GSI Research and Development Basic Plan

April 2014

Geospatial Information Authority of Japan

The GSI Research and Development Basic Plan is a plan that designates the basic directionality, for research and development at Geospatial Information Authority of Japan (GSI). It lays out the guidelines for proceeding steadily with research and development for the implementation of the Long-Term Plan for Basic Survey, and necessary measures for achieving this objective.

It should be noted that the plan was formulated in April 2014. The period for this plan was set at 5 years, from fiscal 2014 to 2018 inclusive, after considering the necessity of maintaining continuity of research and development, and future changes in social conditions, and rapid advances in technology that are expected to occur.

The GSI will make every effort to achieve the goals laid out in the plan within the 5-year plan period.

Contents

1. Introduction

In surveying technology, since utilization of digitization, information and communication technologies (ICT) and space technologies have been advancing, efficiency of surveying will be improved to materialize a society which considers it a matter of course to receive and utilize surveying results and geospatial information.

Regarding geospatial information policy, the Basic Plan for the Advancement of Utilizing Geospatial Information was decided by the Cabinet in March 2012 based on the Basic Act on the Advancement of Utilizing Geospatial Information (NSDI Act of Japan). In January 2013, the Basic Plan on Space Policy was adopted by the Cabinet to expand the use of outer space and ensure autonomy. Also in June 2013, the Japanese Cabinet issued the Declaration to Be the World's Most Advanced IT Nation.

Regarding policies related to science and technology in general, the Fourth Science and Technology Basic Plan in August 2011 and the Comprehensive Strategy on Science, Technology and Innovation in June 2013 were set by the Cabinet. In December 2012, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) decided on the MLIT Technology Basic Plan.

In addition, in December 2012, the new "Fundamental Guidelines for Evaluating Government Funded Research and Development" were established based on the Science and Technology Basic Plan. These guidelines improved evaluation methods in order to help ensure that research evaluation results will be used in a fitting manner to conduct subsequent research.

The 2011 off the Pacific coast of Tohoku Earthquake that occurred in March 2011 once again raised awareness of the threat of natural disasters, and researchers and engineers were once again made aware of their missions and approaches to the society. There was also renewed awareness among the general public about the importance of geospatial information and surveying for preventing and mitigating disasters.

In December 2011, after the 2011 off the Pacific coast of Tohoku Earthquake, concerted efforts were made to strengthen earthquake and tsunami measures. For example, the Basic Disaster Management Plan was revised to include measures for dealing with tsunami disasters. Furthermore, in September 2012, revisions were made to the Disaster Countermeasures Basic Act to, for example, strengthen measures for dealing with large-scale and widespread disasters. Also in September 2012, the Headquarters for Earthquake Research Promotion revised the "Comprehensive Policy for the Promotion of Earthquake Observations, Measurements, Surveys and Research" which emphasized the strengthening of surveys and observations needed to increase the

accuracy of earthquake predictions.

In November 2013, the Council for Science and Technology established the "Plan for Observations and Research of Earthquakes and Volcanoes to Help Mitigate Disasters" that was based on the effects of the 2011 off the Pacific coast of Tohoku Earthquake, and proposed it to relevant government ministers. The government policy was changed to promote the Plan for Observations and Research of Earthquakes and Volcanoes as a part of the disaster science, indicating that the Plan should be promoted as comprehensive and interdisciplinary research.

Against the backdrop of these technological advancements, revisions to legal systems and plans, GSI revised the "Long-term Plan for Basic Survey (hereafter, LT Plan)" in April 2014 to indicate such things as directionality for future surveying and various measures required for proceeding with this.

The GSI Research and Development Basic Plan (hereafter, "RD Plan") is based on the abovementioned background. It lays out basic directionality for research and development at GSI, describes research and development that should be undertaken to make steady progress with the LT Plan, and compiles measures required for achieving these goals.

The period for this plan was set at 5 years, from fiscal 2014 to 2018 inclusive, after considering the necessity of maintaining continuity of research and development, future changes in social conditions, and rapid advances in technology that are expected to occur.

However, part or all of the RD Plan may be revised if necessary.

2. Basic Concepts

GSI is an institute that deals with the planning, formulation, and smooth implementation of administrative measures related to the development and use of surveying and geospatial information, and it conducts research and development (hereafter "R&D") with the main objective of proceeding with this work in a precise manner. Its R&D targets cover a wide range of fields, from fundamentals related to surveying, to application. Among these fields, R&D needed for administrative measures, including policy research is necessary. It is also necessary to place emphasis on R&D that is needed to obtain results that can be utilized as common infrastructure by society.

In addition to obtaining R&D results during the 5 years of the RD Plan and incorporating them into policies and measures, it is also necessary to take a medium- to long-term perspective of conducting R&D which will lead to significant results in the future and to be incorporated into measures that will contribute to the proper development of society.

Naturally, R&D results will be utilized in measures, but it is also necessary to take the perspective of being able to utilize them in other R&D work.

Given these fundamental concepts, the RD Plan first of all summarizes the premise of the plan: results and problems that emerged in previous plans; goals indicated in the LT Plan and measures for achieving them; the R&D needs of society; and necessary R&D promotion measures into Basic Science and Technology Plan and other Plans. Secondly, the RD Plan introduces priority issues in overall GSI's R&D framework (hereafter "key themes"), and further introduces priority R&D issues for implementation within each theme (hereafter "priority issues"), taking the premises into account.

3. Current State and Background of Research and Development

(1) Results and topics of the previous Research and Development Basic Plan ("GSI Research and Development Basic Plan," formulated in June 2009 and revised in August 2012)

Regarding the results and topics of the previous plan, the following items were established based on the mid-term evaluation results that were compiled in August 2012, and progress that was made in subsequent R&D.

