Research & Development

Connective Industries

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Innovation & R&D, Manufacturing & Industry

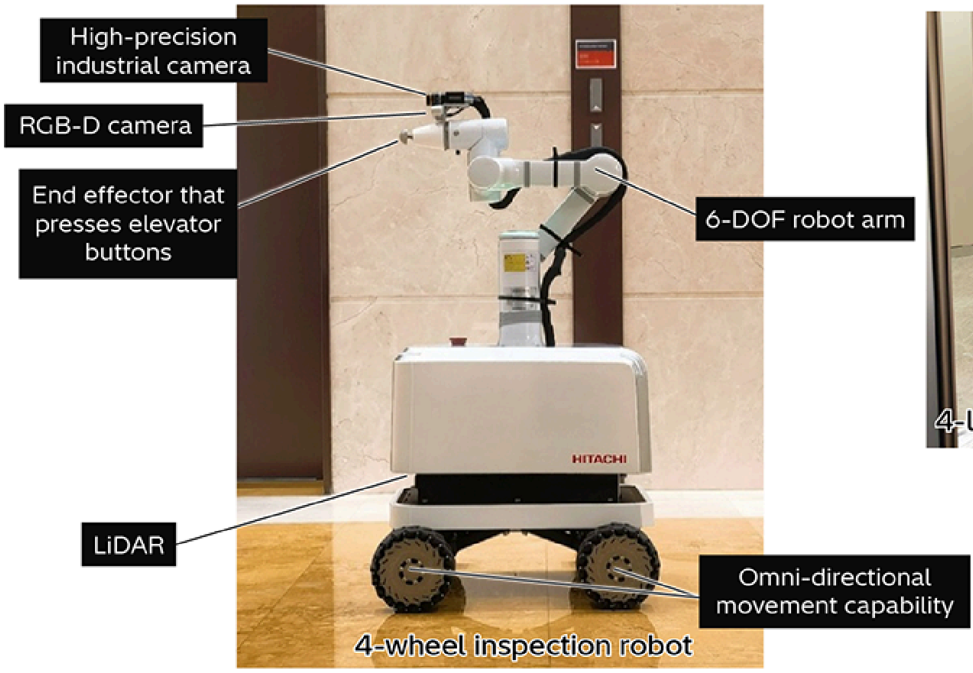
1. Development of Robot System for Automatic Inspection of Elevator Cars

With the increasing number of high-rise buildings in China, the rising cost and effort of elevator maintenance is becoming a serious issue. In the market for high-end buildings in particular, a growing number of customers have high expectations for the ride comfort of elevator cars and are concerned about faults, creating demand for inspections to be conducted more frequently than legally required. This has led Hitachi to draw on expertise it gained in the development of automatic elevator installation robots to develop a robot system that automates elevator car inspections.

To provide freedom of movement within the narrow confines of an elevator car, the system is equipped with an omni-directional movement capabilities and uses light detection and ranging (LiDAR) to determine its position. The robot arm has six degrees of freedom and is equipped with a high-precision industrial camera capable of identifying even very small anomalies; a red, green, blue and depth (RGB-D) depth-sensing camera; and an end effector designed to press elevator buttons. These give the system the ability to perform inspections that require measurement precision of 1 mm or less. Another notable feature is the ability to correct the arm position autonomously based on object orientation and relative distance information obtained by the RGB-D camera. This enables precise image recognition by keeping the camera steady and at a constant distance from the object being viewed.

Where possible, the hardware configuration incorporated general-purpose components that can be sourced through China's robot supply chain so that development resources could instead be focused on enhancing the recognition and control software. This helped shorten the development timeline and improved the ease of future maintenance.

The system attracted considerable interest when it was exhibited at a trade show in China as part of an integrated automatic inspection solution that also included a 4-legged inspection robot that was developed in parallel to facilitate use of the technology under a wider range of conditions. Hitachi plans to expedite the practical deployment of the system by conducting trials at customer buildings to build operational experience.



[1] Robot System for Automatic Inspection of Elevator Cars

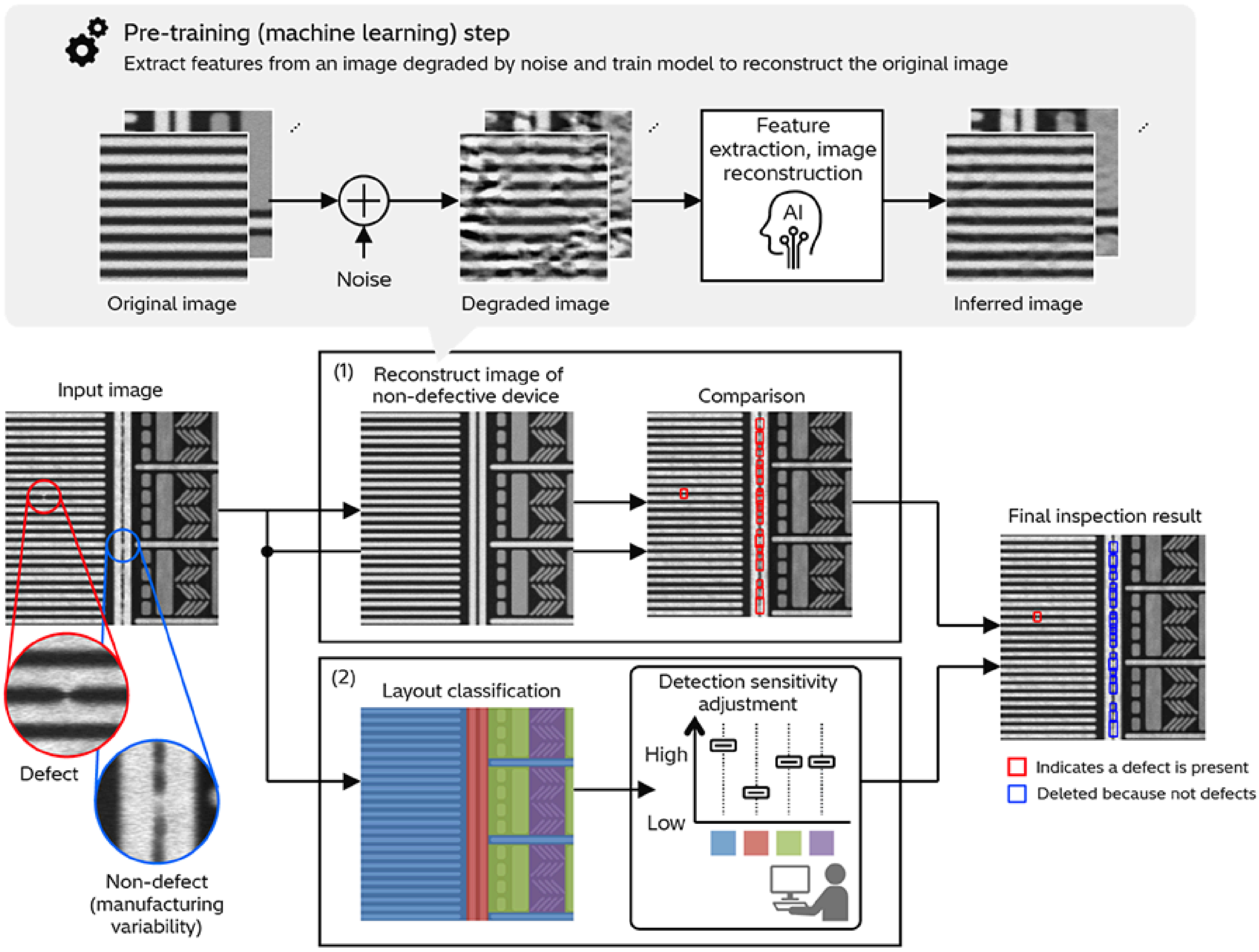
2. Highly Sensitive Defect Detection for Improving Efficiency of Semiconductor Device Production

The manufacturing processes used for semiconductor devices are becoming more complex and sophisticated as the devices themselves achieve the higher levels of miniaturization needed to underpin the rapid progress and uptake of artificial intelligence

(AI). This has led to rising demand for highly sensitive detection techniques that can identify performance-damaging fabrication defects of only a few nanometers in size.

