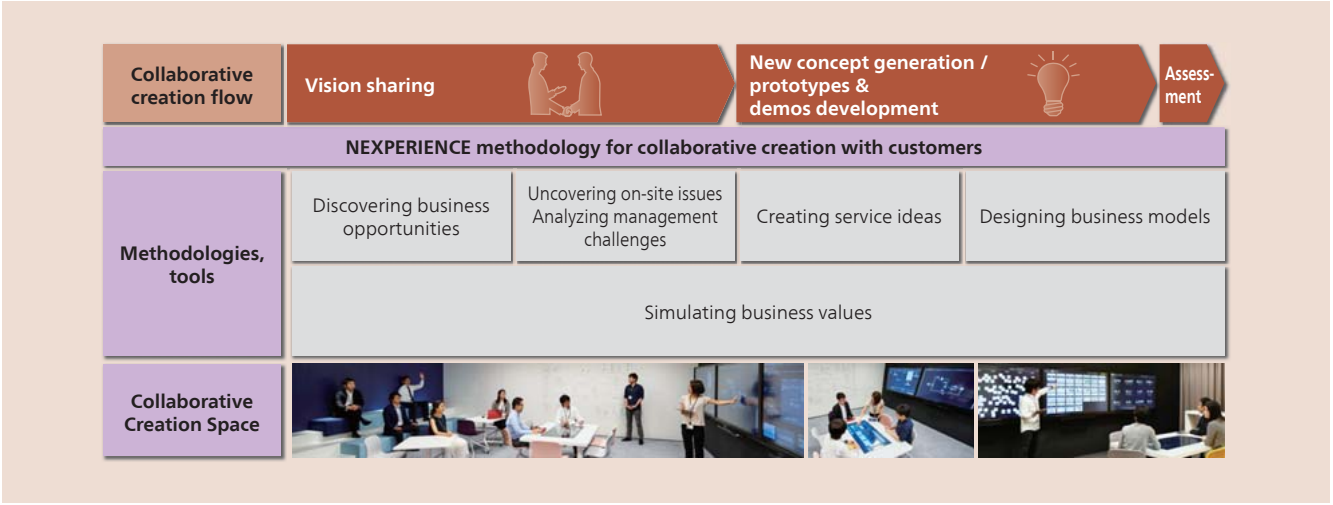
Collaborative Creation with Customers



1 Methodologies, tools, and Collaborative Creation Space that form part of the NEXPERIENCE collaborative creation methodology

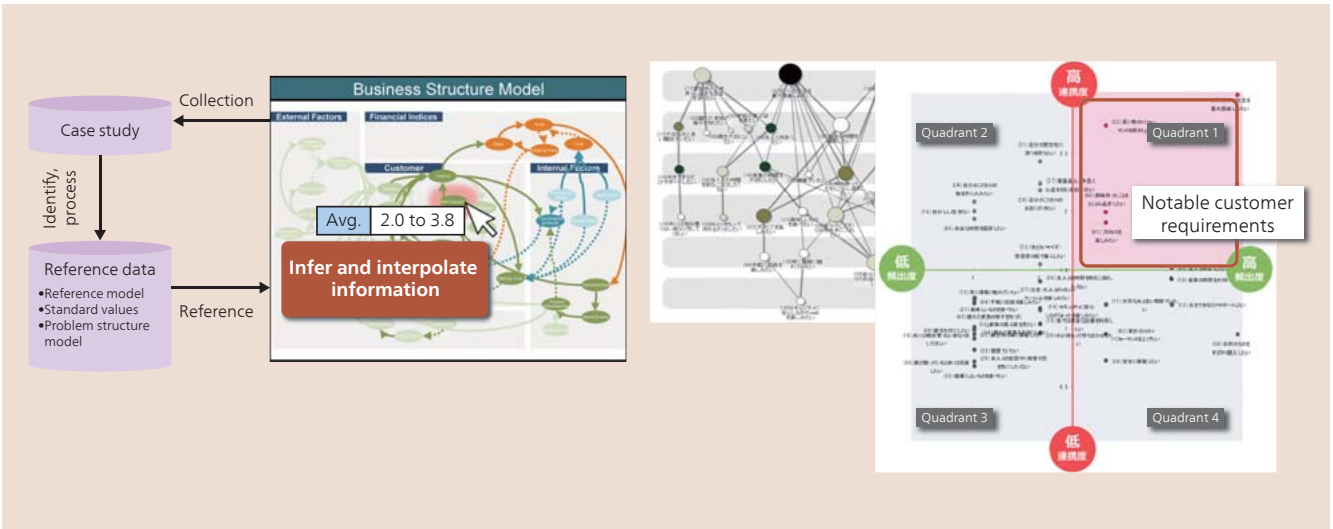
1 Collaborative Creation with Customers Establishment of NEXPERIENCE

The transformation of manufacturing into a service industry is growing. In its Social Innovation Business, Hitachi is required to create acceptable service businesses by analyzing and evaluating the profitability and feasibility of multiple stakeholders. However, a holistic investigation of complex issues is difficult with conventional methodologies and tools.

Therefore, NEXPERIENCE has been systematized and information technology (IT) tools have been developed to conduct collaborative creation for service businesses while visualizing ideas in multiple perspectives based on knowledge from customers and partners.

NEXPERIENCE covers a wide range of phases from discovering business opportunities and designing business models, to simulating business value in order to satisfy customers' goals. And Hitachi has built the Collaborative Creation Space in Akasaka (Tokyo) that supports NEXPERIENCE activities. Through methodologies, tools, and a Collaborative Creation Space that promote a series of collaborative creations, it is capable of accelerating the Social Innovation Business and increasing the ratio of promising service businesses by carrying out intensive and high-quality discussions in a short period of time.

It is essential to increase the number of people able to use them, and apply them on actual business projects. Furthermore, expanding NEXPERIENCE to locations outside Japan has been planned to foster the Social Innovation Business globally.



2 Screens used for identifying business challenges and structured analysis of user requirements

2 Methods for Visualizing Customer Value from Individual and Management Perspectives

The era of the Internet of things (IoT) will make it possible to collect data from a wide variety of devices at a level of granularity that was inconceivable in the past, and many companies see this as increasing the scope for business improvement and new business opportunities. In this current period of transition, however, not only are there few cases in which sufficient data can be collected and stored to enable its use for management and business analysis, but workplace analysis is also made difficult by the complications of human factors, such as people's values and emotions, which are not available as electronic data. Whereas past practices have included workplace analysis techniques for observing business workplaces and identifying the sort of problems that are otherwise prone to being overlooked, as well as methods for the visualization of issues in all parts of the organization and their impact on operations, the burden that this data collection places on the customer is a problem.

In response, Hitachi has developed and implemented a method for identifying business challenges that facilitates the obtaining of information about business conditions from the customer, even from a limited amount of information, and a structured analysis method for user requirements that uses questionnaires as a basis for collating customer requirements and identifying which requirements have the highest priority.

In the future, Hitachi intends to further enhance practices for the collaborative creation of services and other solutions that satisfy customers from the perspectives of both workers and management.

3 Collaborative Creation with Customers of Smart Branch Solution for Banks

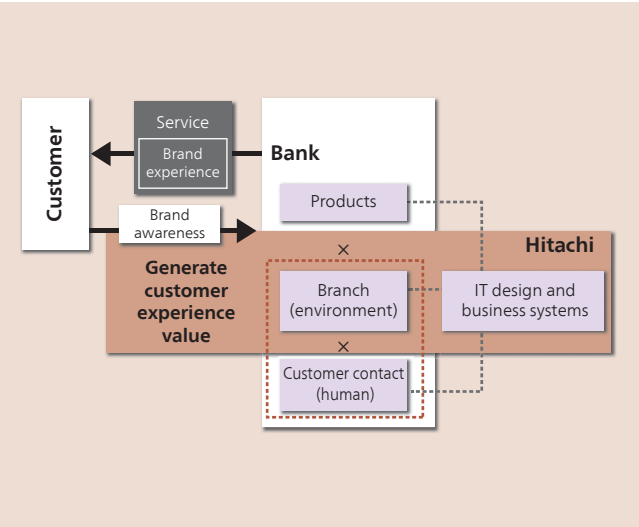
Along with the growth of "Internet finance," the banking industry is under pressure from the increasing pace at which the industry is opening up and interest rates are being deregulated. Banks have come to place an emphasis on using business innovation to improve customer service and profitability. Working with partners in the finance sector in China, Hitachi has developed a smart branch solution for banks through joint innovation with its customers in the industry.

The solution utilizes branch design and an IT solution to provide self-service tools, security plans, and precision marketing plans. In addition to improving the bank's brand image, the efficiency of branch (outlet) operation, and marketing, these features also increase customer satisfaction.

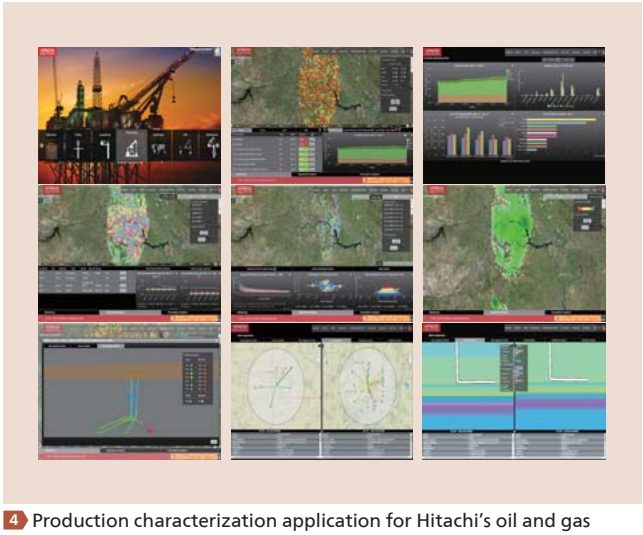
4 Customer Collaborative Creation Activities at Digital Oil Field

Disruptive innovation in an unconventional oil and gas industry such as the shale industry offers a promise to change the world's economies. Advances in technologies including horizontal directional drilling and hydraulic fracturing technologies have fueled growth in the industry. However, oil and gas industry operators are facing tough business challenges. Shale sub-surface geology presents challenges in terms of proper characterization. Operators want to maximize production output from their acreage through assembly-scale operations. The orthodox approach of modeling the shale upstream operations has proven inadequate. Big data technologies can augment traditional methods in developing a deep understanding of the shale oil and gas operations to address the challenges faced by operators in a holistic way.

Hitachi has evolved an approach to prioritizing and understanding such customer challenges through voice-of-customer surveys. Collaboratively creating and collaboratively evolving the lifecycle of the solution with customers as the focus has been championed by Hitachi's oil and gas analytics technology. Hitachi's oil and gas analytics solution is uniquely positioned to address the ability to incorporate data from across the entire suite of upstream processes and provide a full suite of descriptive, predictive and prescriptive analytics to its customers. The robust architecture allows scalable solutions to be deployed securely. Working closely with Hitachi's partners and business units, Hitachi's Big Data Laboratories are rapidly furthering the development of Hitachi's oil and gas analytics solution as well as engaging multiple customers to enhance the solution.



3 Concept behind smart branch solution for banks



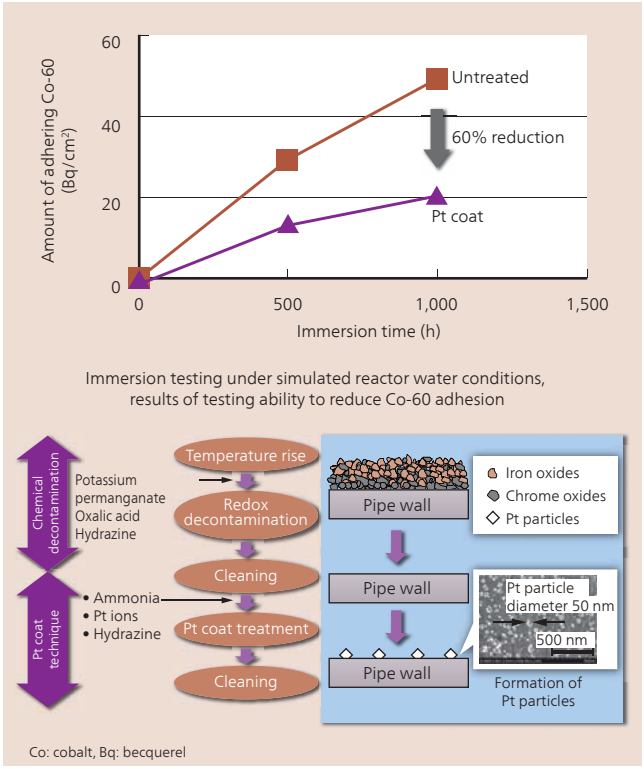
4 Production characterization application for Hitachi's oil and gas analytics solution

Technology Innovation

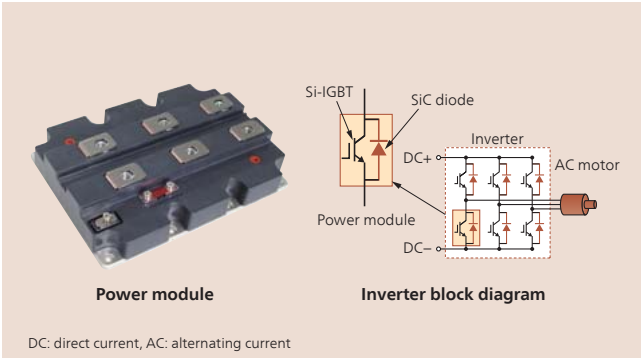
1 Pt Coat: Pt Coating Technique for Inner Surface of Pipes at Nuclear Power Plants

Reducing worker exposure to radiation is one of the obligations of a nuclear power plant. The formation of an oxide layer on the inner surface of the pipes that circulate hot reactor water can trap radioactivity from the water, resulting in the emission of radiation from the pipes. The practice adopted in response to this is to use chemical decontamination to remove this layer prior to major maintenance work. Unfortunately, because the oxide layer reforms and the radiation level around a pipe rises once more after operation resumes following chemical decontamination, the decontamination process needs to be repeated. A study into techniques for slowing the formation of the oxide layer to reduce the frequency of decontamination found that tiny particles of platinum (Pt) acted as a catalyst for dissolving the oxides. Accordingly, Hitachi has developed Pt coat, a technique for coating the inner surface of pipes with these Pt particles prior to restarting operation after decontamination. Laboratory testing demonstrated a reduction in the adhesion of radioactivity, and the practical viability of Pt coat was confirmed in a 1:20 scale model.

In the future, Hitachi intends to help reduce worker exposure to radiation by deploying the technique in actual plants.



