Chapter 3 Future Perspectives of Science, Technology and Innovation

Chapters 1 and 2 introduced actual examples of science, technology and innovation activities and support programs in Japan over 20 years, reviewed the science, technology and innovation policies and outlined the results. The clear message was that science, technology and innovation underpin sustainable national and international development and needs to strongly and strategically continue such policies in future.

From FY 2016, science, technology and innovation policies will be implemented in the latest 5th Science and Technology Basic Plan. Advancing these policies will require a view on medium- to long-term future vision while taking ever-changing socioeconomic circumstances into account.

Therefore, Section 1 of this chapter consolidates the socioeconomic circumstances relating to science, technology and innovation in Japan and identifies particularly important changes for science, technology and innovation in Japan. Next, Section 2 consolidates the direction of science, technology and innovation policies in the immediate future, taking changing socioeconomic circumstances into account and introduces the progress of discussions about the launch of the 5th Science and Technology Basic Plan inside and outside the Cabinet. Finally, Section 3 forecasts the science, technology and innovation set to emerge in Japan in 2020, the final year of the 5th Science and Technology Basic Plan, and a further decade onward, in 2030.

Section 1 Socioeconomic Changes in Future

Japan's society and economy are currently undergoing significant change, which not only affects the future trajectory of science, technology and innovation policies, but may also transform future concepts in such fields, including approaches to science.

This section consolidates the major socioeconomic changes relating to science, technology and innovation from three perspectives[1].

1 Changes in Population Composition

Changes in the population composition in Japan are the primary focus when discussing the future vision.

(1) Society of declining population

As the birthrate is declining in Japan, the total population is on the decrease after peaking at 128.06 million in 2010; expected to fall to 116.62 million by 2030 and below 100 million in 2048[2]. This population decline, alongside the declining birthrate, is a major threat to sustainable maintenance and improvement of the economy and individual living standards.

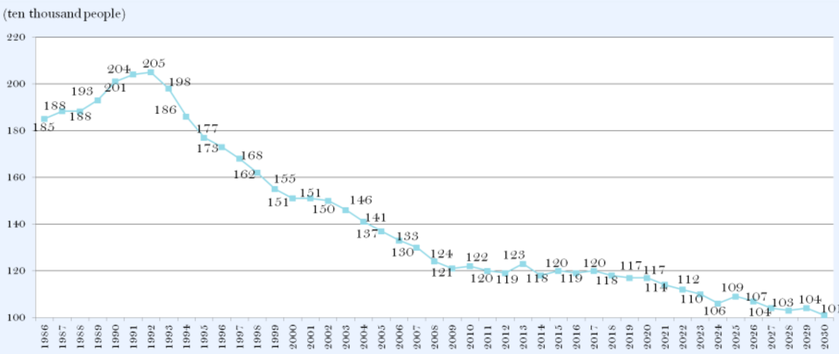
As for the declining birthrate, the 18-year-oldpopulation, i.e. university freshmen, which had remained

1 The future perspective in this chapter is an extension of the current socioeconomic situations, including changes. The present government has explored various potential ways of solving issues that the nation will face in future, including science, technology and innovation policies, birth dearth countermeasures, regional revitalization and financial reconstruction. The future perspective will vary significantly depending on the current efforts to deal with these issues.

2 Population Projection for Japan (January 2012, National Institute of Population and Social Security Research)

at around 1.2 million for about a decade up to FY 2017, as shown in Figure 1-3-1, entered again a long-term period of decline from FY 2018 and is expected to reach 1.01 million by FY 2030. The number is less than half the population of 18-years-olds in FY 1992 and turned 40 in FY 2014. The serious decline in the younger population indicates the difficulty in maintaining sufficient human resources engaging in science, technology and innovation activities. From this perspective, it seems there is no choice but to reform STI activities.

■ Figure 1-3-1 / Changes and estimates of 18-year-old population



Source: Created by MEXT based on "School Basic Surveys" (data up to 2026) and "Population Projection for Japan" (National Institute of Population and Social Security Research) (data after 2027).

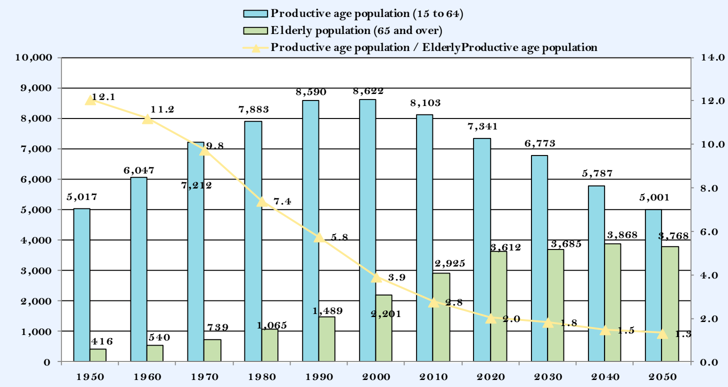
(2) Progress of super-aged society and waning local communities

As shown in Figure 1-3-2, the elderly population (65 and over) in Japan is growing annually and is forecast to reach 36.85 million in 2030. Consequently, the proportion of the productive population (15 to 64 years old) relative to an elderly individual is expected to decrease from about 2.8 in 2010 to about 1.8 in 2030 and even about 1.3 in 2050. This accelerating super-aged society is raising concerns about problems such as a shortage of labor and medical care, increased care burden and social security charges. The population aging, combined with the declining birthrate and the concentration of population into urban areas, which accelerates the depopulation of local communities, causes local economies to decline. Figure 1-3-3 shows estimated social welfare benefits created by the Ministry of Health, Labour and Welfare (MHLW), suggesting a significant future increase in medical and nursing care charges and ballooning social security expenses will be a heavy financial burden in future[1].To cope, establishing innovation in response to the super-aged society and contributing to a sustainable social security system is crucial for continuous national development.

Switching to a global focus, however, we realize that problems such as aging and concentration of population into urban areas are not inherent to Japan. For instance, as shown in Figure 1-3-4, aging similar to that in Japan is expected to progress in many major countries in future. Japan is an "advanced nation" in terms of the issues such as aging and the concentration of population into urban areas and is inevitably first to globally showcase a new model solution. In other words, an outstanding solution model will not only increase labor and trigger finance reform, but also pave the way for us to access world markets through new business.

1 According to "Economic and Fiscal Projections for Medium to Long Term Analysis" (February 16, 2015, document submitted to the Council on Economic and Fiscal Policy), Cabinet Office, social security-related expenses in national spending in FY 2011 were estimated at about 40.5 trillion yen, or an increase of about 38.7% from FY 2013

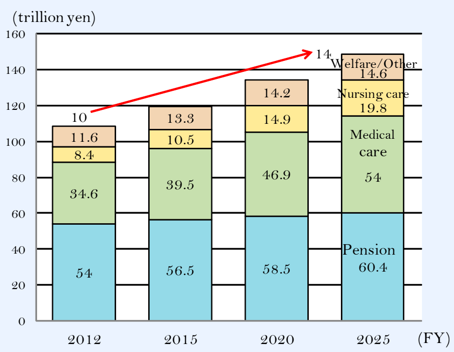
■ Figure 1-3-2 / Changes and estimates of elderly and productive populations



Note: The left axis indicates the population of elderly and the right axis the number of people in productive age bracket for an elderly.

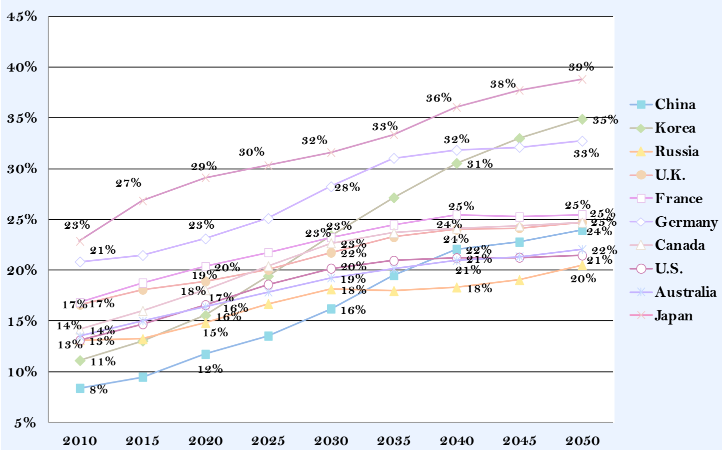
Source: Created by MEXT based on "National Census" (data up to 2010), MIC and "Population Projection for Japan" (data after 2020), (National Institute of Population and Social Security Research)

■ Figure 1-3-3 / Future estimates of social security benefit



Source: Created by MEXT based on "The Financial Statistics of Social Security in Japan(FY 2012)" (National Institute of Population and Social Security Research) and "Revised Projections for Social Security Expenses (March 2012)" MHLW

■ Figure 1-3-4 / Changes share of elderly population in total population in major nations

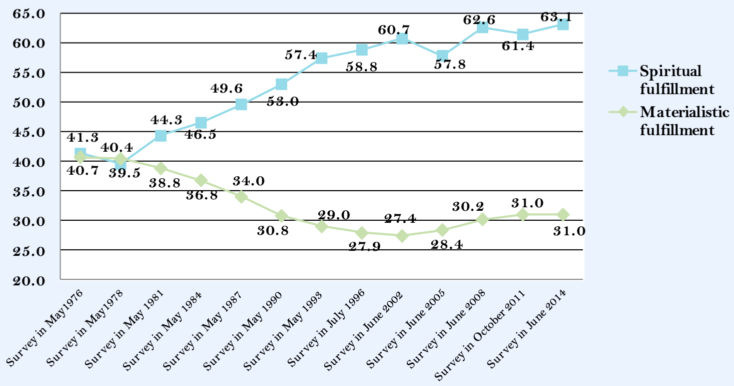


Source: Created by MEXT based on the United Nations "World Population Prospects: The 2012 Revision" (other than Japan) and "Population Projection for Japan" (January 2012, National Institute of Population and Social Security Research) (Japan).

(3) Maturation of society

The maturing society following changes in the population composition must also be taken into account. Figure 1-3-5 shows a profound change in people's sense of value after the 1980s, in which they tend to prioritize "spiritual fulfillment" over "materialistic fulfillment." Many are inclined to consider what kind of services they can receive by hardware or software, whichever available, and whether these services make them happy. Meeting a diversified sense of value and individual needs will be required to create innovations.

Figure 1-3-5 / Changes and future trend in importance in daily lives



Note: "Spiritual fulfillment" indicates the percentage of those who "want to prioritize spiritual fulfillment in living as materialistically satisfied to some extent," and "materialistic fulfillment" indicates the share of those who "want to prioritize materialistic fulfillment for the time being."

Source: "Public Opinion Survey on the Life of the people," Cabinet office

2 Continued Progress of Globalized and Knowledge-Based Society

The continued progress of globalized and the knowledge-based society helped significantly reform the creation processes of science, technology and innovation in Japan, as explained below:

(1) Progress of globalization

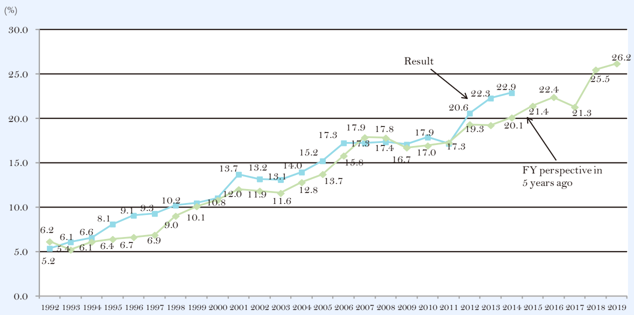
As globalization has progressed, various activities have expanded across national borders and more information and people move actively.