In response to this demand, Hitachi has developed a technique for identifying microscopic defects using scanning electron microscope images. This works by reconstructing the scan image to show a non-defective device and then comparing the before and after images. By doing so, it can accurately identify defects of only a few pixels in size. To reduce instances where manufacturing variability causes the false detection of non-defective structures, Hitachi also developed techniques for identifying mis-detection and for adjusting defect detection sensitivity using automatic recognition of the device circuit layout. Testing on leading-edge devices demonstrated the viability of the system for identifying microscopic defects of 10 nm or less, with false detections being reduced by more than 90%. The new technique has been incorporated into a multi-beam scanning electron microscope to provide rapid and highly sensitive inspection.

In addition to the existing use of dimension measurement in semiconductor manufacturing, the goal is to improve production efficiency by utilizing this new technique along with techniques for electrical and material properties measurement to enable wider use of sensing information in the development of digital twins of the fabrication process.



[2] Detection of Defects by Comparison with Image Reconstructed to Show Non-defective Device

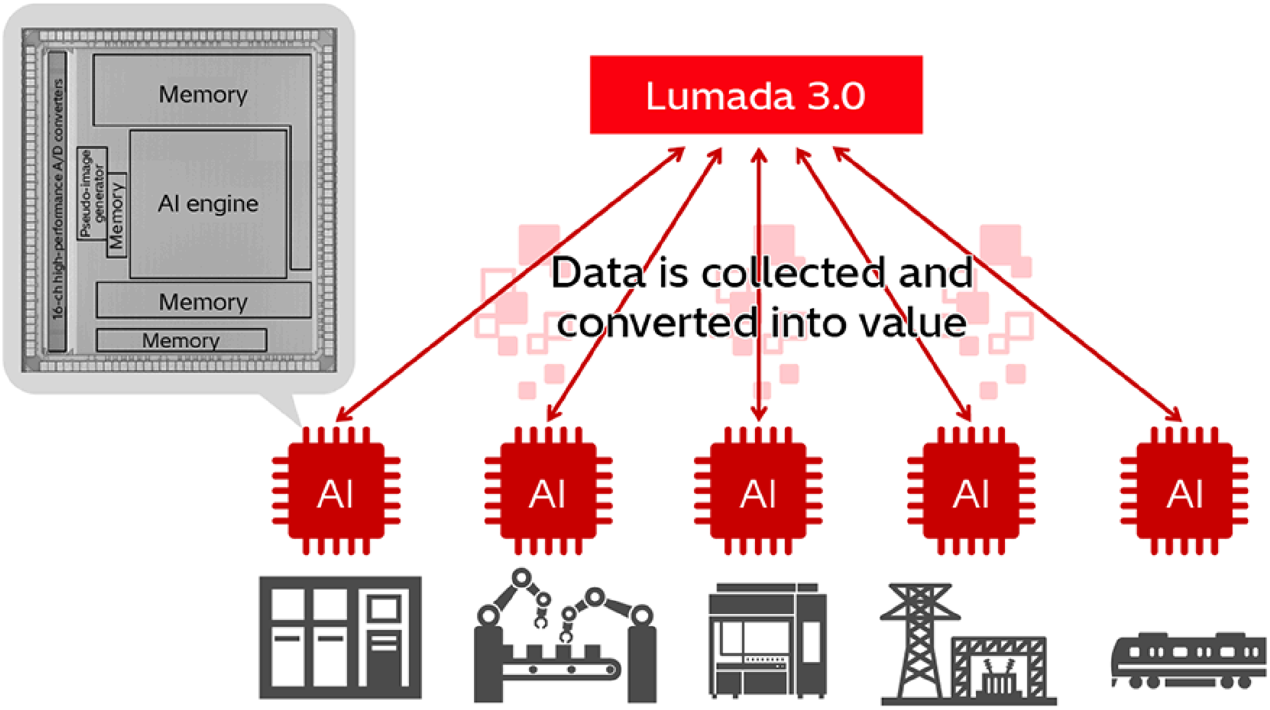
3. Semiconductor Chip for Edge AI to Accelerate On-site Data Processing

Hitachi has developed an AI semiconductor chip with low power consumption and high performance using the latest complementary metal-oxide-semiconductor (CMOS) process as an edge AI technology to boost the frontline application of Lumada 3.0.

The chip consumes only about a tenth of the power of previous AI chips that operate at similar speeds. In addition to its AI engine, the new chip also includes 16 high-performance analog-to-digital (A/D) converters to enable the application of AI recognition to a wide variety of sensor signals, not just images.

Hitachi is seeking to use the widespread adoption of this edge AI semiconductor chip as a means of accelerating data processing at industrial sites and other such facilities and to enhance the value of digitalized assets.

Reference: T. Oshima et al., "A 7 nm CMOS Anomaly-Detection Deep-Learning Processor with Embedded A/D Converters and Pseudo-Image Generation for Sensor Fusion," IECON 2025 (2025.10)

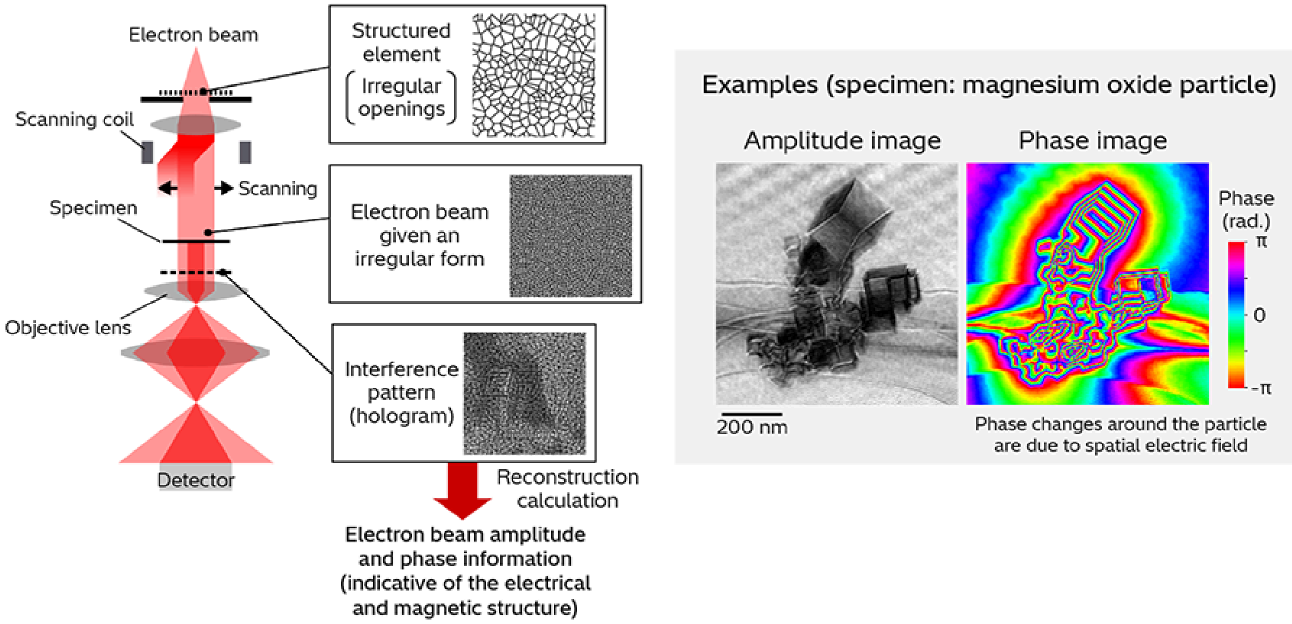


[3] Edge AI Semiconductor Chip to Boost Frontline Application of Lumada 3.0

4. New Electron Microscopy Technique for Quantitative Characterization of Advanced Semiconductors

Semiconductor device structures are becoming ever more complex in pursuit of higher performance and lower power consumption, making their fabrication more demanding than ever. Electron microscopy plays an essential role in precisely evaluating nanoscale structures in the manufacture of these advanced semiconductors, but it remains challenging to observe materials containing light elements that interact weakly with electrons and to quantitatively assess electrical characteristics, specifically the electrostatic potential and dopant distributions inside devices.

