ロボット革命・産業IoTイニシアティブ協議会
Robot Revolution & Industrial IoT Initiative

PLATTFORM INDUSTRIE 4.0

DISCUSSION PAPER

German-Japanese Discussion Paper on Manufacturing Data Spaces

Introduction

Climate change, geopolitical tensions, interrupted supply chains: Around the globe, manufacturing industries are facing challenges that often take on specific characteristics in individual countries, but nevertheless are based on developments and trends that transcend national borders. Digitalization and the use of data promise to offer solutions to many of these challenges, from reducing the carbon footprint of manufactured products to increasing the resilience of supply chains. On top of this, they also allow the development of new business models, from digital marketplaces to pay-per-use services. And due to the availability of large amounts of data and advances in artificial intelligence, we are now able to make better use of these options than ever before.

So far, however, turning the promises of the digital transformation into reality has proven to be difficult. The reasons include an unwillingness to share valuable data, a nearly unmanageable number of competing solutions and the need to commit large amounts of financial and human resources to get smart manufacturing projects off the ground.

What the manufacturing industry needs, therefore, is a willingness to cooperate. In times of international value chains and complex supply chains, data needs to be shared across national borders and between companies to life up to its potential. Necessary investments in infrastructure need to be made for the benefit of industry – and society – at large. Furthermore efforts must be made to support these developments with international standardization and appropriate national or regional regulation. This is nothing one company or one country can do on its own.

With this paper, the authors hope to contribute to such a collective effort by focusing on one significant piece of the puzzle to “make data work” on a global scale: The creation of a federated, decentralized and collaborative data ecosystem for smart manufacturing via dedicated data spaces. More specifically, the document is intended to help build a common understanding of data spaces, to identify the problems they can help solve and to highlight the technical and organizational challenges that need to be overcome together. In addition, current initiatives and activities in Japan and Germany that are already contributing to the creation of manufacturing data spaces are highlighted.

Background and Motivation

This document was written under the auspices of Robot Revolution & Industrial IoT Initiative (RRI) from Japan and Platform Industrie 4.0 (PI40) from Germany. The two initiatives share the common goal of strengthening competitiveness through Industrie 4.0 and Industrial IoT in both countries, and of facilitating a smooth transition to digital production. Based on this common goal, they have built a successful history of cooperation that goes back to the announcement of a joint action plan at Hannover Messe 2016. The following year, cooperation was further deepened at CeBIT and again highlighted in the Hannover Declaration 2017 between the German Federal Ministry for Economic Affairs and Energy (BMWi), the Japanese Ministry of Economy, Trade and Industry (METI) and Ministry of Internal Affairs and Communications (MIC).

The partnership between the two initiatives so far has mostly focused on the topics of cyber-security, international standardization and digital business models. It also has looked closely at how to promote small enterprises, shared best practices on work, education and training, and supported several research projects. In all these areas, it has resulted in numerous joint publications and contributions to conferences, a better understanding of common challenges and potential solutions, and above all the strengthening of trust between the partners.[1]

The German-Japanese Discussion Paper on Manufacturing Data Spaces naturally reflects the specific circumstances in the two countries. However, as previously stated, manufacturing industries in other parts of the world face similar challenges, and it is not the goal of the document to give the impression that manufacturing data spaces should be a bilateral endeavor. In fact, only a multilateral approach based on collaboration, inclusiveness, transparency and equality is suited for the creation of open, global and cost-effective data networks. RRI and PI40 therefore support the development of International Manufacturing-X, a unified effort to drive the global coordination of data spaces for industry.

The views and opinions expressed in the document are those of the authors and do not necessarily reflect the views or positions of any entities they represent. It should not be understood as a definitive statement, but as a step towards a common understanding, and as a humble contribution to an ongoing discourse that invites feedback and can be further discussed by the societies in Japan, Germany and elsewhere.

1 *For a list of joint publications, see Plattform Industrie 4.0 Website: https://www.plattform-i40.de/IP/Navigation/EN/ThePlatform/Structure-Organization/InternationalCooperation/Japan/japan.html.*

Core Aspects and Design Elements of Manufacturing Data Spaces

Manufacturing data spaces create a secure and interoperable environment for sharing and utilizing data across the manufacturing value chain, thus enabling data-driven innovation and optimization by supporting processes such as production planning, quality control, predictive maintenance and supply chain management. They provide a technical framework (e.g., data exchange protocols, security mechanisms, identity and access management) that allows for seamless data exchange and collaboration, regardless of the underlying technology stack or proprietary protocols, ensuring interoperability and integration between different systems, machines and devices commonly found in manufacturing environments.

