Overview

Hitachi R&D Strategy

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R&D UNDERPINNING SOCIAL INNOVATION BUSINESS

THROUGH its 2015 Mid-term Management Plan, Hitachi is seeking to strengthen its Social Innovation Business, the role of which is to work alongside customers to achieve social innovation by jointly identifying the problems they face, and then mobilizing the technologies, products, services, personnel, and other business resources of Hitachi to deliver solutions to those problems. Since customers operate around the world, Hitachi seeks to bring about social innovation on a global scale. To achieve this, the group is embarking on a transformation that will allow it to fully mobilize its capabilities.

To drive this process, research and development (R&D) at Hitachi is pursuing the following four core strategies in accordance with the Mid-term Management Plan.

The first strategy is to expand its R&D facilities outside Japan. In particular, Hitachi is embarking on new R&D activities in emerging regions. It is also setting up new laboratories at existing overseas facilities to study those fields in which stronger capabilities are required to meet the needs of the Social Innovation Business in that region. Hitachi is also seeking to become more closely engaged with each region by increasing the proportion of research leaders who are recruited locally.

The second strategy is to shift R&D resources toward those research topics that are of most importance to Hitachi's Social Innovation Business. In keeping with the approach described above, Hitachi is focusing on research into products and services, as well as cloud computing and other forms of information technology (IT).

The third strategy is to pursue those R&D topics that are needed to transform the structure of Hitachi's business into a form that suits the Social Innovation Business. This means boosting R&D aimed at reforming product cost structures.

The final strategy is open innovation. Since interaction with customers is the basis of the Social Innovation Business, the R&D divisions are strengthening their dealings with customers around the world, including through Hitachi's growing network of overseas R&D facilities. Alongside this, they are also strengthening collaboration with technology partners in order to satisfy customers' diverse needs. Coordination at the national level, led from Japan, is essential to pursuing innovation on a global scale, and Hitachi's R&D divisions are striving to enhance their ability to achieve this.

The following sections provide an overview of R&D at Hitachi, and a description of the key policies for FY2014 based on these strategies. This is followed by a summary of the articles in this issue of *Hitachi Review* that describe innovative R&D and its role in implementing Hitachi's R&D strategy.

R&D AT HITACHI

Hitachi currently has seven core business groups, consisting of the Infrastructure Systems Group, Information & Telecommunication Systems Group, Power Systems Group, Construction Machinery Group, High Functional Material & Components Group, Automotive Systems Group, and the newly formed Healthcare Group. The groups are organized by market segment, with the Infrastructure Systems Group, for example, dealing primarily with markets and customers in the manufacturing, public sector, urban infrastructure, and transportation sectors, while the Information & Telecommunication Systems Group deals primarily with the finance, public sector, industrial, logistics, and telecommunications sectors. To help create a society in which people can enjoy a healthy and long life, the new Healthcare Group aims to utilize IT and medical technology to meet the diverse needs that arise at each stage of the care cycle, which encompasses prevention and examination, testing and diagnosis, treatment, and recuperation.

