Factory-X
Project Overview

- Business Models
- Operating Model
- Transfer Measures

Factory-X
Use Cases

FACTORY-X

Manufacturing-X

- International Manufacturing-X
- M-X Guidance Board

M-X Port

factory-x.org

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FACTORY-X

Factory-X

The Digital Ecosystem for Factory Outfitters and Operators

View our LinkedIn Profile

PART OF MANUFACTURING-X

Supported by:
Federal Ministry for Economic Affairs and Energy
Funded by the European Union
NextGenerationEU
on the basis of a decision by the German Bundestag

Factory-X
Project Overview

The Digital Ecosystem for
Factory Outfitters and Operators

The Factory-X Consortium

FACTORY-X

Industrial Partners

ARVATO SYSTEMS, BASF We create chemistry, berger, codewerk, DMG MORI, Empolis, EPLAN, FESTO, GEC, hilscher, ifm, igus, inovex, InstaWerk, Lenze, matchory, mt ANALYTICS, OPEN INDUSTRY 4.0 ALLIANCE, PAKIC, PHOENIX CONTACT, prenode, Proalpha, RIF Engineering & Consulting, SAP, Scheer, SCHUNK, sdfs Smarte Demonstrationsfabrik Siegen, SICK Sensor Intelligence., SIEMENS, soffico, software AG A SOFTWARE GMBH BRAND, TRUMPF, T Systems, TÜV SÜD, UHLMANN GROUP BEYOND PACKAGING, WITTENSTEIN

Associations & Research Partners

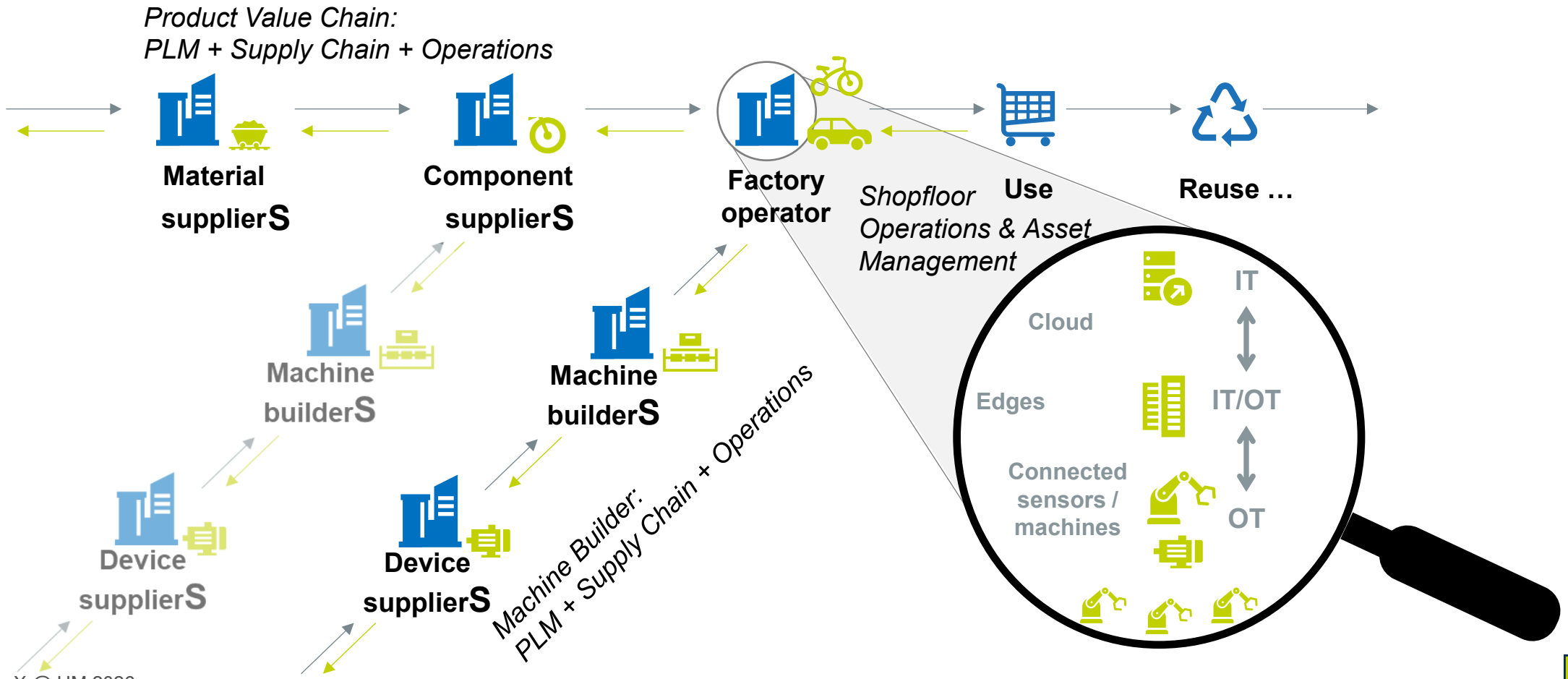
August-Wilhelm Scheer Institut Digital Research, Fraunhofer, IFW Institut für Fertigungstechnik und Werkzeugmaschinen, ISW, RUHR UNIVERSITÄT BOCHUM, RUB, smartFactory KL, Catena-X, ESTAINIUM Association, LNI4.0 LABS NETWORK INDUSTRIE 4.0, VDMA, zvei electrifying ideas

Associated Partners

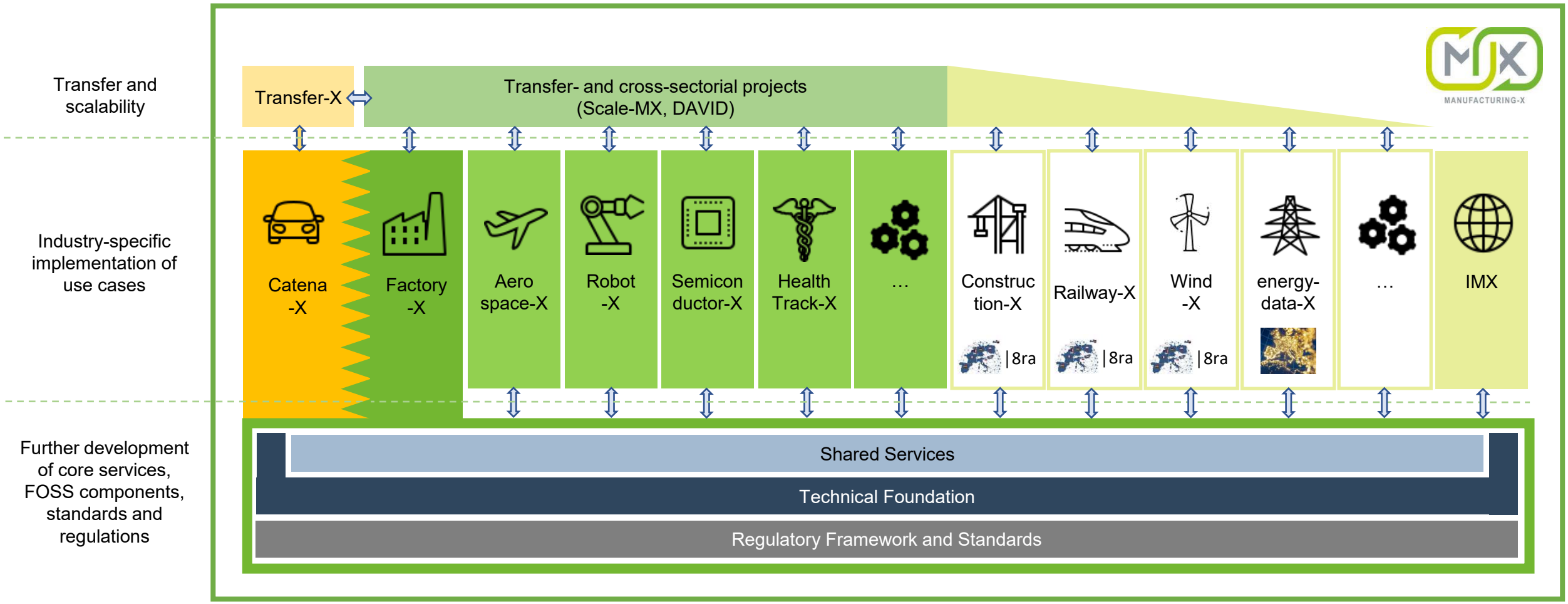
ARENA2036, bayern innovativ Innovation leben, BECKHOFF, BOSCH, Digital Data Chain Consortium, EVIDEN, IDTA, Sharecat, STANDARDIZATION COUNCIL INDUSTRIE 4.0, zvei electrifying ideas

Factory-X
Our Scope and claim

Building the foundation of an open and collaborative digital ecosystem for factory outfitters and operators!



Germany
Cooperation between the projects



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Way forward to M-X DATA ECOSYSTEM

Factory-X
- MX-Port Hercules
- MX-Port Leo
- MX-Port Orion

Factory-X proposal for
- Governance „M-X Verstetigung“
- Operating Model
- Set of common rules

Catena-X

CHEM-X

Machinery

Automotive industry (Catena-X)