1 Results of testing to demonstrate the ability of Pt coat to reduce the adhesion of radioactivity (top) and overview of Pt coat treatment procedure (bottom)



2 3.3-kV/1,800-V SiC/Si hybrid power module

2 3.3-kV/1,800-A Hybrid Power Module for Rolling Stock

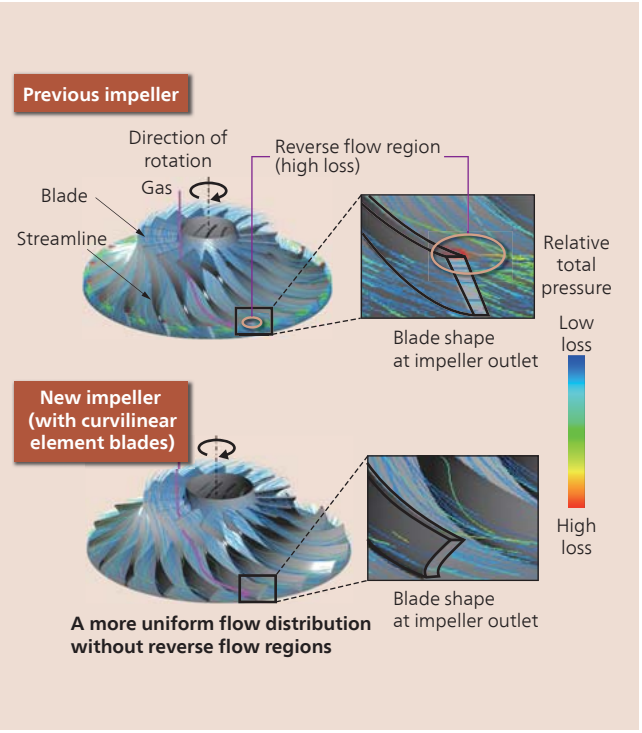
Hitachi has developed a heavy duty 3.3-kV power module for rolling stock that uses silicon carbide (SiC) semiconductor devices. Power modules are used as components in electric power conversion systems such as inverters. Conventionally, they have been built using insulated-gate bipolar transistor (IGBT) and diode switching devices made from a silicon (Si) semiconductor.

Hitachi jointly developed SiC diodes rated for 3.3 kV with Hitachi Power Semiconductor Device, Ltd. and used them to build a SiC/Si hybrid power module. As SiC/Si power module is lower energy loss compared to Si power module, it can carry a heavier current density with minimal heat generation. This made it possible for a 1,800-A module to have the same size as a previous 1,500-A module (20% improvement). It has also halved switching losses compared to inverters built using previous Si modules. Use of these technologies has succeeded in providing highly efficient motor control together with an approximate 40% reduction in power use by rolling stock compared to previous models.

3 Curvilinear Element Blade Design Technique for More Efficient Centrifugal Compressors

Improvements to the efficiency of the centrifugal compressors used in industrial plants to pressurize and pump gas are needed to cut operating costs. The key components of a centrifugal compressor are its impeller blades. Hitachi has developed a design technique for improving efficiency by stabilizing the flow through the impeller blades up to the point where flow separation occurs.

The technique combines a multi-objective optimization algorithm capable of optimizing a large number of design parameters at high speed with a method for defining curvilinear element blade shapes in centrifugal turbomachinery that uses only 10 parameters and provides detailed control of blade surface



3 Comparison of streamlines in impeller and blade shape at impeller outlet

curvature. This combination enables the rapid design of highly efficient blade shapes that minimize reverse flow through the impeller blades.

This has resulted in the development of centrifugal compressors with curvilinear element blades that have 2.4% higher efficiency than previous models.

Hitachi plans to apply the technology for a wide range of different centrifugal compressors in the future.

4 Use of X-ray Phase Imaging for Realtime Analysis of Ion Concentration during Charging and Discharging of Lithium-ion Batteries

Hitachi has developed a technique for the realtime analysis of the distribution of electrolyte ion concentration during charging and discharging of lithium-ion batteries. The technique uses X-ray phase imaging, an effective imaging technique for light elements that uses phase changes to measure the distribution of ion concentration in the electrolyte resulting from the flow of lithium ions during charging or discharging. The measurements found that the distribution of ion concentration in the electrolyte sandwiched between the cathode and anode is inclined toward the cathode while charging, and that this non-uniformity does not immediately disappear after charging is complete. While a lack of appropriate design methods in the past has made the dynamic behavior of ions in the electrolyte during charging and discharging an entirely "black box" process, the knowledge of the associated inclining of the ion concentration distribution obtained by these measurements will be important for the development of batteries for automotive applications that feature repeated rapid charging and discharging.

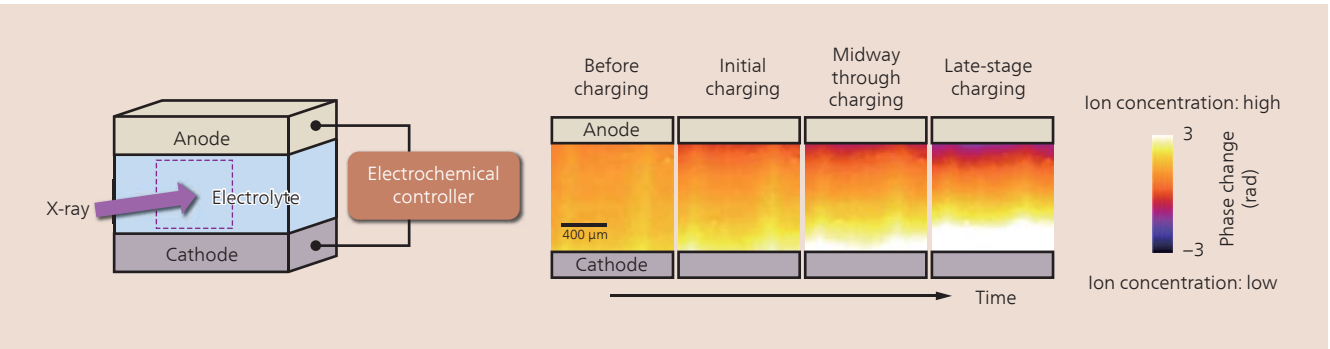
In the future, Hitachi intends to use the technique to help develop high-output batteries by analyzing the movement of ions in lead-acid batteries as well as lithium-ion batteries.

5 Platform Technology for Realtime Data Analysis for the Internet of Things

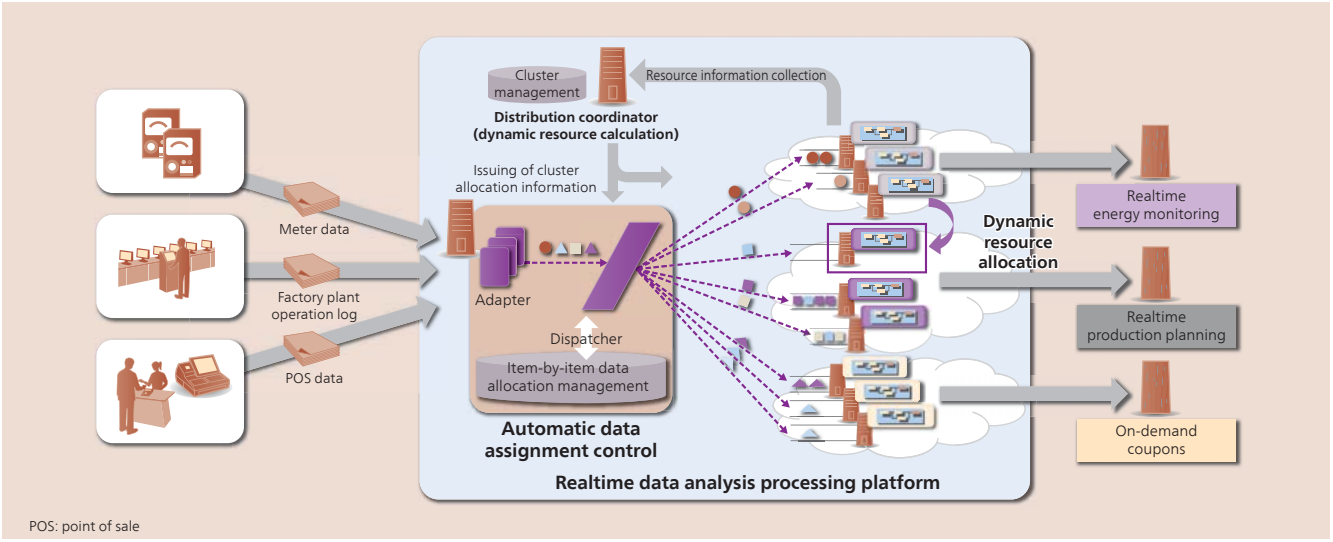
The growing uses in business for data from the Internet of things (IoT), such as sensors and other devices, are creating increased demand for a focus on individual movements and the realtime analysis of data to prompt business actions. Along with business changes that occur on a daily basis, realtime data analysis is subject to frequent changes to the processing design (the quantity and type of data collected and the modification or augmentation of analyses) and to system resources in response to the processing requirements. However, because the required resources and data allocation for individual items are complicated by increases in data and processing workloads, making rapid changes to system resources is difficult.

In response, Hitachi has developed a platform technology for realtime IoT data analysis that dynamically calculates server resources based on the level of load, such as the quantity of data held for each analysis, and automatically determines where to assign the data for each item based on the extent to which allocated resources are being used. The technology automates resource allocation and data assignment in the system design (which is more complex) in accordance with the processing requirements, and makes it easy to expand the system by adding servers.

In the future, Hitachi aims to implement solutions that speed up every step along the value chain from processing design to system configuration by developing modeling design methods that use flowchart representations to facilitate changes to the analysis as well as system expansion.



4 Use of X-ray phase imaging for realtime analysis of ion concentration



5 Realtime data analysis platform

6 UPS for Long-duration Backup with Hot Swapping of Batteries

The progress of the information society has increased the importance of ensuring that information technology (IT) equipment has a reliable supply of electric power. There is demand for uninterruptible power systems (UPSs) that prevent loss of data from power outages to deliver higher reliability and longer backup times. Responding to these demands requires the development of highly reliable UPSs that allow batteries to be replaced without halting the supply of electric power (hot swapping).

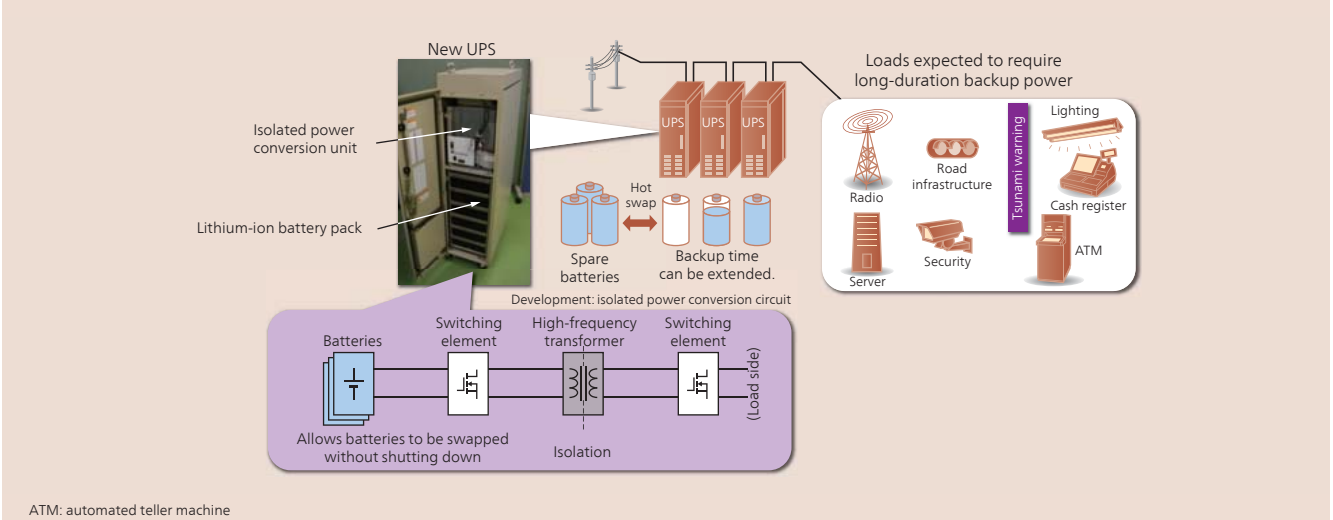
Hitachi has recently developed a UPS that uses an isolated power conversion technique to isolate the mains power grid and batteries from each other. The isolated power conversion circuit achieves its hot swapping capability by using a high-frequency transformer and incorporating a control algorithm for initiating battery discharge as soon as a power outage occurs. By using a number of UPSs to supply power in turn, the backup power supply can be maintained for a long period of time by progressively swapping batteries.

In the future, Hitachi intends to utilize the features of the new isolated-battery UPS to deploy it in applications such as commercial buildings or for wireless base stations and other communication infrastructure.

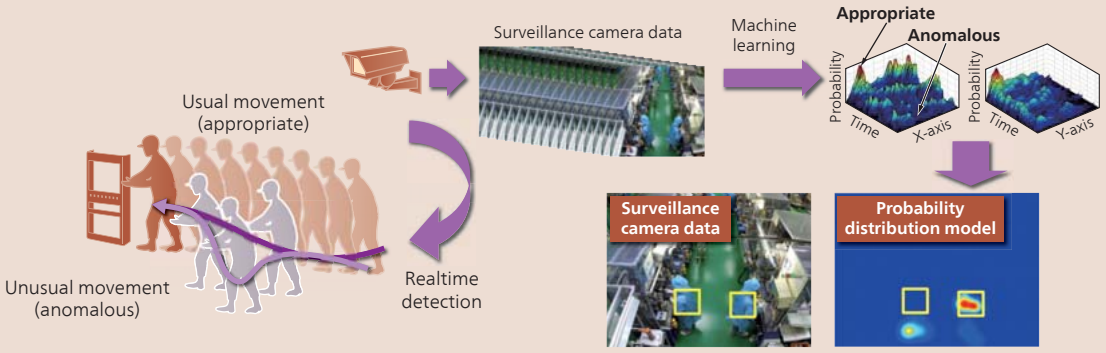
7 Worker Activity Monitoring and Anomaly Detection Technique Based on Big Data Analysis of Surveillance Camera Data

The growing use of close-to-market production means that improving the quality of locally produced products has become an urgent challenge. In particular, there are concerns about the thoroughness of education, instruction, and monitoring of workers at assembly plants in emerging economies where use of manual labor to minimize capital expenditures is common practice.