1) Research and development to facilitate preparation / distribution / utilization of geospatial information

In order to materialize a society where everyone can lead fruitful and peaceful lives, GSI has been proceeding with three important research and development topics as common and basic R&D that will make a direct contribution to promote the utilization of geospatial information.

In "Research and development to facilitate preparation / distribution / utilization of geospatial information through Standardization, etc.," work that is essential for promoting the widespread use of geospatial information has been and is being done. This includes creating Japan Profile for Geographic Information Standards based on international standards, formulating guidelines for handling personal information, and drafting a protocol for systematizing geographical identifiers, among other things. In addition, various tools have been developed for supporting this work, and an environment has been created for smoothly developing, distributing and utilizing geospatial information. With regard to standardization and the formulation of guidelines and specifications, it will be necessary to deal with rapid revisions that will have to be made in response to popularization and technological and social conditions.

In "Research and development to help advanced maintenance / management / dissemination of geo-referencing infrastructure," the creation of "the quantitative equivariation map" based on the results of GNSS-based control stations provides areal and quantitative understandings of local surface movements, and thus the methodology was established to determine surveying areas which are required for revision of coordinates of a ground control station. The method was effectively utilized in GSI work, such as the geodetic survey for emergency analysis of the 2011 off the Pacific coast of Tohoku Earthquake. GSI will continuously maintain, manage, and provide positional information infrastructure by clarifying mechanisms of steady and unsteady crustal movements in Japan.

In "Research and development to help advanced preparation / management / dissemination of basic geospatial information," a totally automatic software was developed to create 1:50,000 maps from road center lines in original data of topographic

maps and the Digital Japan Basic Map (map information). Using the Digital Japan Basic Map (map information), which contains 2,500 level data, a system for publishing 1:25,000 digital topographic maps was developed which enables users to select the area of coverage and map symbols. An environment was also created to effectively and efficiently develop and provide fundamental geospatial information. Topics for the future include such things as the utilization of new methods for creating geospatial information; and R&D for raising the efficiency of developing and upgrading geospatial information.

2) Research and development to realize a next-generation, advanced geospatial information utilization society

With an eye on next-generation technologies, groundbreaking and fundamental R&D is being conducted to promote the use of geospatial information to enhance economic and social wealth and to create new businesses. This has involved progressing with three important R&D themes.

In "Research and development on advanced geospatial information utilization technology that brings affluence to people's life," experts, government ministries and agencies, companies and other stakeholders, have been working together to decide on the basic specifications of location information codes and are compiling them as guidelines for actual operation of the location information codes. They have also designed a system for issuing and managing codes.

On the other hand, data for creating "tangible maps," etc., for people with vision impairments that are compatible with the Digital Japan Basic Map (map information) were examined for their necessity and usefulness, but this did not lead to the implementation of specific services. It will be necessary to continue to study the needs of the challenged members of society and to work to verify the location information codes in places of actual use.

In "Research and development on leading-edge technologies surrounding survey and geospatial information," experiments that have been conducted to downsize the VLBI observation system using a prototype of a 1.6 m small-size Very Long Baseline Interferometry (VLBI) antenna, have produced a geodetic solution, among other results, and steady progress is being made with research to materialize the next-generation VLBI observation system (VLBI2010 Global Observing System; VGOS).

At the same time, research on the utilization of geospatial information with new media has involved such things as developing native map applications for smart phones, and creating experimental background map data using map expressions that are appropriate for smart phone use. It will be necessary to continue to investigate application to VGOS standards and geospatial information that is compatible with new

media.

In “Research and development on how to conduct survey with the vision of next-generation Space-based Positioning, Navigation and Timing,” work was done to corroborate the accuracy of GLONASS satellite positioning, and the effectiveness of using that in surveying. The results were incorporated into the Rules for Operating Specifications and the Performance Standards for Surveying Equipment that were revised in March 2011.

Furthermore, progress is being made with the development of a multi-GNSS analysis system that uses a combination of different Space-based PNT systems (GPS, GLONASS, QZSS, and Galileo). Future topics will include technical developments that will serve as preparations for practical use of multi-GNSS surveying oriented toward a system comprised of 4 quasi-zenith satellites.

3) Research and development on disaster prevention

In order to create a society where everyone can enjoy safe and secure lives, joint fundamental R&D is being conducted to ensure preventive measures, to help quicken responses in times of disaster. This involves three important R&D themes.

In “Research and development to contribute to real-time disaster response,” methods are being developed to understand crustal movements within a few minutes of occurrence, and to make quick and automatic estimation of earthquake fault models. The creation of a prototype system for analyzing crustal movements in real-time have automatically estimated fault models, and the creation of post-processing near real-time analysis system, etc. have greatly shortened the time required to estimate fault models in crustal movement analyses. Continued R&D will have to be made to understand crustal movements in real-time so that the data can be used as information for confirming tsunami predictions.

In “Research and development on natural disaster prediction,” information is being obtained for predicting temporal changes in crustal movements which involves such things as understanding the special features of spatio-temporal changes in the slow slip that is occurring in the Boso Peninsula, the Tokai region, and the Bungo Channel, and making quantitative estimates of temporal changes in pressure sources at Izu-Oshima Island, Sakurajima, and Mt. Kirishima (Shinmoedake). This information is being used to monitor crustal movements. R&D will have to be conducted to further understand crustal movements and improve the accuracy of predictions.