Chemical & pharmaceutical industry

Manufacturing-X
Intelligently networked industry

Electrical components industry

Semiconductor-X

Food industry

Other industries

Railway-X

Aerospace-X

Further data spaces

TODAY

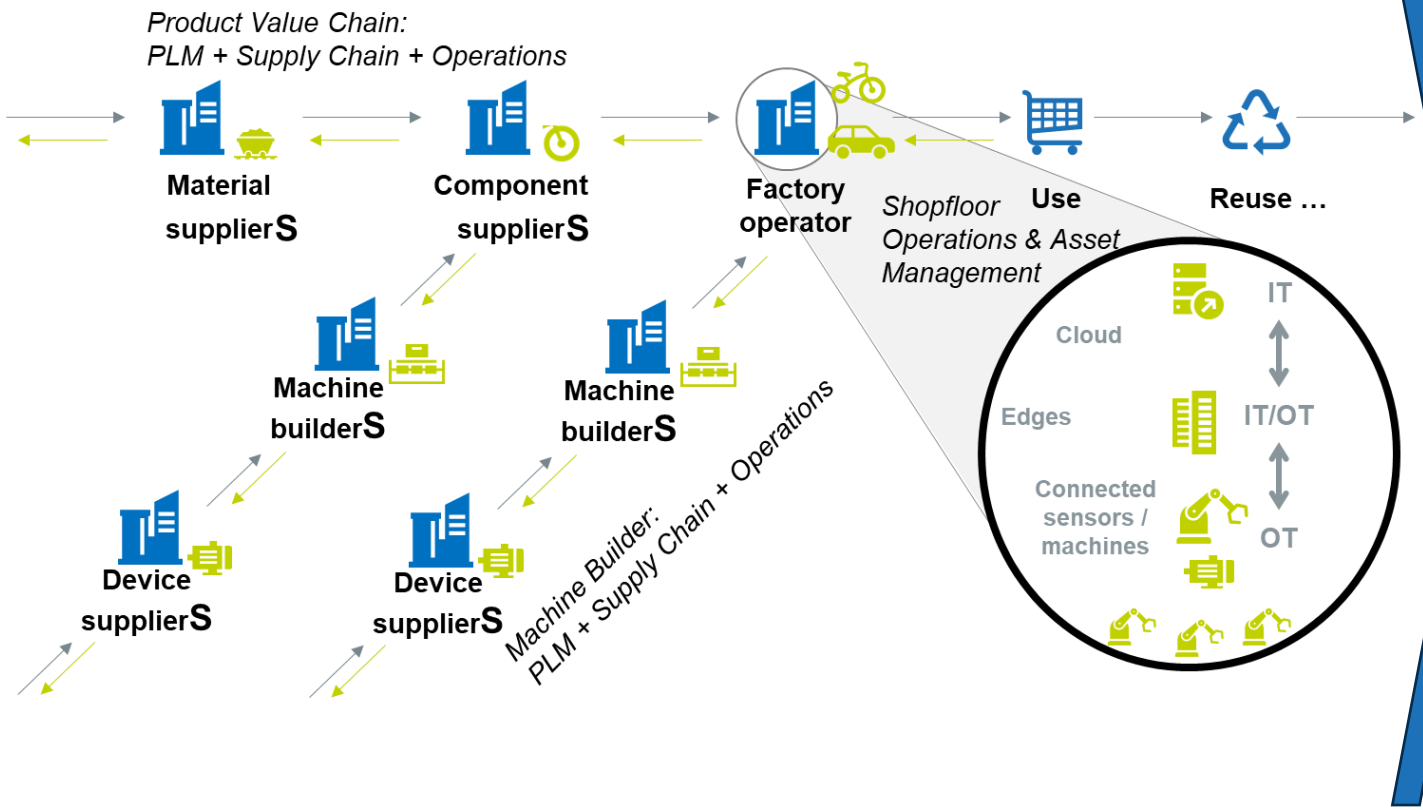
M-X Governance

M-X DATA ECOSYSTEM
(set of interoperable data spaces)

TOMORROW

“One size fits all” does not work. We need a modular approach to achieve interoperable data spaces

The Factory-X Continuum



Foci of MX-Port Configurations

Supply Chain oriented
“HERCULES”

PLM +
Operations Mgmt. for Production Equipment
“LEO”

Operations Mgmt. for Production Equipment
“ORION”

Factory-X Use Cases Generate Business Benefits For Participating Companies Through Cross-Company Data Sharing

11 Use Cases for data transfer along product and production system supply chain

Int. Toolchains & Collab. Engineer.

optimization of engineering of a product

Inform. Update and Change Service

optimization of operations

Collaborative Information Logistics

optimization of operations

Condition Monitoring led Services

optimization of operations

Modular Production

optimization of operations

Manufacturing as a Service

optimization of operations

Autonomous Operation aaS

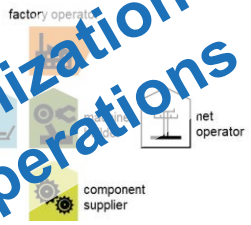
optimization of operations

Traceability

optimization of supply chain

Energy-Consump. & Load Mgmt.

optimization of operations



Carbon Footprint Management

optimization of supply chain

Circular Economy

assessment of remaining life

MX-Port: a common technical concept that can be implemented in different ways

MX-Port as common technical concept for cross-company data sharing

Layer	Purpose
MX Discovery	... is used to find business partners, data assets (e.g. devices) or business applications.
MX Access & Usage Ctrl.	... is used to ensure that data providers can define and restrict the data access and usage of the provided data.
MX Gate	... is used to exchange data in a uniform way.
MX Converter	... provides the semantic model for the data to be exchanged.
MX Adapter	... enables any business application to use the MX-Port.

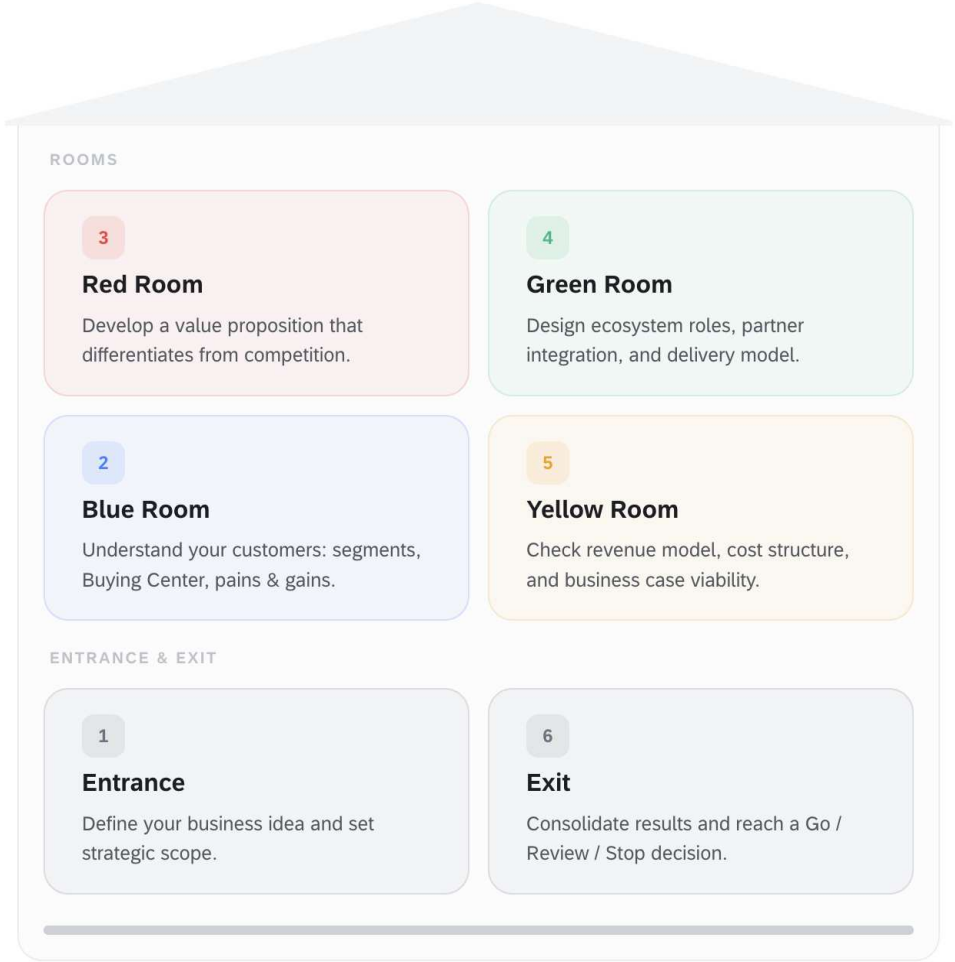
Different MX-Port configurations implementing the MX-Port concept

Implementation mainly driven by requirements of the use cases

Business Models

Business Models

From Vision to Value



Our Scope

We help to adapt business models to increase revenue with data:

- We provide a methodology to develop data- and service-oriented business models
- We deliver the supporting implementation tools

Key Results

The science-based so-called "house-building logic", which can be applied independently in three different ways with our provided tools:

- 5-day workshop format
- Hybrid workshop with AI-assistant
- Only with an AI-Assistant (single-prompt or agentic)

Use case oriented demonstrators

Business Models

AI Assistant for Business Models

What It Does

- Works with any standard AI engine
- Uses the structured “Housebuilding Logic”

How You Use It

- Interacts via intuitive, chat-like guidance
- Let you progress at your own speed

Why It Helps

- Faster business model development
- Consistent structure and higher quality
- No external data transfer → full confidentiality

TP3 Business Models

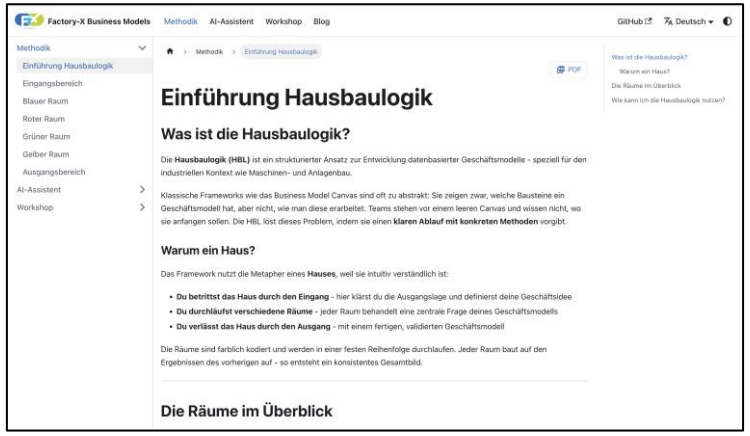
Website for Business Models Innovation

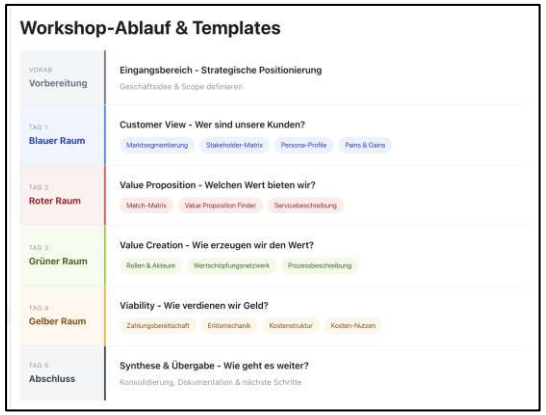
FACTORY-X

Description

Documentation website showcasing the House Building Logic methodology for data-driven business models.

- Hosts full methodology with interactive navigation, templates, and quality gates
- Integrates an AI assistant directly usable via ChatGPT, Claude, or Copilot
- Provides downloadable workshop materials and multilingual content (DE/EN)





Benefit

Single entry point for practitioners to learn, apply, and scale business model innovation.

- Combines documentation, AI tooling, and workshop resources in one place
- Self-service access – no training required, just follow the guided structure
- Open source (Apache 2.0 / CC-BY-4.0), ready to fork and adapt

Operating Model

Operating Model

Enabling multi-lateral collaboration

The Operating Model as a playbook for multi-lateral collaboration

Our Scope

Define a guideline for a **governance framework** that **enables** and fosters **multi-lateral collaboration** and ensures alignment among participants by establishing **shared principles, structured processes and clear compliance rules** for roles and services to facilitate mutual understanding, cooperation, and trust across the Manufacturing-X ecosystem.