To address these challenges, Hitachi, in collaboration with Nagoya University, has developed a new, highly sensitive technique for evaluating the electrostatic and magnetic structure of materials based on electron-wave phase information. Whereas conventional electron microscopes use a uniform electron beam, this new technique scans the specimen with a structured, non-uniform electron beam and reconstructs the specimen's electrostatic and magnetic structure from the interference pattern (hologram) formed by electrons transmitted through the specimen. In addition to its use in investigating the electrostatic potential and dopant distributions inside semiconductor devices, the technique is expected to be useful in a wide range of areas, including improving material performance and elucidating the underlying mechanisms.

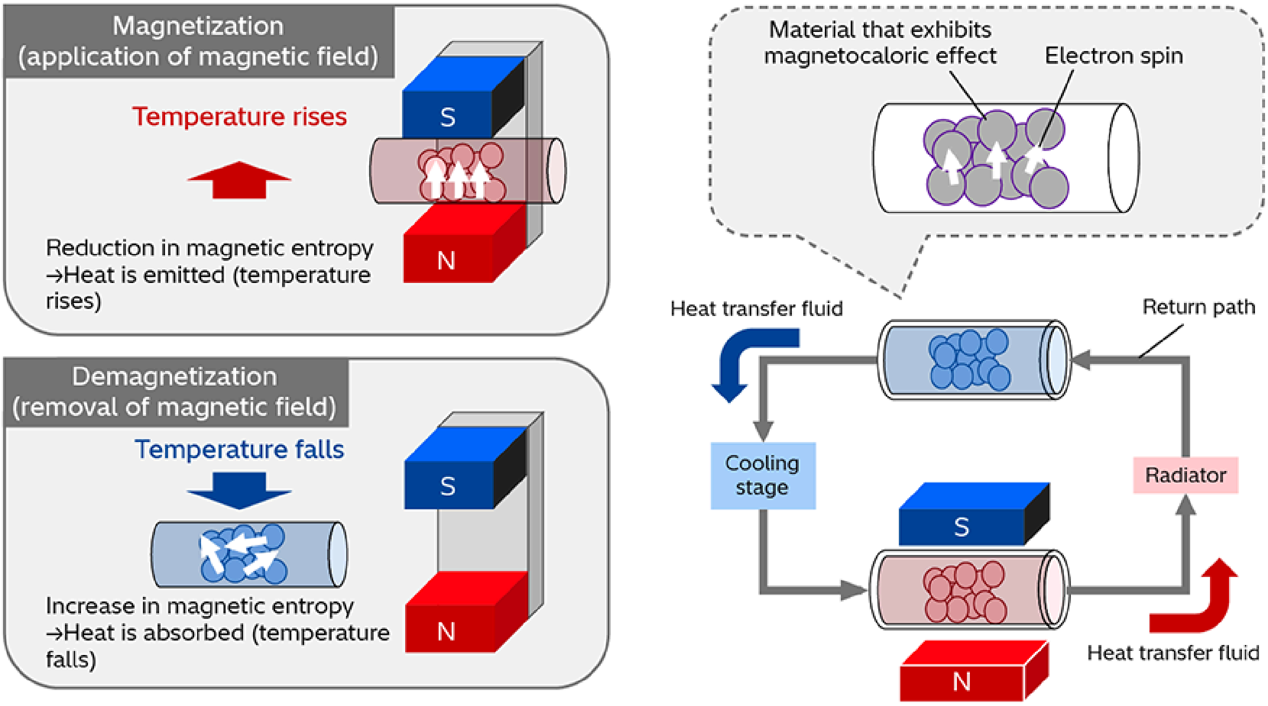


[4] Overview of the Newly Developed Electron Microscopy Technique and Example Results

5. Innovative Cooling Technique for GX in Semiconductor Manufacturing

Cooling is vital to the semiconductor manufacturing process and reducing the amount of electric power consumed for this purpose is an important objective for minimizing the load that the industry places on the environment. Moreover, stricter restrictions are being placed on the use of gas refrigerants with a high global warming potential (GWP). Overcoming these societal challenges calls for the development of cooling techniques that are free of hydrofluorocarbons (HFCs) and make efficient use of electric power.

Hitachi has been developing room-temperature magnetic cooling, a technology based on changes in magnetic entropy, an entirely different principle from conventional compressor-driven cooling. Magnetic cooling utilizes materials that exhibit the magnetocaloric effect, which is the ability to release heat when a magnetic field is applied and absorb heat when the field is removed. This can be used to build highly efficient cooling systems without using gas refrigerants. The goal of this development is to facilitate the green transformation (GX) of semiconductor manufacturing by improving the energy efficiency of cooling systems used in production equipment and elsewhere, and by eliminating the use of HFCs.

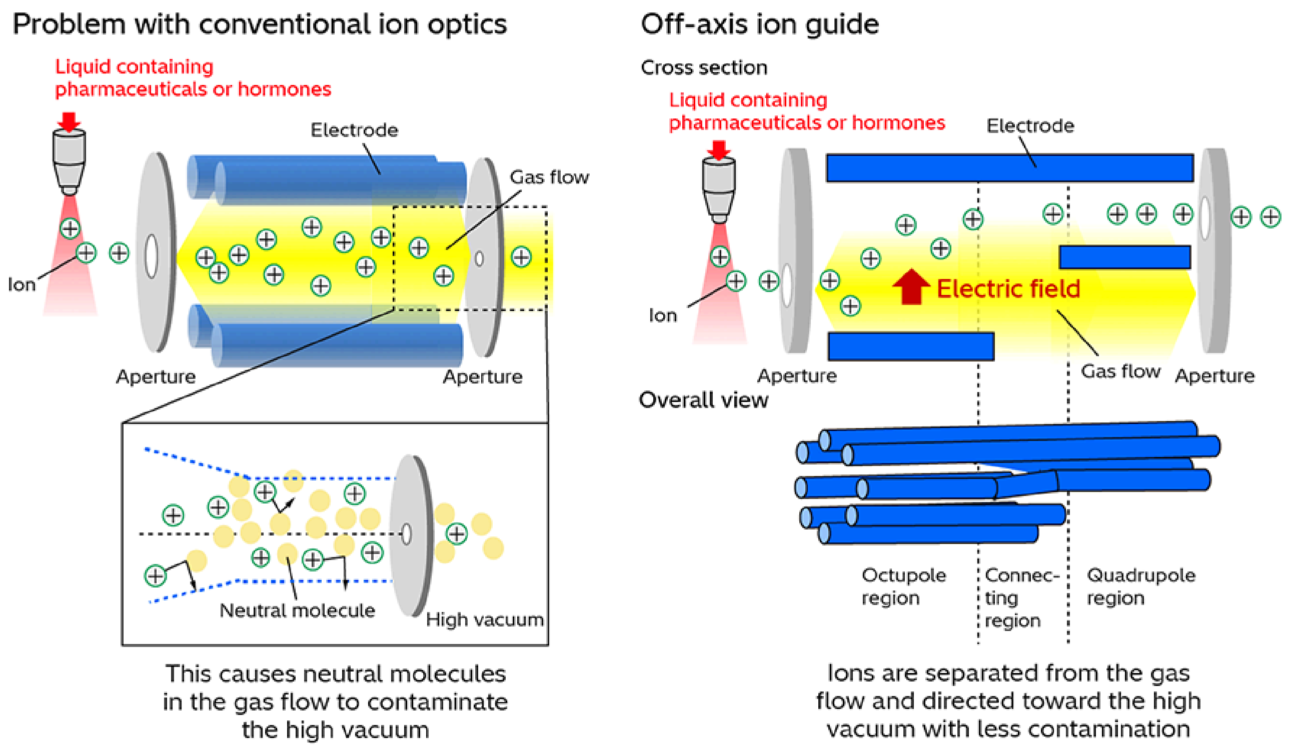


[5] Use of Magnetic Entropy for Cooling

6. Ion Optics for In Vitro Diagnostic Mass Spectrometers

Mass spectrometry works by ionizing the specimen and then separating the components out by mass-to-charge ratio to measure the different species present. Mass spectrometry can deliver high detection selectivity in applications where other measurement techniques struggle to achieve accurate quantitative results, such as the analysis of low-molecular-weight hormones or pharmaceuticals. A problem with existing ion optics, however, is that neutral molecules present in the gas flow can contaminate the high vacuum and impede the measurement of blood sample components present in very low concentrations.