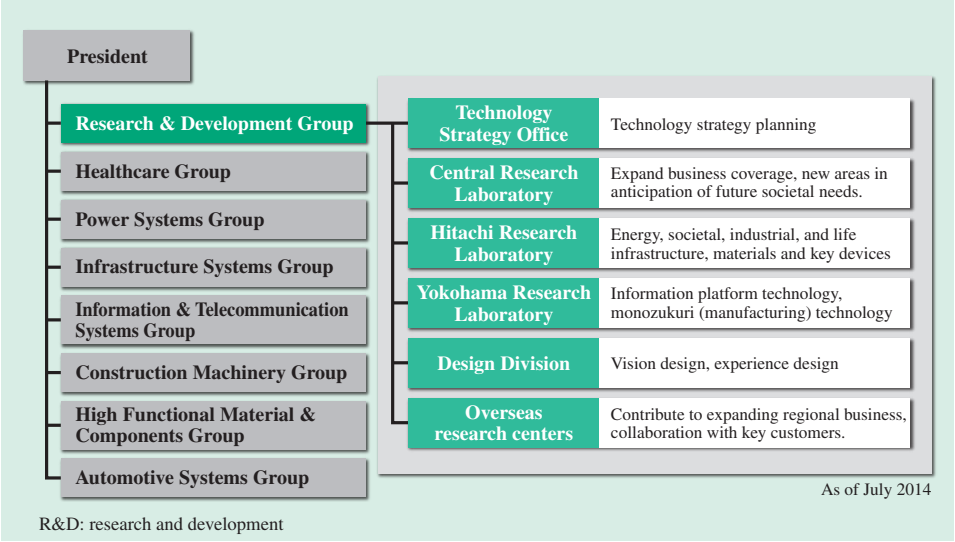

Fig. 1—Hitachi's Main Business Groups and R&D Organization. The R&D Group engages in methodological and other research from a perspective that transcends the framework of the seven business groups, and that is aimed at the development of common core technologies and the creation of future markets.

Hitachi's annual investment in R&D totals approximately 350 billion yen. The vast majority of this is spent directly by the seven business groups on R&D aimed at meeting the requirements of the markets they serve and their customers in the short to medium term. Accompanying this, Hitachi also has a research and development organization that operates independently of the business groups. This organization operates under the Research & Development Group and consists of four facilities in Japan (the Central Research Laboratory, Hitachi Research Laboratory, Yokohama Research Laboratory, and Design Division) and six overseas (in the USA, Europe, China, Asia, India, and Brazil). It employs approximately 3,300 researchers. The Research & Development Group also includes a Technology Strategy Office to manage the overall R&D strategy for this organization (see Fig. 1).

The Research & Development Group has the following three primary roles:

Developing Technologies that are Difficult to Deal with within Individual Business Groups

Specializing in R&D allows an organization to establish business resources that suit R&D in humanistic/materialistic or tangible/intangible terms. It also makes it possible to establish methodologies for ensuring best practices as well as universal and standardized platform technologies by building on many years of experience in broad market and technology sectors that transcend the framework of business groups. Furthermore, it facilitates selectivity and consolidation through the flexible allocation of research resources based on the priority of each topic. The use of these leads to the solution of problems at a high level in accordance with the research topic requirements from the business groups, or from the market via a business group.

Developing Technologies that Span Multiple Business Groups

Because Hitachi's business groups are organized by market segment, as described above, care is needed to avoid developing the same technology separately in two or more different groups. Also, there are numerous cases in which a technology developed by one group can be used by another, either directly or after further development work. R&D aimed at establishing business infrastructure such as cost structure reform is also essential. Furthermore, beyond considerations of operational efficiency, the centralized development and aggregation of technologies applicable to a broad market segment, or to a number of different market segments, has in many cases led to this technology developing into something with unprecedented significance. Such technologies are not only an important future resource for the Research & Development Group described above, they also provide the impetus for pioneering new markets like those described below.

R&D Aimed at Entering New Markets not Served by Existing Operations, and Helping to Create Future Markets

R&D is being undertaken on the basis of the following core strategies in order to satisfy this proposition, which is of the utmost importance if dramatic progress is to be made by society, customers, and Hitachi.

(1) Acquiring detailed knowledge of the broad range of market information that can only be obtained by operating a diversified business.
(2) Acquiring detailed knowledge of the broad range of advanced scientific information that can only be obtained by undertaking R&D in the diverse technical fields that underpin these businesses.
(3) Researching the humanities, system science, and other methodologies that can identify indicators of social change from this information (big data).

Open innovation (described below) is the key to all three of these strategies.

These are managed for the medium to long term through the formulation of a long-term technology plan under the direction of the Technology Strategy Office.

HITACHI'S MEDIUM-TERM R&D PLAN

Expansion of Overseas R&D Facilities

To achieve a major expansion of its Social Innovation Business in overseas markets, Hitachi is expanding its overseas R&D facilities to strengthen its locally based R&D (see Fig. 2). This expansion is proceeding in terms of three aspects: geographical, quantitative, and qualitative.

