DATA SPACE 4.0

A European Common Digital Manufacturing Infrastructure and Data Space Pathway for Connected Factories 4.0 Data Value Chain Governance

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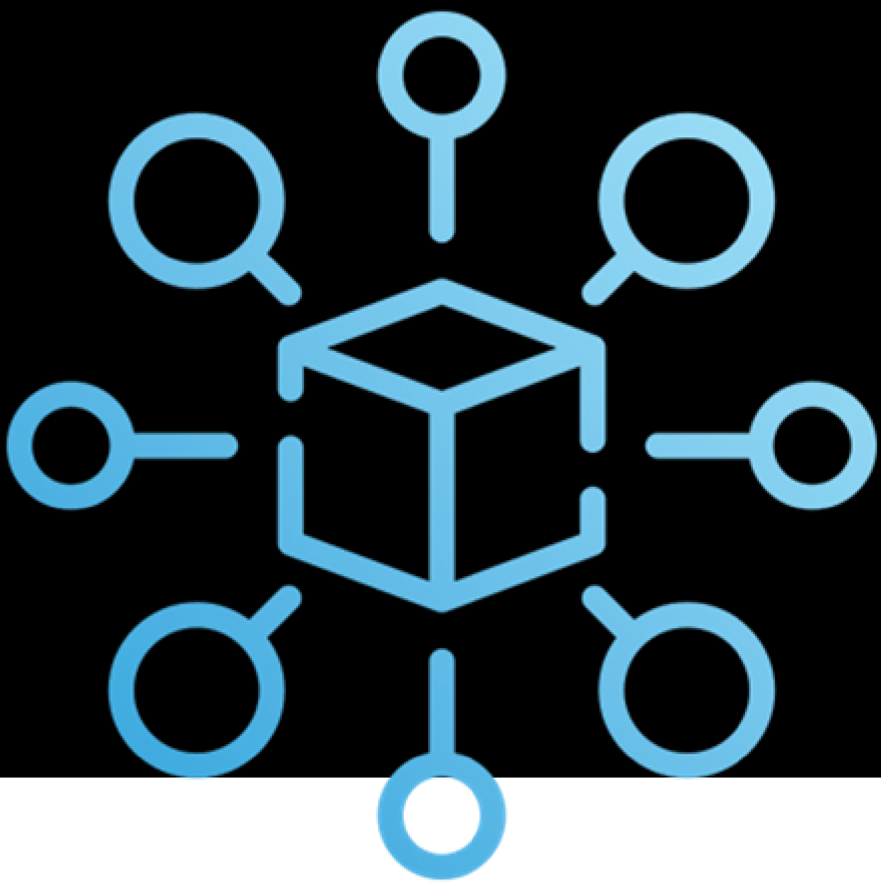

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Executive Summary

The EU DATA SP4CE initiative aims to establish a European-wide digital infrastructure for manufacturing by promoting data spaces that support collaborative efforts in predictive maintenance and agile value networks. The project responds to challenges faced by the manufacturing sector, such as the need for multilateral data exchanges and advanced analytics to enhance operational autonomy, resilience, and sustainability.

Key drivers include:

Multilateral Data Integration: Moving beyond bilateral data sharing, the project advocates for the development of 360° data integration strategies. These strategies emphasize vertical and horizontal integration within manufacturing ecosystems, ensuring that real-time data can drive self-optimizing systems and predictive analytics.

Collaborative Asset Management: The guidelines define frameworks for hierarchical and non-hierarchical data networks that facilitate collaborative business applications and smart asset management. These networks promote trust, data sovereignty, and interoperability, key elements for manufacturers to exchange data securely while optimizing asset performance.

Supply Chain Networks: The initiative emphasizes open supply chain collaboration, focusing on agile data-driven responses to disruptions. It advocates for the integration of semantic standards to enhance interoperability between manufacturers and suppliers across different systems, fostering a more resilient and adaptable supply chain.

Governance Framework: The governance model provides a blueprint for managing cross-sectoral data spaces, ensuring the alignment of stakeholders from industry, technology providers, and public authorities. This framework supports the deployment of digital services that enable predictive and prescriptive maintenance in line with Industry 5.0 standards.

The document concludes with recommendations for scaling data space ecosystems, focusing on interoperability, security, and stakeholder collaboration to drive the digital transformation of European manufacturing. By fostering advanced data sharing practices, the EU DATA SP4CE project aims to support manufacturers in achieving greater competitiveness and innovation.

Keywords: Data Integration Collaborative Asset Management Supply Chain Networks Governance Framework digital transformation Industry 5.0

Disclaimer

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Abbreviations and Acronyms

Acronym	Meaning
CA	Consortium Agreement
CPPS	Cyber-Physical Production System
DoA	Description of Action
EC	European Commission
GA	General Assembly
IPR	Intellectual Property Regulations
KPI	Key Performance Indicator
REI	Responsible Exploitation & Innovation Board
RRI	Responsible Research & Innovation
TCC	Technical Coordination Committee
WP	Work Package

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1 Introduction

1.1 Motivation and Purpose of the document

The need to evolve from bilateral to multilateral data exchange is intimatelly connected to the the current European and global landscape where manufacturing industry has to act upon is characterised by increased Volatility Uncertainty Complexity and Ambiguity (VUCA), becoming particular challenging for small and medium-sized companies. Climate change, supply chain disruption and conflict plague the global system and are increasing the pressure to act on the digital and ecological transformation of the entire European industry. But the innovative use and exchange of data in manufacturing could actually be a stabilising force for the global manufacturing industry supporting higher levels of manufacturing autonomy and sovereignty. This data (industrial, open and/or private) can: (1) Provide actionable intelligence and insights by discerning patterns from data through human AI collaboration. (2) Predict future outcomes for business stakeholders to act upon, using advanced analytics on historical data. (3) Enable self-optimizing systems that take autonomous action through self-learning self-steering algorithms, with input from historical and real-time data; e.g., predictive & prescriptive maintenance.

Europe's manufacturing industries' MANUFUTURE vision for 2030 is to reinforce its global position in terms of competitiveness, productivity, and technology leadership. This is to achieved by means of an industrial integration into complex and closely intertwined and hyperconnected global value-added networks. Beyond increased sustainability, industry must master new forms of hierarchical and non-hierarchical data exchange to be able to react much faster (smart rapid response and active control) than before to disruptions in its supply chains or in the supply of raw materials and energy. This requires digitization & transparency about processes and resources used across all stages of the value chain. The adaptation and optimization of processes across the various value-added stages and life cycle phases requires the cooperation and collaboration of all stakeholders. Information becomes available with the help of digital, data-based solutions.

The purpose of this document is to describe the different scenarios that Data Spaces in manufacturing will facilitate as well as the methodologies to build and scale the most required ecosystems. This document also describes the main services provided by the embryonic data spaces in operation as well as a first attempt to bring together a coherent cross-sectorial framework to characterise different pilots that are being implemented in different projects and initiatives.

1.2 Structure of the document

The Chapter 2 introduces the notion of hierarchical and non hierarchicla manufacturing data networks and present different strategies to achieve 360º data integration. The scenarios for collaborative asset 4.0 management and open supply network implementation are presented and the differences compared to traditional digital approaches presented to highlight the data space for manufacturing benefits.

Chapter 3 discuss a methodology proposed for building and scaling manufacturing data ecosystems around data spaces.

Chapter 4 present the approach to build a data space 4.0 continuum to deal with cross-sectorial vertical and horizontal integration of manyfacturing data networks.

Chapter 5 reviewed the approaches of Factory-X, SCSN and Catena-X in terms of setting up their use cases and briefly notes the notion of KITs adopted by Catena-X (This is further explained in the bootstrapping activities in WP7). The Chapter proposes an initial taxonomy to characterise the different pilots and use cases.

2 Hierachical & Non Hierarchical Networks

This Section address the need to define and develop new scenarios for the establishment of multilateral hierarchical as well as non-hierarchical manufacturing network as evolution of more traditional bilateral data exchanges. The work reported in this document has contributed to two critical publications, namely "Multilateral data sharing in industry" and "Manufacturing-X Data Space Study". Hence, the interested reader is referred to those documents for additional content on the subject of this deliverable.

"Data as a Resource/Product" becomes crucial to leverage new forms of Actionable Industrial Intelligence. However, an important prerequisite for leveraging this very much needed actionable industrial intelligence are trustworthy data ecosystems based on open standards, the so-called common data spaces for manufacturing. Such data spaces should facilitate a much easier establishment, management and dismantling of (multilateral) data value chains in manufacturing; the so called *"data rooms"* in the Manufacturing-X context. As illustrated in the Figure below, the data space technology adds to traditional data exchange guarantees in terms of data usage control and sovereignty that could not be obtained otherwise.

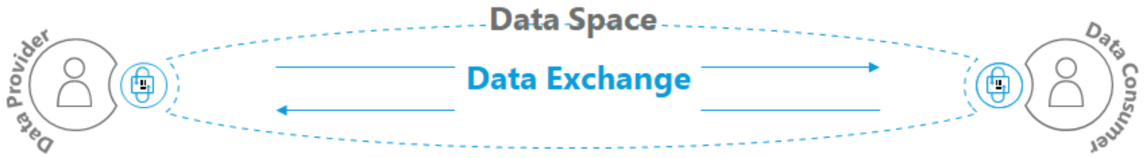

Figure 1 – Data Space 4.0 extension to traditional data exchange.

According to WEF 2021 study over 39% of industry has already succeeded in operationalising smart industrial automation. On the other hand, the 2022 WEF Unlocking Value in Manufacturing through Data Sharing initiative has revealed that although cutting-edge plug-and-produce technologies, advanced robotics and AI-enabled systems now permit the encapsulation of product and manufacturing knowledge through Digital Twins, powered by data, the need for manufacturing companies to collaborate in hyperconnected value networks to address VUCA operational challenges is more urgent than ever.

2.1.1 Industrial Value Networks

The ultimate goal of data-driven industrial value networks is to timely and cost-effectively implement their business processes and workflows. Industrial value networks are increasingly dependent on nurturing suitable data value ecosystems facilitating trusted sharing and effective distributed data processing over common data spaces.

However, it is important to understand that the implementation of data spaces to allow hierchical and non-hierarchical data exchange and data transactions with trust, is not and should not be decoupled from more traditional IT, OT, ET and IIoT digital architectures. As shown in the Figure below, Data Ecosystems & Data Spaces become an integral part of the company digital transformation strategy and should naturally exploit digital legacy (brownfield data space operation) and enable multiple forms of data network implementation (see data chains, multilateral data chains (highly hierarchical) and multilateral data networks (non-hierarchical) later in this Section).

Data Spaces 4.0 and trusted multilateral industrial data exchange is the enabler to a new form of applications that in the context of Data Space 4.0 we regard as Collaborative Business Applications. These new type of business applications can be identified as new types of services that will support manufacturing operational excellence or can be simple regarded as extensions of already digital manufacturing platforms dealing with Industrial Cloud-based solutions or remote engineering, operation and maintenance solutions enabled by Edge/fog IIoT systems.

As shown in the Figure below, Data Space 4.0 creates a new technology dimension between traditional OT and IT domains, fundamentally enabling the interconection and interworking with trust of sovereignty among enterprises in an industrial value network.