Private companies aggressively deploy their business worldwide as globalization soars. For instance, Figure 1-3-6 shows the proportion of overseas on-site production for private companies (manufacturers), which is increasing each year. These private companies are also exposed to severe international competition in global society and there are concerns about declining competitiveness of key technologies in Japan, drain of intellectual property and the decline in high value-added production in Japan through corporate mergers and acquisitions.

Amid progressive and fast-moving globalization, competitiveness is largely affected by how to make best use of various knowledge, technology and capability of talented human resources in the world. This intensifies international brain gain race. For instance, as shown in Figure 1-3-7, more and more students cross the national borders, and the total number of foreign students who registered in higher education facilities in the world has more than doubled over the last decade.

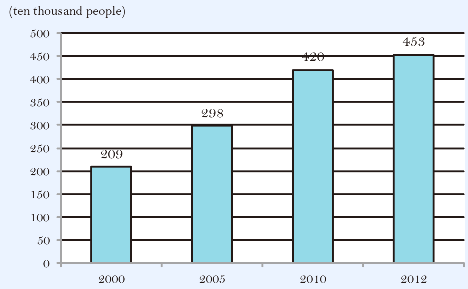
As nations are further globalized in future, relationships between social and economic activities and national borders will become more ambiguous. Every stakeholder of science, technology and innovation must be aware of these circumstances and always consider things from an international perspective.

Figure 1-3-6 / Results and perspective of overseas production rate of Japan



Source: Created by MEXT based on "FY 2014 Annual Survey of Corporate Behavior," Cabinet Office

Figure 1-3-7 / Changes in the total number of foreign students in higher education facilities of world



Source: Created by MEXT based on OECD "Education at a Glance 2014"

(2) Development of a knowledge-based society and full-scale open innovation

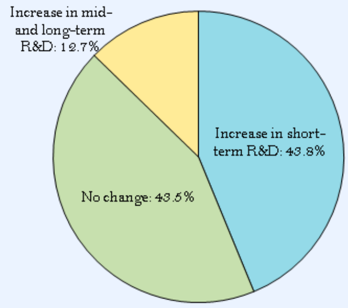
The 21st century is the age of a "knowledge-based society", in which the importance of new knowledge, information and technology will radically increase as the activity base in every area. The borderless nature of knowledge promotes the globalization of knowledge, and social changes will be accelerated, as knowledge is constantly refined, and new knowledge may often result in paradigm shift. These changes, combined with the expanding intellectual frontier, will increasingly hinder efforts to predict emerging new issues. Once a new issue takes place, therefore, it must be resolved faster, more flexibly and dynamically than ever before. In some cases, this may also hinder the linear industry-academia-government model to function for fostering basic, application and development research in a row.

The concept of knowledge and value creation has been turned on its head. Coupled with the expanding intellectual frontier and the dramatic emergence and deployment of telecommunication technology, the globalization of knowledge and the development of a knowledge-based society have increased the volume of knowledge and information with acceleration, making it increasingly difficult for individuals or individual organizations to collect and manage all required knowledge and technology. Teamwork or cooperation among multiple organizations is thus of growing importance.

In private companies, there is a tendency to cut the period of R&D to survive severe international competition, as shown in Figure 1-3-8. Private companies are increasingly concerned over "open innovation" for the proactive utilization of external knowledge and technology, rather than traditional self-sufficient R&D. Figure 1-3-9 shows an international comparison of survey results concerning the importance of universities and public institutions as sources of information for product or process innovations. In Japan, the proportion of companies which replied "large" for importance is relatively large, comprising 10.4%, compared to major European nations. This reflects a trend of strong awareness on the part of private companies, particularly concerning the importance of knowledge and technology owned by universities and public research institutions when creating innovation.

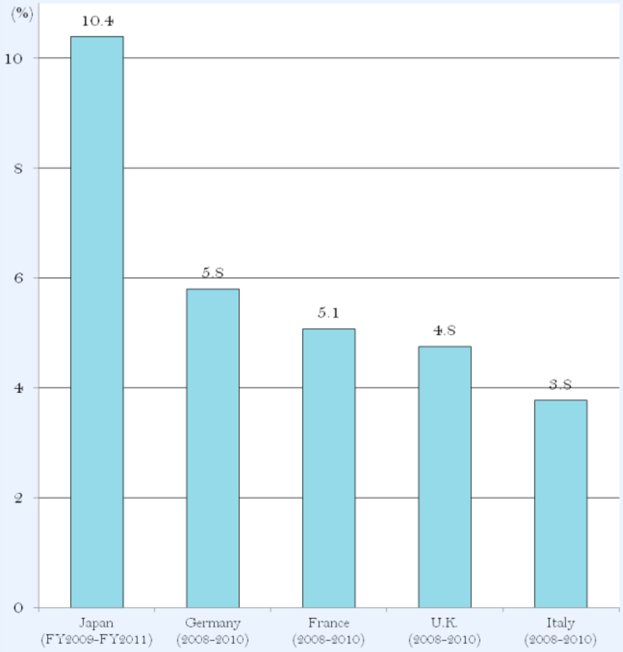
As mentioned above, progress of globalization and knowledge-based society has largely transformed the processes of creating science, technology and innovation, including industry-academia-government collaboration. A new innovation system adapted to such changes is required.

■ Figure 1-3-8 / Changes in type of R&D in private companies



Note: Responses for the questionnaire concerning the comparison of the proportion of costs for mid- to long-term R&D (5-10 years) and those for short-term R&D (1-4 years) at present and a decade ago. 858 companies replied.
Source: Created by MEXT based on "Research on Industrial Technology (FY 2010)"METI

■ Figure 1-3-9 / Proportion of companies prioritizing universities and public research institutions as sources of information for produce or process innovations (international comparison)



Note 1: The numbers are the estimated proportion of companies to product/process innovation. Higher education facilities such as graduate schools, government and public research institutions are included in universities and public institutions.
Note 2: The numbers for Japan are estimated values of all (core) industries only, including core industries in CIS2010, to adapt to similar standards overseas for an international comparison.
Note 3: Created by National Institute of Science and Technology Policy based on "The 3rd Nationwide Survey on Innovation" (Japan), National Institute of Science and Technology Policy and "Science, Technology and Industry Scoreboard 2013"(other nations), OECD

3 Progress of Science and Technology and Arrival of Revolutionary Times

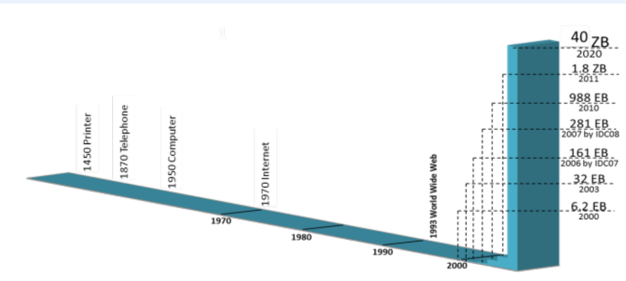
Amid recent progress in telecommunication technology, a virtual space on the Internet called cyberspace has remarkably evolved and transformed socioeconomic activities in Japan. Similarly, progress in various areas of science and technology, including cyberspace, has transformed the socioeconomic structures of Japan and the world as well as changing the fundamental procedures of scientific study and other science, technology and innovation activities.

(1) Dramatic progress of cyberspace

In the 1990s, the telecommunication environment changed drastically following the emergence of a new virtual space on the Internet called cyberspace. This was followed by the development of digital information devices, sensor technology and network technology, which grew at a ferocious pace, whereupon a tremendous amount of diversified digital data, so-called big data, was created in cyberspace and distributed online. Figure 1-3-10 shows the estimated increase in the amount of digital data worldwide. Digital data has increased in bulk annually and is forecast to reach about 40 times the 2010 total by 2020 (40 zeta bytes[1]).

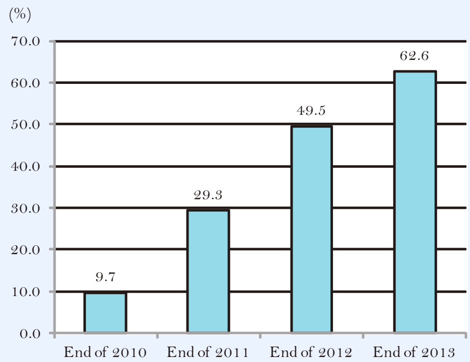
The recent explosive diffusion of smartphones has also sparked significant change. As shown in Figure 1-3-11, the penetration rate (for households) of smartphones in Japan soared to 62.6% at the end of 2013 as opposed to 9.7% in 2010. The number of users[2] who signed into social networking services (SNS) such as Facebook also reached about 1,440 million[3] as of the end of 2015. Now cyberspace contains huge socioeconomic areas of activity, involving numbers which exceed the populations in China and India. Unlike actual space, cyberspace is hardly affected by geographical and time constraints, which means its socioeconomic activities will also continue to expand rapidly in future.

Figure 1-3-10 / Forecast increase of digital data worldwide



Source: Excerpt from p. 15 of "ICT Kotozukuri (value-creation) review conference report (June 2013)" MIC

Figure 1-3-11 / Changes in penetration rate (for households) of smartphones in Japan



Source: Created by MEXT based on "2013 Communications Trend Usage Survey" MIC

The recent evolution of sensor networks with the expansion of cyberspace has spawned IoT[4] to connect people, people and objects and objects and objects, globally and ceaselessly.

Cyberspace has become crucial for all human activity and the emergence of wearable sensor technology has integrated cyberspace and actual space to generate a Cyber Physical System (CPS). Expanding big data and developing artificial intelligence (AI) technology has allowed intellectual information processing within cyberspace. For instance, there is a service that automatically detects people's state or desire and provides useful information or knowledge in advance (ambient service), mainly in the U.S. The role of cyberspace in creating new services and values is increasing.

1 1 zetabyte (ZB) = 1,000 exabytes (EB) = 1 million petabytes (PB) = 1 billion terabytes (TB) = 1 trillion gigabytes (GB)
2 Number of users who log on to the service at least once a month。
3 "Facebook Reports First Quarter 2015 Results"
4 Internet of Things

The concept of robots, which used to be sorted into a machine, must also be considered more flexibly[1].

Moreover, dramatic development is anticipated for big data analysis, IoT and AI technologies. Changes in relations between cyberspace and real space according to the progress of technology[2] suggest a great reform of future socioeconomic structures, including the reform of wide-ranging industrial structures such as production, physical distribution, sales, transportation, health, medical care and public services, all of which were formerly limited to real space. At the same time, cyber security issues and new social issues such as legal responsibility for cyberspace operations will arise as cyber activities expand and permeate.

Some nations describe the arrival of a new society caused by rapidly developed cyberspace as "the 4th Industrial Revolution," and engage in science, technology and innovation policy competition to spearhead the new age, such as "Industry 4.0" in Germany (see Column 1-12). Japan urgently needs to promote industry-private collaborative approaches to create new values and services coherently while establishing cyber security and social systems and human resource development and retention to keep up with global trends.