Key Results

Guidelines for:

- **Fundamental principles** or golden rules to ensure quality characteristics (e.g. interoperability and sovereignty).
- **Processes and workflows** required for the effective and efficient operation of the data space (e.g., standardization, certification).
- **Role definitions** as well as their associated **rights and responsibilities** within the MX data ecosystem.
- **Governance**, which ensures **operational continuity and compliance** with all rules through binding guidelines and policies.

Operating Model

Our Key Benefits

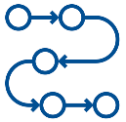
- **Establish a legally binding and accepted ground** for all participants of the data ecosystem
- **Agreement on common guidelines** and rules to share data between different vertical industries
- **Avoidance of lock-in effects** by enabling **barrier- and -discrimination-free business models** for all participants
- **Enable scalable & interoperable solution offerings** by integrating Hercules, Leo and Orion
- **Enable Co-Evolution and Co-Innovation** over time without losing **compatibility and interoperability** within Factory-X and Manufacturing-X and with other data ecosystems

Operating Model

Our Focus

Key Components:

Fundamental principles to assure the quality characteristics



Processes and procedures that are required for the effective and efficient operation of the Data Space.

Technologies and fundamental enablers (e.g. MX-Port) required to ensure compliance with the fundamental principles.

Role definitions and the associated **rights and responsibilities** within the Factory-X Data Space.

Objectives:

- **Establish shared principles** as the foundation for mutual understanding
- **Establish a collaborative framework** that ensures alignment among participants
- **Establish structured processes** to enhance efficiency and assure legal compliance
- **Establish clear compliance guidelines** for all roles and services to maintain transparency and trust

Operating Model

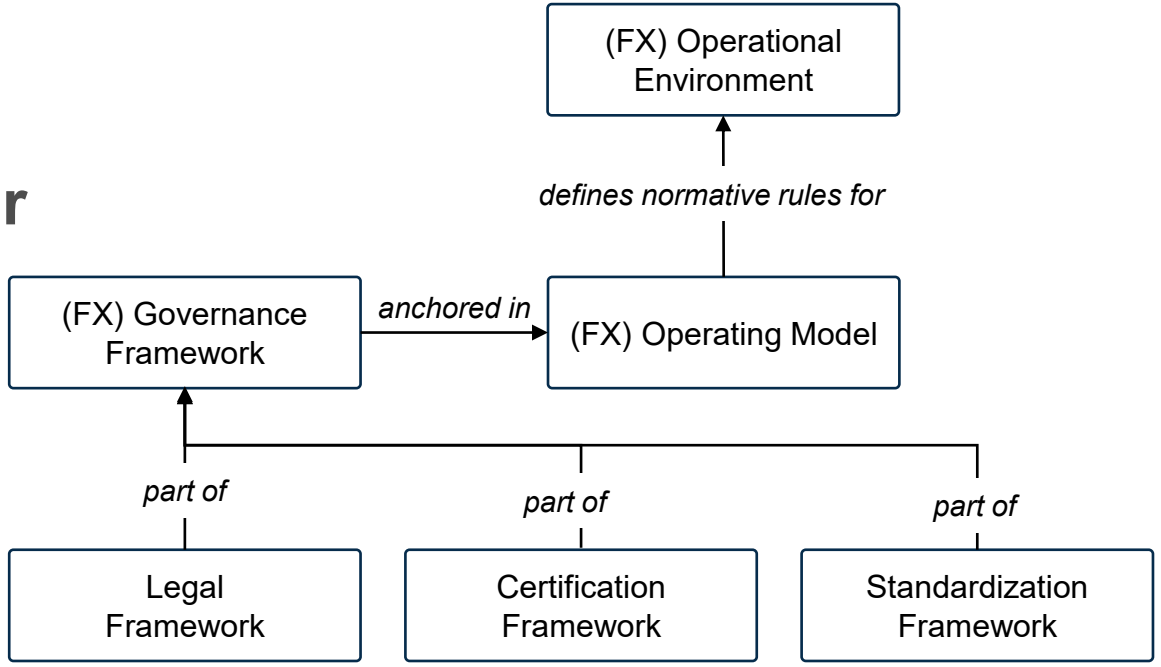
Our Concrete Building Blocks of an Operating Model

The Operating Model anchores the Governance Framework of a given Dataspace and its compliance mechanisms with the

- Legal Framework
- Certification Framework
- Standardization Framework

as its foundation and extends it with clear

- overall organizational structure
- roles and responsibilities,
- their collaboration mechanisms,
- their mandatory services and
- the lifefycle / release management



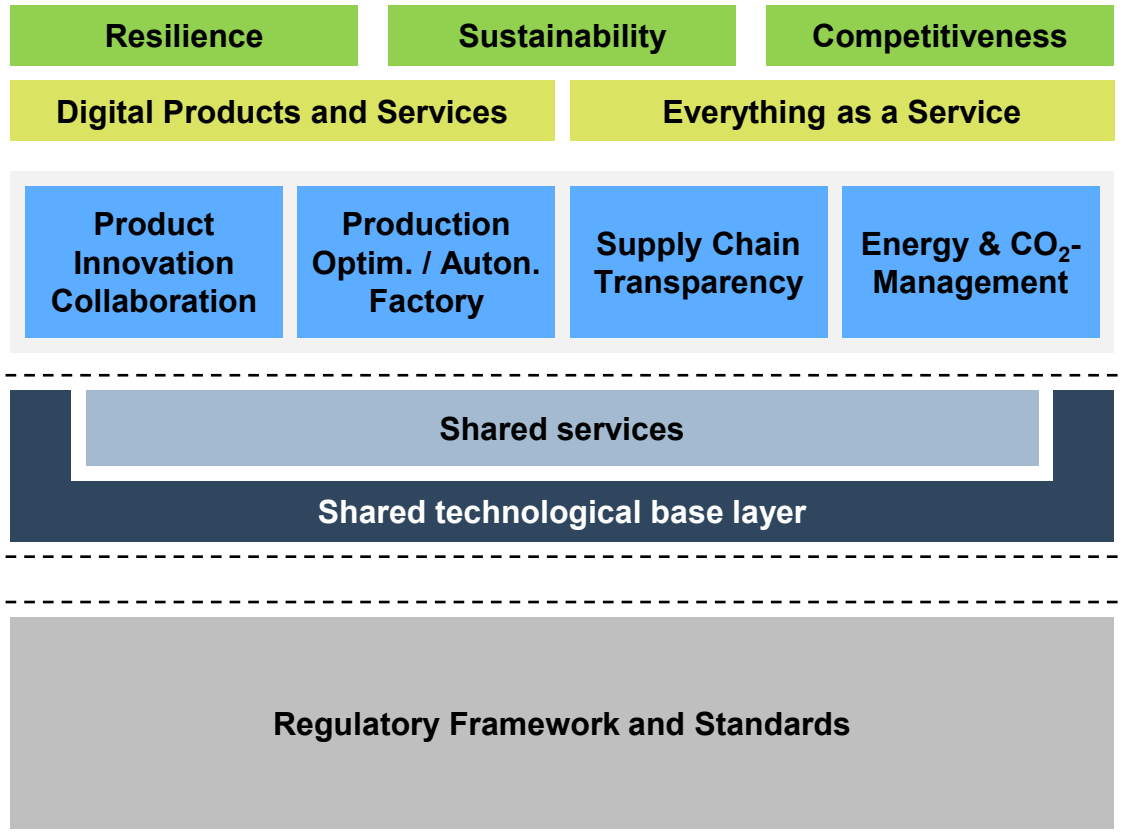
Operating Model

Key Results

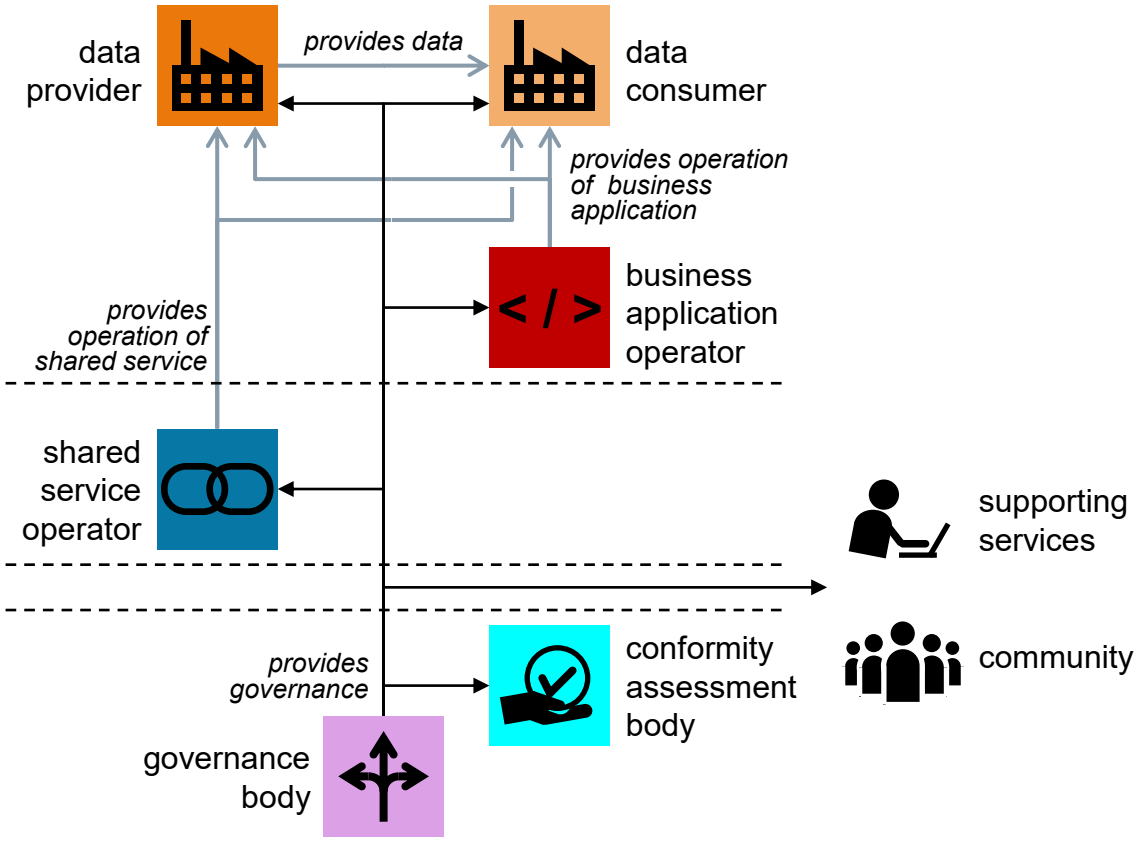
	Standardization Framework	Certification Framework	Legal Framework
		Technical Compliance	Legal Compliance
Main responsibility	• **Technical specifications**	• **Technical compliance**	• **Legal compliance**
Main objective	• Provide a collaborative environment to jointly create technical specification / standards while assuring legal compliance (e.g. anti trust and intellectual property) • Enable interoperability and compatibility between independent implementations	• Proof and assure interoperability and compatibility between independent implementations • Proof and assure compliance with the value proposition and quality requirements of Factory-X	• Ensure compliance with relevant legislation (such as data protection) • Provide contractual frameworks to assure (e.g.) legal accountability and data sovereignty accepted by all participants
Main challenge	• Achieve and maintain interoperability over time while enabling technological evolution	• Minimize certification costs while assuring compliance and reliability	• Establish clear, predictable liability rules and data usage conditions to mitigate risk and encourage data sharing

