that will be promoted with a long-term national strategy (national key technologies)” (“Important Measures of the Third Science and Technology Basic Plan (interim report), Special Committee on Science and Technology Basic Plan, Council for Science and Technology”). In the interim report, the Council cited an integrated observation and monitoring system on a global scale as a representative example of national key technologies.

The Space Activities Commission then proceeded with investigations and deliberations for the development plan and optimal data utilization of Earth observation satellites in the future. The results, “Japan’s Earth Observation Satellite Development Plan and Data Utilization Strategy, are reported here.

## 2. Present Status of Earth Observation Satellites

### (1) GEOSS 10-Year Implementation Plan and Japan's Strategy

GEOSS was advocated with a strong understanding of international society and the necessity of obtaining and distributing wide-ranging and accurate observation information of a global scale phenomena to avoid the crises that human society faces, such as major natural disasters, diffusion of harmful substances beyond national borders, exhaustion of energy resources, global warming, and water shortages.

Its purpose is to achieve comprehensive, coordinated, and sustained observations of the Earth system to improve Earth observing of the atmosphere, oceans, lands, ecosystems and their functions; increase the understanding of Earth processes; and improve predictions of the Earth phenomena.

These observations provide information that will be used as the basis for sound decision making for a wide-range of benefits to mankind in various fields, such as prevention and mitigation of damage from disasters, understanding environmental impacts on health and well-being, improved energy resource management, prediction of climate variability and change and avoidance of danger, improved water resource management through understanding of water cycle, improved weather forecasts, enhancement of the management and protection of ecosystems, achievement of sustainable agriculture, prevention of desertification, and conserving biodiversity.

The GEOSS 10-year implementation plan will proceed through full-scale coordination to integrate the Earth observations planned by national and international organizations, under the Group on Earth Observations (GEO), which will become the promoting entity of the plan.

Japan expressed its willingness to contribute to acquisition and delivery of complex and useful observation information by fully utilizing its advanced science and technology, and also to promote capacity building efforts for developing countries, primarily in three fields: global warming and carbon cycle change, climate change, including water-cycle variation, and natural disasters (hereafter referred to as “three contributing fields”) at the 2<sup>nd</sup> Earth Observation Summit. Japan is geographically located in the Asian monsoon region and a quake-prone zone; therefore has undertaken many experiments in measures against the water cycle change and natural disasters, and can provide its rich knowledge to the world.

In the report of “The Earth Observation Promotion Strategy”, the Council for Science and Technology Policy presented three basic strategies of Japan, which is in a leading position in Earth observations. These strategies included development of an integrated Earth observation system driven by user needs, securing Japan's

uniqueness and displaying its leadership in international integration of Earth observation systems, and establishment of an Earth observation system by reinforcing cooperation with the Asia and Oceania regions. The Council also indicated that improving the Earth observation capability of Japan through development of an integrated Earth observation system will strongly promote implementation of the GEOSS 10-year plan, and in this way Japan, a country with advanced Earth observation abilities, can fulfill its duties to international society. The Council also proposed that it would be appropriate to create comprehensive promotion organization under the Council for Science and Technology to create practical implementation policies based on the “Earth Observation Promotion Strategy”.

This promotion organization is organized as an Earth Observation Promotion Section under the Subdivision on R&D Planning and Evaluation, Council for Science and Technology, and will conduct the required investigations and deliberations.

## (2) Present Status of Earth Observation Satellites and Related Issues in Japan

### 1) Present status

Japan has developed and operated six geostationary satellites from the development of Himawari, based on the technologies introduced by the United States, up to the Multifunctional Transport Satellite 1 Replacement (MTSAT-1R), Himawari No. 6 in 2005. Japan also developed and operated five orbiting satellites up to the Advanced Earth Observing Satellite II (ADEOS-II), “Midori II” in 2002 and an additional three types of Earth observation sensors for orbiting satellites. These sensors are the Precipitation Radar (PR) on the Tropical Rainfall Measuring Mission (TRMM), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on Terra, and the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) on Aqua.

Procurement and operation of a geostationary satellite by the Ministry of Land, Infrastructure and Transport was achieved as “Himawari No. 6” through collaborative development and operation between the Japan Meteorological Agency, under the former Ministry of Transport as the user organization, and the former National Space Development Agency of Japan (NASDA) as a R&D organization. In contrast, no domestically-produced orbiting satellites have been operated since the accident of “Midori II” and only three sensors (PR, ASTER, and AMSR-E), which are flying on orbiting satellites operated by foreign organizations, are in operation.

Japan’s technologies for sensors, analyses of satellite data, and related areas have advanced to a level comparable with any other country due accumulated development experience. However, long-term and continuous responses to user needs are still insufficient in Japan due to the satellite development focused on novel technologies, and the limited launching opportunities. Therefore, satellite

data in Japan is restricted to supplementary utilization for research or to complementing other observation data, except in limited fields such as weather forecasting. Satellite data are thus not vigorously utilized by a wide range of users.

## 2) Necessity of a satellite plan with long-term continuity

The satellites and sensors planned in Japan from 2006 to 2015, the assumed period for establishing GEOSS, currently include the Dual-frequency Precipitation Radar (DPR) on the core satellite of Global Precipitation Measurement (GPM) plan, and the Greenhouse Gas Observing Satellite (GOSAT). These will follow the Advanced Land Observing Satellite (ALOS) planned to be launched in the summer of 2005, which has been approved by the Space Activities Commission. Development of the Multifunctional Transport Satellite No. 2 (MTSAT-2) is in progress. However, the satellites and sensors that are currently in operation or under development are an insufficient Japanese contribution as part of GEOSS, so Japan must establish a satellite development plan that specifically correspond to the three contributing fields consisting with the plans of other countries.

Therefore, the plan should take account of assuring the long-term continuity required for utilizing satellite data not only for research but also application field. The plan should cover the next 15 years from the standpoint of long-term observation for global climate change, and the period required for satellite development.

## 3) Issues in promoting satellite utilization

In developing Earth observation satellites it is essential that sufficient cooperation and coordination exist between developing organizations and users of various Earth observation data including satellite data, such as ministries and agencies, research organizations, and researchers.

Furthermore, the scope of satellite utilization can be expanded by aiming at actualization of a collaborative structure such as the above-mentioned example of meteorological satellite development, for which the user ministries, agencies and organizations play appropriate roles according to the objective and promote the plan in cooperation with the organization engaged in research and development of the satellite and sensor technologies. To establish the structure, the usefulness of satellite data must be clearly recognized by the user ministries, agencies and organizations, and advanced efforts toward application of the satellite data must be promoted through academic, business and governmental circles. The benefits must also be presented positively to society.

It is also necessary to develop a system that can provide various Earth observation data in line with user needs and provide an environment in which users can obtain necessary data at the appropriate time and in the proper form.

## (3) Trends of Earth Observation Satellite Development in Foreign Countries

Foreign countries that have promoted utilization of Earth observation satellites are developing satellite data applications in the fields of meteorological observation

and land management, based on the accumulated results of research and development.

### 1) Trends in the United States

Development and operation of Earth observation satellites in the United States are proceeding as follows. The National Aeronautics and Space Administration (NASA) conducts research and development as well as technical demonstrations of advanced sensors as a R&D organization, while continuous and regular satellite observations are undertaken by operational organizations.

