The 5th Science and Technology Basic Plan

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Government of Japan

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Introduction

Both Japan and the world are in the midst of an era of drastic change.

The question is whether science, technology and innovation (STI) can contribute to sustainable and inclusive development here and abroad. The Fifth Science and Technology Basic Plan is expected to be the answer to this question and to provide a compass that will guide the Japanese people, as well as people across the globe, to a more prosperous future.

In the 17th century, the fledgling years of modern science, Robert Boyle wrote future predictions about what we today now know as organ transplants, satellite positioning systems, and other forms of technology. It has taken many long years to bring those predictions to fruition, but recent science and technology, especially the development of information and communications technology (ICT), is now changing economic and social rules in the blink of an eye, while also impacting our lifestyles and the very existence of society and humanity. Innovation is now manifesting itself in places beyond the traditional boundaries and is spreading across the world almost instantaneously.

With the advance of globalization, nations have become ever more interdependent, and the various issues of each country now escalate to a global scale in a flash. Domestically, the declining birthrate and the aging of our population are weakening the vitality of our rural areas. These issues must be addressed, and a social framework must be built that will ensure that each citizen can flourish and achieve a prosperous life.

As information networks advance and people become more mobile on a global scale, flexibility and receptivity will be essential to enjoying the diverse values of society.

In the Fifth Science and Technology Basic Plan, STI policy is mainstreamed as a major policy for the economy, society, and the public.

A culture of "boldly challenging the future" will be cultivated to create future industries and transform society. A "super smart society" (Society 5.0) designed to make people prosperous will be posed to shape our future, and efforts will be enhanced to build a framework to continually create new value, services, and businesses. STI will also be strategically utilized in international collaboration to help address both domestic and international issues. To respond flexibly to any change, the foundations of STI will be strengthened to achieve knowledge implementation with a sense of speed into society. An open, global innovation system will be built to better develop and secure brilliant professionals.

The Science and Technology Basic Plan must resonate with and be executed by those in the fields of research, development, and innovative initiatives. To maximize the potential accumulated from investments to date, universities must be reformed with the recognition that they contribute to society through their education and research, and partnerships between industry, academia, and government must be expanded. Additionally, working with the public will be promoted with the aim of transforming society through STI.

Executing the Fifth Science and Technology Basic Plan will require a wide spectrum of parties—including the government, academia, industry, and citizens—to work together. By executing the Basic Plan, we will grow the national economy and create jobs, secure safety and security for our country and citizens, make lives more prosperous, and contribute to global development.

Chapter 1 Basic Concepts

(1) Recognition of the Current Situation

The economy and society encompassing Japan is in a period of great change.

Entering the 21st century, it is clear that science and technology (S&T) have made great progress. In addition, the rapid progress of information and communications technology (ICT) in recent years has brought about a new reality in which information, people, organizations, logistics, finance—in reality, almost everything—are constantly connected on a global level and mutually influence one another. This is starting to produce hitherto non-existent synergy without being bound to the confines of existing industrial structure and technology fields, thereby creating new businesses and markets. It is also starting to change how we work and live.

Furthermore, as our economy and society matures, values are diversifying, with people's interests shifting from the tangible to the intangible. Rather than just seeking conventional technological innovations, users now demand new values and services to be created that resonate with their diverse needs.

Globalization is progressing further and further, and various social activities are expanding beyond national borders. As companies actively scramble to expand their activities worldwide in anticipation of changing global markets, they are being exposed to tough international competition. Under these circumstances, competitiveness is largely coming to be predicated by how well a company utilizes various knowledge and technology spread across the globe, and the abilities of highly skilled personnel.

Additionally, as the intellectual frontier expands, it is becoming increasingly difficult for individuals and individual organizations to produce all the knowledge and technology necessary for success. Thus, when creating new knowledge and value, it is increasingly important to form and act in teams by bringing together people with diverse expertise. Furthermore, with ever intensifying global competition surrounding innovation, open innovation initiatives that actively incorporate outside knowledge and technology will be of increasing significance to companies. In the same vein, open science is also becoming a worldwide trend in scientific research activities. Promoting to share and make mutual use of research findings beyond existing academic disciplines and national borders is increasing the possibilities for creating knowledge and value outside conventional frameworks.

Meanwhile, networks are rapidly expanding on a global scale and have the potential to overturn the conventional rules of society and people's values. It has become essential to create new rules for protecting personal information and establish codes of conduct to handle the security ramifications. With the emergence and development of the Internet of Things (IoT), robots, artificial intelligence (AI), regenerative medicine, and neuroscience, it is clear that advancements in these new sciences and technologies will have a great impact on not only people's lifestyles but also the foundation of its existence. This will require a rethinking of the relationship between S&T and society.

These different changes are all interrelated and progressing at an accelerating rate. The process of creating knowledge and value has changed dramatically, and it is ushering in an "era of drastic change" where the structure of our economy and society go through significant change on a daily basis.

It must also be noted that issues to be addressed in Japan and the world are increasing in number and becoming more complex.

In Japan, the most pressing issues are energy, resources, food limitations, a declining birthrate and aging population, and the declining rural economies and communities. In particular, the importance of stable and inexpensive supplies of energy and resources in supporting the basis of our economy and society was once again highlighted in the Great East Japan Earthquake. Additionally, the increasing social security costs that come with the progression of an aging society and our deteriorating infrastructure are increasing social costs and becoming a major constraint to upholding and improving our economy, as well as the living standards of our citizens.

Furthermore, there is demand for appropriate responses to the risks of large-scale earthquakes, volcanic eruptions, and other natural disasters, as well as to the changes in Japan's security environment, and the need to increase the resilience of our land and social functions. It should also be noted that the reconstruction from the Great East Japan Earthquake is still a work in progress and efforts must be made to stay its course.

Global issues abound. The world population continues to increase, and food and water resources are becoming increasingly scarce. There are also the threats of infectious diseases and terrorism, widening income disparities, and environmental issues such as climate change and reduced biodiversity. As nations become more and more interdependent, Japan must actively contribute to a global framework for handling such issues and, as a developed country, make proactive contributions to international peace and development with the people of emerging and developing countries. In doing so, it is important for Japan as an Asian country with the most advanced science and technology to make comprehensive use of our knowledge in the humanities, social sciences, and natural sciences to promote and disseminate internationally initiatives for building economic and social systems that will simultaneously help solve these challenges and grow the economy.

Thus, as the economy and society go through significant changes, continued strong promotion of STI[1] is vital in paving the path to a new future and continuing to meet these challenges at home and abroad. Recognizing that the fruit of science and technology have the potential to make impacts in multiple areas, and the fact that research and development (R&D) findings in one area can be applied to others, it is important to make the functioning processes of innovation dynamic while skillfully capturing R&D findings.

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1 Science, Technology and Innovation (STI) comprises all spectrum of creating intellectual and cultural value based on new knowledge from scientific discoveries and inventions, and technology advancement that expands this information to create economic, social and public value

(2) Achievements and Challenges in 20 Years of Science and Technology Basic Plans

It's been almost 20 years since the First Science and Technology Basic Plan (hereinafter "Basic Plan") was developed in 1996 based on the Science and Technology Basic Law, enacted in 1995.

At the time the Science and Technology Basic Law was enacted, there was a demand for Japan to contribute to addressing the issues facing mankind and shift our policy from following the West's lead in science and technology to challenging unexplored science and technology fields ourselves, and to opening our own path to the future as a world frontrunner. With that said, in Basic Plans to date, emphasis has been placed on strengthening policy actions in areas including securing government R&D investments, reforming the R&D system (by enhancing post-doctorate programs, developing competitive environments, etc.), strategically focusing R&D, consolidating R&D facilities and equipment, and promoting international exchange and collaboration.

In terms of government R&D investments, clear target figures have been set since the First Basic Plan. Subsequently, the Japanese R&D environment has been firmly established, with growing amounts of investment for 10 years, as well as growing numbers of researchers and articles published. Japan has become increasingly competitive internationally, even as emerging nations and other countries have gotten stronger in their science and technology endeavors, and as science and technology activity increases both in scale and complexity. We have done so through many types of initiatives, including focused investment in research areas of high importance, development of research centers with world-class competitiveness and large-scale research equipment, and the introduction and promotion of highly competitive human resource management systems.

Meanwhile, with the changes in Japan's international competition environment since the turn of the 21st century, there has been strong demand for R&D findings to be used in society, and for Japan to be more competitive and contribute further to social reform. In response to these changes, the Basic Plan has also evolved by promoting industry and academia collaboration and interaction. In the Fourth Basic Plan, the importance of innovation took the forefront, and the R&D focus was diverted from a science-and-technology-fields-based approach to a problem-solving approach. With these developments, joint research between universities (including inter-university research institutes; hereinafter the same), R&D institutions, and companies has steadily increased, as has the numbers of patents held, and license permissions. Moreover, income for patents in universities and R&D institutions has also increased.

In addition, in view of deploying STI to address various economic and social issues, new initiatives for industry, academia, government, and relevant ministries to work together in R&D and social implementations have been advanced, such as the Cross-ministerial Strategic Innovation Promotion Program (SIP). Furthermore, in 2014, the Council for Science and Technology Policy (CSTP), which oversees science and technology policy, was reorganized to become the Council for Science, Technology and Innovation (CSTI), and has started new approaches.

Thus, over the past 20 years, a concerted effort by the country as a whole in advancing science

and technology policy based on the Basic Plan continues to contribute to development in Japan and across the world. Several examples of science and technology that have either brought about great lifestyle and economic change, or which could make changes in the future, have appeared. The invention of blue light-emitting diodes (LEDs) has given rise to numerous lighting applications, and the creation of human-induced pluripotent stem (iPS) cells has developed into applications in regenerative medicine. There have also been contributions to addressing global issues, such as infectious diseases. Through it all, the fact that Japan has the world's second-most Nobel Prize laureates in the natural sciences in the 21st century is a testament to our great presence in science and technology in the world.

Despite these achievements, there are several issues of concern. As the first point to be addressed, Japanese STI has seen its foundation rapidly weakened in recent years. Our research papers are dropping in international ranking, both in quantitative and qualitative terms. There have been delays in building an international research network, and Japanese science and technology activity is regrettably starting to fall behind the world leaders. Additionally, in terms of human resources in STI, no environment is yet in place in which young researchers can fully demonstrate their abilities, and many of our high-capability students are hesitant to pursue doctoral courses. Because Japan's young population is expected to shrink even further, solving such human resource problems is a pressing issue for STI.

It is also noteworthy that industry–academia collaboration has yet to reach full maturity. Indeed, much of the current industry–academia collaboration is on a small scale, and there is still little mobility for researchers across organizations and sectors. Startup companies and the like have yet to reach the point of structurally transforming Japanese industry. Therefore, we need to clearly recognize that the mechanism for filling the gap between company needs and the knowledge and technology generated by universities has not fully performed its function to date. This is leading to deficiencies in Japan's ability to innovate through science and technology.

In addition, due to the Great East Japan Earthquake and the followed nuclear power incident, as well as the recent case of research fraud and other incidents, confidence in Japanese science and technology, as well as our researchers and technical experts, is falling. Thus, the importance of reconsidering the relationship between S&T and society, as well as promoting STI together with the various stakeholders of society, is increasing.

Government R&D investment targets indicated in the Basic Plans have not been met since the Second Basic Plan, and government R&D investment growth has stagnated the last 10 or so years compared to the world's leading nations.

Various systematic factors are in play in the background of the issues mentioned above. Universities, the main proponent in STI activity, are lagging behind in terms of management and human resource management systems, and other organizational reform. Furthermore, there are barriers between organizations, between industry and academia, between ministries, between research fields, and more. These points must be swiftly improved.

As has been described to this point, Japan's world standing in science and technology is falling

as a whole, just as other countries are further strengthening their STI policies. In addition, the shift from S&T policy to STI policy as given in the Fourth Basic Plan may not be progressing sufficiently. These issues must be addressed with bold reforms that recognize the strong pressure of necessity and urgency. In the interest of extracting the most out of the results of the R&D investments of the past 20 years, it is particularly important to reform the systems for addressing the various issues related to human resources in STI, and to reorganize and enhance the function of universities and National R&D Institutes.

(3) Target National Profile

STI policy is one of major national policies for the economy, society, and the public that will enable our country to shape a better future. Therefore, it is essential to policy promotion that the policies clearly present what kind of country is to be achieved and share this profile with its citizens.

In the Fifth Basic Plan, with the economy and society changing so rapidly and extensively, and with the bevy of issues emerging both nationally and globally, the following four policy goals have been defined as the Target National Profile to ensure sustainable development for Japan and the world into the future. In the policy implementation phase, the Japan Revitalization Strategy will be promoted in line with the other major policies for the economy, national security, diplomatic relations, and education, with aims to achieve this national profile to its fullest extent.

① Sustainable growth and self-sustaining regional development

Economic growth and job creation are the core supporting our national development. As such, Japan will strive to increase production to revitalize regional communities and society as a whole and create adequate jobs domestically, as well as to achieve sustained improvement in economic strength.

② Ensure safety and security for our nation and its citizens and a high-quality, prosperous way of life

To protect citizen lives and property and to help them achieve prosperity is the mission of a state. Given this, Japan will aim to ensure the safety of our nation and citizens, and to guarantee citizens' richness in minds and high-quality way of life.

③ Address global challenges and contribute to global development

Japan must continue to be the country that constantly contributes to the advancement of mankind. Thus, Japan will aim to proactively apply our STI ability to responding to global issues and improving the quality of life in developing countries. We will also strive to actively contribute to sustainable world growth.

④ Sustainable creation of intellectual assets

Achievement of the national profile described in items 1) to 3) is contingent upon Japan as a

nation having a high level of STI. Thus, Japan will aim to ceaselessly ensure excellence in knowledge creation in diverse fields, and to promptly use the results in society to create economic, social, and public value.

(4) Basic Principles
① Four pillars of the Fifth Science and Technology Basic Plan

In promoting STI policy to achieve the Target National Profile, both the ability to be visionary and strategic in predicting what will come, and acting strategically, as well as the ability to mobilize diversity and flexibility in responding appropriately to any changes, will be stressed in this era of drastic change.

Currently, Japanese STI activity is hampered by various barriers and is often domestically oriented, and is thus unable to explore its full potential. Based on this, the Basic Plan will guide Japan toward becoming "the most innovation-friendly country in the world." Japan will achieve this by having all constituents compete and collaborate in international open innovation systems and by building a framework allowing each constituent to fully mobilize their abilities and competencies, across all fields of science, including humanities and social sciences, to create a rich variety of Japan-led innovation.

Based on this approach, the following four initiatives will be positioned as policy pillars of the Fifth Basic Plan and they will be strongly promoted.

i) Acting to create new value for the development of future industry and social transformation

In this era of drastic change, for Japan to remain competitive and strong in the future, it is critical that we ascertain domestic and international trends despite uncertain prospects and act strategically with vision to create future industries and pursue social transformation.

Therefore, Japan will be acting proactively to be in a position to lead the era of drastic change by initiating disruptive innovation. Furthermore, we will enhance our efforts in building a framework aimed at creating prosperity for citizens. This will involve sharing the value of a "Super Smart Society," the shape for our future society, supported by the major trend of times such as advancement of ICT, networks, and other enabling technologies in which new values and services will be continuously generated.

ii) Addressing economic and social challenges

With the economic and social structure changing daily, appropriate preemptive action addressing various emerging issues is imperative to ensure sustainable development in Japan and worldwide. Japan will be addressing these challenges by selecting the key national policy issues, and acting comprehensively and coherently on the basis of the Target National Profile.

iii) Reinforcing the "Fundamentals" for STI

To respond appropriately to the various possible future changes through STI, it is essential to strengthen the foundations of STI, namely 1) the abilities of the researchers at the core of STI, 2)

the academic and basic research needed for ensuring excellence and diversity in knowledge creation at the source of innovation, and 3) funding to support all STI activity. To do so, initiatives for strengthening these foundations will be advanced strongly. These will focus on reform of universities' function and strengthening of their management capacity, along with training and career advancement for younger researchers, who will be the ones to lead us in an era of uncertain prospects.

iv)   Building a systemic virtuous cycle of human resources, knowledge, and capital for innovation

Japan's future competitiveness is contingent upon the utilization of its human resources, knowledge and capital domestically and abroad, the creation of new value, and the prompt implementation of these new values in society as part of the progressing global initiatives for open innovation. To bring this about, an innovation system will be built to ensure the mobility of human resources, knowledge, and capital beyond all kinds of barriers, and keep Japan at the leading edge of worldwide innovation. This will be achieved through building effective collaboration between companies, universities, and public research institutions, and by both creating and strengthening venture businesses.

In advancing these four initiatives, it will be essential to work in coordination with science and technology diplomacy, and to act strategically in an international context.

STI activity has recently been expanded past national borders. In this context, questions related to how well an international research network can be established and whether a framework that will promptly and effectively utilize intellectual resources across the globe can be built will have a great impact on Japan's international competitiveness. Amidst the great ongoing changes in the international environment, Japan needs to raise its international profile by utilizing its ability in STI and by demonstrating leadership in the pursuit of common interests shared by Japan and the world.

Given all this, it is important in the promotion of STI policy for Japan to always take the global perspective into consideration and act strategically in its international collaboration. In this way, Japan will work to bolster global brain circulation and position a framework capable of disseminating Japan's science and technology to the world, within its science and technology diplomatic strategy, as part of the visible face of the nation.

② Important issues in the promotion of the Science and Technology Basic Plan

Upon effectively and efficiently advancing the above four initiatives, it is essential to deepen the relationships between STI and the various stakeholders of society, and to strengthen the ability of these stakeholders to promote this STI.

i)   Deepening the relationship between STI and society

The perspectives of users with diverse values have become essential to the creation of innovation. Additionally, the basic premise for STI to meet social expectations is that it must win

the understanding, trust, and support of society. Thus, we will engage the various stakeholders of society in dialogue and collaborate with them in promotion of STI activity.

ii) Enhancing capacity to promote STI

To advance STI effectively, it is essential for it to resonate with universities, public research institutions, companies, and the other various main proponents involved in STI activity. The keys are to flesh out initiatives aimed at strengthening the functions of each player and to expand industry–academia–government partnerships.

In addition, with accelerating economic and social change, along with developing a 5-year Basic Plan as the basic objectives for STI policy, every year a Comprehensive Strategy on Science, Technology and Innovation (hereinafter "Comprehensive Strategy") will be developed to facilitate flexible policy management.