Its geographical expansion includes a new facility established in June 2013 in Sao Paulo in the Federative Republic of Brazil. In addition to R&D that combines Hitachi's expertise in information and telecommunication technologies with leading markets such as agriculture and mining in which Brazil has a leading role internationally, the facility will also research and develop solutions that bring about social innovations by studying the nation's social infrastructure issues such as transportation and the supply of electric power. To identify new areas of business in Brazil, Hitachi launched the joint "Kizashi Project[(a)]" with the University of Campinas in FY2013 to predict future trends in that nation.

The quantitative aspect of the expansion involves a plan to increase the number of staff at overseas R&D facilities from approximately 150 in 2011 to approximately 400 in 2015. In particular, the framework of the expansion involves the establishment of four new laboratories beginning in FY2013. The first was the establishment of the Hitachi China Materials Technology Innovation Center at the Chinese R&D facility [Hitachi (China) Research & Development Corporation] in April 2013. This will provide manufacturing technology development and design support for the incorporation of Chinese-made materials into Hitachi products based on joint research into advanced analytical techniques for Chinese-made materials with the School of Materials Science and Engineering at Shanghai Jiao Tong

(a) Kizashi Project
This is a project to envisage the future state of a nation using the "kizashi" methodology of identifying new businesses by predicting social trends based on future changes in the values held by consumers. To envisage the future, desktop research is conducted based around looking at printed or web-based material from the perspectives of politics, economics, society, and technology, and considering how these will interact as they change over time.

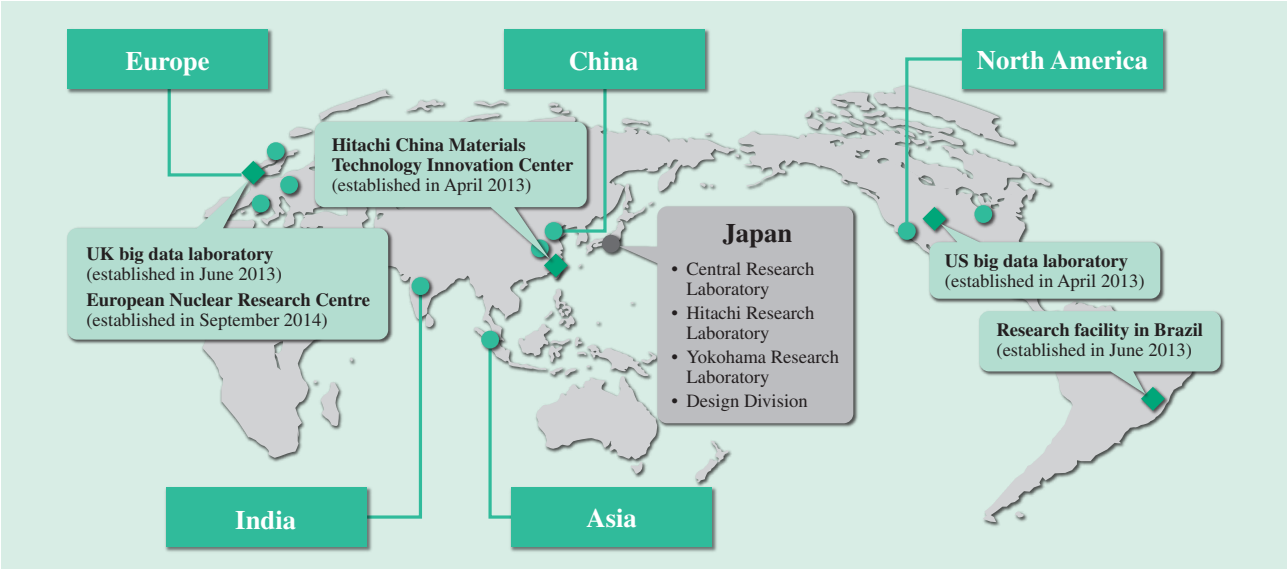

Fig. 2—Expansion of Global R&D Facilities.
Hitachi intends to strengthen locally based R&D by expanding its overseas facilities in terms of geographical, quantitative, and qualitative aspects.