In response, Hitachi has developed an anomaly detection technique for monitoring work-flow-line and movement of assembly workers with the aim of preventing the outflow of defects caused by work. The technique uses statistical analysis to generate a probabilistic model of appropriate worker movements based on big data from assembly work captured on camera, and then uses this model to detect anomalous work in realtime. In



6 Long-duration UPS that enables hot swapping of batteries



Work anomalies are detected by comparing worker location against a probability distribution.

7 Concept behind technique for worker activity monitoring and anomaly detection

addition to providing the detection results to workers and supervisors as feedback, they are also utilized in analyses that include product quality data to help improve the quality of local products.

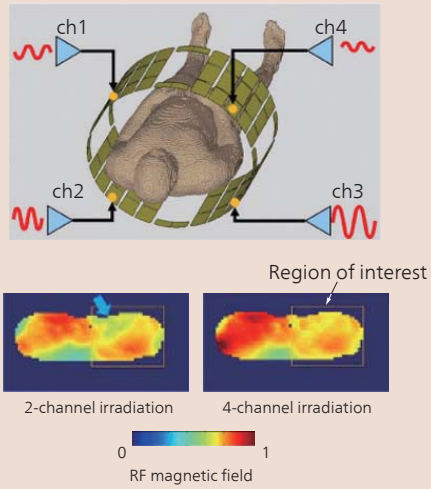
Along with extending use of the technique to in-house manufacturing divisions in the future, Hitachi also intends to commercialize it in the form of a product quality cloud service for external customers in the automotive, precision machinery, and other industries.

8 RF Transmission for High-magnetic-field MRI with Four Independent Channels

Higher magnetic field strengths have been a feature of magnetic resonance imaging (MRI) system development over recent years. The improved image signal-to-noise (SN) ratio on MRI system with a field strength as high as 3 T has the potential to provide better image quality and a wider range of functions. However, because the radio frequency (RF) is proportional to the magnetic field strength, this brings problems such as image distortion due to poor uniformity in the RF magnetic field distribution, and an increase in the specific absorption rate (SAR) (a measure of how much RF is absorbed by the body).

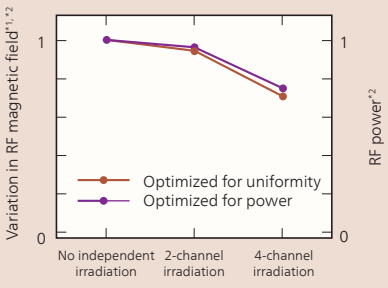
To overcome these problems, Hitachi has developed a technique for RF transmission with four independent channels. It features independent control of the amplitude and phase of the RF waveforms applied to each channel of the RF transmission coil. The technique improves the uniformity of the RF magnetic field in the region of interest. It also has the potential to reduce the SAR by reducing the transmitted RF power.

Hitachi intends to continue contributing to the development of core technologies for various types of imaging using high-magnetic-field MRI, including ongoing work on image evaluation.



Simulation of RF magnetic field distribution cross-section of shoulder joint and surrounding area. In a diagnostic scan of a shoulder joint, use of four channels improved the RF magnetic field strength in the region where it was low (indicated by blue arrow).

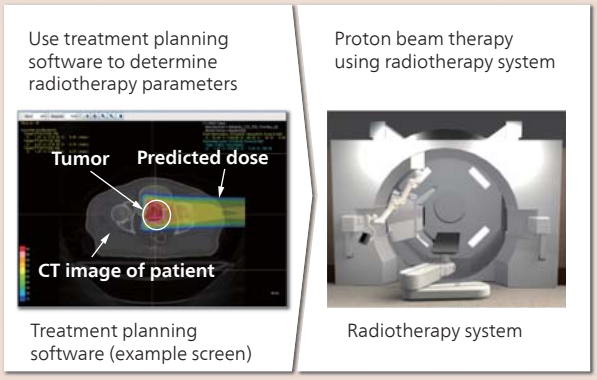
The system splits the RF transmission coil into four independent channels. The distribution of the RF magnetic field inside the body is controlled through independent control of the amplitude and phase of the RF waveforms sent to each channel. This provides greater flexibility in the generated RF pattern (combination of amplitude and phase) than the previous two-channel method.



Changing from two to four channels improves RF magnetic field uniformity and enables the power to be reduced.

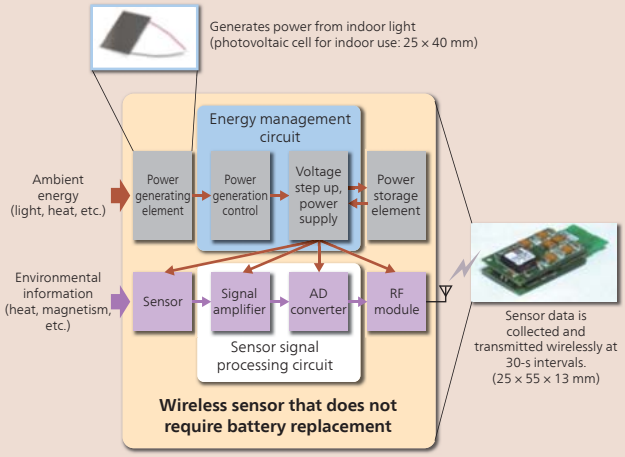
*1 Standard deviation/mean value of RF magnetic field
*2 Normalized, with variation when no independent control used = 1.0

8 RF transmission system with four independent channels



CT: computed tomography

9 Treatment planning software for proton beam therapy system



AD: analog-to-digital

10 Wireless sensor that does not require battery replacement

9 Faster Dose Distribution Calculation for Treatment Planning Software Used with Proton Beam Therapy System

Hitachi is able to provide precise radiotherapy thanks to the development of a technique that concentrates the dose on the tumor by scanning a narrow beam over its shape, and by combining it with a tumor-tracking technique that tracks the movement of the tumor during therapy. As the treatment planning system (TPS) software uses simulation to optimize the beam scanning path and dose, two important parameters for this scanning radiotherapy method, it requires accurate calculation of the dose distribution inside the patient's body. While the Monte Carlo (MC) method, which achieves precise calculation by simulating the behavior of individual proton beams, is one way to calculate the dose distribution, general-purpose MC tools are impractical for TPS use because they take several hours to complete the calculation for a single patient.

Hitachi has now developed a high-speed dose distribution calculation that uses an enhanced MC method. The new method shortens the calculation time to a few minutes without compromising accuracy by restricting the MC analysis to the scattering that determines accuracy, using modeling for other physical processes such as nuclear reactions. It will be incorporated into the TPS in the future.

10 Wireless Sensor that Uses Ambient Power to Eliminate Battery Replacement

The collection and use of sensing data have potential applications in overcoming a variety of societal problems. Unfortunately, battery replacement and other maintenance take a lot of work and are obstacles to the wider use of systems that collect data wirelessly from large numbers of installed sensors. In response, Hitachi has developed wireless sensors that can operate using the small amounts of energy available in the environment.

While solar-powered wireless sensors that do not require battery replacement are already available, they are restricted to outdoor use. By developing an ambient energy management circuit that can efficiently collect small amounts of energy from the environment and sensor signal processing circuits that operate on low levels of power without losing their high accuracy, Hitachi has made it possible to operate wireless sensors using indoor light (with only 1/500 the brightness of sunlight).

Hitachi has used the technology to build a prototype sensor for measuring the current drawn by industrial machinery and tested its ability to take measurements inside factories.

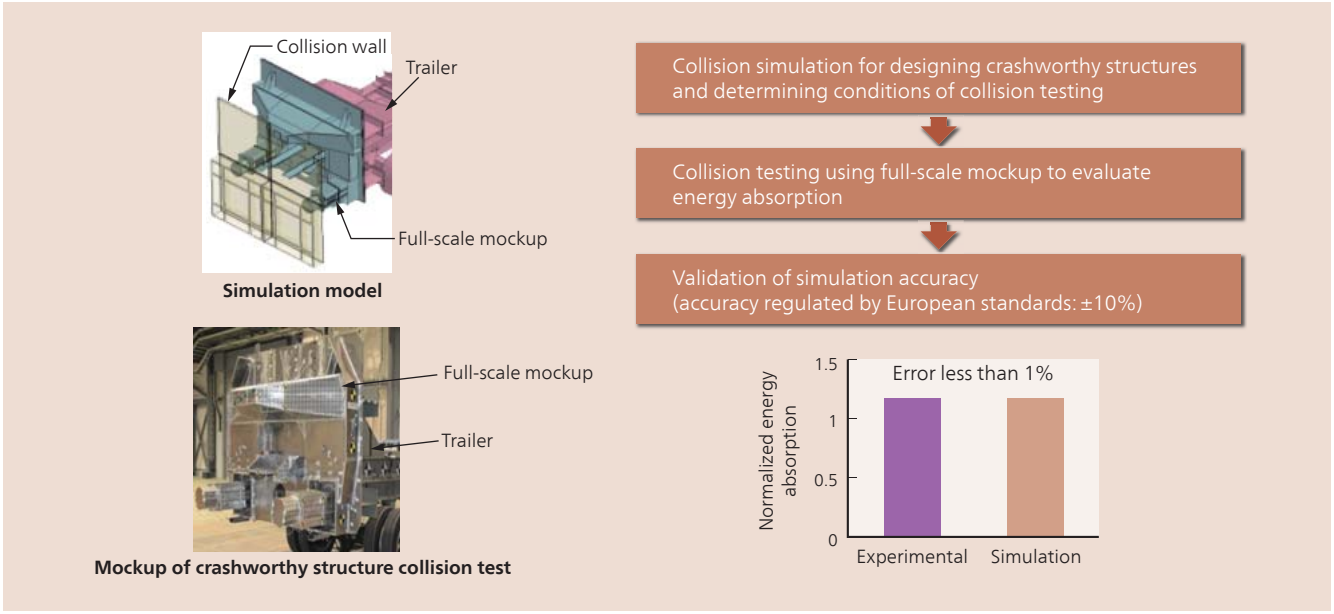
In the future, Hitachi intends to contribute to the provision of sensor solutions by utilizing the technology in applications such as the monitoring of industrial machinery and the use of beacons to monitor the movement of people.

This research was undertaken as part of a joint "The Sensor System Development Project to Solve Social Problems" by the New Energy and Industrial Technology Development Organization (NEDO).

11 Crashworthiness Assessment of Railway's Rolling Stock for Europe Using Full-scale Collision Test

In railway systems in Europe, a structure specified for absorbing collision energy by plastic deformation, called a "crashworthy structure," is deployed at the ends of the railway's rolling stock to comply with European standards that regulate the crashworthiness of rolling stock. For designing a crashworthy structure, the structural energy absorption must be evaluated by a collision test using a full-scale mockup of the crashworthy structure, and a collision simulation is required to validate its prediction accuracy with an error of less than 10%.

Accordingly, Hitachi developed a testing procedure in which the crashworthy structure is attached to a trailer and collided with a rigid wall, and also developed a collision simulation model that includes the test equipment. The collision simulation was performed prior to the testing to determine appropriate measurement points that would secure the collection of test data required to verify the simulation accuracy. Prediction accuracy with an error of less than 1% was validated with respect to energy absorption, which satisfied the accuracy regulated by European standards. It also succeeded in shortening the time taken for testing and reduced its cost by eliminating the need to repeat trial-



11 Use of full-scale collision testing to evaluate energy absorption performance

and-error testing.

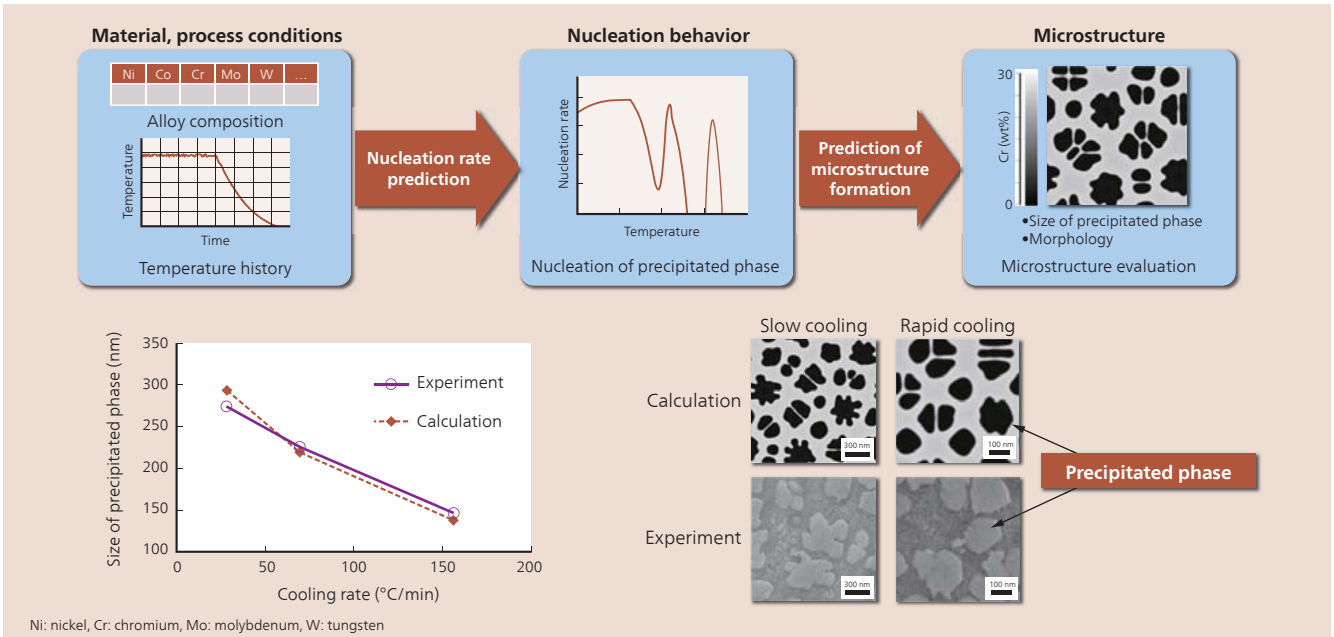
Hitachi is applying this testing method to the development of crashworthy structures of high-speed and commuter trains for Europe.

12 Microstructure Prediction Technique for Faster Alloy Design

As super heat-resistant alloys for use in turbines for aircraft engines or generators operate at high speed and are exposed to harsh environments with severe temperature changes, there is a need to improve their characteristics, including high temperature strength, creep strength, and low cycle fatigue strength. These characteristics are strongly correlated to the microstructure of the metal, as represented by parameters such as grain diameter and the size of precipitated phases. As microstructure varies significantly depending on factors such as material composition and manufacturing process, the design of alloys can be expedited considerably by using simulation to conduct preliminary studies prior to experimental testing.