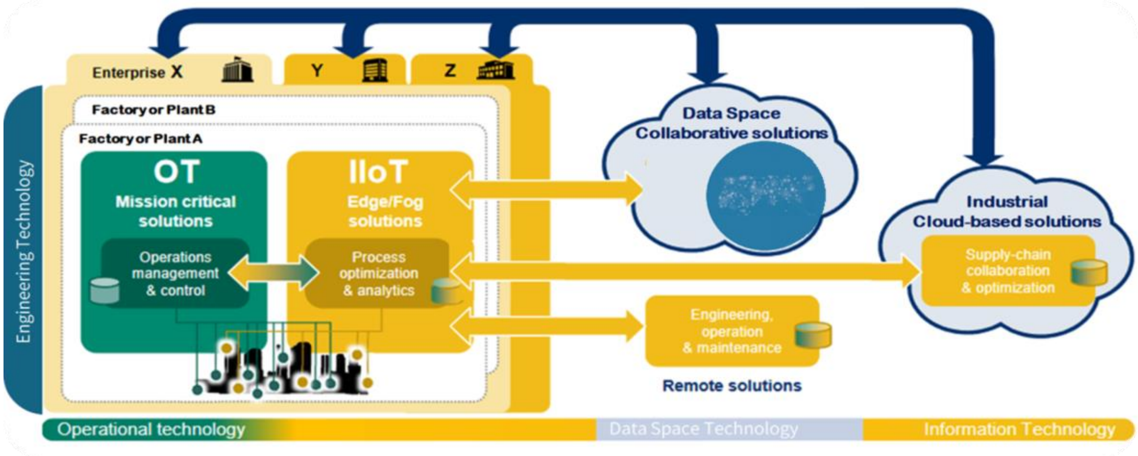

Figure 2 – Data Space 4.0 business solution in a digital manufacturing context.

In order to better understand the technical domain that is enabled by data space technologies, Data Space 4.0 has defined the industrial value chain framework showned in the Figure below. The framework extends Gaia-X vision with Catena-X, SCSN and IDSA best practices and aims at deliniating the areas where (1) industrial cooperation should be expected to realise the data space technical, business and organisational enablers; and (2) the areas where competition can in case be allowed and facilitate for manufacturing operational excellence.

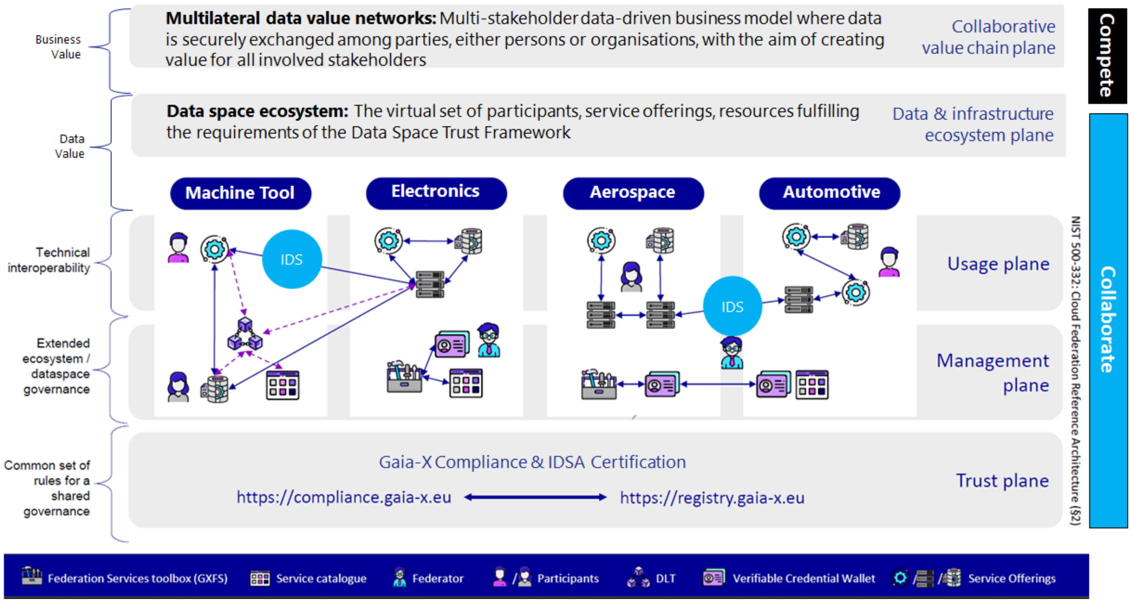

Figure 3 – Data Space 4.0 and multilayerd framework for Multilateral Data Value Network (MDVN) deployment

The Data Space 4.0 adopts a 3 plane approach:

1. Trust plane. Defining the rules for shared governance and establishment of multilateral industrial value chains.
2. Management plane. Allowing the implementation of policies and rules to govern the extended ecosystem.
3. Usage plane. Where the actual data exchange and interoperability is enabled.
4. Data ecosystem. The virtual layer where the actual set of stakeholders come together and raw data gains value.
5. Multilateral data value network. The layer where the actual collaborative business applications are realised and ultimatelly where the business value and data is monetised/valorised.

Please note, that layers 1 and 2 would reconcile to the Data Space Control Plane, where as layer 3 would reconcile to the Data Plane in terms of the Data Space Protocol (DSP) terminology.

2.2 Implementation of a 360º Data Integration Strategy: Multilateral Data Value Chains

The development of collaborative business applications realised by MDVN supported by data space technologies is intimatelly connected with the ability to set 360º data integration mechanisms with trust. As shown in the Figure below, traditional Industry 4.0 value chains need to be extended to facilitate an ecosystemic approach to the development of I4.0 applications and services.

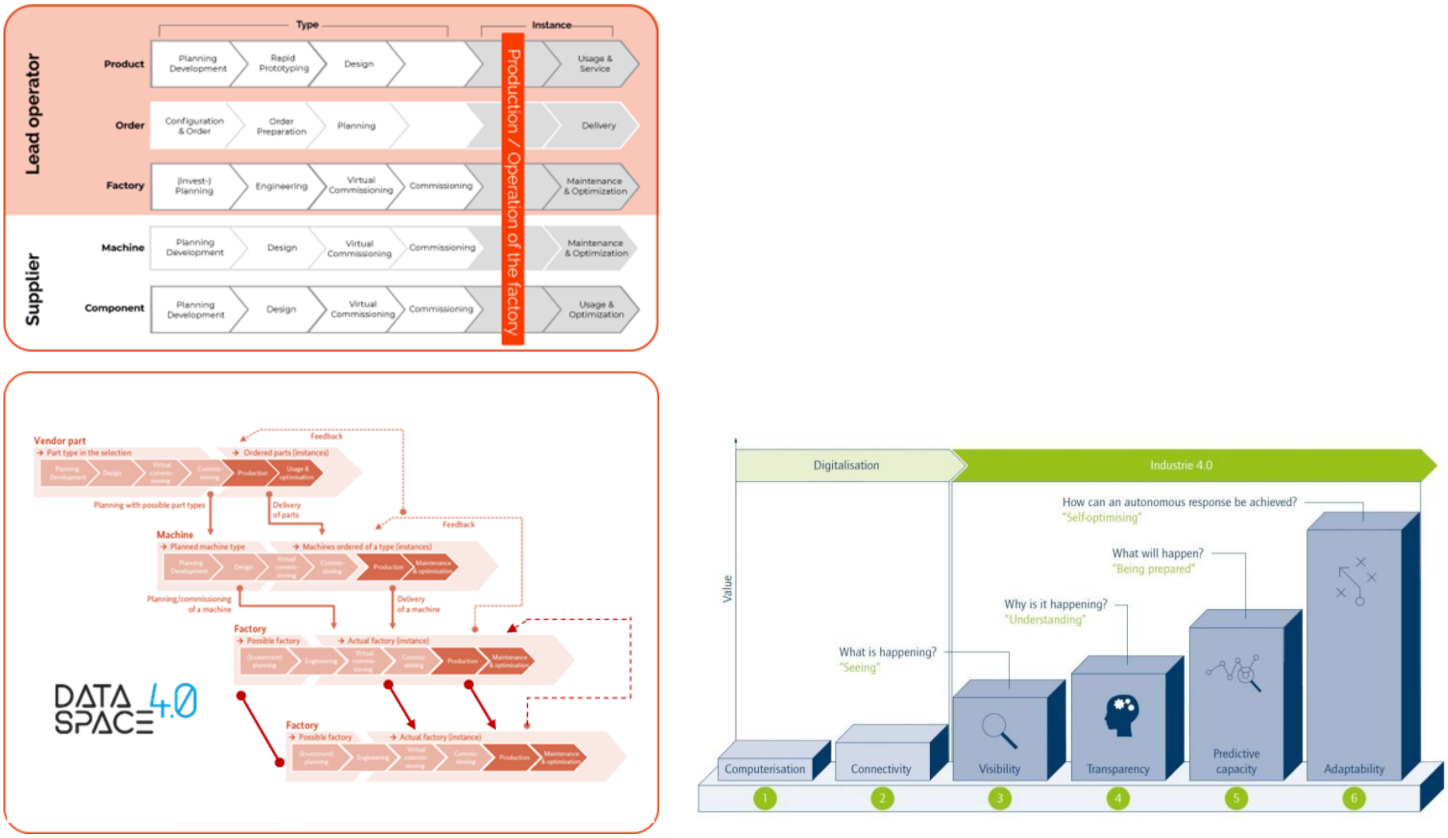

Figure 4 – (a) Data Space 4.0 Multilateral Data Value Chain vertical & horizontal integration (b) Industry 4.0 digital service evolution (autonomous systems)

The definition and implementation of hierarchical and non-hierarchical manufacturing data networks implies that advanced forms of horizontal and vertical integration of manufacturing stakeholders needs to be facilitated. However, one needs to understand is that such integration is realised with the business objective of implementing increasingly advanced Industry 4.0 digital services that leverage operational excellence, competitiveness, resilience and sustainability of manufacturing operations.

As illustrated in the figure below, traditional forms of vertical and horizontal data integration (360º data integration) across digital platform owners and stakeholders is neither efficient nor cost efficient. Therefore, Data Space 4.0 advocates for a data space approach to such distributed and decentralised approach to deal with data integration at scale – See Figure below.

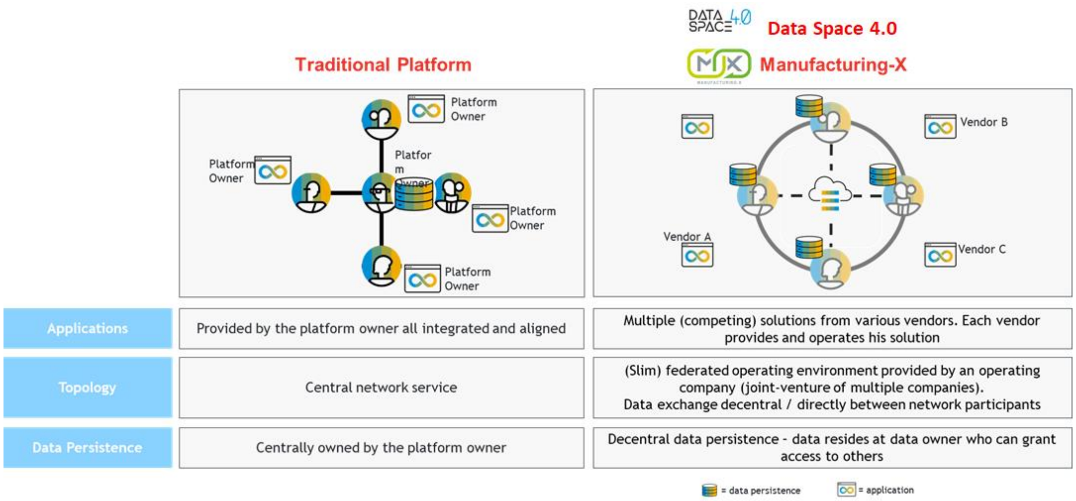

Figure 5 – Traditional 360º data integration approach vs Data Space 4.0 M-X approach

With such data space approach it will be possible to articulate horizontal integration of stakeholders across the value chains (automotive, aeronautics, machine tools) but as well consider the interworking and interaction across and among such stakeholders when business services involve stakeholders from multiple domains. A practical concept from Factory-X and Catena-X data spaces is ilustrated below.