Column 1-11

Artificial Intelligence Research and Challenge of National Centers

Overseas, R&D and commercialization of AI with unprecedented performance by combining various artificial intelligence element technologies are currently being promoted, mainly by major IT companies. For instance, an automobile that autonomously runs with onboard cameras, sensors and GPS is referred to as innovative artificial intelligence. Such AI allows us to use transportation time as time for work or amusement, which may change our lifestyles.

Outstanding researchers are asked to participate in these R&D projects from all over the world. The AI which they developed is used in the real world, whereupon knowledge is accumulated and fed back from the real world to basic research again, forming such a good circulation.

In Japan, various AI researches have been conducted individually, many of which are outstanding, but cases where these researches are amalgamated to develop innovative AI that is usable in the real world are few and far between.

Under these circumstances, METI founded the "Artificial Intelligence Research Center" in the National Institute of Advanced Industrial Science and Technology (AIST) in May 2015 to integrate the finest young researchers and excellent technologies domestically and overseas for building a platform to establish a good cycle of advanced AI, from development and commercialization to basic research. The main purposes of this Artificial Intelligence Research Center are: "To integrate various technologies; accelerate commercialization in collaboration with user companies; apply outcomes to resolve real-world problems and businesses and feed the results back into new technologies," "Conduct extensive basic research to solve real-world problems by a host of front-line researchers and accelerate basic research by demonstrating research outcomes," "Upgrade AI research as a public research institution by developing evaluation techniques and a benchmark data set" and "Perform commercialization and carving-out[3] of developed outcomes and intellectual properties; to be a hub of academia and industry in addition to joint research with companies."

R&D at the Artificial Intelligence Research Center is expected to accelerate the development of Japanese-made AI

1 "New Robot Strategy" (decision of the Headquarters for Japan's Economic Revitalization on February. 10, 2015) said "traditionally, robots were considered as machines equipped with three main elements such as sensors, intellectual and control system and driving system, but as digitalization and network infrastructure such as cloud and AI have developed, a structure allowing an independent intellectual and control system to access and drive various things and people in the real world without a dedicated driving system is emerging. When IoT has evolved sufficiently and actuator-driven devices are standardized, various robots functioning with only intellectual and control systems may be available in various aspects of society. If this is achieved, the definition of robots limited only to machines equipped with all three elements will no longer fit reality. This type of future vision must be taken into account when designing next-generation robots.

2 For example, "Japan's STI Policies Looking beyond Mid-Long Term(mid-term report)" (January 2015), Special Committee on Comprehensive STI Policy, Council for Science and Technology (CST), MEXT cites a society that complements or replaces the real world, autonomously conducts various activities in cyberspace that exceed the real-world scope and largely affect the real world following integration and fusion with the same, as a "Advanced cyber society" resulting from the rapid development of cyberspace.

3 To found an independent new company for a promising business while accepting capital participation by external investors.

technologies that will spark major reform to the society and economy in Japan and worldwide.

The rapid development of cyberspace not only changes society and the economy but also triggers drastic change to the concepts of science, technology and innovation. Particularly now, a new approach to pursue the creation of innovation by allowing easy access to research outcomes and data for utilization, paving the way to create knowledge and effectively advance S&T research, has spread worldwide. This is so-called "open science", which is explained in detail in Section 3 of this chapter. The global trend towards open science is predicted to have a key impact on science, technology and innovation activities around 2030 and strategic and drastic approaches to deal with open science are required in Japan.

Column 1-12 What does Germany's Industrie 4.0 target?

Industrie 4.0 is one of the action plans for promoting the digitalization of manufacturing industry announced by the German government in 2011. It is an ambitious initiative to lead the world with next-generation manufacturing technology utilizing a Cyber Physical System (CPS).

Specifically, the whole cycle of manufacturing design and development, production design, production control, sales and maintenance is uniformly managed with digital data to cut lead time and to save the energy and high value-added products is produce at low cost. Production automation in itself has already started in the 1980s and some companies have already used smart factories for actual production in Japan. However, Germany's Industrie 4.0 aims to optimize overall production by digitizing factories and connecting them via the network or software. An open platform is required to network manufacturing systems and equipment, rather than a closed system for a single factory or company.

The German government announced a roadmap for implementing Industrie 4.0 by around 2025. Standardization is to be tackled in Phase 1 of this roadmap. First of all, the rules of participation are clearly defined. Standardization is the key issue for Industrie 4.0, involving not only major companies, but also small- to medium-sized companies, which comprise over 90 percent of domestic companies. Security is the next issue. As far as factories are connected via a network, data protection is the most serious problem. It is no exaggeration to say that success in these two areas determines the future of Industrie 4.0.

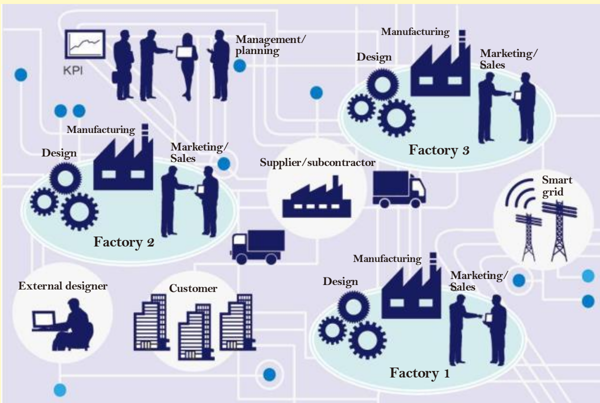


Image of connected factories

Source: Created by JST based on the final report of the Industrie 4.0 Working Group.

(2) Evolution of various innovative technologies

Considering the year 2030, the evolution of technologies that have a key impact on the concept of society and the economy are not limited to the progress of cyberspace.

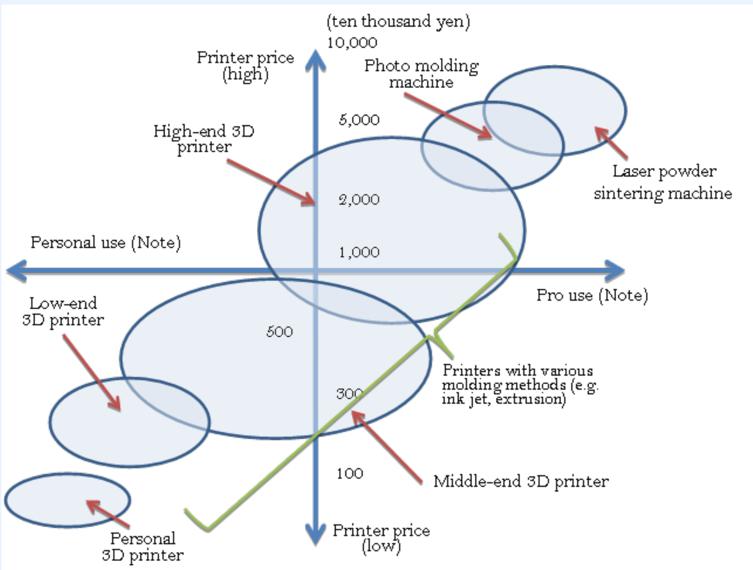
For instance, the 3D printer market has recently been rapidly expanding. As shown in Figure 1-3-12, the market offers various types of 3D printer, from professional models, which may be directly used to manufacture parts and components, to personal models now on sale in mass retailers. When 3D printers are more sophisticated, diversified and affordable, the market is further expanding and required revisions of social systems are achieved, manufacturing is allowed not only at factories but in households. In this way, 3D printers have the potential to change the production trajectory of companies.

Machine translation has also steadily improved (see Column 1-13). When the machine translation technology has evolved sufficiently to allow multilingual translation, global communication will be accelerated and we can eliminate the "language" barrier, generally considered a major bottleneck to innovation in Japan. In addition, there is probably a need to rethink language education.

Improvements in robot suits and automated driving techniques may lead to the establishment of an efficient and convenient society for us, and at the same time, have the potential to significantly transform the way of work and employment similar to the progress of cyberspace.

These technologies are only some of the many examples. It is essential to investigate future science, technology and innovation policies by carefully monitoring their progress and foreseeing the future society and economy in Japan. Section 3 of this chapter explains the above-mentioned open science in detail and changes in science, technology and innovation activities which occur as science and technology progress.

Figure 1-3-12 / Current status of 3D printers

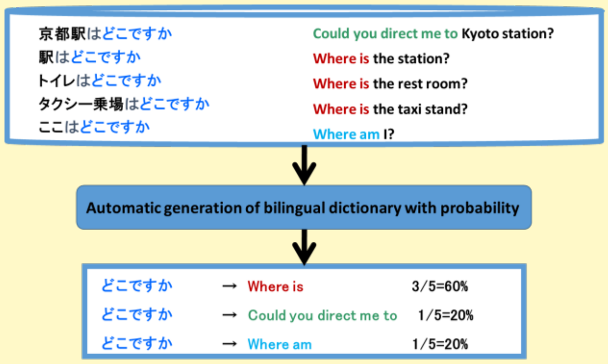


Note: Personal and professional models are divided based on METI classification.
Source: Created by METI (Excerpt from the document distributed at the 1st Monozukuri Workshop in October 2013)

Column 1-13 Overcoming the "language barrier": Progress of machine translation technology

The government launched the "Global Communication Plan" aiming to eliminate the global "language barrier" through multilingual translation by the Tokyo Olympics and Paralympics in 2020. This plan is based on three visions, namely, "global and free exchange," "increase in the presence of Japan" and "hospitality at the Tokyo Olympics and Paralympics."

The machine translation technology the key to enable multilingual translation has been mainly researched by the National Institute of Information and Communications Technology (NICT). While conventional translation R&D was based on syntax rules and dictionaries containing words and their meanings, it was subject to limitations of man-made work. Meanwhile, a tremendous volume of linguistic data has been compiled in computer and hardware has been remarkably enhanced. After 2000, an approach called "statistical machine translation" has been rapidly developed and machine translation technology has been improved considerably. With this approach, a large volume of bilingual data including original texts and associated translation is fed into the computer for learning and translation. For instance, the computer automatically learned from a tremendous amount of data that the Japanese text "どこですか" is translated as "Where is" at a rate of 60 percent, based on which the computer generates the most likely translation.

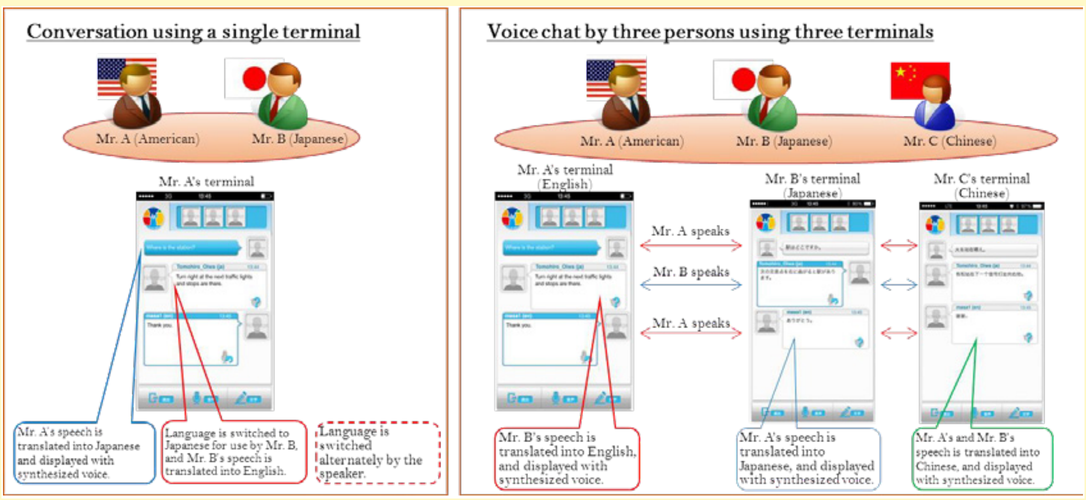


Outline of statistic translation technology

Source: NICT

NICT announced its voice translation application for smartphones "VoiceTra" in 2010. Using this application, Japanese is automatically translated into English. When the user brings his or her smartphone close to the ear, as when he or she makes a call, a brief vibration takes place as a cue to enter voice data. When the user talks to the smartphone, translated sentence is returned by voice. VoiceTra is designed for travel use and its translation capability is equal to individuals with a TOEIC score of 600. NICT collaborated with research institutes in other nations to develop the technology acquired by VoiceTra into a global standard system and released "VoiceTra4U" in 2012. This application is capable of translating 27 languages, inputting voice data in 17 languages and outputting voice data in 14 languages and allows five smartphones to engage in voice chat simultaneously.