The newly developed technique couples prediction of nucleation rate and microstructure formation to provide a visualization of the formation of the metal microstructure during heat treatment, something that is difficult to observe experimentally, enabling evaluation of factors such as the size and morphology of precipitated phases that influence mechanical properties. Calculations of precipitated phase size under different heat treatment conditions made using this technique agree with experiment to within 10%.

In the future, Hitachi intends to help shorten the time taken to design alloys by using microstructure parameters to predict mechanical properties.



Ni: nickel, Cr: chromium, Mo: molybdenum, W: tungsten

12 Method for predicting formation of microstructure under different heat treatment conditions

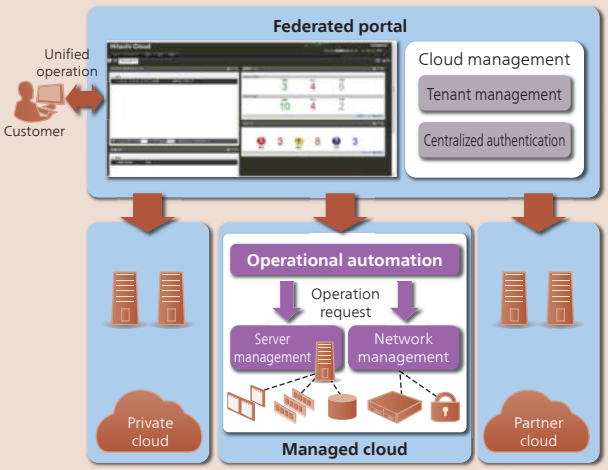
13 Next-generation Warehouse Incorporating AI and Robotics

Factors such as the expansion of the electronic commerce (EC) market on a global scale and more diverse consumer needs are making flexibility an important consideration for future distribution operations, along with efficiency. While there are problems with the flexibility of automated warehouses that use special-purpose equipment, placing an emphasis on manual labor limits efficiency.

In response, Hitachi has developed an artificial intelligence (AI) technique that provides both flexibility and efficiency by using big data collected from the workplace to control people and robots, and has set up a model for the warehouses of the future in collaboration with Hitachi Transport System, Ltd. This includes control techniques for manual work performed by an AI that updates its task model on a daily basis, control techniques for coordinating the work of people and automated guided vehicles, control techniques for autonomous mobile dual-arm robots that can perform picking in a similar manner to a person, and a cockpit that helps present details with an overview of operational and physical information for the large space controlled by these AIs and robots.

In the future, Hitachi intends to integrate these newly developed techniques to make further improvements to efficiency and flexibility, and to deploy them in other fields such as production and retail.

13 Operation of autonomous mobile dual-arm robot (top) and cockpit (bottom)



14 Overview of federated cloud technology

14 Technology for a Federated Cloud

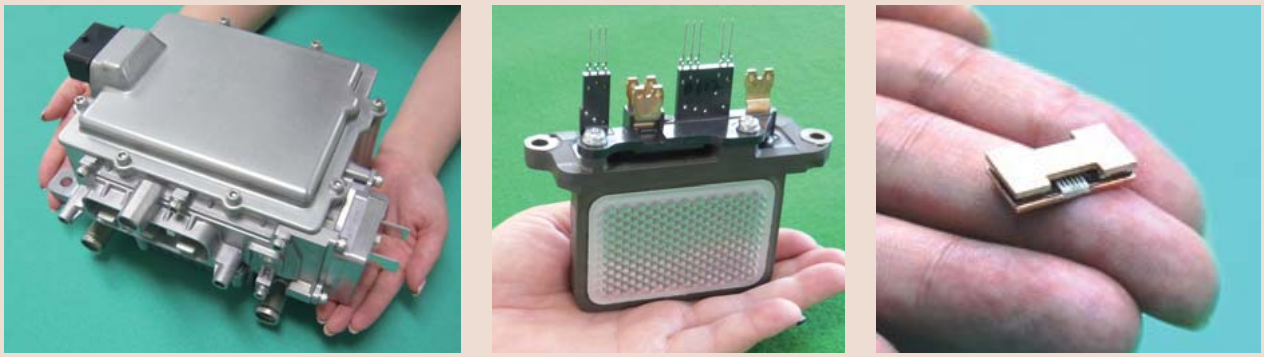
The use of various clouds provided by different cloud providers depending on customers' demands is becoming important for introducing cloud services in their business systems. For business systems that are dispersively built in multiple clouds, unified monitoring and management are required.

Hitachi has developed federated cloud technology that enables resources from the customer's private cloud, the managed cloud provided by Hitachi, and partner clouds such as that provided by Amazon Web Services to be logically partitioned and allocated for each customer system, with monitoring and administration of these resources by a single account. It also integrates with individual administrative functions, such as server and network management, to provide automatic allocation of server memory, disk, networking, and other resources required to configure business systems in response to customer resource operation requests entered via a federated portal. This significantly improves convenience by allowing the customer to monitor and modify the distributed servers that constitute a business system in a single pane view.

The new technology is applied to the federated cloud services provided by Information & Telecommunication Systems Company of Hitachi, Ltd.

15 Highly Efficient Inverter for Environmentally Conscious Vehicles Incorporating Full SiC Power Module with Double-sided Cooling

Environmental regulations that require a reduction in the emission of carbon dioxide (CO_2), nitrogen oxides, particulate matter, and other pollutants are being progressively tightened in the USA, Europe, and elsewhere, creating a demand for reducing the power consumption of hybrid electric and other environmentally conscious vehicles and improving their performance as a



15 Prototype inverter (left), full SiC power module with double-sided cooling (middle), and parallel connection design for chips (right)

means of transportation. If these requirements are to be satisfied, improvements of the efficiency and output of the inverters and other components used in electric vehicles will be essential.

Hitachi has recently developed a power module with double-sided cooling and balanced wiring impedances so that the current through each chip is the same. The power module uses previously developed techniques for the parallel mounting of power semiconductors and double-sided cooling that provides a high level of cooling performance, as well as small silicon carbide metal-oxide-semiconductor field-effect transistors (SiC-MOSFETs) mounted in parallel. These technologies have led the new power module to achieve roughly twice the current capacity of the Si-IGBTs used in the past.

Furthermore, Hitachi has developed a prototype inverter for environmentally conscious vehicles incorporating the new power modules. This inverter has reduced power loss by 60% by taking advantage of the low resistance and high switching speed of SiC-MOSFETs.

16 Supply Chain Simulation for Optimizing Business Resource Allocation

The rapid revision of supply chains over a wide area has become an important challenge for manufacturers over recent years, including the reorganization of sites and improvements to inventory management, so that they can respond quickly to things like market globalization and changing business conditions, and achieve ongoing profits and cashflow.

In response, Hitachi has developed techniques for supply chain simulation that enable the rapid assessment of changes to the supply chain.

These techniques facilitate the creation of a simulation model by pre-defining templates representing the companies that make up the supply chain.

Furthermore, the production planning and dispatch instruction functions at each company are implemented as agents and the simulation can handle a variety of products and supply chain configurations by combining assorted different logic based on Hitachi's own know-how.

Along with expanding use by in-house production divisions, Hitachi also intends to continue developing the techniques as a solution for use by external customers.

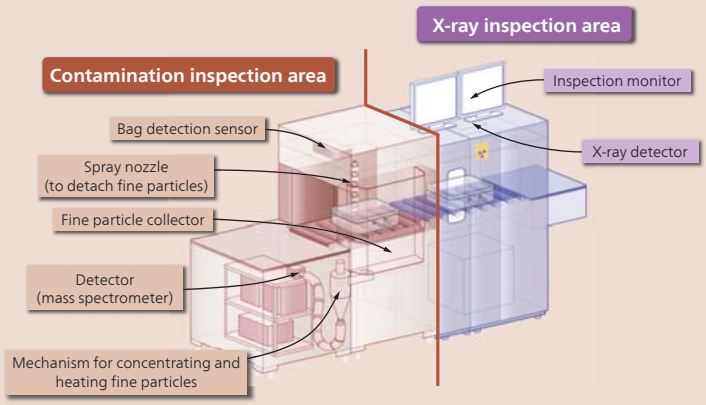
16 Key performance indicators assessment screen for supply chain simulator

17 Automatic Explosives Detection System

One method for detecting concealed explosives is to test the bag or other item for contamination by traces of explosive material. Unfortunately, past inspection of such contamination has required the operator to swab the surface of the bag, meaning that each inspection takes about 20 s.

In response, Hitachi has developed a high-throughput explosives detection technique that automates the swabbing procedure. This involves spraying compressed air at the person or item being inspected to detach any adhering contamination and then recovering it for immediate composition testing. The inspection process is fully automated, taking about 3 s for a person or 5 s for a bag. A prototype explosives detection unit was coupled to an X-ray baggage inspection machine to create an integrated system that can test for contamination at the same time that it performs X-ray scanning, without increasing the operator workload.

Note that this research was conducted under the "Funds for integrated promotion of social system reform and research and development" program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).



Placing a bag in the machine automatically checks for contamination and performs an X-ray scan.

17 Explosives detection system (for baggage inspection)

18 Decommissioning Support System for Drastically Reducing Volume of Waste and Dismantling Workload

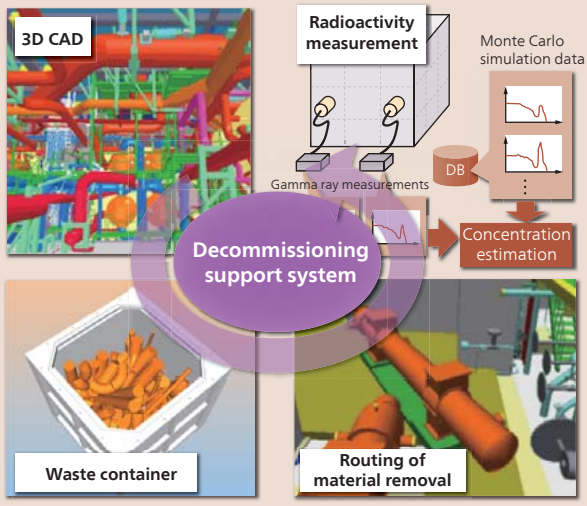
Hitachi has developed a decommissioning support system for safe handling of the several thousand tons of radioactive waste that results from the decommissioning of a nuclear power plant. The system dismantles and cuts up the waste, then places in waste containers for transportation.

After studying past methods based on design drawings for dismantling and cutting up waste, placing it in waste containers, and determining the transportation route, Hitachi developed a technique for calculating parameters such as how to pack the waste into the containers and the number of containers required based on a three-dimensional computer-aided design (3D-CAD) model that includes information on weight and radioactive materials using a calculation that optimizes these with respect to a variety of constraints, and a technique that uses a Dijkstra's algorithm route search and multibody dynamics to automatically determine the transportation route that minimizes the cumulative dose for the radioactive waste while also preventing collisions between machinery, pipework, structural parts of the building, and fittings. Hitachi also developed a technique that can predict the radioactivity concentration in the containers to an accuracy of ±20% from multiple gamma ray measurements and Monte Carlo simulation data using maximum a posteriori probability estimation to calculate the distribution of concentrations in the containers.

In the future, Hitachi intends to use these techniques to help perform decommissioning in a safe, reliable, and rational manner.

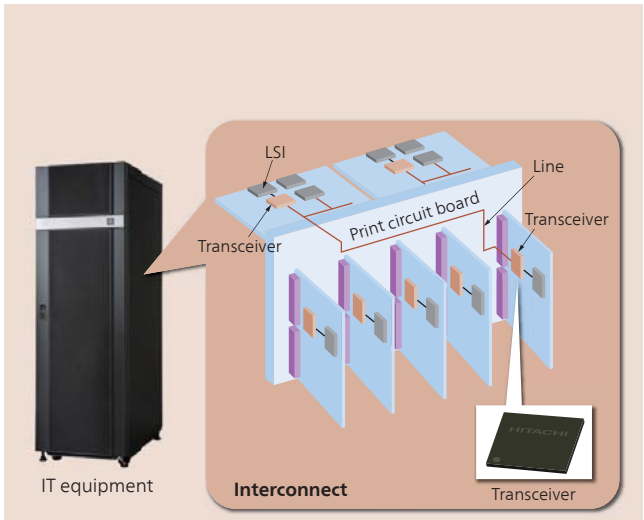
19 25-Gbit/s Transceiver for IT Platforms

In recent years, with the analysis of explosively generated data, brand new businesses and services are being created. To deal with this huge amount of data analysis, there is demand to upgrade the data rate per channel of IT platforms from 10 Gbit/s to 25 Gbit/s. However, this upgrade still has a critical issue due to channel loss



DB: database

18 Decommissioning support system



LSI: large-scale integration

19 High-speed interconnect

increases. For example, the signal amplitude changes from 1.0 V in the transmission signal to 10 mV in the received signal through a 40-dB channel loss. This means that the 10-mV received signal might be smaller than the power supply noise. To achieve long transmission at 25 Gbit/s, Hitachi developed a transceiver with a printed circuit board that achieves channel loss of more than 40 dB and cable transmission for 25 Gbit/s applications that is more than the 35 dB IEEE 802.3bj specification. The key technique is the proposed decision feedback equalizer. It can accurately compensate for deteriorated received signals due to its over 40 dB long channel transmission capability.

The proposed transceiver can achieve a bit error rate of less than $1E^{-14}$. The developed high-speed transmission technique including this transceiver is a key technique for next-generation IT platforms.

20 Reliability Analytics

The life of an infrastructure product that operates outdoors, such as a wind turbine or construction machine, is strongly influenced by how and where it is used. This means that, in order to supply highly reliable products, there is a need to collect and analyze operational data from a variety of sites to assess how and under what conditions they are used, and then to utilize this information in reliability design.

Hitachi has recently developed a reliability analysis technique that combines measurements and product knowledge to make maximum use of operational data by estimating those items that cannot be measured. To minimize the amount of work required to perform an analysis, Hitachi has also developed an analytics platform that provides a wide range of users with shared access to the analysis technique.

This platform, which is cloud-based and operates 24 hours a day, includes libraries of sophisticated analysis techniques and a database with functions for the high-speed analysis and transfer of data. Users can access the cloud from anywhere using a web browser graphical user interface (GUI) to produce highly-reliable product designs using methods verified by reliability design specialists for data analysis and visualization.