The National Oceanic and Atmospheric Administration (NOAA) and the United States Department of Defense (DOD) are presently developing the National Polar-orbiting Operational Environmental Satellite System (NPOESS), which is designed for meteorological observations and environmental observations as the successor to the Polar Operational Environmental Satellite (POES) series and the Defense Meteorological Satellite Program (DMSP) series currently in operation. NASA is developing and demonstrating the primary sensors in preparation for configuring NPOESS. The results will be provided to NOAA and DOD which will perform full-scale preparation of the system.

The policy for management of satellite data states that the operational organization performs long-term storage, as indicated by the Federal Geographic Data Committee (FGDC). The satellite land data obtained by NASA is transferred to the U. S. Geological Survey (USGS) and the marine data to NOAA.

In addition, NASA plans to develop advanced sensors for specific observations, such as for global rainfall observation in the Global Precipitation Measurement (GPM) plan, carbon dioxide concentration in the atmosphere by the Orbiting Carbon Observatory (OCO), global sea surface salinity by Aquarius, and soil moisture content by the Hydrosphere State Mission (HYDROS).

### 2) Trends in Europe

The European Space Agency (ESA) and European Union (EU) are planning to integrate the satellites that are already in operation and those that will be launched in the future to establish the Global Monitoring for Environment and Security (GMES), with the objective of autonomous monitoring of the global environment and security issues. ESA is currently implementing the Earth Watch missions as the first phase of that plan.

The Earth Watch missions were designed to perform observations for application fields related to strategically and economically important fields (agriculture, forestry, geology, environment monitoring, risk management, marine and coastal monitoring, cartography, utilities and planning, and security). Though the development and initial operation of the system, including satellites, will be implemented by ESA, essential to the system is the concept of guaranteed provision of services in the long-term outside ESA.

The Earth Explorer missions, which are also implemented by ESA, are research and development plans to contribute to Earth sciences providing advanced observation for ice sheets, gravity field, three-dimensional wind vector, soil

moisture, ocean salinity, geomagnetic field, and other areas.

The European Organization for the Exploitation of Meteorological Satellites (EUMESTAT) will participate in the above-mentioned NPOESS plan in the United States through the development and operation of a polar-orbiting meteorological satellite (MetOp).

### 3) Trends in Asia

Development of Earth observation satellites in Asian countries is steadily transitioning from the technical testing and demonstration stages to the application stage. The fields of satellite data utilization are also expanding.

India has vigorously implemented space development since the 1970s. The Indian Space Research Organization (ISRO) and National Remote Sensing Agency (NRSA) have undertaken continuous meteorological, marine and terrestrial observations (resource exploration, agricultural use, and disaster monitoring) by satellites since the 1980s.

China began utilizing Earth observation satellites in the 1970s. Currently the China National Space Administration (CNSA) is systematically implementing development and utilization of satellites for meteorology, natural resources, marine, and disaster monitoring based on the white paper on space development published in November 2000, "China's Space Activities."

Korea has implemented development of space technologies on a large scale since the 1990s. The Korea Aerospace Research Institute (KARI) and Korea Advanced Institute of Science and Technology (KAIST) are developing satellites and sensors based on the technologies introduced from Europe and America for ocean observations, land-use assessments, and disaster monitoring from Earth orbit as well as meteorological observations and ocean observations for fisheries from geostationary orbit.

### 3. Characteristics and Roles of Earth Observation Satellites

#### (1) Characteristics of Earth Observation Satellites

Satellites enable surface observations of the entire globe with uniform accuracy, which is difficult to achieve by in-situ observation using ground observation networks, balloons, ships, buoys, and airplanes. However, there are some technical restrictions, such as the observation accuracy being less than that of in-situ observations and the requirement for a large system consisting of multiple satellites to enable observations at a high frequency. In contrast, in-situ observations are extremely accurate and also enable continuous observations by permanent observation devices. However, installation of those observation devices is restricted by geographical conditions, and the observation area by individual devices is limited.

Development of a satellite takes several years including the research phase, and also requires substantial funds. However, attempting to achieve the same observation area and spatial resolution as those of satellites with a ground observation network would require a tremendous amount of time and funds for installation and operation of observation devices, which is simply not realistic.

Thus, it is important to establish an effective observation system through a combination of the features of satellite observations and in-situ observations to implement accurate, temporally and spatially continuous observations of the entire globe. It is presently possible to mutually complement the accuracy as well as the temporal and spatial continuity between them and produce value-added information by integrating satellite-observation data and in-situ observation data using data-processing technologies and numerical models that are currently being developed.

#### (2) Contribution to Social and Economic Activities

##### 1) Provision of the basis for sound policy decisions

Satellite observations enable us to observe the entire globe uniformly within a short time, and thus a huge volume of data concerning the Earth phenomena can be obtained promptly and objectively. It is possible to contribute to sound policy decisions in international society by providing scientific information based on such data for deliberations at the Intergovernmental Panel on Climate Change (IPCC), verification of the achievement level of the greenhouse gas reduction target based on the Kyoto Protocol, and elsewhere.

##### 2) Contribution to the applications in various fields

Observation data obtained from satellites are applied to numerical models in the field of weather forecasting, thereby contributing to the enhancement of forecasting accuracy. Furthermore, satellite observations enable us to obtain a wide

range of data within a short time, which can improve the efficiency of operations in the fishery field by utilizing data of sea surface temperature, and ocean color. Satellite data is used in the fields of agriculture and forestry to assess crop conditions, obtain high crop prospects, and survey forest changes. Contributions to such fields as resource and energy management and water resource management are also expected in the future. Information obtained from ALOS could also be used as basic information for land management, such as cartography and land use classification.

It will be possible to prevent and mitigate damage from disasters such as large-scale fires, volcanic eruptions, strong earthquakes and tsunamis, oil spills, typhoons, landslides, floods and inundations, and droughts promptly and appropriately by monitoring the disaster site and predicting the influences through the use of satellite data.

### 3) Support for developing countries

The state of developing countries can be difficult to assess due to the lack of a fully arranged social infrastructure. Support through the delivery of satellite data would contribute to efficient and effective land management, including agriculture and forestry and land use, and a wide range of measures against disasters.

## 4. Earth Observation Satellite Development Plan in Japan

### (1) Basic Policy

Japan is actively facilitating the promotion of global Earth observation and is expected to make positive contributions to the establishment of GEOSS. Efforts to achieve an Earth observation system with integrated satellite observations and in-situ observations can only be enhanced through an initiative of the government. Therefore, a basic policy must be implemented to continuously promote the development of Earth observation satellites under the initiative of the government. However, it is necessary to establish and promote a satellite development plan by considering the Earth observation system to be part of the social infrastructure of Japan and to propose long-term continuity and independent operation of data acquisition and provision.

Japan should also further develop its unique technology by making the best use of its technological advantage and display international leadership in cooperation with the satellite development plans of other countries.

It is crucial that Earth observation satellites that play an important role as part of the social infrastructure be reliable, and thus it is necessary to implement their development based on the policy found in “Measures to Be Taken in the Future for Improving the Reliability of Satellites” (March 2005, Promotion Subcommittee, Space Activities Commission).