In “Research and development to help advanced extraction of ground deformation and topographic information concerning disaster prevention,” technical development has been steadily and effectively conducted to detect ground deformation using satellites and airborne Synthetic Aperture Radar (SAR) and to understand more

accurately crustal movements using GPS. This includes development of advanced technology for processing multiple interferometric SARs and its introduction of this technology into a project of highly accurate surveying of ground deformation, and development of integrated analysis methods to obtain consistent solutions using regular GPS observation data and GEONET data. R&D will have to create application with ALOS-2 and enhance accuracy of analyzing technology for ground deformation and crustal movements.

4) Research to understand the earth and national land scientifically

R&D activities are designed to gain a better scientific understanding of the earth and national land by improving surveying technology, and acquiring knowledge and results for enhancing applied fields such as disaster prevention and environmental protection. There are three priority issues in this area.

In "Research on elucidation of crustal movements," it is necessary to proceed with research to get a better understanding of phenomena related to seismic and volcanic activity through medium- to long-term monitoring of crustal movements. Steady progress is being made to reveal the tectonics and generation mechanisms of inland and interplate earthquakes that often occur in Japan and elsewhere, and to reveal the mechanisms of the build-up and release of strain that occurs in plate boundaries in and around the Japanese Archipelago. In the future, it will continue to be necessary to monitor crustal movements and crustal activities that have occurred since the 2011 off the Pacific coast of Tohoku Earthquake, and address new issues such as viscoelastic relaxation.

In "Research on advanced geodetic reference system based on scientific understanding of the earth and national land," the variation of height at the space geodic observation sites at Tsukuba is being revealed, and comprehensive methods incorporating GPS, leveling, groundwater levels are being devised to conduct monitoring.

In addition, tide level data are being created after removing the effects of crustal movements, tide, atmospheric pressure, at each tidal observation station. Similarities in the regional distribution to the trends in sea level variation are being confirmed, and methods for estimating gravity potential values on the mean sea surface at each tidal observation station are being developed. These and other activities are providing information that can help improve the quality of the geodetic reference system. In the future, it will be necessary to continue to conduct research that increases our understanding of mechanism of deformation of the earth and the deformation field of the Japanese archipelago.

In "Research to scientifically understand the earth's surface and national land," it

has been confirmed that quantitative analyses of vulnerability of landslide disaster can be roughly evaluated using the slope and degree of unevenness/bumpiness of topographic quantities based on detailed DEM (Digital Evaluation Model) from aerial laser surveying. At the same time, evaluation technologies are being advanced for understanding the three dimensional structure such as vegetation elevations and tree crown thickness based on detailed DSM (Digital Surface Model) and DEM from aerial laser surveying. These and other activities are being undertaken with greater efficiency and effectiveness. GSI will continue to develop and update methods for obtaining data in an economical and efficient manner.

5) Topics spanning the entire research and development spectrum

In their mid-term evaluation of the previous plan in 2012, the Research Evaluation Committee[1] indicated that the following were topics that span the entire research spectrum:

(a) Dealing with the 2011 off the Pacific coast of Tohoku Earthquake

It is believed that the work that GSI had done up until the 2011 off the Pacific coast of Tohoku Earthquake was of great use in responding to that disaster. Every effort should be made to make this work appealing to people outside of GSI. While the results of R&D such as emergency analyses of crustal movements are actually being utilized in the field and effectively incorporated into operations, more efforts should be made to verify experiences of collecting and providing geospatial information about the disaster, in order to undertake more advanced R&D to improve the technical and pragmatic aspects of responding to major earthquake disasters, such as the predicted Tonankai Earthquake.

(b) Public release of research and development results

The GSI's publicly released R&D results that have been internally evaluated have been acclaimed in academic papers, but we would also like for their presentation to the general public through the Internet and other media to be acclaimed, too. Points that would make this particularly appealing would be to collect various types of information on the Digital Japan Basic Map, and make digitized hazard maps available for viewing on the Internet. The "Web Map for Knowing Elevation at your point" is remarkable because elevation of a point appears with just a click, so it appears that every effort must be made to widely distribute useful information that is obtained. Because GSI is producing numerous results, it should work to publicly release them and incorporate

[1] The Research Evaluation Committee is composed of external experts to evaluate R&D themes, organizations, and policies of GSI.

them into public information materials.

(c) Policy-related research

GSI is proceeding with the administrative aspects of publicly releasing and utilizing geospatial information, but it should also consider how to do this as policy from an R&D perspective. Therefore, GSI should consider not only technical research topics, but also topics for policy-related research.

(d) New technologies in the foreseeable future

Regarding satellite positioning, Rules for Operating Specifications were revised in March 2011. However, we would like to pay close attention to the direction of quasi-zenith satellite development.

The basic specifications of the location information codes have been decided, and the fundamental development is more or less complete, but we would like for this to advance further. It appears that progress in research related to new media such as portable information terminals is slowing down, so we would like to take recent advancement in this field into account when proceeding with our research.

6) Topics related to measures for advancing research and development

In their mid-term evaluation of the previous plan in 2012, the Research Evaluation Committee indicated that the following were R&D policy topics that involve the nurturing of human resources:

GSI has been recommending research presentations in Japan and abroad to nurture researchers, but under the current conditions where budgeting has been cut across the board, it is difficult to attend conferences overseas. We should consider recommending substantial research presentations in Japan and abroad. Moreover, no other organization has the kinds of advanced geodetic and geographic facilities that GSI has, and in human terms as well, not to mention physical terms such as actual data and observation equipment, GSI has extremely important possessions. GSI should consider working to raise the level of geodetic and geography science throughout Japan by having a system where joint research can be conducted by, for example, inviting people from outside GSI to become members of GSI research groups.