While they provide a very attractive environment for data-driven innovation, manufacturing data spaces also need to meet the varying needs and requirements of different actors involved in the manufacturing value chain. For example, large enterprises need to deal with much larger amounts of data, while small companies have limited resources to utilize data effectively. A simple and easy to use data-utilization structure is desired.

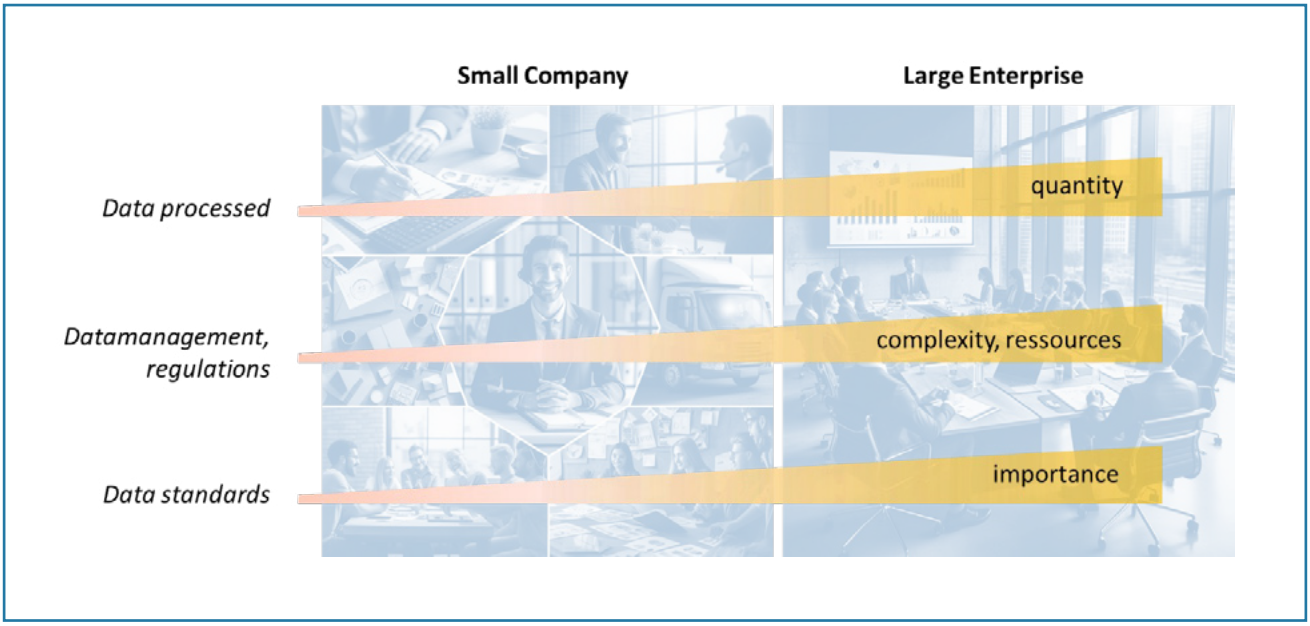
The concept of data spaces encompasses several key aspects that are crucial for smarter decision-making and more efficient production in the manufacturing industry. Core aspects and design elements include:

Data Integration and Governance

Manufacturing data spaces involve integrating data from various sources within the manufacturing ecosystem. This includes data from machines, sensors, production lines, supply chains and other relevant systems. Effective data management ensures that information is accessible, reliable and up to date. It involves organizing, storing and processing data efficiently. In the future, it must be considered that data from production and the office flow together, which is why data governance in organizations will become mandatory.

Interoperability

Data space solutions aim to bridge the gap between different data formats, protocols and systems. Interoperability ensures seamless communication and data exchange across heterogeneous platforms. By enabling interoperability, manufacturers can connect disparate devices, applications and databases, leading to better collaboration and streamlined processes.