University. The second and third are the establishment of a big data laboratory at the US R&D facility in April 2013 and another at the European R&D facility in June 2013. These laboratories will work closely with research teams in Japan and elsewhere to develop technology analyzing large quantities of data and supplying solutions based on the results of this analysis. The fourth is the establishment of the European Nuclear Research Centre at the European R&D facility in September 2014. This laboratory will work on the development of safe and highly efficient nuclear power technology including preventive maintenance technologies for advanced plants in Europe and proven reactor abolishment technology for nuclear power facilities.

The qualitative aspect of the expansion involves the appointment of more local staff in place of the practice in the past which has been for most overseas facility and laboratory leaders to have been seconded from Japan. The aim is to achieve a major expansion in the Social Innovation Business in global markets by more tightly aligning R&D activities at overseas facilities with their local environment. Local staff were appointed as facility leaders in April 2014. Also, strategy implementation was expedited across all aspects of global R&D, with numerous measures being adopted to achieve tighter coordination of technology strategies between overseas facilities and R&D groups.

Shift in R&D Topics

Hitachi is focusing on the following priorities to shift its R&D resources toward those topics that are most important to the Social Innovation Business.

For markets served by the Infrastructure Systems Group, Hitachi is focusing on innovative technical developments in such fields as transportation and water treatment. These are both examples of infrastructure that existed in ancient Rome, from where the term social infrastructure derives. In the transportation sector, for example, Hitachi is seeking to expand its railway business in Europe by working on technology developments primarily associated with achieving certification for its railway signal system, including obtaining SIL4[(b)], the highest safety rating under the Euro safety standard, and assessing the safety of rolling stock with respect to cross winds in accordance with the European standard.

(b) SIL4
An abbreviation of "safety integrity level," SIL is a measure of safety level specified in the IEC 61508 international standard for functional safety based on the magnitude of risks posed by plants or other systems. SIL4 represents the highest of the four safety levels.

For markets served by the Information & Telecommunication Systems Group, Hitachi is focusing on the development of innovative technologies such as cloud computing, networks, and big data. In the case of cloud computing, in particular, this includes the research and development of advanced technologies for improving the reliability, boosting the speed, and reducing the cost of cloud systems, for example, among them the world's fastest mid-range storage systems; flash memory control techniques; technologies for integrating servers, storage, networks, and operation management software to dramatically shorten the time taken to deploy virtual servers; and technologies for the distributed operation of data processing nodes at data centers. Research and development of big data includes an ultra-high-speed database engine and analysis and processing services for data on human behavior (human big data) to solve business problems faced by customers.

For markets served by the Power Systems Group, Hitachi is working on developing innovative technologies that include, for example, the detection of radioactive materials, absorbents for radioactive materials, and an underwater "shape deformation" robot for narrow part investigation for use in the cleanup at the Fukushima Daiichi Nuclear Power Station of the Tokyo Electric Power Co., Inc. They also include control techniques for ensuring stability on grids with a large installed capacity of renewable energy, large electrical storage systems for installation at power plants that use renewable energy, and high-capacity lithium-ion batteries and lead-acid batteries for use by such systems.

For markets served by the Healthcare Group, Hitachi is focusing on the development of innovative technologies to satisfy needs throughout the care cycle, including healthcare IT, medical equipment, and solutions for hospitals. In the fields of prevention and examination, Hitachi is working on researching and developing services that utilize big data analytics for preventing lifestyle diseases. For testing and diagnosis, examples include ultrasound diagnostic equipment and associated diagnostic applications for the early detection of heart disease, and magnetic resonance imaging (MRI) scanners and associated measurement applications that assist with the treatment of neurodegenerative disease through the differential diagnosis of early-stage brain disease. For treatment, examples include Hitachi's long-time involvement in the research and development of cancer therapy equipment that uses particle beams

and automated cell culture equipment for regenerative medicine.

Hitachi Business Infrastructure R&D

Hitachi has embarked on the group-wide Hitachi Smart Transformation Project aimed at transforming the infrastructure of its business to make it optimally suited to the global operations of its Social Innovation Business. Along with their own internal reforms, the R&D divisions are also working on developing technologies that can bring benefits to operations throughout Hitachi.