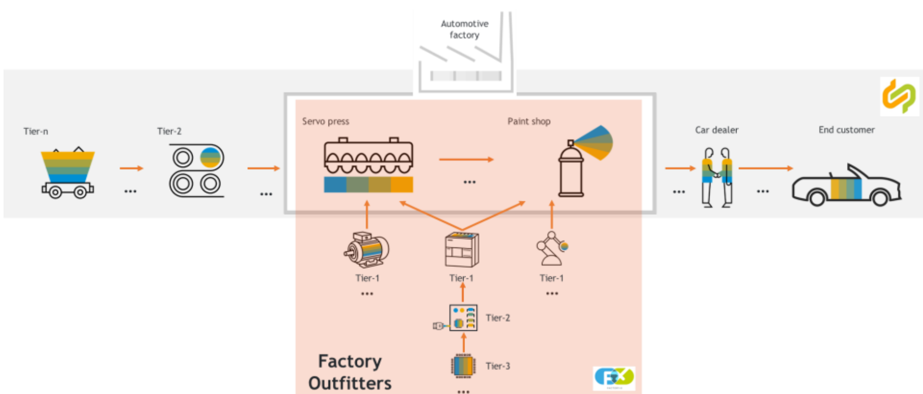

Figure 6 – Factory-X and Catena-X data space integration

As already mentioned, Data Spaces 4.0 and the availability of a Data Space 4.0 continuum that allows cross-sectorial Data Spaces seamless interactions should enable the realisation of multiple forms data exchange.

Data Space 4.0 defines and enables different types of data exchange mechanisms; i.e. 1:1, 1:N, N:N, N:M. This is implemented by means of different levels of data integration (data chains, multilateral data chains and multilateral data networks). The implementation of these different strategies for data integration is intimatelly connected to (1) the maturity of the digital (AI-powered) manufacturing services that need to be deployed as part of the digital transformation. (2) the maturity of the data strategy supported by the industrial partners. This is connected with the EFFRA data space maturity pathway defined by EFFRA in CF2 project and that has been the basis for WP3 Data Space 4.0 activities (The interested reader is refered to D3.1 and D3.2 for further information).

The implementation of these data integration strategies is motivated by the need to depart from data exchange/transaction scenarios where data is shared on the basis of one data-one use and one partner-one project towards data sharing scenarios of one data-many uses and one partner-many projects.

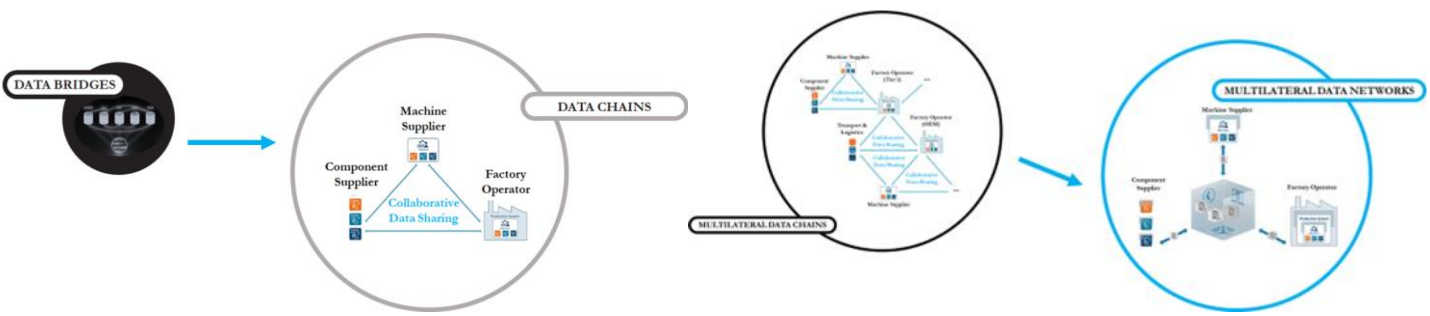

Figure 7 – Data integration strategies and hierarchical and non-hierarchical data networks

As illustrated in the Figure below the evolution of the different data integration strategies into the realisation of more or less complex multilateral data value networks relies on the ability of individual companies and the overall ecosystem facilitating the data space data exchange process to come to a common agreement of some core & basic principles.

As it will be discussed in the next section this requires from dedicated methods and frameworks to ensure that such common design principles can be reached.

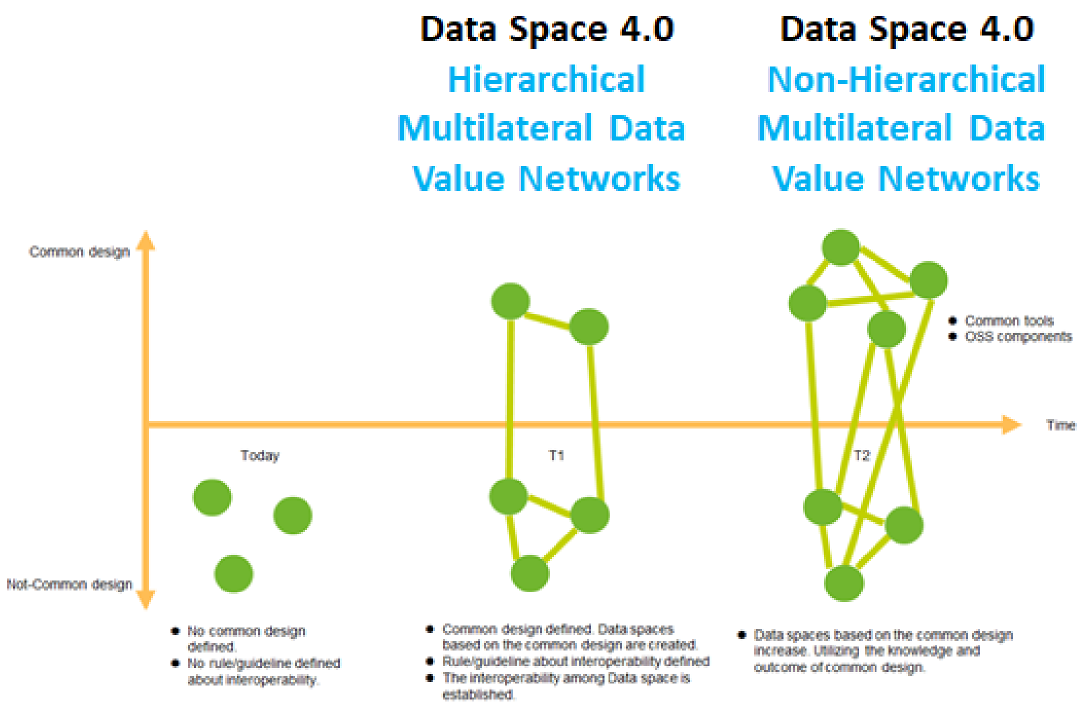

Figure 8 – Hierarchical MDVN and Non-hierarchical MDN vs Common Design principles

2.3 Collaborative Asset Management Networks

This section is intended to present the potential operation scenario for a Data Space 4.0 that is supporting the implementation of collaborative asset 4.0 management services. As shown in the figure below, the data space technology is the enabler for the implementation of a "lightweight" operating system that allows that different stakeholders to implement different data-driven services in specific factories.

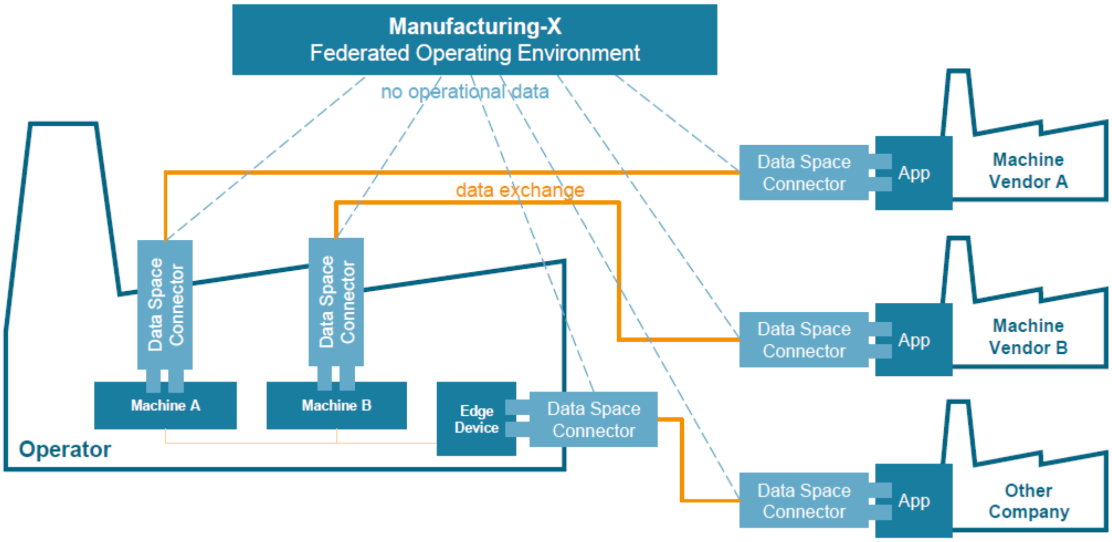

Figure 9 - Manufacturing-X Collaborative Asset Management Scenario

The Data Space 4.0 scenario envisions the implementation of both a managament layer (dotted lines) that enables the implementation of the hierarchical and non-hierarchical data networks. On the other hand, the scenario also considers the data plane, where the actual data exchange is performed with sobereignty once the data network has been established with sovereignty. The element enabling the realisation fo the network and the data exchange is the data space connector. Data Space connector implementations are increasing – see IDSA connector report for an updated view on the latest efforts in data connector developments. Via Data Space Connector access can be provided to edge devices and/or machine itself. Such access is related to the role that the different stakehodlers play in the value network. Machine or component vendors could for instance be granted to the actual equipment, whereas service companies for instance can be granted access to edge devices to implement and provide added value services, without gaining direct access to the actual manufacturing equipment. This flexibility in the scenario allows that different trust domains can be established based on the criticality of the data and the assets.

The realisation of the maintenance scenario shown in the figure above, allos that manufacturing companies and machine tool and service providers can work together in the provisioning of more advanced digital services powered by AI and driven by intensive use of data.