To overcome this problem, Hitachi has developed an off-axis ion guide. This is made up of an octupole region, connecting region, and quadrupole region. The octupole region uses a static electric field to extract ions from the gas flow and direct them toward the connecting region. In the connecting region, some of the octupole electrodes connect to the quadrupole electrodes, thereby guiding ions toward the quadrupole region. As the quadrupole region is offset from the gas flow, it can collect the ions efficiently and direct them toward the high vacuum while avoiding the influence of the gas flow. This off-axis ion guide successfully reduces contamination of the high vacuum and achieves an approximately four-fold improvement in sensitivity compared to the previous method.

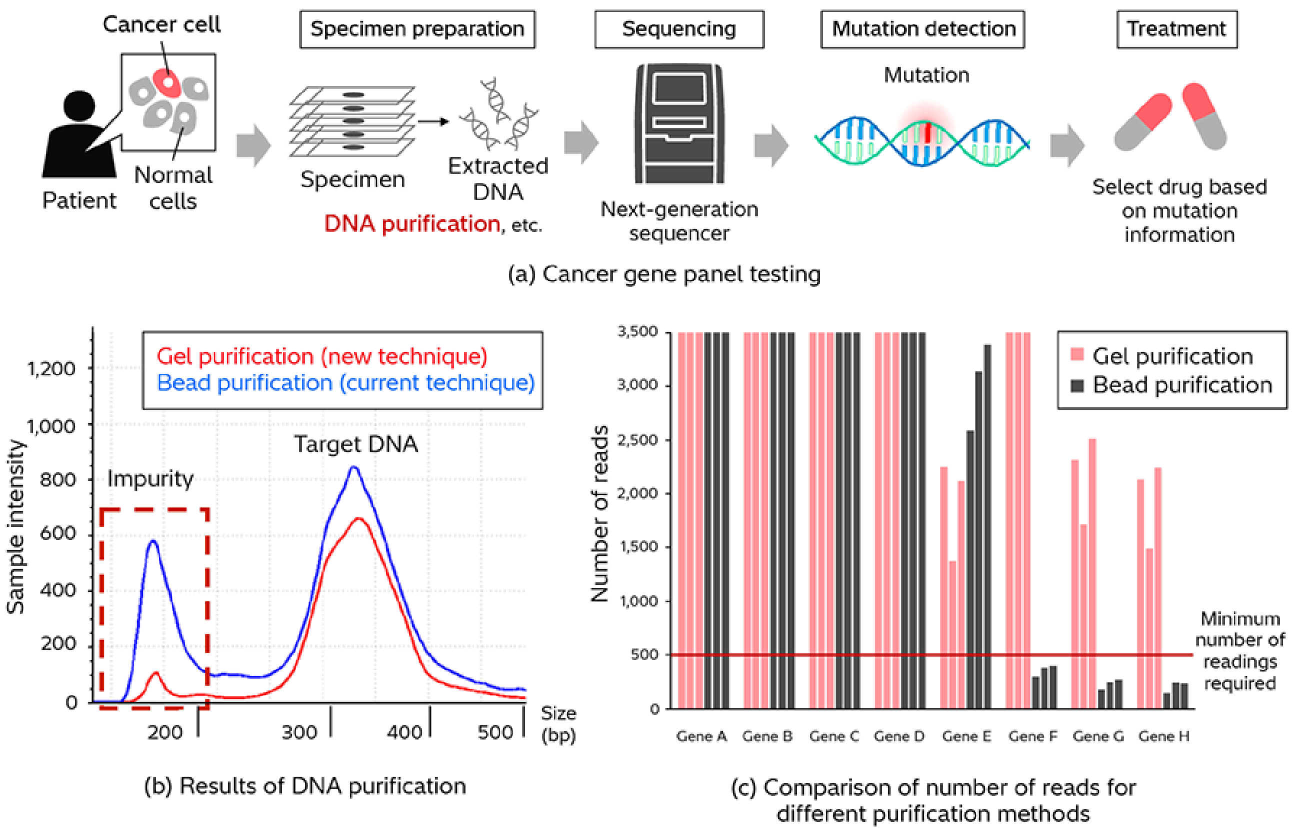


[6] How Ion Optics Enhances In Vitro Diagnostic Mass Spectrometer

7. Genetic Testing System that can Analyze Specimens under a Wide Range of Conditions

Use of gene panel testing for cancer is growing, a technique that involves using a next-generation sequencer to analyze hundreds of genes and assess treatment strategies based on gene mutation information. Unfortunately, given the variability of the size and condition of tumor tissue used in analyses, there are instances when testing is not completed successfully due to insufficient reads for a certain proportion of genes. In response, Hitachi is developing a purification technique for the precise elimination of impurities that would otherwise cause testing to fail, the aim being to enable analyses to cope with specimens in a wide range of conditions.

This has involved demonstrating that the use of gel purification in the deoxyribonucleic acid (DNA) purification step for cancer gene panel sequencing improves impurity removal compared to conventional purification using beads. It has also been shown that minimizing the off-target reads can ensure sufficient reads for the targeted genes. Hitachi is also working to automate gel purification in response to the demand for test automation to handle rising testing volumes. In the future, Hitachi intends to contribute to the wider use of cancer gene panel testing by providing the ability to test specimens that would be difficult to analyze using existing techniques.



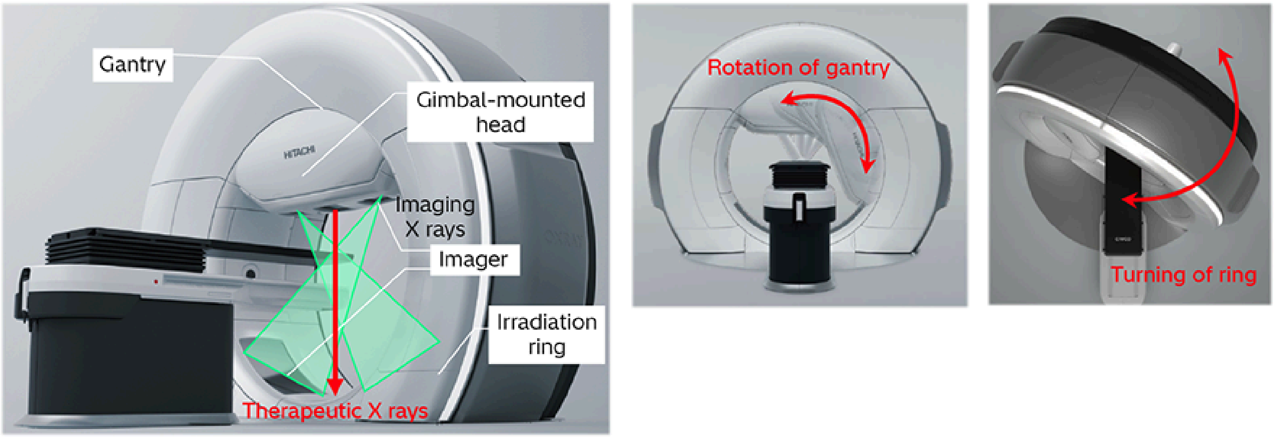
[7] Genetic Testing System

8. Digital Technology for Linear Accelerator Systems

Hitachi has developed an image enhancement technique called cone beam computed tomography (CBCT) for making cancer therapy less invasive and more precise. Linear accelerator systems from Hitachi High-Tech Corporation feature a dual-axis radiation delivery configuration made up of a gantry and ring. They also have two opposing imagers and a gimbal-mounted head to enable tumor-tracking operation that follows the motion of the tumor to ensure highly concentrated dose delivery.

To make the most of these functions, it is essential accurately assess the patient’s posture, tumor location, and any changes in the surrounding tissues before starting radiotherapy. It is for this purpose that the system has been equipped with CBCT.

Common issues with CBCT include image distortion caused by metal implants in the patient's body and loss of contrast in the central abdominal region due to the scattering of radiation inside the body. To overcome this, Hitachi has developed an image processing technique for eliminating false images caused by metal in the body and an image correction technique that uses a simulation of X-ray transmission. In addition to further development of hardware, Hitachi also intends to contribute to improved image quality through both software and hardware.