A well designed development strategy for sensors should place the highest priority on meeting the technical requirements for long-term observations. The development strategy should also consider that advanced technologies will lead to further sophistication and diversification of data utilization, which may ultimately produce a technical development breakthrough.

### (2) Specific Development plans

The observation parameters and observation levels (accuracy and frequency) to which the highest priority should be given in efforts by Japan for promoting Earth observation in the future examined by a working group on Earth observation under the Expert Panel on the Promotion Strategy for Prioritized Areas, Council for Science and Technology Policy. The working group which had the participation of many academic experts identified the parameters and levels, and it is appropriate to use their counsel as the basis for establishing the satellite development plan.

The types of sensors required to meet the observation needs in the three contributing fields identified through the working group and discussions in this subcommittee are summarized in Table 1. The plans for Earth observation satellites that will be required over the next 15 years in the three contributing fields are summarized in Fig. 1-1 (outlined version where the representative observation parameters alone in each contributing field are designated in Fig. 1-2.), based on

Table 1. The number of satellites and the replacement time of each satellite to achieve continuous observation over a long period will be clarified in the process of designing each satellite system; the observation continuity with multiple satellites is represented by a single line in Figs. 1-1 and 1-2.

Concepts concerning responses to the observation needs in the three contributing fields and the satellite development plans presented in these figures are as follows.

#### 1) Field of disaster prevention

Observations using primarily medium- to high-resolution optical sensors to enable fine detection of the Earth's surface and active microwave sensors (synthetic-aperture radar) to enable day and night observations regardless of weather are required in the field of disaster prevention.

Therefore, observations using the high-resolution optical sensor and the synthetic-aperture radar on ALOS are essential to meet the observation needs in the field of disaster prevention and must be implemented continuously, even after ALOS.

Various candidates can be assumed for the observation system with the satellite after ALOS, such as continuous observation with a geostationary satellite with optical sensors, high-frequency observations with multiple orbiting satellites, and private satellite plans; however, the observation needs that can be met by these satellites differ. Therefore, a next-phase disaster monitoring satellite must be developed in the future after determining the actual user needs in detail. The contents of the observation system can then be designated based on the user needs, including the configurations and specifications of the satellites and sensors. This work must be carried out based on examinations of the total picture of the observation system in the field of disaster prevention.

Expectations for utilization of satellite data in this field are increasing, and thus it is necessary to establish a promotion structure in which operational organizations as well as disaster management ministries and agencies play greater roles in the development and operation of satellites.

#### 2) Climate change and water cycle field, global warming and carbon-cycle field

Various types of information are required to assess the overall state of the Earth in the fields of climate change, water cycle, global warming and the carbon cycle.

Thus, observations with sensors that encompass a wide range of wavelengths from visible and infrared radiations to microwaves are essential.

Therefore, successors to the multi-wavelength radiometer and microwave radiometer on "Midori II" will be developed to implement long-term continuous data acquisition. Development of Cloud Profiling Radar (CPR), which plays an important role in clarifying the climate-change mechanism, will be implemented by utilizing technologies of active microwave sensors, an area where Japan has an advantage.

A successor to GOSAT will also be developed for continuous greenhouse gas observations, and the accuracy of measuring the concentrations and spatial

distributions of sink and source volumes of greenhouse gases, which are required to verify any reduction of greenhouse gas in each country, will be improved. Many methods can be considered for improving the accuracy, such as modification of the passive optical sensor adopted in GOSAT and development of a new active optical sensor; however, it is necessary to continuously conduct examinations, including technical feasibility evaluations.

Satellite observation technologies are still in the demonstration phase and further technical development is needed for transition into application fields. Development and operation of satellites should be undertaken primarily through the initiative of the R&D organization under the assumption of future work divisions with user organizations, and under cooperation with researchers who are presently the primary users.

These plans will meet a wide variety of needs in application fields in addition to the needs in these three contribution fields, including (a) clouds, rainfall, and water vapor volume related to weather forecasts, (b) sea surface temperature and ocean color distribution related to fisheries, (c) tree-planting areas and farmland areas related to agriculture and forestry, (d) land use related to land conservation, and (e) crustal movements and stereoscopic images of ground surfaces related to surveying and cartography.

Development of Earth observation satellites in which the government plays the leading role should be implemented using this plan. However, revisions based on social circumstances should be made appropriately as needed.

## 5. Ideal Ways to Utilize Earth Observation Data

### (1) Basic Concepts

A system that integrates diversified data obtained from satellite and in-situ observations and continuously provides it as value-added information is an important component of an Earth observation system which should be made part of the social infrastructure, and it is appropriate for the system to be developed through the initiative of the government.

This system must be established considering the overall data flow, ranging from data collection, integration, and archiving to supply. Examination of the system architecture including standardization of the interface specifications, will be necessary to configure a system composed of connections of multiple functions while maintaining consistency between those functions and also securing interoperability between some systems. Expansion of data utilization must be required while proceeding steadily with this process by configuring parallel pilot systems in individual fields. A system for operational use will ultimately be achieved through fusion of these attempts.

Designing the system from the viewpoint of the users is essential in achieving a system that is convenient for various users. This work must be performed through collaboration among data providers and users.

Moreover, the social value of the data will likely increase rapidly through a wide range of data sharing beyond the differences in observation methods, such as satellites, ground observation networks, ships, and borders of nations and organizations, and thus it is necessary to establish the system within the framework of international cooperation.

### (2) Developing an Earth Observation Data Integration and Provision System

#### 1) Basic configuration of the system

The many work items listed below, and functions to achieve them, are required to make Earth observation data valuable information for users.

- (a) Standardization of items and contents required for data sharing
- (b) Various data observations
- (c) Search for, collection, and compilation of widely available observation data
- (d) Collection and compilation of social and economic data as required
- (e) Quality control, archiving, and lifecycle management of collected data
- (f) Integration of multiple data with different observation times and places to handle them integrally
- (g) Advanced analysis and visualization process to depict the behavior of the real world, such as natural phenomena, from the data
- (h) Data assimilation to improve the accuracy of numerical models and to secure temporal and spatial continuity of the observation data
- (i) Conversion of data obtained from observation and models into valuable information

- (j) Fusion of information to flexibly meet user needs
- (k) Support for utilization of data, such as data retrieval functions
- (l) Provision of information and data to users

It is also essential to enable not only users but data acquisition organizations to realize the effect of the data integration and provision system, such as by promoting data provision by feeding back the result of data integration and requests for data integration to the organizations so that data directly provided by the organizations is also easy to use.

A schematic diagram depicting the above functions and elements is presented in Fig. 2; the Earth observation data integration and provision system will be achieved through connections of these functions and elements.

## 2) Promotion policy

The development of the data integration and provision system should proceed systematically under a clear strategy after repeated discussions attended by both data providers and users and by considering the discussions on the system architecture as a whole. This process must also proceed steadily based on international agreements in close cooperation with national and international data acquisition organizations and data centers of research communities.

The data integration and analysis functions in particular must be designed for the maximum convenience of the users. Data users must therefore play important roles in the process of configuring the system, such as selection of data as the object of integration as well as development of the collection and analysis functions. The Global Ocean Data Assimilation Experiment (GODAE) and Coordinated Enhanced Observing Period (CEOP) can be cited as sample models of configuring a system through the initiative of users.