Furthermore, we will constantly be working to improve the quality of our policies by determining the status of key indicators and achievement levels for numerical targets. The key indicators for determining the progress and outcomes of the Fifth Basic Plan are to be determined separately, and numerical targets will be defined in this Basic Plan for items for which the situation to be achieved must be, and can be, clarified quantitatively. Note that the numerical targets described here are for determining progress toward achieving STI targets by the nation as a whole and are not intended for unaltered use in evaluating individual institutions or researchers. The government must take care not to let the pursuit of the target values in and of itself become the goal, or to invite unwanted results or divergence from the original aims. Moreover, universities and National R&D Institutes are required to proceed with initiatives to achieve visions that leverage their individual strengths and characteristics based on the policy objectives and content described in this Basic Plan. It is imperative that the collective actions of these institutions achieve the numerical targets by the nation as a whole given in this Basic Plan, and that an environment be built in which STI can proceed effectively.

Chapter 2 Acting to Create New Value for the Development of Future Industry and Social Transformation

We have arrived at the era of drastic change where the process of creating knowledge and value has changed considerably, and where the economic and social status quo, as well as industrial structures, are rapidly changing. In such an age, so-called game-changing shifts are expected to occur frequently, as new knowledge and ideas conceived in quick succession significantly impact the competitiveness of organizations and countries.

The driving force of this trend is the rapid development of network connectivity and cyberspace use that has accompanied the evolution of ICT. This development also indicates the overall direction where Japan, as well as the global economy and society, is heading. We are now at a stage where innovation is being generated in a variety of ways. Through the medium of the Internet, we are seeing the dramatic spread of the Internet of Things (IoT), in which objects or "things" are connected and have access to a variety of information, and the Internet of Everything (IoE), in which everything is connected to each other. New knowledge is created from the huge amounts of data that are collected. Furthermore, from the linking and merging of different matters that has never been previously imagined, new products and services are conceived to match consumer needs, thereby expanding markets instantly.

In order to create values and services that cannot be projected from the past and bring about changes to the economy and society, a new approach is necessary—one which strikes out in a new direction—in order to stimulate further challenges in addition to the initiatives that have been pursued through the past Basic Plans.

In this era of drastic change, where predicting the future outlook is difficult, we can only get ahead of the times through creating new game-changing knowledge and ideas. Toward this goal, we will foster initiatives that boldly attempt new ventures and actively generate discontinuous innovation.

Furthermore, in light of the rapid development trends of network connectivity and cyberspace use, we are proposing an ideal form for our future society, a "super smart society" where new values and services are continuously created in order to bring wealth to the people who make up society through initiatives that focus on actively using and applying cyberspace. Over the course of this proposal, we will foster initiatives that are aimed at realizing the world's first super smart society.

(1) Fostering R&D and Human Resources that Boldly Challenges the Future

To foster and sustainably develop Japan's international competitiveness in a world where new knowledge and technology are produced on a daily basis, and then rolled out as economic or social activities on a global scale, and in which the cores of competitiveness are undergoing changes, it is essential for Japan to actively produce new value and be a leader in the transformations.

In particular, the process of setting the bar high, and boldly attempting to consistently create unrivaled innovation without fear of failure, is important. New knowledge and technologies are

created by breaking out of the current customs and paradigms, continually challenging the frontiers of our present knowledge and technology, which are the roots of social transformation, and by conducting trial social implementation. Thereafter, creating groundbreaking value from such new knowledge and technologies is essential. Such value may have a major impact on competitive strength by completely changing the current rules of the competition.

To this purpose, in addition to conventional R&D, we will accelerate the creation of discontinuous innovation by adopting mechanisms for stimulating efforts on R&D that places emphasis on novel, unconventional ideas with economic and social impact. However, these policies will not be possible without the cultivation of a variety of different ideas. Hence, we will also provide opportunities for experimenting with ideas in the form of presenting R&D projects to professionals possessing highly creative ideas and the ability to act toward the implementation of those ideas. In addition, we will work on fostering and securing human resources who can effectively operate and manage projects while considering these features.

Based on all of the above, Japan will widely disseminate a suitable method for promoting "challenging" R&D in the R&D projects conducted by the government ministries. Concretely, this will involve introducing R&D management through project managers, granting opportunities to researchers possessing new ideas by enhancing their authority, implementing an evaluation that encourages research that may not necessarily have a high probability of yield (high-risk research) but that can be expected to have a significant impact if successful, implementing a stage-gate system for developing groundbreaking but highly risky research while confirming results at each stage of progress, adopting an awards system that provides incentives to research based on novel ideas, as well as efforts. Through such dissemination techniques, we will facilitate R&D that would not have been implemented within most conventional R&D projects, and encourage researchers that are up to the challenge to play an active role.

In doing so, the following should be noted: "In high-risk R&D, failure is an indispensable part of the process; there is also value in pursuing the challenge itself." Under this concept, it is clearly also important to create a framework that will make full use of such failure going forward to the next stage, or to solving other issues.

Moreover, we plan on devising ways to further develop and expand ImPACT (IMpulsing PAradigm Change through Disruptive Technologies Program) R&D project. As a model case of "challenging" R&D project, we plan on extending similar schemes to the R&D projects under the auspices of relevant government ministries.

Note that to be able to produce game changers from the knowledge arising from "challenging" R&D, knowledge must be speedily converted into value. The role of venture businesses, in particular, is extremely important for this conversion, and developing an environment where such businesses can be created continually and flourish is vital.

(2) Realizing a World-leading "Super Smart Society" (Society 5.0)

In a world where ICT is evolving, and where the use and application of networks and IoT is advancing, ICT is being leveraged to its fullest in the manufacturing sector, such as in Germany's

"Industry 4.0," the United States' "Advanced Manufacturing Partnership," and China's "Made in China 2025." Such efforts to lead change in the so-called fourth industrial revolution are now being laid out under government–private partnerships.

From here on, ICT is expected to further evolve so that "things," which have so far functioned separately, will be connected into "systems" using cyberspace. Furthermore, separate systems in various fields will be able to coordinate and collaborate, widening the range of autonomy and automation, and creating new value throughout society. This is expected to usher in transformational change in a broad range of industrial structures such as manufacturing, logistics, sales, transportation, health and medical care, finance, and public services, thereby changing how people work and live, and providing the impetus to realize an abundant and high quality of life for citizens.

For Japan in particular, where the impact of the falling birth rate and aging population are becoming more evident, these efforts to create intelligent "systems," and their coordination and collaboration that encompass various fields aside from the manufacturing industry, are extremely important for shaping economic growth and a healthy, long-lived society, which will lead to further social transformation toward realizing an abundant society in which each individual can live a vigorous life. Such endeavors will also spur the spreading of the fruits of science and technology, such as ICT, into fields and domains that have not been adequately reached until now, and is expected to enhance business strength and improve the quality of service.

Through an initiative merging the physical space (real world) and cyberspace by leveraging ICT to its fullest, we are proposing an ideal form of our future society: a "super smart society" that will bring wealth to the people. The series of initiatives geared toward realizing this ideal society are now being further deepened and intensively promoted as "Society 5.0."[2]

① Super smart society (Society5.0)

A super smart society (Society 5.0) is characterized as follows:

a society that is capable of providing the necessary goods and services to the people who need them at the required time and in just the right amount; a society that is able to respond precisely to a wide variety of social needs; a society in which all kinds of people can readily obtain high-quality services, overcome differences of age, gender, region, and language, and live vigorous and comfortable lives.

Such a society is expected to, for example, develop and realize an environment in which humans and robots and/or artificial intelligence (AI) coexist and work to improve quality of life by offering finely differentiated customized services that meet diverse user needs. The society must also be capable of anticipating potential needs and providing services to support human activities, resolving gaps in service due to differences in region, age, etc., and enabling anyone to be a service provider.

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2 So called to indicate the new society created by transformations led by scientific and technological innovation, after hunter–gatherer society, agricultural society, industrial society, and information society.

In the future, with the progress in efforts toward a super smart society, one can anticipate not only the integration of several systems such as energy, transportation, manufacturing, and service but also the integration of organizational management functions such as personnel, accounting, and legal departments, as well as the work value implemented by people such as manpower and idea creation, which will further lead to the creation of value.

On the other hand, because of the high degree of merging between cyberspace and the real world in a super smart society, the damage that cyber attacks can inflict on the real world will also become increasingly severe and may seriously affect people's lives, including their economic and social activities. Thus, achieving a higher level of "security as a quality feature"[3] is required. Such efforts will serve as a source of industrial value and international competitiveness.

② Efforts required to realize a super smart society

In order to realize a super smart society, it is necessary to connect various "things" via a network, create highly advanced systems out of these things, and integrate several diverse systems so that they can coordinate and collaborate with each other. This integration allows for a wide variety of data[4] to be collected, analyzed, and applied across all the coordinating and collaborating systems in order to continuously produce new values and services.

However, it is not realistic to believe that a framework capable of enabling the coordination and collaboration of all kinds of systems could be constructed right away. Working toward this goal, 11 systems[5] were identified and given priority for development in the 2015 Comprehensive Strategy, based on the economic and social issues that require the strongest national efforts. By increasing the sophistication of these individual systems, we will incrementally work toward their coordination and collaboration.

First, through collaborations between industry, academia, and government, as well as the relevant ministries and agencies, initiatives for increasing the sophistication of these 11 systems will be worked on steadily, based on the tasks that are set as performance goals for each individual system. Successful cases and problematic issues will be shared across all the initiatives to allow for cross-application over the systems.

Alongside the individual initiatives for the 11 systems, a common platform will be built in stages that will allow for coordination and collaboration between multiple systems and that can be used in various services, including new services that have not yet been anticipated. In particular, because of their ability to accelerate coordination of multiple systems and improve industrial competitiveness, "Intelligent Transport Systems," "optimizing the energy value chain," and "new manufacturing systems" will be developed as core systems. Coordination and collaboration with

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3 It means that safety and security are pre-installed as essential service quality features, which is expected by individual customers and businesses users.
4 Web data, human activity data, 3D geographical data, transportation data, environmental observation data, production and distribution data of manufacturing and agricultural produce, as well as others.
5 Optimizing the energy value chain, building a global environment information platform, maintenance and upgrade of an efficient and effective infrastructure, attaining a resilient society against natural disasters, Intelligent Transport Systems, new manufacturing systems, integrated material development systems, and promoting integrated community care systems, hospitality systems, smart food chain systems, and smart production systems.

the other systems such as "promoting integrated community care systems," "smart food chain systems," and "smart production systems" will be worked on as soon as possible in order to create new value in the economy and society.

However, based on the concept of security by design, it is important to promote these initiatives while incorporating security into the overall system from the planning and design stage.

Based on all these factors, Japan, through collaborations between industry, academia, and government, as well as the relevant ministries, will promote the initiatives necessary to build a common platform ("super smart society [Society 5.0] service platform") that effectively utilizes the IoT toward realizing a super smart society.

Concretely, this will involve working on standardizing the interfaces, data formats, etc., in order to facilitate the use of data between multiple systems, promote the development and trial implementation of a highly sophisticated common security technology shared by all the systems, and develop a function that will appropriately perform risk management.

In addition, for information provided by Japan's common platform system, such as the three-dimensional mapping and positioning data and meteorological data obtained from the Quasi-Zenith Satellite System, Data Integration and Analysis System (DIAS), and the Japanese Public Key Infrastructure (JPKI), we will work on providing a framework and developing related technologies that will enable the broad use of these data between systems.

Moreover, in order to respond to increasingly large-scale and complex systems, we plan on intensifying the development of fundamental technologies for information and communication, and building up social measurement functions that will show their impact on the economy and society along with the social costs.

Furthermore, we plan on promoting a science that is instrumental in responding to issues regarding the protection of personal information and the responsibility of manufacturers and service providers in terms of strengthening ethical, legal, and social initiatives aimed at integrating the humanities and science toward trial implementation in society. We will also promote deregulation and system reforms that will allow the provision and operation of new services and the creation of appropriate systems and regulations.

Alongside all these initiatives, we will also foster the R&D researchers needed to build the super smart society service platform, as well as those that will utilize this platform to create new value and service.

Note that these initiatives are also conducive to forming a healthy, long-lived society, which is a key issue in Japan. In this regard, CSTI is furthering cooperation and collaboration with the Headquarters for Healthcare Policy, as well as with the ICT-related command center, the Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society, and the National Center of Incident readiness and Strategy for Cybersecurity. Together with laying the foundation for a cooperative network encompassing industry, academia, and government, as well as with the relevant ministries for building the super smart society service platform, CSTI prioritizes initiatives and sets detailed targets in its Comprehensive Strategy, which is formulated each fiscal year.

(3) Enhancing Competitiveness and Consolidating Fundamental Technologies in a "Super Smart Society"

① Initiatives required to enhance competitiveness

For Japan to maintain and strengthen its competitiveness in a super smart society, the country will have to lead the world in implementing such initiatives in order to accumulate the necessary knowledge and know-how for advancing intellectual property and international standardization. Together with continuously enhancing functionality for the future platform to stimulate the creation of new businesses that will respond suitably to diverse needs, it is also important to provide unique and distinctive Japanese features to the platform and its individual systems in order to establish their advantage.

To this purpose, Japan, through collaboration between industry, academia, and government, as well as the relevant ministries, will implement intellectual property strategies and international standardization related to technologies and interfaces for the realization of the super smart society service platform.

Moreover, consolidating the fundamental technologies necessary to build the super smart society service platform and further consolidating Japan's technological strengths, which form the core of new value creation in individual systems, are essential. The specific technological domains and their corresponding promotion measures are presented in the next section.

In addition, through promoting exports of system packages verified to have achieved their performance goals, we can create new global businesses made in Japan, and turn the issues troubling the nation, such as the falling birth rate and aging population, energy restrictions, and natural disaster risks, into strengths.

At the same time, we will foster human resources that can use the super smart society service platform to generate businesses that create new values and services, and build new business models, as well as foster those who possess basic knowledge such as data analysis and programming, and who can use the fundamental technologies such as big data and AI in discovering new issues and solving them.

② Strategic consolidation of fundamental technologies

i) Fundamental technologies necessary to build the super smart society service platform

The fundamental technologies necessary to build the super smart society service platform, in other words, the technologies concerned with distribution, processing, and accumulation of information in cyberspace, are the essential technologies in forming our world-leading super smart society and creating added value from big data.

Hence, Japan will speed up consolidation of the following fundamental technologies in particular.

- Cybersecurity: technology that supports safe information and communication, considering the characteristics of the IoT, such as the long life cycles from design to disposal
- IoT system architecture technology: technology that enables the modeling of hardware and

software as components, and the building and operating of large-scale systems

- Big data analytics: technology deriving knowledge and value from large amounts of a wide variety of data, including unstructured data
- AI: technology that supports IoT, big data analytics, and advanced communication
- Device technology: technology that enables the high-speed, real-time processing of large amounts of data with low power consumption
- Network technology: technology that distributes growing amounts of data at high capacity and high speed
- Edge computing: technology that enables increasing speed and diversification of real-time processing at the actual system location, which is necessary for increasing the functionality of IoT

In addition, since mathematical sciences is an inter-disciplinary scientific technology that supports all these fundamental technologies, we will promote it together with strengthening collaboration in R&D of each technology, and when fostering professional development.

ii) Fundamental technologies that are Japan's strengths, which form the core of new value creation

By embedding components that make use Japan's technological strengths in each system's element, we can establish Japan's advantage and make it possible for the system to create new value that meets the diverse needs of the economy and society in Japan and overseas.

Hence, Japan will consolidate the following fundamental technologies in particular, which function as core technologies in the real world, for new value creation in individual systems.

- Robotics: technology expected to be used in various fields such as communication, social service/work assistance, and manufacturing
- Sensor technology: technology that collects information from humans and all kinds of "things"
- Actuator technology: technology related to activating mechanism, drive, and control devices in the real world, as well as the results of information processing and analysis obtained in cyberspace
- Biotechnology: technology transforming sensor and actuator technologies
- Human interface technology: technology using augmented reality, affective engineering, neuroscience, etc.
- Material/nanotechnology: technology that leads to differentiated systems through enhanced functionality of various components, such as innovative structural materials and new functional materials
- Light/quantum technology: technology that leads to differentiated systems through enhanced functionality of various components, such as innovative measuring techniques, information/energy transfer technology, and processing technology.

For the fundamental technologies given in i) and ii), since connecting several technologies organically is expected to stimulate mutual technological development, such as the way collaboration between AI and robotics is expected to bring about the enhancement of both AI recognition and robot motor functions, sufficient attention must be paid to the connections

between and the integration of differentiated technologies.

iii) Principles on consolidating fundamental technology

To consolidate the fundamental technologies given in i) and ii), setting high performance targets for each technology that consider the direction of change toward a super smart society from the medium- to long-term perspective of around 10 years into the future, and then working toward achieving these goals, is the key.

In working on these goals, building the framework for industry–academia–government collaboration and for facilitating R&D is vital to actualizing smooth progress toward trial use of the technology in society. In particular, it is important to move forward with R&D not in a linear model, which begins from the basic research stage, advances to the development stage, and then proceeds on to use in society, but instead in a spiral fashion, in which the development, use in society, and basic research stages mutually stimulate each other. This will provide an environment in which new science can be created and innovative technology can be produced, and where developing the technology into a practical application and commercialization can be worked on simultaneously in parallel.

While going forward for R&D and human resource development with outstanding professionals, knowledge and capital tapped from around the world, there is also a need to deeply work through the possible impact such technological developments will have on humans and society. In such technology domains as AI and security, researchers from both social and natural sciences will have to carry out integrated and actively collaborative R&D. In creating such an R&D environment, an administrative structure that can flexibly manage projects will need to be set up by gathering outstanding human resources from both inside and outside of Japan, and providing them with eminent leadership.

For the key fundamental technologies, CSTI will formulate overall strategies based on the abovementioned contents, considering the perspective of all government ministries and agencies, and lead in promoting effective and efficient R&D. To accomplish this, the state of progress of R&D in each key technology domain will be evaluated to set priorities for use when going forward. At the same time, CSTI will flexibly promote R&D, including appropriate revisions of technological domains and goals, in order to respond to changes in technological trends and the economy and society.