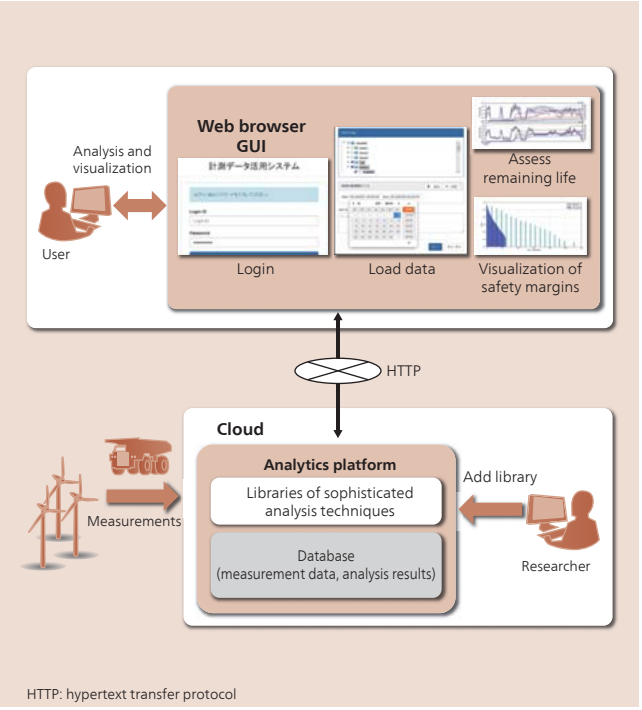
21 Elucidation of Solid Lubrication by Molecular Simulation to Reduce Wear in Resin

Hitachi has developed a technique based on molecular simulation for the efficient screening of low-wear resin-metal interfaces that enables materials design to help improve the reliability of industrial machinery.

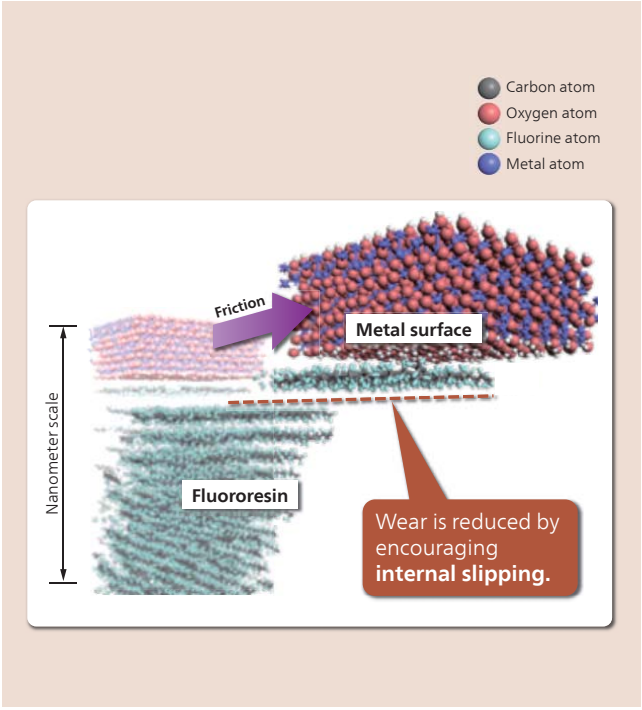
Fluororesins act as a solid lubricant for metal components that does not require oil, thereby enabling longer intervals between maintenance of air compressors and other industrial machinery. Unfortunately, the tendency for fluororesins to wear more quickly in low humidity can shorten equipment life.

With the aim of reducing fluororesin wear, Hitachi adopted molecular simulation to analyze wear for fluororesin on metal. This analysis found that solid lubrication worked by encouraging slipping in the resin, thereby resulting in lower wear. Humidity in the atmosphere acted to strengthen the adhesion between the fluororesin and metal and to encourage internal slipping. On the other hand, because internal slipping was less able to occur under conditions of low humidity, a metal that adhered more strongly to the fluororesin was required to reduce wear. Utilizing this strategy, Hitachi was able to improve the wear durability of compressors by designing a metal that would reduce fluororesin wear.

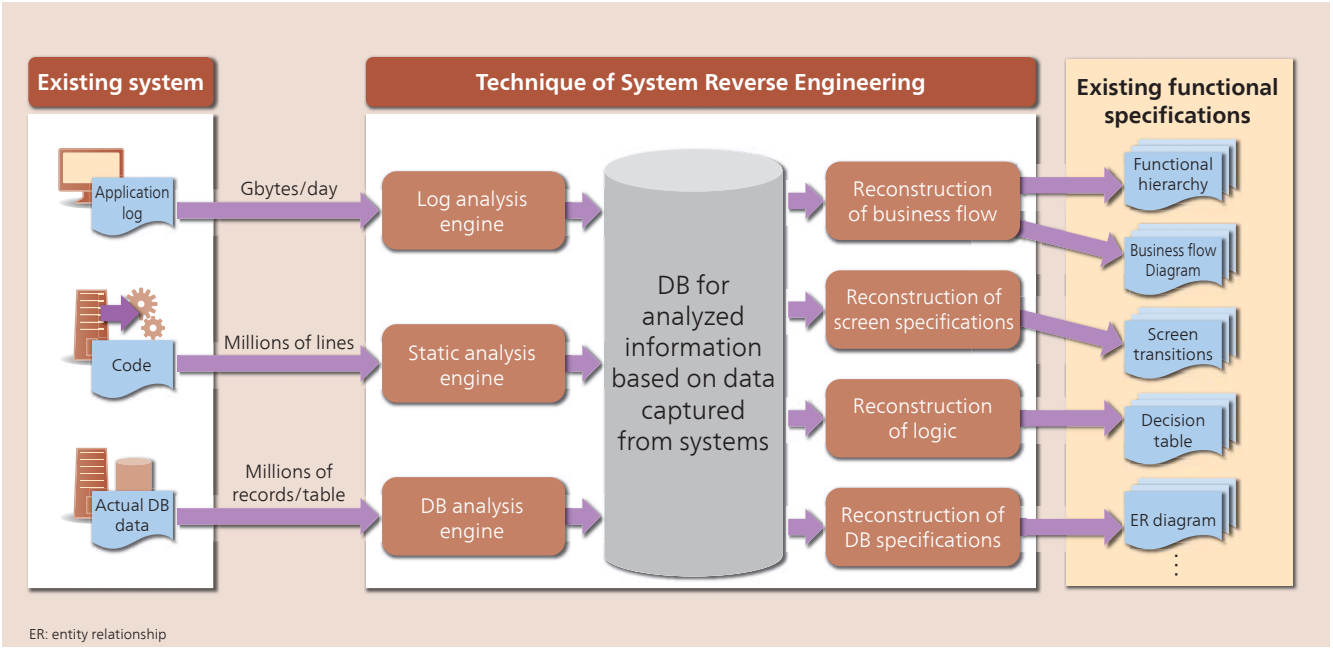
In the future, Hitachi intends to use the technique for the design of composite resins to save energy and improve the efficiency of products such as automotive parts and home appliances.



20 Analytics platform for utilizing measurement data in design



21 Molecular simulation on fluororesin-metal interface



22 Technique of system reverse engineering

22 Technique of System Reverse Engineering

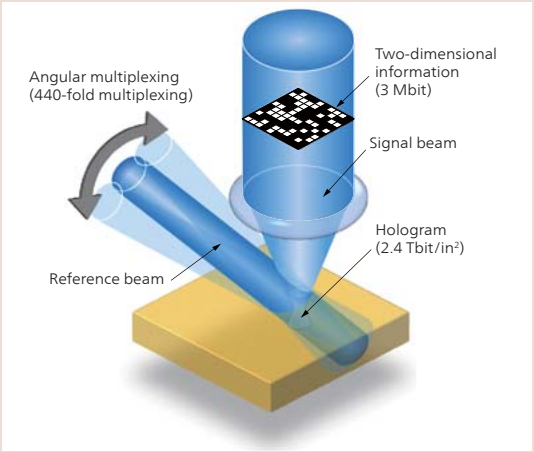
It is said that nowadays 90% of enterprise information system developments engage system migration. In a migration project, the existing system's functions are quite important for the customer's business continuity because the existing system runs the customer's current business. However, a lack of the existing system's specifications makes it difficult to migrate perfectly. Unfortunately, through unrenewed and/or lost documents, and also the resignations of experts, those specifications are often unclear.

To overcome the problems above, Hitachi developed a technique of System Reverse Engineering. This technique reconstructs functional specifications from the capturable data of the existing system. At first, analysis engines analyze and store large amounts of information, which includes system logs, source code, and actual data. Then the functional specifications are reconstructed by combining that analyzed data. This process is automated. The reconstructed specifications are based on data captured from the customer's system in operation. Therefore, our technique enables the customer to make the existing system's specifications clearer than just following the experience and assumptions of developers.

Hitachi is using this technique to improve the quality of our system development and deliver migrated systems by the due date.

23 Large-capacity Holographic Memory

It has been predicted that the total quantity of data produced worldwide will reach 40 Zbyte in 2020*. There is increasing demand for utilizing this large amount of data that is growing at an astonishing rate, with IT systems needing low-cost ways to store this data securely for the long term.



23 Holographic memory system

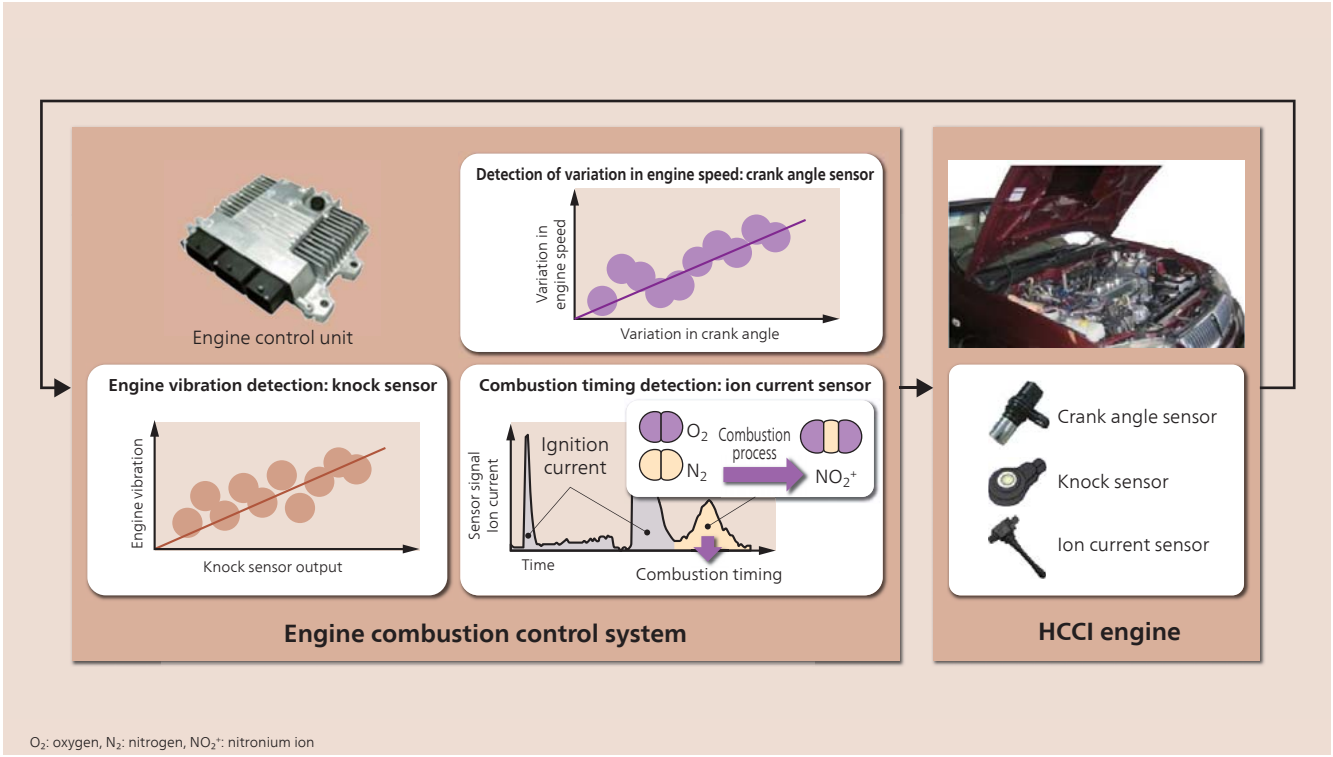
Optical storage is characterized by long life and low cost per bit, and it is seen as having significant potential as a way for data archives to store data in the era of big data. A large-capacity holographic memory developed by Hitachi uses angular multiplexing to store the interference patterns (holograms) formed by the interference of a signal beam carrying two dimensional data and a reference beam in a recording medium.

A prototype achieved a recording density of 2.4 Tbit/in^2 with 440-fold multiplexing. The new technology is recognized as having the potential to provide large-capacity optical storage with each disk having a storage capacity in the terabyte range.

* From"The Digital Universe in 2020: Big Data, Bigger Digital Shadows, Biggest Growth in the Far East," John Gantz and David Reinsel, Proc. IDC iView, December 2012.

24 Next-generation Engine Combustion Control System

Research into homogeneous charge compression ignition (HCCI) as an alternative to spark ignition has led to interest in its use as a



O_2: oxygen, N_2: nitrogen, NO_2^+: nitronium ion

24 Next-generation engine combustion control system

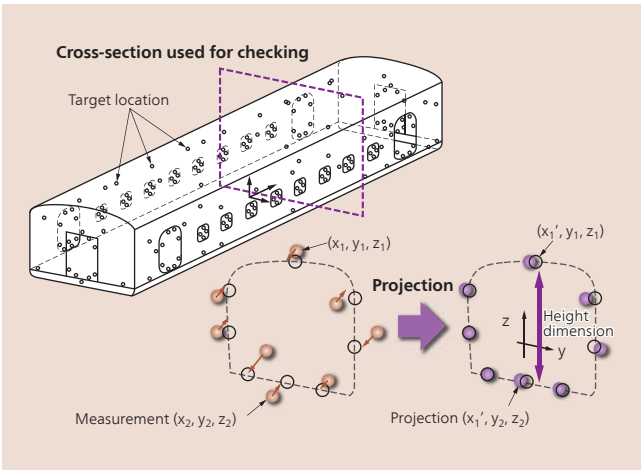
way to improve the thermal efficiency of gasoline engines so that they can comply with future regulations on emissions of CO_2. It is estimated that use of HCCI can increase the thermal efficiency of gasoline engines to about 40% from their present level of around 35%. One of the challenges to the practical adoption of HCCI is that the associated combustion has a low level of robustness with respect to changes in the operating conditions (such as temperature or fuel).

In this current development, Hitachi looked at how a deterioration in combustion results in increased vibration or variations such as in engine speed or combustion timing, and considered different methods for sensing this, namely using a crank angle sensor to detect variations in engine speed, a knock sensor to detect engine vibration, and an ion current sensor to detect the combustion timing. A key feature of the work was that it used existing sensors to minimize any cost increases due to combustion conditions detection.

Hitachi has established a way forward toward the commercialization of HCCI engines by building a next-generation engine combustion control system that uses the technique and achieving highly robust HCCI combustion.