(2) The Long-Term Plan for Basic Survey

In the LT Plan that was revised in April 2014, two important strategies were laid out for enhancing the capacity of the nation as a whole to develop and utilize geospatial information that initially in disaster prevention fields; and for distributing and utilizing geospatial information that the public organizations possess in order to help create new

industries and provide greater convenience in people's lives. In this plan, GSI must make every effort to undertake cutting-edge R&D with a long-term perspective, and establish alliances with relevant organizations to undertake technical research and development that is necessary for making steady progress with policy research discussed in the LT Plan, and for responding to changes in society and technology. At the same time, fundamental technical R&D should be conducted to aid in the development of various academic fields, and the results obtained therefrom should be used as feedback for the work of GSI and academic fields.

The RD Plan is required to compile necessary R&D activities and their promotional measures to fulfill the targets outlined in the LT Plan, the R&D needed to achieve these targets, and measures to promote this must be compiled in the RD Plan.

(3) Social needs for research and development

Regarding social needs for R&D related to the surveying technology and development and utilization of geospatial information, sufficient consideration has been given to maintaining conformability with measures related to the Basic Plan for the Advancement of Utilizing Geospatial Information and the Basic Plan on Space Policy when formulating the LT Plan as it involved basic surveying. However, when formulating the RD Plan, social needs are being considered again for R&D based on a variety of related measures.

In the Basic Plan for the Advancement of Utilizing Geospatial Information, the utilization of geospatial information is an important means for resolving social issues such as declining and aging population. Complex social phenomena should be unraveled to provide by geospatial information new openings for considering measures. It appears that geospatial information is leading to a new future vision where satisfied life and society are materialized based on its advanced utilization. R&D will have to be promoted with this in mind.

The Basic Plan on Space Policy brings up guidelines (expanding the use of outer space) for utilizing outer space to improve and enhance industries, government, and daily living, maintaining the guarantee of security in a wide sense, and achieving economic development. Against this backdrop, it is necessary to promote R&D related to the utilization of outer space. In addition, in the Basic Concepts for Promoting the Practical Quasi-zenith Satellite System Project (Cabinet decision of September 30, 2011), Japan should address the development of the Practical Quasi-zenith Satellite System as quickly as possible. Specifically, a four-satellite system should be developed in the latter half of 2010s, and after that a seven-satellite system should be developed to enable continuous positioning. R&D must be undertaken with an eye to materializing this system.

In order to ensure national security and strengthen the key technology to maintain the infrastructure necessary for the nation's existence, the Science and Technology Basic Plan is designed to promote R&D of technologies for geospatial information. In the Comprehensive Strategy on Science, Technology, and Innovation, there are various elements that are needed to materialize a strong infrastructure to deal with natural disasters. Among these elements are ground observation data obtained from satellites, and observations, analyses, and predictive technologies that use such things as geospatial information. Against this backdrop, it is necessary to proceed with relevant R&D.

In the Declaration to be the World's Most Advanced IT Nation, the Japanese government expressed the need to promote "open data" (opening public data to the private sector) in order to utilize its geospatial information (G-spatial information) with other types of "big data." Against this backdrop as well, it is necessary to proceed with relevant R&D.

In the Basic Disaster Management Plan, basic guidelines for preventing disasters at the damage prevention stage are designed to promote research related to disaster prevention, including forecasts and estimates, provide information about the results and utilize that in disaster prevention policy. For the emergency disaster measures stage, the plan discusses gaining a quick understanding about the scale of damage immediately after the occurrence of a disaster, and the rapid collection and transmission of disaster information. Against this backdrop as well, it is necessary to proceed with relevant R&D.

In the MLIT Technology Basic Plan, geospatial information is treated as one type of shared infrastructure. To materialize a new society (one that is safe and secure, where people can live satisfied and convenient lives, a society where there is energy to create new businesses, etc.) by utilizing this information to a high degree, geospatial information should be used to merge new and existing information services provided by the various organs of the industry-academia-government as a base for comprehensively understanding a wide variety of issues related to disaster prevention, disaster mitigation, the declining youth population, and the environment, among other things. The plan points out the need to conduct technical R&D that can contribute to a truly sustainable society.

The proposed "Plan for Observations and Research of Earthquakes and Volcanoes for Contributing to Disaster Mitigation" of the Council for Science and Technology, and the "Basic comprehensive policy for the promotion of earthquake observations, measurement, surveys and research" of the Headquarters for Earthquake Research Promotion, proposed that research be continuously being conducted to predict the occurrence of earthquakes and volcanic eruptions, be also being conducted to estimate

causes of damage resulting from earthquakes and eruptions, recognizing the emergence of numerous earthquake issues in the wake of the 2011 off the Pacific coast of Tohoku Earthquake. Against this backdrop, relevant R&D will have to be conducted that will contribute to policies and measures for preventing and mitigating disasters to protect the lives and livelihoods of the people.

(4) Items that should be considered for proceeding with research and development

The Research Evaluation Committee has partially indicated directionality for future R&D. The following is a description of things that should be considered for this purpose.

Regarding the methodology for evaluating R&D, the "Fundamental Guidelines for Evaluating Government Funded Research and Development in Japan" which were established in December 2012, contain guidelines for individual themes and organizational evaluations, and stipulates items for research evaluation which will help to improve R&D activities. It is necessary to evaluate research based on these guidelines.

To promote the use of R&D results, the Fourth Basic Science and Technology Plan and the MLIT Technology Basic Plan indicate that efforts should be made to provide results to society, so it will be necessary to more vigorously address this in the future.

To maintain human resource and funding for R&D, while establishing important R&D themes, as indicated in the Fourth Basic Science and Technology Plan. It is necessary to properly allocate personnel and funding that are required for R&D.

To promote the development and use of intellectual infrastructure, the Phase 4 Basic Science and Technology Plan provides rules for the development of intellectual infrastructure. In addition, the MLIT Technology Basic Plan provides rules for systematizing and sharing knowledge. It is necessary to approach this in an appropriate manner.