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Chapter 3 Addressing Economic and Social Challenges

The emerging domestic and global challenges facing Japan are becoming increasingly wide-ranging and complex. In order for Japan to fulfill its vision by realizing the stated goals of "sustainable growth and autonomous regional development," "ensuring safety and security for our nation and its citizens and a high-quality, prosperous way of life," and "responding to global challenges and contributing to global development," it needs to mobilize STI and work strategically for solutions to problems.

In light of this, from the various domestic and global challenges that are evident, we will identify the most important policy themes—those judged to have the potential to make a strong contribution to STI that lead to solutions that will help to realize our vision of Japan. In addition, we will present the initiatives and technology challenges that are keys to resolving the identified policy themes. With a focus on these initiatives and technology themes, industry, academia, and government (including relevant government agencies) will collaborate in taking a streamlined approach to everything from R&D to commercialization.

Furthermore, they will cooperate in this effort with a diversity of community stakeholders and make best possible use of the Cross-ministerial Strategic Innovation Promotion Program (SIP), which identifies issues by cutting across the traditional boundaries of government ministries and disciplines. In doing this, it will be vital for the nation to make strategic use of intellectual property and international standardization in order to rapidly convert the fruits of research into commercialization and international deployment, and to improve competitiveness. At the same time, it is also important for the government to reflect on the progress of recovery from the Great East Japan Earthquake and other major disasters and continue working together with local governments in efforts to pursue STI that lead to new technologies and new industries for disaster-affected areas.

Still, economic and social conditions change from year to year. Therefore, while working toward solving these technical challenges, the most important and urgent goals are liable to change. For this reason, in pursing R&D to solve these challenges, we will set new points of focus and detailed goals in the Comprehensive Strategy that is formulated each year, while remaining centered around the goals of the Basic Plan.

In FY2020, the final year of the Basic Plan term, the Tokyo Olympic and Paralympic Games (hereinafter "Olympics") will be held. The Olympics will be used to publicize and showcase the fruits of Japan's STI within and beyond the country, as well as to stimulate international activity of Japanese industry and foreign investment in Japan. Furthermore, the Olympics will be regarded as an opportunity for establishing a virtuous economic cycle even beyond 2020.

With this vision, we will steadily pursue projects that contribute to Japanese STI and which can accelerate efforts aimed at the Olympics, such as multilingual translation technologies that can eliminate the communication and mobility-related stress of tourists visiting Japan, and impressive new image-related technologies—all the while encouraging the participation of companies in these efforts.

(1) Sustainable Growth and Self-sustaining Regional Development

In order to achieve sustainable growth, Japan must now and in the future deal appropriately with the spiraling social costs that it faces. For this, it is necessary to ensure stable supplies of energy, resources, and food and to reduce our level of dependency on foreign suppliers for these commodities, as well as to achieve greater efficiency in all processes such as ensuring citizens long, healthy lives, establishing a sustainable social security system, and maintaining and renewing infrastructure. In addition, in order to promote the autonomous development of regional Japan, it is necessary to revitalize local communities and preserve urban services. Furthermore, since improving the competitiveness of industry is a key element for stimulating national economic growth and regional vitality, there is a need to spawn new businesses from the manufacturing; healthcare; agriculture, forestry, and fisheries; and energy industries. Accordingly, on the basis of the three viewpoints ① to ③ below, we have set seven important policy challenges on which R&D efforts will be focused.

① Ensuring stable energy, resources, and food

i) Ensuring stable energy and improving energy efficiency

Japan's energy supply is based primarily on fossil fuels, the majority of which is imported. The electricity supply is generated using fossil-fueled thermal, nuclear, and hydroelectric power sources. However, since the shutdown of the country's nuclear reactors following the Great East Japan Earthquake, the shortfall in available electricity supplies has been made up primarily by a boost in fossil-fueled thermal power generation. Although renewable energy has been promoted at a national policy level in recent years, Japan's energy supply structure is still very weak when viewed from an international perspective.

Given this situation, it is necessary to achieve a more stable energy supply and higher energy utilization efficiency, with the aim of achieving an optimal energy mix, and with a view toward the future energy supply–demand structure. While promoting the advancement of current technology and the adoption of leading-edge technology, we will strive to create innovative new technology.

More specifically, we will pursue R&D on more efficient energy efficiency technology in the industrial, consumer (residential, commercial), and transportation (road vehicles, ships, aircraft) sectors, and promote their diffusion. We will also pursue R&D aimed at increasing the efficiency and reducing the cost of renewable energy and promoting its widespread adoption, such as technology that enables more stable energy utilization by means of more advanced power grid systems, the use of hydrogen fuel, and the use of energy storage technologies. On top of this, we will pursue R&D aimed at higher efficiency fossil fuel utilization, and on making more effective use of nuclear energy through technology to improve nuclear safety and security, and to develop more-advanced reactors. Furthermore, we will work on R&D aimed at establishing important energy technologies for the future, such as innovative nuclear fusion and nuclear fuel cycle technologies.

ii) Ensuring stable resources and cyclical use

Japan relies on imports for the majority of its fossil fuels and rare earth metals, so restrictions and

delays of import and export as well as price rises due to increasing demands have a direct impact on the country's economy and industry. The proper handling of increasing pollution and waste generated by the mining and refinement of resources is also an urgent issue.

To address this challenge, while working to ensure a stable supply of resources, we will aim to realize a sustainable, lifecycle-based, recycling-oriented society with improved resource productivity and recycling rates as well as reduced final waste disposal amount.

More specifically, we intend to pursue R&D on technologies for assessing the potential of unconventional resources, for using those resources, and for the exploration and production of seabed resources such as hydrothermal deposits in Japan's territorial waters, while simultaneously ensuring the conservation of marine environments. In addition, we will pursue R&D on technology for resource saving and alternative material usages, on low-environmental impact refining technologies, and on resource recovery, separation, and recycling. Furthermore, we will undertake R&D on technologies for the production and utilization of fuels and chemicals from biomass and waste, and on waste treatment technologies.

iii) Securing a stable food supply

In light of potential food shortages and changes in crop suitability due to the increasing global population and global warming, securing a stable supply of food for the people of Japan is an urgent challenge and also an important duty of the government. At the same time, if we look at the current state of the agriculture, forestry, and fisheries industries, which are important for sustaining regional economies, we immediately find that the decline and aging of the available labor force is rapidly worsening. As a result, improving the productivity of these industries and revitalizing related industries is also a serious issue, particularly in view of the Trans Pacific Partnership (TPP).

Accordingly, we intend to increase the number of new, willing workers, promote exports of agricultural, forestry, and fisheries products and foodstuffs, and thereby increase food self-sufficiency.

More specifically, we will promote "smarter" agriculture that utilizes information and communications technology (ICT) and robot technology to achieve lower costs and large-scale production. We also develop high-quality and high-yield agricultural, forestry, and fishery products using advanced breeding technologies including new plant breeding techniques. In addition, we aim to enhance the appeal of these industries by constructing new and more profitable business models. We will also promote R&D on processing and distribution technologies, such as technologies to preserve freshness, with a focus on export markets.

② Achieving a sustainable society to handle hyper-aging, depopulation, etc.

i) Establishment of a society in which people enjoy long and healthy lives with world-leading medical technology

As Japan has already become an ultra-aging society ahead of the rest of the world, the translation of Japan's basic scientific research into efforts to promote the development of the world's most advanced medical technology and the extension of healthy life expectancy through medical care that

utilizes the results of these efforts is an issue, as is the need to ensure the sustainability of Japan's health care system. With these aims, through the efforts that will be made to develop new drugs, medical device, and medical technology originating in Japan, it is hoped that improving industrial competitiveness in the field of medical related industry will contribute to our nation's economic growth.

Accordingly, under the Headquarters for Healthcare Policy, and based on the Healthcare policy and the Plan for Promotion of Medical Research and Development, we will steadily pursue R&D, through the Japan Agency for Medical Research and Development (AMED), in the project for Drug Discovery and Development, the project for Medical Device Development, the project for Japan Translational and Clinical Research Core Centers, the Japan Regenerative Medicine Project, the Japan Genomic Medicine Project, the Japan Cancer Research Project, the Project for Psychiatric and Neurological Disorders, the Emerging/Re-emerging Infectious Disease Project of Japan, and the Rare/Intractable Disease Project of Japan.

In addition, Japanese medical technology and industrial competitiveness will be utilized in efforts to combat global issues such as controlling infectious disease in partnership with various other countries, and to play a leading role in making an international contribution that takes advantage of our nation's strengths.

Furthermore, in addition to adopting a medical identification number system for use in healthcare collaboration and medical research, the establishment of medical ICT infrastructure through the digitization and standardization of medical information and data, and promoting the collection and utilization of diagnostic information for use in examination, treatment, and medication uses, we will actively promote cooperation on regional healthcare relationship. We will also establish an environment that enables greater utilization of data in the fields of medical and long-term care in order to improve their quality, and to promote R&D that facilitates the use of data by private healthcare providers.

ii) Building infrastructure for sustainable cities and regions

In view of the nation's rapidly declining population and birthrate, and its aging of the population, it is necessary not only to preserve living environments in urban and regional Japan by ensuring public transport infrastructure that supports mobility for daily life, services for preventive, medical and care, and commercial activities, but also to provide infrastructure that enables citizens of all generations—young people, people engaged in child-rearing and care-giving, and the elderly—to fulfill their raison d'etre in the areas that they are accustomed to. It is also important to consider these issues not only in relation to Japan. Instead: we should explore possibilities for collaboration and cooperation with other countries facing similar challenges.

Toward this end, we will work to make extensive use of ICT to build infrastructure that will help shape a society in which people of all ages can live comfortable and active lives in the localities that they are accustomed to.

More specifically, we will utilize ICT to promote compact, functional urban planning, and the development of safe and efficient Intelligent Transport Systems that minimize the risk of traffic

accidents and traffic congestion, and that are user-friendly to all. Through services for preventive, medical and care, we will also work to support to be self-reliant for elderly people, including dementia patients and to reduce the burdens faced by their caregivers. Furthermore, we will utilize ICT infrastructure to establish regional comprehensive life care systems in order to promote health and longevity for everyone, while also engaging in overseas collaborations and conducting appropriate assessments of the system's effectiveness from time to time.

iii) Extending service life for efficient, effective infrastructure

For public infrastructure to support the lives of citizens and their economic and social activities, it is important to use ICT, robot technology, and other new technologies, and to efficiently maintain and upgrade these technologies, based on the goal of realizing a sustainable society.

Up until now, the element technologies for inspecting infrastructure, analyzing inspection results, and conducting repairs and upgrades have been developed with the understanding that maintenance and upgrades would be conducted whenever such actions were necessary. However, due to financial and labor limitations, it will be necessary to optimize the implementation of infrastructure maintenance and upgrades from now on.

This will require us to raise the standard of each of these element technologies further, attempt to combine them optimally, and pursue their development as an asset management technology in accordance with regional needs.

Additionally, by taking into account regional characteristics from the state of R&D and maintaining a balance between the technology's performance (degree of perfection) and its cost, we will enhance the viability of developed technologies and present local government bodies with systems that they can readily operate.

③ Improving competitiveness in manufacturing and value creation

Manufacturing is an important pillar of the Japanese economy, but the competitive advantage that Japan has enjoyed up to now is under threat from the low production costs of emerging economies and the global strategies of major Western nations that are using their rapidly advancing ICT to pursue aggressive national initiatives. In light of this situation, Japan needs to forge manufacturing technologies that are capable of flexibly meeting increasingly diverse market needs by blending new production technologies with ICT, as well as developing new business models (value creation) that are capable of impressing and satisfying consumers.

To this end, we will use ICT to promote networking across entire supply chains, and apply "big data" analysis and AI technologies to analyze and make use of a comprehensive range of data on everything from customer needs to product planning, design, production, distribution, sales, and maintenance. This will allow us to pursue new forms of manufacturing and value creation that enable the supply of products and services that deliver high levels of customer satisfaction. In doing all this, we aim to empower small and medium-sized companies that support Japan's manufacturing, as well as enhance the competitiveness of the country's materials industry.

More specifically, we will focus on further advancing production technology which is one of

Japan's main strengths, as well as pursuing the development of product planning that combines goods and services, new design methods that anticipate latent needs, production technologies which enables new methods of processing and assembly for meeting needs more flexibly, and the development of platforms for linking above-mentioned activities together. In addition, to empower small and medium-sized companies, we will promote the utilization of various supply chain data, the employment of expertise of highly skilled engineers, and the use of more "intelligent" robots and machine tools.

Utilizing computer and data science, we will also pursue the creation of innovative functional and structural materials with dramatically shorter development lead time.

(2) Ensure Safety and Security for Our Nation and its Citizens and a High-quality, Prosperous Way of Life

In order to ensure safety and security for citizens and a high-quality, prosperous way of life, it is necessary to work toward disaster prevention, mitigation, and national resilience, as well as to ensure comfortable living environments and occupational health for citizens. In addition to ensuring the safety of Japan, it is essential to appropriately deal with changes in the national safety and security situation and the occurrence of crime, terrorism, and cyber attacks. In view of these factors, we define the following four challenges as important policy issues and focal points for R&D.

① Addressing natural disaster

Japan has been subjected on numerous occasions to the devastation from large-scale natural disasters, such as earthquakes and tsunamis, flooding and landslides, and volcanic eruptions. A massive natural disaster due to an earthquake along the Nankai Trough or directly below Tokyo is reported to be imminent. The occurrence of such a disaster would place the very existence of the nation in crisis. Given the frequent occurrence of various kinds of natural disaster, like the Great East Japan Earthquake of 2011, the Hiroshima landslides and volcanic eruption of Mt. Ontake in 2014, and the torrential flooding in the Kanto and Tohoku regions in 2015, it is very important to apply the lessons learned from such previous disasters to preparing for future large-scale natural disasters.

Toward this goal, we aim to develop a resilient society by ensuring the safety and security of citizens in the face of natural disasters.

More specifically, we will pursue R&D on technologies for constructing disaster-resistant infrastructure; for predicting, sensing, and detecting the true nature of disasters; and for rapidly assessing damage and assisting the safe evacuation of people, in order to minimize the devastation caused by, and enable rapid recovery from, such disasters. We will also aim to combine and link these technologies in order to efficiently reduce risks, and to develop mechanisms that enable sharing and application of disaster information in realtime.

② Ensuring food safety, living environments, and occupational health

Food safety is one of fundamental issues for protecting citizens' health. While diversifying food

production, processing, distribution, and consumption, it has become necessary to assess risks on food more rapidly and effectively in order to ensure food safety, and appropriately to manage those risks.

For this purpose, we will pursue studies and accumulate scientific facts and knowledge related to regulatory affairs concerning hazardous pollutants (including radioactive substances), by encouraging intensive research efforts to contribute accurate predictions, assessments, and decisions on food safety managements. On the basis of sound scientific data, we will also promote research aimed at formulating national standards and codes of practice for food producers (including those related to food additives, agrochemical residues, contaminants and apparatus, containers and packaging, etc.) and at improvement of food sanitation such businesses. In addition, as internationals contribution, we will provide research findings not only to Japanese institutes but also to institutes overseas.

In ensuring the safety and security of living environments, it is necessary to address fine particulate matter (commonly referred to as $PM_{2.5}$) air pollution, including cross-border pollution; the impacts of chemical substance pollution on water, soil, and wildlife; and contamination by radioactive substances, such as those released after the Great East Japan Earthquake, which have hindered recovery efforts.

To do this, we will pursue the development of assessment and management technologies for understanding air pollution phenomena over wide areas using remote analysis techniques, for conserving healthy water cycles, soil environments, and ecosystems, for understanding dynamics of radioactive substances in the environment, predicting their distribution, and developing effective technologies for decontamination and volume reduction.

Since it is also important to assess the risks of the various kinds of chemical substances used in daily life (including nano-scale materials), we will pursue research aimed at more rapid and advanced techniques for assessing health impacts on humans (including children) and measures to address the "sick house" syndrome, as a basis for the formulation and revision of regulations and guidelines. In addition, we will use research findings as basic data for setting the safety ratings of chemical substances, while also working to make international contributions in this area.

At the same time, in workplaces prone to excessive stress due to changing workplace conditions or overwork, it is necessary to ensure the safety and health of workers and create comfortable work environments.

For this purpose, on the basis of a detailed grasp of workplace environments and accumulated medical data, we will research the development of measures aimed at ensuring worker safety, mental health, a good balance between work and healthcare, and prevention of occupational diseases resulting from chemical exposure.

③ Ensuring Cybersecurity

As the use of cyberspace has become an essential infrastructure for social and economic activities, due to advances in ICT, personal computers as well as home electric appliances, automobiles, robots, smart meters, and numerous kinds of other devices are increasingly connected to networks including

the Internet. As a result, the "real world" and cyberspace have become highly integrated. For this reason, ensuring the safety of cyberspace is more important than ever.

However, a wide variety of threats, from individuals defacing websites for fun, scams, the theft of confidential information, cyber attacks targeting critical information infrastructure, and even suspected cyber attacks launched or supported by unfriendly certain governments, have proliferated in recent years. These attacks have impacted the people's lives and the economic and social activities, and year by year the threats to Japan's security have become growing. It is hard to say that there is a sufficient level of public awareness and knowledge of cybersecurity. However, regardless of the people's degree of ICT literacy, the existing danger in a variety of settings is now evident.

In light of this, we are working to raise public awareness of the importance of ensuring cybersecurity and to improve cybersecurity literacy, as well as human resources development in this field, as the cybersecurity experts are currently insufficient both in terms of quality and quantity. Meanwhile, in order to protect the people's lives and social and economic activities from the effects of cyber attacks, we will also pursue R&D aimed at dealing with these continually evolving threats.

More specifically, regarding technologies for detecting and defending from cyber attacks, for enhancing authentication systems, for control system security, for encryption, for security in the field of the Internet of Things (IoT), for verifying the authenticity of hardware, and for monitoring and confirming system integrity in constructing and operating critical information infrastructure systems, we will pursue the development and utilization of these technologies.

④ Addressing national security issues

In view of the increasingly challenging environment surrounding national security, in order to ensure the safety and security of the nation and its citizens, it is important to make use of Japan's many outstanding technological strengths. On the basis of the National Security Strategy (NSS), we will pursue the R&D needed to meet the various security challenges facing Japan, including the establishment of appropriate international systems of cooperation, through relevant government agencies and with industry–academia–government collaboration.