Quelle: Ingo Sawilla

Semantic Understanding and Ontology

Understanding industrial data requires more than just raw information. Semantic technologies and ontologies help interpret data in context. Ontologies define relationships between concepts, allowing machines and humans to understand the meaning behind data. This facilitates smarter decision-making.

Data Sovereignty and Security

Manufacturers must maintain control over their data. Data sovereignty ensures that data remains within the organization's jurisdiction and complies with legal and privacy requirements. Robust security measures protect against unauthorized access, data breaches and cyber threats.

Evolution and Adaptability

The data space framework evolves alongside technological advancements and changing business needs. It adapts to new data sources, emerging standards and evolving manufacturing processes. An agile data space can accommodate customizations, scalability and system enhancements.

A special feature of a manufacturing data space is the convergence of Operational Technology (OT) and Information Technology (IT), in which data from the production machines is placed in the hands of the entire value chain. This increases the degree of complexity, which can be controlled by common standards and process harmonization. In summary, manufacturing data spaces combine data integration, semantic understanding, analytics and smart applications to enhance decision-making, optimize production and drive innovation in the manufacturing sector.

Data Management

Core aspects and design elements of manufacturing data spaces do not only stay inter-organizations, but also reside inside organization. The data space readiness of the organization is another important aspect.

Data management refers to the process by which companies collect, organize and use data. The goal of data management is to balance the requirements for efficiency and organization in an organization against the equally important requirements for security and cost savings. The relationship between data volume and cost in an organization are:

The more data a company collects, the larger the amount of data becomes. This can come from various sources, such as customer data, transactions, production data, marketing analytics, etc. A growing amount of data can lead to storage-related costs as organizations require more resources for data storage.

Storage costs, the cost of storing data on servers or in the cloud can be significant. The more data that is stored, the higher the cost of storage infrastructure and maintenance. Processing costs, when organizations analyze large amounts of data to gain insights, powerful computing resources are required. This may result in additional costs. Security costs, backing up and protecting data requires investments in security measures such as encryption, access controls and privacy policies. Personnel costs, organizations need skilled employees to manage, analyze and protect data.

Organizations need to optimize the amount of data to avoid unnecessary costs. This can be done through data cleansing, archiving, or compression. Cost-benefit analysis: Companies should evaluate the value of the data collected in relation to the costs. Not all data is created equal, and it's important to prioritize correctly. Overall, balanced data management is critical to reap the benefits of data without letting costs spiral out of control.

Once the aspects have been understood, the following steps are proposed for implementation:

- Educate key stakeholders within the company about data space principles, interoperability and data sovereignty and familiarize yourself with the concept of virtual data spaces and how they facilitate secure data exchange.

- Determine the specific use cases for data sharing within the data space. Consider scenarios like supply chain collaboration, predictive maintenance, or quality control.

- Assess the types of data your company generates and collects. Identify relevant data sources, such as sensors, production systems, or inventory databases. Understand the quality, format and frequency of data from these sources.

- Establish clear data governance policies. Define who owns the data, access rights and usage guidelines. Ensure compliance with legal and privacy regulations (e.g., GDPR) when sharing data.

- Research available data space frameworks (e.g., Eclipse Dataspace Connector, International Data Spaces) and select one that aligns with your company's needs. Understand the architecture, components and security features of the chosen framework.

- Prepare your IT infrastructure for data space integration. Ensure compatibility with the chosen framework. Implement necessary connectors, APIs and protocols to enable data exchange. Map your internal data models to the data space ontology. Define how your data aligns with shared concepts. Use semantic technologies to enhance data understanding and interoperability.

- Implement robust security measures. This includes authentication, encryption and access controls. Address potential risks related to data exposure or unauthorized access.

- Engage with other organizations that participate in the same data space. Understand their requirements and expectations. Establish communication channels for collaboration.

- Conduct pilot tests with a limited dataset or a specific use case. Validate data exchange, security and performance. Learn from the pilot to refine your approach before full-scale implementation.

- Train employees on data space concepts, tools and best practices. Prepare for organizational changes related to data sharing and collaboration.

- Data space adoption is an ongoing process. Continuously monitor performance, address issues, and adapt as needed. Stay informed about updates and enhancements to the chosen data space framework.

- Remember that connecting to a data space is not just a technical endeavor; it involves cultural shifts, collaboration and a commitment to data-driven innovation.