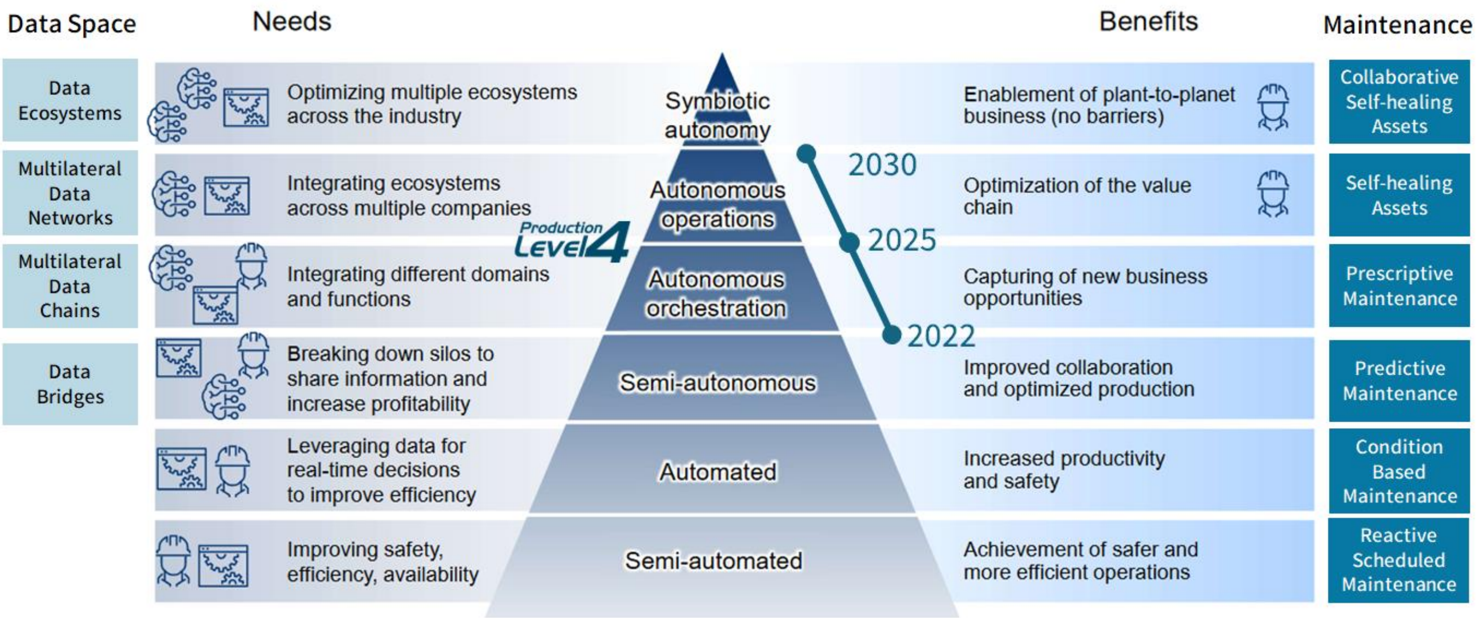

Figure 10 - Collaborative Asset Management Networks & Asset 4.0 collaborative Predictive Management Digital Service Evolution

Collaborative predictive maintenance business applications use sophisticated machine learning and AI techniques to analyse the data generated in the modern factory. Predictive analytics can decrease downtime, optimize asset performance, and increase the lifespan of machines. As manufacturing industry transition from industrial automation to industrial autonomy; operations increase in maturity level from manual (reactive maintenance), semi-automated (reactive and scheduled maintenance), automated (condition-based maintenance), semi-autonomous (predictive maintenance), autonomous orchestration (prescriptive maintenance), to autonomous operations (collaborative self-healing assets) new forms of data sharing facilitated by data space technology needs to be realised. Within this human-centric sustainable and resilient industry 5.0 vision, the workforce will perform tasks in between using special-purpose applications in a seamless human-AI symbiosys.

Manufacturing data spaces will empower manufacturing industries to address a now urgent and strategic circular twin structural transition challenge from current Maintenance & Asset Management Level 3 basic predictive practices supported by semi-autonomous processes to advanced predictive (prescriptive) Maintenance & Asset Management Level 4 practices facilitated by autonomous asset orchestration setting the foundations towards a Human-centric Maintenance & Asset Management Level 5 based on self-healing practices leveraged by autonomous operations.

2.4 Open Supply Chain Networks

The VUCA environment and events such as energy crisis, Uktaine war and/or COVID-19 pandemic have evidenced that it becomes increasingly important to collaborate in the supply chain. Especially for the low volume, high mix, high complexity industry sharing data is crucial.

Digital collaboration in the supply chain is one of the means for manufacturing companies to increase efficiency and reduce costs. However, various supply chain partners do not collaborate in a digital way yet since they use different and non-interconnected ICT systems. Different systems, standards and semantics limit such interconection. As shown in the Figure below the implementation of a hierchacial approach to value chain management is well known to be error prone, characterised by high administrative burden and commonly manual inputs in ERP-system from e-mail or web portal. This results in suboptimal operation of the supply chain.

In order to solve this challenge, the partners of the Smart Connected Supplier Network (SCSN) developed a standard for information sharing based on semantic technology to operate an open supply chain network, thereby ensuring optimal interoperability between the supply chain partners for the most prominent information streams.

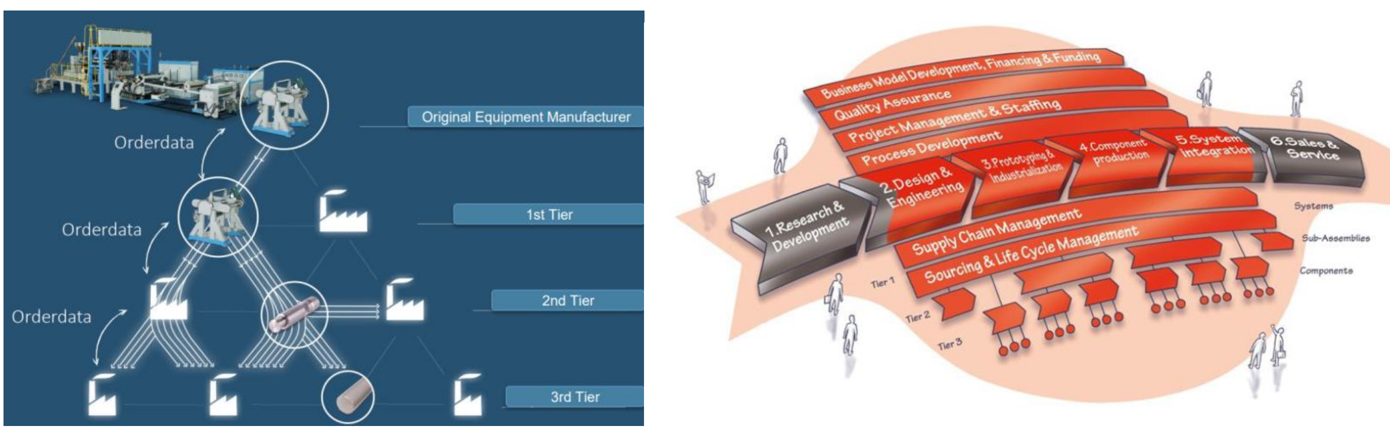

Figure 11 – Traditional Supply chain scenario vs Data Space 4.0 Open Supply chain Network scenario

The SCSN standard builds on the International Data Spaces (IDS) standard. This is a European standard for data sharing that enables data sovereignty developed by the partners of the International Data Spaces Association. SCSN and IDS bring a "connect-once -reach the entire supply chain scenario" to manufacturing companies. This is differing from traditional bilateral EDI connections or the use of centralized (cloud) platforms. Manufacturing companies need to establish a single connection, once, with an ICT Service Provider. There are multiple ICT Service Providers, which are fully interconnected amongst each other using IDS technology. In this way, a manufacturing company can connect to any other company reachable in the SCSN network.

The infrastructure is based on the International Data Spaces Reference Architecture Model 3.0 (IDS-RAM3) and adopts the four-corner model. The Foundation SCSN facilitates generic functionality:

- Address Book based on the IDS Broker and Parls in order to publish and find the connected manufacturing companies.
- Identity Manager and DAPS in order to ensure trusted identities of all participants.

The Service Providers facilitate end-user connectivity:

- Each service provider has a Hybrid IDS Connector to interconnect the end-users.
- The service providers integrate the connector with the end-users' IT systems such as ERP systems.

Figure 12 – SCSN Open Supply Network 4 Cornner model

This approach makes the supply chain collaboration easier to implement and scale, enables manufacturing companies to reduce the administrative burden and helps them to prevent errors. It also enables agility of the entire supply chain and a more successful risk management. In turn, this reduces the time-to-market for manufacturing companies and suppliers, enabling them to respond quicker to changing market demands.

2.4.1 Supply chain collaboration

Ever since the introduction of electronic connection and planning software like ERP (Enterprise Resource Planning), MRP (Material Requirement Planning) and CRM (Customer Relationship Management) the need in industry for automated sharing of production and sales related data in the supply chain has been increasing. Connectivity in combination with information systems has turned supply chains into collaborative business networks, supported by software packages that can handle and align varying data sources and connect organizations.

Often the exploitation of such software is organized as a platform or multi-sided business model. A multi-sided business model supports interactions between interdependent customer groups or between supply and demand. In a supply chain this can for example be a supplier and a manufacturing company.

Such platform business models have network effects. If a manufacturing company is customer of such a platform, the more interesting it becomes for suppliers to become a customer of that platform too. This is often even required in order to do business with a powerful manufacturing company. A strongly connected and integrated supply chain is efficient as it allows for reliable transmission of order and production information. However, for suppliers it can be impractical and expensive to link to multiple platforms, which also creates a lock-in to the platform.

Specifically, in situations where demand changes rapidly, products become more personalized and require smaller batches, potentially from different producers and suppliers that can participate in multiple supply chains, agility is of strategic importance. In order to achieve that, a higher level of interoperability between the manufacturing companies and suppliers in supply chains is needed to form a supply network.

This points to an overarching interest. The supply network as a whole benefits from efficient utilization of production capacity and responsiveness to changing conditions and demand. This requires the platforms to support optimization, growth and agility in the interest of the whole supply network. Interoperability and governance of these platforms as a network of platforms, each supporting and connecting parts of the supply network, is needed to flourish the whole supply network.

2.4.2 Conventional approaches for digital collaborations

Digital collaboration in the supply chain is one of the goals to increase efficiency and reduce costs. However, it is not easy to involve firms with a lower digital maturity level (e.g. SMEs with limited resources) and link at the same time different ICT systems between companies with a higher digital maturity level. Smaller manufacturing companies still do a lot of business processes administration manually (e.g. making stock overviews in Excel).

Most larger companies (i.e. > 50 employees) today use Enterprise Resource Planning systems (ERP). This software supports companies in all kinds of business processes such as stock management and order processing. Almost every large supply chain partner currently has its own ERP supplier, which makes it more challenging to connect the companies since these ERP systems do not match (do not speak each other's language). That means that many companies currently solve this in a time consuming way: employees for instance enter information from an incoming order manually into their own system. However, nowadays there are also several so-called ICT Service Providers. These are intermediaries who make the connections between the ERP systems of the supply chain partners. That leads to the following challenges:

- All connections must be maintained with all involved suppliers to serve one manufacturing company, with additional costs for each connection.
- The scaling effect is limited to a few connected supply chain partners using the same ERP system or cooperating with the same ICT Service Provider.
- Suppliers delivering to manufacturer companies or OEMs results in high connectivity costs when looking at the required connections between each ERP system and ICT Service Provider.

This will result in the multiplication of the (connectivity) costs if you want to have more suppliers (each with their own costs), for example for more capacity and flexibility

The potential consequence is that the manufacturing company focuses on suppliers within a certain ecosystem using the same ERP system and or ICT Service Provider (e.g. because of cost savings). That might result in a lock-in effect as expanding the network results in a cost increase which prevents manufacturing companies to access other ecosystems of suppliers. This situation also limits the growth and agility of the supply network due to path dependence caused by the choice for a specific ERP system or ICT Service Provider. Unless the growth will be realized within fixed supply chains with partners that use the same ERP system. However, in an ideal situation supply chain partners want to be able to connect with each other without necessarily using these connections more often (e.g. for intensive exchange of orders and invoices).

2.4.3 Towards Data Space Operation Scenarios of Open Supply Neworks: Smart Connected Supplier Network

In order to solve these challenges, the partners of the Smart Connected Supplier Network digital innovation hub joined forces to develop a standard for data sharing. Three types of supply chain partners are affiliated with the Smart Connected Supplier Network:

1. manufacturing companies;
2. software companies that offer ERP systems;
3. ICT Service Providers (intermediaries) who make the link with the SCSN network and between the ERP systems.

To solve the aforementioned challenges the partners of the SCSN digital innovation hub developed a standard (based on the International Data Spaces (IDS) standard4) for information sharing, in combination with a semantic standard for supply chain data. A semantic standard was developed for the following prominent information streams:

- invoices;
- production schedules/planning;

- orders;
- logistic data;
- certificates;
- product specifications incl 3D drawings;
- product measurement data (in the future).

