2 Projects That Will Expand Frontiers and Yield Results when the Olympic and Paralympic Games are Held in 2020

This section introduces the return of the asteroid exploration spacecraft Hayabusa2 from space and the completion of the post-K supercomputer project. These are projects that will yield results by 2020, when the Olympic Games and Paralympic Games are held.

(1) The 2020 return of the Hayabusa2 Spacecraft from space

Pioneering efforts at the frontiers of space will lead to the accumulation of intellectual assets for humanity. The Hayabusa asteroid exploration spacecraft, which was launched in 2003, was the world's first spacecraft to land on the solid surface of a celestial body (the Asteroid Itokawa) outside of the gravitational range of the earth and bring back samples of asteroid surface material. The Asteroid Itokawa was named in honor of the late Dr. Hideo Itokawa, the father of rocket development in Japan. Many people must have been impressed on seeing Hayabusa return from its 7-year trip on June 13, 2010, after overcoming a number of obstacles.

Streak of light from the Hayabusa rocket and its capsule
Courtesy of Japan Aerospace Exploration Agency (JAXA)

In addition, by analyzing the particulate samples brought back by Hayabusa, the component materials and the history of formation of the asteroid were elucidated for the first time. The results of the analyses were selected by the American journal *Science* as one of its annual top-ten scientific breakthroughs.

The asteroid exploration spacecraft Hayabusa2, the successor to Hayabusa, will be launched in 2014. It will return from space in 2020. Hayabusa2 will visit a C-type asteroid in order to explore the origin of the earth, the sea and organic molecules. A C-type asteroid is a more primitive asteroid than Itokawa, but it is thought that water and organic matter might exist there, in addition to minerals. Hayabusa2's main mission is to collect samples. Hayabusa2 will create an artificial crater by launching an impacting sub-satellite to strike the asteroid. Observations will be made of subsurface materials that have not been exposed to solar wind and sunlight. Hayabusa2 will showcase new technologies, including that for collecting materials from inside the crater it will create.

(c) Akihiro IKESHITA

Hayabusa2
Courtesy of JAXA

When Hayabusa2 succeeds in its mission of bringing back samples, they will be the world's first samples returned from a C-type asteroid. Success in the sample gathering mission will lead to the unlocking of mysteries of the solar system, such as the origin of the water and organic matter that were present about 4.6 billion years ago when the solar system was born.

Further, Hayabusa2 will blast off into space with messages from many of Japan's citizens, including disaster victims of the Great East Japan Earthquake.

Daring to investigate the unknown and unexplored is what makes space science and space exploration so fascinating. In 2020, Hayabusa2 will return after achieving its mission. It will be a major event which

people from around the world can share, with thrills and excitement comparable to those of the Olympic and Paralympic Games.

(2) Completion of a Post-K Supercomputer in 2020

A supercomputer of the highest level is a powerful tool for obtaining results in the world's most advanced research. It is indispensable for Japan to improve its capacity of supercomputers, in order to survive the fierce international competition in science, technology and innovation. Many countries, including the United States, China and those of the EU, are competing to develop superior supercomputers. This is based on the recognition that computer technology is a key technology of national importance for the establishment of cutting-edge science and technology, and for the establishment of a safe, secure country. In light of this, Japan has been making national efforts to promote the development and improvement of supercomputers, including the K computer.

Work on the K computer started in FY2006 as part of the development of Key Technologies of National Importance. In addition to taking first place in the computing speed world ranking of supercomputers (TOP 500 ranking) for two consecutive terms, the K computer also won the Gordon Bell Prize[1] in two consecutive years in recognition of its results. Thus, the K computer is a supercomputer that has gained accolades for its results.

The K computer
Courtesy of RIKEN

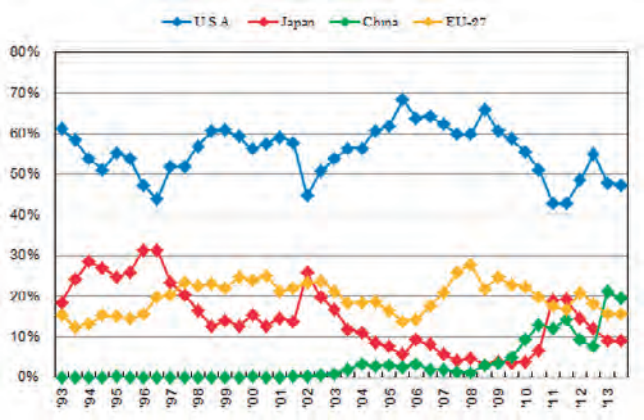
In addition, since the beginning of the shared use of the K computer at the end of September 2012, the computer has been utilized in world-leading cutting-edge research as a high-performance supercomputer that represents Japan. At the same time, the K computer has been widely used, by more than 100 companies, for strengthening industrial competitiveness, with about a quarter of the computational resources[2] of the K computer being used for solving problems that businesses are facing. R&D has advanced with respect to innovative product development and the creation of services by utilizing the industry-university cooperation that is built on the platform of the K computer. Use of the K computer has achieved excellent results in cardiac simulations, the material design of fuel cells, aerodynamic simulations of automobiles and more. The K computer has been contributing to the solution of social and scientific issues.

