HITACHI

HITACHI Group R&D White Paper

IWIM: The Infrastructure Intelligence Model Enabling Autonomous Evolution

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Prologue:

Infrastructure faces increasingly complex challenges, including labor shortages, aging assets, decarbonization, and natural disasters. Growing interdependence across manufacturing, logistics, mobility, energy, and digital infrastructure means that advancing individual systems alone can no longer address society-wide challenges.

Future infrastructure must anticipate changes in the physical world and continuously update its functions, configurations, and operating methods without human intervention at every step. We call this Autonomous Evolution. Physical AI is key to bringing AI capabilities into the physical world and opening new possibilities for infrastructure.

Deploying Physical AI in infrastructure requires aligning AI outputs with reality, including mitigating hallucinations, while enhancing safety and reliability. Interdependent infrastructure systems also have different objectives and constraints and must coordinate to create greater value for society.

To meet these challenges, Hitachi is developing IWIM, the Integrated World Infrastructure Model, as an intelligence foundation model that enables Autonomous Evolution. This white paper presents the IWIM vision, its three core technologies, and current research and future directions across key domains.

Contents

01. Autonomous Evolution and Physical AI for Infrastructure

02. Scaling Autonomous Evolution: From Products to Cross-Domain Operations

03. Barriers to Autonomous Evolution and Approaches to Overcoming Them

04. IWIM: Enabling the Autonomous Evolution of Infrastructure

05. Three Core Technologies Enabling IWIM

06. IWIM Use Cases

07. IWIM Suites: Enabling Knowledge Circulation

* Infrastructure：
Systems and services that underpin people's lives and economic activity. In this white paper, infrastructure encompasses systems and services in mobility, energy, industry, finance, and related domains.

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01.
Autonomous Evolution and Physical AI for Infrastructure



Infrastructure must not only adapt to changing environments and societal needs but also create new value through coordination across multiple systems. Physical AI is key to Autonomous Evolution, enabling infrastructure to update its functions, configurations, and operations without step-by-step human intervention.

The operating environment for infrastructure is constantly changing due to labor shortages, aging assets, decarbonization, disasters, and demand fluctuations. As a result, infrastructure must deliver increasingly advanced and diverse value, including stability, efficiency, lower environmental impact, safety, resilience, and responsiveness to diverse user needs. What society values most also continues to change with circumstances.

Meanwhile, manufacturing, logistics, mobility, energy, and digital infrastructure are becoming increasingly interconnected. No single system can deliver all these forms of value alone. Infrastructure systems must understand each other's operating conditions and constraints and coordinate to create value beyond what individual advances can achieve.

Human experience and judgment alone cannot continuously evaluate the vast range of options spanning multiple domains. Future infrastructure therefore requires Autonomous Evolution, enabling it to anticipate change and continuously update its functions, configurations, and operations without human intervention at every step.

Physical AI makes this possible by applying AI-based perception, prediction, and decision-making in the physical world, opening new possibilities for infrastructure.

Continuous Evolution Is Needed as Conditions and Expectations Change

☐ Accelerating Environmental Change ☐ Evolving Societal Expectations

Trade policies

Supply chain disruptions

Geopolitical risks

Growing demand for AI computing

- Continuity of supply during disasters
- Highly reliable operations with fewer personnel
- Expanded production and computing under energy constraints

Growing Interdependence Requires Coordination Across Infrastructure Domains



Production / Shipping

EV Charging

Multimodal

Renewable Energy

Data Processing

Physical Internet

Watt-Bit Integration

Human effort alone cannot continuously assess these impacts or design, update, and operate the right system configurations and coordination mechanisms.

Diversity of Societal Needs
×
Pace of Change
×
Complexity of Interdependence



Autonomous Evolution Enabled by Physical AI

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02.
Scaling Autonomous Evolution: From Products to Cross-Domain Operations