25 Technique for Measuring Structural Dimensions of Rolling Stock Using Three-dimensional Measurement System

In response to growing demand for rolling stock from outside Japan, Hitachi is expanding overseas production at sites that are close to customers. Ensuring that overseas production achieves the same quality and productivity levels as production in Japan requires the establishment of manufacturing practices that are not dependent on worker skills. Rolling stock is produced by using welding to assemble the car body and then installing the internal

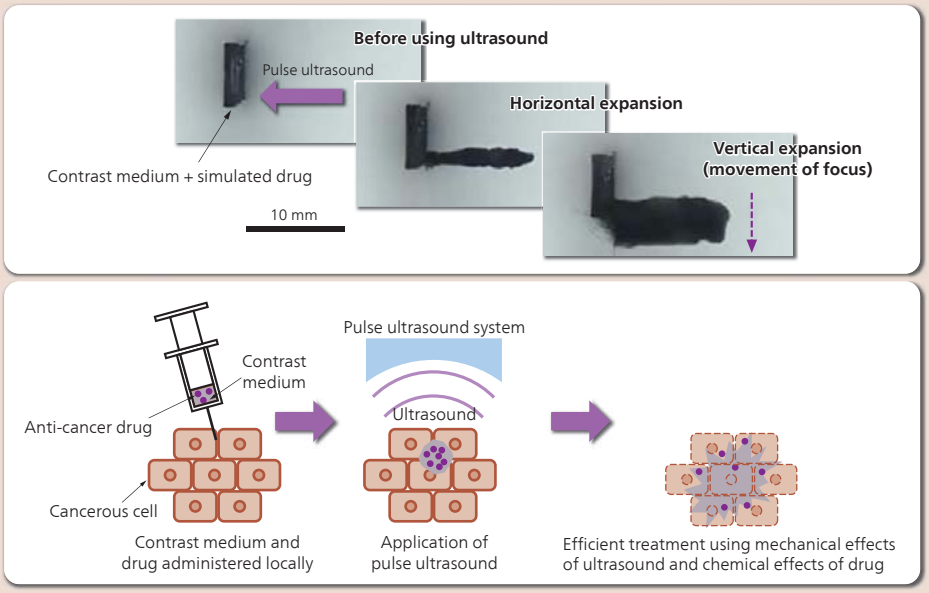


25 Automatic technique for determining dimensions

fittings, electronics, and other parts. The step involving the installation of parts requires that workers make adjustments based on their experience.

To eliminate this adjustment step, Hitachi has developed techniques for the precise and efficient measurement of structural dimensions and for providing work instructions to install parts based on these measurements.

The technique developed for measuring structural dimensions uses a contact-based three-dimensional measurement system. It achieves precise measurements by using a function for determining a measurement location that prevents incorrect measurements by checking the deviation between the actual location and the pre-defined target location, and a function for determining the actual dimensions by projecting the measurements onto a cross-section used for checking. Hitachi has also developed a work guidance function that processes the measurements automatically and issues measurement work instructions, and is using the system to check car body dimensions.



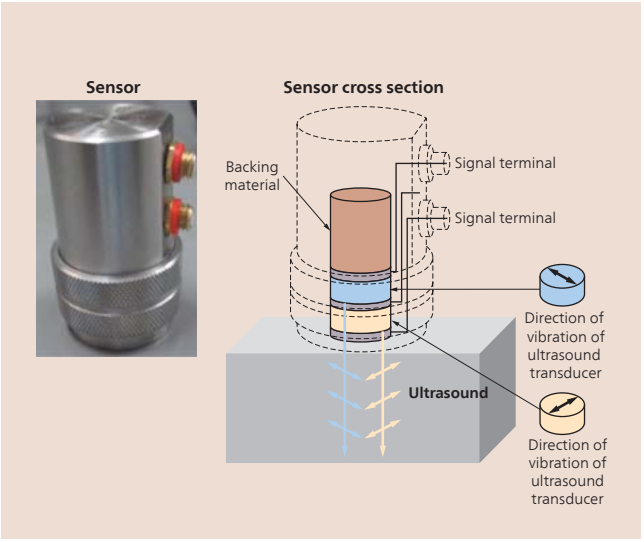
26 Control of drug distribution using pulse ultrasound and a contrast medium in a transparent gel (top) and concept behind new cancer treatment (bottom)

26 New Cancer Treatment Using Ultrasound to Control Distribution of Medication

Hitachi has verified the principle behind a minimally invasive treatment for cancer based on a new mechanism. It works by locally administering an anti-cancer drug into tumorous tissue and then using the mechanical effects of ultrasound to activate the drug throughout the tumor.

In the past, the technique has been difficult to use in practice because it required ultrasound at very high intensity. Hitachi has now demonstrated that its newly-developed method can work at intensities similar to existing ultrasound treatment systems using pulse ultrasound together with a contrast medium formed from minute droplets that can be administered in high concentration.

It has also confirmed that, in a transparent gel, the application of ultrasound changes the drug distribution by causing the gel structure to break down, with the drug moving in the direction of the applied ultrasound. It is anticipated that this will enable treatment at low-dose concentrations while also minimizing side effects from the anti-cancer drug.



27 Ultrasound sensor with two directions of vibration

27 Dual-axis Ultrasound Inspection Technique for Detecting Sub-millimeter Defects

Hitachi has developed an inspection technique that uses two ultrasonic waves with vibrations that are perpendicular to each other. Some metals, such as those produced by rolling, have a crystalline structure in which the speed of propagation of ultrasound varies depending on whether the vibration is parallel to or perpendicular to the crystal axis. As a result, the different directions of vibration produce defect signals that indicate different locations. The identification of defect signals is also complicated by the presence of reflection noise generated at crystal boundaries. As a result, previous techniques have only been able to detect defects in the order of several millimeters.

Hitachi's new technique uses two ultrasound transducers (each of which transmits and receives ultrasound with a different direction of vibration) and acquires signals for these two directions independently. When the defect data is corrected for the different speeds of propagation, it results in a consistent defect signal with a higher signal to noise (SN) ratio. This enables the detection of sub-millimeter defects.

In the future, Hitachi plans to use the technique in applications such as acceptance inspections.

28 Recording and Playback on Quartz Glass with Storage Density Similar to Blu-ray Discs

Quartz glass has excellent resistance to heat and water. Hitachi has developed a technique for the long-term storage of digital data in this material that uses a laser to write the data and an optical microscope to read it. This joint research with Kyoto University

28 100-layer sample (left), quartz glass carried on *Shin-en 2* (middle), and sample included in British Museum exhibition (right)

has devised a technique for using a femtosecond laser to record multiple layers of data in quartz glass. This involved creating a 100-layer sample in quartz and achieved recording and playback with a storage density similar to a Blu-ray Disc* (approximately 1.5 Gbyte/in^2). This sample was able to withstand a temperature of 1,000°C for two hours, equivalent to a fireproof safe, and was shown to have a room-temperature life of 300 million years or longer in accelerated temperature testing.

The technique can be used for the quasi-permanent archiving of valuable data such as historically important cultural material or public documents. A quartz sample produced using the technique is carried on the *Shin-en 2* spacecraft developed by Kyushu Institute of Technology and Kagoshima University, and another was exhibited at Kobe City Museum from September 2015 to January 2016 as part of the 'A History of the World in 100 Objects' exhibition of the British Museum, appearing as the "101st object" selected by the host museum.

* See "Trademarks" on page 140.

29 Simulation of Movement of People in Railway Station

Hitachi has developed a simulator for predicting the movement of people in railway stations with the aim of making them more convenient and pleasant places through initiatives such as the optimal layout of facilities, the modification of train schedules in response to passenger trends, and the provision of passenger information to help avoid congestion.

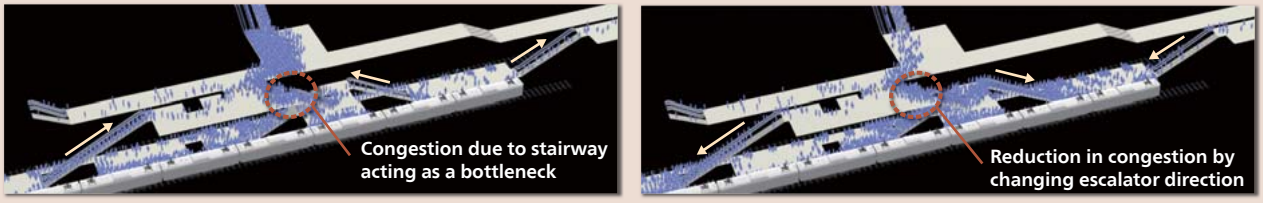
The new simulator incorporates general-purpose modeling that uses an agent-based technique for simulating the behavior of people at railway stations based on knowledge obtained from on-site surveys at a number of railway stations. For example, the behavior when getting on or off a train at the platform varies from station to station, depending on factors such as where the train stops, the number of doors, and how people wait in line. The model developed by Hitachi can reproduce this behavior flexibly by splitting these into three levels based on train arrival and departure and specifying detailed parameters such as where people wait in line for each stage. Hitachi also developed a 3D display function to provide a more intuitive presentation of the predictions.

The simulator can be used to determine in advance how changes such as upgrades to existing railway stations or the construction of new lines and stations will influence the movement of people.

30 Cost-benefit Analysis and Control Strategy for Battery Systems

The massive introduction of renewable energy sources in electric power grids has significantly increased the need for fast-ramping resources to continuously balance power demand and power supply and thereby to stabilize the grid frequency. Battery Energy Storage Systems (BESSs), with their flexible and fast-ramping capabilities, have the potential to become a key solution for grid stabilization issues. In the USA, grid utilities have recently created an ancillary service market that compensates by providing resources as regulating reserve to help maintain the frequency at its nominal value. And, several initiatives have been taken to foster the deployment of energy storage.

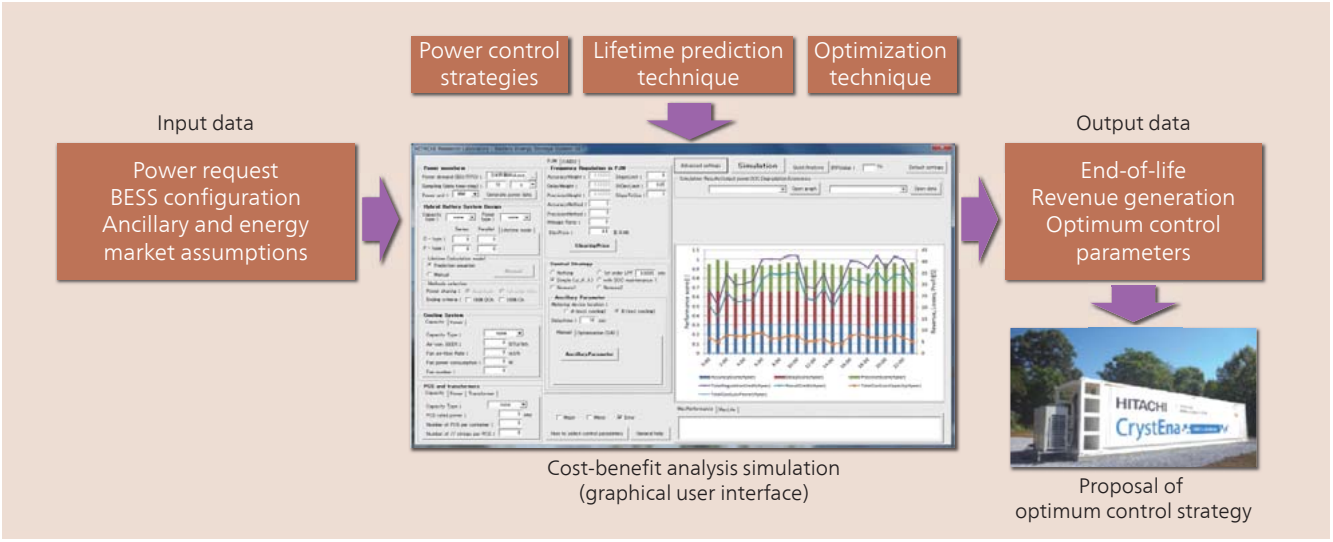
With the aim of entering the North American ancillary market with BESSs, Hitachi has developed a cost-benefit analysis simulation tool to assess stationary BESSs and overcome the challenging



(1) Interval between trains: 6.4 minutes, up escalator only

(2) Interval between trains: 6.4 minutes, down escalator only

29 Example prediction by railway station people movement simulator



30 Concept of the cost-benefit analysis simulation tool

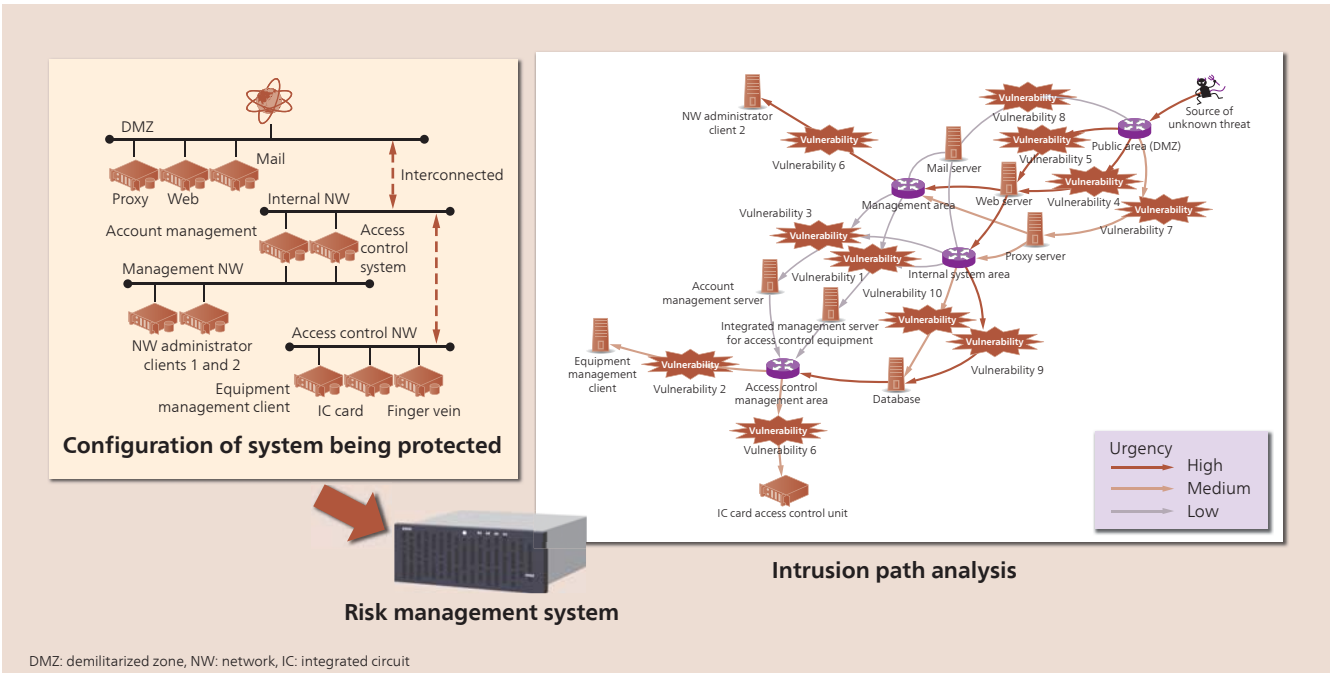
task of designing and controlling a BESS. The cost-benefit analysis simulation tool relies on battery lifetime prediction, on power control strategies design, and on optimization techniques developed by Hitachi Research Laboratory. Simulation and optimization are performed to support the selection of an optimum control strategy to maximize both the performance and the lifetime of a BESS.