In doing this, we will pursue R&D on technologies to help ensure Japan's national security. This will include fields where technologies addressing risks relating to the oceans, space, and cyberspace, and where countering international terrorism and disasters, can make contributions.

Furthermore, it is important that, in addition to pursuing these R&D efforts, we also strive to grasp science and technology trends from the perspective of safety and security, and in collaboration with relevant government agencies.

(3) Addressing Global Challenges and Contributing to Global Development

To help find solutions to the global challenges facing humanity and strategically contribute to global development, it is important for Japan to utilize its potential and actively get involved in international cooperation and collaboration efforts, so that it can help combat climate change, declining biodiversity, food and resource shortages, and infectious diseases. With this goal in mind, we have set the two goals below as important policy issues and focal points for R&D.

Furthermore, in seeking solutions to these and other global challenges, we will work to establish collaborative relationships worldwide, taking into consideration the use of international organizations such as the Organization for Economic Cooperation and Development (OECD), the United Nations (UN), and the Group on Earth Observations (GEO), and we will make strategic efforts aimed at setting agendas, R&D, and commercialization.

In addition, through collaboration with international organizations, we will propose ways of effectively combining technologies in which Japan is predominant with plans relating to international and regional goals, such as the U.N.'s sustainable development goals (SDGs) developed in 2015, based on objective, scientific grounds. Furthermore, the timely and appropriate use of earth observation data obtained through the implementation of relevant R&D should be taken into consideration to contribute to solving problems in the above-mentioned activities.

① Addressing global climate change

The major factor of global warming, one of the key global challenges, is considered to be increasing emissions of anthropogenic greenhouse gases, and the climate changes resulting from this warming threaten to have serious economic and social impacts in the years ahead.

For this reason, we will aim to substantially reduce greenhouse gas emissions on a global scale and will contribute to adapting to the impacts of climate change, not only in Japan but also throughout the world.

More specifically, for monitoring climate change, we will pursue continuous observation of the global environment using artificial satellites, radar, sensors, and others, the advancement of prediction technologies using supercomputers, and thus work toward a better understanding of climate change mechanisms while also contributing to the establishment of the global earth observation system. In addition, for mitigating climate change, we will promote R&D on technologies for carbon dioxide capture and storage (CCS), and for computing and verifying greenhouse gas emissions. We will also implement strategic plans for a radical reduction of such emissions based on a long-term vision.

The Arctic region, where climate change occurs apparently, is attracting more and more international attention, including interest in making use of the Northern Sea Route (NSR). Regarding this, we are working on observation and research, including development of technology for Arctic observations, and on predicting the possibility of navigating the NSR. Furthermore, for adapting to the impacts of climate change, we are also pursuing R&D on technologies for predicting and assessing climate change impacts and for climate risk management. In addition, we aim to capture information about the global environment in the form of "big data" and to develop the Global Environment Information Platform for meeting the economic and social challenges arising from climate change, as well as pursue research in cooperation with stakeholders both in and outside Japan, for example, under the Future Earth concept.

② Responding to biodiversity loss

Rich biodiversity and healthy ecosystems are important as "natural capital" that serves as the basis

for the continued existence of human society. In light of the global-scale reduction in biodiversity and deterioration of ecosystems in recent years, achieving coexistence with nature has become an important goal, not just for Japan but also for the international community as a whole, and it is now necessary to strive to prevent further biodiversity loss. Another challenge is the conservation and utilization of the secondary nature represented by areas of *satochi-satoyama* (community-based natural landscapes). The declining level of direct human involvement with nature has resulted in changes in their biodiversity and ecosystems, and the conservation and utilization of these areas are necessary to help enhance the value of Japan's national land.

Therefore, we are focusing efforts on biodiversity conservation through the pursuit of R&D on technologies relating to the protection of endangered species, and the prevention of damage by invasive alien species and the eradication of invasive alien species, and technologies for the monitoring, maintaining, and restoring ecosystems, including secondary nature zones. We are also pursuing R&D on technologies for assessing the economic and social value of ecosystem services (including genetic resources) and "natural capital" and for sustainably managing and utilizing them, as well as on technologies for utilizing ecosystem functions for adaptation to climate change and other fields.

(4) Pioneering Strategically Important Frontiers

In addition to enhancing industrial competitiveness and addressing the above economic and social challenges, (1) to (3), a range of science and technology to support the appropriate development, utilization, and management of the oceans and space serves as a firm foundation for Japan's subsistence. At the same time, since such science and technology are assets of national strategic importance that produce significant levels of additional value, such as by enabling Japan to earn admiration and respect in the international community and promoting the scientific education of citizens, it is necessary to continually enhance this asset based on a long-term perspective.

As a "oceanic state" that ranks as sixth in the world in terms of the size of the country's exclusive economic zone (EEZ), it is important that Japan strive steadily to improve its STI to a level befitting this status. Some examples of marine-related science and technology efforts include technologies for ocean surveys and observation—including areas of sea ice, deep seas, and below the seabed— and technologies for contributing to sustainable development and utilization of the seas. This includes marine resources (including biological resources), transportation, tourism, and environmental conservation, as well as technologies to help ensure the safety of the seas, and the scientific knowledge and fundamental technologies necessary to support all these efforts.

While space-related science and technology contributes to the common intellectual property of humanity and offers the potential to expand the frontiers of human activity, the growing international importance of space for security and civilian applications makes it necessary for Japan to promote its fundamental science and technology systematically in line with its space development and utilization efforts. Some examples of the areas in which Japan's space-related technology efforts are focused are satellite positioning, satellite remote sensing, satellite communications and transmission, space transport systems, space science and exploration, manned space activities, and assessing space

conditions.

While engaged in ongoing collaboration with the Headquarters for Ocean Policy and the Strategic Headquarters for Space Development in order to ensure coordination between the Basic Plan on Ocean Policy and the Basic Plan on Space Policy, CSTI is pursuing initiatives aimed at developing solutions to R&D challenges relating to the oceans and space.

Chapter 4 Reinforcing the "Fundamentals" for STI

In an era of drastic change, when prospects for the future are difficult to determine, achieving sustainable development requires the promotion, as a nation, of core capacities that will enable it to respond with accuracy and flexibility when confronting any new challenges or situational shifts. To this end, in addition to highly specialized knowledge, and together with the development and securement of human resources with innovative ideas and flexible ways of thinking not caught up in the traps of convention or common sense, it is essential to continue to strengthen a foundation for the generation of diversified and outstanding knowledge that will serve as a source of innovation.

Therefore, we are making efforts to thoroughly reinforce the human resources potential that undergirds STI. In addition to the development and securement of highly trained personnel who will generate new knowledge and values, and a diversified workforce that will accelerate the creation of innovation, we seek to create environments that enable each and every individual to maximize his or her contributions in the most appropriate settings, according to their own capabilities and motivations. Moreover, in order to maximize the potential for the creation of innovation in Japan, we will not only promote the success of diverse human resources in terms of their knowledge, perspectives, and ideas but also facilitate the flow of personnel.

Additionally, in recent years, changes in the international competitive environment have seen an increasing tendency in the business sector and elsewhere to seek short-term results, and the importance of the role of universities and public research institutions in knowledge creation is increasing. While making suitable provision for new trends such as open science, in addition to advancing reforms and reinforcements toward the promotion of academic and basic researches, we seek also to strengthen the facilities and equipment that support R&D activities, including information infrastructure.

Furthermore, we are promoting reforms to the funding models that support STI activities. In particular, in order to more effectively and efficiently make use of government-backed funding, we are promoting the integration and reinforcement of organizational and research funding reforms for universities that will play an important role in the strengthening of these core capacities.

(1) Developing High-quality Human Resources

People drive STI. Despite increasing competition over the recruitment of highly trained personnel around the world, Japan's population of young people continues to decrease. Under these circumstances, improving the quality and exerting the capabilities of STI professionals are becoming even more important.

However, the situation for STI professionals in Japan is critical, particularly the circumstances facing young researchers who play a vital role in these fields. Many, including some extremely capable students, have become hesitant at being doctorates who are assumed to play core roles in knowledge production and other STI activities, and this represents a serious problem for ensuring Japan's continued STI capacity. For this reason, we will surely and swiftly promote initiatives to develop and activate young researchers in universities and other research settings.

In conjunction, it is also important to provide continued encouragement in order to ensure that STI professionals are able to play an active role suited to their particular strengths in a variety of social settings. As industry, academia, and the government continue to promote STI activities, we will promote the establishment of career paths, and the development and securement of human resources for a variety of occupational sectors. In addition, with a view to improving the quality of STI professionals, we plan to move forward with educational reform from the elementary and secondary levels up to and including graduate school education, and will seek, moreover, to enhance learning among adults.

Furthermore, in order to maximize the potential for the creation of innovation in Japan, in addition to promoting the success of diverse human resources including women and foreign nationals, it will be necessary to continue to promote the use of research outcomes in society and knowledge integration in a global environment that facilitates the flow of personnel across fields, organizations, sectors, borders, and other barriers. The fact that these initiatives have not necessarily been sufficient up until now means that we must strengthen initiatives to recruit diversity and facilitate flows in terms of personnel.

It is also worth noting that promoting professional development entails the importance for universities and other public research institutions to assume, as organizations, a keen sense of responsibility to engage with the formation of career paths for the young researchers whom they develop and employ. At the same time, PhD students, postdoctoral researchers, and other younger employees themselves are also conscious of their role in forging their own career paths, and there is a need for them to develop their own abilities and to continue to exert their abilities in a variety of social settings.

Through these initiatives, in Japan, we are continuously developing and securing diverse and talented pool of professionals, and creating a society in which through their activities, STI professionals can play an active role as knowledge professionals in a variety of sectors, both in academia and in industry.

① Developing, securing and improving career prospects of human resources as intellectual professionals
i) Developing and improving career prospects of young researchers

Postdoctoral researchers and other young researchers represent the backbone of STI. However, with opaque career paths for young researchers in universities and other sectors, their employment situation is unstable, and measures taken thus far to enable young researchers to carry out their research autonomously have been insufficient.

For this reason, in addition to clarifying the career paths for independent researchers who have completed their doctorates, up to and including university faculty members, we seek to provide an environment in which young researchers will be able to exert their capabilities and motivations to the maximum according to the stage of their career.

In universities and public research institutions, there have been calls to expand the number of posts without fixed terms for young researchers who have established impressive postdoctoral track

records. In this regard, it is necessary to promote initiatives such as the introduction of an annual salary system and cross-appointment system for senior researchers, the introduction of personnel evaluations, and the introduction of reflection on and re-evaluation of the treatment of the results of such evaluations, as well as the promotion of a shift toward fixed-term employment through external funding.

Additionally, at the same time, when hiring young researchers as candidates to become principal investigators (PI), there have been demands that the assurance of permanent posts should be premised on the introduction in principle of a tenure track system, or some other fair and highly transparent hiring system that works along similar lines. In this regard, it is important that proper assessment is given to considerations that include overseas experience, as well as the acquisition of new skills and research achievements during this time, and the provision of opportunities for receiving appropriate mentoring by more experienced researchers. At the national level, Japan is promoting the construction of such hiring systems in its various institutions, while also making use of frameworks such as project performance evaluations by National R&D Institutes and the weighted allocation of subsidies provided for the national universities.

In addition, Japan is promoting initiatives to enhance funding support in order to ensure that young researchers will be able to enhance their research abilities and exert their capabilities and motivations to the maximum extent. In particular, we seek to establish institutions and strengthen support for youth in order to ensure that young researchers of the highest caliber will be able to be active in autonomous and open research environments while being employed in stable posts.

Furthermore, Japan is continuously promoting the reform of public funding from the perspective of developing and improving career prospects of young researchers. As a part of such efforts, on the basis of the implementation of reforms to the personnel payroll system at national universities (hereinafter assumed to include inter-university research institutes), necessary measures are being taken to move forward with examinations toward increasing the flexibility of direct cost expenditures in order to enable personnel expenses, such as those for hiring PIs, to be met directly from public funds.

Through these initiatives, first of all, we aim to increase the proportional representation of younger faculty members in universities. Specifically, during the period of implementation of the Fifth Basic Plan, we plan to increase the proportion of full-time university faculty less than 40 years old by 10%, and we also aim to bring the proportion of full-time university faculty less than 40 years old to 30% or more on a nationwide level in the future.

ii) Developing and improving career prospects of various people in STI

In universities and other public research institutions, promoting the creation and social implementation of high-level knowledge requires a diverse type of personnel, including program managers in charge of the planning and administration of R&D projects, university research administrators (URAs) tasked with the overall management of research activities, technical support staff who assist with research facilities and equipment, and technology transfer personnel and university administrators. In addition, promoting the rapid and effective social implementation of

knowledge in the corporate sector requires personnel to be in charge of management strategies such as business model transformation and new business development, as well as the personnel to have a high level of expertise with regard to technology management and intellectual property. Such personnel, while taking advantage of their respectively high levels of expertise, are essential to the creation of environments in which people are able to perform to the best of their abilities.

However, qualitative and quantitative mismatches in terms of human resources can sometimes occur between universities and the industrial sector, generating problems such as a dearth of personnel to fill such occupations or capabilities on the part of individuals that have not been adapted to a rapidly changing society.

For this reason, we are promoting initiatives to establish career paths for the diverse pool of STI professionals, as well as the development and securement of personnel. At the national level, as well as establishing a frame for the investigation of measures for the development of such diverse personnel in industry, academia, and government, we are promoting undergraduate and graduate school educational reform through collaboration by industry, academia, and government in order to ensure that students and other will be able to gather a breadth of experience that will allow them to entertain the prospect of diverse career paths. In addition, we are moving forward with the development and utilization of a database of PhD professionals. Moreover, we are working toward the further clarification of occupational requirements in terms of knowledge and skills for particular jobs, such as program managers, URA, and technical support personnel.

Furthermore, STI fields require support from the numerous engineers employed in the business sector. In collaboration with the industrial and academic sectors, the Japanese government is not only promoting educational reform with a view toward engineer development but is also encouraging advancements in the development and securement of engineers in universities, colleges of technology, and Specialized Training Colleges, particularly in the information and communication sector where the labor shortage is most significant. In addition, we are undertaking a review of the engineer certification system of professional engineers in line with current demands with a view toward the promotion of its use in the industrial sector.

iii) Promoting reforms of graduate school education

Graduate school education has a large role in enhancing the quality of STI professionals. In particular, it is required to train high level doctoral professionals under the cooperation among industry, academia, and government, so that they can think, act independently based on highly specialized knowledge and ethical standards to create new knowledge and values, and play active roles globally.

For this reason, the government will promote reforms of graduate school education in cooperation with universities, industry, and other areas. Moreover, graduate schools with doctoral courses are required to implement acts to guarantee the quality of doctoral degree recipients, develop educational programs collaborating with industry, enhance the opportunities of experiences among a wide variety of social places for faculties, and enhance the doctoral educations for researchers and engineers in the corporate sector. The government also promotes these actions.

In addition, economic supports for graduate school students, particularly in doctoral courses, will be enhanced to attract outstanding students and adults both domestically and abroad. Universities and other public research institutions are required to expand the employment of doctoral students as teaching assistants and research assistants, and improve their treatments. The government tries to expand fellowship, promoting the efforts of each institution. With these actions, the government and institutions concerned make efforts toward achieving early the goal, "to enable 20 percent of doctoral students to receive an amount equivalent to their living expenses", which the Third and Fourth Basic Plans list.

Furthermore, to vigorously promote the reform of graduate school education, the government will establish a system for the constitution of graduate schools, which have the highest level abilities of education and research in the world and promote integrated education in disciplines that span different fields, such as the fields of humanities and sciences, as well as leading-edge education in fields in which Japan is strong.

In addition to focusing on initiatives such as those already mentioned, the government is also formulating and moving forward with the plan that clearly indicates systematic and intensive initiatives and the orientation of reform of graduate school education during the implementation period of the Fifth Basic Plan.

iv) Development for the next generation of STI professionals

In order for Japan to improve its STI capacity on an ongoing basis, it is important to work toward the development of the next generation of STI professionals and encourage the enhancement of their capabilities and talent through education at the elementary, secondary, and university levels, and to promote the popularity of science and mathematics among children.

For this reason, we are promoting initiatives to foster talent among children and students who show excellent promise through efforts such as providing education that stimulates creativity and opportunities for learning sciences and mathematics. Japan, in addition to promoting improved methods of learning and instruction in schools from the so-called "active learning" perspective (subjective, behavioral learning oriented toward the identification and solution of problems), is supporting high schools and other educational institutions that carry out high-level teaching in the areas of math and science. In addition, we are working to enhance opportunities for motivated and capable students to carry out research, as well as opportunities for students from home and abroad to develop their own abilities through diligent efforts. Furthermore, we are moving forward with the integral reform of high school and university education, as well as university admissions.

In addition, we are promoting initiatives to heighten children's interest and literacy in the sciences and mathematics, as well as in science and technology. At the national level, Japan is not only promoting education based in demand for learning and instruction that seeks to enhance problem-solving-based learning, and mathematics and science education but is also striving to enhance advanced scientific and mathematical education that makes full use of personnel with highly specialized knowledge as well as personnel in the business world and the community.

② Promoting diversity and career mobility

i) Improving women's career prospects in STI

In order to incorporate a broad array of perspectives and excellent ideas in the stimulation of STI activities, it will be essential to develop environments in which women have opportunities to exert their abilities to the fullest and to continue to promote the advancement of their careers. Even though representation of women is increasing within Japan's research communities, it still remains at a low level in comparison with other leading nations. Few female researchers participate at the decision-making level of organizations, and the numerical targets of the proportion of female researchers among new hires listed in the Fourth Basic Plan (30% of the total in the natural sciences overall, 20% in the physical sciences, 15% in engineering, 30% in agriculture, and 30% in medicine, dentistry and pharmacology combined) have yet to be achieved.

In order to overcome this state of affairs, we are accelerating efforts to ensure that women will be better able to participate in actively as researchers, engineers, or other members of the diversity of human resources involved in STI. In this regard, it will be important to build transparent hiring processes that ensure fair assessments regardless of sex. It is also important that there should be a broader awareness shared among stakeholders that new ways of working and active participation by a more diverse base of human resources would serve to stimulate STI activities.