Outstanding issues include the technology to translate other areas in addition to travel, to translate longer texts more accurately and for contextual processing to keep translated word consistent in overall sentences.



Outline of voice translation application for smartphones

Source: MIC

Section 2 Future Science, Technology and Innovation Policies

This section consolidates considerations during the discussion of future science, technology and innovation policies while taking into account the socioeconomic changes described in the previous section. Dealing with this issue, the 5th Science and Technology Basic Plan is currently discussed within and outside government and this section also describes the process.

1 Promoting Future Science, Technology and Innovation Policies

Key considerations in future science, technology and innovation policies include socioeconomic changes, problems faced by Japan and the world, current status and issues of science, technology and innovation in Japan when investigating measures to be taken under the two-decade-long Basic Plans. These are discussed below.

(1) Socioeconomic changes

Bearing in mind the foresight into the medium- to long-term socioeconomic changes described in Section 1 of this chapter, the potentially significant effects on future science, technology and innovation policies can be itemized as shown in Figure 1-3-13.

Table 1-3-13 / Effects of socioeconomic changes on future science, technology and innovation policies

1) Major effect of changes in population composition

- ○ Progress of the falling population, super-aging society and decline in the regional vitality significantly affect efforts to maintain and improve the future economic scale and people's lives in Japan. It is important to create science, technology and innovation that boost the active participation of females and the elderly in society, revitalization of the region and help establish a sustainable social security programs in future.
- ○ Long-term, continuous decrease in young population is obvious, which suggests an increasing difficulty in retaining sufficient number of human resources to underpin science, technology and innovation activities in Japan. Efforts to focus on boosting the "quality" of human resources must be made.
- ○ People seek "service" and "sense of satisfaction." It is important to create innovation that meets their diversified individual value systems and needs.

2) Major effects of globalization and progress of the knowledge-based society

- ○ As globalization progresses worldwide, it is important for those who are engaged in science, technology and innovation to retain a global perspective.
- ○ Social changes are accelerating. Together with the expansion of knowledge frontier, it is becoming increasingly difficult to forecast new issues which must be dealt with promptly and flexibly. As the industry-academia-government linear model often fails to function, a new industry-academia-government collaboration system is required.
- ○ Amid changing concepts of knowledge and value creation, private companies are shifting their focus from R&D on their own account to open innovation. It is important to provide the environment that helps such open innovation.

3) Major effect of the revolutionary era emerging with the progress of S&T

- ○ As telecommunication technology advances, cyberspace grows dramatically and integrates or fuses with IoT or real space to make a cyber physical system (CPS). Progress in big data and AI technology will transform industry structures. To realize such a society, public and private sector collaboration is crucial to create new values and services and deal with cyberspace.
- ○ Rapid progress of cyberspace means drastic change in the science, technology and innovation activities including open science will be required. Strategic and innovative efforts are required in response.
- ○ Progress, not only in cyberspace but also 3D printer technology and machine translation, will transform future work approaches. It is important to promote efforts combining R&D, the construction of a social security system and development and retention of human resources by keeping the future vision of society resulting from technological progress in mind.

Source: Created by MEXT

(2) Problems faced by Japan and the world

Science, technology and innovation are required to solve problems faced by Japan and the world. Several political issues, such as the progress of decline in population, super-aging society and decline in regional vitality were discussed in paragraph (1). This paragraph covers the important issues which were not discussed in (1), as well as relations of society with science, technology and innovation as the basic premise to solve problems and meet social expectations.

1) Solving key domestic issues

Ensuring economic recovery through science, technology and innovation and achieving continuous economic growth and creating employment for coping with significant changes in population composition are essential for Japan to achieve sustainable development. As a country lacking natural resources, energy security and energy cost remain big issues and efforts to acquire stable resource energy are required. Recovery and reconstruction from the Great East Japan Earthquake remain underway and sure and steady efforts should be continued for now and with the vision up to 2030 in mind.

Japan is also a country which always faces with the risk of natural disaster, including big earthquakes and volcanic eruptions. Aging infrastructure such as roads, water and sewerage systems and public facilities is also serious. It should be noted that the national security situation surrounding Japan is also changing. Retaining and developing technologies to maintain the basis for the nation and technologies to deploy unknown and unexplored frontiers are important. Taking these into account, creating a nation where people can live spiritually rich and comfortable lives is required.

2) Solving global problems

Worldwide, as the global population increases, shortages of food, water and energy are being exacerbated, while threats of infectious diseases, pandemics and terrorism are intensifying. Environmental problems such as global warming and climate change need to be tackled continuously under worldwide cooperation. Japan must strive to solve such key global issues by leveraging its scientific and technological strength and thus continue to help humankind progress.

For these problems, for instance, “Comprehensive Strategy on Science, Technology and Innovation 2014” sets out five issues to tackle: “Realization of a Clean and Economical Energy System,” “Realization of a Healthy and Active Aging Society as a Top-runner in the World,” “Development of Next-Generation Infrastructure as a Top-runner in the world,” “Fostering of New Industries by Utilizing Regional Recourse” and “Early Recovery and Revitalization from the Great East Japan Earthquake” (for details, see Section 3, Chapter 1 of Part II).

In the modern era when social change is increasingly fast, keeping constant control of issues is crucial. The government must take measures to solve problems while overviewing the whole international community.

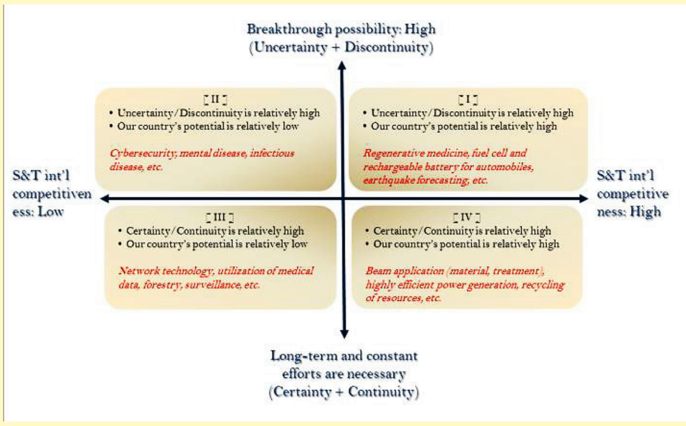
Column 1-14 Science and Technology Foresight: Think of the Future, Create the Future

Foresighting Activity involves finding signs of change by systematically looking into the future with the involvement of all parties concerned and considering how to proceed by assuming potential favorable opportunities and risks, which is namely "think of the future and create the future."

Foresight surveys on science and technology have been continuously conducted in Japan since 1971, targeting contributions to science, technology and innovation policies and the National Institute of Science and Technology Policy took over such surveys since its foundation in 1988. For instance, in the 1992 survey, the future perspective of a range of science and technology, from areas currently gaining popularity to those under R&D, including personal mobile communicators allowing global communications, fuel cell vehicles, accurate short-term local weather forecasts and artificial eyes were all presented.

The National Institute of Science and Technology Policy started its latest science and technology foresight survey from FY 2013 to foresee future S&T and society for the long term. First of all, the society vision in the future and measures to implement the future society were discussed based on changes in population and industrial structures. Subsequently, science and technology topics relating to these measures were selected and expert feedback on their characteristics were collected through questionnaire. Based on this survey result, science and technology topics were typified in terms of uncertainty, discontinuity and international competitiveness to clarify the feature of R&D and differences in strategic placing. The choice of issues for implementing the society vision in the future and direction of problem-solving scenarios are discussed at present based on the characteristics and placing of science and technology.

Speaking of overseas activities, the U.K and Germany started full scale research in the 1990s, gradually followed by other nations. Japan also proactively promotes collaboration and partnership with these international foresight activities, mainly by the National Institute of Science and Technology Policy as well as offering cooperation and support for East Asian nations as part of application.



Typifying science and technology topics

Source: National Institute of Science and Technology Policy

3) Improving relations of society with science, technology and innovation

Public understanding, reliability and support are the fundamental prerequisites to solve the above issues, accelerate social reforms and meet social expectations through science, technology and innovation.

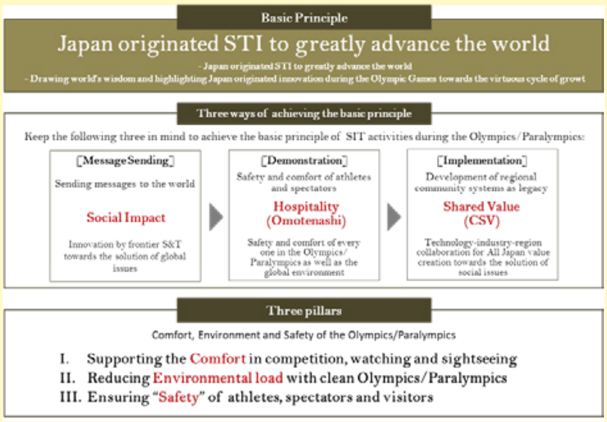
Some pointed out that people's trust in researchers and technicians has been declining after the Great East Japan Earthquake and recent research misconduct in Japan. The trustworthy relationship of society with science, technology and innovation should be re-established to promote science, technology and innovation policies in future.

The Tokyo Olympics and Paralympics are scheduled for 2020, the last fiscal year of the 5th Basic Plan. It is crucial to seize the opportunity of a major stage like the Olympic Games to show the people of Japan and the world that science and technology are deeply rooted in Japan, together with innovative research outcomes befitting a nation where science and technology are deeply rooted in our culture in the same way as the history and tradition.

Column 1-15 Innovation for Everyone 2020

In 2020, the Tokyo Olympics and Paralympics, the sports festival attracting the global attention, will be held The Cabinet Office founded a "Task Force for Science, Technology and Innovation for the 2020 Tokyo Olympics and Paralympics" featuring the collaboration of key figures, ministries, the Tokyo Municipal Government and organization committees to launch science, technology and innovation projects for utilization or practical application in the Olympics/Paralympics and is currently examining measures to improve the basic concept and add value to the projects.