Scope of Business Roles in Relation to the Foundational Framework for Manufacturing-X

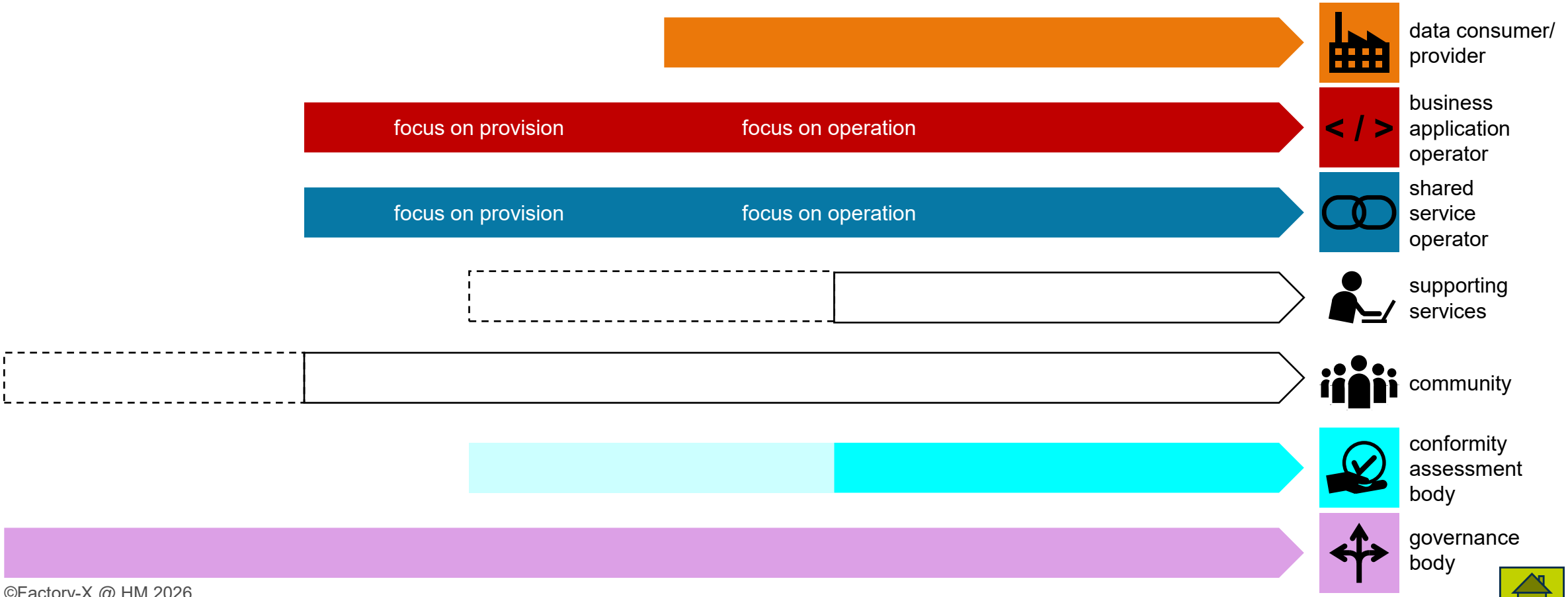
Foundational Framework for Manufacturing-X



Business Roles of Manufacturing-X



Main Scope of Business Roles in Relation to Development of Industrial Data Ecosystems



Commercial Implementation in the Market

Establishing data spaces (bottom-up)

enable the commercial implementation of use cases

data space …

data space “Orion”

data space “Hercules”

data space “Leo”

governance body (architecture governance)

technical architecture based on MX-Port (“Leo”, “Hercules”, “Orion”)

operating model: business roles in a data space and their collaboration

commercially available products, solutions and services

Implementation of use cases (top-down)

concrete use case

interested companies agree on governance body for application governance

governance body for application governance can build on another governance body

commercially available products, solutions and services

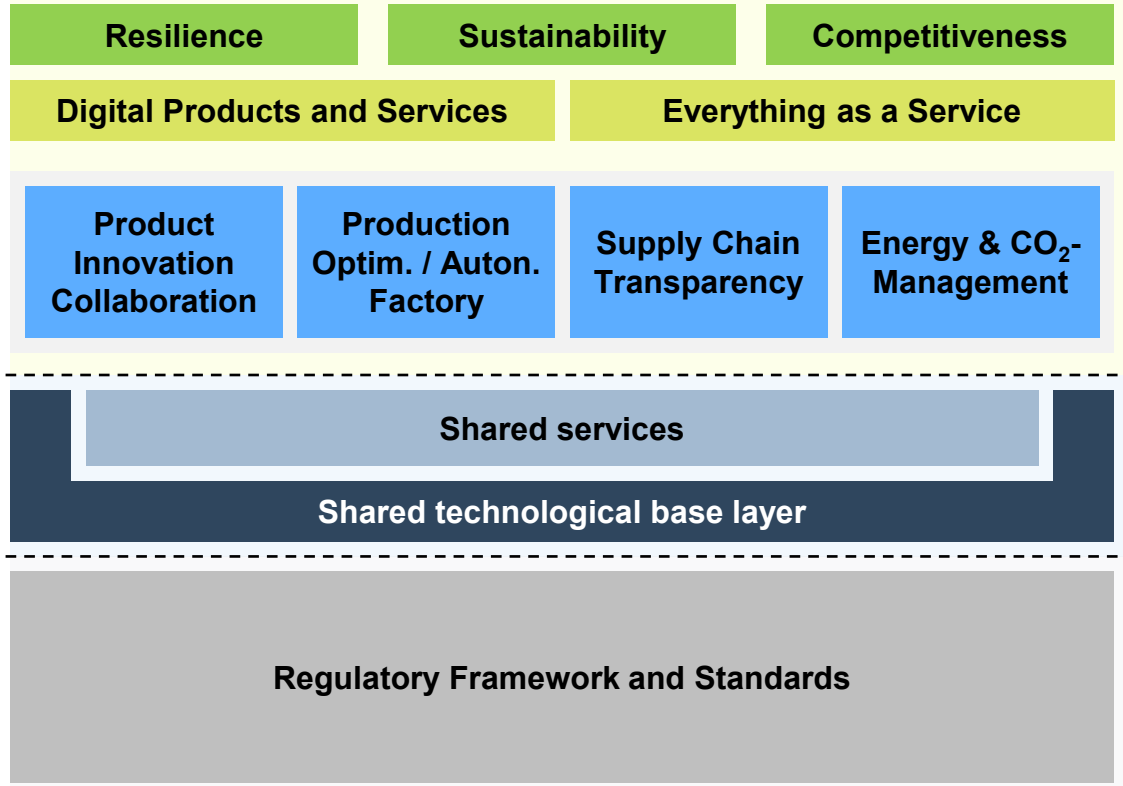
data space

governance body (application governance)

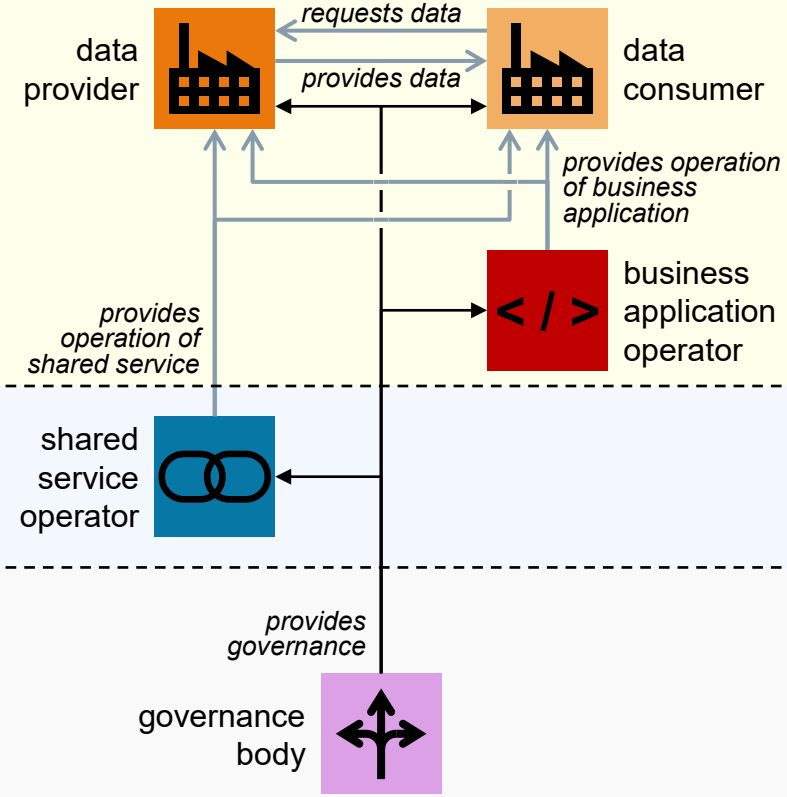
can build on (example)

Standardized cross-company data sharing requires a well-defined interplay between different business roles

Foundational Framework for Manufacturing-X



Business Roles of Manufacturing-X



A company must strategically decide in which business roles it wants to operate within data ecosystems

Transfer Measures

Transfer Measures

Bringing Factory-X solutions to the industry!

Building community: Factory-X Day 2025

Our Scope

Transferring project results to the public:

- clearly communicate content, added value and benefits of the Factory-X data space
- develop FX-specific transfer packages, formats, and methods for adoption my multipliers

Key Results

A set of tested and applied transfer tools including videos, events, demonstrators, and more!

- Factory-X Day 2025 and 2026
- Workshops with use cases using LEGO® Serious Play®
- XR platform with avatar and videos on use cases
- Slide decks, e.g., on value proposition of Factory-X
- Fair representation and demonstrators

Cross-Use Case Demonstrator

Consistent, smart, interoperable: MX-Port "Leo" for AAS-based data exchange

FACTORY-X

Description

The demonstrator shows how the AAS-based MX-port "Leo" can be used to realize **continuity and interoperability in data exchange** in the areas of Smart Products, Smart Engineering, Smart Production, Smart Operation, Smart Services, and Smart End of Life

- Experience the demonstrator virtually: Factory-X Demonstrator

Benefit

Data exchange along the entire product life cycle improves transparency, efficiency, and value for products and services.