At the national level and in universities, public research institutions, and the industrial sector, we are making use of the Act on the Promotion of Success in Women's Professional Lives and accelerating efforts to set and publish targets for measures such as employment rate and proportion recruited to leadership positions. In particular, with regard to the target values noted above for the proportion of female researchers among new hires listed in the Fourth Basic Plan, in order to quickly achieve these during the period of implementation of the Fifth Basic Plan, Japan is comprehensively promoting all related initiatives through a concerted effort by industry, academia, and the government.

In addition, Japan is not only undertaking workplace environmental improvements and providing support in order to ensure that women will have the ability to balance their research careers with life course events but is also working to share information and raise broad-based awareness of role models and best practices. Moreover, we are promoting initiatives by universities and other public research institutions actively engaged in the development and recruitment of female leaders as PIs, and at the management level of organizational decision-making. Through these efforts, we are striving to promote awareness with a focus on the management level of organizations.

In addition, Japan is promoting a national effort to deepen interest and understanding of science and technology career paths among female junior high and high school students, as well as their parents, in order to enable the women of the next generation to have successful careers in connection with STI. In addition, by strengthening cooperation among industry, academia, and government with the involvement of relevant ministries, the business world, the academic community, and private sector organizations, among other stakeholders, Japan is deepening the broader public understanding of women who are advancing their careers in the field of science and technology.

ii) Enhancing the international research network structure

For Japan, working to build and strengthen international research networks represents an urgent issue. In this context, breaking the inward-facing tendency of Japanese researchers and actively promoting their success overseas will be essential not only for contributing to the acquisition of global knowledge and the maintenance and enhancement of Japan's global competitiveness but also for securing prestige and a firm position in international research networks. At the same time, continuing to bring in and foster the success of top-tier foreign researchers is important from the perspective of serving to further strengthen international research networks as well as to create knowledge and value based in a diverse array of perspectives and ideas.

For this reason, we are enhancing support for researchers desiring to go overseas to develop their research activities at the global level. More specifically, Japan, in addition to promoting initiatives such as the creation of inter-organizational networks with overseas research agencies with rich potential, participating in international joint research projects, dispatching researchers to research institutions such as international agencies and overseas universities, and participating in the Global Young Academy in universities and other public research institutions, is also promoting the creation of networks involving researchers dispatched overseas and foreign researchers who have had experience living in Japan.

In addition, after returning to Japan, it is also important for researchers who are developing their research activities at the global level to be able to carry out their research in independent environments. Accordingly, there has been a demand in universities and other public research institutions to devise recruitment and hiring processes that facilitate applications by researchers who have returned from overseas, as well as for the introduction of evaluation measures for actively assessing such overseas experiences.

Furthermore, we are enhancing efforts to bring in and establish outstanding foreign researchers and overseas students. Japan, in addition to striving to enhance and improve its treatment in order to acquire world-class researchers, is also enhancing supports, including a scholarship system to promote the acceptance of overseas students and outstanding young researchers, such as foreign postdoctoral researchers, while also working toward the enhancement of partnerships and exchanges with emerging and developing nations in the fields of science, technology, and education. Furthermore, to promote the acceptance and establishment of these outstanding foreign nationals, we are moving forward a variety of initiatives, including providing living arrangements that include educational and employment opportunities for researchers' accompanying children and spouses, establishing research environments with English-language research support in universities and public research institutions, and promoting the use of a point system for highly trained personnel.

iii) Promoting cross-field, cross-organization, and cross-sector mobility

Efforts are being undertaken to heighten the quality and capabilities of individuals through the facilitation of the flow of personnel, as well as the social implementation of research outcomes and the promotion of the creation of new knowledge through the integration and cross-pollination of a variety of knowledge perspectives. However, in Japan, there is an underlying way of thinking about

the development and securement of personnel that is premised on long-term employment, and a great many social systems are also established on the basis of this way of thinking. As a result, there has not yet been any increase in the fluidity of personnel between fields, organizations, or sectors.

For this reason, we are aiming for personnel from all generations, from young researchers to senior researchers, to be able to play active roles in the most appropriate settings, and will build mechanisms that facilitate the flow of STI professionals. In universities and other public research institutions, in addition to demands for the active introduction of new compensation and hiring systems such as annual salary and cross-appointment systems, it is also expected that there will be a broad implementation of initiatives that are not premised on internal advancement and that will actively assess cross-organizational experiences at the time of recruitment.

Furthermore, in universities and other research institutions, it is important that exchanges of personnel be promoted between all fields in the social sciences and humanities, as well as in the natural sciences, and that systematic efforts be implemented to promote interdisciplinary and cross-disciplinary research. In addition, in order to promote cross-sector movements, it will also be important to enhance opportunities to gain experience in external research institutions such as those in the corporate sector from the student stage.

Japan, in addition to promoting initiatives to facilitate such personnel fluidity, is also propelling efforts to develop a diverse labor pool of people involved in STI. Moreover, we are diversifying the career paths for STI professionals and urging that the findings and capabilities being cultivated by STI activities be utilized in a variety of social sectors, including not only research agencies but also entrepreneurship and management, elementary and secondary education, and public service.

(2) Promoting Excellence in Knowledge Creation

To secure the creation of sustainable innovation, it will be essential to strengthen foundations for producing excellent and diverse knowledge that will serve as a constant source of innovation. In this regard, the implementation of research that emphasizes innovative ideas and flexible ways of thinking that have not been caught up in the traps of convention or established thought will be particularly important. However, growth in the numbers of articles and highly cited articles produced in Japan remain inadequate, and the growth of international co-authored papers is also relatively slow. This has given rise to concerns over the decline of Japan's basic research potential.

For this reason, we have turned to the promotion of academic research that produces a variety of creative and high-quality results grounded in researchers' intrinsic motivations, as well as basic research driven by policy strategy and demand, and are engaged in reforms and enhancements while giving consideration to how the two are balanced. Furthermore, for Japan to exert its presence in the world, in addition to promoting interdisciplinary and integrated cross-disciplinary research and international joint research projects, we are forming a world-class research center that will attract leading researchers from throughout Japan and around the world.

In addition, in implementing this initiative, we would also like to note the importance of preparing an environment in which researchers can settle in to focus on their research, and of safeguarding the production of results over the longer term, while also respecting organizational diversity and

autonomy.

Furthermore, as well as responding proactively with efforts that include reinforcing informational infrastructure and the establishment and sharing of an intellectual infrastructure, advanced research facilities and equipment, and technologies with common platforms to support such R&D activities, we are also responding suitably to the global trend toward an "open science" that will lead to the creation of innovation.

Through these above-mentioned efforts, the plan aims to reinforce the foundations of knowledge from the perspectives of both quality and quantity. However, since it is difficult to evaluate the real quality of scientific publications, we are focusing on the highly cited papers, which is commonly used as a proxy indicator for quality assessment. While increasing the total number of papers published from Japan, we are aiming for the proportion of the top 10% most-often cited papers among the total number of papers from Japan to reach 10% during the fifth Basic Plan.

① Promoting academic and basic research as a source of innovation

i) Reform and enhancements to promote academic research

In the midst of rapid expansion and innovation on the frontiers of knowledge, academic research grounded in researchers' intrinsic motivations is not only creating new interdisciplinary and integrated cross-disciplinary areas of research, it is also becoming a source of innovation, with the potential for the creation of additional innovation across a wide range of fields.

For this reason, we are moving forward with reforms and enhancements from the perspectives of challenging minds, comprehensiveness, unification, and internationality toward the promotion of academic research, and are continuing to respond to the public mandate for academic research.

Specifically, with regard to Grants-in-Aid for Scientific Research (KAKENHI), we are reviewing the screening system, research classifications and frameworks, as well as promoting the flexible and appropriate use of research funding. In this regard, in addition to working to promote international joint research projects and initiatives, we are enhancing supports that will enable researchers to actively seek out and grapple with new challenges.

We are also moving forward with initiatives that will contribute to the formation of a research base in order to allow for researcher independence, and are engaging in other initiatives with an eye toward the increased visualization and utilization of research outcomes, such as the construction of a database that includes the results of KAKENHI supported projects. While pushing these reforms and targeting a 30% adoption rate, we are working to enhance KAKENHI system.

In addition, to enhance their functionality as bases for human resources development and the opening up of new interdisciplinary fields and cross-disciplinary cooperation and integration, inter-university research institutes and joint usage/research centers have seen calls for reform and enhancement through the re-affirmation of the significance and mission of each institute and center. Japan, while also carrying out support tailored to each institute and center, is working strategically and systematically to promote large-scale academic research projects that will contribute to the establishment of a nationwide joint usage/research system.

ii) Reform and enhancements to promote strategic and on-demand basic research

From the viewpoint of further promoting cross-disciplinary cooperation and integration while pioneering attempts in unexplored fields that have not been sufficiently addressed by the corporate sector, basic research grounded in the strategies and demands of national policy, together with academic research, represents a vital source of innovation. For this reason, Japan is working to enhance and strengthen basic research grounded in the strategies and demands of policy at the national level.

In the implementation of basic research grounded in national policy, as well as engaging in reform oriented to the formulation of strategic targets grounded in objective evidence, we are working from the viewpoint of strengthening support for creative and innovative research in order to enhance research opportunities across disciplinary and organizational lines, as well as to provide opportunities for women and younger researchers to engage in path-breaking research.

In addition, we are working to enhance interdisciplinary and cross-disciplinary integrative research. In this regard, the cooperation of relevant ministries and organizations is crucial. Particularly in the interdisciplinary and integrated areas of medicine and other fields, we are strengthening cooperation between related organizations, including the relevant ministries and funding agencies, through institutional cooperation and collaboration with CSTI and the Headquarters for Healthcare Policy.

iii) Promoting joint international research and forming world-class research centers

In order for Japan to be able to occupy an important position in global research networks and exert its presence on the global stage, it is important not only to take a strategic approach to the promotion of international joint research but also to build a research center that can become a hub of international intellectual circulation for the nation.

For this reason, Japan, while making use of inter-university research institutes and joint usage/ research centers, is working to enhance Japan-based international joint research. As a nation, we are making advances in such areas as planning the use and operation of facilities in Japan and overseas for big science projects such as nuclear fusion, particle acceleration, and space development and utilization, as well as constructing mechanisms to stimulate international joint research with a variety of overseas partners. In addition, in order to strengthen bilateral and multilateral collaboration and build mutually beneficial relationships, we are working to enhance fund-matching partnerships and the operation of jointly managed overseas research centers while cooperating strategically with partner nations with regard to the identification of common problems and similar matters.

Furthermore, Japan is working to form world-class research centers that can show high research standards and top-tier research environments in order to attract leading researchers from throughout the nation and around the world. In addition, we are working to achieve the necessary expansion by engaging with efforts at the Okinawa Institute of Science and Technology.

② Strategic enhancement of common-platform technology, facilities, equipment, and information infrastructure supporting research and development activity

i) Strategic development and use of common-platform technology and research equipment

Common-platform technologies and advanced research equipment that provides cross-sectional support to a wide and diverse array of research areas and applied fields are important for contributing to Japan's varied scientific and technological developments, as well as for supporting key national industries.

For this reason, Japan is promoting R&D relating to common platform technologies as well as R&D relating to sciences with translational utility in multiple fields. In this regard, we are taking steps to ensure that R&D gives adequate consideration to the needs of a broad user base. In addition, Japan has taken users' perspectives in account when promoting the development and diffusion of advanced research equipment.

ii) Maintenance, sharing, and networking of research facilities, equipment, and intellectual infrastructure used by industry, academia, and government

Making cutting-edge and large-scale research facilities, as well as research equipment, available for joint use by industry, academia, and government contributes to the expansion of R&D and is also expected to result in the sustainable creation and acceleration of STI through the interaction of a varied and diverse pool of personnel passing through and utilizing such facilities and equipment.

For this reason, Japan, with regard to cutting-edge large-scale research facilities as based on the Act on the Promotion of Public Utilization of the Specific Advanced Large Research Facilities is working to provide appropriate support for initiatives including the construction, planned upgrading, and related technical development of institutions in order to facilitate broad-based collaboration between industry, academia, and government. In addition, as a country, we are actively promoting the joint use by industry, academia, and government of research facilities and equipment that envision utilization by a broad base of researchers in diverse areas and disciplines and in the industrial sector, and are working to expand the facilities and equipment available for joint use at the national level.

Furthermore, we are encouraging the creation of networks connecting these facilities and equipment and the sustainable improvement of systems for maintenance, operation, and joint use based in organizational strategy and user perspectives in the context of these respective facilities and equipment. We are also working on public research institutions strategically and systematically to develop intellectual infrastructure that includes the databases, measurement standards, and biological and genetic resources that are essential to the stable and effective promotion of broad R&D activities, as well as social and economic activities.

iii) Maintenance of university facilities and equipment, and enhancement of information infrastructure

The research facilities and equipment that belong to universities and public research institutions constitute vital infrastructure for supporting all STI activities. For this reason, while promoting the planned updating and maintenance of research facilities and equipment in universities and public research institutions and encouraging the implementation of joint initiatives by each institution

regarding updated and maintained facilities and equipment, Japan is also giving appropriate support for ensuring systems that facilitate the efficient operation time and utilization of these resources at the national level.

In particular, with regard to facilities at Japan's national institutions of higher education (hereinafter meant to include educational entities incorporated as national universities, inter-university research institutes, and national colleges of technology), we are moving forward with the planned and focused development of such facilities through the provision of stable and ongoing support based on the facilities development plan formulated by Japan for the national institutions of higher education as a whole.

In the context of these institutions, we are also promoting the development of facilities that make use of strategic facilities management and a variety of financial resources. With regard to facilities at incorporated R&D institutes, we are taking the necessary steps after considering the direction of maintenance for aging facilities, and while referencing the facilities development plan for national institutions of higher education.

In addition, information infrastructure carries an essential functional role in the creation of STI, and we are working toward the enhancement and smooth operation of information infrastructure, including strengthening the security functionality introduced into the latest ICT, the cloud consolidation of information system resources, and the enhancement of research information networks.

③ Promotion of open science

Open science is a concept that encompasses open access by making research data into open data. As open access is promoted, research outcomes will become available to all manner of users, including both those in the academic community, the business world and private citizens. This will result in the accelerated production of knowledge through new collaborations between researchers in different organizations, as well as between specialized fields and across borders, thereby enabling the production of new sources of value.

In addition, the move toward open data will result in the achievement of social transparency in the research process and the broad utilization of research outcomes, with the additional prospect of results that will encourage international exchange and public participation in such cooperative endeavors. Furthermore, as interest grows with regard to new research strategies, such as the provision of basic research data to the citizenry or the participation of citizens in research projects as observers, the outlook seems positive for the expansion of participatory science (so-called citizen science). In recent years, this concept of open science has demonstrated a rapid spread worldwide, and it has been attracting attention as an important foundation for open innovation.

In light of such trends, Japan is partnering with other stakeholders, including funding agencies, universities and other research institutes, as well as individual researchers, to build systems for promoting open science. Japan's basic stance on the promotion of open science is to expand the utilization of the outcomes of publicly funded research to the maximum extent possible. Even with regard to secondary research data as other research outcomes, we are making these available to the

maximum extent possible while keeping in mind disciplinary differences in the methods of storing and sharing research data.

However, within research outcomes, certain data, such as data relating to national security or which have been collected for commercial purposes, are regarded as being exempt from public availability. In addition, data access and utilization are subject to restrictions from the perspective of protecting personal privacy and deliverables valued as property. It is also important to maintain an awareness of disciplinary differences in the methods of storing and sharing research data and to take note of matters such as the implementation of intellectual property regimes and open-and-close strategies that are conscious of the national interest.

In addition, Japan is aiming to improve the productivity and efficiency of scientific and research activities at the national level, as well as building platforms to share research outcomes and data through appropriate international partnerships based on the rules of promoting open science.

(3) Strengthening Funding Reform

Government-backed funding includes fundamental funds including national university budget subsidy, facilities improvement grants, financial aid to private educational institution, and other public application funding allocated to promote research excellence and studies that contribute to specific goals. All of these work together to support STI core activities, and their design can have significant impact in such areas as research capacity and research outcomes, organizational management, and staff allocation.

In the future, it will be particularly necessary to enhance the functionality of national universities, to which much of the funding open for public application is delivered, by promoting the strengthening of governance, while simultaneously carrying out fundamental organizational reforms and establishing environments that facilitate the effective and efficient use of various sources of research funding.

For this reason, Japan is both promoting reforms to fundamental funds and funding open for public application and promoting the integration of organizational reforms with reforms to governmental research funding institutions, particularly national universities. In this regard, it will be important to remain cognizant of the optimal combination of fundamental funds and funding open for public application.

① Fundamental funds reform

Fundamental funds that support research and education are essential if universities and R&D institutes are to accomplish their respective missions. However, for universities, discretionary expenses are decreasing as fundamental funds decrease year after year. This, coupled with other factors such as the delay of reforms to administration and hiring systems, has given rise to the problem of a relative decline in research diversity and basic research capacity, as well as the destabilization of employment for younger personnel. In addition, for R&D institutes, there has been a downward trend in national university budget subsidy and facilities improvement grants, which are the fundamental funds supporting their activities, and problems are also beginning to appear for

planned research activities and upgrades to facilities and equipment.

In light of these circumstances, in addition to encouraging efforts to diversify financial resources and reform organizational foundations in order to help universities and R&D institutes fulfill their roles properly, Japan is working to move forward with reforms that will enable the more efficient and effective operation of individual institutions with the securement of fundamental funds.

In this regard, Japan is implementing more closely tailored allocations of financial aid to private educational institution and related funding in order to ensure that private universities will be better able to engage in the high-quality education and research that takes advantage of the founding spirit and features of private education.

② Reform of public funds

In Japan, public funds open for application include a system classified as "competitive grants", which are important funds that secure diversity within the R&D that takes place in Japan, and which contribute to the formation of a competitive R&D environment. As a result, Japan seeks to maximize the research capacity and research outcomes of competitive grants, aiming at the more effective and efficient use of these funds.

Specifically, we are working to reorganize the targeting of competitive grants on the basis of policy objectives, to achieve a 30 percent allocation in principle concerning indirect costs for all competitive grants, and to ensure the thorough application of unified rules across all government ministries, including the improvements to usability. In addition, with a view to expanded university reforms, we are also making progress and taking necessary steps with regard to a review of the possibility of implementing the introduction of indirect costs and usability improvements for research funding other than competitive grants. Furthermore, along with working to promote the sharing of research instruments while maintaining the premise of securing diversity in funding agencies, we are carrying out a review and taking necessary steps toward facilitating inter-system links that might enable seamless support tailored to research progress and the combined use of multiple sources of research funding from multiple institutions and ministries, as well as the facilitation of multi-year research implementation.