Thus, the K computer, a domestically produced supercomputer, has proven to be a supercomputer that can produce results and has proven to have high performance, reliability and usability. This attests to Japan's world-class science and technology capabilities and manufacturing skills.

1 An award granted by the Association for Computing Machinery for the paper that produces the world's best results regarding the development of hardware and applications for a certain year
2 Based on initial allocation performance in FY2013

Japan's share of the total computing power of the world temporarily increased after large-scale systems, such as the K computer, were introduced. However, it has been showing a gradual long-term downward trend (Figure-9). Therefore, the development of post-K supercomputers, much faster than the K computer, is expected to solve various social and scientific issues, including the promotion of the development of innovative medicines with fewer side effects and of the prediction for damage caused by complex, widespread disasters.

Figure 9 / Changes in the National Share of Total Computing Power of The Top 500 Supercomputers, Broken Down by Country



Source: MEXT

Under these circumstances, in order for supercomputers to continue to bolster Japan's competitiveness, MEXT will start a project in FY2014 to develop a post-K supercomputer that is a successor to the K computer by 2020, toward realizing exascale[1] computing. Also, by developing several supercomputers that are smaller than the post-K supercomputer but have specifications to supplement the post-K supercomputer in a multi-tiered manner and by integrating those supercomputers with the post-K supercomputer, MEXT will address social and scientific challenges than cannot be solved with the K computer alone.

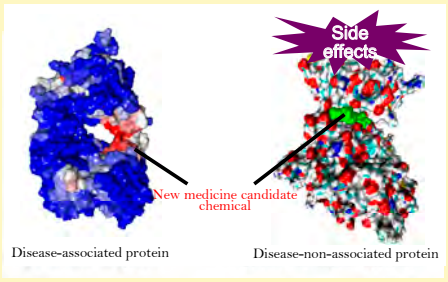
In 2020, when starting the full-scale operation of the post-K supercomputer and fully utilizing supplementary supercomputers, Japan will create results to address successive issues that human society will face. Thus, Japan aims to lead the world with its science, technology and innovation.

Column Feature-5

Achievements expected for the post-K supercomputer, a successor to the K computer

The post-K supercomputer, whose performance will far exceed that of the K computer, will be able to perform higher-order calculations than those of its predecessor. It will contribute to the solution of extremely complex phenomena and issues.

For example, in the field of drug discovery, the challenge is to efficiently discover new medicine candidate substances (chemical substances) that bind to the target proteins causing certain diseases. The K computer has already made it possible to predict which new medicine candidate substances will bind to a target protein. The post-K supercomputer, in addition to this, can simultaneously analyze the bonds between a chemical substance and multiple proteins as well as predict the side effects. This promises to lead to the development of innovative medicines.

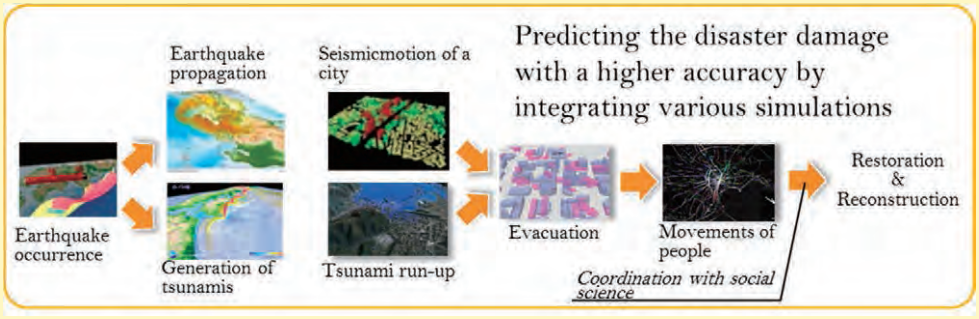


Analysis of the effects of new medicine candidate substances on multiple proteins