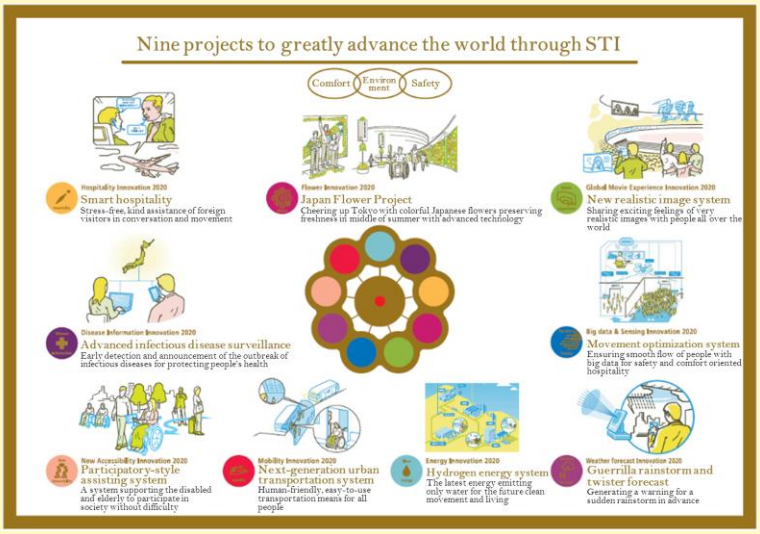
The basic concept was determined as "Japan originated science, technology and innovation to greatly advance the world a giant leap forward" and the slogan as "Innovation for Everyone 2020: Society allowing all people to take a central role" The slogan is very meaningful for sharing values among people as "all Japan" to realize a new society and new affluence, to change the nature of Olympics/Paralympics to a people-centered sports festival and respond to actual global issues through innovation.



Basic concept for implementing and promoting projects

Source: Cabinet Office Image of connected factories

The government will implement "Nine projects to greatly advance the world through science, technology and innovation" as actual projects including smart hospitality and next-generation urban transportation systems. The success of Olympics/Paralympics and raising global awareness to help solve social issues and global deployment of Japanese industry as well as the powerful promotion of the Japanese economy are expected through these efforts.



Nine projects

Source: Cabinet Office

(3) Results of Science and Technology Basic Plans over 20 years

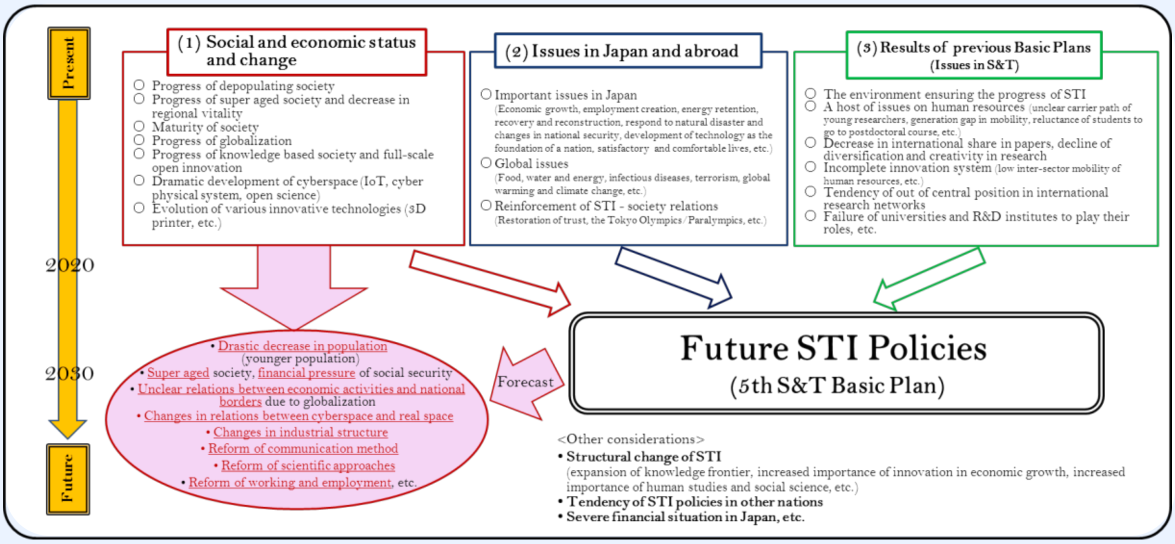
Section 2 of Chapter 2 in Part I reviewed 20 years of Basic Plans and described the steady development of the environment for promoting science, technology and innovation. Simultaneously, the section also highlighted issues such as the reluctance of students to attend doctoral courses due to unclear career paths and the generation gap in mobility; tendency toward a declining international ranking of papers in terms of quantity and quality; decrease in diversification and creativity of basic research; insufficient innovation system due to the lack of inter-sectoral mobility of human resources and only limited industry-academia-government collaboration; deflection from the centerpiece of international research network; failure of universities and national R&D institutes to take central roles with inherent features due to basic research funding shortfalls and failure of competitive funding to completely function.

These issues must be addressed and resolved sincerely for Japan to be "the world's most innovation-friendly country"

(4) Conclusion

Figure 1-3-14 shows an overview of the above description. Diversified circumstances as consolidated below must be taken into consideration in future science, technology and innovation policies in Japan, particularly the 5th Basic Plan to be launched in FY 2016.

Figure 1-3-14 / Overview of circumstances affecting future science, technology and innovation policies



Source: Created by MEXT

2 Preparations in Related Organization for Implementing the 5th Science and Technology Basic Plan

Organizations in and out of the government are preparing the 5th Basic Plan at present. This section briefly explains the state of preparation in the related organizations.

(1) MEXT

MEXT founded the Special Committee on Comprehensive STI Policy under the Council for Science and Technology (CST) in June 2014 and the committee has investigated the medium- to long-term direction of the science, technology and innovation policies in Japan with the 5th Basic Plan in mind. An interim report[1] was created based on the survey results in January 2015 (Figure 1-3-15). For details, see Section 4, Chapter 1 of Part II (Figure 2-1-6).

Figure 1-3-15 / Points of interim report issued by the Special Committee on Comprehensive STI Policy, CST

【Background】

- ✓ 20 years have passed since the enactment of the Science and Technology Basic Law in 1995, during which improvement of the research environment, accumulation of human resources, and creation of outstanding research outcomes have been promoted.
- ✓ Meanwhile, issues have piled up. In particular, clear carrier path of young researchers, diversification of basic research and an innovation system leading to the social reform are pressing issues.
- ✓ Importance of taking action for changes in society and economy (population decline, progress of globalization, intensifying international competition, full-scale knowledge based society, arrival of "ultra-cyber" society, changes in national security, severer global issues, etc.)

Medium- to long-term perspective of Japan in light of "what to do for the sustainable development of Japan and the world," and proposal of a comprehensive policy to combine university, academia, science, technology and innovation policies.
Also noted are the integration of human studies, social science and natural science, and dialog and collaboration of all stakeholders in light of leading social reform by innovation.

【Point 1】 Presentation of the importance of reinforcing "the innovation creation platform" to deal with a variety of issues with speed in future

- ✓ "Human resources" are indispensable for STI activities. System reform is the most important for improving the quality of individual human resources and promoting innovation creation. Every possible measure should be taken.
- ✓ Amid the progress of open innovation in companies, reform and enhance scientific and basic research to create new knowledge and value which is the source of innovation.
- ✓ Turn the industry-academia-government collaboration from the linear model to a new innovation system for co-creation through flexible flow of men, things, money and information in the industry, academia and government sectors.

【Point 2】 Presentation of new issues arising from social and economic change

- ✓ Importance of activities to lead to the "ultra-cyber society" as a dramatic progress of cyber society, and the development of technologies by the government which is responsible for acquiring, maintaining and accumulating such technologies in long-range standpoint.
- ✓ Importance of "the restoration of trust by society" for S&T and researchers by improving measures against research misconduct.

【Point 3】 Proposal of a comprehensive plan across organizations and framework of policies for a flexible link of all related measures

- ✓ Clarify, reform and strengthen the roles of universities and public research institutions.
- ✓ Reform funding for the expansion and effective use of national R&D investment based on the retention of 1% as the ratio of government R&D funds to GDP

Source: Created by MEXT

(2) METI

METI drafted an "interim report" in June 2014 in the R&D and Evaluation Subcommittee, Industrial Science and Technology Policy and Environment Bureau of the Industrial Structure Council. The report focused on the importance of creating innovation based on innovative technology and the special need to produce innovative technology seeds and establish a system to immediately "bridge linking" the seeds to commercialization, the importance of entities comprising the innovation system and mutual cooperation and importance of developing and mobilizing human resources to promote innovation. Based on this report, several reform efforts were made, including setting of medium- to long term objectives at the National Institute of Advanced Industrial Science and Technology (AIST) and NEDO to enhance the "bridge linking" function, and increases in incentives in R&D taxation and the foundation of the Japan Open Innovation Council (JOIC) to promote open innovation. The subcommittee has also consolidated the points to discuss for the launch of the 5th Basic Plan in March 2015, suggesting the importance of improving collaboration between "bridge linking" bodies such as the National Institute of Advanced

1 "Japan's STI Policies looking beyond Mid-Long Term -Toward the 5th Science and Technology Basic Plan- (interim report)" (January 20, 2015, Special Committee on Comprehensive STI Policy)

Industrial Science and Technology (AIST) and universities, promotion of prioritized R&D with the "problem-solving based" technology and common-based technology that provides the fundamental power for innovation in various fields as two driving forces, eliminating quantitative and qualitative mismatching between industry and academia in human resource development and the importance of fundamentally improved university management power.

(3) MIC

MIC engaged in consultation with the Telecommunication Council on the "concept of new telecommunication strategy" for five years from 2016 in December 2014 to discuss the 5th Basic Plan and determine medium- to long-term targets of NICT, discussion of which has been promoted in the council from January 2015.

(4) Industry

The Japan Business Federation announced the "Implementation of the 5th Science and Technology Basic Plan" in November 2014 and "Evolution to the 'Science, Technology and Innovation Basic Plan' for future creation: Second Proposal Toward Formulating the 5th Science and Technology Basic Plan" in March 2015. The second proposal specified three critical perspectives for future creation; "Arrival of 'new industrial revolution' by ICT: IoT," "Measures for system-focused international standardization" and "Full promotion of open innovation," five important issues for future creation including "Challenges for Cross-ministerial/Innovative Issues of the Nation," and seven approaches for enhancing the innovation national system including "Further enhancement of the control-tower function of the Council of Science, Technology and Innovation" and "Assured acquisition of S&T budget."

The Council on Competitiveness-Nippon (COCN) announced "Recommendations for formulating the 5th Basic Plan" in March 2015, discussed four actual fields as "a group of technologies addressed on a preferential basis in Japan" in terms of business model innovation and specified critical issues including "Cultivation Development of human resources capable of dealing with technology and market (reform of university management)" and "Ideal industry-academia-government collaboration (open innovation)."

(5) Scientific community and research fields

The Science Council of Japan (SCJ) announced "Recommendations on the Fifth Science and Technology Basic Plan" in February 2015, consolidated by a committee to discuss the Science and Technology Basic Plan from an academic perspective. The recommendations emphasized the importance of pursuing "balanced development" and "sustainable development of science" to ensure academic development, with particular focus on "the concept of universities," "the importance of basic research" and "academic leadership of Japan in the international community" in the 5th Basic Plan.