In addition, with regard to expenditures intended to promote reforms in R&D systems such as those in universities and other public research institutions, we are carrying out a review and taking the necessary steps with regard to devise mechanisms that might secure the achievement of goals after project completion.

③ Integrated promotion of national university reform and research funding reform

An urgent issue for the promotion of STI is the effort needed to fundamentally reform and strengthen the function of the national university organizations that constitute the chief players of STI, and we are working toward the integrated promotion of reforms to both national universities and the government's research funding institutions.

Universities, themselves, are the chief drivers of higher education reform and carry the responsibility for implementing reforms to research and education settings based on their own

concepts. For this reason, Japan is working to stimulate competition between national universities from a global viewpoint while providing special assistance to those that are working proactively to reform themselves while taking full advantage of their own distinct strengths and characteristics. Specifically, from the third-phase medium-term target period, a new system for allocating and evaluating subsidies for the budget subsidy is being implemented in response to the orientation of national universities toward their own functional enhancements. Each university is being called on to make the fullest use of their own distinct strengths and characteristics in order to build mechanisms for their own improvement and future development.

In particular, there have been demands for initiatives that include the bold restructuring and self-renewal of education and research organizations, enhancements to the leadership and management strengths of school presidents, reform of personnel and payroll systems, and the development and securement of administrative personnel.

Furthermore, it will also be important to take measures to strengthen a financial base oriented to the enhancement of administrative capacity, and there have been calls for initiatives such as the construction of cooperative frameworks and efforts at universities to promote dialogues with industry that are aimed at the expansion of joint research with the corporate sector both in Japan and overseas. Japan is working to assess the state of such initiatives and will reflect this appropriately in the allocation of the budget subsidy.

In conjunction with such efforts, and particularly in order to markedly strengthen institutional and other efforts to diversify the financial resources and the organizational infrastructure of national universities that have satisfied certain conditions to a degree that will enable them to respond to the fiercely competitive global environment, Japan is instituting a special exception within the national university system, and will be carrying out a review and taking the necessary steps with regard to its support and assessment of these national universities.

Furthermore, in addition to clarifying the role of fundamental funds and public funds open for application in universities, Japan is encouraging the effective and efficient use of funding in national universities by distributing these funds properly and working toward their integrated and effective use.

Chapter 5 Establishing a Systemic Virtuous Cycle of Human Resources, Knowledge and Capital for Innovation

Due to the increasing severity of global competition, the speed with which the fruits of scientific research can be commercially implemented and rendered profitable has become a very important economic factor in today's world. Consequently, the "open innovation" approach, which mobilizes all available knowledge and technology within and outside an organization, offers great advantages.

While it is principally companies that bring innovation to fruition, much of the new knowledge and values needed for innovation are now generated throughout the world by universities, national research institutes, companies, and consumers. Today in Japan, however, the elements needed for innovation such as human resources, knowledge, technology, and capital are unevenly distributed between large corporations, small and medium-sized enterprises and startup companies, universities, and national research institutes.

In order to expand the opportunities for Japan's companies and entrepreneurs to utilize and rapidly commercialize these kinds of domestic and international intellectual resources, it is essential to establish a society-wide mechanism that enables human resources, knowledge, and capital to circulate between organizations, sectors, and even across international borders. Such a mechanism should also allow the talents and capacities of individuals and organizations to be fully harnessed. This kind of swift implementation can also ensure that Japan's companies and entrepreneurs earn profits, some of which can then be reinvested to strengthen the fundamental scientific and technical research capacity of the country. In this way, an innovation system that is self-sustaining and beneficial to all stakeholders can be developed.

In view of this, mechanisms that genuinely promote full-scale open innovation will be strengthened. Companies, universities, and public research institutes will all be enhanced in their competitiveness and the fluidity of their human resources and knowledge will be increased such that the right person can quickly and flexibly utilize the appropriate resources in the right place. This will also facilitate and promote industry–academia–government collaborations.

Furthermore, by creating and nurturing startup companies that have a sense of urgency and the potential to tackle commercialization with agility and a willingness to take risks, by effectively utilizing intellectual property throughout society, and by working to set up and revise systems for innovation creation, we can cultivate a virtuous circle of human resources, knowledge, and capital, as well as provide support for rapid and flexible commercialization. In addition, we will pursue innovation from a global perspective, based on the understanding that the knowledge, technology, needs, and business opportunities that serve as the starting points of innovation are spread out across a wide variety of locations, both in Japan and elsewhere around the world.

All these measures will further deepen our "National system of innovation" initiative, focused on an ongoing reorganization of universities and public research institutes. They will also enhance the international competitiveness of Japan as a whole, effectively address overseas demand, and accelerate economic growth.

(1) Enhancing Mechanisms for Promoting Open-innovation

Although it is principally companies that bring innovation to fruition, collaboration with universities and public research institutes is essential to achieving rapid use of the fruits in society. In order to promote open innovation on a global scale, it is important to build mechanisms that can tap the unique strengths of individual companies, universities, and public research institutes, and then synergistically combine and merge them.

With this aim, we will push to strengthen initiatives that promote open innovation by each of these entities. We will also strive to increase the flexibility of the human resources, knowledge, and capital that are now unevenly distributed between large corporations, SMEs and startup companies, universities, and public research institutes, and to set up environments conducive to the flourishing of innovation. In addition, we will establish "spaces for co-creation" for urging the human resources, knowledge, and capital available to industry, academia, and government to come together and nurturing collaborative innovation between these sectors.

Through these initiatives, the goal is to increase the mobility of researchers between Japan's companies, universities, and public research institutes by 20% over the term of the Fifth Basic Plan. Since the mobility of researchers from universities to companies and public research institutes has been particularly low, we are aiming to double its level by the end of the term. At the same time, we will work to increase the amount of funding received from industry for collaborative research with universities and National R&D Institutes by 50%.

① Enhancing systems of promotion in companies, universities, and public research institutes

To increase Japan's capacity for innovation, it is necessary to promote open innovation in the form of both inter-industry and industry–academia–government collaborations in order to enable the effective utilization of new ideas, knowledge, and technology emerging within and outside those organizations. To enable this, however, management reforms are required in each type of these organizations.

Based on an understanding that the science and technology of today are transforming business models, companies in the industrial sphere are expected to take proactive measures to promote open innovation and to invest their human resources, knowledge, and capital in order to pursue serious collaborations with companies of different scale and different sectors, as well as with universities and public research institutes. Because such open innovation will contribute to rapid acquisition of the fruits of innovation, improving the skills of their researchers, etc.

Universities and public research institutes are required to attach great importance to collaborative projects with companies and to enhance their ability to accurately grasp the needs of companies and propose solutions to them. On top of this, they need to work on reforming management systems and setting up systematic structures to facilitate industry–academia–government collaboration. This can be done, for example, by enabling appropriate management of human resources, knowledge, capital, and other intellectual resources, as well as the risks associated with research activities. It is important that, through such measures, these universities and research institutes are internationally recognized as desirable research partners. For these

institutions, the open innovation trend also presents valuable opportunities to enhance both education and research because it enables researchers to learn how industry recognizes and utilizes technologies through their experience, and to discover new subjects for basic research in the course of tackling technical problems. It is therefore desirable for them to take a positive and active approach to open innovation.

In accordance with their own characteristics, National R&D Institutes need to develop and strengthen mechanisms for promoting joint and contract research efforts with companies. Additionally, in order to convert technology "seeds" into innovative company activities, those institutes that should play intermediary functions need to establish management systems that enable this role to be executed effectively.

In addition to providing incentives to universities and public research institutes that actively engage in these kinds of industry–academia–government collaborations, the government will promote open innovation activities in Japan by prioritizing the allocation of funds for the operating expenses of national universities and the use of a framework for evaluating the business performance of National R&D Institutes.

Enhancing the role played by national universities and National R&D Institutes requires not only funding from the government; various forms of financing such as from the private sector also need to be ensured. Therefore, the government must examine and devise necessary ways to increase incentives for the acquisition of external funding. To encourage greater funding by companies and with a view toward accelerating industry–academia–government collaboration, there is a need to improve the financial transparency of participating institutions, as well as a need to enable overhead expenses to be met more flexibly. Companies and institutes are also expected to collaborate more closely and fine-tune their partnerships based on their individual requirements. The government will provide information to assist companies and institutes in tailoring their specific collaborations.

Furthermore, to make open innovation a success, it will be increasingly necessary to collaborate with foreign universities, public research institutes, and companies. It will also be useful to try and share the experiences resulting from collaborating with foreign organizations with different organizations. To that end, the government will conduct necessary investigations and develop appropriate measures. It should be noted that technologies and information that are closely subject to Japan's industrial competitiveness and national security need to be appropriately managed at the organizational level by all entities involved in such collaborations, in accordance the Unfair Competition Prevention Law and the Foreign Exchange and Foreign Trade Control Law, along with other relevant laws, regulations, and/or guidelines.

② Inducing a virtuous cycle of human resources for innovation creation

Ultimately, it is people that give rise to innovation. The exchanges of people between organizations and sectors enable the flow of various kinds of knowledge, resulting in cross-stimulation and cross-fertilization, and merging into the creation of new value. We can observe that overseas, the movement of personnel between universities and companies, between

companies of different scale and different sectors, and the concurrent deployment of people in multiple organizations, contributes to the rapid achievement of innovation. However, researchers and professionals engaged in business strategy in Japan are unevenly distributed between large corporations, SMEs and startup companies, and universities. As a result, the movement of personnel and the concurrent deployment of people across organizations and sectors is limited due to the influence of employment practices. Thus, as a society, we have not been able to harness the full capability of our human resources. This presents an obstacle to innovation creation.

In order to rapidly and effectively achieve innovation, it is necessary for the personnel of large corporations, SMEs and startup companies, universities, and public research institutes to engage in exchanges across different sectors, organizations, and disciplines. This will allow us to create a virtuous cycle within the whole of society that makes available the right people at the right place and time.

In order that researchers and professionals engaged in business strategy are allowed to exercise their abilities across organizations, universities, public research institutes, and other organizations need to actively utilize systems that enable cross-appointment, internships, and employee loans, and to ensure that work experience in the corporate sector is actively evaluated. The government will examine and devise necessary ways to offer incentives to individuals and organizations in order to improve such mobility.

③ Creating "spaces for co-creation" to concentrate human resources, knowledge, and capital

In order to create an environment conducive to sustainable innovation in which companies, universities, and public research institutes actively collaborate and interact, it is necessary to establish "spaces for co-creation" that concentrate human resources, knowledge, and capital from industry, academia, and government in order to facilitate collaborative innovation. Such spaces, which include Tsukuba Science City and Kansai Science City, have already been formed in other parts of Japan. In recent years, there has also been a shift from the linear development model characterized by one-way progression (from basic research to applied research and then development research) to a more spiral-like model in which there is constant interaction between those activities. Thus, establishing places that pull together diverse people and organizations can substantially increase the efficiency of rapid innovation creation.

In light of this, the government promotes the formation and utilization of such places, which are centered around universities and public research institutes, based on the needs of large corporations and SMEs and startup companies. To facilitate this, the government must not only pursue new initiatives but also make effective use of previous initiatives and accumulated stocks, as well as the resources of university-affiliated research institutes, university hospitals, etc. All stakeholders should be prepared to take self-sustaining measures to achieve reform.

Furthermore, in order to enhance the function of such places, it is necessary to define appropriate spheres of competition and cooperation, and to share common goals from the very first stage of R&D, based on a broad vision of society's needs. By creating and utilizing such

places around universities and public research institutes, it will be possible to promote partnerships among companies in fields in which companies alone cannot easily pursue tie-ups.

(2) Enhancing the Creation of SMEs and Startup Companies to Tackle New Business Opportunities

It is important to establish an environment that encourages companies to take risks and create new value and also assists them in tackling a diversity of challenges successively. Generating innovations capable of transforming technology "seeds" into new businesses in a short period of time is naturally better suited to SMEs and startup companies that are quick and agile than to large corporations that are restricted by their required minimum market size and slow decision-making processes. Up to now, however, Japan has invested little in venture capital compared to other major industrialized nations. Additionally, due to the strong reluctance of highly talented people to work in smaller startup companies, the number of startup companies has not been increasing, making it difficult to generate innovation by means of small and medium-sized companies.

For reasons such as this, Japan is transforming itself into a society that puts a high value on SMEs and startup companies that strive to create new businesses, and the government is committed to helping startup companies without sacrificing the speed to establish new markets, by providing appropriate assistance in areas such as entrepreneur training, starting businesses, and commercializing products and services, and providing continued support until the new companies reach their growth phase. To facilitate this, it is vital to organically integrate and link venture-related policies that have thus far proved insufficiently effective because they were deployed separately by various different entities, and to develop a unified system across industry, academia, and government aimed at sustainably and effectively supporting SMEs and startup companies.

Through these kinds of initiatives, we will increase the number of R&D-type startup companies. At the same time, by diversifying exit strategies for such ventures, through mergers and acquisitions (M&As), for example, we will try to double the number of initial public offerings (IPOs) of R&D-type startup companies, which is currently available, within the term of the Fifth Basic Plan..

① Cultivating an entrepreneurial mentality

In trying to strengthen the creation of startup companies, it is essential to cultivate professionals with an entrepreneurial mentality. Although various measures aimed at achieving this have been tried since the Second Basic Plan, they have not proved sufficiently effective. In addition, as a result of traditional customs, social trust in startup companies and social tolerance of their failure has been low in Japan. As a result, the culture of generating new industries and new kinds of startup companies has not flourished.

With this understanding, we will try to expand the human resource base of entrepreneurially minded people and increase the social acceptability and status of entrepreneurial activity and startup companies through a variety of education and training initiatives at the elementary, secondary, and high school levels.

More specifically, to foster the creativity and entrepreneurial spirit needed to generate new value among the highly talented elementary and secondary school students, who will become future leaders, we will try to cultivate within them a positive attitude toward taking on challenges and embracing different and diverse ideas and behaviors. We can do this by increasing opportunities for young students to interact with entrepreneurs and by encouraging high school and university students to experience cultural diversity through overseas student exchanges, so that they can become more familiar with the concept of business startups and be more inspired to consider the challenges of work in a startup company as a viable career option.

In addition to an education in entrepreneurship aimed at fostering entrepreneurial spirit, universities should also afford opportunities for gatherings and meetings of students desiring to become entrepreneurs, and they should provide contacts and networks with successful entrepreneurs and other supporters. The government will also promote the creation of new businesses and support the training of globally competent professionals by sending young people of enterprising spirit to overseas hotspots where there is a high concentration of startup companies.

② Promoting the creation of startup companies at universities

It is hoped that academic startups (originating in universities) can contribute greatly to innovation by generating new businesses and by turning university research findings into novel products or services. However, the number of new ventures started by universities has slumped in recent years. Some of the likely reasons behind this are the difficulties involved in procuring funding, in searching for compatible technologies, and in cultivating sales channels both within and beyond Japan, as well as a lack of personnel capable of supporting the business and operational aspects of such ventures. In some cases, even if they get off the ground, some ventures stall for operational reasons.

To address these issues, the government is trying to improve support for academic startups. Specifically, it will promote, from before the initiation of startup, greater integration between R&D support for transforming the innovative technologies possessed by universities into new products, as well as business training delivered by active business people such as entrepreneurs with expertise and experience with commercialization and startups. In addition, we will work to establish "spaces for co-creation" where universities and companies can jointly nurture venture possibilities, and to create a framework aimed at accelerating the process of cultivating academic startups. In this process, the joint research findings produced by universities and companies can be utilized to help create and nurture startup ventures, and the partnerships between startup companies originating from universities or public research institutes and large corporations will be strengthened. Furthermore, the government will also encourage national universities to make equity investments in companies that support academic startups.

③ Creating environments conducive to new business

In order to revitalize startup companies, it is important to establish a systemic virtuous cycle of venture creation. In such a cycle, startup companies grow through funding provided by investors

and venture capitalists with management and business support, and the invested funds are earned back by investors. This process further stimulates the flow of personnel, funding, and business support to other startup companies. Compared to other major industrialized nations, however, SMEs and startup companies in Japan receive only a small fraction of the R&D funds provided by government, which means that they are not currently given sufficient opportunity to achieve their potential. The number of startup companies that result in IPOs is also low, and there is a lack of diversity in available exit strategies for entrepreneurs, e.g., by means of M&As.

In light of this, we should aim at diversifying exit strategies after startup, through M&As or other means. We should also aim at establishing a virtuous cycle for the flow of personnel, knowledge, and funds through facilitating repeated ventures and supporting startup companies with business and financial resources by experienced startup founders and business managers. Thus we should provide greater opportunity for serial entrepreneurs and angel investors.

The government will promote initiatives to make available R&D and business support, as well as support for launching R&D-type ventures, that fit the needs of SMEs and startup companies by making use of local and international venture capitalists and the expert knowledge of corporate professionals with a wealth of expertise in commercialization, such as business planning, marketing, and cultivating sales channels. In addition, we will promote partnerships between companies so that a company can promote the establishment of spinoff and "carve-out" ventures based on technologies and ideas that it has not yet commercialized.

Furthermore, to further invigorate the environment for investment in startup companies, as well as to train venture capitalists with special expertise in new fields of technology and create startup ventures on a global scale, the government will strive to implement systematic improvements to expand "angel" investments, to encourage large corporations to invest in startup companies, and to promote the supply of risk money utilizing various funding methods.

④ Helping initial demand and endorsing the trustworthiness of new products and services

When a small or medium-sized startup company launches a new business in which it provides a state-of-the-art technology or service, cultivating a market is a big challenge. For this reason, the government needs to devise effective measures from the demand side standpoint in order to help address this demand issue. This can be done by stimulating initial demand via "pump priming" the market, by certifying the effectiveness of the new product or service and documenting its performance, and by supporting efforts to cultivate sales channels. Another important way to help increase the market's trust in SMEs and startup companies and thus support their business activities is by implementing an award system for SMEs and startup companies and by actively supporting their R&D.

