Technology Cooperation Survey on the Technology Cooperation of China-Japan-Korea: Physical AI and Sustainability

Introduction

The Chinese Academy of Engineering, the Engineering Academy of Japan, and the National Academy of Engineering of Korea are jointly conducting the 14th survey on technology cooperation among China, Japan, and Korea. This initiative aims to establish a cooperative platform for the mutual development of East Asia and to resolve common regional challenges.

Co-prepared by members of the National Academies of Engineering of the three countries, the questionnaire is structured in three sections, consistent with previous joint surveys:

• Section I: The Cooperation Indicator monitors current trends and conditions among the three countries annually.
• Section II: The Fact-finding Survey explores technology cooperation within specific sectors. This year's special focus is Physical AI and Sustainability.
• Section III: Personal Matters is a questionnaire designed to be analyzed in connection with the findings from the first two sections.

For the purpose of this survey, Physical AI refers to the integration of artificial intelligence with cyber-physical systems that interact with and control physical environments through sensing, reasoning, planning, and actuation under real-world operational constraints. Examples include industrial robotics, intelligent manufacturing systems, autonomous control systems, AI-enabled digital twins, and distributed edge-cloud architectures.

The Fact-finding Survey for this year examines technology cooperation priorities among China, Japan, and Korea in addressing the challenges and opportunities of Physical AI and Sustainability.

The survey recognizes that technological maturity in laboratory environments and readiness for large-scale industrial deployment may differ significantly. In addition to technological innovation, successful implementation depends on factors such as system integration, interoperability, safety certification, workforce development, resilient manufacturing and semiconductor ecosystems, and international collaboration.

Particular attention is given to industrial AI deployment, sustainable manufacturing, data infrastructure, regulatory frameworks, talent development, and collaborative testbeds that can accelerate practical implementation and trilateral cooperation among China, Japan, and Korea.

Thank you in advance for your participation.

I. Survey on Cooperation Indicator

1. Do you think technological cooperation is necessary among China, Japan, and Korea? (　　)

A. Very necessary

B. Necessary

C. Neutral

D. Unnecessary

2. Do you think technological cooperation among China, Japan, and Korea would be mutually beneficial? (　　)

A. Very beneficial

B. Beneficial

C. Somewhat unbeneficial

D. Completely unbeneficial

3. In terms of quantity, how would you evaluate the level of technological cooperation among China, Japan, and Korea? (　　)

A. Very high

B. Somewhat high

C. Neutral

D. Low

4. In terms of quality, how would you evaluate the level of technological cooperation among China, Japan, and Korea? (　　)

A. Very high

B. Somewhat high

C. Neutral

D. Low

5. What is your opinion on the future prospects for technological cooperation among China, Japan, and Korea? (　　)

A. Very optimistic

B. Optimistic

C. Pessimistic

D. Very pessimistic

II. Fact-finding Survey

Survey on Physical AI and Sustainability

II-1. Physical AI in Next-Generation Industrial Systems (single select)

1. Physical AI Definition

1. Which of the following best characterizes "Physical AI" in industrial Cyber Physical Systems (CPS) environments?

1. Closed-loop integration of AI with cyber-physical systems under real-time constraints
2. Embodied intelligence with perception-planning-control stack under uncertainty
3. AI-augmented digital twins for predictive, prescriptive, and adaptive optimization
4. Distributed multi-agent AI across edge-cloud continuum with latency-aware orchestration
5. Other

2. System Architecture

2.1. Which Physical AI system architectures are most critical? (Select up to two)

1. Ultra-low latency edge AI (sub-millisecond deterministic control)
2. Hierarchical edge-cloud orchestration with federated learning
3. Multi-agent reinforcement learning (MARL) for decentralized coordination
4. Physics-informed neural networks (PINNs) for hybrid modeling
5. Event-driven and asynchronous AI control systems
6. Other

2.2 What are the key system-level trade-offs in deploying these architectures? (Select up to two)

1. Latency vs model complexity
2. Centralized vs decentralized intelligence
3. Energy efficiency vs performance
4. Robustness vs adaptability
5. Scalability vs system reliability
6. Other (please specify)