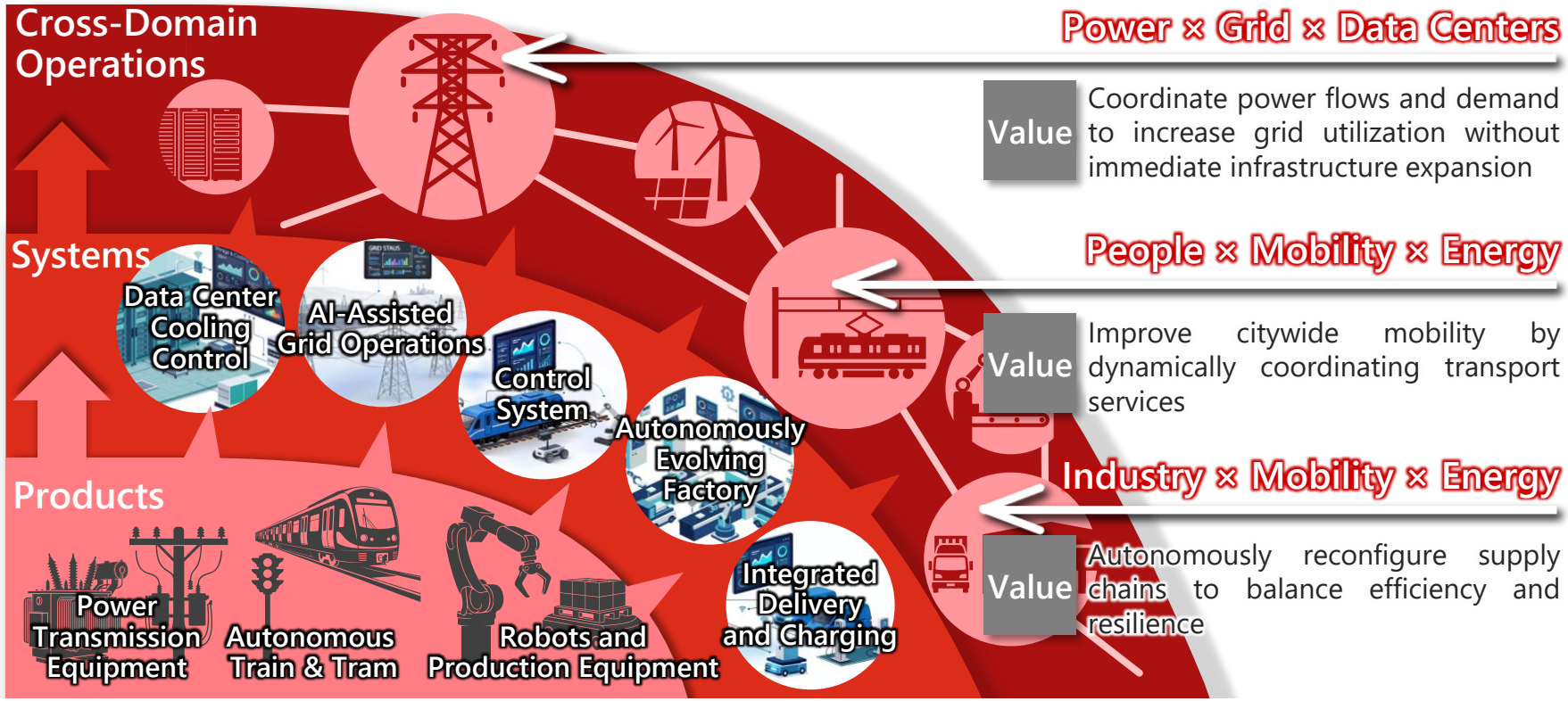
Autonomous Evolution expands from individual products to systems and cross-domain operations, enabling front-line adaptation, system-wide advancement, and value creation beyond what any single system can achieve.

Autonomous Evolution begins with products that act directly on the physical world, sensing changes in their environment and updating their functions and actions. For example, robots can automate skill-dependent tasks by detecting contact conditions and adapting to variations in object position, shape, and deformation.

The next step is to integrate multiple products into a system. In manufacturing, equipment, robots, intralogistics, and production planning share operational data and update roles and operations as demand and equipment conditions change. Extending this approach to logistics, mobility, and energy improves system-wide productivity, flexibility, and stability.

Autonomous Evolution then expands to cross-domain operations. Delivery and charging, railway operations and energy use, and power grids and data centers can coordinate based on their respective conditions and constraints, creating value beyond what any single system can achieve.

By expanding from products to systems and cross-domain operations, Autonomous Evolution progressively advances front-line adaptation, system-wide advancement, and cross-domain value creation.



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03.
Barriers to Autonomous Evolution and Approaches to Overcoming Them

To achieve the autonomous evolution of social infrastructure, we must overcome three barriers: aligning Physical AI with the real world, ensuring safety and reliability against erroneous reasoning and misinterpretation, and coordinating interdependent infrastructure systems.



Infrastructure cannot evolve autonomously without Physical AI that perceives and predicts the real world and translates those insights into control actions. However, three key barriers remain.

The first barrier is the mismatch between Physical AI decisions and the real world. Erroneous reasoning, including hallucinations, can lead to decisions that violate physical laws, operational limits, safety requirements, or operating rules. Physical AI must therefore incorporate physical models and operational knowledge to align its decisions with the real world.

The second barrier is the mismatch between Physical AI decisions and human or societal intent. Misalignment can lead to decisions or actions that do not reflect human or societal objectives. Mechanisms are therefore needed to maintain safety and reliability even when hallucinations or misalignment occur.

The third barrier is the trade-offs among infrastructure systems. Each domain has its own objectives and constraints. Maximizing societal value requires not only local optimization but also cross-domain coordination.

Overcoming these barriers requires a new intelligence foundation model that integrates real-world alignment, safety and reliability, and cross-domain coordination.

Barrier 1: Hallucinations (Erroneous Reasoning)

Inconsistency with physical laws and infrastructure operational knowledge caused by reasoning errors and uncertainty

Barrier 2: Misalignment (Misinterpretation)

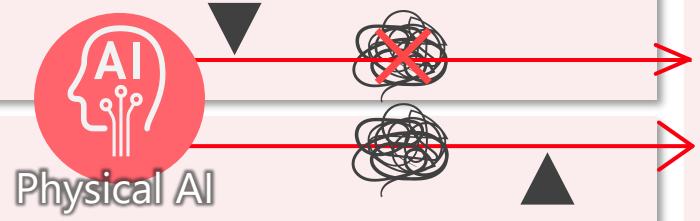
Deviant actions caused by misinterpreting human and societal intent, objectives, or context

Barrier 3: Trade-offs Among Infrastructure Systems

Compromises that may conflict with individual infrastructure objectives in pursuit of overall societal value

① Reducing Hallucinations

- Understanding physical states and phenomena
- Operating and deployment knowledge



System-level fail-safe and governance knowledge

② Robust Systems Resilient to Hallucinations and Misalignment

③ Autonomy-Preserving Cross-Infrastructure Coordination



Coordination

Societal Expectations

- Mission of each infrastructure
- Continuous value improvement
- Priorities
- Acceptable risk levels

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04.
IWIM: Enabling the Autonomous Evolution of Infrastructure

IWIM is an intelligence foundation model that understands the physical laws of the real world and infrastructure operations knowledge, aligning AI outputs with reality while enabling coordination across multiple systems.