With these aims, the government will promote greater use of tender systems that take into account technological sophistication (namely, a "comprehensive evaluation bid system") for the procurement of products utilizing new technologies, while taking care to always ensure transparency and public accountability. It will also aim and devise necessary ways to expand opportunities for participation in tenders by SMEs and startup companies that contribute to

technological innovation. To facilitate tender participation even further, the government will streamline application procedures and other bureaucratic hurdles. This can be done, for example, by developing systems that enable startups to easily check comprehensive tender information of each government department. Additionally, to improve public perception of startup ventures, we will publish lists of companies that have received government support and enrich an award system to actively support startup activities.

(3) Strategic Use of International Intellectual Property and Standardization

With the globalization of corporate activity and deepening of open innovation, open and closed strategies that appropriately use both R&D findings that should be protected by intellectual property (IP) rights and findings that are better protected as trade secrets have become increasingly important. To substantially enhance the quality of IP management from the viewpoint of increasing industrial competitiveness and developing science and technology, it is especially vital that companies not just make use of their own intellectual and technological assets but also incorporate the use of other companies' IP into their business models and devise IP strategies (including international standardization and trade secrets) that maximize value for themselves.

Therefore, in the area of IP assets and standardization strategies, we will aim not merely at acquiring rights and achieving standardization but also at utilizing IP as an essential part of business strategies, by identifying technologies that should be protected and making appropriate use of trade secrets. To help maximize the value of IP possessed by companies, universities, etc., we will promote new open innovations by raising awareness of IP and pursuing standardization among these organizations, and by promoting collaborative use of patents. To promote IP and standardization strategies, CSTI will work with the Intellectual Property Strategy Headquarters.

① Promoting use of IP assets in innovation creation

In IP strategies, the creation, use, and protection of the IP are all closely related, but it is in the application of IP that its value is demonstrated. In many cases, however, patents that represent R&D findings do not lead to commercialization, so it is important that IP be utilized more in developing innovations.

There is an increasing degree of collaboration between industry and academia in Japan, but many of the technology "seeds" possessed by universities are concentrated at the basic research stage and few are mature enough to allow companies to consider commercializing them. Furthermore, there are still many issues affecting technological intermediation for commercialization, such as the attitude differences between the industrial sector and universities with respect to the importance of joint patent applications and the protection of IP assets.

Given these realities, we will promote initiatives for generating innovation through the utilization of IP assets currently scattered across universities and companies. In addition to identifying the needs of small and medium-sized companies and then matching them with IP assets and other technology "seeds" held by large corporations and universities, we will raise awareness of patent applications and promote the use of IP assets among small and medium-sized companies

by deploying personnel to support commercialization and intermediation. In this way, we aim to increase the proportion of patent applications made by small and medium-sized companies to 15% (of all Japanese patent applications) by the end of the Fifth Basic Plan term. By substantially improving and strengthening Japan's patent examination system, we will also enable faster acquisition of IP rights. Furthermore, to convert R&D findings in Japan to commercial implementations as efficiently as possible, we will examine IP management in the country's R&D projects and ensure that it is thoroughly implemented in accordance with the characteristics of each project.

To promote the use of the IP assets of universities, it is important that the universities themselves formulate their IP strategies and independently implement IP management in accordance with them. The government can support these efforts. Through such initiatives, we aim to increase the number of license agreements on university patents by 50% over the term of the Fifth Basic Plan.

② Accelerating strategic international standardization and enhancing related support systems

In fields associated with social systems that have huge economic ripple effects and fields of leading-edge technology in which global competition is increasingly severe, an agile and precise international standardization strategy that is coordinated worldwide is very important. This is because delays in meeting international standards lead directly to reduced competitiveness and loss of market share. Where standardization by an existing industry organization is difficult— such as in the case of technology that straddles multiple fields, or leading-edge technology of small and medium-sized companies with the potential to acquire significant global market share— it is necessary for the government to transcend conventional industry boundaries in order to promote appropriate initiatives.

Accordingly, in order to quickly identify important technologies with which Japanese companies can demonstrate superiority in the field of promising global market, and promote their international standardization and market penetration, the government will continue to promote collaborations with universities and public research institutes and comprehensively support the acquisition of international standards from the R&D stage. In accordance with the evolution of the Internet of Things (IoT), the government promotes initiatives for their international standardization as well as supports to establish and verify essential technologies in relevant technical fields.

Furthermore, to accelerate the standardization of outstanding technologies and products developed by small and medium-sized companies, the governmental will establish a comprehensive support system. This system will extend from the discovery of a project to the formulation of standards and certification, and will operate in collaboration with a wide range of stakeholders, such as local governments, industry support bodies, certification bodies, and other relevant organizations. On top of this, through an industry–academia–government collaboration, the government will implement education and training to nurture professionals to take responsibility for international standardization in the future.

(4) Reviewing and Improving the Regulatory Environment for Innovation

As global competition becomes more intense, how quickly knowledge and technology, the sources of innovation, can be converted into a viable business, and whether there are social mechanisms that enable this commercialization process, are key elements in determining a country's international competitiveness. Therefore, it is vital that existing systems be reviewed to ensure that they do not impede the innovation creation process. Reforming systems sooner than other countries will lower the entry barriers to foreign capital and help to attract investment aimed at innovation.

Furthermore, in addition to spawning new services and business models, tremendous advances in ICT also serve to disrupt intellectual property systems and other prevailing systems. Therefore, systems also need to be reviewed to ensure that the potential of innovation for social transformation is being harnessed as fully as possible. As the trading of information and services and business becomes more global, international coordination becomes indispensable.

① Reviewing systems in accordance to new products, services, and business models

As science and technology advance, they give rise to new game-changing products, services, and business models that did not previously exist and that can quickly become widely implemented. However, under current systems and rules, which were formulated on the basis of earlier technologies, these new products, services, or models may be impermissible or fall within a gray area. Advances in ICT, for example, have enabled the delivery of services such as cloud and sharing services across international borders, giving rise to situations that were inconceivable when the prevailing legal system was formulated.

In view of the fact that systems can no longer keep up with the pace of innovation, and with an understanding that this lag is worsening, CSTI, together with related government agencies, is identifying systematic problems associated with the accelerating use of ICT and robots, as well as the widespread diffusion of new products, services, and business models. Additionally, the government and other stakeholders will examine and devise necessary ways to address these issues, including by means of system revisions.

Furthermore, if real-world verification is necessary, corrective action will be implemented, including by the use of special zone systems, in order to enable issues to be addressed under existing systems. For products, services, and business models understood to fall within gray zones under current systems, ways to promptly define the status of items in question within those systems will be examined and devised. In doing this, issues will continue to be identified, through initiatives such as promotion of SIP and also through advancement in the 11 systems, in order to help realize a super smart society.

② Improving IP systems in response to the tremendous development in ICT

The development of technologies such as IoT and AI has significantly reduced the transparency of international boundaries in cyberspace. As a result, cyberspace now contains considerable

amounts of IP of vague status and uncertain jurisdiction, and increasingly new innovations are being generated through the use of such IP by third parties. The evolution of three-dimensional (3D) printing and other digital manufacturing technology is also leading to a growing integration of information with "things". This is making the protection of rights under an IP framework based on earlier concepts of "country" and "things" increasingly difficult. Therefore, in addition to improving old systems, it is necessary to create new worldwide systems and mechanisms that transcend the concept of countries and, through these, to construct international cooperative relationships.

Accordingly, on the basis of technological and social progress and changing needs, the government will examine and devise systems and strategies appropriate to the new emerging age, such as highly flexible rights regulations and a smoothly functioning licensing system. This will be accomplished by taking into consideration the balance between IP protection and the promotion of IP use, as well as international trends.

(5) Developing Innovation Systems that Contribute to "Regional Revitalization"

While population decline and aging are major challenges facing all of Japan, it is especially important to address the worsening birthrate and aging populations adequately in each region, by generating new businesses and economic activity to revitalize local economies. Fortunately, a variety of regions have strengths and "sprouts" from which innovations can be produced. In order to leverage the strengths of these areas into the creation of new products and services, and to generate greater added value for existing industries, it is important to locally establish self-regulating, sustainable innovation systems.

Up to now in Japan, regional policies have been centered on the concept of "clustering" in accordance with the characteristics of each locality and the available "seeds" of technology from local universities. However, for the most part, the use of resources from outside a particular region has been limited, with a tendency for economic activity to remain closed within the locality. Additionally, since policies were applied uniformly across the country, local characteristics have not been sufficiently exploited in many cases, and too few initiatives have been able to take root and achieve sustainability.

Conscious of these points, the government needs to support STI through local leadership and use that as the basis for promoting "regional revitalization".

① Revitalizing regional companies

So-called "global niche top" (GNT) companies with particular products that boast high market share and good profitability both in Japan and abroad play an important role in driving local economies. This is done, for example, by generating work for large numbers of suppliers in the regions where they operate. In addition to promoting the vitality of such core companies, which drive local economies while also developing their businesses beyond the region and even internationally, it is necessary to discover other companies with the potential to grow and become

similarly successful, and to support them in taking up the challenge of generating and expanding their business activities.

To this end, the government is identifying regional small and medium-sized companies in Japan that have the potential to develop advanced technologies that can dovetail with demand within and beyond their regions, and even overseas. To promote their growth into core companies, the government will make available systematic support that covers everything from the formulation of R&D strategies to product development, including matching their needs to technology "seeds" beyond the region, standardization, cultivation of sales channels, and expansion into international markets. By leveraging the particular strengths of regional universities and public research institutes, we will build strong partnerships between such regional institutions and companies with the potential to become core companies. In addition, we will support joint R&D and greater standardization of outstanding local technologies and products in order to help generate new and higher value-added businesses in local economies.

② Driving innovation systems that make use of local characteristics

In order to make use of the various resources and technology "seeds" that are locally available and to effectively cultivate "sprouts" of innovation, it is important to have a broad network of collaboration appropriate to local characteristics between the various stakeholders. These stakeholders might include universities, technical and vocational schools, and public research institutes (including National R&D Institutes and national research and testing institutes) with their stores of knowledge, as well as local companies, local government bodies, and local financial institutions. However, if such a system is to take root locally, the presence of professionals who can engage constructively with resources and experts both in and outside the region is absolutely vital. These include, for example, individuals capable of putting together joint industry–academia–government research projects, individuals capable of creating businesses that harness the potential of the region, and individuals to support the launch and growth of startup companies.

To realize this vision, the government will collaborate with relevant ministries and local authorities and invest effort in cultivating these kinds of professionals and getting them settled locally. It will also promote innovation that strengthens local competitiveness and revitalizes local economies and offers appropriate support for generating a self-sustaining virtuous cycle in order to expand and invigorate the young members of the regional labor force and revive local communities. The government will also enhance both intermediation functions to help commercialize "technology seeds" and matching functions, at both the local and national levels, through collaborations between research and testing institutes, National R&D Institutes, and universities, along with others.

③ Promoting policies that encourage local initiative

The government needs to promote the development of an innovation system led by local communities, utilizing local strengths and unique local characteristics, to support the independent and sustainable growth of those communities. In developing these policies and measures, the

government will take into account the reality that it may take decades to go from initiating innovation to achieving the substantial result of creating businesses. In addition, it is important to identify the factors behind the various examples of successful community-led initiatives along with the factors behind unsuccessful initiatives that did not yield commercial success, in order to widely share those factors with other regions, and to provide support for analyzing the dynamics relating to the industrial structure and economy of communities.

Through collaboration with the Headquarters for Overcoming Population Decline and Vitalizing Local Economy in Japan and the Intellectual Property Strategy Headquarters, and in addition to various measures by public institutions to support small and medium-sized companies, CSTI will work on establishing an environment that enables local communities to implement all appropriate measures to tackle these challenges. In doing this, CSTI will create a system that enables support for local initiatives, thereby bringing together all relevant institutions more closely than ever. In accordance with this system, CSTI will continually review the circumstances of the community in order to see whether it has a clear and effective strategy for generating innovation that exploits its particular strengths and characteristics, and whether local government bodies and the wider community are really committed to leading the effort. Then, in accordance with these reflections, it will collaborate with relevant ministries to address issues as needed. The results of these measures will be widely shared in order to help with the effective implementation and revision of comprehensive strategies for local revitalization formulated by prefectural and municipal governments, based on the "Towns, People, Work Revival Law".

(6) Cultivating Opportunities for Generating Innovation in Anticipation of Global Needs

Many of the serious problems that Japan grapples with relating to energy, resources, food security, and natural disaster responses are shared by other countries around the world. Thus, the technologies that Japan has developed (or is developing), and the knowledge derived from those technologies to deal with these challenges, can be increasingly put to good use internationally. Therefore, by using Japan's technological prowess and practical experience in these fields and anticipating global needs, as well as by taking strategic initiatives to pursue common benefits for the whole world in addition to Japan, we can cultivate global innovation and advanced opportunities for business development.

① Promoting R&D that anticipates global needs

In Europe and the Americas, the government and companies are strategically developing initiatives aimed at new business creation by building cooperative relationships on a global scale, setting an agenda that anticipates global needs, and promoting R&D. On the other hand, despite the fact that Japan possesses sophisticated knowledge about the needs of the world and a wealth of technologies, it is currently unable to effectively utilize these resources for the development of global business.

For this reason, Japan will develop international activities such as identifying and defining issues and producing suitable policies ahead of the rest of the world, not only from the viewpoint

of making a contribution to the world but also in order to contribute to enhancing the country's industrial competitiveness.

More specifically, working in partnership with international organizations with a view to establishing greater international collaboration and cooperation, the government will construct a cross-sectional analysis system for making science and technology forecasts and exploring long-term changes, with the aim of generating R&D and new business ideas in anticipation of global needs. In addition, to facilitate the use of the results of these findings in society, it will also set up systems and mechanisms for sharing information and for follow-up. Furthermore, by leveraging the strengths of Japan's universities and public research institutes, we will strategically promote international joint research and research exchanges with the world's leading science and technology nations with a view toward addressing the economic and social challenges that we face.

② Developing systems to promote inclusive innovation

In scientific and technological cooperation with emerging nations and developing countries, it is important to break away from the aid-driven forms of cooperation that have prevailed up to now, and move instead toward strategically establishing frameworks for more equitable partnerships with such countries in order to facilitate the generation of socially inclusive and sustainable innovation ("inclusive innovation").

In addition to promoting bilateral knowledge exchanges and developing mechanisms to leverage each party's strengths in order to try to resolve the problems faced by emerging and developing countries, we will widely disseminate the findings of such work to other developing countries. Through such measures, we will be able to build mutually beneficial relationships with many different countries.

To strengthen relationships with emerging and developing countries, the government will promote joint research in the field as part of efforts to actively utilize and improve frameworks for international science and technology cooperation that aim at addressing global-scale problems, and will implement inclusive innovation in science and technology. In addition, the government will examine and promote the design of programs that emphasize initiatives that offer practical use in society and foster professionals.

To help the industrial development of developing countries, we will also promote inclusive innovation by investigating coordination measures between sustainable businesses that target low-income earners in those countries, who total approximately 4 billion people worldwide, and promotion of science and technology. In pursuing these initiatives, we will keep in mind that they will also be useful in solving social problems in Japan and other advanced countries.

It is also important to strengthen international professional networks. Therefore, in our science and technology cooperation with emerging and developing countries, we will pursue collaborations with the partner country's government, universities, public research institutes, funding bodies, and industries, and also help to foster young researchers and industry professionals in the country. In doing this, we will collaborate with other developed countries and

multilateral frameworks and strive to cooperate in initiatives implemented by partner countries for training professionals.

Chapter 6 Deepening the Relationship between STI and Society

The history of humanity has been rewritten by the interactions between science and technology on one hand and social systems on the other. However, with the rapid evolution of science and technology, the relationship between these two forces has become ever more intimate. In an era of drastic change like our own, STI drives the creation of future industries and social transformations. Thus, having dialogue and cooperation between varieties of stakeholders is now essential when formulating responses to economic and social challenges. For this reason, science and technology and society, which have traditionally worked at cross purposes, need to have a deeper relationship in order to facilitate dialogue and cooperation, or "co-creation," between a diverse range of stakeholders, including researchers, citizens, media, industry, and policymakers.

To achieve this, it is important that the national government, universities, national research institutes, and science museums take the lead in setting a co-creation forum, and that the stakeholders each enhance their capabilities in order to enable more effective co-creation. To accomplish this, it is necessary to build a relationship of trust between stakeholders, but that is only possible if the integrity of research is assured.

(1) Promoting Co-creative STI
 ① Dialogue and collaboration with stakeholders

Since the Third Basic Plan, outreach initiatives such as "science cafés", in which researchers have participated of their own accord, have spread, in part because science and technology communication has been encouraged as a matter of policy. On the other hand, as a result of the Great East Japan Earthquake and the ensuing nuclear reactor accident, as well as recent incidents of misconduct by researchers, the relationship between science and technology and society is being seriously questioned.

Looking ahead, it is important to improve outreach activities, but researchers must also face up to the questions of STI's place and influence in society. It is also essential that the various stakeholders genuinely interact with each other in the spirit of dialogue and cooperation in order to engage in "co-creation" that leads to policymaking and knowledge creation. For this reason, the government will work together with universities, national research institutes, science museums, etc., as part of efforts to generate more-effective dialogue and to set up forums for dialogue and cooperation. This will include roundtable meetings with various stakeholders and science and technology-related meetings that are open to all citizens. The opinions gathered in this way will be taken into account during government policymaking, with the aim of creating new value and identifying and addressing social issues. As well as promoting citizens' science, we will try to create a methodology and environment that enable researchers to work together with citizens and policymakers in formulating research plans, implementing research, and disseminating the fruits of that research.

② Stakeholder initiatives for co-creation

To promote co-creation between stakeholders in science and technology, it is important to raise both the scientific and technical literacy of citizens, who are the stakeholders on the side of society, and the social literacy of researchers.

It is particularly vital that citizens develop a deeper understanding about the limits and uncertainties of science and technology and the methods of logical debate from the elementary and secondary school stages in order to stimulate dialogue about use of new science and technology in society and communication about the risks of natural disasters and climate change.

Public education facilities, such as science museums, have a major role to play in this. In these kinds of places, science communicators—professionals who connect researchers with the various stakeholders representing society—are expected to actively function as mediators in order to facilitate dialogue and cooperation between the two sides, so the government will support their efforts.

Newspapers, TV, the Internet, and other media also have a significant role to play in science education. By striving to provide science and technology information that is as objective as possible, including discussion about uncertainties and opposition to the views of specialists, the media should consciously aim at increasing the scientific and technical literacy of citizens and, by extension, help to foster co-creation.