Within SCSN, ICT Service Providers connect manufacturing companies in the supply chain to the SCSN network. This connection is established by implementing a single connection, usually with the ERP system of the manufacturing company, using the SCSN semantic specification and/or translators for the specific ERP system. The ICT Service Providers communicate amongst each other using the SCSN semantics and the IDS technical standard. This solution enables that each supply chain partner can continue to use its own ERP system and its own ICT Service Provider. Since all ICT Service Providers involved in SCSN are interconnected, a manufacturing company can do business with any other manufacturing company, even when the other partner uses a different ICT Service Provider.

This is a different approach as the bilateral EDI connections or the use of centralized platforms: within traditional EDI connections a bilateral connection needs to be established between any two partners. Within centralized platforms a manufacturing company needs to connect to a single (cloud) platform, containing all data of all manufacturing companies involved. This is less feasible given commercial sensitivity and market structuring, resulting in a situation whereby manufacturing companies need to connect to multiple cloud platforms.

The SCSN approach therefore makes the supply chain collaboration easier to implement and scale. This potentially enables manufacturing companies to achieve the desired benefits of digital collaboration faster: it provides a reduction of the administrative burden and the prevention of errors. It also enables agility of the entire supply network and a more successful risk management, which in its turn reduces the time-to-market for manufacturing companies and suppliers.

3 Manufacturing Data Value Network Ecosystems Governance

The previous Section has presented two scenarios for the implementation of hierarchical and non hierarchal data integration strategies and networks. In the Section, we address the governance approach that could facilitate the emergence, realisation and scale up at the required scale of such ecosystems. Manufacturing data ecosystems need to move faster as an industry. In fact, such ecosystem should:

- Look for Quick Wins
- Drive the Process of Business Benefits
- Meet Regulatory Challenges
- Set economies of scale on Core Principles

Data Spaces meet these demands as they:

- Reduce Interfaces
- Exploit Data Standards
- Ensure Interoperability
- Data Sovereignty
- Data Security

The context in which the development of the Data Space 4.0 ecosystem framework shoul be unfold must acknowledge that:

- Manufacturing is a Global Activity
- Manufacturing is an Information Activity
- Manufacturing is an Economic Activity

- Manufacturing is a National Activity
- Manufacturing is a Supply-Chain Activity
- Manufacturing is an Individual Activity
- Manufacturing Affects Quality of Life
- Manufacturing has Global Sustainability Impact

Hence, It is worth noting that the effective development of these ecosystems is crucial for the added value of data space technology-based trusted data exchange. To realise a Data Space 4.0 business applications with sovereignty it is necessary that a number of stakeholders participate and leverage a number of digital services and standards. In particular, the realisation of Data Space 4.0 scenarios demand that cloud-edge-iot infrastructure providers align with data space operators, machine tool, automation and digital manufacturing platform providers, value added service developers and providers as well as the manufacturing factory owners themselves.

The challenge of a wide variety of stakehodlers as shown in the Figure below is augmented with the fact that the manufacturing landscape is highly fragmented, heterogeneous and with a very big role and value delivered by small and mediun small businesses.

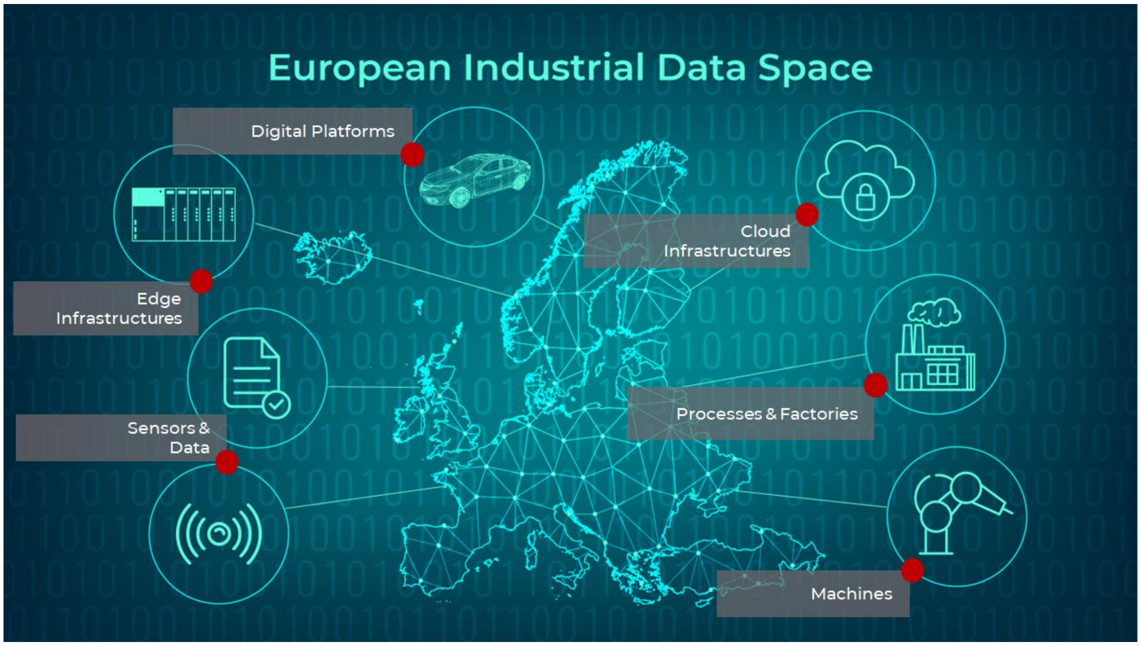

Figure 13 – European Industrial Data Space stakeholders

Furthermore, one we should not keep from focus that the main aim of manufacturing industry is actually to provide goods of high quality, at competitive cost being respectful with environment and society. Hence, Data Space 4.0 technologies and ecosystems should become an enabler not a final aim of the manufacturing industry. Therefore, as it will be discussed later in the document, the development of ecosystems and uses of Data Space 4.0 must be use case driven to ensure value and not conversely – see Figure below.

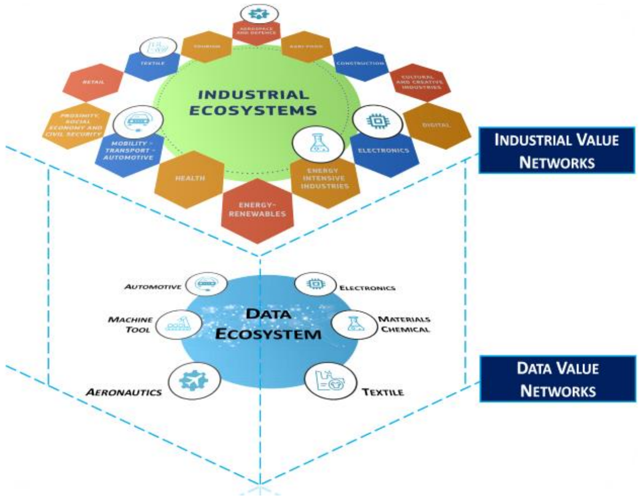

Figure 14 – Industrial value network vs hierarchical and non-hierarchical data networks

In this context, Data Space 4.0 has developed with Manufacturing-X a governance model for the development of the data space 4.0 ecosystems that can support the operationalisation of the proposed scenarios and business cases for collaborative services in different manufacturing sectors.

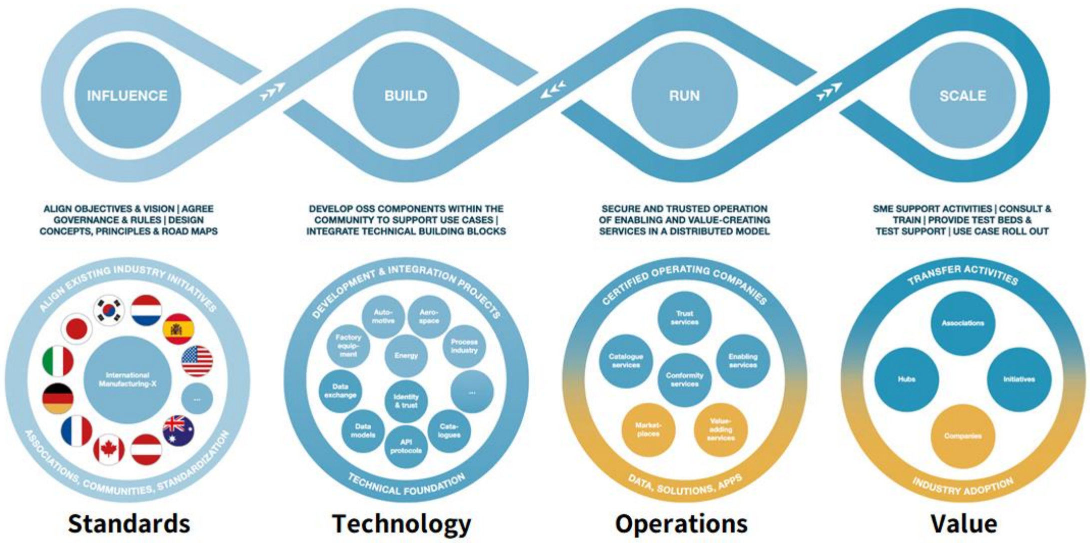

Figure 15 – Data Space 4.0 Ecosystem Governance Model adopted by Manufacturing-X

As shown in the Figure above, the Data Space 4.0 ecosystem governance model is defined in 4 main blocks of interconnected activities that define a double helix model. The double helix unfolds standards, technologies, operations and value unders a unfied effort that is driven by the IMX-C (see D2.3 for further details on Data Space Governance):

Influence:

Objective: Align existing initiatives towards common objectives and vision based on an agreed governance & rules

Principle: IMX will align and coordinate existing global and national initiatives but not create own versions of existing artefacts)

- Define governance structure (e.g. committees, working groups) and decision process (→ e.g. proposal joint technical committee in the back of this doc)
- Identification of existing initiatives (Government, Research, Associations, Private Sector) and mapping of the respective scope

- IMX members will act as conveyer to the existing national industry initiatives/associations

Deliverables:

- Interoperability Requirements, Design Concepts & Principles
- Aligned Interoperability Objectives and -Requirements
- Design Concepts & Principles for global interoperability are jointly being developed by mapping of existing solutions and the identification of interoperability gaps (from a technological and operational perspective). By aligning existing organizations and standards the IMX governance shall drive an iterative
- Road Map towards an interoperable manufacturing data ecosystem

Build

Objective: Support the alignment of Open-Source communities (and commercial vendors) in the specification, development, documentation and testing of software to realize the agreed design concepts, principles and defined standards. The portfolio of software solutions ideally is shared across participants but will also allow individual solutions with a commitment to interoperability.

Deliverables:

- Landscape of existing software components and building blocks (OSS and commercial software) their respective communities and repositories
- Support the setup of new communities (if necessary)
- Aligned Release and Lifecycle Management across all artefacts to ensure technical interoperability
- Alignment with existing initiatives to build and operate Testbeds
- Common documentation and publication framework

Run

Objective: Services which support the IMX use cases are provided on an agreed technical, legal and commercial basis to be able to operate a "federated, distributed and collaborative eco-system*". The operation of the "Run Services" supports all participants with defined Service Level Agreements as a technical basis to support use cases. Operators have demonstrated compliance to the agreed policy rules.