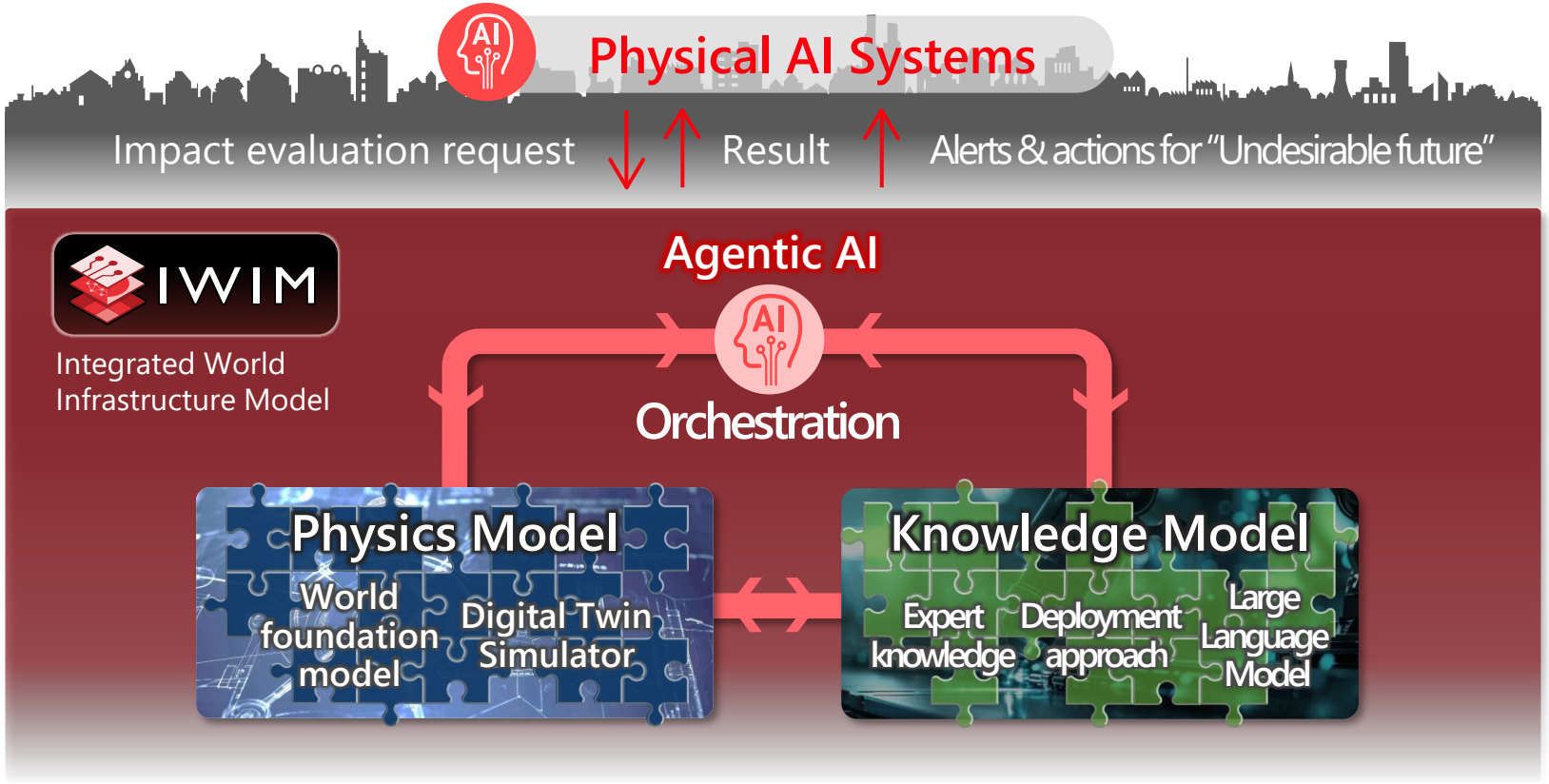
IWIM is an intelligence foundation model that evolves infrastructure into Physical AI systems capable of perceiving and predicting the physical world and acting upon it. By understanding physical laws and infrastructure operations, IWIM aligns AI outputs with reality and coordinates systems with different objectives and constraints.

IWIM's Physical Model combines physics-based models, digital twin models, and world models to predict the current and future states of equipment and systems.

Its Knowledge Model enables AI to use expert know-how, operating rules, safety requirements, deployment knowledge, and other forms of operational knowledge.

Agentic AI configures and executes these models according to the objective and situation. It generates and validates response options, recommends proactive measures against undesirable futures, and coordinates different systems.