Voluntary discussions on the implementation of the 5th Basic Plan at research fields are a distinct feature. A group of young volunteers "Science Talks" started the

Exchange of opinion at Science Talks open forum
Source: Science Talks

plan "we made the 5th Science and Technology Basic Plan of our own!" in March 2014 with the theme "more vital and interesting research in Japan" and announced the "Proposal for the 5th Science and Technology Basic Plan" following the discussion on websites and networks. The proposal suggests "academically and socially enthusiastic research" as the central theme and presents visions for innovation on four themes; "organization for individuals willing to work," "gathering and utilizing interesting talents," "an evaluation system for competition and co-creation" and "obtaining social trust and support through joint efforts with society" with proposals based on actual cases from the perspectives of field researchers.

(6) Council for Science, Technology and Innovation

The Basic Plan was implemented through discussion at the Council for Science, Technology and Innovation. Related bodies (1) to (5) have already started preparing to implement the 5th Basic Plan in FY 2014, as shown above and the Japan Revitalization Strategy, placed as a growth strategy and other basic policies with relevant boundaries such as the Health and Medicine Strategy, Basic Plan on Ocean Policy and Basic Space Plan are also subject to discussion. The Council for Science, Technology and Innovation comprehensively consolidates these varied discussions and basic policies to form the 5th Basic Plan, showing the science, technology and innovation policies for five years with a decade-long vista.

Specifically, at the 4th Council for Science, Technology and Innovation in October 2014, the expert panel was established to conduct surveys and investigations on the 5th Basic Plan. Subsequently, the expert panel has been engaged in surveys and investigations. In the 8th Council for Science, Technology and Innovation in April 2015, experts made a proposal "Concept for formulating 5th Science and Technology Basic Plan," suggesting three pillars of the 5th Basic Plan; 1) preempting the great revolutionary times (approaches toward future industry creation and social reform), 2) taking initiative for solving socioeconomic issues (dealing with social and economic issues) and 3) reinforcing all potential to cope with uncertain changes and allow challenge (development and enhancement of basic ability), with proposals for the direction of science, technology and innovation policies that may induce or can facilitate cycles of human resources, knowledge and funds in the innovation system.

Through the surveys and investigation of the Council for Science, Technology and Innovation, the government will determine the 5th Basic Plan and seek a cabinet decision in FY 2015.

Section 3 Science, Technology and Innovation in the prospective of 2030

What changes will the development of cyberspace and the evolution of science and technology bring to science, technology and innovation in 2030?

This section explains the changes in the science, technology and innovation in Japan in 2030, a decade after the last year of the 5th Basic Plan and the effects they will have on the future society and economy in Japan, together with the introduction of cases preempting the new era and perspectives concerning efforts to cultivate human resources for supporting the future science, technology and innovation.

1 Changes in Scientific Procedure: Arrival of the Open Science Era

(1) Significance of open science

As described in Section 1 of this chapter, the concept of open science has proliferated worldwide. Open science is a concept encompassing open access and open research data (open data).

As the open access becomes increasingly available, all users, including the scientific community, industry and general citizens will be widely able to exploit research outcomes (papers, data) in digital format. Consequently, this will accelerate knowledge creation via a new form of cooperation beyond research institutions, specialties and national borders and pave the way for inconceivable new values, which would be otherwise impossible with conventional research approaches.

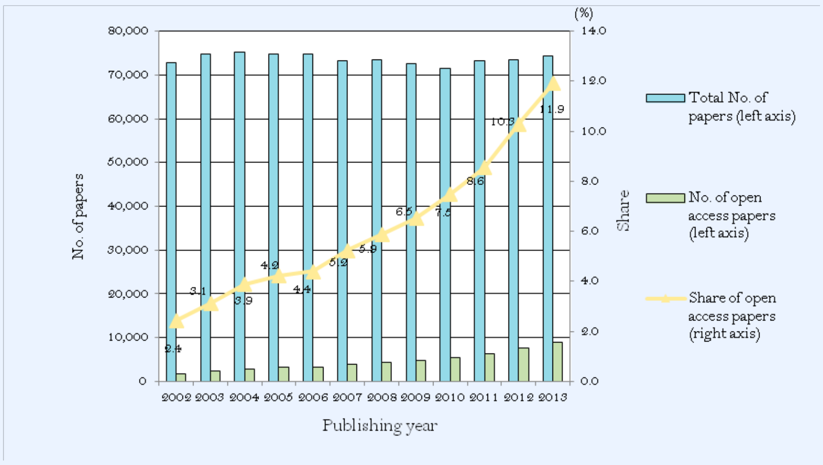
As open data progresses, research processes will become transparent to society, and interest and understanding among people for science and technology will increase. The new form of cooperation, as mentioned above, is also expected to be effective in urging citizens to participate in new cooperation.

Achieving sustainable development in Japan is contingent on continuing to generate diversified and outstanding value as the basis for innovation. Open science is key to drastically increase this potential.

(2) Government approaches toward open science

Data sharing and utilization have been steadily promoted in Japan by increasing the number of open access papers (Figure 1-3-16) and instituting repositories. Data sharing and utilization mainly thrive in the life science field. However, the unified concept of open science has not been clarified by government and discussion on open science in particular remains insufficient.

Figure 1-3-16 / Changes in the number and share of open access papers in Japan



Source: "Science and technology trend 2014 July - August edition" No. 145, National Institute of Science and Technology Policy

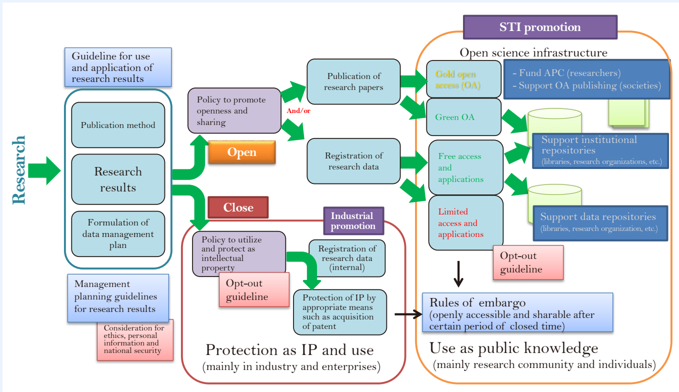
Discussions concerning open science have intensified worldwide in a debate which commenced in June 2013 when the G8 Science Ministry Meeting was held in the U.K. Open access to papers and open research data was contained in the joint communique, which accelerated the debate. Research fund allocation bodies increasingly open research outcomes supported by public research funds in some countries and many researchers from all parts of the world join the debate at international organizations, providing a venue for discussion on open access and open data.

Under these circumstances, the government must promote efforts to achieve open science and prevent international discussions passing through Japan and international standards are virtually provided (de-facto standard) while Japan does not show its intention to the world and allow Japan to lead the world in terms of cooperation and strategy in the mainstream of open science in future.

Aware of the above problems, the Cabinet Office held the "Expert Panel on Open Science based on Global" from November 2014 and examined the basic approaches of Japan and measures to be taken immediately for research outcomes supported by public research funds. Consequently, The Cabinet Office issued "Promoting Open Science in Japan" in March 2015.

In this report, "Increasing the utilization of research outcomes by public research funds (papers, research data, etc.)" is defined as the basic approach of Japan for open science and the policy of opening research data in papers and evidence of papers of research results by public research funds in principle[1]. In addition to this policy, stakeholders, including ministries, fund allocation bodies, universities and research institutions determine the actual policy and action plan on open science. Common terms and notes to be referred to by the stakeholders are clearly indicated as basic policy.

Figure 1-3-17 / Promotion of open science



Source: Created by the Cabinet Office

As described in the report, many issues remain to be discussed when promoting open science, including rules for data and incentives for researchers, but the government needs to support measures to promote the open science promptly and strategically to generate unprecedented values, one after the other.

2 Prospective Science, Technology and Innovation in 2030

Rapid progress of cyberspace with the development of telecommunication has accelerated the global trend of open science. Such progress in science and technology is expected to continue and as well as science, technology and innovation, the society and economy in Japan will have been totally changed in 2030.

This section forecasts the science, technology and innovation in 2030 in terms of three perspectives and introduces preemptive cases in Japan.

(1) New scientific progress and innovation creation

"Data science" has been noted recently as generating new knowledge by integrating diversified big

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1 It is recommended that private data, commercially intended data and data concerning national security be exempted from disclosure.

data in bulk. The methodology of science previously long comprised two wheels, empirical science (experiment) and theoretical science. As the performance of computer rapidly enhanced," computational science (simulation) used as alternatives or complements of experiments and predicting unknown circumstances has been established as "the 3rd mode of science." Then data science has emerged as what can be called "the 4th mode of science."

Big data will increase the importance in 2030 and alongside the progress of open science, science, technology and innovation using new science approaches will be produced one after the other. Some of these new scientific approaches have already been used and are described below.

1) New heal and medical service using big data

As big data is extensively applied, new services to help prolong longevity within a healthy society are available.

Hirosaki University analyzes diversified and a large volume of big data, such as information from health checks, genome data, omics data[1] and information concerning the ability to exercise and living conditions under the JST "Center of Innovation Program (COI)" to determine signs of diseases such as dementia and lifestyle diseases and intends to propose new preventive methods for such diseases and develop groundbreaking anti-aging products.

Health checkup of residents

Source: Hirosaki University

Tohoku University, TOSHIBA Corp. and Nihon Kohden Corp. jointly launched R&D, targeting a society allowing constant health monitoring, where everyone can live comfortably while constantly monitoring their health by simply doing domestic chores under the same COI from FY 2013. This new approach is based on big data concerning the genome data. Tohoku University conducts "Tohoku Medical Mega Bank" jointly with Iwate Medical University and as one of the genome cohort research outcomes of this project, acquired the complete genome sequence data from 1,000 Japanese and constructed "All Genome Reference Panel" which contains an enormous amount of genome data. COI used the result to develop a groundbreaking genome analysis tool, which enables highly accurate and cost-effective analysis of genome data collected from 660,000 locations showing the characteristics of Japanese by Tohoku University and Toshiba and which has been successfully placed it on the market.

Further promotion of R&D in industry-academia-government collaboration allows various new health and medical services and business development, including a system that can offer drugs suitable for the build of a patent or risk of disease, highlighting individual health conditions or the propensity to disease and the signs of disease found by the patient or his/her family in advance.

According to the latest science and technology prediction survey by the National Institute of Science and Technology Policy, for instance, "services for analyzing all health data of an individual concerning medicine, food and exercise and offering prediction or preventive medical care" and "an information

1 All molecular information on the biological body

system allowing estimated disease onset or severity increase, improving daily habits and judging the diagnosis and effect of treatment on an individual basis by integrating individual genome data, clinical information and environmental information" will be installed in society in 2025. These systems are expected to make a key contribution to longevity of a healthy society in future.

2) Disaster response using SNS and big data

Information in SNS such as Facebook and Twitter is instantaneous and easy to diffuse. The application of SNS information with these advantages and big data to disaster response has been discussed after the Great East Japan Earthquake.