Hitachi has installed a 1-MW/450-kWh containerized lithium-ion battery system in New Jersey, USA, and started a demonstration project aimed at verifying the effectiveness of the developed techniques, the commercial viability, and testing the system's performance for providing frequency stabilization service.

31 Security Risk Assessment Technique that Takes Account of Cyber-attack Intrusion Path

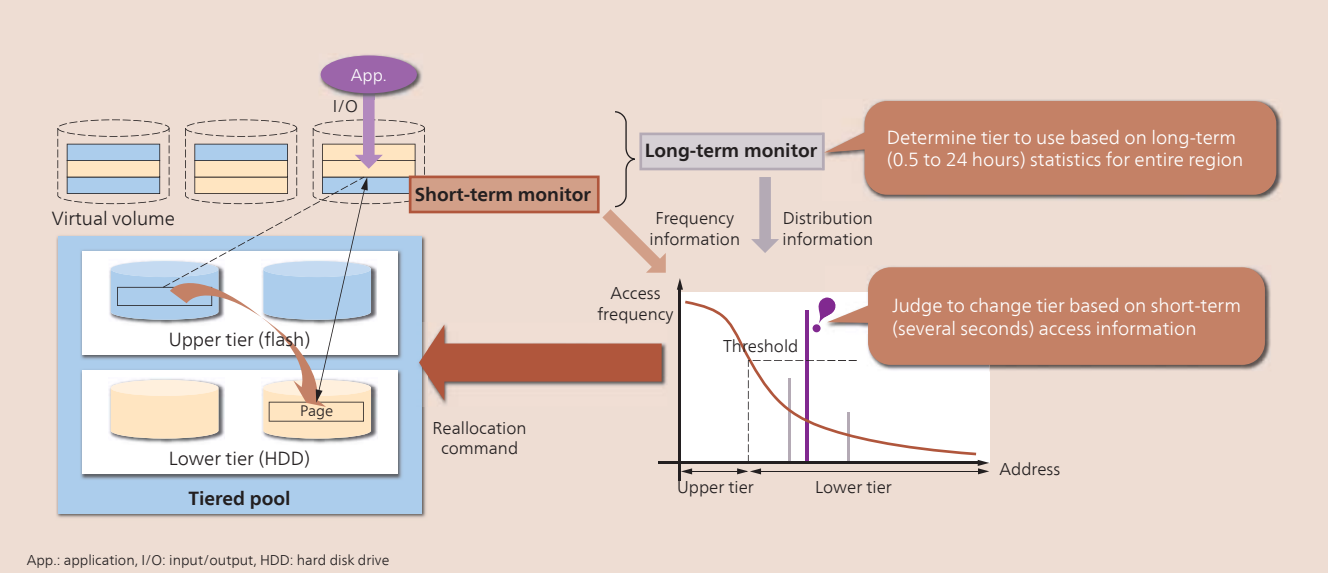
The number of reports of IT system vulnerabilities continues to grow year after year, with the US National Institute of Standards and Technology (NIST) making approximately 8,000 such reports during 2014. One such vulnerability that has attracted a high level of concern is the Heartbleed vulnerability. There was a sudden rise in the number of attacks exploiting this vulnerability after its details were made public, meaning that information system departments at companies and other organizations need to adopt prompt countermeasures. Cases like this call for a high level of information security skills due to the need to prioritize and decide which of the many vulnerabilities to take action on. Unfortunately, it is difficult for individual organizations to retain or train such specialists.

In response, Hitachi has developed a technique for rapidly identifying system vulnerabilities, determining all the possible routes (intrusion paths) by which predicted cyber-attacks can come, and prioritizing which vulnerabilities to address. This enables a uniform and rapid response to vulnerabilities by providing an



DMZ: demilitarized zone, NW: network, IC: integrated circuit

31 Prioritization of countermeasures by predicting cyber-attack intrusion paths



32 Overview of active flash

easy way to clarify the relative priorities of countermeasures, even at organizations that lack the relevant specialists.

To counter cyber-attacks that are becoming ever more complex, Hitachi intends to utilize security risk assessment techniques and expand services that support security activities by organizations, including their information system departments and Computer Security Incident Response Teams (CSIRTs).

32 Data Access Acceleration Technology for Hitachi Virtual Storage Platform Mid-range Family

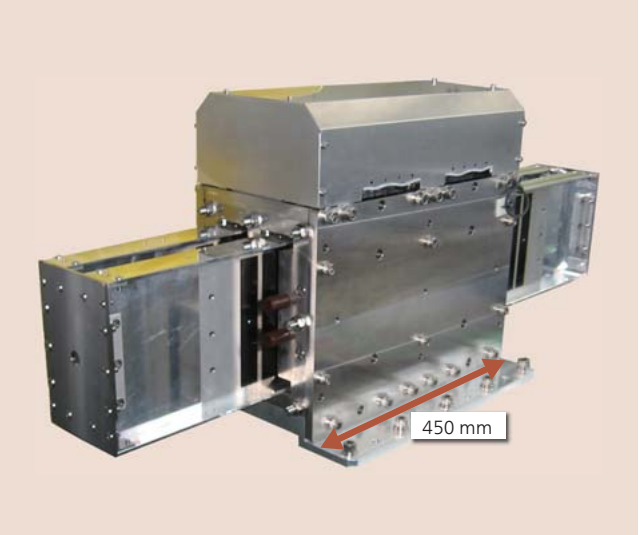
A variety of applications work on IT systems. The behavior of applications varies moment by moment. Therefore, it is extremely difficult and complicated for a system administrator to tune the configuration of the IT system following the changing behavior.

The Hitachi Virtual Storage Platform Mid-range family relieves this difficulty and complexity using "active flash." "active flash" is a new feature that provides automated tuning through rapid data detection and migration for frequently-accessed data onto high-speed flash media.

Through automated tuning, the system administrator can start and operate applications without a strict system design, and agilely expand the capacity of the system to keep up with business growth.

33 High-speed Linear Motor with Fast Acceleration

The use of linear motors has been growing in recent years in response to rising demand for drive mechanisms with higher speed and acceleration to improve the throughput of semiconductor production equipment, machine tools, etc. Making linear motors with faster speed and acceleration requires higher thrust and strength while also reducing the weight of the forcer (moving part). In response, Hitachi has developed a prototype linear motor with a novel design that can operate at higher speed and acceleration.



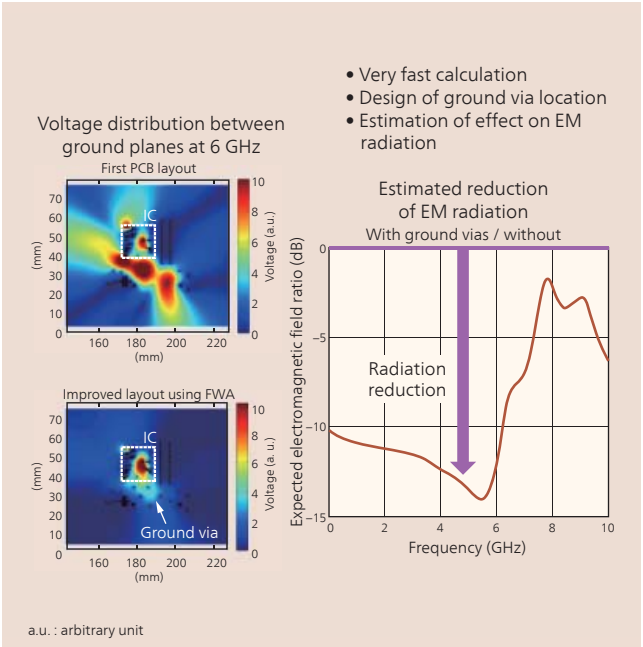
33 Prototype linear motor with acceleration of 1,670 m/s^2

The design of the linear motor reduces the weight of the forcer relative to the thrust by using opposed magnetic poles with the moving magnet located between them to make effective use of the magnetic flux on both sides of the magnet. To achieve a lightweight and strong forcer, it also uses a two-stage design that reduces deflection by having two forcers coupled together. In prototype testing, these features were able to reduce the weight of the forcer significantly (one-third previous model), with a maximum speed of 14.0 m/s and acceleration of 1,670 m/s^2, 4.3 times that of Hitachi's previous model.

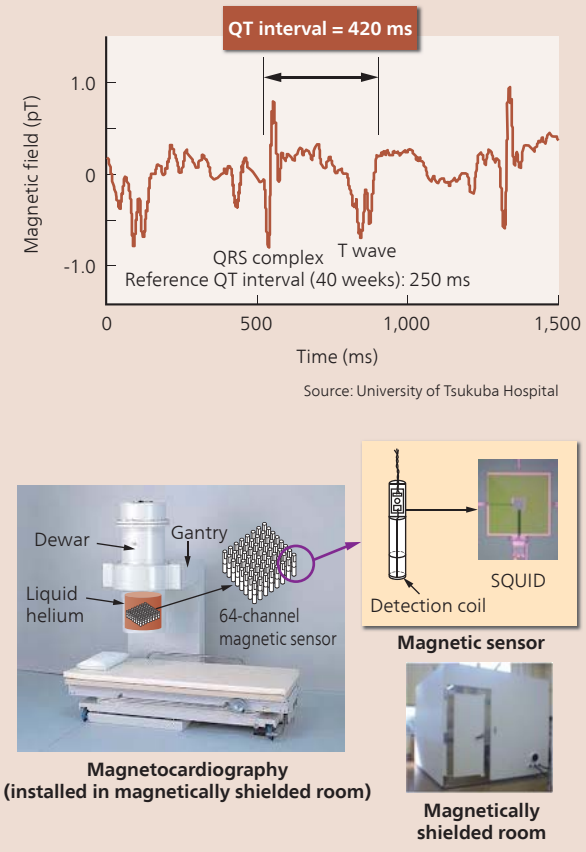
34 Fast Analysis Technique for Electromagnetic Compatibility Design of Printed Circuit Boards

Hitachi has developed the forward wave analysis (FWA) technique to improve the electromagnetic compatibility design of printed circuit boards (PCB) above 1 GHz.

The simultaneous switching of large-scale integrated circuits generates noise that propagates among the power supply planes of PCBs and radiates electromagnetic (EM) waves from the edges, creating interference with other electronic equipment. In order to



34 Improvement of layout design using FWA and reduction of EM radiation



35 Magnetocardiogram of a fetus with long QT syndrome and congenital 2:1 ventricular block (top) and magnetocardiography manufactured by Hitachi High-Technologies Corporation (bottom)

reduce the radiated noise, bypass capacitors, ground vias, and other current bypass devices can be used.

The design challenges are the calculation time of EM simulations and the lack of accurate component models above 1 GHz.

FWA achieves an approximate solution with very fast simulations (50-100 times faster than whole board simulations) and only a moderate amount of layout information, which is an advantage because simulations can be conducted before the design is completed. This is possible because above 1 GHz the radiation is strongly affected by a large number of resonances with moderate quality factors, making statistical quantities a more suitable target of the analysis. Simulations are made only on a local area close to the noise source integrated circuit and assuming infinite power supply planes, but they can be used to select the suitable location for current bypass devices, to estimate their effect on the radiated EM field, and also to analyze the vertical distribution of the noise among the power supply planes.

35 Use of SQUID Magnetocardiography for Fetal Arrhythmia Diagnostics

Obtaining electrophysiological information from fetal hearts has been difficult in the past. Now, Hitachi, in collaboration with University of Tsukuba Hospital and the National Cerebral and Cardiovascular Center, has established a diagnostic technique for fetal arrhythmia based on electrophysiological information collected using magnetocardiography that incorporates superconducting quantum interference devices (SQUIDs).

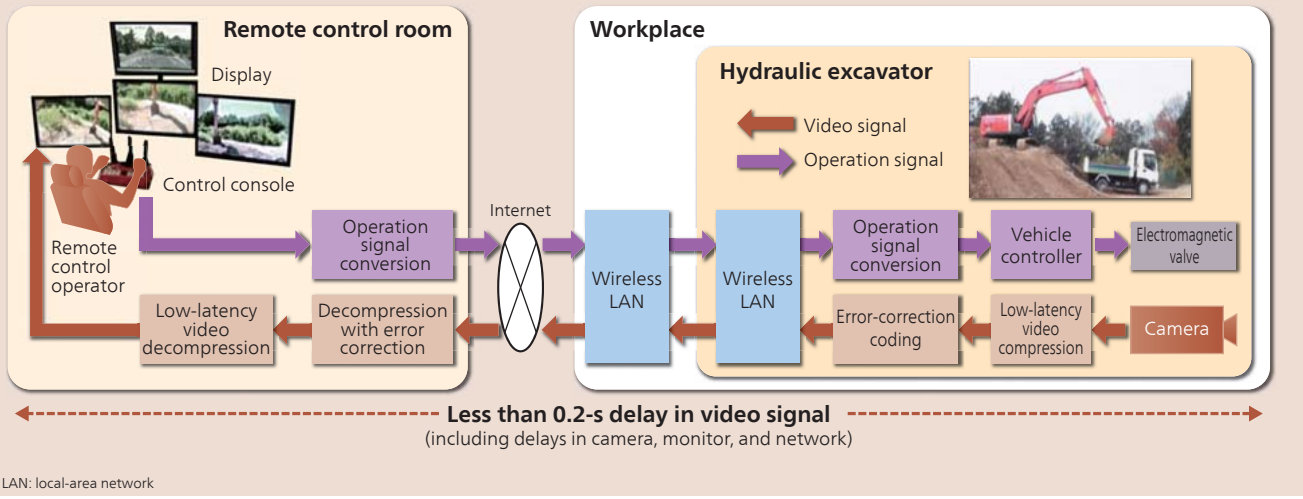
Magnetocardiography incorporates a number of SQUIDs and can record the faint magnetic signal from the fetal heart (less than one-millionth the strength of the Earth's magnetic field) with a good SN ratio from the top of the mother's abdominal wall. Magnetocardiography has been used to record more than 1,000 examples of normal fetal magnetocardiographic signals and obtain reference values with respect to the number of weeks of pregnancy for temporal indicators that are important for the diagnosis of fetal arrhythmia, including the atrioventricular conduction time and the QT interval [the time between the start of ventricular depolarization (QRS complex) to the end of ventricular repolarization (T wave)], for example. These reference values can be used for diagnosing conditions such as congenital long QT syndrome, which is suspected of involvement in intrauterine fetal death from unknown causes, due to life-threatening arrhythmia from the fetal stage.