Together, these capabilities continuously update the functions, configurations, and operations of infrastructure in response to environmental and societal change, while drawing on human knowledge and responsible judgment.

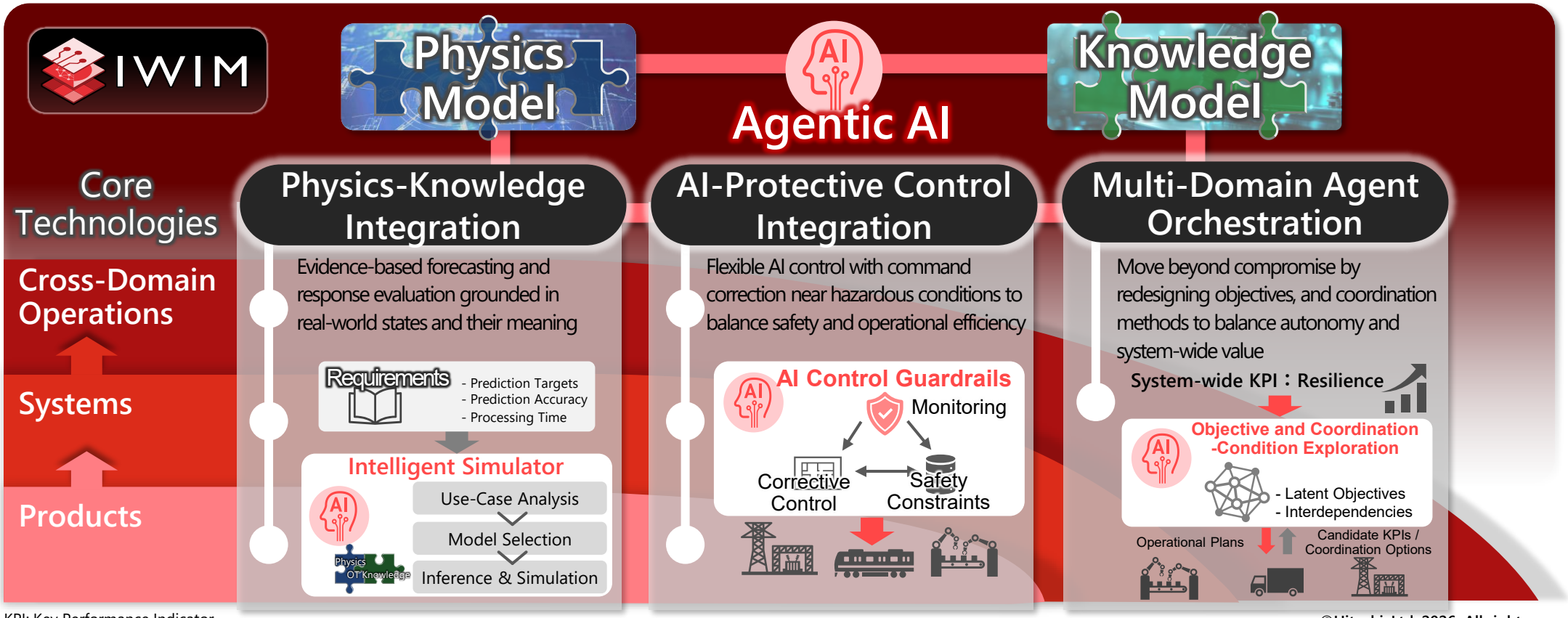


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05.
Three Core Technologies Enabling IWIM



To realize IWIM, Hitachi is advancing three core technologies: (1) Physics-Knowledge Integration to better align AI decisions with reality; (2) AI-Protective Control Integration to combine adaptability with dependability; and (3) Multi-Domain Agent Orchestration to support coordination across infrastructure systems with different objectives and constraints.



KPI: Key Performance Indicator

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06.
IWIM Use Cases

Concrete R&D is underway to realize Autonomous Evolution of infrastructure through IWIM. Examples from frontline operations in factories and construction sites, logistics, mobility, and energy highlight current research achievements and future possibilities.









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Key Models Used



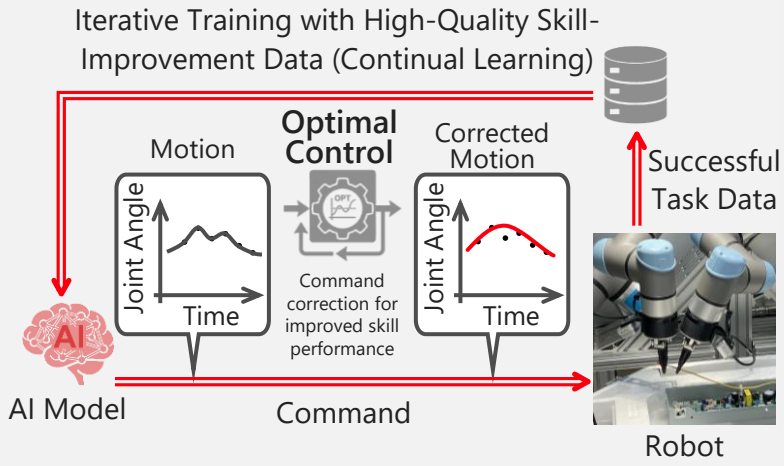
Case 1 : Frontline Work Innovation

From Adaptive Motion Control to Robotic Work System Design

Where We Are Today — Products

Contact-Rich Task Automation

Using vision and force sensing, robots adapt their motions to changes in objects and contact conditions, automating delicate tasks such as wiring and assembly.