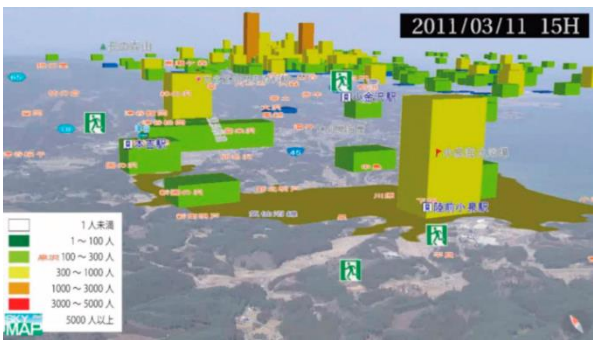
NHK (Japan Broadcasting Corporation) analyzed the big data on the sequence of the Great East Japan Earthquake to clarify the overall picture. In particular, the visualization of disaster was attempted using 179 million tweets in the week after the earthquake in Japan[1], driving record data, including location, speed and acceleration on a car navigation system of 1.4 million cars, position information of mobile phones, rescue records of Japan Self Defense forces , road recovery and other digitalized data. When tweets immediately after the earthquake were analyzed and sorted, most of the data was reaction to the quake and calls for evacuation, but communication means and safety confirmation increased an hour later, topics such as railway services and difficulty in returning home rapidly increased two hours later, returning home on foot and rest places three hours later and evacuation centers, coldness and lavatory issues four hours later. Changes in post-disaster concerns were clearly indicated.

Real time version DISAANA

Source: NICT

SNS information during disasters contains useful data but the satisfactory means to analyze or search this data is not available and false data inevitably set in. NICT started R&D into a system called "DISAANA" for analyzing useful data from a tremendous amount of twitter data immediately and accurately and replying with useful information for simple questions from afflicted people and people engaged in recovery and rescue. The system offers false data detection means by displaying inconsistent data simultaneously. A real-time analysis and search trial system, available for smartphones, was released on the website in April 2015[2].

NHK also estimated the number of people in the tsunami inundation areas based on positional mobile phone information. At the time of the earthquake, around 21,000 people were in an area later hit by the tsunami, in Natori City of Miyagi prefecture. The number of people in this area decreased in the initial 20 minutes, but only 5% could escape. Subsequently, the number of people



Next-generation Sky Map

Source: NHK Broadcasting Culture Research Institute, Research of Broadcast media No11, (2014) p. 287

1 Short message posted in Twitter.
2 http://disaana.jp

continuously increased after 15:05, and 40 minutes later, exceeded the number of people at the time of earthquake. Soon after that, the tsunami hit this area and many people died. Tracking the movement of people in this area during the disaster, the potential cause of the increased number of people before the tsunami was a "pick-up action" in which temporarily evacuated people returned home and evacuated with their family. Based on this assumption and other information, Tohoku University is currently researching a system that can analyze the traffic situation from the movements of people and vehicles acquired from GPS in probe cars[1] and smartphones immediately after a disaster and provide post-disaster information to people. NHK promotes R&D into a "Next-generation Sky Map" that immediately superimposes information obtained over live action.

Japan is a nation prone to the risk of large natural disasters such as metropolitan near-field earthquakes and Tokai/Tonankai/Nankai earthquakes. In 2030, big data will be enlarged by the dissemination of SNS and the progress of sensor technology, while the progress of AI technology will produce services to respond to disasters, such as urging people to take action according to various individual features and disaster circumstances using big data. Significant progress in disaster prevention and mitigation is expected.

(2) Citizens participating in science, technology and innovation

In open science, science, technology and innovation activities will not be limited to researchers and experts, but are also expected to extend to citizens. In creating innovation that changes society, the perspective of "citizen's science" that incorporates the concept of containing the living situation is important. When the opportunity for new coproduction between experts and citizens increases, this paves the way to create innovation. Knowledge, capability and motivation of citizens can also outweigh experts. If this is used effectively in open science as "aggregated knowledge," the quantity and quality of science, technology and innovation activities, including research, can be increased in 2030, despite a decline in the number of researchers.

These activities are nascent in Japan but some are underway now, examples of which are shown below.

1 A system that generates road traffic information such as traffic flow by collecting driving speed and position data from vehicles assumed as sensors.

1) Large scale survey in which citizens participate

Tohoku University and Yamagata University launched a "HanamaruMaruhana Project" in FY 2013 to determine the cause of the global decrease in bumblebees, which pollinate many major crops, and started investigating the accurate distribution of bumblebees in Japan. A nationwide survey would previously have been difficult given the limited number of researchers, but the progress of the Internet and spread of SNS make the survey possible with significant information donated from citizens, while the ease and dissemination of smartphones allows anyone to take pictures with positional data and send them to the survey program easily.

Disclosure of the survey result

Source: "HanamaruMaruhana Project" website

In this survey, citizens took pictures of bumblebees and sent them by e-mail, for storage on the server. Research at universities identifies pictures of the type and location of bees, which, once identified, are included in the website map, which is updated immediately. More than 2,000 pictures were collected as of February 2015, based on which Tohoku and Yamagata Universities are currently examining the instantaneous distribution status and analyzing survey results opened in the website in an easy-to-understand display. The survey results can be easily used by researchers and citizens and could spawn new research.

As open science progresses, this type of research technique will be increased. Rules for these techniques, for example, intellectual property and incentives for citizens to contribute, are required in future. Clear rules can encourage citizens to participate in research projects and increase the amount of research via an enormous volume of information and knowledge in the short term.

2) Venue for citizens to participate in research "NicoNico Gakkai β"

"NicoNico Gakkai β" was founded as a common venue for professional researchers and various citizens wishing to conduct research of their choice or known and present and share outcomes.

At the NicoNico Gakkai β, papers are not necessary to present the research results. Participants present the details of research via video media in the "NicoNico video sharing site" and receive audience feedback through the comment function. As well as online activities, NicoNico Gakkai β also holds offline activities such as residential training and symposia for presenting wide-ranging research themes from new technology to art.

These diversified approaches lower the barriers for scientific research, allowing even amateur citizens to enjoy participating at hobby level if interested in science and learning, or researchers and citizens to collaborate on particular themes. An approach allowing paperless presentations and various research techniques implies the future evaluation of research.

(3) R&D and socioeconomic reforms triggered by progress in science and technology

The perspective in 2030 highlights progress in science and technology which may change the concept of science, technology and innovation activities and trigger drastic change in socioeconomic activities in Japan. Some current activities that may herald the future are introduced below.

1) Drug discovery research using supercomputers

The development of drugs that support our lives usually takes 10 to 15 years and enormously costly R&D, because "candidates for new breakthrough drugs are hard to find, given the need to select potential compounds having pharmaceutical benefits from vast amounts of known compounds through empirical screening," "commercialization of candidate compounds for a new drug must undergo time-consuming and costly clinical trial procedures, such as animal experiments and human clinical trials" and "pharmaceutical benefits and side effects are often discovered only when clinical trials start, meaning design to verification procedures have to be repeated many times."

To eliminate these problems, "IT drug discovery" using a supercomputer is currently underway. For instance, the University of Tokyo and Fujitsu started an exhaustive search using a supercomputer in FY 2011 and concluded the potential for the virtual production of a new compound with high pharmaceutical benefits, which could not be obtained by modifying the known compound. They also suggest the potential to predict the pharmaceutical benefits of candidate compounds by accurately simulating the activity of protein substances in the body to candidate compounds.

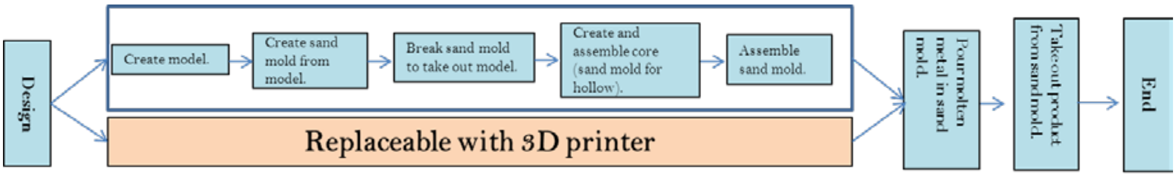
These new approaches suggest the potential for significant savings on time and R&D costs required for drug discovery. The research facilities and equipment required for R&D can be used more efficiently and human resources reshuffled by replacing experiments with computer operations. This may also affect the current R&D activities and researchers in the drug discovery field.

2) 3D printer based product development and changes in business

3D printers were developed 20 years ago, but not widely used due to their high price and the limited production materials available. However, the recent availability of various material, increased modeling accuracy and reduction in price of the printers themselves have accelerated the use of 3D printers, which look set to transform production methods in Japan.

Specific changes include acceleration of manufacturing processes by introducing a 3D printer, which allows molding without molds, for faster molding and design and shorter cycles of development and trial production. A highly functional product can be manufactured with less effort and for less money. For instance, automobile engine parts can be produced with a 3D printer in the casting process to omit processes from modeling to sand mold, which allows the production of a metal pouring mold within a few hours. The 3D printer can produce any form of part, including complicated forms which would otherwise be conventionally impossible. Companies using this process have successfully cut the production period from two weeks to a few days. The accelerated manufacturing procedure will increase the potential for creating innovation in companies and simultaneously, affect company investment and the work of employees, similar to the IT drug discovery mentioned above.

3D printers meet various production needs in a short time, which would otherwise be impossible with conventional mass-production methods. When 3D printer technology is improved and penetrates widely to allow production outside the factory, business practice in, for example, retail and distribution industries may need to change drastically.



Shortened casting process

Data: Compiled by MEXT based on "Economy and Industry Journal, August-September version, 2013," METI

Other than the examples above, various evolutions of science and technology suggest the potential for changes in R&D and industries and people's future work approach, employment and lifestyle.

For instance, the development of sensor technology and expansion of big data have resulted in the emergence of IoT. Combined with progress of AI and robot technologies and the construction of cyber physical systems, this will further accelerate the efficiency of all socioeconomic activity toward 2030.

Simultaneously, AI and robot technologies are expected to generate new businesses such as robot suits and automated driving technology, increase labor productivity and help solve issues such as the aging society and declining birthrate in Japan. As described in Column 1-16, peoples' work approach and employment may also be transformed.

Progress in machine translation technology will accelerate smooth, cross-border communication in both real and virtual spaces, as mentioned in Column 1-13. It provides potential for Japanese to eliminate the linguistic barrier, which was formerly so difficult to overcome.

Column 1-16

The Future of Employment

In March 19, 2015, Mizuho Bank, Ltd. announced the introduction of emotion-recognition humanoid robot "Pepper" for customer service at stores as a world first in the banking industry, with nationwide deployment in mind and service roll-out at some stores from July. Mizuho Bank, Ltd. wants ""Pepper" to work as a universal concierge for its One-to-One service by fusing customer communication, existing business information and the latest financial information and multilingual and interactive service linked with AI technology used in the call center." This is the time robots "work" as employees.

Pepper

Source: SoftBank Robotics Corp.

Noriko Arai, director of the Research Center for Community Knowledge at the National Institute of Informatics (NII) and author of "How Computers Can Take Our Jobs" said in her book, "Technological innovation called information science at the late 20th century replaces the intellectual work of humans. As a natural consequence, those engaged in work which computers can do, so-called white-collar, may find themselves deprived of their work in the 21st century, in which information science technology rushes into society with reality." Can white-collar workers survive? In her book, she evaluates computers as good at learning by heart, calculation and pattern recognition, but not good at representing high level thinking using logic and language and information processing using five senses such as vision, hearing and touch, which are easy for humans. One of the answers for the white-collar to survive is "to be obliged to compete with computers in areas requiring a capability that computers lack to produce difference in labor value."