With respect to disaster prevention and mitigation, the K computer is currently used for predictive simulations of the arrival of tsunami waves for the drafting of hazard maps, as part of disaster prevention measures for the development of disaster-resistant cities. A conventional supercomputer makes separate calculations for each of the following: the

1 1 exa = 1,000 peta = 1,000 quadrillion = 1,000,000 trillion

occurrence and propagation of earthquakes, the ground-motion of an entire city, seismic damage to structures, and the generation and run-up of tsunami waves. In contrast, the post-K supercomputer can integrate all of these simulations and thereby predict the damage from complex widespread disasters with higher accuracy, thus contributing to the proper and precise implementation of disaster prevention and disaster mitigation measures.



In the field of automotive design, the post-K supercomputer can contribute to product development that cannot be achieved only by experiments. It does this by integrating outcomes of individual simulations of aerodynamics, combustion, collisions and other factors. Moreover, it can contribute to the elucidation of the origin of the galaxy and the process of evolution by simulating the whole universe, from the formation of the universe's large-scale structure to the formation of the galaxy. Thus, the post-K supercomputer is expected to achieve unprecedented breakthroughs by contributing to the solution of various social and scientific issues.

3 Science and Technology That Support Athletes

The performances of top athletes bring a sense of pride, joy, dreams and excitement to the nation. Japan's sports medicine and science, which are the most advanced in the world, support the performances of these athletes. Also, science and technology contribute to the realization of fair play, upon which all sports events, including the Olympic and Paralympic Games, place great value. This section outlines the sports medicine and science that support top athletes, and the science and technology that promote fairness in the sporting world.

(1) Sports medicine and science that support top athletes

Since FY2008, MEXT has implemented the Multi-Support Project for athletic events and for athletes who are regarded as likely medalists. The Multi-Support Project provides specialized, advanced support in various areas, such as assistance to athletes and the development of sports medicine and science strategically and comprehensively. In FY2014, MEXT will apply the programs of this project on a trial basis to Paralympic athletic events and to other Olympic athletic events, while analyzing what the project should involve.

The results of R&D on the Multi-Support Project conducted for the London Olympic Games include the creation of an immediate video feedback system for wrestling competitions. First, support staff take a video of a wrestling competition. Then, the video is edited by means of a dedicated software application. Under this system, a variety of information is added to the video, and the results are delivered to athletes and coaches so that they can instantly browse the video on a tablet terminal. To win a medal in wrestling, where skill and physical strength differ only slightly among competitors from leading nations, it is absolutely necessary to develop tactics and strategy by utilizing immediate images. This system helped one wrestler to become the first Japanese woman to medal at three consecutive Olympics, and helped Japan's wrestling team to win six medals at the London Olympics.

In light of the issues that athletes, coaches and other field staff hope to scientifically clarify, the Japan Institute of Sports Sciences (JISS[1]) conducts research to produce knowledge that is useful for cultivating world-class competitive power, in collaboration with sports associations and universities, by fully utilizing the characteristics of JISS, which integrates sports medicine and science.

For example, JISS addresses the development of a training method that uses changes in oxygen concentration. Utilizing its high-oxygen and low-oxygen facilities, the JISS is developing training methods that can produce results in a short period of time and is examining which training methods are the most effective in improving athletic performance. It was found that subjects who stayed in a low-oxygen chamber for five days were better able to adjust to low-oxygen environments, and the quality of their sleep improved. It was also found that high-intensity interval training[2] in a high-oxygen environment is effective for improving aerobic capacity.

The JISS High-Performance Gym is equipped with a low-oxygen training room and an ultralow-temperature recovery room cooled by vaporized liquid nitrogen. Athletes can improve their restorative capacity by staying in a cylindrical machine or recovery room that is maintained at temperatures of minus 170-130 degrees Celsius for 2 or 3 minutes. Special training is implemented, and new training methods are being developed.

In addition, in the Wind Tunnel Experiment Building, training using bicycles is implemented and a simulation training method that assumes various aerodynamic environments is being developed.

It is hoped that the support provided by Japan's cutting-edge sports medicine and science will contribute to outstanding performances by Japanese athletes. These performances promise to inspire the hopes and dreams of people around the world at the 2020 Tokyo Olympic and Paralympic Games.