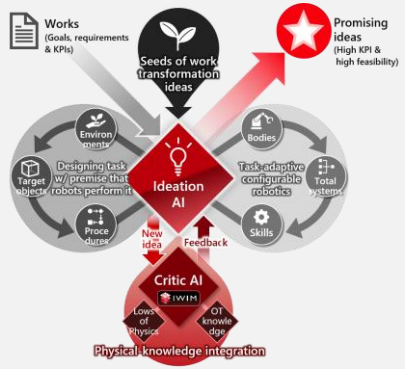


Where We Are Going — Systems

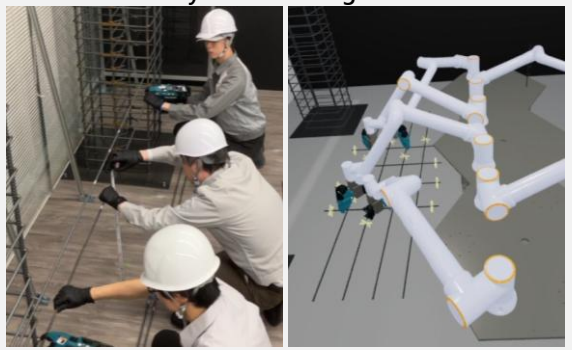
Robotics-Native Systems

Unconstrained by the premise of work methods human can execute, AI jointly redesigns task objects, procedures, environments, and robots to create work systems beyond conventional wisdom.

Work Method Ideation AI
(Simultaneously redesigning Work procedure and robotic system)



Example of work method ideation: Assembly of reinforcing bars for wall



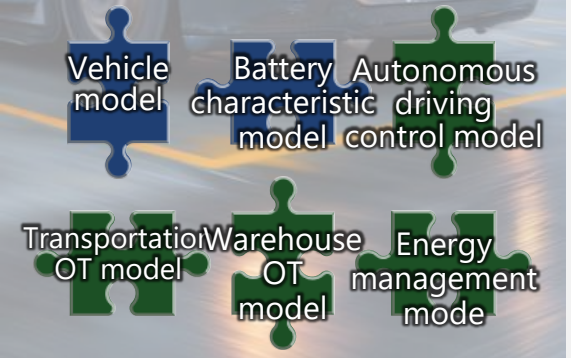
Conventional work method for humans (Attaching each bar to pillars one by one)

AI-generated work method for robots (Assembling bars on the floor, & attaching them to pillars at once)

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Key Models Used



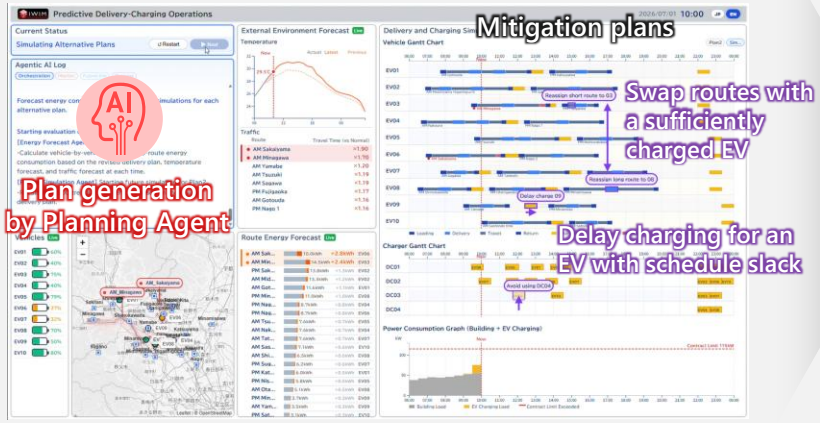
Case 2 : Logistics Innovation

From More Efficient EV Logistics to a 24/7 Network for the Seamless Flow of Goods

Where We Are Today — Systems

Integrated Delivery and Charging Planning

Delivery and charging are planned together based on demand and infrastructure conditions, securing transport capacity while enabling an economically viable transition to EVs.



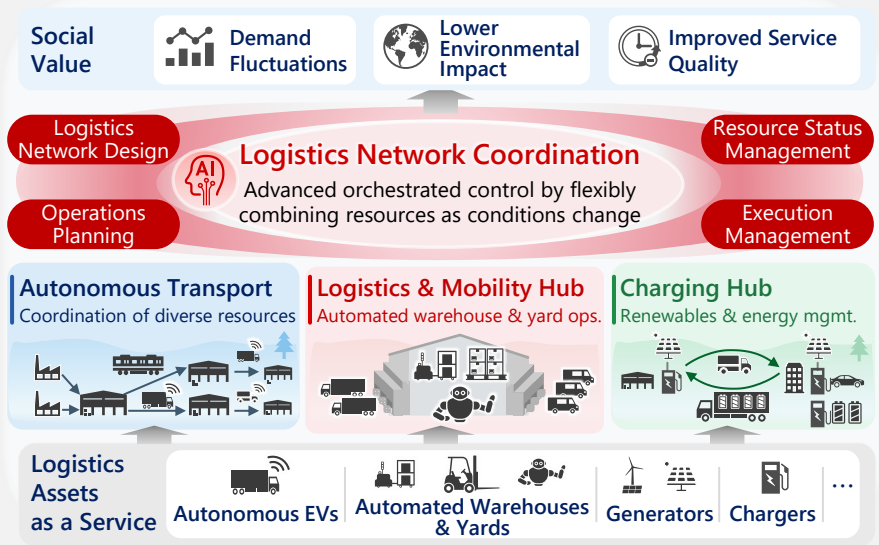
Prime Minister's Award,
55th Japan Industrial Technology Grand Prize [Apr. 2026]

OT: Operational Technology, Ops.: Operations, Mgmt.: Management

Where We Are Going — Cross-domain

Physical Internet

Logistics resources are flexibly combined as demand and conditions change, enabling a green logistics network where goods flow without bottlenecks.