*Ref: IMX playbook draft (v0.5)

Deliverables:

- "Federated, distributed and collaborative" Operating Model covering technical, legal and commercial agreements
- Validation schema for services and operators which are part of the collaborative eco-system

Scale

Objective: Usage and adaption by industry in the IMX countries. Especially Small and Medium Enterprises need to have a fair access and business shares

Deliverables: Consulting and training capacities, Test Beds, Test & Implementation Support

- Publication of IMX Referential documents
  - Vison & Mission; Design Principles; Landscape of existing Initiatives, Industry Associations & Standards
  - Localized versions of IMX artefacts incl. mapping to local initiatives
  - Road Map
- Templates and best practices to enable existing initiatives and associations to support the adaption of IMX in their countries and across different types of companies
  - Assessment (semi-automated)

    - Onboarding (semi-automated)

- Feedback loop to the IMX governance as input for improvement of next iterations

4 Data Space 4.0 Continuum

As already described in Section 2 the implementation and support of 360° data integration strategies (vertical and horizontal data) do not only call for the implementation of a Data Space 4.0 but for the realisation of the Data Space 4.0 continuum that is able to serve and interwork and interoperate a number of sectorial data spaces. As it is depicted by the Figure below the evolution in the digital services demands as well an evolution of the integration startegies and implementation of the Data Platforms. Starting from Big Data digital services for the Factory and Industry 4.0 that are mainly focused on the exploitation of own data we move into a continuum that allows the integration of external data in the form of a variety of data chains (highly hiercarchical. The final approach that is intended to shift to focus to Common data is the one that calls more clearly for the implementation of Data Space 4.0 and the one that requires from the implementation of multilateral manufacturing data networks and the support from an smart interoprable middleware.

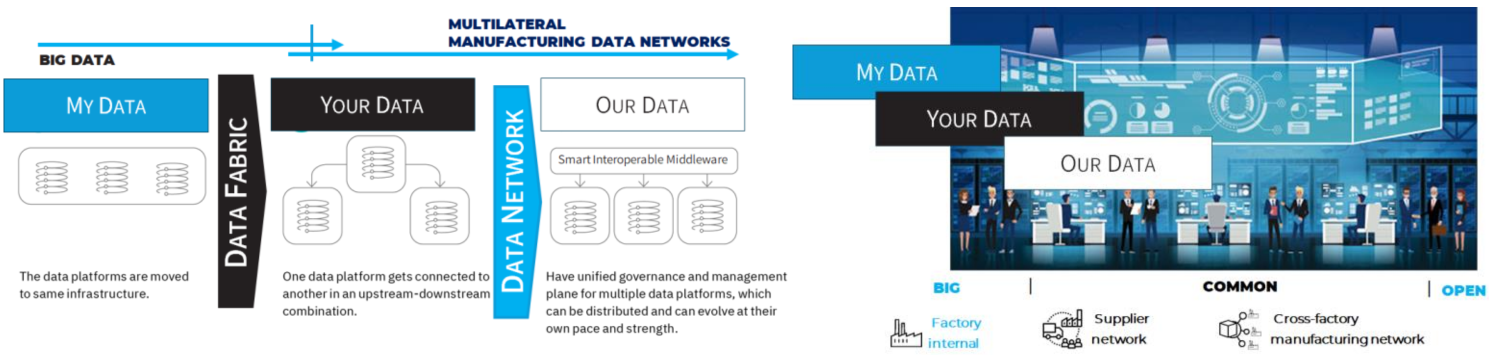

Figure 16 – Data Space 4.0 Continuum support to multilateral DVN.

The shift in applications and digital services that rely on my data (Big) – your data (Big) – our data (Common) also calls for different types of data platforms that allows the implementation of the requred DVN. As shown in the Figure below Data Space 4.0 has defined 3 different types of Data Integration solutions that best suit the evolutionary implementation of hierarchical and non hierarchical DVC.

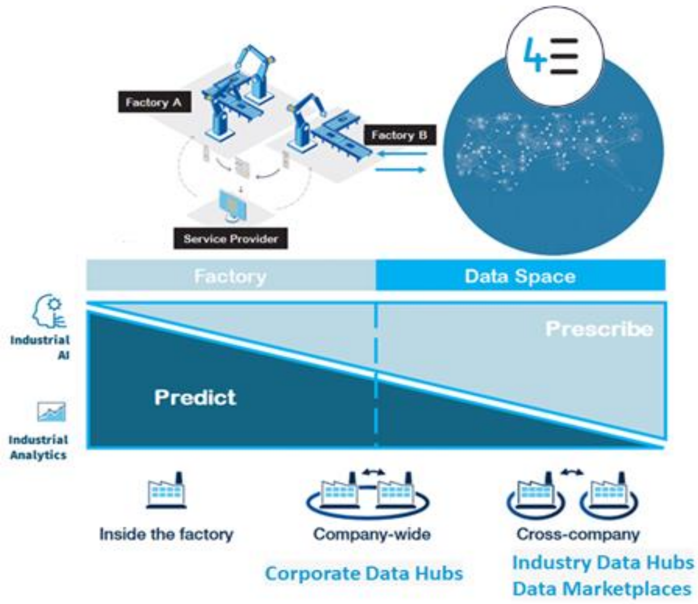

Figure 17 – Different modalities of Data 4.0 integration solutions

Data Space 4.0 distinguish between the needs for manufacturing companies to implement:

- Corporate Data Hubs: The focus here is to integrate via a Data Platform my data and your data to enrich and imporve the performance and operation of digital services.
- Industry Data Hubs: The focus here is to integrate my data and our data going beyond the corporate boundaries. These industrial data hubs are the natural realm for data Space 4.0 technologies and should fully support the implementation of Multilateral DVN.
- Data Marketplaces: The focus here is to integrate again my data and our data. However, the focus here is to access data in a more static, hierarchical and controlled manner. Usually with the adoption and use of data marketplace there ia a monetisation element associated with the exploitation of data in the marketplace.

While the focus today is the support of Corporate Data Hubs and Data Marketplace solutions, see Figure below, the implementation of Industry Data Hubs demands the evolution from a Data Platform environment to a multilateral Data ecosystem that calls for the implementation and support of a Data Space 4.0 continuum. As shown in the Figure below, the implementation of the Data Space 4.0 continuum requires from specific interoperability and federation services to be leveraged at the Data Space level. Moreover, this also require, as discussed in Section 3, that at ecosystem level some core principles agreements are reached. In particular, Data Space 4.0 recommends to focus core principle agreements in blueprint, standards, SW stacks and operational and management procedures. These agreements need to facilitated for the scalable and cost effective implementation of Data Spaces 4.0.

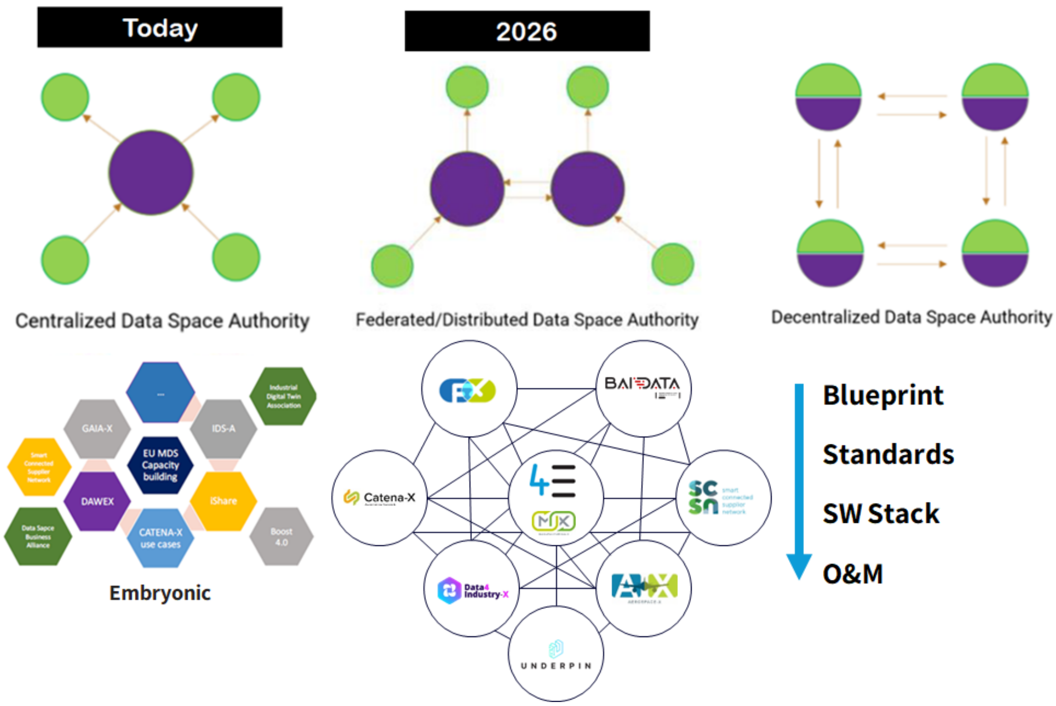

Figure 18 – Data Space 4.0 evolution

In order to implement a distributed/federated data space 4.0 in manufacturing, data Space 4.0 has identified the elements shown in the following picture as critical for the realisation of the Data Space 4.0 continuum.

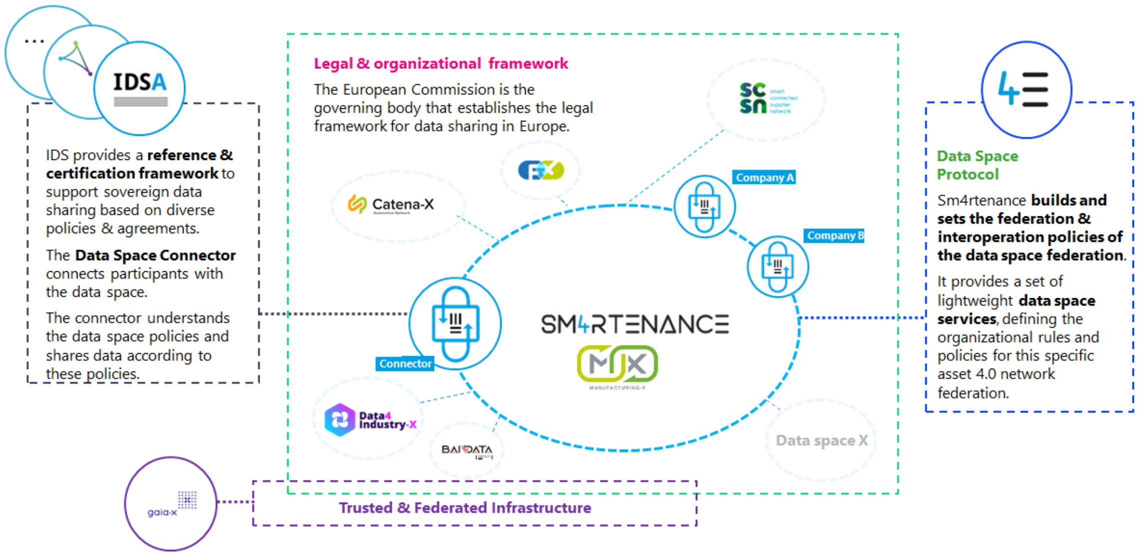

Figure 19 – Data Space 4.0 federation enablers

The distributed of the data space federation requires from a legal and organisational framework of cross-sectorial nature. This should not be confused with the Data Space 4.0 governance model and rule book. The focus here is in mutual recognition and interoperation of cross-sectorial services across data spaces. So far, Data Space 4.0 has established IMX-C as the data space for manufacturing body capable of articulating the comon understanding at this level. Projects such as SM4RTENANCE can and will contribute with alternatives that will be discussed and agreed at IMX-C level.

The second core element to ensure the distributed operation of cross-sectorial manufacturing data spaces is the interoperability enabler. Data space 4.0 has identified the Data Space Protocol, currently under fast track ISO standardisation, as the most relevant initiative to ensure Data Space connector interoperability and hence supporting the operation of multilateral DVN across different sectors.

Similarly, the implementation of the Data Space 4.0 continuum and support to Multilateral DVN requires that specifications are set on the technical features and capabilities that the data space connectors should support. To this respect the certification and V&V infrastructures discussed as part of WP4 are of key importance here.