Moreover, participation by information technology professionals is essential as well since advanced information technologies are required to develop a system that manages diversified and substantial volumes of data.

It is also important to arrange an environment in which data holders and organizations can provide data to the system through such means as securing funds to process the conversion into the required data.

Points to consider configuring the data integration and provision system in each of three contributing fields are described below.

A system to provide data both domestically and to the Asia-Pacific regions must be established promptly since ALOS data is widely expected to contribute to monitoring disasters. Cooperation between related ministries and agencies as well as organizations both domestically and internationally will facilitate developing the system for comprehensive data utilization including data communication and information distribution.

It is necessary to configure a pilot system that processes and provides data in the fields of global warming, carbon-cycle changes and climate change and water cycle, not only for research and policy examinations but for the fields of

agriculture, fishery, and weather forecasting. This system must be developed and maintained so that data can be utilized constantly.

Discussions will progress further in the Council for Science and Technology to configure the data integration and provision system based on the concepts described above and in line with the Earth Observation Promotion Strategy.

### (3) Ideal Ways to Provide Data

Data and information obtained from Earth observations implemented by the initiative of the government must be made widely available to the nation to benefit society.

The data acquisition organizations must therefore implement standard data processing and provide it to users to enable people other than observation technology experts to utilize the data. An environment must then be established in which various needs can be met through contributions by private entities. Utilization of Earth observation data should be promoted effectively by connecting these activities to the configuration of the Earth observation data integration and provision system.

Visual images on the Internet and as public relations activity for Earth observations could be implemented by the data acquisition organizations.

Users of Earth observation data can be broadly divided into two categories. One consists of users of a very public nature who are generally expected to contribute to the promotion of data utilization through establishment of GEOSS and research. The other consists of users for other purposes including commercial use.

In principle, only the actual cost for copying data is generally charged to users in the former category. Since the lowest possible price is desirable for promoting utilization of data, data for the users should be provided at almost no charge by facilitating online data access on networks.

In contrast, while a low price is desirable from the standpoint of users in the latter category, it is necessary to take care not to undersell the data sold by private companies.

In addition, rules must be established for developing and distributing secondary processed data as to solve issues of Earth observation data provision services, and they must be encouraged to promote data utilization.

## 6. System Development through International Cooperation

### (1) International Cooperation Policy

Japan has so far played a leading role in international cooperation concerning Earth observation, primarily in the field of satellites, through the Committee on Earth Observation Satellites (CEOS) and Integrated Global Observing Strategy (IGOS). Japan should enhance its leadership in the future to respond to expectations held by international society.

It is important for Japan to introduce proposals for the global Earth observation plan and the data integration and provision system configuration plan when discussing GEO to lead the realization of the GEOSS 10-year implementation plan. It is also necessary for the Asia-Pacific regions to promote cooperation among nations in developing the Earth observation system and to positively promote capacity building in Earth observations, primarily to those of developing countries, through data delivery and other means.

### (2) International Cooperation Plan

#### 1) International cooperation in developing a satellite observation system

In addition to implementing the offer of ALOS data to the International Charter “Space and Major Disaster”, which Japan joined in February 2005, Japan intends to establish a framework for sharing disaster monitoring data, primarily using a near real-time ALOS data distribution system through the Asia-Pacific Regional Space Agency Forum (APRSAP).

Japan will provide international society with the objective information required in the field of global warming and carbon cycle to verify the reduction of greenhouse gas through development and operation of GOSAT and its successor.

Furthermore, Japan will provide the DPR for the field of climate change and water cycle, since it has an advantage, as the calibration standard for satellites in developing an international observation network by GPM. Japan will also contribute to improving the observation frequency and accuracy by operating the successor to “Midori II” in cooperation with the international global Earth observation plan of NPOESS. Japan will contribute as well to the progress of international climate change research by providing foreign countries with satellite observation data that can be obtained by Japan’s advanced technology.

#### 2) International cooperation in utilizing Earth observation data

Japan will positively contribute to preparation of international standards to enable Earth observation data-sharing held by organizations of individual countries, and will further enhance human resources development and technical demonstrations aiming at promoting data utilization and upgrading utilization technologies, primarily in developing countries.

## 7. Conclusions

GEOSS is a plan that is expected to contribute significantly to the sustainable development of Japan and the whole world.

To steadily promote its establishment, it is essential to obtain understanding and support from a wide variety of beneficiaries, ranging from researchers in ministries, agencies, organizations, enterprises and universities as direct users, to common people who should ultimately enjoy the benefits. This can be accomplished through sufficient clarification and coordination with regard to the benefits that will accrue to society and the ideal ways for promotion by those who engage in the establishment.

The same can also be said about the development of satellite as a primary method of observation.

Those who engage in the development of satellites are compelled to consistently attempt to expand dialogues and extend cooperation with those who directly utilize satellite data and with common people. Accumulation of such efforts is the only way to make Earth observation satellites a part of the social infrastructure. We hope that every person who engages in the development of Earth observation satellites will strive for the fulfillment of GEOSS by actively responding to this imperative.

Furthermore, we hope that related ministries, agencies and organizations, including the Ministry of Education, Culture, Sports, Science and Technology (MEXT), will take the necessary measures by acting in concert toward configuring the Earth observation data integration and provision system and by promoting data utilization.

Table 1 Types of sensors required to meet the observation needs in the three contributing fields of Japan

[ Global Warming and Carbon Cycle Change ]

	Source of requirement	Category	Observation needs	Priority	Optical sensor				Radio wave sensor				Notes
					High resolution (several m - dozens m)		Middle resolution (hundreds m - several km)	Low resolution (several km - dozens km)	Low resolution (several km - dozens km)			High/middle resolution (several m - hundreds m)	
					Visible high resolution sensor (panchromatic)	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar	
1-1	CSTP global warming sub working group SAC special subcommittee (global warming field)	Monitoring of actual emission and concentration	Vertical profile and time series data of CO2 and methane gas in the atmosphere	E				B					Sensor development is necessary to achieve 1ppmv observation accuracy (target of current sensor is 4ppmv).
1-2	CSTP global warming sub working group SAC special subcommittee (global warming field)	Monitoring of actual emission and concentration	Absorption and emission of CO2 by land ecosystem	E		A	A					A	Land vegetation, biomass, forest fire, etc.
1-3	CSTP global warming sub working group SAC special subcommittee (global warming field)	Understanding of global warming process	Comprehensive data	E			A		A	A	A		Combined satellite observation, water cycle data measurement, etc. for verification of global climate model.
1-4	CSTP global warming sub working group SAC special subcommittee (global warming field)	Understanding of global warming process	Distribution and change of global primary production in the ocean	E		A	A						chlorophyll density, suspended solid, etc.
1-5	CSTP global warming sub working group SAC special subcommittee (global warming field)	Understanding of global warming process	Cloud, aerosol, radiative forcing	E			A (distribution)		A	A	A (Cloud profile)		Cloud, aerosol, precipitation, water vapor, etc.
1-6	CSTP global warming sub working group SAC special subcommittee (global warming field)	Understanding of global warming process	Tropospheric ozone	H				A					
1-7	CSTP global warming sub working group SAC special subcommittee (global warming field)	Influence of global warming	Global change of cloud, aerosol, precipitation, vegetation, snow and ice, ground surface temperature, sea surface temperature	E		A	A		A	A	A	A	
1-8	CSTP global warming sub working group SAC special subcommittee (global warming field)	Influence of global warming	Sea ice distribution in the Sea of Okhotsk.	H		A	A		A			A	
1-9	CSTP global warming sub working group	Influence of global warming	Ice sheet distribution in the Antarctica	E		B	A		A			A	Estimate from image in case of high resolution multispectral sensor.
1-10	CSTP global warming sub working group	Influence of global warming	Ecosystem change in the damage area	H		A	A					A	
1-11	CSTP global environment sub working group	Monitoring of actual emission and concentration	wide area monitoring of total amount and vertical profiles of ozone by satellite observation	H				A					
1-12	SAC special subcommittee (global warming field)	-	Sea surface wind speed	Not defined					A				