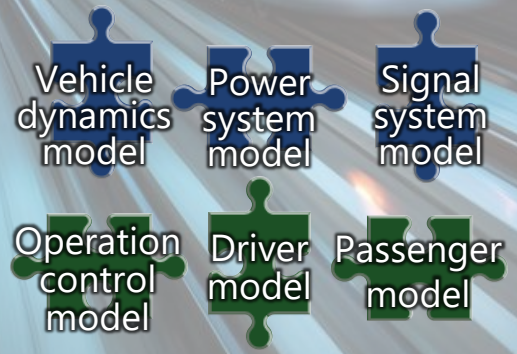


* In this white paper, the "Physical Internet" is a next-generation logistics network that connects and coordinates diverse logistics resources across organizational and system boundaries.

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Key Models Used



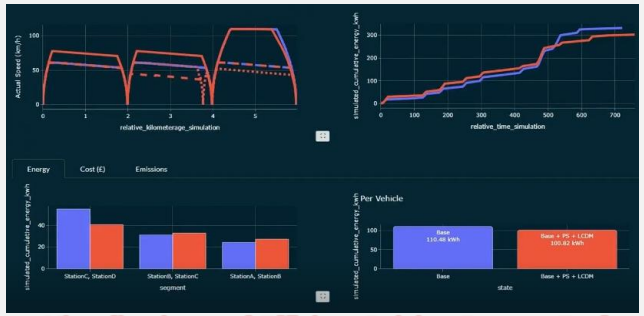
Case 3 : Mobility Innovation

From Energy-Efficient Driving Support to Integrated Mobility-Energy Control

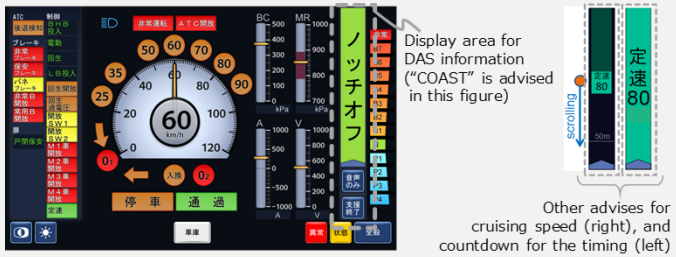
Where We Are Today — Systems

Energy-Efficient Driving Support

Railway operations and energy consumption are simulated using vehicle, route, and timetable data to support driving that balances punctuality and energy efficiency.



Energy Visualization and Efficient Driving Pattern Exploration



Display area for DAS information ("COAST" is advised in this figure)

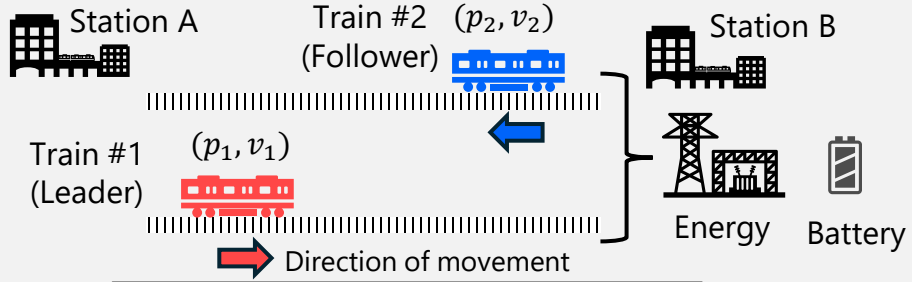
Other advises for cruising speed (right), and countdown for the timing (left)

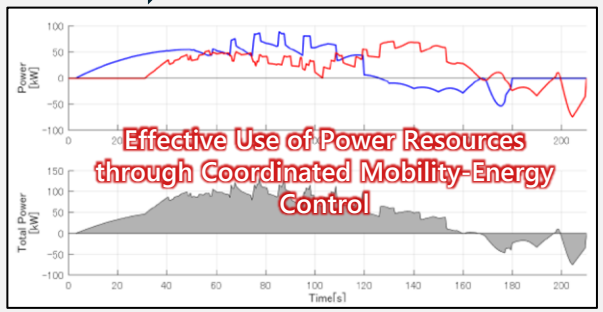
Energy-saving Driver Advisory System (DAS)

Where We Are Going — Cross-domain

Integrated Mobility-Energy Control

Public transport operations and energy demand are forecast to enable integrated control across multiple transport modes and energy infrastructure.