- AAS data can be retrieved through scan of QR-Codes on devices
- Videos of software demonstrations showcase several use cases in Factory-X

Transfer Measures

XR-Demonstrator - Experience the FX use cases in a game-like environment

Main features of the XR-Demonstrator

- User journey through all Factory-X use cases
- Immersice experience via interactions and 3D models
- Gamification-based learning
- Personal guidance by Colette (AI Avatar)
- Integrated glossary of Factory-X relevant terms

Visit the XR demonstrator here at the Hannover Fair and try it out for yourself!

Elevator pitches
Presentations of 11 Use Cases

Description

Short video statements of POs of the Use Cases describing their work.

Watch the video statements on the Factory-X website:

Videos - Factory-X

Elevator pitch - Information Update and Change Service

Factory-X
6 Abonnenten
Abonnieren
0
Teilen
Speichern

Benefit

- Quick overview of the use cases
- Get to know the responsible leaders of the projects

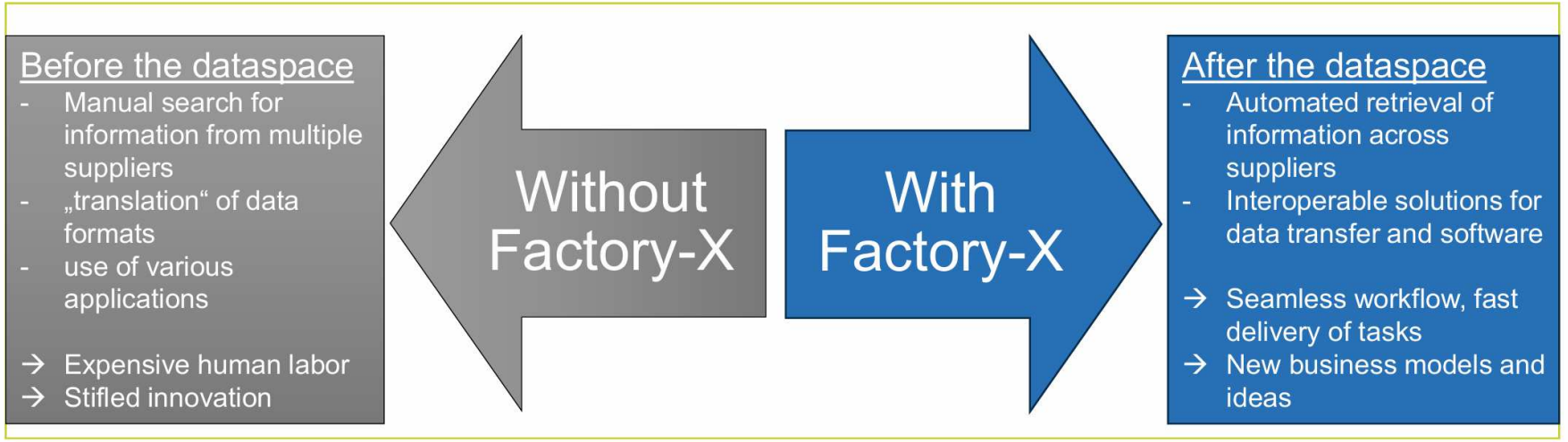
Elevator pitches
Presentations of 11 Use Cases

Description

Slidedeck that makes the benefits of Factory-X tangible, relatable, and easy to understand for non-technical audiences!

Download here:

Factory-X



FACTORY-X

Factory-X Use Cases

11 Use Cases of Factory-X

11 Use Cases for horizontal and vertical data transfer

Demo-Booklet:

Integrated Toolchains and Collaborative Engineering

Information Update and Change Service

Collaborative Information Logistics

Condition Monitoring led Services

Modular Production

Manufacturing as a Service - On Demand Manufacturing

Autonomous Operation-as-a-Service

Traceability

Energy-Consumption and Load Management

Carbon Footprint Management

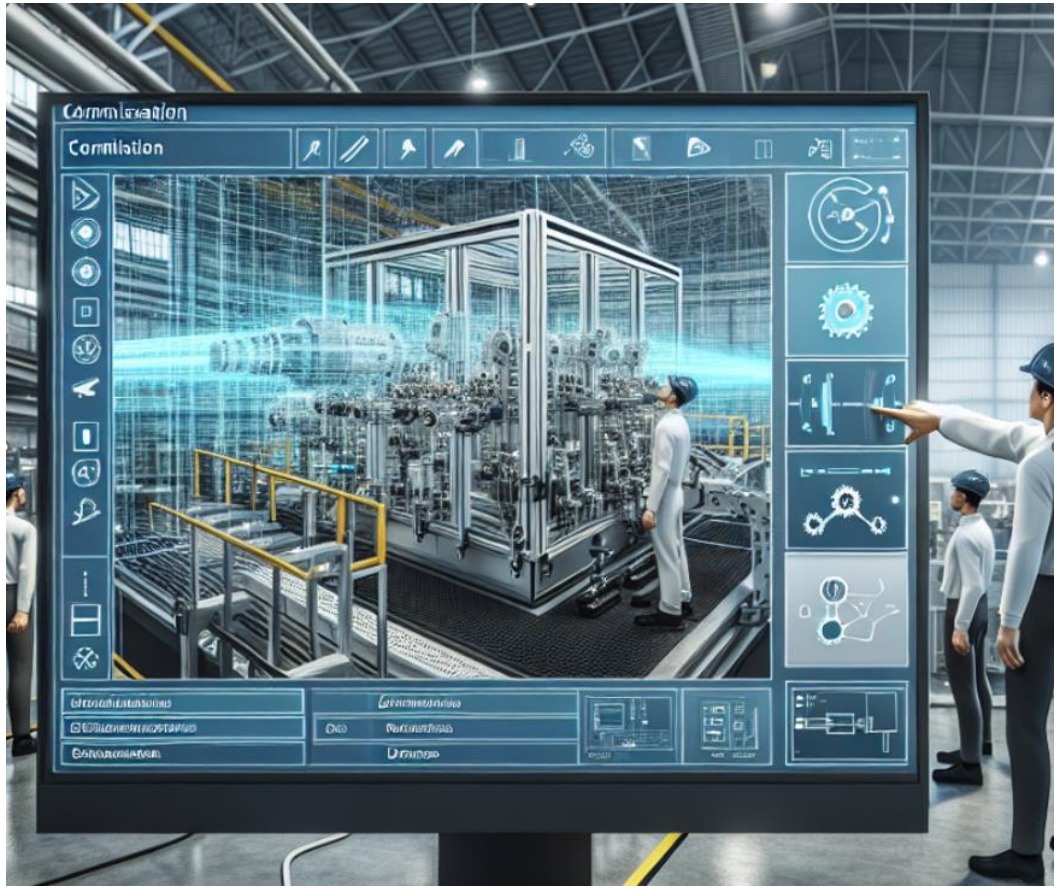
Circular Economy

FACTORY-X

Integrated Toolchains and Collaborative Engineering

Integrated Toolchains & Collaborative Engineering

Productivity by Engineering Data Continuity



Productive Engineering of Machines through end-to-end Digitalization

The Challenge

Missing data continuity across the multiple engineering stakeholders, tools, and disciplines involved **in factory equipment engineering**

The FX-Solution and Offering

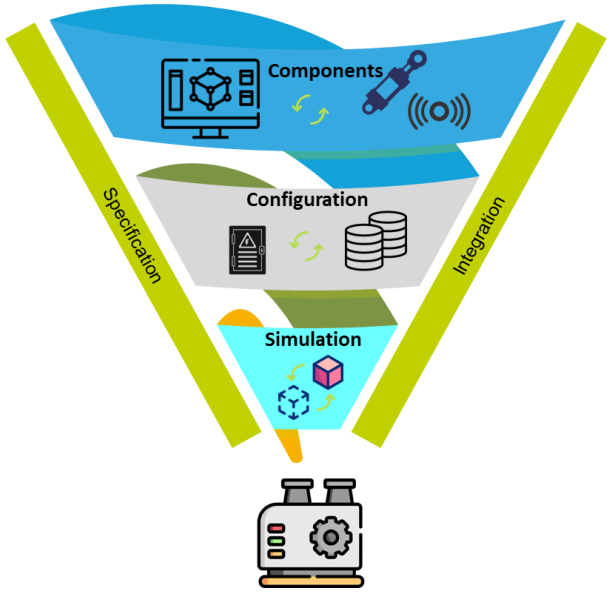
- Data continuity along integrated vendor-independent toolchains based on **common standards**
- Collaborative use of engineering data based on a **trusted framework (MX Port)**
- **Digital twins** for simulating and optimizing production processes and systems during life cycle

Integrated Toolchains & Collaborative Engineering

Productivity by Engineering Data Continuity

FACTORY-X

Productivity by Data Continuity across Engineering Process



Organizational benefits

- engineering ecosystem
- collaborative use of data
- data sovereignty

Economic benefits

- accelerated engineering
- increased productivity
- improved competitiveness

Technical benefits

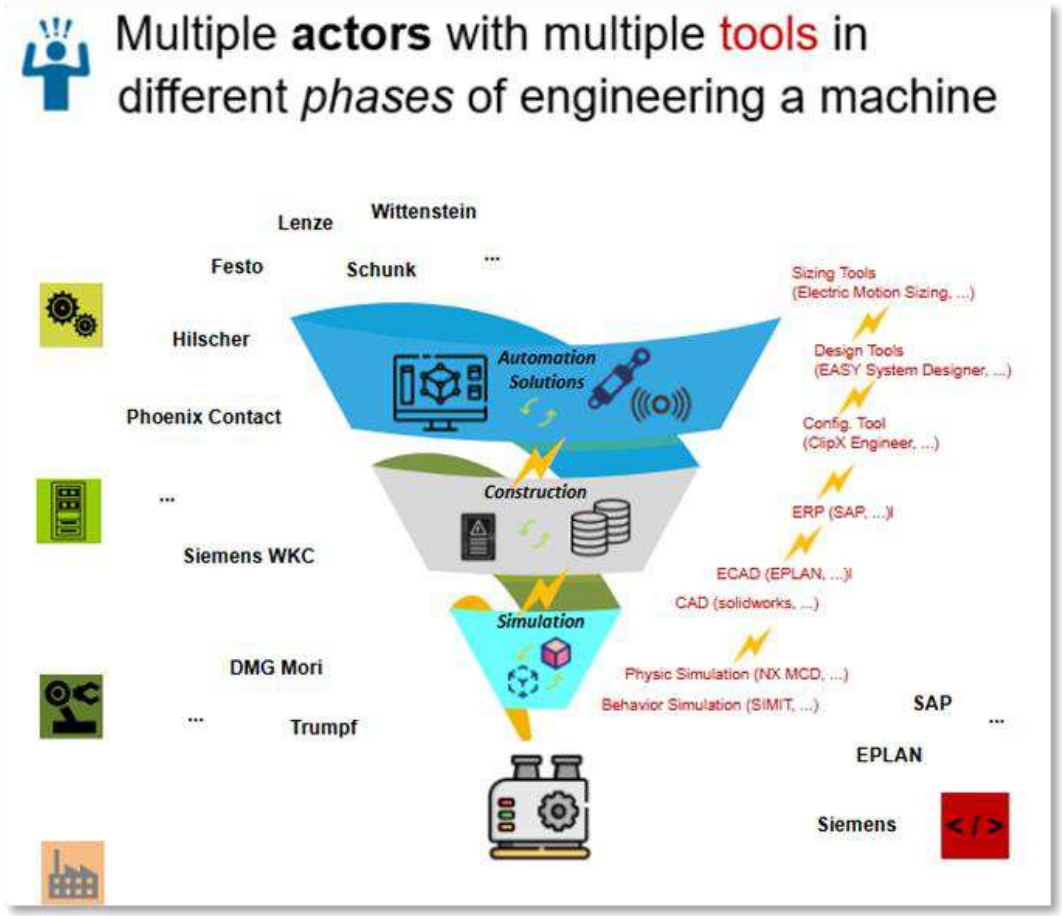
- seamless data exchange
- integrated toolchains
- standardized digital twins