Finally, the federated identity & trust management are key elements for the implementation of a distributed data space. While it is clear that Gaia-X is providing a solid foundation for a large scale implementation of distributed multilateral DVN, it maybe the case that more intermediary solutions can be put in place extending current DAPS technologies for small scale and medium scale solutions, till the data space ecosystem grows to a width and depth that requires of such large scale distributed ID and Trust management. Data Space 4.0 should take advantage and align in the future with public administration eIDAS 2.0 deployment to create synergies and reduce frustration and costs of implementation and ensure backwards compatibility with small and medium scale solutions till the migration to large scale scenarios take place.

5 Data Space 4.0 Collaborative Business Application Use Case Pilot Taxonomies

Data Space 4.0 has made an effort to collect use data space 4.0 cases in manufacturing. These cases are being gradually and wil continu to be upgraded in the different repositories and radars that are collecting this type of information (DSSC Radar, Data Space 4.0 Catalogues). This has been implemented with the support of WP3.

This Section reviews the most prominent use cases implemented in the area of Collaborative Asset 4.0 Management and Open Supply Networks. This Section reviews the cases proposed in the context of Factory-X, Catena-X and SCSN. This Section also address the initial efforts from catena-X and SCSN as well as factory-X and catena-X to bring their hierarchical and non-hierarchical MDN together as well as their services.

As shown in the Figure below, factory-X has selected 11 use cases for the realisation of asset 4.0 data spaces. The cases cover a wide variety of business processes across the product and process lifecycle.

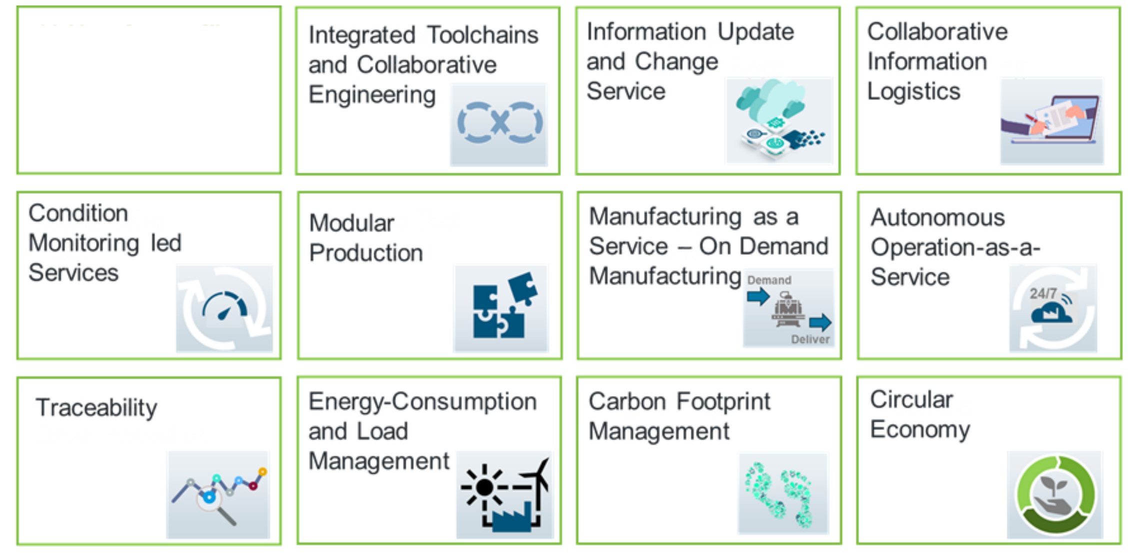

Figure 20 – Factory-X Use Case Piltos.

These cases are connected with the Collaborative Asset 4.0 management networks.

On the other hand, SCSN already defined a modular approach to use case/service and pilot identification. The Figure below illustrates the Catena-X use cases. The most important element of the use case implementation from Catena-X is the fact that each use case is implemented with the suppport of a KIT (Keep It Together) approach that includes a Full Open Source Software implementation anchored in Catena-X Standards (FOSS only/CX Standards)

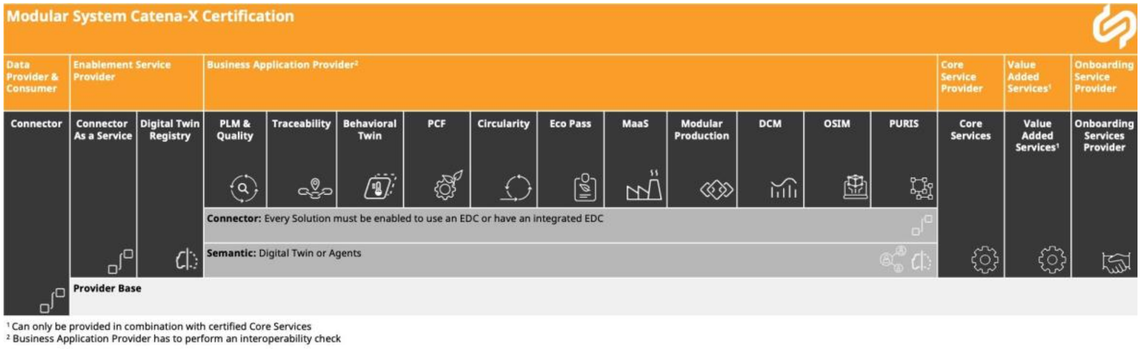

Figure 21 – Catena-X services & certification approach for Open Supply Networks

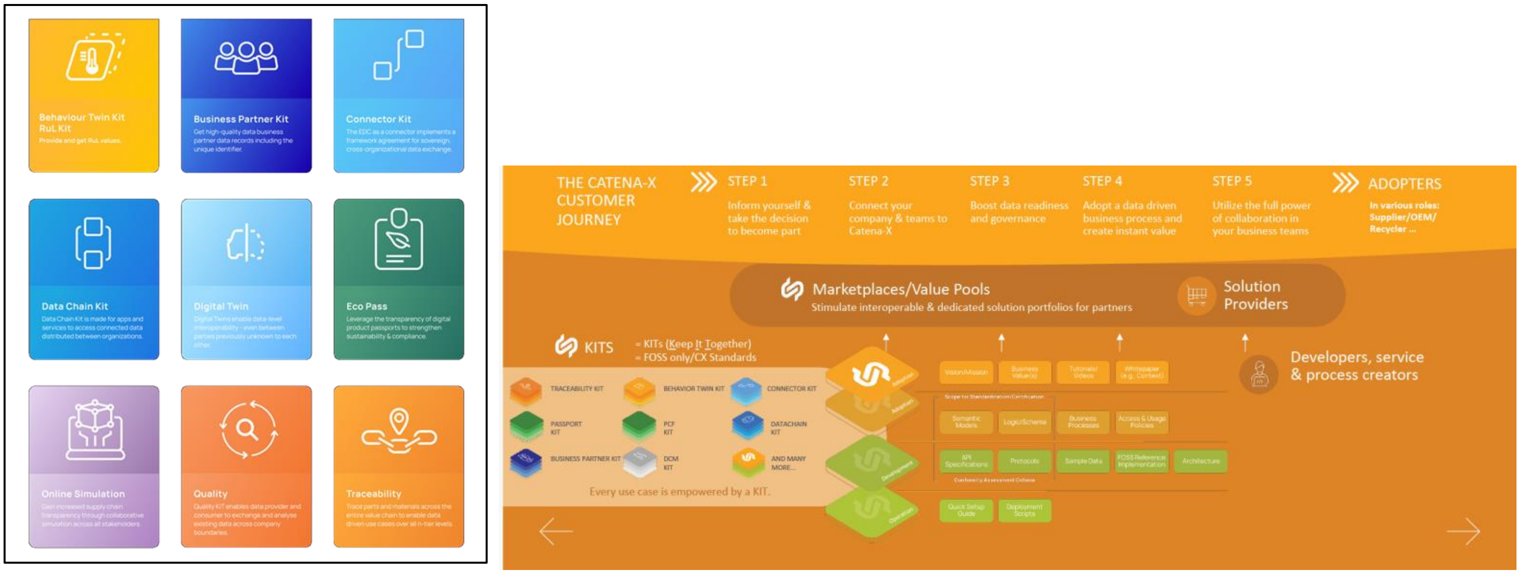

Figure 22 – Catena-X services KITs

On th other hand SCSN has also defined services for the support of their ecosystem and supply chain.

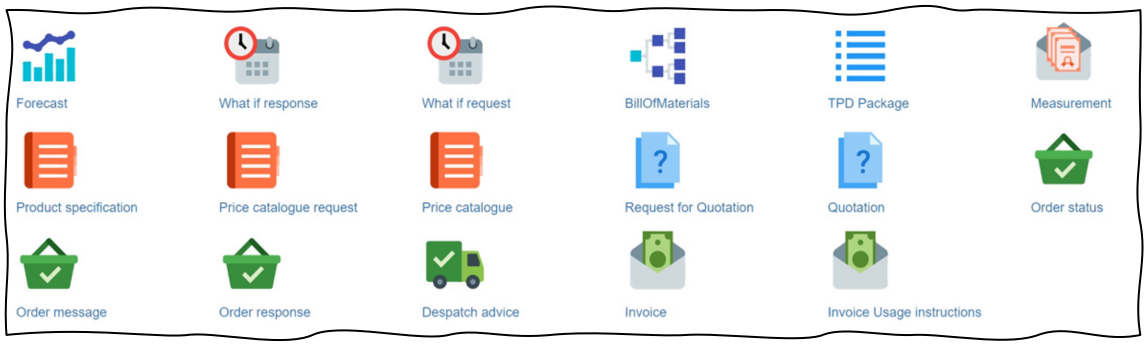

Figure 23 – Catena-X services KITs

The Smart Connected Supplier Network:

- Focus on the purchase-to-pay process + supply chain resilience
- Managed through Semantic Treehouse

The Catena-X

- Focus on digital twin, carbon footprint, traceability
- Managed through KITs on Eclipse Tractus-X

Catena-X and SCSN aim at creating an interoperable data space so that the members of one dataspace can choose to access the data from selected partners in the other without additional technical, organizational or legal burdens.

This enables the customers of the two data spaces to realize additional business value by unlocking new use-cases, connect to partners outside of their data space or a simplified onboard to the other space."

From the analysis performed on embryonic data spaces and the R&I pilot use cases collected, it is clear that the diversity of analysis, presentation and implementation is hindering the development and replication of scalable use cases. This calls for a more integrated framework that would allow to identify common scenarios, common services and common technical frameworks across national initiatives and european projects.

Data Space 4.0 has worked with Manufacturing-X on the provision of such cross-sectorial framework that would allow the identification of synergic initiatives that can accelerate and increase the width and depth of use case implementation for data space 4.0.

The guiding principles of the exercise have been:

1. Improving cross-sectorial collaboration and common understanding
2. Transparency about projects, use cases and technology
3. Responsibility of the partner as to which project should be visible and in what detail
4. No disclousure of sensitive information on what is in progress overall.

The development of such common framework will enable Use cases for external projects to the Data Space 4.0 community

1. Query on existing data objects
2. Project self registration incl. all data object
3. Documentation and query of guidance / conformance

4. For each project provide a feedback of conformity / non conformity

The common framework will be managed from a single point of knowledge (as clearly explained for the Data Space 4.0 catalogues in WP4). Data Space 4.0 has already been able to agree on the main solution categories for the piloting activities. This is important for identification relevant solutions to onging projects successfully addressed via data spaces 4.0. The set of use cases are maintaned via the DFA portal and Data Space 4.0 Innovation Catalogue.

5.1 Data Space 4.0 Taxonomy

Data Space 4.0 has defined a reference model to classify and organise the information related to the various initiatives, projects and pilots associated with the project. The Figure below depicts the selected approach.