Effective Use of Power Resources through Coordinated Mobility-Energy Control

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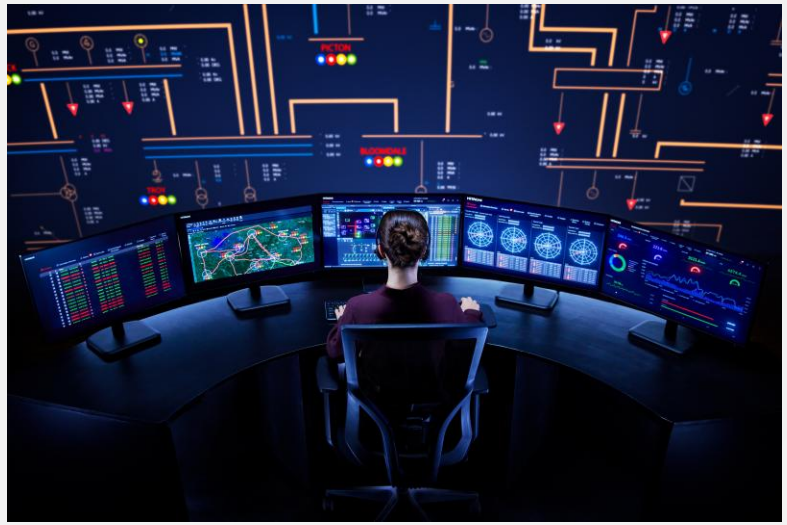
Case 4 :
Grid Innovation

From Grid Operations Support to Coordinated Grid-Demand Operations

Where We Are Today — Systems

Grid Control Support AI

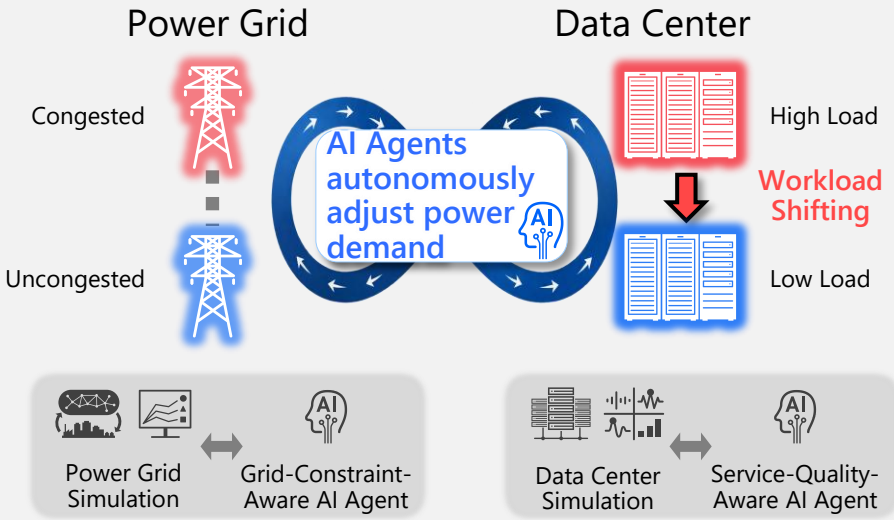
Analyzes vast grid data to identify complex correlations, cascading events, and early signs of anomalies, providing response options to support grid operators' decisions.



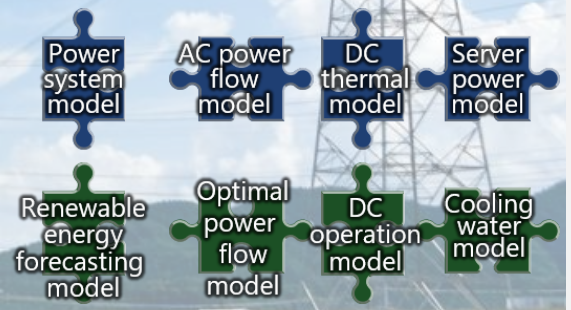
Where We Are Going — Cross-domain

Grid-Demand Coordinated Watt-Bit Integration

Coordinates grid constraints and computing loads while maintaining service quality, based on forecasts of power supply and demand and data center workloads.



Key Models Used



AC: Alternating Current, DC: Data Center

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07.
IWIM Suites: Enabling Knowledge Circulation

