The Development and Use of the Next-Generation Supercomputer
A supercomputer is an ultra-fast computer that can be used for large-scale scientific calculations across a wide range of fields. Simulations using supercomputers have become vitally important as a third method of research and development, alongside experiments and theory. These supercomputer simulations can be extremely effective in a variety of situations in which experimental approaches are not applicable. Such situations include, for example, those where the object of study is too large or complex for analytical solutions, or in which experimental observation would require excessive time or high cost, or involve extreme or dangerous conditions (for instance radioactivity or high temperature). Simulations are also useful in cases where the subject of study is not amenable to experiment, such as in the case of the natural environment, geographic regions, or societies.

Supercomputers are now used in weather forecasting, in the design of cars and aircraft for analyzing structures and fluid flows, and for a wide range of other purposes. They are indispensable for the future of science and technology and the competitiveness of industry.

Comprehensive and high-level electronics skills in high-performance, low power dissipation semiconductor technology, optical communication technologies, network technologies and quality control technology, are all required in supercomputer development. Japan is at the top of the world in this field, but continued research development is needed to maintain and improve the country’s technological capacity.
A key technology of national importance

The term “key technology of national importance” denotes scientific technology heavily invested in large-scale national projects and aimed at improvements in comprehensive national security and the realization of world-class research capabilities. Japan’s Council for Science and Technology Policy considers the Next-Generation Supercomputer a “key technology of national importance” serving as a foundation of national scientific technology and industrial competitive strength, and has clearly designated the project as a long-term strategic national goal.

A continuous process of development

Supercomputers in Japan have been developed under the leadership of the national government. Numerous pieces of technology developed under these national projects have been deployed to other major computer systems across the country. Japan’s continuing research on supercomputer development will strengthen its R&D infrastructure and improve its overall level of technology.
The Next-Generation Supercomputer project

Overview of the project (Policy of the Ministry of Education, Culture, Sports, Science and Technology)

Supercomputing technology is recognized today to be as vital to scientific research and development as experiments and theory, and the Next-Generation Supercomputer is being built with the aim of further developing this technology. Due to be ready in 2012, the new supercomputer will ensure that Japan continues to lead the world in science and technology, academic research, and industry.

The elements of the project are as follows:

1. Design, build, and set up the Next-Generation Supercomputer, the world’s fastest and most advanced computer, with a speed of 10 petaflops

2. Develop and distribute large-scale software applications (the “Grand Challenge” software) that make full use of the supercomputer

3. Connect the supercomputer to the Cyber Science Infrastructure, a multilayered environment for the shared use of supercomputers across Japan using the Science Information Network (run by the National Institute of Informatics)

4. Set up a center to run the supercomputer, to be the world’s top center of excellence in the field of supercomputing

The Next-Generation Supercomputer project is being carried out by RIKEN, with partners in industry, universities, and the government, under an initiative by MEXT (the Ministry of Education, Culture, Sports, Science and Technology).

Schedule

Partial operation of the system in FY 2010, full completion planned for 2012

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The Next-Generation Supercomputer will be a general-purpose computer system with the highest performance in the world. RIKEN is the core organization for the development of this world-leading supercomputer.

**The world’s most advanced scalar-type supercomputer system**

**[System architecture and features]**

- The system will use scalar CPUs (SPARC64™ VIIIfx, 8 cores, 128 gigaflops) manufactured with 45nm process technology. To achieve high performance and high scalability to ultra-large-scale system, the CPU will additionally support SIMD (Single Instruction Multiple Data) processing, and will be furnished with functions for instruction retry as well as conventional error detection/correction, contributing to high performance and reliability in application execution in an environment with huge numbers of CPUs.
- The network between the computing nodes will consist of a direct-connection network\(^2\), ensuring high flexibility and scalability and enabling ultra-large-scale connectivity. Users can create application programs adapted to either a one-, two- or three-dimensional torus network, contributing to improvements in convenience, fault-tolerance and interoperability.
- With its water cooling system, the supercomputer will maintain a low temperature in the CPU and other LSIs, minimizing the failure rate and reducing power consumption.
- An ultra-large-scale file system with high functionality, scalable to several hundred petabytes, will provide several dozen petabytes for user areas.
- The system will have an interface for the NAREGI (National Research Grid Initiative) middleware, one example of external uses of the system through the Science Information Network (SINET).