Examples of industrial data usages are:

Data Correlation and Analytics

Data spaces correlates data from various sources to extract meaningful insights. This involves identifying patterns, trends and anomalies. Advanced analytics techniques, such as machine learning and predictive modeling, help optimize production processes, quality control and resource allocation.

Smart Applications and Decision Support

Data space platforms enable the development of smart applications that leverage industrial data. These applications can automate tasks, provide real-time alerts and enhance decision-making. Decision support systems within the data space assist operators, managers and engineers by providing relevant information for timely and informed choices.

Shaping Digital Ecosystems in Germany and Japan

The manufacturing industry has traditionally been a space where digitalization struggles to get off the ground. However, over the past decade, the pace of digitalization has picked up significantly, both in Japan and Germany. This has been due to several internal and external factors, including:

- Increasing competition from newly industrialized countries, interrupted supply chains, rampant energy and resource prices, as well as shortage of skilled labor and growing demographic pressure have strengthened the need to innovate.
- Automation suppliers and equipment OEMs have started to shift their value generation towards software and to recognize the power of digital ecosystems.
- Governments and companies are increasingly wary regarding an over-dependence on a few hyperscalers.
- In Europe, new regulation intended to reduce the emission of CO2 or to increase the transparency, resilience and traceability of supply chains has created the need to find ways to share data across organizational boundaries.

Europe and Germany

In Europe and Germany, these developments have led to multiple large initiatives that all center around the governance and privacy of data in open and federated data spaces that enable sovereign multilateral data exchange without dependencies on centralized platforms:

Gaia-X

Gaia-X is a European initiative to develop a federated secure data infrastructure by specifying common requirements and developing a reference implementation. In early 2022, the initial implementation of Gaia-X started with the launch of the first data spaces and related services. Since then, several so-called Gaia-X Ecosystems have been established for various industries, including Aerospace, Energy, Finance, Health, Manufacturing, Mobility and Logistics.

To provide national contact points for local supporters and interested parties, numerous Gaia-X Hubs have been established, including in Japan.

Catena-X

Building on technical foundations pioneered by Gaia-X, IDSA, IDTA and others, Catena-X aims to build the first fully operational and scalable data ecosystem for manufacturing supply chains. It will provide an environment for the creation, operation and joint use of end-to-end data chains along the entire automotive value chain. Originating in Germany but aiming for a global ecosystem, it brings together automotive OEMs, Tier 1 suppliers and software providers.

In 2023, the first operating company intended to provide products and services based on Catena-X was established.

Manufacturing-X

Based on the experiences gained with Catena-X and elsewhere, the Manufacturing-X initiative aims to implement open, decentralized and collaborative data ecosystems for further sectors of the manufacturing industry, such as plant engineering, aerospace and the chemical industry. In Germany, the initiative is flanked by a federal funded program for R&D projects.

Factory-X, the central lighthouse project in that program, was launched in early 2024 and will further develop core technologies and implement data space use cases for machinery and plant manufacturers. Other projects focusing on specific industries will follow. Together, the projects aim to facilitate the cross-industrial, joint development of an open and interoperable architecture for a smart connected industry across all supply chains.

Japan

In 2016, the Japanese government announced the concept of Society 5.0, which is defined as “A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space.”

The globalization of the economy is progressing, international competition is becoming increasingly severe, and problems such as the concentration of wealth and regional inequality are growing. Social problems that must be solved in opposition (as a tradeoff) to such economic development have become increasingly complex. Here, various measures have become necessary such as the reduction of greenhouse gas emissions, increased production and reduced loss of foodstuffs, mitigation of costs associated with the aging society, support of sustainable industrialization, redistribution of wealth and correction of regional inequality, but achieving both economic development and solutions to social problems at the same time has proven to be difficult in the present social system.

Data space activities are considered as the technical and business approach to realize Society 5.0. Three major activities in Japan are:

DATA-EX

DATA-EX is a collaboration of existing efforts related to data linkage. This is a platform that aims for "federal-type cross-sectoral data collaboration." DATA-EX will become a hub for data linkage, and it will also promote social implementation through repeated discussions with major overseas organizations, with a view to interoperability with international data linkage platforms such as Gaia-X.

In 2023, DATA-EX formed the International Open Forum on Data Society with European partners such as Gaia-X, IDSA, FIWARE, etc. It is expected to pave the way for the trusted data exchange between Europe and Japan.