Training in the Wind Tunnel Experiment Building
Courtesy of JISS

High-Performance Gym
Courtesy of JISS

(2) Science and technology that contribute to fairness in the sporting world

In recent years, doping techniques have rapidly become much more sophisticated and subtle. Throughout the world, there is an urgent need to promote research and technological development in order to deal with this situation. In light of this, from FY2013, Japan has implemented the Research and

1 Japan Institute of Sports Sciences
2 In recent years, high-intensity interval training has been attracting attention as a training method for improving athletic endurance in a short period of time. In this training, 5 to 7 sets of a 30-second full-speed pedaling exercise are carried out with a 4-minute break after each set.

Study Programs on Blood Sampling for Doping Control, with the aim of establishing doping inspection and analysis technology that uses blood samples and the Athlete Biological Passport[1].

In addition, the Anti-Doping Unit (known as the JADA[2] Car), which is the world's first mobile doping inspection unit to conform with international standards, was developed in Japan. The JADA Car is now utilized at various sports events.

As a permanent member of the council of World Anti-Doping Agency, and as the host nation of the 2020 Tokyo Olympic and Paralympic Games, Japan is determined to further encourage and promote research and technological development on the prevention of doping, with a view to delivering clean sports to the world.

The JADA Car has made it possible to conduct doping inspections even at competition venues without toilets or blood collection facilities

Courtesy of Japan Anti-Doping Agency

(3) Measures against heat at the Olympic and Paralympic Games

The 2020 Tokyo Olympic Games will be held from July 24 to August 9 and the Paralympic Games will be held from August 25 to September 6. During this period, we might see extremely hot days.

It is expected that new measures against the heat will be taken by fully utilizing Japan's technology, in order to create an environment where athletes can realize their best performance.

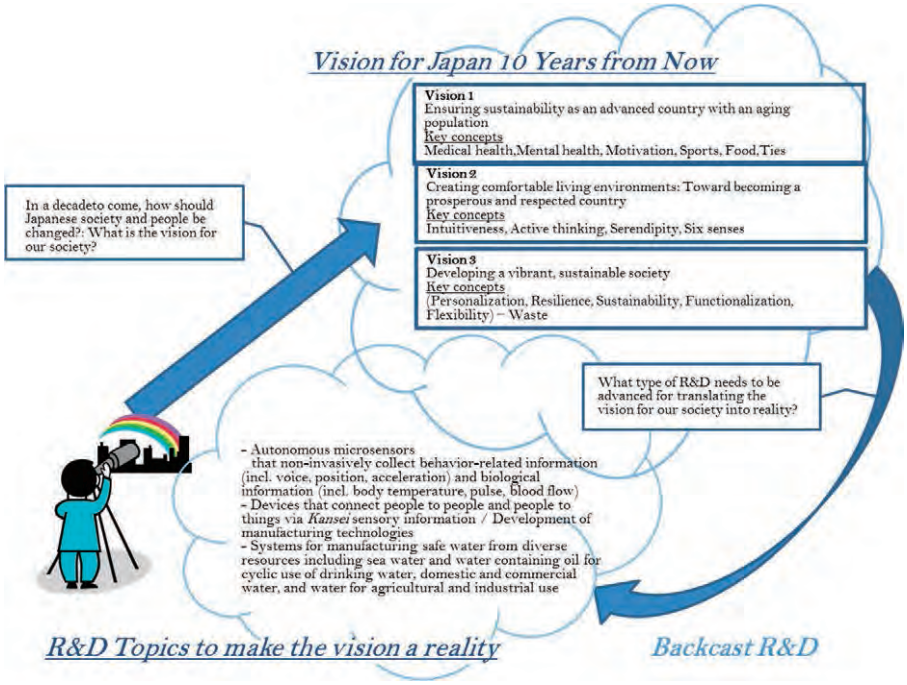
4 Japan's Choice for the Future

Alan Kay, who is known as the father of the personal computer, said "The best way to predict the future is to invent it." It is not possible to predict the future with 100% accuracy. However, by contemplating what future should be realized by 2020, when the Tokyo Olympic Paralympic Games are to be held, and visualizing that future vision by ourselves as well as by making efforts to realize that future vision, we can make a "choice for the future."

In FY2013, MEXT launched the Center of Innovation Science and Technology-based Radical Innovation and Entrepreneurship Program (COI STREAM), which is a vision-driven challenging and high-risk R&D program, to discuss "how people should be" and "how society should be" in 10 years and to realize that future vision. This program aims to develop innovation platforms for creating unprecedented innovations by breaking down existing concepts. The program distinguishes itself by placing a high value on "discussion forums" where universities and private companies can freely and equally exchange ideas about how to utilize knowledge that universities have accumulated for society in the future.