1 A scalar-type supercomputer is a set of computing nodes with scalar CPUs connected by a network. CPUs operate on data in small chunks in sequential order. Scalar-type supercomputers are today a common style of supercomputer system used throughout the world. These supercomputers are well-suited to computations involving complex data access, such as those involved in structural analyses of nano-scale devices as well as analyses of gene and protein data.

2 There are two styles of networks, direct-connection networks and indirect-connection networks. In a direct-connection network, the entire network consists of numerous connections between pairs of nodes. In an indirect-connection network, a switch sits between multiple nodes. A three-dimensional torus network is a kind of direct-connection network where the nodes are organized into a three-dimensional structure, and each is linked to six others, forming a ring structure in each dimension.

**[System software]**

System software, which manages hardware and application software, is indispensable in making full use of hardware capability. The Next-Generation Supercomputer harnesses the following system software in order to offer users a high-performance computing environment:

- The adoption of Linux Operating System (OS) providing high portability
- A rich programming language suite that allows for continuity of software assets
- MPI (Message Passing Interface) Library used in advanced data communication for parallelization
- High-performance, highly functional and system-optimized scientific and numerical library
Breakthroughs in science and technology

Results anticipated from the Next-Generation Supercomputer

Development of the Next-Generation Supercomputer will contribute to society by uncovering the secrets of natural phenomena occurring across all scales of existence, from the ultra-small world of quantum particles to the vast expanse of outer space and its countless galaxies.

At a micro scale, for example, simulations of viruses in solution and long-time simulation of liposomes (made up of several hundred thousand atoms) contribute to the field of medicine, while simulations of cellulolytic enzymes will in the future provide inexpensive biofuel and contribute to the energy field. At a somewhat larger scale, full simulation of next-generation semiconductor nanodevices and exploration of materials with new functions such as non-silicon materials will bring momentum to the area of next-generation electronics technology. At a yet larger scale, the combination of seismic wave propagation and structural earthquake resistance simulations will contribute to disaster preparation, and the simulation of typhoon path and intensity will play an important role in meteorological forecasting.

Examples of simulations using the Next-Generation Supercomputer: From nano to galactic scale

- Contribution to electronics: full simulation of post-32nm generation devices
- Contribution to meteorology: elucidating complex atmospheric phenomena and correctly measuring the path and intensity of typhoons
- Contribution to medical treatment: full simulation of virus in water
- Contribution to the energy field: affordable biofuels through simulation of cellulolytic enzymes
- Contribution to disaster preparation: seismic wave propagation and structural earthquake resistance simulations

From nano to galactic scale:

10^-10 m

10^-8 m

10^-6 m

10^-3 m

10^0 m

10^7 m

10^21 m
RIKEN is developing new simulation software that will make full use of the Next-Generation Supercomputer’s potential in helping us to understand a wide range of diverse phenomena, from the level of the molecule to that of the entire organism. In developing this new petaflop-scale simulation software, we adopt both an analytic approach, where we study phenomena through basic principles, and a data-analysis approach, where we attempt to discover new processes and laws by analyzing large quantities of experimental data. The new software we are developing takes full advantage of the Next-Generation Supercomputer’s potential by integrating research results from across diverse scales with micro- to macro-scale experimental data. In addition, RIKEN also plans to actively collaborate with industry in applying research results to the real world in areas such as medical diagnostics, drug discovery and health science.

The Next-Generation Integrated Simulation of Living Matter

RIKEN is developing new simulation software that will make full use of the Next-Generation Supercomputer’s potential in helping us to understand a wide range of diverse phenomena, from the level of the molecule to that of the entire organism. In developing this new petaflop-scale simulation software, we adopt both an analytic approach, where we study phenomena through basic principles, and a data-analysis approach, where we attempt to discover new processes and laws by analyzing large quantities of experimental data. The new software we are developing takes full advantage of the Next-Generation Supercomputer’s potential by integrating research results from across diverse scales with micro- to macro-scale experimental data. In addition, RIKEN also plans to actively collaborate with industry in applying research results to the real world in areas such as medical diagnostics, drug discovery and health science.