To reduce direct material costs, for example, which account for the bulk of product costs, Hitachi is working on developing alternative materials that can eliminate the need for rare metals. This work has already produced high-performance electric motors that can achieve equivalent performance despite not using rare metals. These feature a new electromagnet and mechanical design comprising an amorphous(c) stator and permanent magnet rotor, and a technique for speed control without using an angle sensor. Hitachi has also developed new materials for joints in electrical and electronic circuits, including low-melting Vanadate glasses that have a similar soldering temperature to gold-tin solders, but at only one-fifth the cost.

Production accounts for the next largest proportion of product costs. To improve production costs, Hitachi is undertaking R&D on the optimization of global supply chains, for example. This involves working on R&D that considers a variety of factors, ranging from the characteristics of production line design to the tariffs imposed by nations along the chain in particular, and that seeks to optimize everything from suppliers to transportation routes and methods, as well as the location of overseas warehouses and other sites. Hitachi is also developing advanced computer simulation techniques to reduce the number of product prototypes significantly. Simulations that take advantage of the latest information processing have already achieved notable results in reducing the production costs of fluid machinery in particular, including double-suction centrifugal pumps or scroll compressors and fans for air conditioning.

(c) Amorphous
A non-crystalline material with a structure that, like a liquid, is not periodic. An amorphous metal is a solid formed by the rapid cooling of certain alloys from the molten state such that, like a liquid, it does not adopt a crystalline structure. As amorphous metals have lower energy losses than the electrical steel sheet used in motors in the past, their use in motor cores can significantly improve efficiency.

Open Innovation

Hitachi's R&D strategy involves strengthening links with external customers, technology partners, and society through open innovation.

As noted at the beginning of this article, interaction with customers is the basis of the Social Innovation Business. The European Rail Research Centre located in Hitachi's European R&D facilities, for example, has incorporated knowledge of the issues faced by European customers, which are different to those in Japan, into technology development from an early stage. Hitachi has also undertaken a joint experiment with King Abdulaziz University in the Kingdom of Saudi Arabia on water quality monitoring in that nation. It is also researching advanced information and communication technology (ICT) integration platforms for electric vehicles together with 13 partners, including European automobile manufacturers.

To respond to the diverse challenges faced by customers, it is important that Hitachi works with technology partners as well as on its own in-house technology development. For example, the European R&D facility is collaborating with the Cavendish Laboratory at the University of Cambridge in the UK to strengthen basic research. Hitachi is also working with Hokkaido University on particle beam cancer therapy systems and with the Institute of Physical and Chemical Research (RIKEN) on holographic electron microscopes(d) with atomic resolution.

In addition to these specific collaborations, Hitachi has also been working to bring about major innovations in society in cooperation with government innovation policies, including through the activities of the Council for Science, Technology and Innovation of the Cabinet Office.

Hitachi established a research section in 1918, the first such independent research organization, eight years after the company was founded. This was accompanied by the first publication of *Hitachi Hyoron*. The first edition stated the founding principle of the publication to be achieving innovation through the open publication of information in order to "reach a genuine consensus between producers and

(d) Holographic electron microscopes
Also called an electron interference microscope. A microscope that uses electron beam interference to measure phase changes in a material. It can measure not only the three-dimensional topography of a material surface but also atomic-scale electric and magnetic fields by using an image sensor or similar to record the pattern formed by interference between electrons that have passed through the material and the incident beam from the electron source, and then subjecting this to image processing.

consumers." Now, 96 years later, this remains the core principle of *Hitachi Hyoron*. Beyond this, it has also been adopted as an important business principle underlying Hitachi's latest mid-term plan. As the most upstream part of a "producer" organization, measures aimed at achieving a "genuine consensus" with "consumers" are at the heart of Hitachi's strategy for R&D.

KEY R&D POLICIES FOR FY2014

To achieve this mid-term plan, Hitachi has identified the following four key strategies for FY2014.

Shift to a Customer-driven Research Approach

Hitachi is placing greater emphasis on three approaches in particular to make its R&D divisions more customer-driven, this being the basis of its Social Innovation Business (see Fig. 3).