To secure collaboration and alliances with relevant organizations, and international alliances, various plans have indicated that it is necessary to utilize technologies from other fields and the private sector, engage in international exchanges, and conduct joint research, among other things.

4. Establishment of Directionality for R&D and Key Themes in the RD Plan

In the RD Plan, consideration is given to social needs for research and development. To clarify the direction that should be taken to address this for the next 5 years, it is first necessary to establish four themes for GSI's R&D.

In addition to the LT Plan, it is also necessary to review the previous plan and consider social needs for future R&D. Against this backdrop, the following concepts for directionality of R&D have been laid out.

・Enhancing the capability to develop and utilize geospatial information

Given the important strategies for basic surveying in the LT Plan, the Basic Plan for the Advancement of Utilizing Geospatial Information, the Basic Plan on Space Policy, Declaration to be the World's Most Advanced IT Nation, the MLIT Technology Basic Plan in order to materialize a society where everyone can live secure and rich lives, fundamental research is being carried out to make direct contributions to enhance the capability to develop and utilize geospatial information by, for example, improving the efficiency of collecting, compiling, and analyzing data.

It should be noted that of this R&D is taking an approach that will enable results to be obtained in a relatively short time.

・Materialization of a society that utilizes next-generation geospatial information

Given the important strategies in the LT Plan, the Basic Plan for the Advancement of Utilizing Geospatial Information, the Science and Technology Basic Plan, the MLIT Technology Basic Plan, etc., in order to achieve a richer economy and society and create new businesses, cutting-edge research is being conducted to materialize a society that utilizes next-generation geospatial information. R&D is also being carried out to enhance convenience using geospatial information as society undergoes structural changes brought about by an aging and declining population.

It should be noted that this research is essentially carried out with a medium-to long-term perspective.

・Promoting approaches to disaster prevention and mitigation

Given the strengthening of disaster prevention and disaster response in the LT Plan, and the promotion of the Comprehensive Strategy for Scientific and Technological Innovation, the Basic Disaster Management Plan, the MLIT Technology Basic Plan, and the Research Plan for Seismic and Volcanic

Observations to Contribute to Disaster Mitigation (Proposal), among others, in the aftermath of the 2011 off the Pacific coast of Tohoku Earthquake, there has been a growing awareness of disaster prevention among the people. In order to achieve a society where everyone can lead safe and secure lives in a world where natural disasters are increasing due to earthquakes and global-scale changes in the environment, basic R&D is being conducted to understand risks, make steady preparations for dealing with disasters by strengthening infrastructure, and help quicken emergency response to disasters.

It should be noted that this R&D is designed to obtain results in a relatively short time. However, given the need to further address disaster prevention, R&D also needs to be carried out with a medium-to long-term perspective.

・Understanding the current conditions and changes of the earth and national land and associated mechanisms

Given the description of promoting R&D in the LT Plan, the Comprehensive Strategy for Scientific and Technological Innovation, the Basic Disaster Management Plan, the MLIT Technology Basic Plan, and the Research Plan for Seismic and Volcanic Observations to Contribute to Disaster Mitigation (Proposal), among others, research is being conducted to obtain knowledge and data that will help to advance surveying technologies, enhance applied fields such as disaster prevention and environmental protection, and develop academic fields such as geosciences. This will be done by obtaining a better scientific understanding of the current conditions and changes in the earth and national land, and understanding the mechanisms of such things as crustal movements and changes in topography.

It should be noted that this research is essentially carried out with a medium-to long-term perspective.

Against this backdrop, GSI has established the following key themes for addressing the above four concepts:

Key theme No. 1: Research and development to enhance development and utilization capability

Key theme No. 2: Research and development to create a geospatially enabled society in the next generation

Key theme No. 3: Research and development for disaster prevention and mitigation

Key theme No. 4: Research for scientific understanding of the earth and national land

In addition, the following priority issues have been established in order to clarify the fields that are of particular importance.

(1) Research and development to enhance development and utilization capability

Priority issues have been decided based on the following perspectives:

- Measuring technologies such as mobile mapping system (MMS), ground-based and aerial laser surveying, unmanned aerial vehicle (UAV), that are expected to make the development of geospatial information more efficient and effective, should be incorporated into R&D, which must be done to enhance the capability to develop geospatial information.
- Research and development must be carried out to promote advanced uses of geospatial information in all of society by using, for example, open data.
- Research and development must be carried out to maintain and update highly accurate locational information using space technologies.
- Research and development must be carried out to adapt to the diversification of geospatial information such as information with layered structure, information that is becoming three-dimensionalized, information that has time-attributes, and so on.

Priority issue No. 1: Research and development for building up geospatial information development capability
Priority issue No. 2: Research and development for promoting advanced use of geospatial information
Priority issue No. 3: Research and development for developing, maintaining, and updating positional base using space technology
Priority issue No. 4: Research and development for dealing with diversified geospatial information

(2) Research and development to create a geospatially enabled society in the next generation

Priority issues have been decided based on the following perspectives:

- With an eye on trends in technology for next-generation satellite positioning, R&D must be conducted to enhance the efficiency and effectiveness of utilizing satellite-positioning technology.

- With an eye on the various changes in social structure, such as aging society and declining population as well as changes in the environment that people use geospatial

information due to the development of future ICT, it is necessary to carry out cutting-edge research and development on methods for developing and providing geospatial information, and for using it in the social environment of the next generation.