Legend symbol

Priority  
E : Observation needs especially with high priority  
H : Observation needs with higher priority

Availability to observation needs  
A : Available.  
B : Observation object, accuracy, frequency, etc. are insufficient.

[ Climate Change including Water Cycle Variation ]

	Source of requirement	Category	Observation needs	Priority	Optical sensor				Radio wave sensor				Notes
					High resolution (several m - dozens m)		Middle resolution (hundreds m - several km)	Low resolution (several km - dozens km)	Low resolution (several km - dozens km)			High/middle resolution (several m - hundreds m)	
					Visible high resolution sensor (panchromatic)	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar	
2-1	CSTP global warming sub working group	Monitoring of actual emission and concentration	Vertical profile and time series data of CO2 in the atmosphere	E				B					Sensor development is necessary to achieve 1ppmv observation accuracy (target of current sensor is 4ppmv).
2-2	CSTP global warming sub working group	Monitoring of actual emission and concentration	Absorption and emission of CO2 by land ecosystem	E		A	A					A	Land vegetation, biomass, forest fire, etc.
2-3	CSTP global warming sub working group	Understanding of global warming process	Comprehensive data	E			A			A	A	A	Combined satellite observation, water cycle data measurement, etc. for verification of global climate model.
2-4	CSTP global warming sub working group	Understanding of global warming process	Distribution and change of global primary production in the ocean	E		A	A						chlorophyll density, suspended solid, etc.
2-5	CSTP global warming sub working group	Understanding of global warming process	Cloud, aerosol, radiative forcing	E			A (distribution)		A	A	A Cloud profile		Cloud, aerosol, precipitation, water vapor, etc.
2-6	CSTP global warming sub working group	Influence of global warming	Global change of cloud, aerosol, precipitation, vegetation, snow and ice, ground surface temperature, sea surface temperature	E		A	A		A	A	A	A	
2-7	CSTP water cycle sub working group	Overall understandings of water cycle variation Improvement of prediction of water cycle variation	Observation of Asia-Australia monsoon and its water cycle variation	E		B	A		A	A	A	A	
2-8	CSTP water cycle sub working group	Exact monitoring of water cycle variation parameters	High frequency observation of global precipitation	E					A (distribution)	A (3D distribution)			
2-9	CSTP water cycle sub working group	Exact monitoring of water cycle variation parameters	Global observation of soil moisture	E					A	A		A	
2-10	CSTP water cycle sub working group	Exact monitoring of water cycle variation parameters	Global observation of snow			B	A		A				Estimate from image in case of high resolution multispectral sensor.
2-11	CSTP water cycle sub working group	Exact monitoring of water cycle variation parameters	High frequency global observation of water vapor	H					A				
2-12	CSTP water cycle sub working group	Exact monitoring of water cycle variation parameters	Global observation of cloud				A (distribution)		A		A (Vertical profile)		
2-13	CSTP water cycle sub working group	Overall understandings of water cycle variation	Water cycle variation observation of high latitudes of the Eurasian Continent	H		B	A		A	A		A	

	Source of requirement	Category	Observation needs	Priority	Optical sensor				Radio wave sensor				Notes	
					High resolution (several m - dozens m)		Middle resolution (hundreds m - several km)	Low resolution (several km - dozens km)	Low resolution (several km - dozens km)			High/middle resolution (several m - hundreds m)		
					Visible high resolution sensor (panchromatic)	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar		
2-14	CSTP water cycle sub working group	Overall understandings of water cycle variation	Systematic and automatic hourly observation of weather and hydrology, and vegetation investigation in an Asia region	H		B	B			B	B	B	B	Total solar radiance, net radiation, wind vector, temperature, humidity, air pressure, underground temperature, soil moisture, precipitation, snow depth, vegetation. Hourly observation is difficult only by Japanese satellite.
2-15	CSTP water cycle sub working group	Exact monitoring of water cycle variation parameters	Promotion of research and development of satellite sensor for water cycle observation	E						A	A		A	Soil moisture.
2-16	CSTP operational observation sub working group	Satellite observation (Monitoring of ocean and weather)	Clarify of ocean circulation											Sea surface salinity. Not planned in Japan (because of many difficulty such as high resolution and high accuracy sensor development and requirement for establishment of cal/Val system) As a foreign sensor, experimental observation by SMOS (ESA) and Aquarius (NASA) are planned.
2-17	CSTP operational observation sub working group	Satellite observation (Monitoring of ocean and weather)	Maritime and weather forecast, disaster monitoring, economic passage route	H						A				Sea surface wind and water vapor
2-18	CSTP operational observation sub working group	Satellite observation (Monitoring of ocean and weather)	Monitoring of primary production in the ocean				A							
2-19	CSTP operational observation sub working group	Satellite observation (Monitoring of ocean and weather)	Weather forecast Fisheries prediction Climate change prediction	E			A			A				Sea surface temperature
2-20	CSTP disaster, map and resource sub working group (energy and resource)	Estimation of forest biomass	Carbon stock and growth of trees	H	A	A	A						A	
2-21	SAC special subcommittee (water cycle field)	-	Combination of active/passive microwave sensor and high frequency observation	Not defined						A	A	A	A	As a active sensor for ADEOS-II follow-on mission, loading of microwave scatterometer is considered. High frequently observation will be realized by international cooperation as GPM project.
2-22	SAC special subcommittee (water cycle field)	-	Atmosphere water vapor measurement (183GHz-band sensor technology)	Not defined						B				Although microwave radiometer is available for observing columnar water vapor, development of new sensor is required for measuring vertical profile using 183GHz bands. As a foreign sensor, CMIS (NPOESS) will be available.
2-23	SAC special subcommittee (water cycle field)	-	Vertical profile of water vapor (Active sounder technology)	Not defined					B					Although IR spectrometer is available for observation of water vapor profile, it is not active type. As a foreign sensor, CMIS and CrIS/ATMS (NPOESS) will be available.
2-24	SAC special subcommittee (water cycle field)	-	Soil moisture (1GHz-band sensor)	Not defined						B	B		A	Although microwave radiometer and precipitation radar are available for observing soil moisture, development of new sensor is required for 1 GHz band measurement. As a 1 GHz band passive sensor, SMOS (ESA) and HYDROS (NASA) are planned.