The first is ethnographic(e) research. This is a technique whereby researchers observe the workplace to identify customers' latent needs and underlying challenges. It has already been used to identify workplace efficiency measures for rolling stock maintenance in the UK. Approaches based on this technique have already been tried in such workplaces as data centers and a factory that produces particle beam therapy systems in North America; construction machinery maintenance in Australia and the Republic of South Africa; and a software development center in China.

The second is the experience-oriented approach(f). This is used in the planning stages of system development to ensure system requirements development is undertaken in the best way possible by having the people involved learn and share information about the problems faced by an activity or service, and their solutions. Having already utilized it in several dozen projects involving customer activities such as sales, sales agencies, reception desks, call centers, and maintenance and operation, Hitachi intends to further extend this technique.

The third approach is "vision design." This technique is used to identify future challenges for society and then to paint a detailed picture, from a consumer's perspective, of what society would be like after overcoming these challenges. Called the "Kizashi Project," it has already been deployed in Japan and the Republic of Indonesia, with plans in the near future for its use in the prediction of future trends in Brazil in collaboration with the University of Campinas, as noted earlier.

(e) Ethnography
Originally used in fields such as anthropology and sociology, ethnography is a methodology for conducting field work to survey and record the behavior patterns of a society or other group. The term is also used for survey documentation. It has been increasingly used by corporations in recent years to study consumers. Unlike statistical or quantitative analyses such as questionnaires, it is characterized by qualitative analysis using techniques such as interviews or observation.

(f) Experience-oriented approach
The experience-oriented approach is a new system development technique proprietary to Hitachi for working together with the customers who use IT to generate "experiences" (human experience values such as delight, impressions, or intellectual gratification) and share "impressions" during the progress of a project.

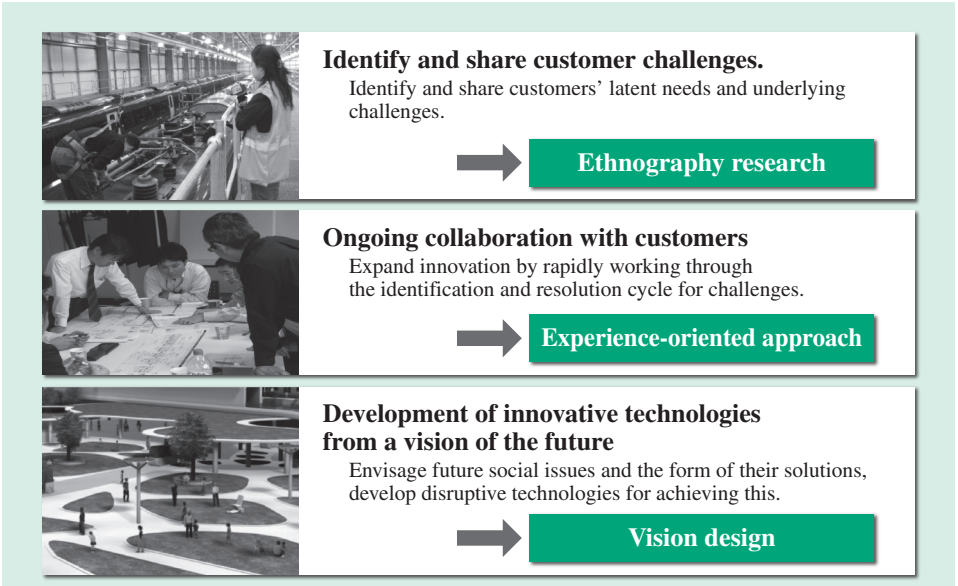

Fig. 3—Customer-driven Approach to Research.
Because a policy of working with customers to identify challenges is important to the Social Innovation Business, Hitachi is placing greater emphasis on its three "research approaches" of ethnographic research, the experience-oriented approach, and vision design.

Expansion of Service Businesses

Hitachi is seeking to expand its service businesses to bring about early-stage innovation with reference to the challenges and other needs identified by adopting a customer-driven approach. To lead this process, R&D at Hitachi is expediting the development of service platforms that utilize such technologies as the cloud or big data, and work aimed at supporting the specific services described below that operate on these platforms.