Priority issue No. 1: Research and development for utilizing next generation satellite navigation technology
Priority issue No. 2: Research and development for developing methods to utilize next generation geospatial information

(3) Research and development for disaster prevention and mitigation

Priority issues have been decided based on the following perspectives:

- In response to the people's heightened awareness for disaster prevention and the necessity for strengthening the country's infrastructure in the aftermath of the 2011 off the Pacific coast of Tohoku Earthquake, R&D must be undertaken to fully understand the vulnerabilities of the nation's infrastructure such as risks of disaster that all regions of the country face, and provide relevant information.
- It is necessary to proceed with R&D that is required for acquiring, sharing, and providing, as quickly as possible, geospatial information to understand that state of damage during a disaster, and geospatial information that can be utilized for subsequent restoration and recovery efforts.

Priority issue No. 1: Research and development for grasping risks on national territory and providing them to the public
Priority issue No. 2: Research and development for grasping land situation at the occasion of disasters and rapid information sharing

(4) Research for scientific understanding of the earth and national land

Priority issues have been decided based on the following perspectives:

- Research must be conducted to gain a deeper understanding of seismic and volcanic phenomena by conducting long-term monitoring of crustal movements.
- Research must be conducted to gain a deeper understanding of such things as mechanisms of deformation of the earth in order to enhance the maintenance and management of the geodetic reference system with a medium- to long-term perspective.
- Research must be conducted to gain a deeper understanding of environmental changes and the occurrence of disasters by gaining a better understanding of environmental conditions in the ground surface in Japan and the world and associated

changes.

Priority issue No. 1: Research for grasping crustal deformation
Priority issue No. 2: Research for improving the geodetic reference frame based on scientific comprehension of the earth and national territory
Priority issue No. 3: Research for understanding the environment on the earth and national territory

5. Priority issues

A brief overview and the purposes of each priority issue are listed below. Regarding detailed information about the contents, purposes of R&D activities, it is decided to establish implementation plan for each fiscal year and address the issues flexibly.

(1) Research and development to enhance development and utilization capability

1) Research and development for building up geospatial information development capability

In order to enhance the ability to develop geospatial information, GSI is using not only conventional technologies, but also new technologies, such as the mobile mapping system (MMS), land-based and aerial laser surveying, and unmanned aerial vehicles (UAVs). It is also aiming to develop more efficient methods and methods for producing previously unavailable geospatial information, and acquire results that can be used in surveying and other endeavors.

2) Research and development for promoting advanced use of geospatial information

In order to promote the advanced utilization of geospatial information, GSI is examining effective and efficient public data release methods that conform with the nation's open data strategy, and is aiming to analyze the effectiveness of the public survey system and obtain results that can be applied to it. In addition, regarding tile technology used for web mapping, GSI is considering the technical effectiveness and political effects derived from providing vector tiles of surveying results and is conducting R&D to become the world's leader of projects that supply vector tiles. At the same time, GSI is proposing and implementing technical and political measures for promoting international development with geospatial information using ICT. This involves such things as conducting R&D for promoting the advanced use of geospatial information in, for example, global maps in Japan and abroad, in order to contribute to sustainable development. It is also aiming to gain international standing through such things as international standardization, technical exchanges, and technology transfers to developing countries.

3) Research and development for developing, maintaining, and updating positional base using space technology

In response to trends in space technologies, such as the upcoming four-satellite constellation of QZSS, standard specifications for international VLBI observations

(VGOS) to ensure positional accuracy of 1mm for promoting the Global Geodetic Observation System (GGOS), and the launch of ALOS-2 satellite, GSI is aiming to conduct technical and systemic examinations for developing multi-GNSS analysis methods and applying them to public survey and formulating guidelines and incorporating then into Rules for Operating Specifications. GSI is also conducting R&D on such things as methods for efficiently maintaining and managing the geoid model of Japan which is necessary to determine heights with a high degree of accuracy, advancing the GNSS continuous observation system (GEONET), VGOS observation system and associated analytical technologies, and wide-area monitoring of crustal movements with Interference SAR using ALOS-2. The knowledge and data obtained therefrom will be applied to surveying and other work.

4) Research and development for dealing with diversified geospatial information

In order to adapt to the diversification of geospatial information, such as layering including underground space, information that is becoming three-dimensionalized, information that has time attributes among others, research is being done at GSI to three-dimensionalize basic geospatial information in the Digital Basic Map, and other products GSI is also examining specifications for providing three-dimensional information, geographical identifiers, time attributes, and is aiming to obtain useful results.

(2) Research and development to create a geospatially enabled society in the next generation

1) Research and development for utilizing next generation satellite navigation technology

With an eye on trends in next-generation satellite positioning, GSI is aiming to obtain the knowledge required for future research and development by starting surveys and R&D related to the effective and efficient utilization of next-generation satellite positioning technologies. This involves such topics as greater accuracy and correction methods for Precise Point Positioning (PPP), the possibilities for further increasing the accuracy of responding to needs for highly accurate positioning in the next generation, and a dynamic geodetic system that is compatible with the global geodetic system for increasing conformity with maps and other types of geospatial information, and location information such as surveying results.

2) Research and development for developing methods to utilize next generation geospatial information

With an eye on the various changes in social structure, related to geospatial

information such as an aging, declining population as well as changes in the way that people will use geospatial information due to the development of future ICT, GSI, in order to obtain the knowledge needed for future R&D, has started surveys and R&D for optimizing positioning, sensors and geospatial information for controlling robots, and for establishing alliances with augmented reality (AR) fields which connect geospatial information with the real world. In order to obtain knowledge and data that can contribute to the development of new application fields, GSI has also begun R&D to establish methods for using map information in combination with location information, and for acquiring, processing, managing and utilizing massive amounts of geospatial information.