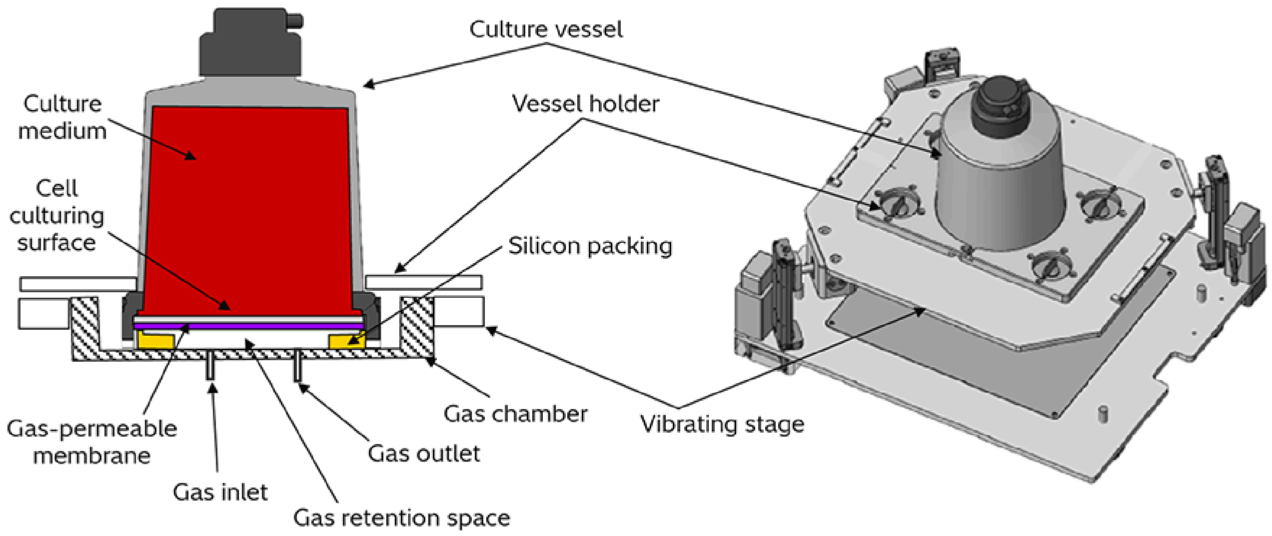
[8] Linear Accelerator System

9. Automatic Culturing to Facilitate Wider Adoption of Cell Therapy

Cell therapy has attracted attention and an advanced form of medical treatment. Chimeric antigen receptor (CAR) T-cell therapy is one such technique. Expected to do well against cancers that are resistant to chemotherapy, it works by extracting immune cells from the blood of cancer patients, adding genes that identify cancer, and then returning the modified cells to the patient.

As the immune cells for CAR T-cell therapy are mainly produced manually by skilled staff, production cost and contamination risk are a problem. On the other hand, fully enclosing the manufacturing process and automating it should enable cells to be produced safely and at lower cost.

Based on the automated and fully enclosed culturing practices it devised for use with induced pluripotent stem (iPS) cells, Hitachi has now developed a gas supply chamber mechanism that augments an automatic culturing system with a culture vessel equipped with gas-permeable membranes suitable for the culturing of immune cells. This enables the automated culturing of immune cells at a quality level similar to that of manual culturing. The system has been incorporated into the iACE mini automated cell culture equipment launched by Hitachi High-Tech Corporation in October 2025.

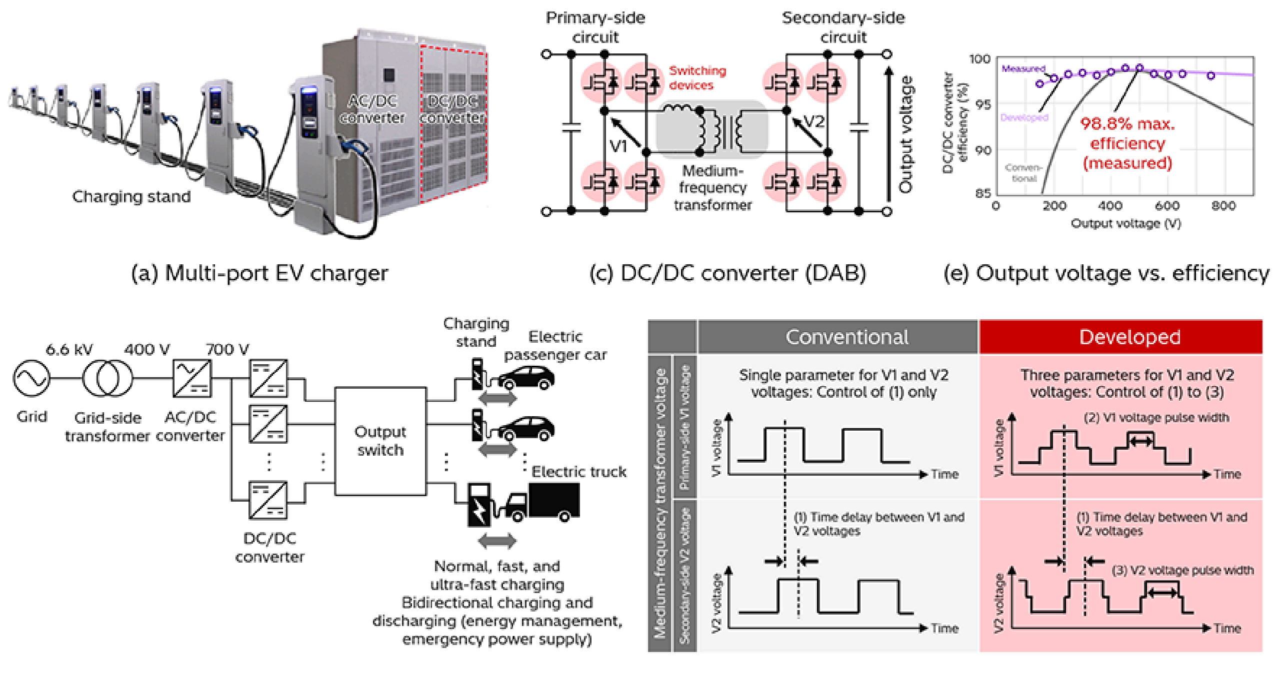


[9] Gas Supply Chamber Mechanism

10. Electric Power Conversion Technology for More Efficient EV Chargers

While the trend in electric vehicles (EVs) is toward higher battery capacity to increase longer range, reducing the charging times for such vehicles requires chargers capable of delivering a wide range of output voltages, typically from 150 V to 900 V. Meanwhile, growing demand to utilize the energy stored in EV batteries has created a need for bidirectional power conversion to enable discharging as well as charging.

The development project described here involved the incorporation into an EV charger of a dual active bridge (DAB) direct-current-to-direct-current (DC/DC) converter to enable bidirectional power conversion for the charging and discharging of batteries. Although DAB converters can operate over a wide voltage range, their efficiency tends to degrade at both the upper and lower ends of that range. To address this issue, Hitachi developed a control technique that enables finer control of switching timing, thereby minimizing losses in the switching devices and medium-frequency transformer across different output-voltage regions. As a result, the proposed technique achieves a peak efficiency of 98.8% and maintains efficiencies of 98% or higher over an output-voltage range of 300 V to 800 V and output currents of 30 A to 60 A. It has been incorporated into multi-port EV chargers from Hitachi Industrial Products, Ltd.