[ Reduction and Prevention of Disasters ]

	Source of requirement	Category	Observation needs	Priority	Optical sensor				Radio wave sensor				Notes	
					High resolution (several m - dozens m)		Middle resolution (hundreds m - several km)	Low resolution (several km - dozens km)	Low resolution (several km - dozens km)			High/middle resolution (several m - hundreds m)		
					Visible high resolution sensor (panchromatic)	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar		
3-1	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Detection of abnormal weather conditions	Real-time and sequential data of extreme phenomenon of meteorological and oceanographic phenomena by stationary monitoring Real-time data of evolution and migration of typhoon, cyclone and hurricane	E		B	B			B	B		B	Cloud distribution is included. Real-time monitoring will be possible by observation from geostationary satellite.
3-2	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Storm and flood damage monitoring	Real-time rainfall data Real-time data of river level and flood flow rate	E		B				B	B		B	Precipitation intensity and inundated condition are included. Satellite observation of flow rate is difficult.
3-3	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Storm and flood damage monitoring	Data of landslides (disaster by sediment, slope failure) Data about disaster on ground and slope	H	A	A					A		A	Landslide, etc. Real-time monitoring will be possible by optical sensor observation from geostationary satellite.
3-4	CSTP disaster, map and resource sub working group (disaster)	Storm and flood damage monitoring	Data about coastal and oceanic disaster and coastal erosion	H	A	A	A						A	Altimeter is required to observe wave height and tide level, but is not planned in Japan because of difficulty such as high accuracy orbit determination and data analysis.
3-5	CSTP disaster, map and resource sub working group (disaster)	Storm and flood damage monitoring	Data about water environmental disaster, preservation of water quality and conservation of ecosystem	H		A	A							Water quality of river and lake. Geostationary satellite can provide Real-time monitoring will be possible by observation from geostationary satellite.
3-6	CSTP disaster, map and resource sub working group (disaster)	Prediction and mitigation planning of storm and flood damage	Data for flood, mudflow, sediment discharge, sediment production prediction, and water-induced landslide monitoring and prediction	H	A	A	A				A		A	Topography, land cover condition, etc.
3-7	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Crustal deformation and earthquake monitoring (Real-time monitoring of earthquake)	Crustal deformation monitoring network Earthquake monitoring network Topography change and tsunami monitoring network	E									B	It is difficult to real-time monitoring of Crustal deformation from satellite (post facto analysis of Crustal deformation is possible by interferometry SAR technique)
3-8	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Disaster monitoring of earthquake	Disaster information and relief operation	H	A	A							A	Change of topography and collapsed houses are included. Real-time monitoring will be possible by observation from geostationary satellite.
3-9	CSTP disaster, map and resource sub working group (disaster)	Earthquake prediction (Earthquake hazard prevention and mitigation)	Clarify of earthquake mechanism and intensive monitoring network	H									B	There is a possibility of detection of sign of Crustal deformation by interferometry SAR technique.
3-10	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Real-time monitoring of volcanic activity	Constant monitoring network of volcano (quake, Earth's crust) and warning	E									B	Real-time monitoring is impossible by LEO satellite (at least a few hours delay). Observation of quake and Crustal deformation are impossible by GEO satellite.
3-11	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Monitoring of influence of volcanic eruptions on atmosphere	Monitoring of volcanic ash in the atmosphere	E		A	A							







	Source of requirement	Category	Observation needs	Priority	Optical sensor				Radio wave sensor				Notes
					High resolution (several m - dozens m)		Middle resolution (hundreds m - several km)	Low resolution (several km - dozens km)	Low resolution (several km - dozens km)			High/middle resolution (several m - hundreds m)	
					Visible high resolution sensor (panchromatic)	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar	
3-12	CSTP disaster, map and resource sub working group (disaster)	Prediction of volcanic eruptions (Hazard prevention and mitigation by the volcanic eruption)	Monitoring for clarify of volcanic eruption mechanism	H	A	A						A	It is assumed that frequently observation of specified area by high resolution sensor are required.
3-13	CSTP disaster, map and resource sub working group (disaster)	Monitoring of recovery from damages by the volcanic eruption	Recovery assessment of volcano erupted area		A	A	A					A	
3-14	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Real-time fire monitoring, and prediction of fire spread	Real-time fired place and area grasp, and warning	E		B	B						Real-time monitoring is impossible by LEO satellite (at least a few hours delay). Real-time monitoring will be possible by observation from GEO satellite.
3-15	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Measurement of gas concentration	Distribution and time-sequential change of gases (CO2, etc.) in the atmosphere	H				B					Real-time monitoring of CO2 gas caused by large fire is difficult by LEO satellite. Monitoring of time-sequential change will be possible by GEO satellite.
3-16	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Monitoring of influence on ecosystem	Estimation of vegetation distribution and recovery of wild fire area		A	A	A					A	
3-17	CSTP disaster, map and resource sub working group (disaster) SAC special subcommittee (disaster field)	Measurement of dry fuel load (biomass with low water content)	Observation for estimation of forest fire potential, fire expansion forecast and emission of CO2 by wild fire	H		A	A					A	
3-18	SAC special subcommittee (disaster field)	-	Operational observation of ground surface temperature (volcano)	Not defined			B						Exact measurement of temperature from satellite is difficult. Real-time monitoring will be possible by observation from GEO satellite.
3-19	SAC special subcommittee (disaster field)	-	Wind distribution (wide area)	Not defined					B				With microwave radiometer, wind observation above land area is difficult.
3-20	SAC special subcommittee (disaster field)	-	Land cover condition (high resolution)	Not defined	A	A						A	
3-21	SAC special subcommittee (disaster field)	-	Topography (high resolution)	Not defined	A	A						A	
3-22	SAC special subcommittee (disaster field)	-	Vegetation distribution (high resolution)	Not defined		A						A	
3-23	SAC special subcommittee (disaster field)	-	Soil moisture (wide area)	Not defined					A	A		A	
3-24	SAC special subcommittee (disaster field)	-	Night light (wide area)	Not defined			B						Without specified sensor for night area observation, sensitivity is insufficient.
3-25	SAC special subcommittee (disaster field)	-	Biomass, height of trees (high resolution)	Not defined		A						A	
3-26	SAC special subcommittee (disaster field)	-	Distribution of smoke (wide area)	Not defined			A						
3-27	SAC special subcommittee (disaster field)	-	Distribution of lightning (large fire, wide area)	Not defined									Not planned in Japan. As a foreign sensor, LIS (TRMM) and OLS (DMSP) are observing.
3-28	SAC special subcommittee (disaster field)	-	High accuracy land surface observing system using hyper-spectrum sensor	Not defined									Private company's satellite is planned by World Spectrum, Inc. in Japan. As a foreign sensor, Hyperion (EO-1) is observing.