Research and Development on Next-Generation Integrated Nanoscience Simulation

This project, based at Institute for Molecular Science (IMS), is developing theoretical and computational methodologies in molecular and materials science which aim to analyze and predict various properties of nanoscale materials through extensive and accurate computations. The project must therefore develop simulation software for computational nanoscience based on theoretical processes, which will be optimized for the Next-Generation Supercomputer. Research activities are being conducted in collaboration with academic and industrial researchers in Japan, and focus on three fields: "Next-Generation Functional Nanomaterials for Information Technology", "Next-Generation Nano Biomolecules", and "Next-Generation Energy", which we refer to as the grand challenge targets.
R&D infrastructure for scientists and engineers in academia and industry

Cooperation with universities and research institutions

In addition to its work with MEXT and Grand Challenge Applications research and development centers, RIKEN is pursuing collaborative ties with various domestic industry, academic and governmental institutions for information sharing, joint research and people-to-people exchange. RIKEN is also advancing a collaborative framework with university information technology centers throughout the country aimed at enhancing the performance of applications. Finally, RIKEN is working to make use of computational resources, personnel and know-how of universities and public research institutions in the development and utilization of the Next-Generation Supercomputer.

Promoting a wide range of industrial applications

In cooperation with the Industrial Committee for Super Computing Promotion (ICSCP), an organization made up of more than 180 corporate, university and research groups from a broad range of industries, RIKEN aims to set up an environment that is easy for private enterprises to use and that encourages industrial innovation.
Applications of the Next-Generation Supercomputer via the Science Information Network

The Science Information Network (SINET3) is an ultra-high-speed network built and operated by the National Institute of Informatics, centered around the Cyber Science Infrastructure (CSI). Once the Next-Generation Supercomputer is connected to this network in early FY 2012, RIKEN will begin offering an advanced remote-use environment for grid computing using NAREGI middleware. This connection will enable the nationwide National Infrastructure System (NIS) to work together with systems at the level of research labs, making available common-use facilities capable of responding to the various demands of its users.

Preparation for shared use of facilities

The Next-Generation Supercomputer will be a legally designated Specific Advanced Large Research Facility available to scientists and engineers throughout Japan. RIKEN will make use of its experience in running SPring-8 (Harima Science Garden City, Hyogo Prefecture), the large synchrotron radiation facility, to set up an efficient system for organizing the use of the supercomputer.
Toward a world-class center for research and personnel development

Creating a center of excellence for research and personnel development around the Next-Generation Supercomputer

In cooperation with research institutions and universities, RIKEN aims to establish a center of excellence for research and personnel development around the Next-Generation Supercomputer.

The supercomputer center is being built in the city of Kobe, within the 2nd stage area of Port Island. Access: The site is a one-minute walk from Port Island Minami station, which is 25 minutes by train from Shin-Kobe station or 10 minutes from Kobe airport. From Narita airport (Tokyo), first take the JR Narita Express to Tokyo station, then take the Shinkansen (bullet train) for three hours to Shin-Kobe.

Address: 7 Minatojima-minamimachi, Chuo-ku, Kobe, Hyogo, 650-0047, Japan
In many fields of science, simulations are an important research method alongside experiment and theory. Simulations will be essential for the future of science and technology. In industry they are highly useful in the development and design of products. For Japan to maintain and improve its international competitiveness in science and technology, it is essential that we carry out top-quality R&D in supercomputing hardware and software.

This is why the government’s third Science and Technology Basic Plan called for the development and utilization of the Next-Generation Supercomputer, as a technological foundation of national importance that requires major investment. A law supporting this recommendation has now come into force. RIKEN is responsible for the development and operation of the supercomputer under this law.

One of RIKEN’s important missions is to design and create the R&D facilities that are essential for the advancement of Japanese science and technology, and to take the lead in putting these facilities to use. We are putting our full efforts into the development of the Next-Generation Supercomputer, which we believe will be recognized as the world’s best. We will create a top-quality environment for the supercomputer, and build a center of excellence for research and the training of future generations of scientists and engineers.
If you are arriving via JR lines:
A five-minute walk from the south exit of Tokyo Marunouchi station

If you are arriving via subway:
Directly connected to Exit 3 of Nijubashimae Station.
Note: This station is connected via underground passageway.