On the other hand, researchers are expected to explain their work to various stakeholders in an easy-to-understand way, making use of broad knowledge and perspectives that cut across different disciplines. Furthermore, researchers need to broaden their outlooks and develop a deeper awareness of the importance of the use of their research in society. Along with such enhanced perspectives, it is important to make effective use of collaboration between the humanities/social sciences and the natural sciences and internships for experts in companies. In addition, personnel performance evaluations at universities and national research institutes and the evaluation of research projects at publicly funded organizations should not be based solely on the number of papers published. Rather, it is necessary to adopt multi-faceted evaluation criteria that include efforts at dialogue and cooperation with a variety of stakeholders and the social impact of research findings.

③ Scientific advice for policymaking

The role of science and technology in the shaping of government policy in responding to natural disasters and climate change, in responding to the needs of our hyper-aging society (such as medical issues), and in ensuring cybersecurity, is bigger than it has ever been before.

In light of this, it is important that researchers strive to ensure the quality of their scientific advices, and that they clearly explain to the various stakeholders of society the limits and uncertainties of scientific knowledge, as well as the fact that there can be differing scientific views on any issue. On the other hand, stakeholders should perceive that researchers are able to deliver scientific views from an independent standpoint, without being swayed by political motives. It is also important that stakeholders recognize that while scientific recommendations should be

respected as part of the policymaking process, they are not the only grounds for making policy decisions. Furthermore, the mechanisms and systems used to make scientific advices in Japan need to be improved while taking into account international trends of recent years.

④ Ethical, legal, and social initiatives

On questions of the social applications of science and technology, there are a growing number of cases in which society as a whole needs to make decisions on ethically or legally contentious issues. These issues include, but are not limited to, genetic testing, regenerative medicine, and AI.

In the social implementation of new science and technology, the government needs to provide a suitable forum for formal or informal communication with the various stakeholders, and undertake research on the ethical, legal, and social issues with the participation of a variety of disciplines in the humanities/social sciences and natural sciences. Then, based on the results of this research, it must predict the social benefits and costs of the new technology, as well as its unintended uses, and examine the construction of a systematic framework for implementation that strikes a balance between advantages and disadvantages. Finally, it must put in place all the necessary measures for this. As and when necessary in response to advances in leading-edge research, the government and academic societies should also work on formulating ethical guidelines.

Furthermore, with a view toward promoting the use of science and technology in society, we will promote research on scientific methods for appropriately predicting, evaluating, and making decisions based on scientific grounds; for producing technology assessments that comprehensively analyze the impacts of science and technology; and for formulating and implementing regulations, as well as researching ways to manage transitions between social systems. These measures will be pursued in coordination with R&D activities.

(2) Ensuring Research Integrity

In order for researchers to engage in meaningful dialogue with a variety of stakeholders in society, it is vital to build a relationship of mutual trust. A prerequisite for this is to ensure the integrity of research. Although most researchers pursue research with integrity, it is a fact that incidents of research misconduct have occurred in the past. Researchers and research institutes such as universities need to fully recognize that dealing consistently with research misconduct is the proper response to the trust and mandate of the public toward STI, and that this ultimately serves to improve the capacity for STI.

Consequently, researchers should reflect on their duty of ensuring the integrity of research and strive to foster a culture in which integrity is self-sustaining, for example, by passing on the research ethics that they have learned and acquired themselves to young researchers. Universities and other research institutes should also develop mechanisms for continuing research ethics education, in accordance with their respective occupations, for example, for specific research fields, for researchers, for personnel who aim to become researchers in the future, and for research support personnel.

They should also be prepared to respond swiftly and appropriately to any suspicion of research misconduct. In the event that research misconduct is observed, the incident should be comprehensively examined by investigating its essential cause and background, and measures should be taken to avoid a recurrence. When doing this, it is important to be careful that researchers not be excessively pursued for legal liability. The national government will revise guidelines relating to research misconduct whenever needed and, in partnership with funding bodies, guarantee the integrity of research through measures based on those guidelines.

The most basic and essential thing in research integrity is not merely to deal with it from the standpoint of the applicable laws and guidelines but rather to create a research environment that enables free and open-minded debate that transcends the barriers within labs, or between labs and research institutes. As long as there are opportunities for casual consultation and discussion with surrounding researchers at the workplace level—thereby enabling frank and lively exchanges of opinion concerning the interpretation of data, the validity of research methods, and the design of studies—and if findings are verified from these different angles, the fruits of research will be trustworthy. The responsibility for creating this kind of research culture lies not only with researchers but also with universities and other research institutes.

A higher level of public expectation of researchers requires a greater level of responsibility that researchers need to bear. To ensure that researchers can work in a free and open-minded way from the earliest stage of their careers, it is also important to consider the work burdens that are placed on them. The government, universities, national research institutes, and funding bodies should work to establish an environment that enables researchers to freely concentrate on R&D work and co-creative activities by increasing the efficiency of administrative processes, etc.

Chapter 7 Enhancing Capacity to Promote STI

In order to effectively and flexibly execute the policies and measures defined in this Basic Plan, it is necessary to enhance capacity to promote STI.

For this reason, we are reforming and enhancing the role of universities and National R&D Institutes, which are the key entities engaged in activities related to STI. In addition, the government needs to coherently and strategically develop STI policies aimed at both domestic and global activities based on an overall vision of the measures implemented by the various players, universities, public research institutions, and companies, along with the relevant office and ministries. In addition to strengthening the systems for this, we will work to enhance the "control tower" role of the Council for Science, Technology and Innovation (CSTI). Furthermore, we will ensure the sufficient R&D investment for the implementation of the Basic Plan.

(1) Reforming Universities and Enhancing their Function

In order to address the demands of our age of dramatic change, it is absolutely vital to foster diverse and excellent human resources and to develop a rich foundation for the creation of diverse and outstanding knowledge, in order to enable flexible and appropriate responses to whatever changes in circumstances and new problems are encountered. In this effort, it is universities that play the key role. Furthermore, the role of universities is expanding, spanning from making new knowledge available to society through to engaging in industry–academia–government collaborations in order to widely deliver economic, social, and public benefits to society.

Universities, which have an extremely important role in generating science, technology and innovation, face a variety of challenges, such as reforming their management and personnel systems, ensuring stable posts for young professionals, participating in international initiatives to promote the circulation of talented researchers, engaging fully in industry–academia–government collaborations, and promoting diversification of funding sources. To appropriately address these challenges, it is necessary to ensure that personnel, knowledge, and funds within a university are utilized effectively and efficiently.

In light of this, universities are required to promote radical reforms based on recognition of the fact that they must contribute to society through education and research. More specifically, they need to establish management systems and pursue reforms that enable universities to operate with unified academic staffs based on the leadership of university presidents who are responsible for reform. More specifically, they need to strengthen their management capability through the appropriate allocation ("portfolio management") of resources across their organizations; enhance their institutional research (IR) and planning, survey, and analysis systems; boldly restructure and metabolize their education and research systems; reform their payroll systems to promote optimal deployment of human resources; radically reform university and graduate school education; and upgrade systems for industry–academia–government collaborations. This can be accomplished by improving risk management; actively publishing information, including data on the state of their finances; diversifying funding sources; and implementing a selection process aimed at appointing

presidents in accordance with each university's mission, and then securing and training personnel to be presidents.

At the same time, the government will provide incentives to universities for actively promoting these kinds of measures, including the use of assessments and allocation methods for grants to national university corporations, and it will review and reform systems to enable more streamlined and efficient financial management by universities including national universities. For national universities that operate in highly competitive international environments and meet certain conditions, the government will provide for exceptions to the national university corporation system and will review and implement ways to support and evaluate such universities in order to significantly strengthen the foundations of the organization and its diverse funding sources, including at the institutional level.

Furthermore, to guide reforms of education and personnel systems at universities, the government will create a system for forming graduate schools in order to promote integrated education in disciplines that span different fields, such as the fields of humanities and sciences, as well as leading-edge education in fields in which Japan is strong. It will also adopt systems for enabling outstanding young researchers to work in independent and free research environments while being employed in stable positions.

(2) Reforming National R&D Institutes and Enhancing their Function

National R&D Institutes are organizations that tackle basic and basic research matters that are difficult to perform in the private sector, as well as the development of element technologies that contribute to the formulation of verification testing and technical standards, and the allocation of funds to other institutions for R&D expenses, all based on national and international requests with a long-term vision. As a driving force behind innovation system, they are required to work on organizational reform and enhancing their functions.

R&D institute presidents are required to demonstrate outstanding management skills, such as the ability to provide and operate appropriate internal controls, as well as to pursue commercialization of technology seeds, facilitate international expansion, conduct personnel exchanges, and more. In addition, for the technologies that serve as the indispensable basis for Japan's sustainable development, R&D institute presidents are expected to facilitate the mustering of technologies and personnel for industry–academia–government collaborations and for integrating technologies in accordance with a long-term vision of the national government, taking into account Japan's international competitive standing and the ripple effects of those technologies on society.

In terms of the national strategy, as well as promoting appropriate, effective, and efficient administration and management of the corporations by setting and assessing medium- to long-term goals and budgetary measures based on R&D characteristics and diversity, the government will ensure that each R&D corporation works in close partnership with the government to fulfill its role and mission, and achieves the maximum possible R&D findings.

The government will also establish a forum in which each institute's role and medium- to long-term strategy can be seen and disseminated within and outside Japan. In addition, the government will strive to improve operational performance levels in areas such as procurement for R&D in order to help increase the competitiveness of each institute, and it will also take measures such as streamlining procurement, reorganizing personnel systems, and enhancing systems for industry-academia-government collaboration.

"Designated National R&D Institutes" (tentative name), which are expected to be established soon, will aim at producing R&D findings of the highest international standard and will serve as core institutions for strongly driving innovation systems. The government intends to eventually deploy these pioneering initiatives to other National R&D Institutes.

(3) Strategic International Implementation of STI Policies

In light of increasing globalization, Japan must not only pursue STI but also utilize the fruits of them to improve Japan's profile and reputation in international society. For this, it is necessary to coherently implement international activities relating to STI, as well as science and technology diplomacy.

Accordingly, the government will not only disseminate the findings produced by universities, national research institutes and companies in relation to the economic and social issues faced by Japan throughout the world but also make use of international organizations and conferences to demonstrate leadership in these fields. Japan will also strategically pursue bilateral and multilateral cooperation with other countries and make efforts to raise its international profile by taking opportunities to exercise science and technology diplomacy through international awards, international academic conferences, and the like. Furthermore, Japan will cultivate and secure professionals capable of undertaking such diplomatic activities and promote their efforts by appropriately evaluating these human resources and enhancing support systems designed to assist them.

To strategically and effectively implement such measures as the government, CSTI will strengthen collaborations with the Ministry of Foreign Affairs and other relevant ministries, as well as with funding agencies and other relevant institutions. It will also continue to share international information and set up agile and continuous networks and management systems.

(4) Pursuing Effective STI Policies and Enhancing the Chief Controller Function

The Basic Plan depicts the state of STI policy over the next five-year period from a medium- to long-term perspective, looking ahead approximately 10 years. Starting in fiscal year 2013 (FY2013), the Comprehensive Strategy was formulated each year to serve as the driving force of policy development. From now on, the direction of medium- to long-term policy will be expressed in the Basic Plan, and the policies that need particular focus in each year will be described in the Comprehensive Strategy, based on changing circumstances.

In this process, policies are developed based on objective grounds, so indicators are set separately in order to quantitatively assess progress and results pertaining to the direction of the

Basic Plan and the points of focus that it defines. In continued collaboration with relevant ministries, CSTI will use these indicators and combine them with qualitative data to perform an interim assessment of the Basic Plan each year, identifying problems and also following up on remedial measures.

The results of these assessments will be comprehensively utilized in formulating the Comprehensive Strategy, and in adjusting resource allocation guidelines and estimation guidelines for science and technology-related budgets in order to appropriately allocate limited resources to necessary fields and policies. These will be based on a broad overarching vision of STI policy. Furthermore, it is important to ensure that these results are reflected back into the STI policies of the relevant ministries through greater use of innovation budget strategy meetings.

We will also work to reflect policies based on objective grounds into policy drafts, assessments, and policies. To this end, we will work to adopt mechanisms for systematically observing and analyzing probable future economic and social developments based on objective grounds, as well as systematically providing data and information for assessing and analyzing policy effectiveness and developing indicators and tools. In relation to public funding, CSTI and the relevant ministries are conducting assessments and analyses of public funding options and providing the results to funding bodies and other stakeholders while continuing to work intensively on recording data to a common R&D administration system for all ministries and then linking this system to the databases of funding institutions.

While this Basic Plan specifies targets relating to STI activities and its results for Japan as a whole, in particular for items for which quantitative definitions of desired goals are necessary and possible, the targets are not applied to specific institutions. Each institute should not focus on only the achievement of targets, otherwise they may hinder the implementation of STI contrary to their expectation. Accordingly, CSTI will constantly monitor and assess the impact of the targets on STI at each institution, and it will devise appropriate corrective measures to facilitate STI whenever necessary.

To further exercise its chief controller role, CSTI will forcefully promote SIP. Industry, academia, and government, including all related ministries, have devoted all their energies on the R&D and market implementation of this technology. CSTI will also push for the further development and deployment of ImPACT. Since existing systems and rules have not necessarily kept up with advances in science and technology, they may become hindrances to future industrial creativity and social change. Therefore, with a sense of urgency, we will promote a variety of reforms, improvements, and other adjustments to systems associated with STI.

In pursuing the above goals, CSTI will further deepen its collaboration with other chief controllers　(Headquarters for Japan's Economic Revitalization, Council for Regulatory Reform, National Security Council, Headquarter for Overcoming Population Decline and Vitalizing Local Economy in Japan, IT Strategic Headquarters, Intellectual Property Strategy Headquarters, Ocean Policy Headquarters, Strategic Headquarters for Space Development, Headquarters for Healthcare Policy, Cybersecurity Strategic Headquarters, and National Resilience Promotion Headquarters) and the Science Council of Japan. Drawing on the resources of relevant ministries, public think

tanks, and other stakeholders, we will devise necessary system enhancements, and strive to address high-priority issues for the nation, as well as issues for which cross-ministerial measures are necessary.

(5) Ensuring R&D Investment for the Future

In today's world of rapid scientific and technological advances, and increasingly globalized markets, the key to overcoming global competition is to generate innovations in science and technology ahead of other countries. In view of this, it should be noted that whereas the governments of China and other countries have invested heavily in R&D, for many years in Japan, the government's proportional contribution to R&D spending has been lower than other countries. Given these tough financial circumstances, science and technology-related budgets are trending downward. In order to sustain a prosperous society in which each and every citizen can thrive, as well as to preserve such a society for future generations, it is essential to make government investment in STI policies a high priority.

In other words, the process of creating knowledge and value is changing dramatically and, day by day, this change is in turn causing significant changes to the structure of our economy and society. Thus, to be ready to flexibly and appropriately deal with any kind of changing circumstances or new challenge in today's world, we need to strengthen research capabilities and fundamental R&D for generating diverse, high-quality knowledge. Since this work must be performed by universities and national research institutes, the supporting role of government is essential. In a world in which the future is so unclear, companies become averse to risk and the fruits of R&D must pay for themselves quickly. For this reason, governments must act all the more to support sustainable long-term R&D, including those types that lack immediate commercial potential.

Furthermore, to promote regional creativity, small and medium-sized companies, which tend to lack funding and vitality, will need backing in order to convert the results of their research into viable products and services, and the government is expected to play a role in this. To pursue these kinds of measures, there is also a need to cultivate and secure the professionals that are the backbone of STI, and it is fitting that in this resource-poor country, built up by human effort, the government should confront such challenges head-on.

With the increasingly fierce global competition of today's world, Japan's companies must take chances in order to fight for their survival, and they are now also being targeted for collaboration by overseas universities. Unlike various other countries, in Japan government, R&D of a suitable scale is essential for supporting the private-sector R&D of this lively nation. Company-sponsored R&D is geared mostly to improving existing technologies. Therefore, if the kind of R&D whose potential market value is unclear is not performed by Japan's universities and public research institutes, companies will either be forced to get their needs met at foreign universities to gain access to the R&D that they cannot conduct by themselves, or they will be pushed to relocate their own R&D center abroad in order to establish a world-class facility.

Since Japan's universities and national research institutes also find themselves competing globally to offer their services to Japanese citizens, the government must continue playing its role of promoting improvements in these institutions and supporting activities that the private sector cannot handle. This is necessary in order to ensure that the universities and national research institutions can provide Japan with high-quality research and education services of the highest international standards. Therefore, it is of crucial importance that universities, research institutes, and companies in Japan keep working together to lead efforts find and address solutions to the challenges, both in and outside Japan, presented by changing industrial and social structures.

So far, up to the term of the Fourth Basic Plan, setting clear goals for government R&D investment has enabled Japan to steadily improve its R&D environment and win numerous Nobel prizes in the process. These prizes are also the fruits of government R&D spending over many years. Under the Fifth Basic Plan as well, government investment in R&D needs to expand, with a view to continuing the efforts for promoting science and technology up to now.

Concrete goals for such government R&D investment should be set with a constant focus on improving policies, comprehensively taking into account a variety of significant factors, such as the fact that many other countries are increasing their government R&D spending, the relatively low level of Japanese government spending as a proportion of total R&D investment, the need for government R&D investment to produce the synergistic effects of promoting private sector investment.

In light of all this, based on confirmation that this conforms to the "The Plan to Advance Economic and Fiscal Revitalization" in "Basic Policy on Economic and Fiscal Management and Reform 2015" decided down by the Cabinet in June 2015, we are setting a target of at least 4% of GDP for total public and private-sector R&D investment, of which the government R&D investment target level is 1% of GDP. Assuming an average of 3.3% of nominal GDP growth rate during the period, we estimate that the total government investment in R&D needed over the term of the Fifth Basic Plan will amount to approximately 26 trillion yen.

Given the challenges of a declining population resulting from our low birthrate and aging population, Japan is facing spiraling social security costs and stagnant tax revenues. However, it still aims to increase economic productivity through STI. In this way, Japan can achieve economic growth and employment creation, ensure the safety and security of the country and its citizens, provide them prosperous lives, and also contribute to development internationally.