3. Technical Bottlenecks and Failure Modes

3.1 What are the major technical barriers to implementing Physical AI? (Select up to two)

1. Sim-to-real transfer gap in RL and robotics
2. Lack of semantic interoperability (industrial ontologies, data models)
3. Deterministic inference under safety-critical latency constraints
4. Poor generalization under non-stationary environments

5. Integration with legacy Operational Technologies (OT) systems (Programmable Logic Controller (PLC) / Supervisory Control and Data Acquisition (SCADA) / Distributed Control System (DCS))
6. Other (please specify)

3.2 What are the greatest concerns regarding the deployment of Physical AI in real industrial environments? (Select up to two)

1. Distribution shift / domain mismatch
2. Sensor degradation and data drift
3. Control instability under uncertainty
4. Cybersecurity vulnerabilities
5. Cascading failures in interconnected systems
6. Other (please specify)

4. Control Paradigms

4.1. Which control paradigms are most viable for Physical AI? (Select up to two)

1. Hybrid Model Predictive Control (MPC) + deep learning controllers
2. Reinforcement learning with safety constraints (Safe RL)
3. Physics-AI co-designed control (gray-box models)
4. Adaptive robust control with AI augmentation
5. Other (please specify)

4.2. What are the key constraints in deploying AI-based control systems? (Select up to two)

1. Safety certification requirements
2. Real-time determinism constraints
3. Lack of explainability for control decisions
4. Integration with legacy control systems
5. Other (please specify)

5. Data Infrastructure

5.1. What data infrastructure is most critical for enabling Physical AI systems? (Select up to two)

1. High-frequency multimodal data acquisition and sensor fusion pipelines
2. Time-synchronized edge-cloud distributed data architectures
3. Industrial data spaces with standardized semantics and data sharing
4. Real-time industrial interoperability standards (e.g., Open Platform Communications Unified Architecture (OPC UA) Field eXchange(FX))

5. Streaming-first architectures for real-time analytics and decision-making
6. Other (please specify)

5.2 What are the major challenges in industrial data infrastructure? (Select up to two)

1. Data ownership and sovereignty
2. Lack of standardized semantics
3. Data quality and labeling issues
4. Real-time data synchronization
5. Other (please specify)

II-2. Green Innovation for Sustainable Manufacturing

1. Decarbonization Pathways

1. Which decarbonization pathways are most effective? (Select up to two)

1. Deep electrification of thermal processes
2. Hydrogen-based industrial processes
3. Integrated carbon capture, utilization and storage (CCUS) systems
4. AI-driven optimization of energy systems
5. AI-driven approaches in circular manufacturing systems
6. Other (please specify)

2. Physical AI Deployment Maturity in Industrial Energy Systems

2.1. What stage best describes the current level of Physical AI adoption in industrial energy systems?

1. Early adoption stage
2. Pilot project stage
3. Monitoring and decision-support stage
4. Semi-autonomous operation stage
5. Fully autonomous operation stage

2.2. What are the key barriers to scaling Physical AI in energy systems? (Select up to two)

1. Lack of real-time data
2. Integration issues
3. Regulatory uncertainty
4. High cost
5. Other (please specify)

3. Industrial Applications of Physical AI

3. Which industrial application areas are expected to be most significantly impacted by Physical AI? (Select up to two)

1. Reinforcement Learning (RL)-based process control
2. Demand response optimization
3. Digital twin optimization
4. AI-driven discovery of new materials
5. AI-based carbon emissions and environmental impact assessment (Life Cycle Assessment, LCA)
6. Other (please specify)

4. Expected Benefits of Physical AI and Sustainability

4.1. What are the most important benefits expected from the adoption of Physical AI and sustainable manufacturing technologies? (Select up to two)

1. Reduced energy consumption and carbon emissions
2. Improved resource efficiency
3. Reduced waste generation
4. Enhanced flexibility of production and supply chain operations
5. Other (please specify) ___________

4.2. What are the most significant sustainability concerns associated with the expansion of Physical AI? (Select up to two)