In the healthcare business, Hitachi is leading the health management service business for health insurers by using big data from the 110,000 people enrolled in Hitachi's health insurance program to study the progression of lifestyle-related and other diseases. Hitachi is also strengthening R&D that provides direction for construction machinery operation and maintenance services used by mining companies, and cybersecurity and physical security services for information and telecommunication businesses.

Strengthening of "Number One Product" Businesses

For product businesses that act as proprietary solution platforms, Hitachi is strengthening, in particular, further technical innovation in "number one products" and the creation of new "number one products" in the following fields.

For the healthcare business, Hitachi is strengthening development of superconducting MRI scanners with strong magnetic fields and particle beam cancer therapy systems. In the case of particle beam cancer therapy systems, Hitachi is engaging in joint development with the Graduate School of Medicine at Hokkaido University and other work under the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST) operated by the Cabinet Office's Council for Science and Technology Policy (as it was known in 2009), having already developed tumor-tracking(g) and spot scanning(h) precision treatment techniques, and with further technology enhancements in progress. Elsewhere, Hitachi is strengthening such technologies as the "remove technology of radioactive nuclide" and large offshore wind power generation for the power systems business; railway signal technology for Europe and a wind tunnel with the highest speed in Japan for the infrastructure systems business; flash modules and high-speed data access platforms for the information and telecommunication systems business; hybrid shovels for the construction machinery business; magnets that do not contain dysprosium for the high functional materials business; and automatic driving technologies for the automotive systems business.

(g) Tumor-tracking
A cyclical radiotherapy technique whereby a gold marker is implanted near a tumor and two X-ray fluoroscopes are used to detect its location and calculate it in three dimensions so that a particle beam can be applied at those instants when the marker is within a few millimeters of the intended location.

(h) Spot scanning
A technique for pinpoint irradiation in which the particle beam is scanned over the target area and applied one spot at a time. This allows the particle beam to be targeted with high accuracy to match the complex shape of the tumor.

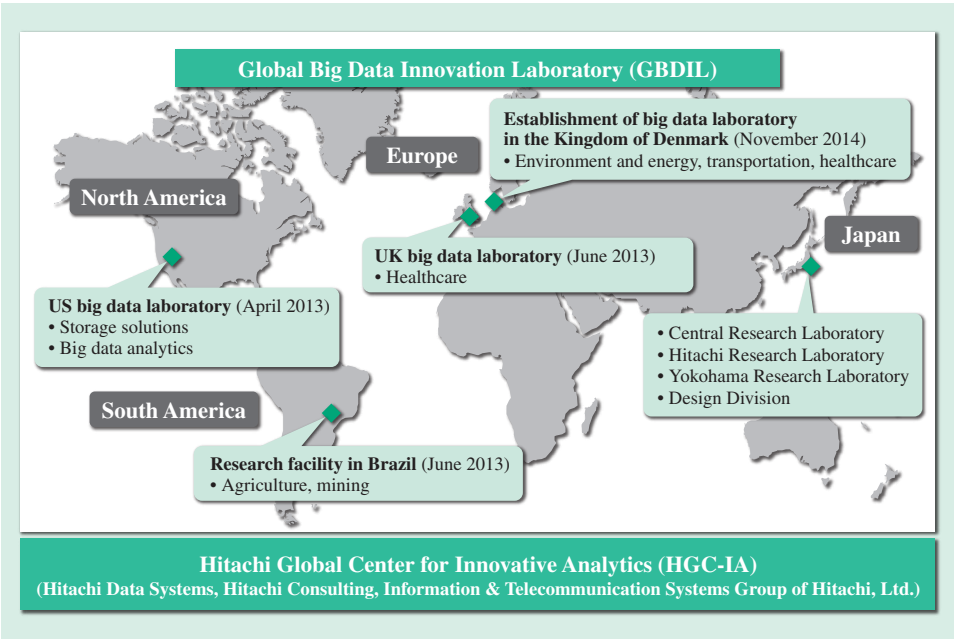

Fig. 4—Overseas Facilities for Big Data Research.
With the research and development associated with big data expected to expand in the future, Hitachi is establishing an organizational structure under which different facilities can work together around its core laboratory in the USA.