Integrated Toolchains & Collaborative Engineering

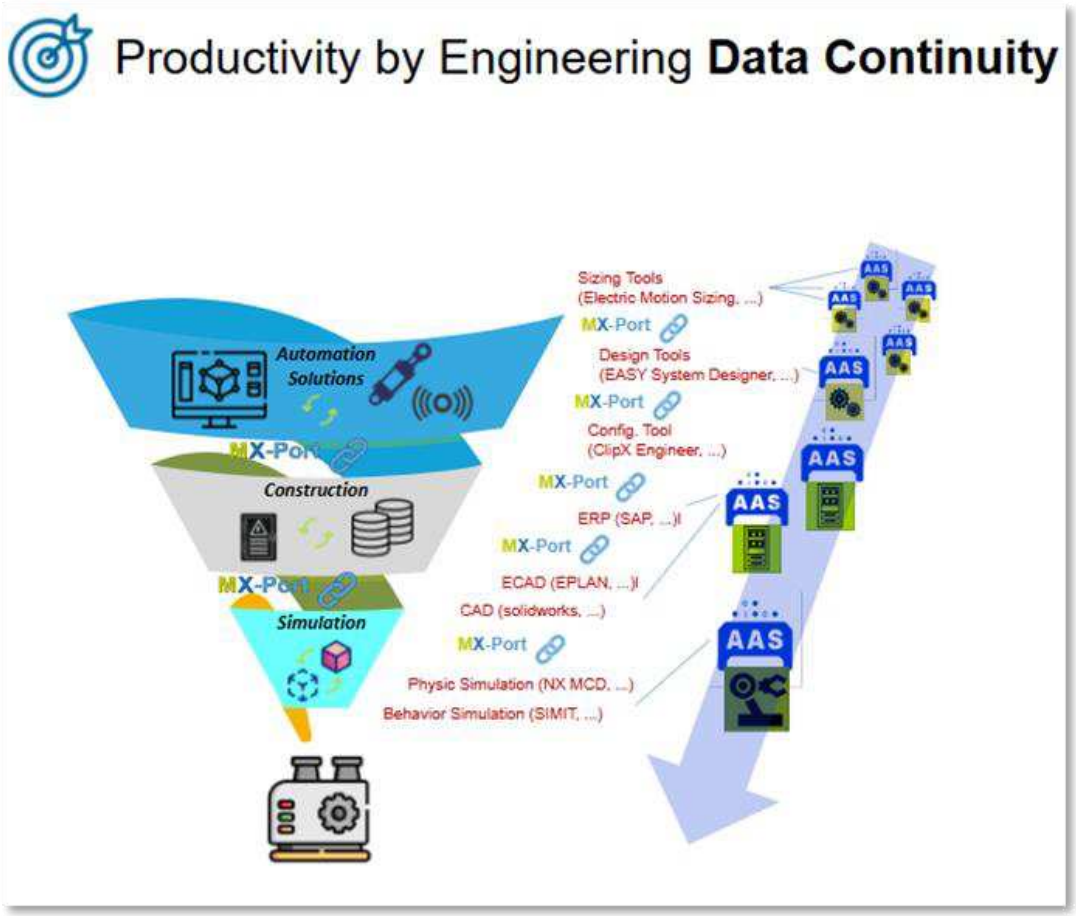
Productivity by Engineering Data Continuity

FACTORY-X

From **Challenges** …



…to **Solutions.**

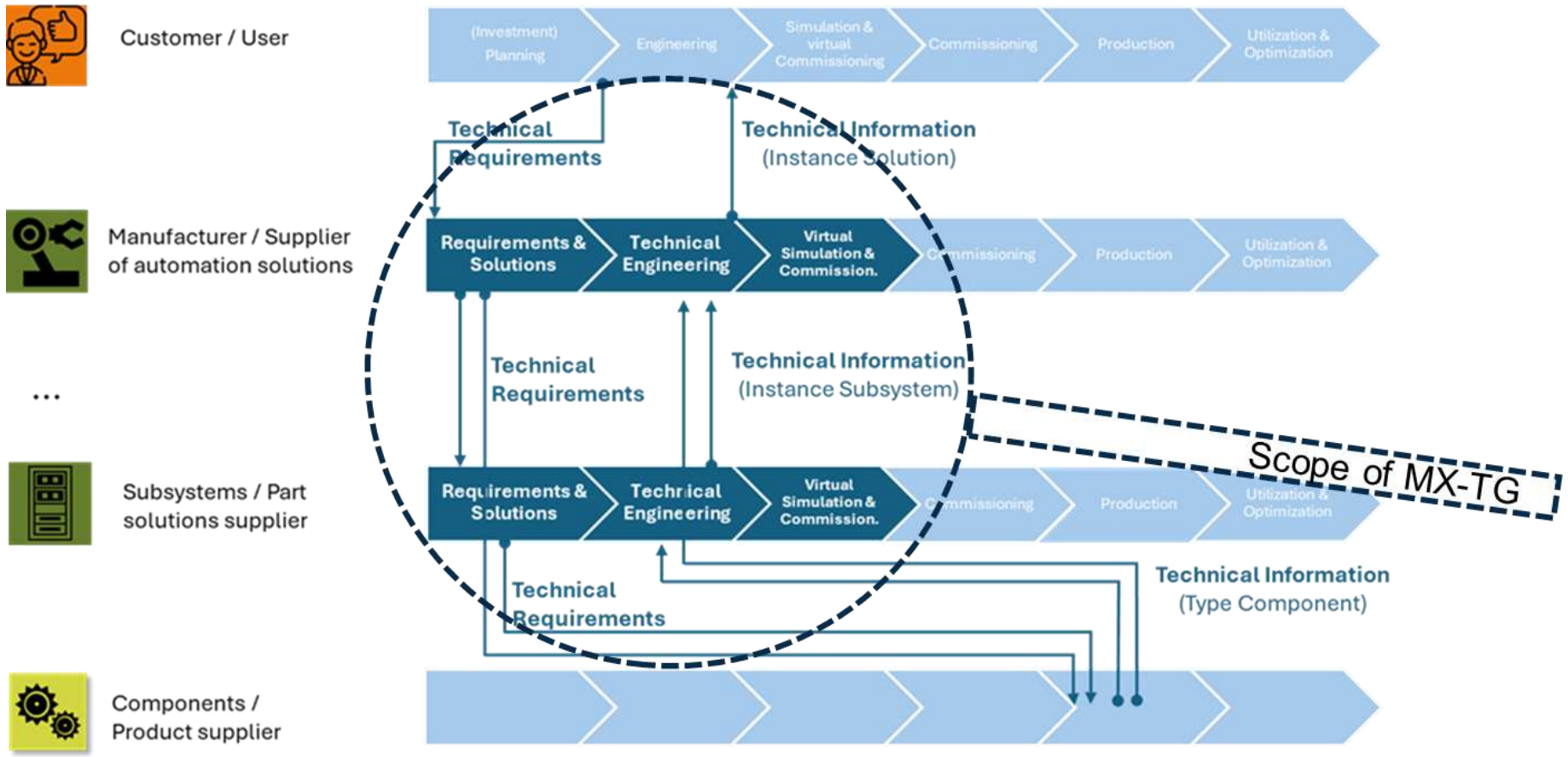


Integrated Toolchains & Collaborative Engineering

Need for seamless exchange of information in Collaborative Engineering

FACTORY-X

Information Exchange along Collaborative Engineering Partners and Phases:



COLLABORATIVE ENGINEERING

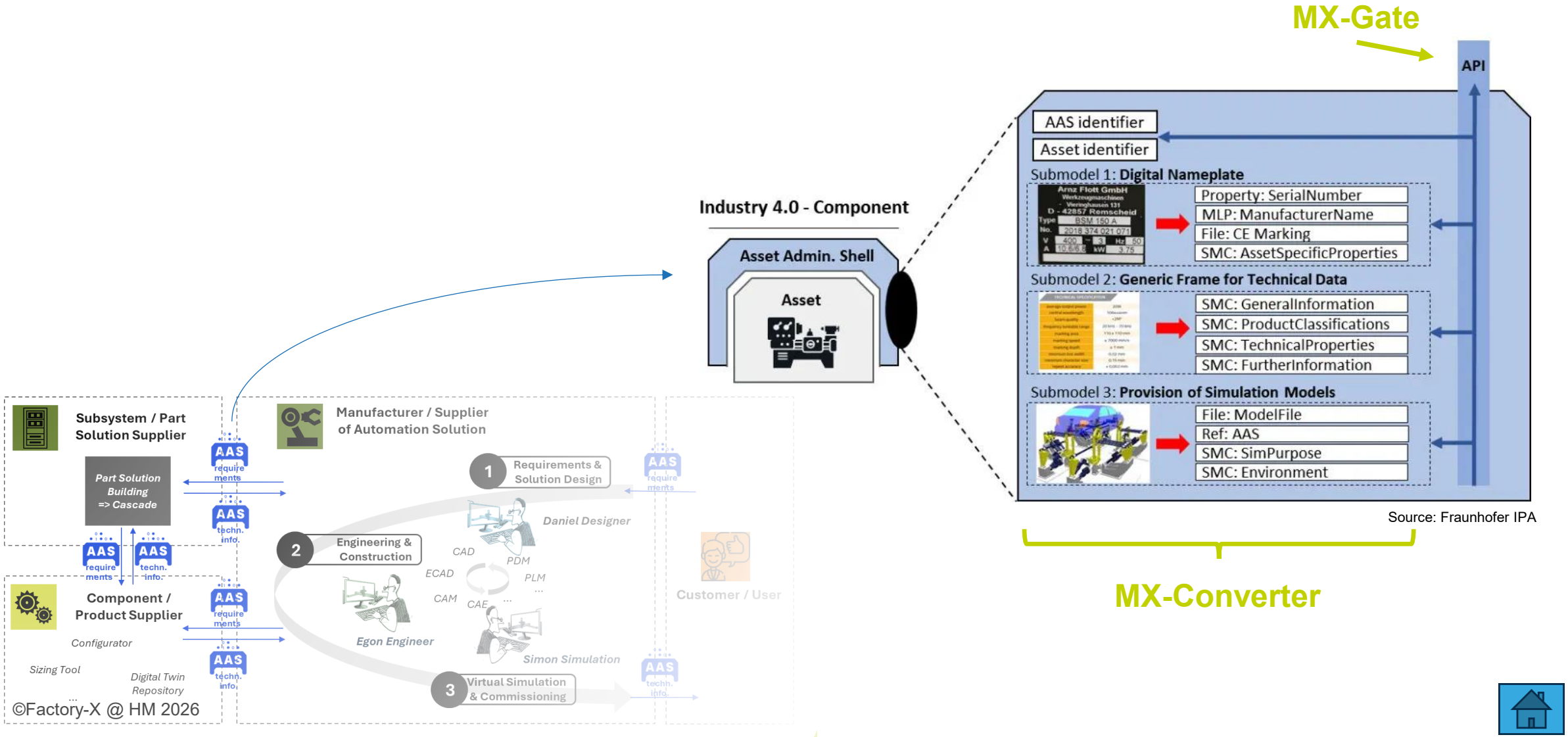
Why & How to use AAS for Collaborative Engineering?

Whitepaper (Version 1)

Manufacturing-X
Guidance Board

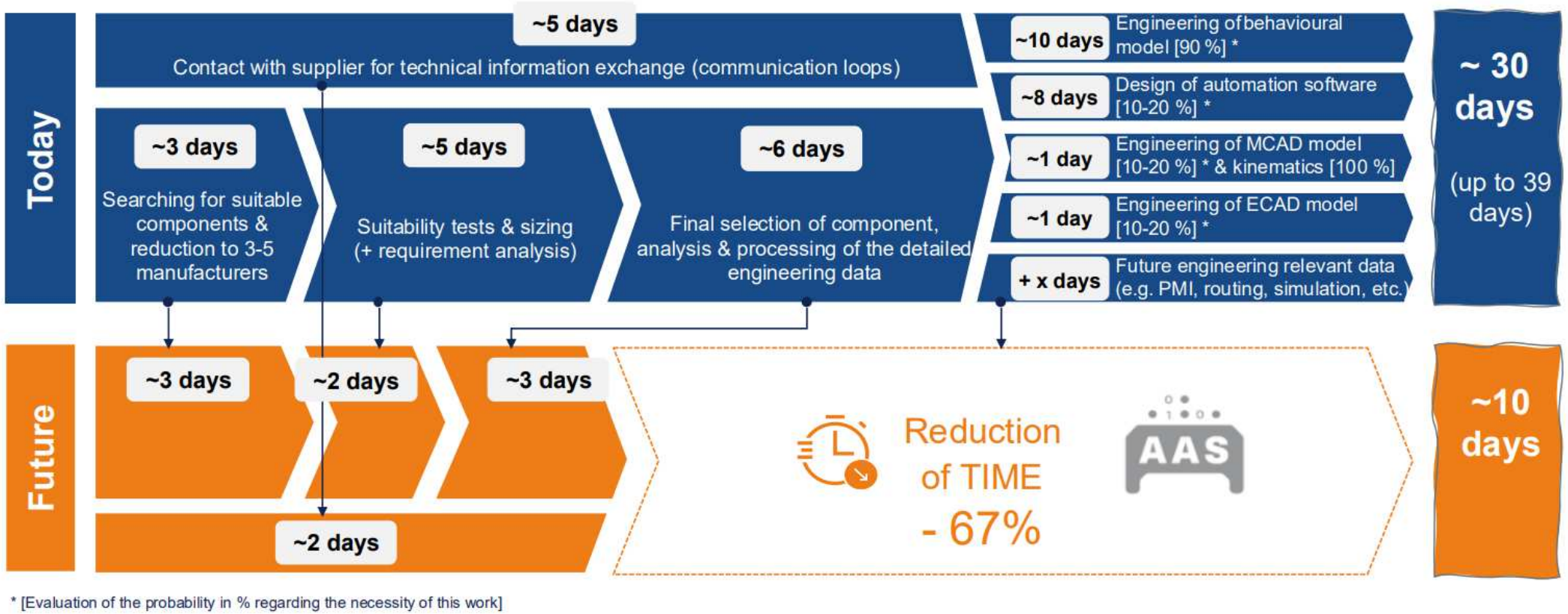
Integrated Toolchains & Collaborative Engineering

Asset Administration Shell (AAS) as standardized representation of Digital Twin



Integrated Toolchains & Collaborative Engineering

Example of accelerated engineering process thanks to AAS



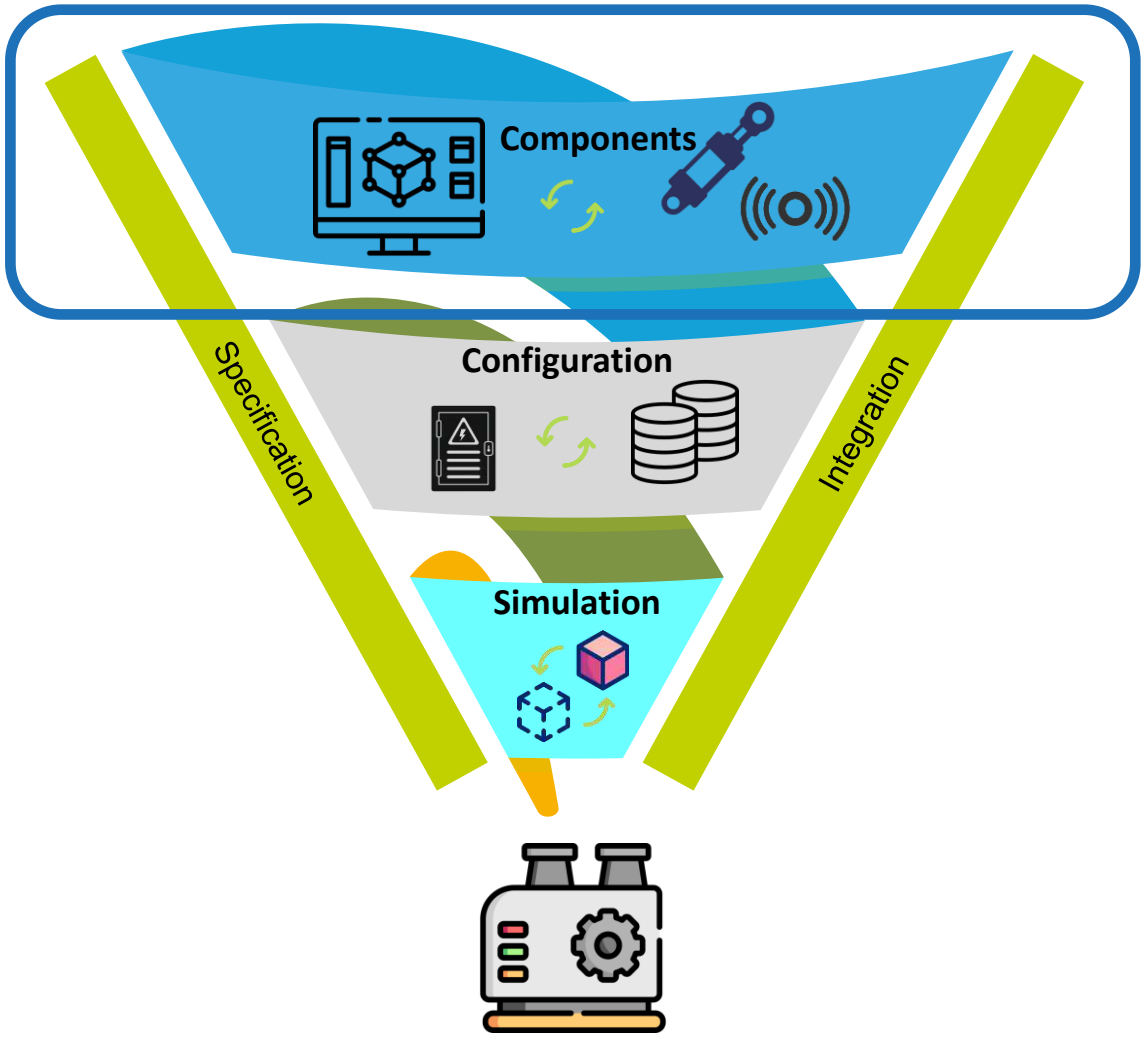
* [Evaluation of the probability in % regarding the necessity of this work]

Source: https://www.zvei.org/themen/whitepaper-aas-in-der-antriebstechnik (Image rights: Siemens Industry Software GmbH. All rights reserved)

Workstream 1
Conception and Design of Automation Solutions (AUT)