Ouranos Ecosystem

"Ouranos Ecosystem" achieves both economic developments, solving social issues and industrial development by integrating cyberspace (virtual space) and physical space (physical space). This is a series of initiatives aimed at realizing this vision through these efforts, together with people who share the vision of realizing a human-centered society.

Currently, Ouranos Ecosystem is making special effort to comply with battery regulations.

Manufacturing Data Space by RRI

RRI is an initiative focusing on the business transformation through the Industrial IoT approach. It hosts the Manufacturing Data Space Action Group, where members of manufacturing industries develop use cases and requirements for the Manufacturing Data Spaces.

Use cases discussed by the action group are categorized into groups. They align with the “Sustainability”, “Resilience” and “Innovation” perspective.

Each use case lists the kind of data to be handled, stakeholders, concerns and bottlenecks related to data exchange. Through this approach, requirements for stakeholders of data space implementation are being discussed.

Along with the improvement of the data space environment, it is thought that collaboration will further advance in the manufacturing business as well. While innovation is expected, there is also concern that the transmission of manufacturing-related context information, which was traditionally shared, as tacit information, within and across the companies, may be disrupted. New considerations are also underway on how to share context information in a data space while preserving the strengths of individual companies.

Manufacturing is a global activity. RRI is also working with global partners, including German Manufacturing-X.

Outlook

Collaborative dialogue on industrial data spaces is of great importance because in today's interconnected world, collaboration and knowledge sharing is more important than ever. These two aspects play a crucial role in personal and professional development and contribute to the promotion of an inclusive and innovative society. By working together, the partners learn to recognize and use their own skills. In addition, they allow stakeholders to recognize and appreciate different perspectives, which can lead to innovative solutions and ideas. Each society will find its own rhythm depending on its culture. Sharing knowledge is a powerful tool for learning and collective improvement. When we share our knowledge, not only the recipients benefit, but also ourselves.

One of the schemes that has proven effective in the history of German-Japanese collaboration is the use case approach, based on common interests. It is broadly accepted that identifying the common interests is particularly effective when driving use cases behind them are formulated and clearly understood. In this respect, a uniform understanding of use cases in the perspective of both Germany and Japan is a central starting point in that cooperation. Use cases are an instrument to build a bridge, from the driving challenges facing the manufacturing industry to the appropriate possible technical solutions. Use cases also offer the possibility to derive new requirements for standardization. It is expected that various discussions centering on this approach will proceed in the manufacturing data space as well.

The introduction of the Digital Product Passport is a legal change that will occur in the European Union with the new Ecodesign Directive and will have a significant impact on the manufacturing industry. This standardized data set, which makes important information about manufacturers, materials, properties, repair and disposal options of a product electronically accessible, is intended to increase transparency and sustainability over the entire product life cycle. However, it also means that companies need to document their products and processes more accurately than ever before. In the process, internal company data silos are broken down and relevant product data is made available to all stakeholders. This requires an overhaul of many companies' data management strategies. Through funded projects such as Manufacturing-X, we can develop this knowledge collaboratively because practical solutions can be found in the implementation of industrial data spaces. However, it is not only technical issues that need to be clarified, but also organizational issues, considering new international legal requirements. Together, we can learn how to deal with the key aspects described to define common standards so that the economy remains successful for the people.

Besides bilateral collaboration, the multilateral discussion on global manufacturing data space has started. Stakeholders from the manufacturing industry are forming International Manufacturing-X to implement a federated, decentralized and collaborative data ecosystem for smart manufacturing. It aims to enable open, global and cross-sector international operation of cost-effective data networks. This will result in:

- Resilience: Reorganize and increase flexibility and autonomy of industrial value chains and networks.
- Sustainability: Increase efficiency and enable data-driven solutions for CO2 balancing and circular economy.
- Competitiveness: Accelerate digital innovations and enable new data-driven business models to create new value for manufacturing.

In addition to the above, broader perspectives from global participants will be discussed. One example of this would be to achieve both the resolution of social issues and economic growth. Through the active participation to this International Manufacturing-X community, the bilateral collaboration between Germany and Japan will eventually expand to the multilateral collaboration and make a key contribution to the manufacturing industries globally.

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