(a) Multi-port EV charger (c) DC/DC converter (DAB) (e) Output voltage vs. efficiency

(b) System block diagram of multi-port EV charger (d) Comparison of conventional and developed control methods

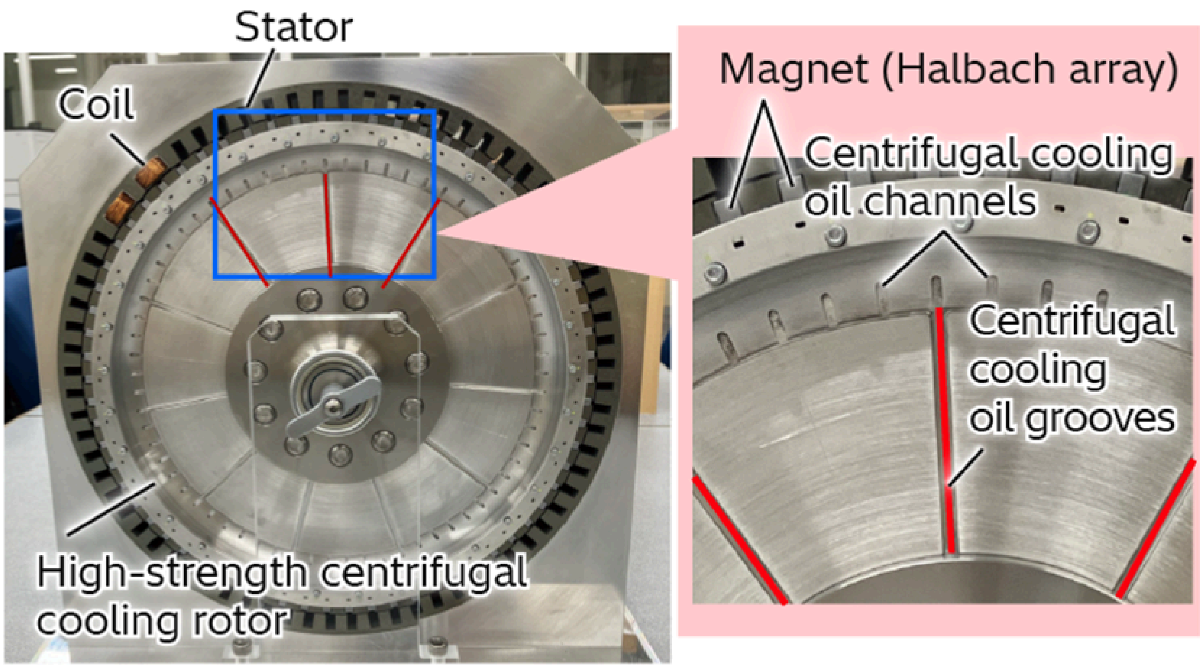
[10] Highly Efficient DC/DC Converter for EV Chargers

11. Motor Technology for High Output Density in Electric Aircraft Powertrains

The electrification of the next generation of aircraft calls for electric motors with high output density and reliability. Hitachi has drawn on expertise in electric motors with a large number of poles that it honed in the automotive industry to develop a motor with high output density and faster speed for use in electric aircraft. In addition to a design that has a large number of poles with the magnets arranged in a Halbach array[*1] to increase the effective magnetic flux and boost torque, the motor has also been made both stronger and lighter by adopting a rotor housing for holding the magnets and a rotor core that is designed to be resistant to centrifugal force. It also features highly efficient cooling by means of centrifugal oil cooling to maintain reliable performance even when operating continuously at high output. These measures equip the new motor to deliver the high output density and reliability that is required in next-generation aircraft and allow it to be fitted to existing engines or airframes without major changes.

In the future, Hitachi intends to use high-flux-density steel sheet to improve performance and to incorporate the motor into products such as large commercial aircraft that require high levels of torque. Note that the work described here drew on the results of the Next-generation Storage Battery and Motor Development (JPNP21026) project, one of the Green Innovation Fund Projects run by the New Energy and Industrial Technology Development Organization (NEDO).

*1. A configuration in which the orientation of the magnets' north poles is offset in 90° steps to generate a high magnetic flux density at each magnetic pole of the motor.

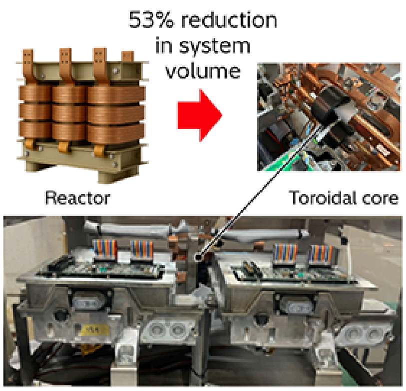


[11] Centrifugal Oil Cooling and Rotor that can Withstand High Centrifugal Force

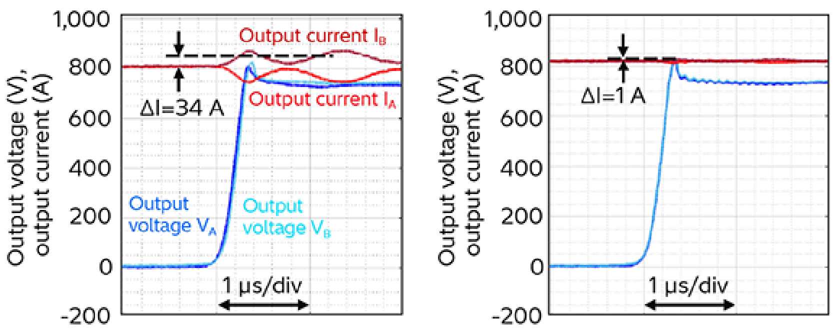
12. Development of Parallel Drive Technique for High-output Inverters

As inverters are a key component in efforts toward electrification that are happening across a range of industries in pursuit of CO_2 emissions reduction, there is a need for technologies that will increase the output of these devices. Hitachi has been working on such technologies that will meet diverse needs by using a modular “unit” configuration for inverters whereby output can be increased by connecting multiple units in parallel. One of the difficulties when connected in parallel is the mismatch in unit currents that occurs due to differences in the characteristics of their respective semiconductor devices. To address this problem, Hitachi has developed a technique for the high-capacity connection of units in parallel that uses gate pulse time adjustment and toroidal cores. By delaying the pulse-width modulation (PWM) signals based on the measured output voltage waveform to minimize timing differences and connecting the output wires in opposite directions through the bore of a small toroidal core instead of using the conventional large reactors, it was able to confirm the improvement of output current balance.

The intention is to put this technology to use in products that require high output such as EV chargers or large commercial vehicles. Note that the work described here drew on the results of the Next-generation Storage Battery and Motor Development (JPNP21026) project, one of the Green Innovation Fund Projects run by the New Energy and Industrial Technology Development Organization (NEDO).



Parallel inverter prototype
Inverter unit A (left) and unit B (right)



Switching test results for parallel inverter
Without (left) and with (right) gate pulse delay adjustment

[12] Testing of High-output Parallel Inverter

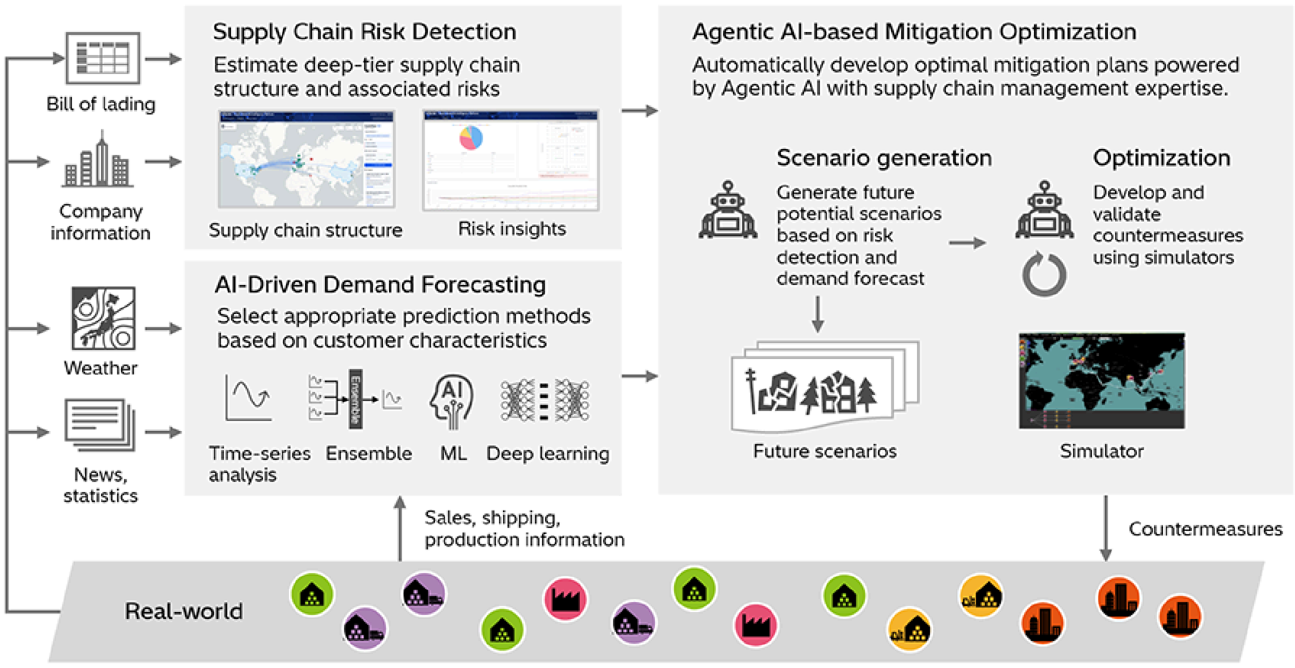
13. Supply Chain Automation by Agentic AI

With increasing geopolitical uncertainty and rising risks in resource procurement, many companies are facing growing challenges such as shortages of critical components due to supplier disruptions and excess inventory caused by inaccurate demand forecasts. In response, Hitachi is developing a supply chain decision automation solution powered by agentic AI, designed to support continuous, highly autonomous operations.