For the topic "Machine versus Man," the paper[1] presented by Michael A. Osborne, Associate Professor of University of Oxford for AI study and others in 2013 has attracted rising attention. According to their estimate, about 47 percent of total US employment is in the high risk category, meaning that associated occupations could be automated over the next decade or two. Frey and Osborne estimated the percentage of automation with nine variables, such as finger dexterity, originality and negotiation, indicative of bottlenecks to computerization. Occupations highly prone to computerization include telemarketers, umpires, legal secretaries and cashiers. For instance, computer software can be said to assist analyzing legal briefs and precedents in pre-trial research. By using the software, one lawyer would suffice for work that once required 500. Computer software capable of analyzing and sorting more than 570,000 documents in two days has been used by law firms.

Frey and Osborne pointed out that big data and sensing technology allow many non-routine cognitive tasks to become computerisable. Medical diagnosis is an example of big data application. At Memorial Sloan-Kettering Cancer Center in the U.S., IBM's Watson computer learned 600,000 medical evidence reports, 1.5 million patient records and clinical trials and two million pages of text from medical journals, to provide oncologists with cancer diagnosis and develop a treatment plan. As for sensing technology, sensors can equally be placed on trucks and pallets to improve company's supply chain management.

Moreover, Computers have the following advantages over humans: Humans must fulfill a range of tasks unrelated to their occupation such as sleeping. Computers lack subjective biases. Disadvantages of computers do exist: Creative and social skills. Elementary school teachers, scientists and designers are occupations that would be difficult to replace with computers.

Based on these facts, employment will no doubt change drastically in future. However, we should not be overly pessimistic about computers replacing human jobs. Humans are "thinking reeds." The future world could be like this: humans trust computers at jobs at which computers excel to improve productivity and humans focus on creative tasks that only humans can do.

1 "The future of employment: How susceptible are jobs to computerisation?" published in 2013, coauthored by Carl Benedikt Frey and Michael A. Osborne

Various changes toward 2030 can encourage the elderly to participate in socioeconomic activities and increase cross-border organization activities. However, only some socioeconomic changes are currently predictable, as science and technology progress and a significant portion remains unclear. The government and citizens must develop a sense of appreciation for the evolution of science and technology and its effect in future.

3 Educational Reform to Nurture Human Resources in Science, Technology and Innovation

Human resources in science, technology and innovation, active in revolutionary times, as mentioned above, are crucial for Japan to be "the world's most innovation-friendly country" in future. The current young researchers, students and children will be central players in science, technology and innovation activities in 2030. It is a time of educational reform, special notes for which are listed below.

(1) University reform as a "knowledge center" for the future society and economy

Universities are venues for researchers to conduct research and students to take education and "knowledge centers." The role of universities as "knowledge centers" is important to foster future human resources in science, technology and innovation and naturally have large responsibilities. Particularly now, amid rapidly changing social and industrial structures, universities must respond to such changes flexibly as organizations capable of predicting the future and always refurbishing human resources, disciplinary and education and research methodologies. It is important to meet social and regional needs and demands of stakeholders such as the industrial sector and remain an organization open to the nation and abroad.

MEXT made proposals for university reform based on these perspectives in April 2015. Efforts reflecting the "knowledge creation capability" are important for sustainable innovation, for instance, national universities promote functional improvements to emphasize the strength of each university such as "increasing the productivity of regional companies," "pursuing unique research fields" and "promoting world-class advanced research." The proposal also addressed the formation of outstanding graduate schools with world-class education and research capability to produce talented people and organizations that can flexibly respond to social changes and new industry[1].

It is expected that prompt implementation of these proposals may turn national universities into "knowledge centers" recognized by society and abroad to lead the future society and economy and nurture human resources in future science, technology and innovation.

(2) Nurturing "knowledge professionals" for science, technology and innovation

While the young population is on the decline in Japan, producing numerous human resources in science, technology and innovation is unlikely. The quality of individuals must be increased.

Elementary , lower secondary education and Higher Education is important for improving the quality of people, but this section explains graduate school education for producing PhDs. or "knowledge professionals" to lead global research and business.

1 (6th) Execution, Implementation and Inspection Meeting, (14th) joint conference (April 9, 2015), MEXT data, Refurbish and innovation WG, Industrial Competitiveness Conference

The qualifications and capability required for postdocs includes, for example, "graduate school education in globalized society" as proposed by the MEXT Central Council for Education in January 2011, with the words "As globalization and the knowledge-based society are underway, highly talented people with international leadership are required in industrial, academic and government sectors to create new social values through innovation and spearhead efforts to solve the issues humans face. The leaders should be able to gain an overview and insight via high professionalism, internationality and wide-ranging knowledge, identify key issues without bias of specialties, construct hypotheses and have the ability and will to act with clear visions, backed by the capability to challenge various issues with creativity and inflexible ethics and a historical perspective." Based on this proposal, MEXT launched the "Program for Leading Graduate Schools" in FY 2011 to reform postdoctoral courses of graduate school (see Column 1-17).

Not limited to graduate school education, industry-academia collaborative development of innovation human resources is underway. METI supports the construction of a framework by several universities and companies for medium- to long-term internships from FY 2013 in light of the emergence of human resources in the field of innovation with a practical focus on social activities. MEXT and METI founded the "Industry-Academia-Government Roundtable Talk (tentative)" in FY 2015 for the strategic development of S&T human resources required for the industrial sector to discuss the roles of industry, academia and government to develop human resources required for the industrial sector and encourage the activities of human resources in the industry.

Based on these measures, university students are expected to work actively in various places in the industry.

However, talented students tend to hesitate to attend postdoctoral courses in Japan in recent days, because of unclear career path and unstable employment. Creating a society where talented young people are willing to go to postdoctoral courses is an urgent issue. A broad array of efforts is required to achieve, for instance, a clear career path from a postdoc to an independent researcher or university teaching staff member, establishing a personnel evaluation and development system for this purpose, expanding stable posts attractive for talented young people, providing various career paths and ensuring postdoctoral position and after.

Prompt execution of these measures is desirable, together with the university reform described in (1).

Column 1-17 Global leader cultivation through postdoctoral education

Debate at Dojo for Economics and Humanities
Source: Tokyo Institute of Technology

Reform of postdoctoral education is underway by the support of the Program for Leading Graduate Schools nationwide to achieve the new image of "PhD" required by society. This column introduces a new program implemented at the graduate school of Tokyo Institute of Technology.

The "Academy for Global Leadership" of the Tokyo Institute of Technology aims to cultivate global leaders for international leadership as a 5-year unified doctoral education system founded in April 2011. Only talented students are selected from all graduate courses of the Tokyo Institute of Technology and receive a high-quality education on integration of arts and science.

One of the major features of this program is the "Dojo" (practice hall) education, which consolidates all the expertise and the knowledge of university. To be a true leader, students must improve their skills as individuals, improve their innate quality and build their career as potential leaders in person. The "Dojo" education provides an environment for students to compete against each other to support the voluntary activities of students, for example, through debate and group work with invited industry lecturers.

Another major feature of this program is the practical "Off Campus" education. Students are obliged to join a project in a domestic or foreign corporation or research institute for more than six months to determine whether their leadership trained by the "Dojo" functions effectively in the practical world. The project for renewable energy development by JICA in Kenya and a new business development project in a private weather company are part of projects involving the students. Students who experienced these medium- to long-term projects changed their mindsets and one of the students commented on the "I have become strongly conscious strong awareness of what I can do for society."

Cross-department support is required for such postdoctoral education. An education program, including all teachers of the graduate course, is provided in the Academy for Global Leadership at present. There were repeated and heated debates in the university for a year during the preparation period of this program in April 2011. The controversy started amid a common sense of crisis by management and teachers at divergence between the education which is provided by the university and which is required by society. Debates involved all graduate faculties for the education program to provide the capability required by society for doctoral student. In addition, topics ranging from the education required for leaders of international community, including industry, to an educational program nurturing such human resources and collaboration with industry were discussed in detail, every day.

Consequently the Academy for Global Leadership was founded in the university as a cross-departmental education organization to implement a system to put debate results into practice. This is surely a new challenge of the Tokyo Institute of Technology.

About 3,000 students from 33 universities nationwide are learning in 62 programs at the Program for Leading Graduate Schools as of October 2014. Soon, students educated in this program will be sent to society one after the other. This type of program is expected to be used in many universities to eliminate the conventional image of postdocs in society as "being entrenched by a bunch of expertise" or "being top-heavy with ideas". In addition, it is also expected that such talented people who have PhDs, as knowledge professionals, succeed in Japan and overseas.

(3) Culturing capability to live in uncertainty

As society changes rapidly, future prediction is more difficult in the age to come. To survive these times, the leadership of talented people is required to overcome unexpected or unknown events and show the way forward.

Basic academic capability, particularly wide-ranging education regardless of arts and science, is required in the elementary and lower secondary education to lead future science, technology and innovation. In addition to identity as Japanese and verbal aptitude, English proficiency and information manipulation are required. Looking into 2030 and onward, some predict that computers will surpass human capability as AI technology progresses. Meanwhile, the key as humans lies in finding and solving problems, creativity and rich feeling. These capability and innate qualities will be more important and required for the era to come, in addition to the basic knowledge and skills.

MEXT is currently investigating the high school - university liaison (integrated reform for upper secondary school education, university education and university entrance selection) based on the proposal of the Central Education Council in December 2014. The "Plan for Implementing High School/University Articulation Reforms" announced in January 2015 presents the key measures to be taken by government with the implementation schedule as shown in Figure 1-3-18. In March the same fiscal year, "High school-university transition reform conference" was held to start discussions on specific measures to implement reform. An interim summary is scheduled for around summer 2015 and the final report will be drafted within fiscal 2015.

■ Table 1-3-18 / Important measures taken by the government (Plan for Implementing High School/University Articulation Reforms)

1) <u>Reform of individual selection of universities</u>
Reform to entrance procedures with multiphasic and comprehensive evaluation of the capability, motivation and qualification of prospective students for universities to accept student of various background.

2) <u>"Upper secondary schools basic achievement test (tentative)" and "University entrance applicant evaluation test (tentative)"</u>
Investigation of a new test method to foster and evaluate real learning ability based on three learning elements required in the age to come: knowledge and skills; the ability to think, judge and express; and voluntary work with various people.

3) <u>Reform of upper secondary schools</u>
Review of the Education Ministry guidelines for the promotion of voluntary and cooperative learning attitude of students to find and solve problems, and the policy of "what kind of ability to acquire," instead of "what to teach."

4) <u>Reform of universities</u>
Reform of the quality of university education in line with the selection of prospective students by multiphasic and comprehensive evaluation to improve the ability of students acquired by the education up to the upper secondary school and develop their ability of solving unpredictable and unanswered problems which may be encountered after graduation.

Source: Created by MEXT

In November 2014, "Criteria for curriculum of elementary and lower secondary school education" were submitted to the Central Council for Education; mainly focusing on the next Education Ministry guidelines, particularly for voluntary and cooperative learning for finding and solving problems (so-called "active learning") and the interconnection of learning and teaching methods with educational content, currently under discussion by the council.

As well as reforming elementary, lower secondary education and higher education, measures such as those to enhance the capability of talented students for science and technology in a competitive environment, nurture global human resources and increase the concern and education of children are interconnected for ensuring human resources for future science, technology and innovation.

Humans take the final responsibility over whether innovation occurs through science and technology based on the evolution of science and technology, or the creation of society which cheers all people, based on the fruits of innovation.

Our future depends on how we foster people. All parties concerned must make concerted and collective efforts based on this notion.