1 The Athlete Biological Passport is a doping inspection method in which doping is detected based on accumulated sample data obtained through the continuous collection of blood and urine from athletes. In this method, changes induced by the use of prohibited substances and methods are analyzed comprehensively by using various indicators.

2 Japan Anti-Doping Agency



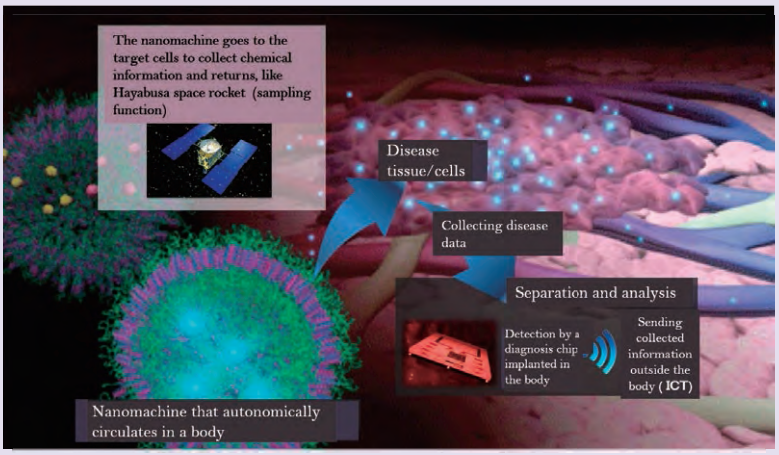
Conceptual diagram of COI
Source: MEXT

The Center of Open Innovation Network for Smart Health, an example of a COI program, is introduced here.

This research center aims at creating a society where people can be free from diseases and achieve health for themselves in daily life without worrying about time and cost. Until now, only limited numbers of patients have been able to benefit from cutting-edge medical technology at advanced healthcare facilities. However, Japan should be a society where anyone can benefit from medical technology anytime and anywhere.

This research center promotes R&D on a nanomachine that can perform all medical roles, such as detection, diagnosis and treatment, toward the realization of an "inner biological hospital" that centralizes all medical care functions in the body. A nanomachine circulates throughout the body, collects disease information and transmits the collected information outside of the body. It can identify and eliminate diseased areas (Figure-10). Toward realizing a society with "smart life care," this research center serves as a co-creation platform, where 23 organizations from industry, academia and local government collaborate not only in conducting R&D but also discussing the social system issues, such as

Figure 10 / Nanomachine for Transmitting Internal Information



Courtesy of Kawasaki Institute of Industry Promotion

the drug evaluation criteria, that need to be addressed in order for the knowledge of industry and academia to be combined and applied for the benefit of society.

In addition, since 2014, the Council for Science and Technology Policy (CSTP) has begun to participate in the Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT), which promotes high-risk and high-impact research with the aim of creating "a new system that, if realized, will create disruptive innovation that brings about change in society." The following are the research themes determined by the CSTP: 1) a release from constraints on resources and innovation in *monozukuri* (manufacturing) capabilities, 2) the realization of an ecologically sound society and innovative energy conservation that changes lifestyles, 3) the realization of a society of highly advanced functionality that surpasses the information networked society, 4) the provision of the world's most comfortable living environment in a society with a declining birthrate and aging population, and 5) control of the impact and minimize the damage from hazards and natural disasters that are beyond human knowing. This is a landmark program that encourages researchers to undertake high-risk research in order to realize the society that Japan is aiming for.

Meanwhile, the Committee for Japan's Future, which was established as an expert examination committee under the Council on Economic and Fiscal Policy in January 2014, will identify the issues to be addressed intensively and in a cross-sectoral manner by 2020, when the Tokyo Olympic and Paralympic Games are held, and will make efforts to overcome those issues in a comprehensive manner, in addition to dramatically changing the future by means of policy efforts and the will of people. Thus, the Committee for Japan's Future aims to "choose a future."

We cannot predict the future. Nonetheless, as a country leading the world with cutting-edge science and technology and as a developed country that faces new problems, Japan needs to create a desirable future vision, courageously tackling challenges by utilizing Japan's world-leading, cutting-edge science and technology despite various risks. Japan needs to realize a desirable future by coordinating all endeavors that are under way in Japan. Then, Japan has to present to the world the future that is chosen and realized by the people.