The solution offers three key capabilities:

(1) Supply Chain Risk Detection: Uses open data such as bills of lading and graph technology to construct end-to-end supply chains, including deep-tier suppliers with no direct transaction visibility, and to assess risks related to geography and supplier exposure.
(2) AI-Driven Demand Forecasting: Uses time-series analysis and advanced AI techniques and integrates both external and internal data sources to predict future demand while selecting the most suitable forecasting methods, considering customer-specific product characteristics.
(3) Agentic AI-based Mitigation Optimization: Builds on these insights by leveraging agentic AI with supply chain management expertise to simulate and execute countermeasures—such as switching suppliers or adjusting production and inventory plans.

Together with the Integrated World Infrastructure Model (IWIM), the technology at the heart of physical AI at Hitachi, these capabilities enable rapid response to disruptions and help reduce losses caused by uncertainty in supply and demand.



[13] Overview of Supply Chain Automation

14. Configurable Automated Warehouse for More Efficient Logistics Centers

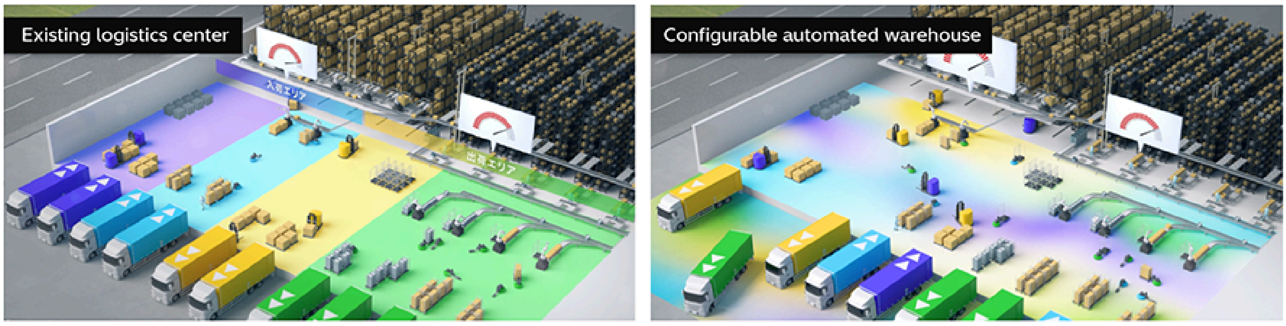
With the growth of electronic commerce (e-commerce), logistics centers are accelerating their adoption of autonomous mobile robots (AMRs) and numerous other forms of automation that reduce labor requirements and enable 24-hour operation. Unfortunately, coordinating all this different automation is difficult, making it a common practice to assign each type of equipment to different tasks or to operate it in different areas. If investment efficiency is to be improved, mechanisms will be needed that enable different types of equipment to operate together in the same area.

In response, Hitachi has developed the following techniques to help implement configurable automated warehouse solutions that equip logistics centers with both automation and flexibility.

(1) Dynamic asset allocation control that considers how the volume of goods will vary depending on the workload in each process, such as inbound or outbound goods handling, and uses this as a basis for determining the optimal mix of AMRs and other transport equipment to assign to each process.
(2) Heterogeneous fleet mixed control that supports multiple different transport systems and works by issuing supervisory control instructions (such as specifying waypoints in

transport equipment routes) so that these different machines can operate efficiently in the same area.

By maximizing utilization of the available equipment and facilitating an asset-light operation that uses the bare minimum of equipment to handle the increasingly heavy flow of goods, these techniques help to boost the efficiency of customer investment in automation. Hitachi is expediting on-site testing as it pursues the rapid commercialization of this technology. Hitachi is also accelerating work on dynamic control solutions for indoor warehouse work and warehouse yards that coordinate with the movement of self-driving trucks.



Current practice: Different types of transport equipment are assigned to different areas
Inbound and outbound goods areas are fixed and each requires sufficient equipment to handle peak workloads

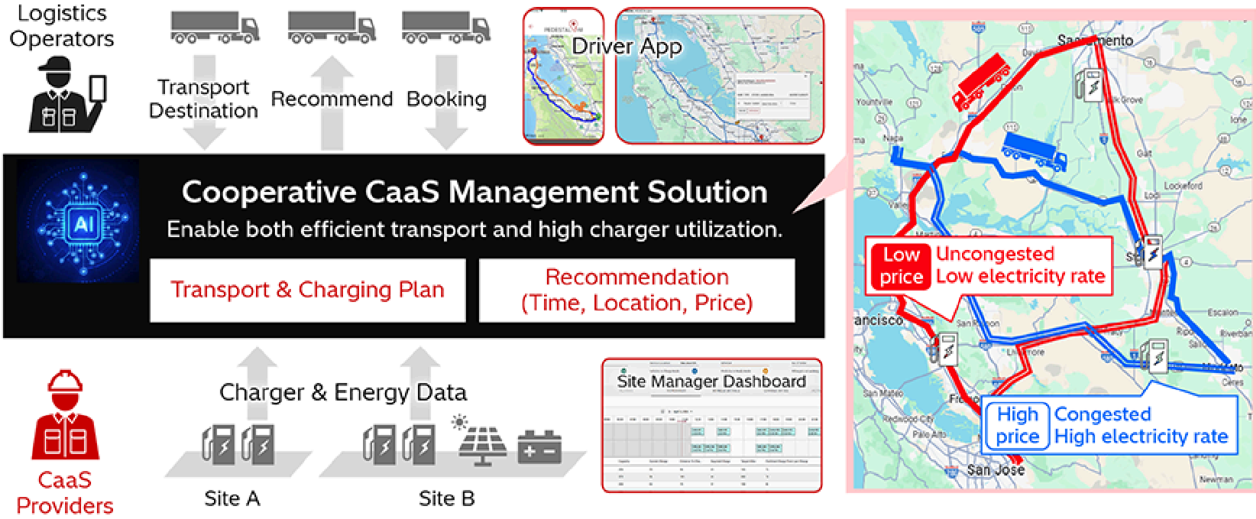
New practice: Different types of transport equipment operate in the same area
Inbound and outbound goods handling share floor space and equipment, achieving higher utilizationworkloads

[14] Overview of Configurable Automated Warehouse

15. Cooperative CaaS Management Solution to Encourage Shift to EVs

As the shift to EVs expands to long-haul transportation, Charging-as-a-Service (CaaS) providers offering high-power on-route charging are expected to emerge. However, if logistics operators use CaaS providers' charging infrastructure at any time and location in an ad hoc manner, it can lead to longer wait times during peak hours, lower charger utilization during off-peak hours, as well as inefficient use of on-site renewable energy and higher grid electricity costs.

To address these challenges, Hitachi has developed the Cooperative CaaS Management Solution. Based on charging requests from logistics operators, the solution optimizes the timing, location, and pricing of on-route charging, enabling cooperative use of chargers among logistics operators by shifting demand toward off-peak hours or sites with low utilization. In addition, based on charging demand forecasts, electricity price fluctuations, renewable energy generation, and opportunities for selling electricity, the solution performs integrated optimization of charging and energy supply and demand. This improves revenue and utilization for CaaS providers while reducing wait times for logistics operators. Hitachi will further develop and commercialize the solution, focusing on Europe where the shift to EVs is progressing.