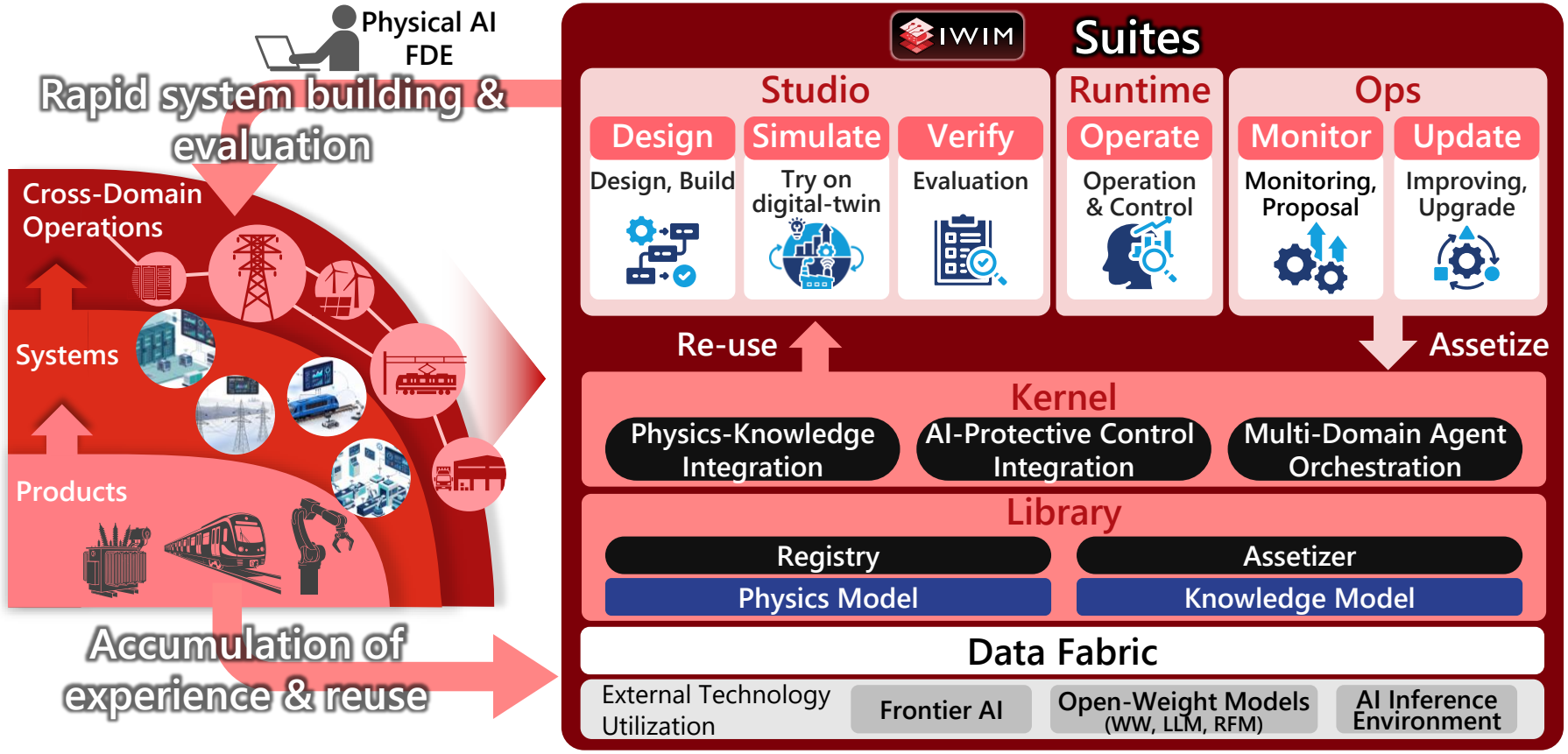


Knowledge gained in the field is captured as reusable assets and shared across organizations and domains. Hitachi is developing IWIM Suites as the platform for this knowledge circulation, fostering an ecosystem in which shared achievements create new value and enabling the Autonomous Evolution of infrastructure.

Autonomous Evolution of infrastructure requires more than building and operating individual systems. Experience and knowledge gained in the field must be captured and circulated to inform future design and operations.

Physical AI FDEs (Forward Deployed Engineers) work with customers and frontline teams to identify challenges across products, systems, and operations, accelerating system development and value validation with Physical AI. IWIM Suites provides the platform for these activities, continuously capturing and reusing knowledge from the field. It connects design, simulation, validation, operation, and improvement in a continuous cycle, transforming physical models, knowledge models, validation results, and operational experience into reusable assets.

These assets are shared and applied across Hitachi and its partners, with knowledge gained from each deployment fed back into the ecosystem. By building on one another's achievements and further advancing the resulting knowledge, the ecosystem can continuously create new systems and value.



LLM: Large Language Model, Ops: Operations, RFM: Robot Foundation Model, WW: World Model

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Epilogue:

Autonomous Evolution enables infrastructure to anticipate social and environmental change and continuously create new value without human intervention at every step. Achieving it requires an intelligence foundation model that understands the physical world, ensures safety and reliability, and supports cross-domain coordination.

IWIM integrates knowledge of physical phenomena with operation knowledge to enable the Autonomous Evolution of infrastructure. It aligns AI decisions with reality, responds flexibly to environmental change while maintaining safety and reliability, and supports coordination across infrastructure systems with different objectives and constraints. R&D in frontline work, logistics, mobility, and energy is bringing this vision to life.

Bringing the vision to life in the field and feeding the resulting knowledge into future design and operations are equally important. Physical AI FDEs work with customers and frontline teams to validate value in the field. To support this process, Hitachi is developing IWIM Suites to transform the resulting knowledge into reusable assets and circulate them across projects. By sharing and applying these assets across organizations and domains, Hitachi aims to foster an ecosystem in which new systems and value continue to emerge.

From infrastructure that responds to change to infrastructure that anticipates change and evolves alongside people. To realize a society in which multiple infrastructure systems are connected and the MEGURI of people, goods, information, energy, and value is enhanced, Hitachi will open up new possibilities through pioneering R&D.

* MEGURI :
Just as blood circulates throughout the body and enhances its vitality, diverse flows across society connect and set one another in motion, continuously creating new energy and value. In this white paper, we call this dynamic “MEGURI”.

Related Websites

About IWIM
https://www.hitachi.com/rd/about/iwim/

About HMAX
https://www.hitachi.com/en-us/products/digital/hmax/

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