Contributing to Expansion of Overseas Business

The three main R&D policies for expanding Hitachi's overseas businesses are as follows.

The first is to build a global research network. In the case of big data in particular, Hitachi has established a structure whereby research facilities in Japan, Europe, Asia, India, Brazil, and elsewhere can work together based around its big data laboratory in the USA (see Fig. 4). In the case of automotive systems, research facilities in the USA, Japan, Europe, China, and elsewhere also work together on engine and chassis development, undertaking R&D that takes account of the different standards that apply in different countries.

The second policy is to build local value chains. In Europe, for example, Hitachi is seeking to establish an organizational structure that spans the entire local value chain, having set up facilities that include the European Rail Research Centre, the European Nuclear Research Centre, and a big data laboratory at the University of Manchester Innovation Centre.

The third policy is the global standardization of operations. For design work, Hitachi has utilized cloud computing to configure an environment under which facilities around the world can access a supercomputer in Japan. For materials procurement, R&D is working on things like materials analysis and production technology to increase the proportion of materials procured locally.

EXAMPLES OF INNOVATIVE R&D

The subject of this issue of *Hitachi Review* is innovative R&D. The seven articles described below provide examples. These articles correspond to the key FY2014 policies for R&D described above.

The first three articles deal with the shift to a customer-driven approach to research. The article entitled "Design Approach based on Social Science for Social Innovation Business" provides a detailed explanation of the ethnographic research, the experience-oriented approach, and vision design referred to above as key policies for customer-driven research. The article, "Concept of Energy Efficient Datacenter in ASEAN Region" has as its starting point customers who, unlike those in Japan, are based in a subtropical climate, describing technology for maximizing the efficiency of data center energy use in such a climate. "Combustion Analysis Techniques for Development of Next-generation Engine Systems" describes technology for designing components and control techniques that are optimal for customers, involving the detailed analysis of the physical phenomena that occur inside an engine.

The next two articles deal with the expansion of service businesses. "Privacy-preserving Analysis Technique for Secure, Cloud-based Big Data Analytics" describes a technology for analyzing customer data in encrypted form. This makes it possible to outsource certain statistical processing to a big data analytics service without divulging the content of the data being processed. "High-definition 3D Image Processing Technology for Ultrasound Diagnostic Scanners—Realistic 3D Fetal Imaging—" describes technology for the ultrasound diagnostic equipment used in obstetrics that provides the basis for a service that provides pregnant women and their families with three-dimensional (3D) fetal images.

The final two articles deal with the strengthening of "number one" product businesses. "First-principles Materials-simulation Technology" describes technology that guides and assists the development of functional materials through the precise analysis of the electronic states of materials. This work is contributing to the development of new materials such as light sources for use in devices that combine photonics and electronics, and magnets that are able to operate at high temperatures. "Light Water Reactor System Designed to Minimize Environmental Burden of Radioactive Waste" describes a nuclear reactor that can burn up the long-lived radioactive waste produced by nuclear power generation as fuel. This dramatically reduces the quantity of long-lived radioactive waste.

All of the technologies described in these articles directly or indirectly contribute to the expansion of Hitachi's overseas business.

POSITIONING FOR THE FUTURE

This article has focused on describing the R&D that is leading Hitachi's 2015 Mid-term Management Plan, with the primary mission of R&D being to lead the future growth of Hitachi over the longer term. In terms of basic research aimed at the further growth of Hitachi that will trigger a paradigm shift, Hitachi is primarily working on human-centered science, life science, information science, and extreme physics. Human-centered science is being approached both from the direction of analyzing such things as brain activity and human behavior, and from the direction of real-world actions performed by artificial intelligence, robots, or

other machines[1]. In life science, Hitachi continues to work in such fields as regenerative medicine and single-cell genome analysis. In information science, Hitachi is working on leading-edge research into building silicon devices that can implement qubits (quantum bits), the core of a quantum computer, and also into information storage and telecommunications. Work in extreme physics includes an electron microscope with atomic resolution, advanced techniques for simulating physical phenomena, and the development of associated theories.

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