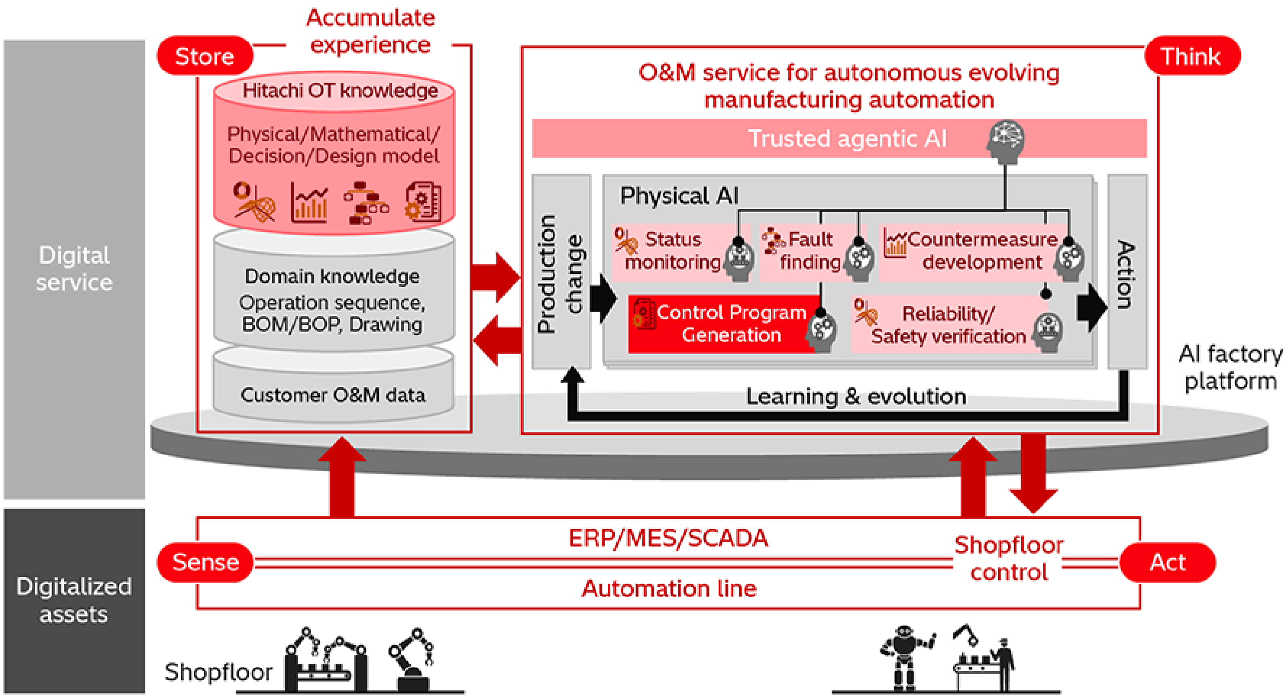
[15] Cooperative CaaS Management Solution

16. Autonomous Evolving Manufacturing Automation

Beset by rising geopolitical risk and economic uncertainty, the manufacturing industry is experiencing rapidly changing conditions. This calls for flexible factory operations that can respond quickly both to on-site issues such as equipment outages and the business risks posed by supply chain interruptions. Meanwhile falling production capacity is also a concern as increasingly severe workforce shortages exacerbate instances of extended production line stoppages or delays in switching production.

To overcome these challenges, Hitachi is building up a portfolio of operational technology (OT) knowledge in a form that can be manipulated by AI, such as physical or mathematical models, and developing autonomous evolving manufacturing automation solutions around a core of physical AI that incorporates this knowledge. These solutions can identify changes in production and automatically generate optimal actions. They use trusted agentic AI to guide themselves through a sequence of work processes, encompassing status monitoring, fault finding, development of countermeasures, control upgrades, and pre-emptive assessment of safety and reliability, and then draw on this experience to continually learn and evolve.

The aim for the future is to accelerate the development and rollout of this solution based around the IWIM technology at the heart of Hitachi's physical AI, targeting the US and Japanese markets where domestic manufacturing is undergoing a resurgence.



[16] Autonomous Evolving Manufacturing Automation

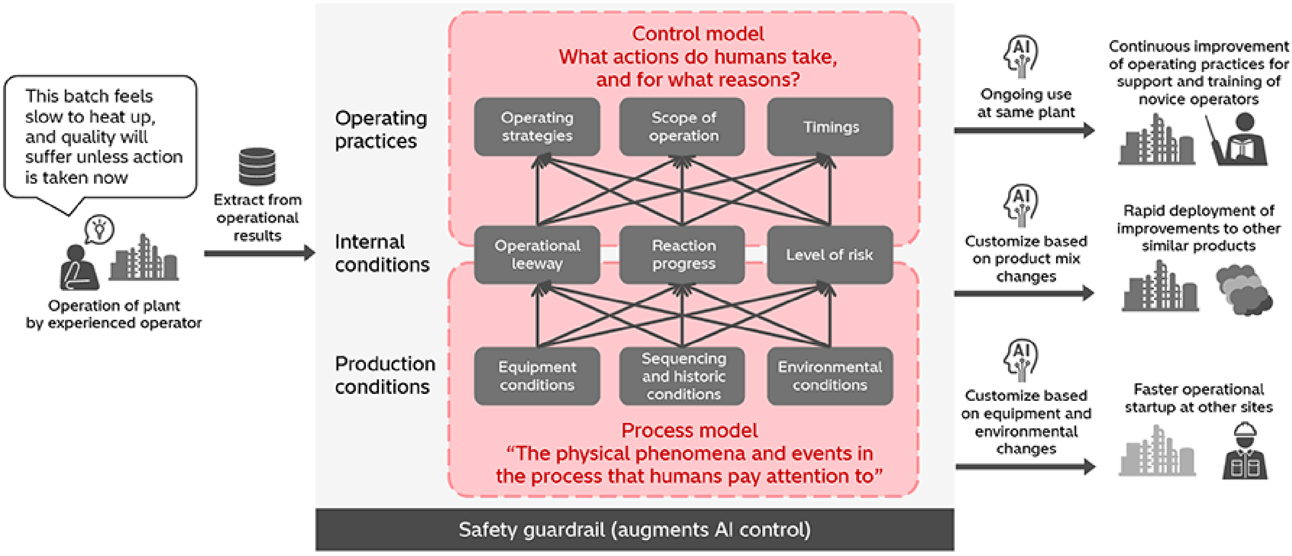
BOM: bill of material, BOP: bill of process, ERP: enterprise resource planning, MES: manufacturing execution system, SCADA: supervisory control and data acquisition

17. Digitalization of Plant Operational Know-how Using AI Operations Guidance

The materials and chemicals industry is suffering from a shortage of plant operators due to the shrinking population and the retirement of experienced staff. Moreover, process characteristics are always changing due to differences between products and other factors such as previous manufacturing and cleaning operations or the ambient temperature and humidity, something that is especially true of the batch processes used to manufacture high function materials. As the current practice of operators is to adjust for this variability using manual operation, there is an urgent need for ways to minimize reliance on specific individuals and pass on operational expertise.

Hitachi has modeled plant operational know-how to develop AI-based guidance techniques that allow anyone to operate a plant in the standard manner. A key feature is the translation of decisions made by experienced workers into structured knowledge for use in machine learning in the form of: (1) process models that predict internal conditions, and (2) control models that interpret these predictions to determine optimal operating practices. More than just replicating a skilled operator, this enables both continuous improvement of operating practices as upgrades are made to the plant and redeployment of the expertise across similar products or other facilities. The system is also equipped with a safety guiderail function that monitors safety during plant operation and augments AI guidance as necessary.

Following the presentation and trialing of this technology at a number of customer plants, products that incorporate it are planned for launch during FY2026. By doing so, Hitachi will contribute to sustainable plant operation by plant operators and the rapid implementation of manufacturing practices at other plants.



[17] Architecture for Modeling Human Decisions Made during Plant Operation in Reusable Form