1. Increased electricity consumption of AI infrastructure
2. Increased carbon emissions from data centers
3. Environmental burden of semiconductor manufacturing processes
4. Increased water consumption for cooling systems
5. Growth in electronic waste (e-waste)
6. Other (please specify) ___________

II-3. Policies, Regulations, and International Cooperation for Physical AI and Sustainability

1. Regulatory Frameworks

1. What are the most appropriate regulatory approaches to support Physical AI and sustainable industrial development? (Select up to two)

1. Risk-based regulation
2. Sector-specific certification
3. Industry-led standards

4. Regulatory sandbox
5. International harmonization
6. Other (please specify)

2. Standardization Priorities

2. What are the most urgent areas for standardization to support the adoption of Physical AI and sustainable industrial systems? (Select up to two)

1. Data interoperability
2. AI performance evaluation and benchmarking
3. Safety validation and certification
4. Carbon measurement and assessment standards
5. Digital twin standards
6. Other (please specify) ___________

3. Barriers to Collaboration

3.1. What are the major barriers to international cooperation in the field of Physical AI? (Select up to two)

1. Data sovereignty
2. Divergent national standards
3. Intellectual property (IP) issues
4. Geopolitical conflicts and tensions
5. Insufficient research and development (R&D) funding
6. Other (please specify) __________

3.2 What are the key challenges in cross-border industrial data sharing? (Select up to two)

1. Data privacy
2. Lack of standards
3. Data localization
4. Trust deficit
5. Other (please specify)

4. Collaboration Models

4.1. What are the most effective forms of collaboration in the field of Physical AI? (Select up to two)

1. Joint testbeds
2. Shared data platforms

3. Standard co-development
4. Public-private partnerships
5. Talent exchange
6. Other (please specify)

4.2. What are the most effective mechanisms for promoting collaboration in the fields of Physical AI and sustainability? (Select up to two)

1. Pilot plants
2. Shared datasets
3. Joint funding
4. Regulatory alignment
5. Other (please specify)

5. Priority Cooperation Domains

5. Which domains are most suitable for trilateral cooperation? (Select up to two)

1. Semiconductor manufacturing and supply chain resilience
2. Industrial robotics
3. Smart grids
4. Digital twins
5. Low-carbon processes
6. Other (please specify)

6. Enabling Conditions

6.1. What are the most important enabling factors for advancing Physical AI and sustainability? (Select up to two)

1. AI + CPS integration
2. Governance frameworks
3. Deployment infrastructure
4. Data ecosystems
5. Talent

6.2. What is the expected timeline for realizing this enabler?

1. Within 3 years
2. 3–5 years
3. 5–10 years
4. More than 10 years

III. Personal Information

1. Have you participated in some form of technological cooperation with Korea, China, or Japan during the last five years? If yes, how many times?

If you are from China, please fill in the blanks below.

A. Japan: (   ) case(s)

B. Korea: (   ) case(s)

C. China-Japan-Korea: (   ) case(s)

If you are from Japan, please fill in the blanks below.

A. China: (   ) case(s)

B. Korea: (   ) case(s)

C. China-Japan-Korea: (   ) case(s)

If you are from Korea, please fill in the blanks below.

A. China: (   ) case(s)

B. Japan: (   ) case(s)

C. China-Japan-Korea: (   ) case(s)

2. Your profession (   )

A. Professor

B. Researcher

C. Business employer or employee

D. Government official or public sector employee

E. Other (please specify)

3. Your area of specialty (   )

A. Civil and environmental engineering

B. Mechanical engineering

C. Technology management

D. Material and energy resource engineering

E. Electric/electronic engineering & ICT

F. Chemical and biomedical engineering

G. Other (please specify)

4. How long have you been engaged in your research field? (   )

   A. Less than 5 years

   B. 5-10 years

   C. 10-20 years

   D. More than 20 years

5. Your age (   )

   A. 35-49

   B. 50-59

   C. 60-69

   D. 70-79

   E. 80 and older

** If you have any suggestions or feedback on this survey, please comment below.

Thank you very much for your input. Your information will not be used for any purpose apart from this survey.