(3) Research and development for disaster prevention and mitigation

1) Research and development for grasping risks on national territory and providing them to the public

In response to the growing awareness of disaster prevention among the people in the aftermath of the 2011 off the Pacific coast of Tohoku Earthquake, GSI is aiming to fully understand the vulnerability to the nation's infrastructure such as risks of disaster that all regions of the country face, and provide relevant information. In order to do this, GSI is aiming to obtain useful results by, for example, conducting steady, long-term observations of crustal movements to improve the accuracy of crustal movement measurements using SAR; understand the vulnerability of Japan using remote sensing and aerial laser technologies; estimate the potential for the occurrence of natural disasters; and conduct R&D for making both rapid and stable observations of regional crustal movements using GNSS that encompass everything from sudden changes to long-term changes.

2) Research and development for grasping land situation at the occasion of disasters and rapid information sharing

When a disaster occurs, it is necessary to quickly acquire, share, and provide geospatial information for understanding the state of damage, and geospatial information that can be utilized for subsequent restoration and recovery efforts. In order to achieve this objective, GSI is aiming to obtain results that can be useful during times of disaster. This includes conducting R&D for; making quick estimates of the scale of an earthquake and the transition process of volcanic activity using real-time GNSS analysis, and other technologies; rapidly understanding the state of damage through combinations of conventional geospatial information, press coverage information, information on networks, and others; rapidly identifying locations of damage occurrence using conventional geospatial information and airborne SAR and displaying

the locations on maps; and developing UAV photogrametric technologies, among other things.

(4) Research for scientific understanding of the earth and national land

1) Research for grasping crustal deformation

In order to get a better understanding of phenomena related to seismic and volcanic activity through medium- to long-term monitoring of crustal movements, GSI is aiming to obtain knowledge and data that can be applied to R&D, in related fields. This involves research on such topics as; building a tectonic model of the region around the Japanese archipelago; understanding the processes of building up and releasing strain in plate boundaries; predicting trends in postseismic deformation after an earthquake; improving methods for estimating short-term slow slip events; and creating source models of intraplate earthquakes and volcanic activities in the preparation, precursor, and transition processes, and improving model estimation methods.

2) Research for improving the geodetic reference frame based on scientific comprehension of the earth and national territory

In order to improve the medium- to long-term maintenance and management of the geodetic reference system through a deeper understanding of such things as the mechanisms for deformation of the earth, research is being conducted to gain better understandings of crustal deformation field of Japan in the global geodetic reference frame and associated mechanisms through the monitoring of geodetic control points, and to develop appropriate methods for application of these understandings to revision of survey results. Research is also being conducted to determine geoids and the Japanese elevation reference system with even greater precision. Through this research, GSI is aiming to obtain results and knowledge that can be applied to other R&D that is related to the geodetic reference system.

3) Research for understanding the environment on the earth and national territory

In order to gain a deeper understanding of environmental changes and the occurrence of disasters through an understanding of the environmental conditions, associated changes in ground layers in Japan and the world, GSI is aiming to obtain knowledge and data that can be used to make future estimates about Japan’s land and infrastructure, GSI is conducting research to develop methods for analyzing surveying and remote sensing data for classifying topography and land cover, analyzing geological structure, and understanding changes in Japan’s land surface, as well as understanding regional classification and their special features from a disaster prevention perspective.

GSI is also conducting research on methods for effectively developing and providing global maps and making effective technology transfers to developing countries in order to obtain knowledge and data that can be used to understand changes in the global environment.

6. Measures for Proceeding with Research and Development

(1) System for undertaking research and development

GSI has operation departments for undertaking projects as its operations and the Geography and Crustal Dynamics Research Center for undertaking research related to its operations. Both of these facilities are engaged in research and development. The operation departments are engaged in survey research and technical development needed for its operations, while the Geography and Crustal Dynamics Research Center is conducting basic research that should contribute to the development of future operations at GSI, and to the development of a society that utilizes geospatial information.

(2) Evaluations

Regarding evaluations of R&D activities, it has been decided that the Research Evaluation Committee consisting of external experts will be set up to evaluate R&D themes, R&D organizations, R&D policies, etc., based on the "Fundamental Guidelines for Evaluating the Nation's Research and Development" that were revised in December 2012. For special research, it has been decided to make preliminary and post-completion evaluations. Post-completion evaluations are to be made in the final year of R&D and based on the prospects of obtaining the expected final results. For long-term R&D themes that will last longer than 5 years, the necessity of a mid-term evaluation will be examined during the preliminary evaluation, and if it deemed necessary, then a decision will be made regarding the year in which the mid-term evaluation will be made.

The object of R&D organization evaluations will be the Geography and Crustal Dynamics Research Center, which is the GSI's research section.

In addition, evaluations about R&D policies will concern the RD Plan. Specifically, this includes evaluations of the state of goal achievement for each of the key themes indicated in Chapter 4. A comprehensive evaluation will also be made based on items, etc., indicated in Chapter 6 that are needed to develop a research and development environment. Evaluations shall be made mid-way through this plan, and at its conclusion. The details shall be considered at the time the respective evaluations are to be made.

In the key themes, there may be a need for short-term results, and there are also themes that must be approached flexibly due to social changes that may occur over the medium term. Therefore, it will be necessary to evaluate the state of achieving R&D objectives based on the purpose of each objective.

1) Regarding themes for which results should be obtained in the short term, the contents

of self-inspections shall be determined from the perspective of whether or not the initial objectives have been achieved, and utilization states in GSI, related organizations, etc.
2) Regarding themes which should be approached with a medium- to long-term perspective, self-inspections of the objectives, reconfirmation of objectives based on social conditions, state of connections with other organizations, etc., examination of themes for which short-term results may be required, possibility of utilization in the future.