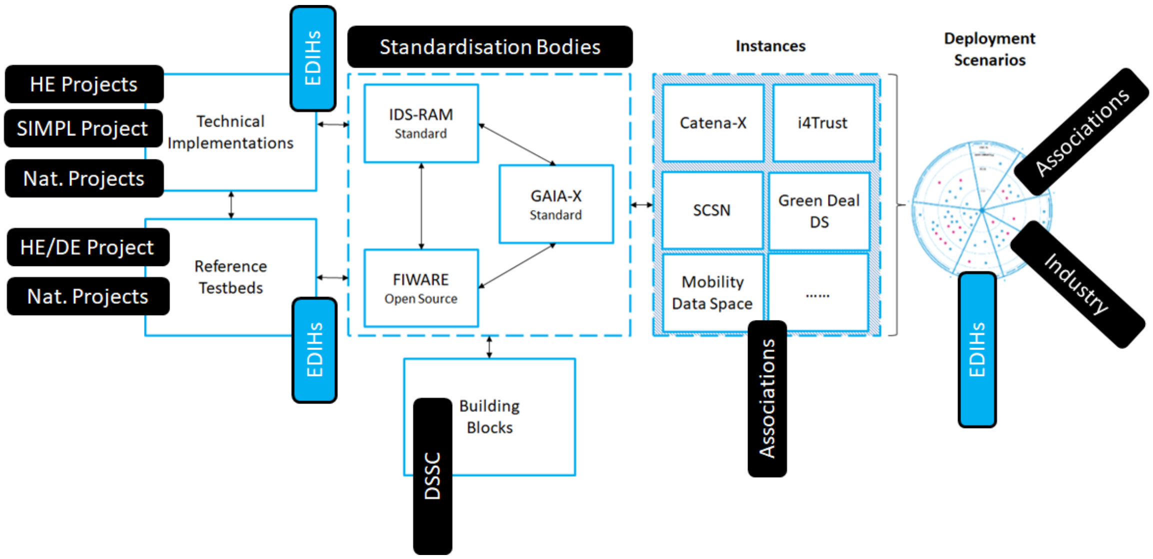

Figure 24 – Common use case reference framework.

The activities of Data space 4.0 can be organised along the axis of Reference test-bed and Infrastructures (provided mainly by WP4 certification & V&V activities), technical implementations driven by OSS and European/national projects. These assets organised in the Data Space 4.0 catalogues are accessible to EDIHs that can power their services and accelerate adoption. These technical implementations and reference testbeds adhere to activities and assets generated by key data space initiatives (Gaia-X, FF, IDSA) that increasingly influence standardisation bodies. With the support of the

DSSC, standards and technical implementations allow the development of Data Space 4.0 buildingblocks. This framework is then customised to the needs of an specific scenario (supply chain, asset management, circular manufacturing) for the establishment of sectorial andor cross sectorial initiatives (Catena-X, Mobility Data Space (MDS), SCSN, Green Deal Data Space….). These initiatives usually cristalise in the establishment of dedicated associations to govern the ecosystem and the services within the data space. Ultimatelly, industry directly or indirectly via industrial associations promotes the development of specific business cases and pilots that are displayed in dedicated Data Space radars and catalogues (M-X, DFA, DSSC…).

With this flow of initiatives and actors Data Space 4.0 has defined a taxonomy to describe the various initiaitves, projects and pilots that are being developed in a way that can be easily explored and shared across the needs of multiple actors (see SPOK approach in D4.1).

5.2 Pilot & use case taxonomy

IMX and Data Space 4.0 have identified a number of categories for the classification of the use cases pilots as shown in the picture below

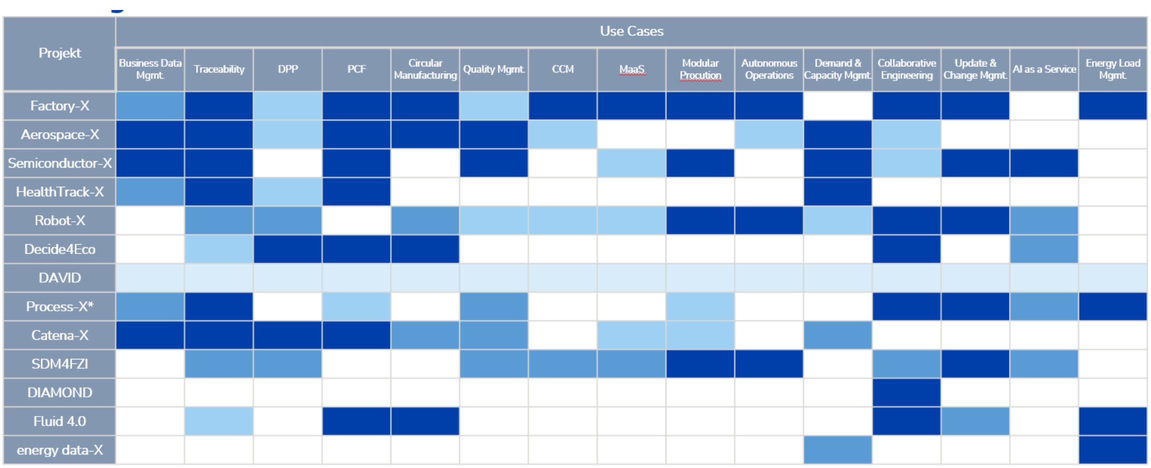

Figure 25 – Data Space 4.0 M-X common use case rcategories.

For each of this pilot a set of relevant information is captured. The catalogue of Use Cases and Pilot Experiments on the field of industry 4.0, manufacturing, digital factories or data spaces, is produced both by the DIGITAL FACTORY ALLIANCE (DFA) itself and by third parties.

Each and every resource may include the following fields (those with an * are compulsory):

- Use Case / Pilot Title* (TEXT)
- Use Case / Pilot Location* (TEXT)
- Use Case / Pilot Partner Logos* (PNG/JPG)
- Use Case Leader partner description* (TEXT)
- Use Case Challenge* (TEXT)
- Use Case Value* (TEXT)
- Use Case Experiment Performance description* (TEXT)
- Use Case Value Chain*^(TEXT/PDF/WORD/PNG/JPG/LINK)
- Use Case Lessons Leaned (TEXT)
- Use Case Replication Potential (TEXT)
- Resource upload* (PDF/WORD/PPT/CSV/LINK)
- Standards used* (TEXT)
- Big Data Platforms & Tools* (TEXT)
- Big Data Characterization* (TEXT)
- Number of sources (TEXT)
- Open Data* (YES / NO)
- Key Facts & KPIs* (TEXT)
- Adoption Assessment*
  - Technical Feasibility
    - Level 1
    - Level 2
    - Level 3
  - Economic Feasibility
    - Level 1
    - Level 2
    - Level 3
  - Replication Potential
    - Level 1
    - Level 2
    - Level 3
- Use Case Keywords* (TEXT)
- Sectors addressed* (Multiple choice)

O Automotive

O Aerospace

O Biotechnology

O Chemicals

O Construction

O Cosmetics

O Cultural & Creative Industries

O Electrical & Electronic Engineering

O Agri-Food

O Maritime

O Mechanical Engineering

O Mobility

O Pressure equipment & Gas appliances

O Raw materials & Metals

O Supply Chain

O Tourism

O Textiles

- Geographic Scope (Multiple choice)

O Austria

O Belgium

O Bulgaria

O Croatia

O Republic of Cyprus

O Czech Republic

O Denmark

O Estonia

O Finland

O France

O Germany

O Greece

O Hungary

O Ireland

O Italy

O Latvia

O Netherlands

O Poland

O Portugal

O Romania

O Slovakia

O Slovenia

O Spain

O Sweden

O Lithuania

O Luxembourg

O Malta

O Netherlands

O Lithuania

O Luxembourg

O Malta

O European Union

O Other

5.3 Reference Publications

The Knowledge Hub consists of a reference resources (publications, documents, reports, Power Point Presentations, Guidelines, Factsheets, Videos and Other), produced both by the DIGITAL FACTORY ALLIANCE (DFA) itself and by third parties.

Each and every resource may include the following fields (those with an * are compulsory):

- Title*
- Brief summary or description*
- Language*
- Author(s)*
- Organization*
- Version
- Own or external publications*
- Publication date*
- Access to the publication (free/members only) *
- Keywords
- Topic*
  - Legal
  - Data
  - Business
  - Ecosystem
  - Skills & Talent
  - Technological
- Type of resource*
  - Technical document

- Popular articles
- Report
- Presentation
- Guide
- Magazine
- File
- Video
- Others

- Resource upload (PDF/WORD/PPT/CSV/LINK)

5.4 Initiative Taxonomy

An initiative is the start of something, with the hope that it will continue. Following this line of thought, the Initiatives Catalogue consists of a catalogue of international, European, national and/or regional initiatives (associations, communities, ecosystems, projects, platforms, foundations, demonstrators, among others) produced both by the DIGITAL FACTORY ALLIANCE (DFA) itself and by third parties.

Each and every resource may include the following fields (those with an * are compulsory):

- Name of the initiative* (TEXT)
- Logo of the initiative * (PNG/JPG)
- Nature of the initiative* (MULTIPLE CHOICE FROM LIST BELOW)

  - Association
  - Community
  - Ecosystem
  - Project
  - Platform
  - Foundation
  - Demonstrator
  - Data Space
  - Other

- Scope of the initiative* (CHOOSE 1 FROM LIST BELOW)

  - Global
  - European
  - International
  - National

  - Regional

- Geographic Scope of the initiative* (MULTIPLE CHOICE FROM LIST BELOW)
  - Austria
  - Belgium
  - Bulgaria
  - Croatia
  - Republic of Cyprus
  - Czech Republic
  - Denmark
  - Estonia
  - Finland
  - France
  - Germany
  - Greece
  - Hungary
  - Ireland
  - Italy
  - Latvia
  - Lithuania
  - Luxembourg
  - Malta
  - Netherlands
  - Poland
  - Portugal
  - Romania
  - Slovakia
  - Slovenia
  - Spain
  - Sweden
  - European Union
  - Other
- Mission of the initiative* (TEXT)
- Sector(s) addressed by the initiative* (CHOOSE FROM LIST BELOW)
  - Automotive
  - Aerospace
  - Biotechnology
  - Chemicals
  - Construction
  - Cosmetics
  - Cultural & Creative Industries
  - Electrical & Electronic Engineering
  - Agri-Food
  - Maritime
  - Mechanical Engineering
  - Mobility
  - Pressure equipment & Gas appliances
  - Raw materials & Metals
  - Supply Chain

- Tourism
- Textiles

- Leading organization*
- Contact Information of the initiative* (Name/E-mail/Contact Form Link)
- Members (approx.) * (NUMBER)
- Foundation Year* (NUMBER XXXX)
- Social Media Presence*
    - LinkedIn (LINK)
    - X (LINK)
- Relevance for Industry 4.0* (TEXT)
- Document Library Link* (LINK)
- Events Link* (LINK)
- Connected Initiatives (TEXT)
- Data Space Technical Specifications * (CHOOSE 1 FROM LIST BELOW)
    - Level 1
    - Level 2
    - Level 3
    - Level 4
    - Level 5
- Data Space Governance * (CHOOSE 1 FROM LIST BELOW)
    - Level 1
    - Level 2
    - Level 3
    - Level 4
    - Level 5
- Data Space Demonstration * (CHOOSE 1 FROM LIST BELOW)

  - Level 1
  - Level 2
  - Level 3
  - Level 4
  - Level 5
- Data Space Adoption * (CHOOSE 1 FROM LIST BELOW)
  - Level 1
  - Level 2
  - Level 3
  - Level 4
  - Level 5
- More information about the initiative* (TEXT)