	Source of requirement	Category	Observation needs	Priority	Optical sensor				Radio wave sensor				Notes	
					High resolution (several m - dozens m)		Middle resolution (hundreds m - several km)	Low resolution (several km - dozens km)	Low resolution (several km - dozens km)			High/middle resolution (several m - hundreds m)		
					Visible high resolution sensor (panchromatic)	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar		
3-29	SAC special subcommittee (disaster field)	-	Volcanic ash constituent observing sensor	Not defined										Accurate ingredient observing from satellite is difficult.
3-30	SAC special subcommittee (disaster field)	-	Development measurement system of tree height using LiDAR	Not defined										Satellite laser altimeter is not planned in Japan, because of technical difficulty such as reliability of high power laser transmitter. Measurement project of tree height by U.S. is also suspended.
3-31	SAC special subcommittee (disaster field)	-	Microwave sensor for all-weather measurement (large fire)	Not defined								A		Assessment of burned area by forest fire.

Attached Summary of sensor specification that was applied to examination of availability to observation needs

Sensor type	Optical sensor				Radio wave sensor			
	Passive				Passive	Active		
	High resolution		Middle resolution	Low resolution	Low resolution			High/middle resolution
	Visible high resolution	Visible and IR high resolution sensor (multispectral)	Visible multi-spectral radiometer	IR spectrometer	Microwave radiometer	Precipitation radar	Cloud profiling radar	Synthetic aperture radar
Observation wavelength / frequency	0.52 - 0.77 microns (1ch)	0.42 - 0.59 microns 0.52 - 0.60 microns 0.61 - 0.69 microns 0.76 - 0.89 microns (4ch)	0.38 - 12 microns	0.75 - 14.3 microns	6.9GHz - 89.0GHz	Ku : 13.6GHz Ka : 35.5GHz	94GHz	1.27GHz
Swath	70 km (nadir) > 35 km (forward/backward)	70km	1150km	Approx. 1000km	1600km	245km	(under examination)	70 - 350km *
Resolution	2.5m	10m (nadir)	250m - 1km	1 - 10km (nadir)	5km - 50km	Vertical resolution 250m Spatial resolution 5km	Vertical resolution 500m FOV 650m	10 - 100m *
Observation cycle	2 days	2 days	2 days	3 days	2 days	-	11 days	within 5 days
Example of existing sensor	PRISM (ALOS)	AVNIR-2 (ALOS)	GLI (ADEOS-II)	GOS (GOSAT)	AMSR (ADEOS-II)	DPR (GPM)	CPR (Phase A study)	PALSAR (ALOS)

\* Vary with observation mode

Japanese Contribution Field	Observation Items	Major Observation Parameter	Sensor Type	JFY																	Notes	
				2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
Reduction and Prevention of Disasters	Floods	Flooded area	Passive optical sensor (Visible and IR high resolution sensor)	<b>Terra/ASTER</b>																	Concrete satellite and sensor plan of the next disaster monitoring satellite missions are examined succeedingly.	
	Landslides	Landslide area (change of topography, land cover change)																				
	Volcanic eruptions	Volcanic ash fall		<b>ALOS / PRISM, AVNIR-2</b>																		
	Oil spills	Ocean color		PRISM : Spectral Range 0.52-0.77μm, Resolution 2.5m, Swath 70km(Nadir) AVNIR-2 : Spectral Range 0.42-0.89μm(4 band), Resolution 10m, Swath 70km(Nadir)																		
	Disaster monitoring	Difference of spectrum before and after disasters																				
	Coastal disasters	3D topography																				
	Floods	Flooded area	Active radio wave sensor (L-band synthetic aperture radar)	<b>Next Disaster Monitoring Mission</b>																		
	Earthquakes	Crustal deformation		<b>ALOS / PALSAR</b>																		
	Landslides	Amount of landslide movement, change of soil moisture		PALSAR : L band 1270GHz, Resolution 10m, Swath 40km-70km																		
	Volcanic eruptions	Amount of crustal deformation																				
	Wild land fires	Dry fuel load (biomass with low water content)																				
	Other disasters	Difference of back scattering factor before and after disasters																				
	Volcanic eruptions	Land surface temperature, volcanic ash fall, aerosol	Passive optical sensor (Multi-spectral radiometer)	<b>ADEOS-II/GLI</b>																		Development of the sensor which introduced new technical elements based on GLI
	Wild land fires	Land surface temperature, aerosol, dry fuel load (biomass with low water content)		<b>ADEOS-II follow-on #2/GLI follow-on sensor</b>																		
	Disaster monitoring	Difference of spectrum before and after disasters		Spectral Range 0.38-12μm(22ch) multiple polarization/direction channel included, Swath 1150km, Spatial Resolution 250m, 500m, 1km																		
	Floods	Precipitation, precipitation prediction by model assimilation of water vapor	Active microwave sensor (Microwave radiometer)	<b>Aqua/AMSR-E</b>																		The sensor which inherits the specification of AMSR and AMSR-E
Landslides	Precipitation	<b>ADEOS-II/AMSR</b>																				
Storm and flood disaster	Wind speed, precipitation	<b>ADEOS-II follow-on #1/AMSR follow-on sensor</b>																				
Storm and flood disaster	Wind vectors (speed and direction)	Active radio wave sensor (Microwave scatterometer)	<b>ADEOS-II/SeaWinds</b>																	The sensor provided by the foreign organization		
		<b>ADEOS-II Follow-on #1/Microwave Scatterometer</b>																				
		Frequency 13.4GHz, Swath 800km, Spatial Resolution 25 km																				
Floods	Precipitation	Active radio wave sensor (Precipitation radar)	<b>TRMM/PR</b>																	Improvement in the observation performance by the dual frequency observation (Ka band and Ku band)		
		<b>GPM/DPR (Dual frequency Precipitation Radar)</b>																				
		Ku band 13.6GHz, Ka band 35.5GHz, Swath 245km, Horizontal Resolution 5km, Range Resolution 250m																				

 Approved Project   
  Planned Project   
  GEOSS 10-Year Implementation Period  
 Legends: Satellite name/Sensor name    Japanese Satellite/Japanese Sensor,    Foreign satellite/Foreign Sensor

Fig.1-1 The earth observation satellite plan in fields with which our country strengthens observations (1 of 3) [ Reduction and Prevention of Disasters ]

Japanese Contribution Field	Observation Items	Major Observation Parameter	Sensor Type	JFY																	Notes
				2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Climate Change including Water Cycle Variation	Precipitation	3D structure of precipitation	Active radio wave sensor (Precipitation radar)																		Improvement in the observation performance by the dual frequency observation (Ka band and Ku band)
	Soil moisture	Soil moisture																			
	Precipitation	Precipitation	Active microwave sensor (Microwave radiometer)																		The sensor which inherits the specification of AMSR and AMSR-E
	Soil moisture	Soil moisture																			
	Evaporation (sea surface)	Water vapor, Sea surface temperature, sea surface wind speed																			Improvement in accuracy is possible by simultaneous observation with a microwave Scatterometer
	Snow water equivalent	Snow cover, snow depth																			
	Cloud	Optical thickness, particle radius	Passive optical sensor (Multi-spectral radiometer)																		Development of the sensor which introduced new technical elements based on GLI
	Aerosol	Optical thickness, particle radius																			
	Transpiration (Land)	Land use, vegetation index, surface temperature																			
	Snow cover	Snow cover, surface temperature																			
	Ocean carbon, nutrient	Primary productivity																			
	Cloud	3D distribution	Active radio wave sensor (Cloud profiling radar)																		Development of new original sensor (94GHz radar) which took advantage of our superiority of radar technology
Aerosol	3D distribution (Observed by ESA sensor)																				