(3) Understanding and management of the implementation of research and development

To proceed precisely with the priority issues in the previous RD Plan, progress management was undertaken for each of the priority issues. For priority issues that spanned multiple divisions, R&D coordinators were assigned to coordinate activities among the divisions and compile evaluation materials. These activities were undertaken within the framework of the GSI's internal evaluation committee.

In the "Fundamental Guidelines for Evaluating the Nation's Research and Development" that were revised in 2012, it is important to make appropriate evaluations that can be linked to subsequent R&D in order to achieve innovation through science and technology, based on the fourth Basic Science and Technology Plan.

At GSI as well, it has been decided to assign R&D coordinators to handle such duties as coordinating respective priority issues in the RD Plan among relevant divisions, and compiling evaluation materials, among other things. These activities will be undertaken within the framework of the GSI's internal evaluation committee.

(4) Promoting the use of Research and Development results

The research and development that is undertaken at GSI has fundamental characteristics that are common to both surveying and geospatial information. The results of GSI's work are utilized by a wide variety of organizations, including not only GSI, but also by external organizations such as government, research, and educational organizations, and private companies, increasing the benefits to society. For that purpose, R&D results are, in most cases, widely distributed through the Internet and other media. At the same time, it has been decided to disseminate easy-to-understand data to the general public by such means as presentations, seminars, lectures, etc., through mass communications. Furthermore, efforts will be made to present the obtained results at academic conferences, etc., and submit papers to academic journals for peer reviewing. Also, in order to utilize these results within GSI itself, information will be shared and exchanged in in-house presentations, research liaison conferences, and so on.

In order to promote the use of results, efforts will be made to do this through alliances with other organizations. This will be done not only for cases where research is done using external sources of competitive funds, but also for cases where individual R&D themes are undertaken with internal budgeting.

Regarding research that is designed to resolve specific issues, efforts will be made to results in relevant administrative policies, and make results and use policies widely known. Special efforts will be also made to disseminate promptly and widely those results related to technical policies such as technical standards and manuals.

Furthermore, in order to give R&D greater significance to future generations, measures for using results that have prospects of being further utilized will be considered. Specifically, this means that the R&D coordinators and the GSI's internal evaluation committee shall work together to exchange information and opinions with people involved with GSI's relevant sections and divisions, joint research organizations, etc., and shall inform GSI staff in charge of R&D of the results. In addition, this series of tasks shall be reported to the Research Evaluation Committee at the mid-term stage of R&D policy evaluation to assist with their evaluation. This will help to build a framework for making more effective use of R&D results.

(5) Nurturing personnel and securing funding for research and development

In order to conduct R&D smoothly according to this plan, and obtain useful results and use them in a satisfactory manner, it is necessary to nurture and maintain a high caliber of staff. For this purpose, GSI shall work to create an environment conducive for nurturing staff from various aspects including personnel, facilities, budget, among others.

To help nurture staff, external researchers will be accommodated from private companies and other organizations. In addition, special researcher and guest researcher systems will be employed to accommodate external human resources, especially young people. Furthermore, efforts will be made to have mutual exchanges of researchers with related organizations, universities, and so on. Particular efforts will be made to secure researchers who will be able to continuously oversee research that is being conducted with a long-term perspective.

In addition to the "Special Research Funds" allocated in the GSI's budget, efforts will also be made to secure funds for R&D through external competitive bidding and other sources.

(6) Development and utilization of an intellectual infrastructure, etc.

The Intellectual Infrastructure Development Plan (drafted in 2001, revised in 2007), which began during the second Basic Science and Technology Plan, notes that the

geographic information database is an important item. It deals with accumulating geospatial information that GSI possesses and releasing it on the Internet and other media. Efforts will be made to improve and advance the intellectual infrastructure based on the fourth Basic Science and Technology Plan, and to promote the accumulation and use of data and results based on the needs of users.

In addition, in view of the nation's open data strategies, GSI should utilize its information in combination with data released by other organizations. The concerted use of intellectual infrastructure owned by external organizations is one effective means of increase the efficiency of conducting R&D. For that purpose, it has been decided to make every effort to collect and utilize information related to intellectual infrastructure that is owned by other research organizations, universities, and others.

Furthermore, it has been decided that superior R&D results will be used to apply for appropriate patents, etc., based on main points of the Intellectual Property Basic Act and the Industrial Technology Enhancement Act.

(7) Securing collaboration and alliances with related organizations in Japan and oversea

To proceed with R&D, collaborative research and stronger alliances with related organizations, academic societies, universities, public-sector companies, both in Japan and abroad, are being promoted to introduce new survey technologies, and promote the wide use of data. At that time, every effort is made to form alliances with fields related to surveying and geospatial information, as well as with users in other fields who would likely use R&D results, such as local governments, educational organizations, NPOs, and so on. In addition, suitable alliances among industry, government and academia are being made for standardization activities related to geospatial information in the ISO (International Standards Organization), and R&D of fundamental technologies for using geospatial information.

In research fields related to disaster prevention as well, alliances are being secured with universities, public organizations, etc., that are involved with disaster prevention, and R&D is being conducted while keeping an eye on trends in such organizations as the Coordinating Committee of Earthquake Prediction, Japan. In addition, concerted efforts will be made to provide R&D results to these organizations.

Furthermore, continuous international joint observations and R&D with IVS (International VLBI Service), IGS (International GNSS Service), etc., will be promoted, and international conferences related to surveying and mapping fields will be attended, such as those held by ISCGM (International Steering Committee for Global Mapping), and the UN-GGIM-AP (Regional Committee of United Nations Global Geospatial Information Management for Asia and the Pacific). Through these international

frameworks, efforts will be made to accumulate knowledge and expand the provision and use of data.