It is anticipated that the establishment of this diagnostic technique will contribute to perinatal care, including both prenatal treatment and the planning of postnatal treatment.

36 Long-distance Remote Control System for Construction Machinery

The remote control of construction machinery has attracted attention as a key technology for ensuring operator safety and implementing more advanced working practices in situations such as disaster recovery sites and large overseas mines.

Remote control involves an operator operating a construction machine remotely with the aid of video images sent from the site via a network. Its technical challenges include poor visibility due to low image resolution or distortion caused by data transmission



LAN: local-area network

36 Long-distance remote control system for construction machinery

errors and cumbersome operation due to transmission delays.

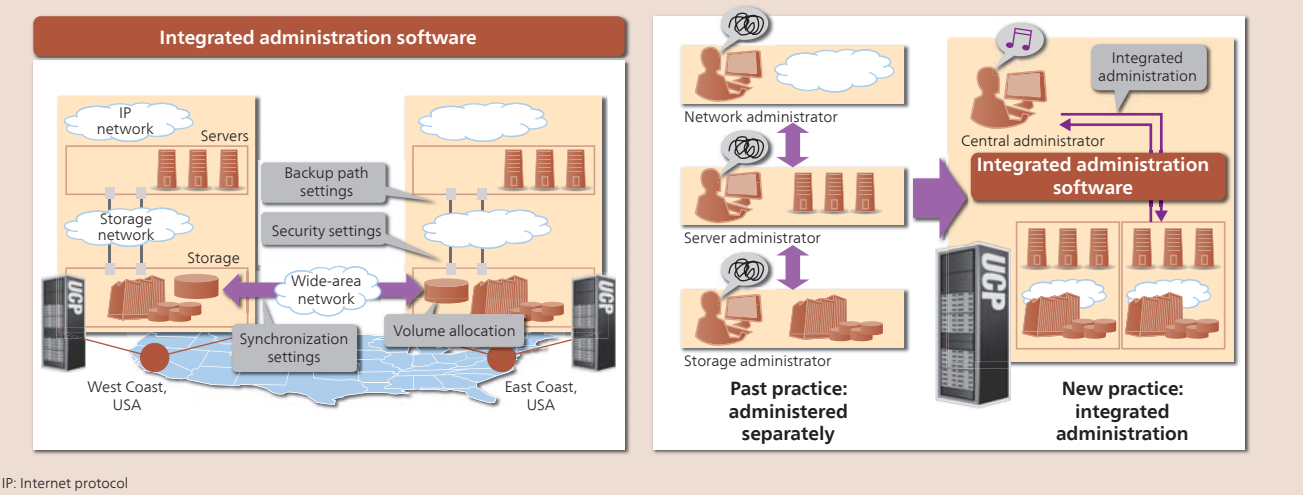
In response, Hitachi has developed a video transmission technique that corrects data errors caused during transmission and compresses and decompresses site video with low latency while still maintaining full high definition (HD) image quality. It has also built a long-distance remote control system for construction machinery that ensures efficient operation by using this technique to transmit highly realistic site video. A trial demonstrated that the system could perform remote control by transmitting video signals with a delay of 0.2 s or less over a network link approximately 800 km long.

Hitachi intends to enhance the performance of the technology further in the future.

37 Technique for Simplifying DR Setup on Hitachi Unified Compute Platform

With corporate information systems making greater use of virtualization in recent years, there is demand for virtualization platforms that are easy to manage and that have high availability and reliability, with disaster recovery (DR) being another important requirement. A problem with the configuration of DR environments in the past has been that setting up storage systems has required storage administrators with specialist knowledge, increasing the administrative workload due to factors such as these administrators needing to coordinate with each other. In response, to provide a simpler way to set up DR on integrated platforms for virtualization systems, Hitachi has developed automated techniques based on best practice and DR setup based on information about the virtualization environment. By reducing the number of settings required for DR setup by 86% and eliminating hardware-level settings altogether, these enable DR setup to be performed by one central administrator.

Hitachi believes that the proposed techniques will reduce administration workloads by eliminating the need for administrators to coordinate with each other and by making it possible for DR setup to be performed using a minimal number of settings.



IP: Internet protocol

37 Simplified DR setup function for Hitachi Unified Compute Platform (left) and simplified administration using Hitachi Unified Compute Platform (right)

Exploratory Research

1 New Wearable Sensor for Happiness (Level of Organizational Activity) that is Correlated with Workplace Productivity

Improving the productivity of service and knowledge work (which account for 70% or more of employment in developed economies) is an important challenge for society, despite being more difficult than for routine tasks. Based on a million or more days of human activity measurements spanning 10 years, Hitachi has developed a wearable sensor for measuring the level of happiness in groups, an index that is correlated with the organization's productivity.

The sensor uses a built-in accelerometer to detect the presence of small body movements and quantify the diversity of movement within a group. It has been shown that this index agrees to a high level of accuracy with the results of happiness surveys. It has also been shown that this measure of the level of group "happiness" is correlated with workplace productivity. For example, it has been found that the rate of orders taken by a call center on days when staff had a high happiness score was 34% higher than on days when the score was low, and that per-customer sales at a retailer were 15% higher. It has also been found that work by research and development projects with a high happiness score makes a higher contribution to sales.

The sensor has already been adopted in a wide range of sectors, including finance, aviation, telecommunications, the automotive industry, and logistics.

(Hitachi High-Technologies Corporation)

1 Wearable sensors in use

2 Atomic-resolution holography electron microscope

2 Atomic-resolution Holography Electron Microscope

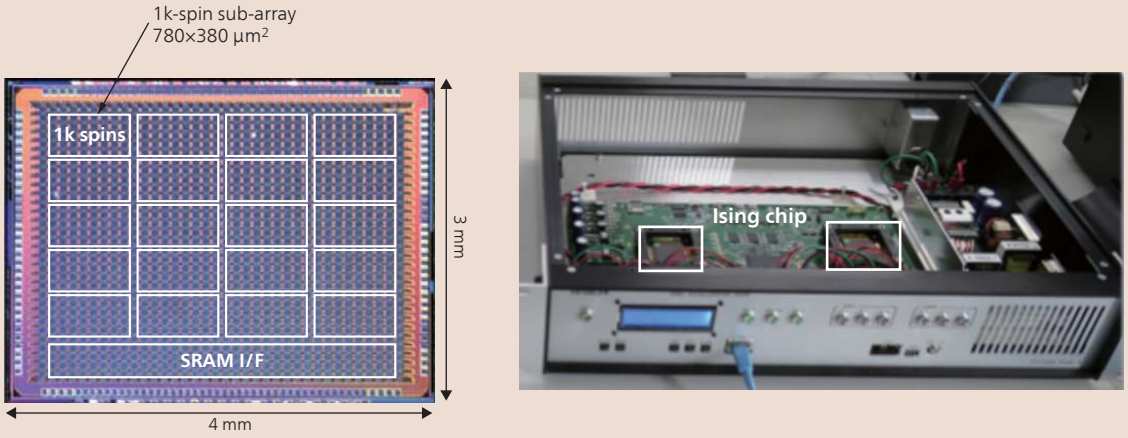
With the aim of developing materials with groundbreaking functions and properties, work is progressing on the development of techniques for atomicresolution measurement of the internal electromagnetic fields that govern these material properties. The atomic-resolution holography electron microscope has been developed, with assistance from the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Program), a national project. It is the world's first ultra-high-voltage electron microscope equipped with a spherical-aberration corrector. The highly stabilized electron microscope system enabled the equipping of the corrector. In this development, a number of new technologies (as follows) were successfully applied to improve the stability of the electron microscope system.

(1) A 1.2-MeV electron beam with suppressed energy dispersion

(2) An electron gun emitting high-brightness electron beams with long-term stability

(3) Development of facility technologies to eliminate degradation factors of resolution

Performance testing succeeded in transmitting structural information from a crystal to a camera with a world-record resolution of 43 pm. Hitachi intends to use the microscope to help develop the new materials that will underpin a sustainable society by studying the quantum phenomena responsible for the functions of such things as magnets, batteries, and superconductors.



SRAM: static random access memory, I/F: interface

3 CMOS Ising chip at the heart of the Ising computer (left) and the Ising computer itself (right)

3 New Computing Paradigm for Analyzing Increasingly Complex Social Systems (CMOS Ising Computer)

In the future, Hitachi's Social Innovation Business will necessarily involve the control of social systems, and this will require parameter optimization. This in turn requires the solution of combinatorial optimization problems to determine the optimal combination of parameters.

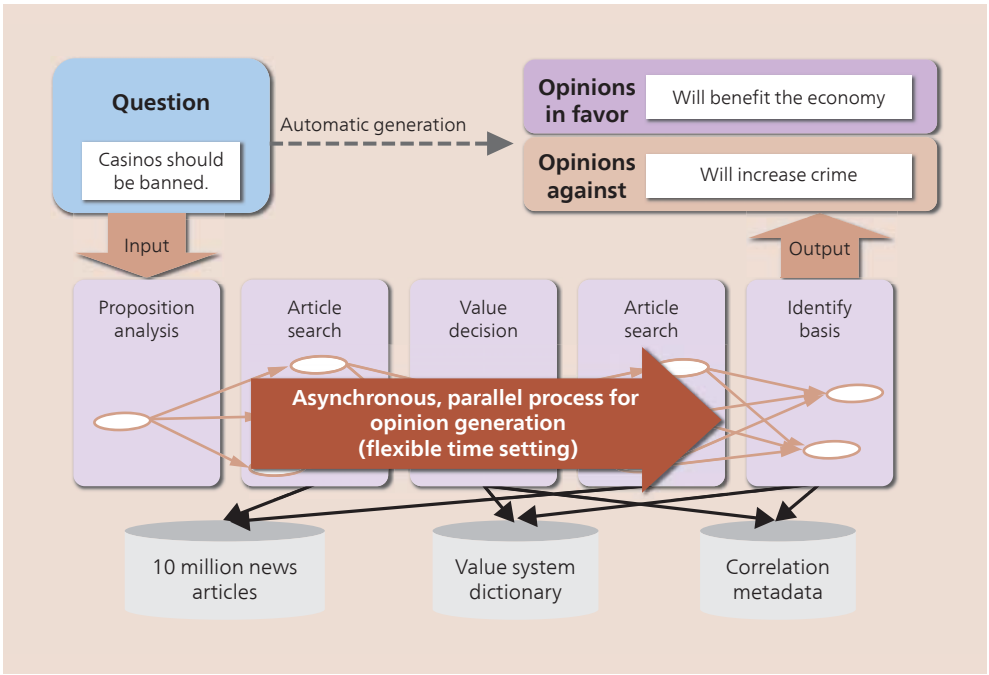
Hitachi has devised a computing technology based on a new paradigm that is capable of solving combinatorial optimization problems efficiently by simulating an Ising model on a complementary metal oxide semiconductor (CMOS) circuit, and has built a prototype 20,000-spin CMOS Ising computer using a 65-nm process. An Ising computer represents a combinatorial optimization problem by mapping it onto an Ising model of spin behavior in magnetic materials, and then uses convergence to solve the problem. This convergence is achieved by the operation of the CMOS circuit and randomness introduced by noise.

The prototype computer can operate at 100 MHz and has demonstrated its ability to solve actual combinatorial optimization problems. Furthermore, it consumed 1,800 times less power to obtain the solution than would have been required by a conventional von-Neumann architecture computer running an approximation algorithm.

4 Core Technology for AI Capable of Rational Interaction

Hitachi has developed a technique that analyzes large amounts of text data to present opinions for and against a question on which opinions are divided in a way that indicates their basis or rationale.

The technique identifies bases or rationales with a higher degree



4 Process for automatic generation of opinions for and against accompanied by justifications

of certainty by focusing on the values associated with subjects like health, economics, and public order that are considered important by people and communities when expressing opinions, and analyzing how a question relates to these values based on a large quantity of news articles and other material.

Whereas information based on objective facts has been provided in the case of past artificial intelligences (AIs) that operated on a question-and-answer basis, this technique can also provide information accompanied by a rational explanation in accordance with the values of the person conducting the interaction. Another advantage of the AI is that, by using a number of different values as reference criteria, it can present bases and rationales that are not biased toward any one particular aspect.

This new technique represents a core technology for use in developing AIs that can enable rational interaction between people and computers. In the future, Hitachi intends to utilize the technique in systems that analyze information such as corporate documents, published reports, or electronic medical records at hospitals to generate opinions that underpin operational activity.

5 Automated Cell Culture Technique

Hitachi has developed an automated cell culture technique for the reliable supply and large-scale production of safe and viable cells for regenerative medicine. It has also been working on the development of a system for closed culturing that provides the high level of sterility demanded by medical applications, and features a technique for parallel culturing using multiple culture vessels.

This system, called Automated Cell Culture Equipment 3 (ACE3), forms a circuit that links the liquid feed tube to the culture vessels that are in contact with the cells and culture medium. It also uses gamma rays to fully sterilize the interior prior to use. To prevent cross-contamination between patients, the circuit is fitted with an insertion and removal mechanism that enables single-use. ACE3 automates seeding, the maintenance of constant temperature and humidity, gas exchange, and culture medium replacement, and also provides for both automatic observation of the cells at designated points and manual observation as required.

Hitachi is currently engaged in joint research with Tokyo Women's Medical University on its use for regenerative medicine treatment of esophageal cancer. The aim is to use these techniques as a basis for encouraging the wider adoption of regenerative medicine through the future deployment of automated cell culture technology for different types of cells or diseases.

The research described in this article was undertaken as part of the Cell Sheet Tissue Engineering Center (CSTEC) under the Creation of Innovation Centers for Advanced Interdisciplinary Research Areas Program, a Project for Developing Innovation System Establishment Project of the Ministry of Education, Culture, Sports, Science and Technology.

* CellSeed Inc.

5 ACE3 automated cell culture system (left), closed culture vessel (top right), and cell sheet after automatic culture in an ACE3 (bottom right)