Approved Project   
 Planned Project   
 GEOS 10-Year Implementation Period  
 Legends: Satellite name/Sensor name   
 Japanese Satellite/Japanese Sensor, Foreign satellite/Foreign Sensor

Fig.1-1 The earth observation satellite plan in fields with which our country strengthens observations (2 of 3) [ Climate Change including Water Cycle Variation ]



Japanese Contribution Field	Observation Parameter	Sensor Type	JFY																	Notes
			2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Reduction and Prevention of Disasters	Land-cover change, volcanic ash fall, flooded area, etc.	Passive optical sensor (Visible and IR high resolution sensor)	Terra/ASTER			ALOS / PRISM, AVNIR-2		Next Disaster Monitoring Mission										Concrete satellite and sensor plan of the next disaster monitoring satellite missions are examined succeedingly.		
	Crustal deformation, biomass, flooded area, etc.	Active radio wave sensor (L-band synthetic aperture radar)	ALOS / PALSAR			Next Disaster Monitoring Mission														
Climate Change including Water Cycle Variation	3D structure of precipitation, soil moisture, etc.	Active radio wave sensor (Precipitation radar)	TRMM/PR			GPM/DPR (Dual frequency Precipitation Radar)										Improvement in the observation performance by the dual frequency observation (Ka band and Ku band)				
	Precipitation, water vapor, sea surface temperature, etc.	Active microwave sensor (Microwave radiometer)	Aqua/AMSR-E			ADEOS-II follow-on #1/AMSR follow-on sensor											The sensor which inherits the specification of AMSR and AMSR-E			
	Sea surface wind vector, etc.	Active radio wave sensor (Microwave scatterometer)	ADEOS-II/SeaWinds			ADEOS-II follow-on #1/Microwave Scatterometer										The sensor provided by the foreign organization				
	Cloud optical thickness, aerosol optical thickness, land biomass, etc.	Passive optical sensor (Multi-spectral radiometer)	ADEOS-II/GLI			ADEOS-II follow-on #2/GLI follow-on sensor											Development of the sensor which introduced new technical elements based on GLI			
	3D distribution of cloud and aerosol, etc.	Active radio wave sensor (Cloud profiling radar)	EarthCARE/CPR			EarthCARE/CPR										Development of new original sensor (94GHz radar) which took advantage of our superiority of radar technology				
	Global Warming and Carbon Cycle Change	Carbon dioxide(CO <sub>2</sub> ), methane(CH <sub>4</sub> ), etc.	Passive optical sensor (IR spectrometer)	ADEOS-II/IAS-II			GOSAT / Greenhouse gas Observation Sensor (GOS)										The concrete sensor which realizes improvement in observation accuracy (4ppmv -> 1ppmv) is examined succeedingly.			
Active optical sensor (LIDAR)			Next Greenhouse Gas Observation Satellite																	

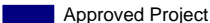
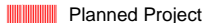
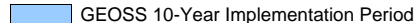
 Approved Project    
  Planned Project    
  GEOS 10-Year Implementation Period  
 Legends: Satellite name/Sensor name     Japanese Satellite/Japanese Sensor, Foreign satellite/Foreign Sensor

Fig.1-2 The earth observation satellite plan in fields with which our country strengthens observations

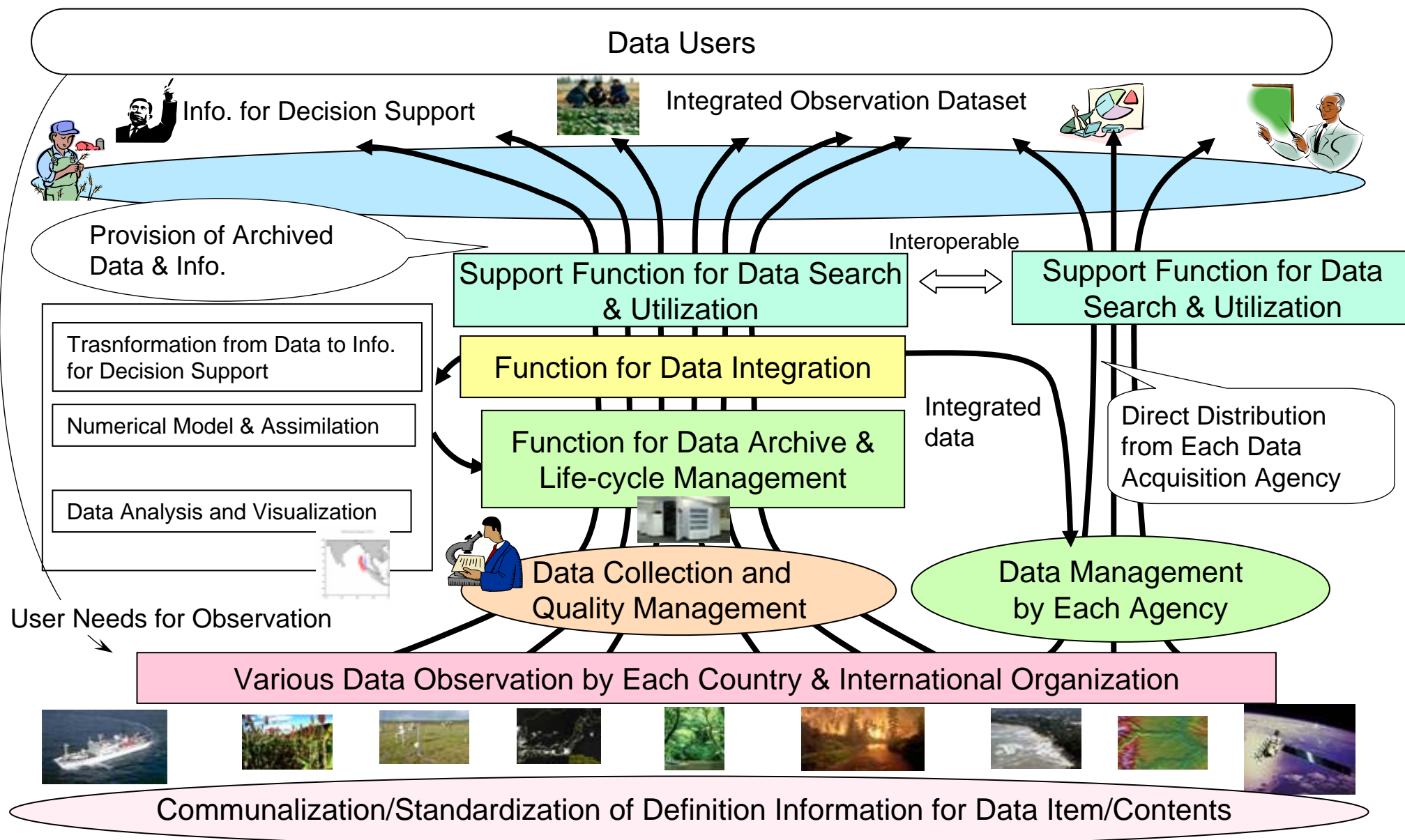


Fig.2 Components of Earth Observation Data Integration & Distribution System