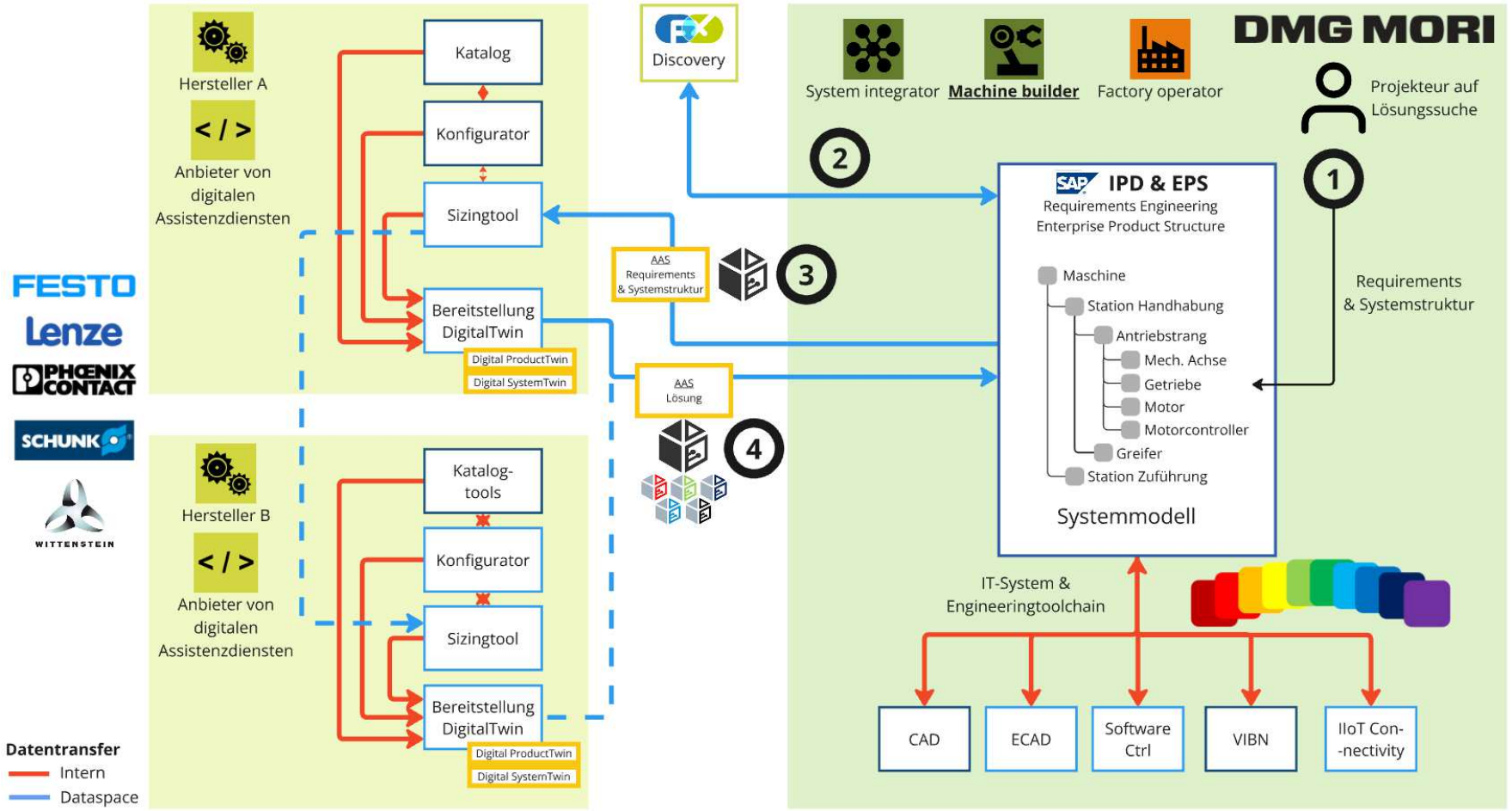
Integrated Toolchains & Collaborative Engineering

Productivity by Engineering Data Continuity



Workstream 1: Conception and Design of Automation Solutions (AUT)

Workstream 1 (AUT) Overview



What?

Simple and efficient solution finding

Why?

Simplicity

Efficiency

Quality

How?

Requirements Engineering

Automatic discovery of vendor services

Semiautomatic solution finding

Workstream 1 (AUT) Overview

Digital Twin

Create system model based on requirements

Engineer looking for solution

FACTORY-X

Automation Problem

WITTENSTEIN

Lenze

FESTO

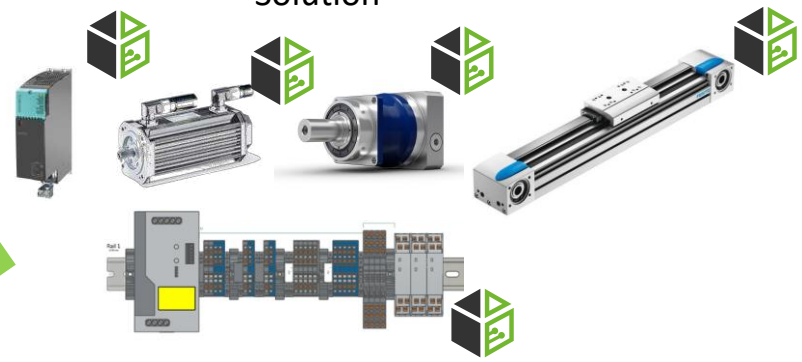
SIEMENS

SCHUNK

PHOENIX CONTACT

Simplified, efficient and vendor independent solution finding with high quality

Solution

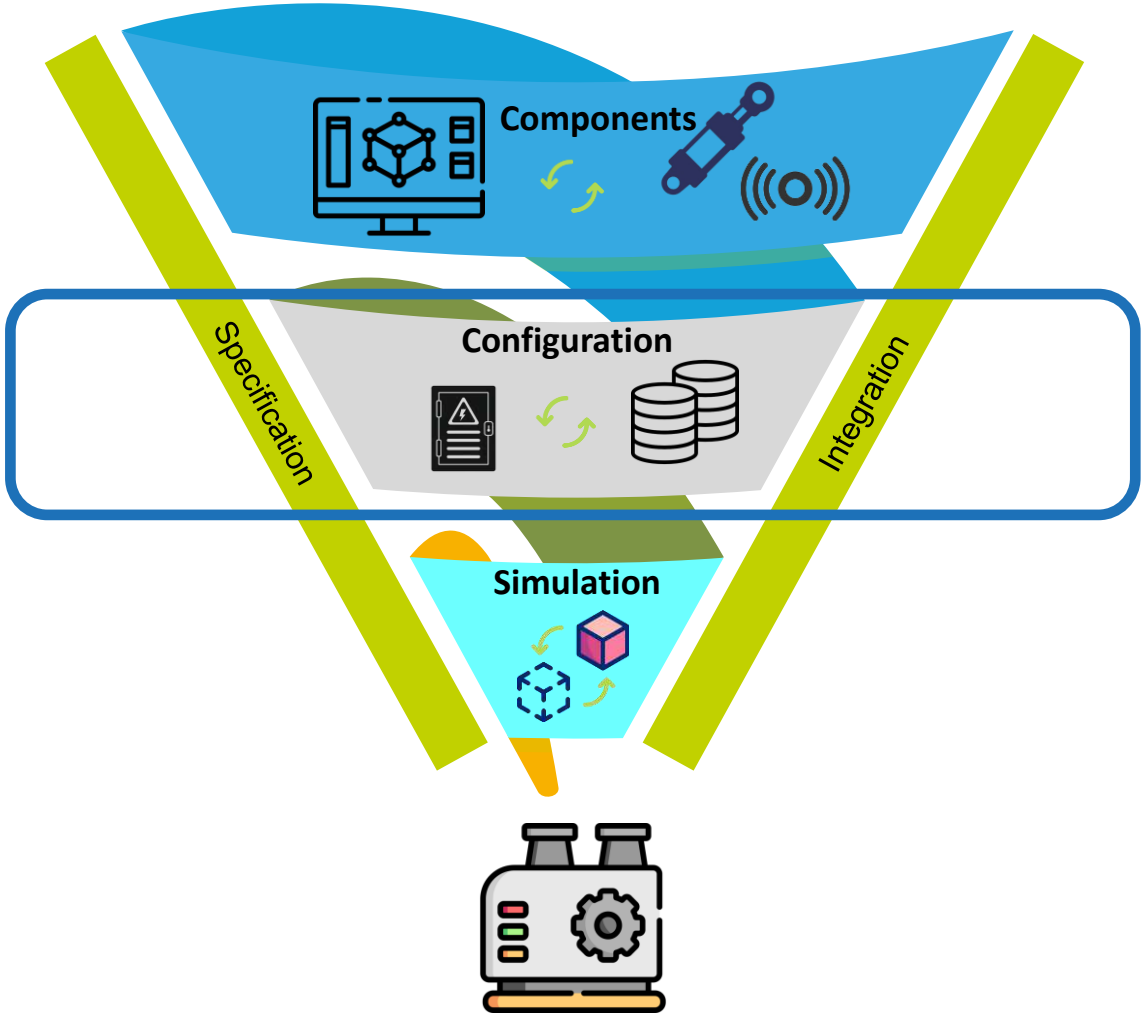


Integration into machine builders IT- and Engineering system

Workstream 2
Engineering and Manufacturing of Electrical Systems (ELK)

Integrated Toolchains & Collaborative Engineering

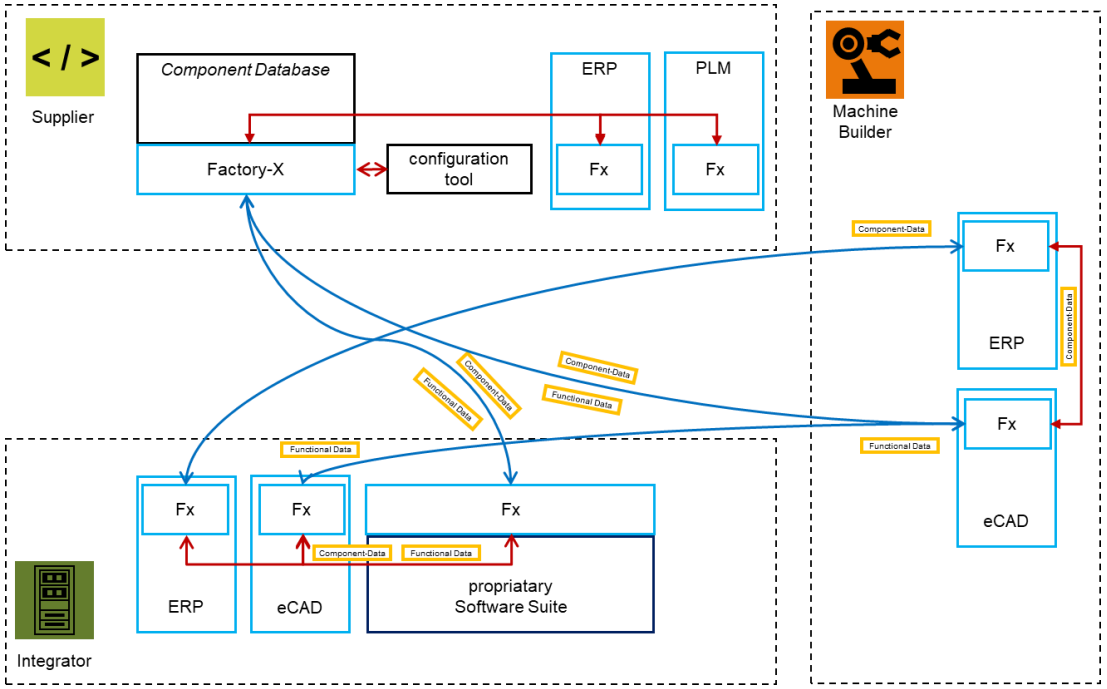
Productivity by Engineering Data Continuity



Workstream 2: Engineering and Manufacturing of Electrical Systems (ELK)

Workstream 2 (ELK)
Overview

Usage View



Why?

- increase productivity by data continuity

How?

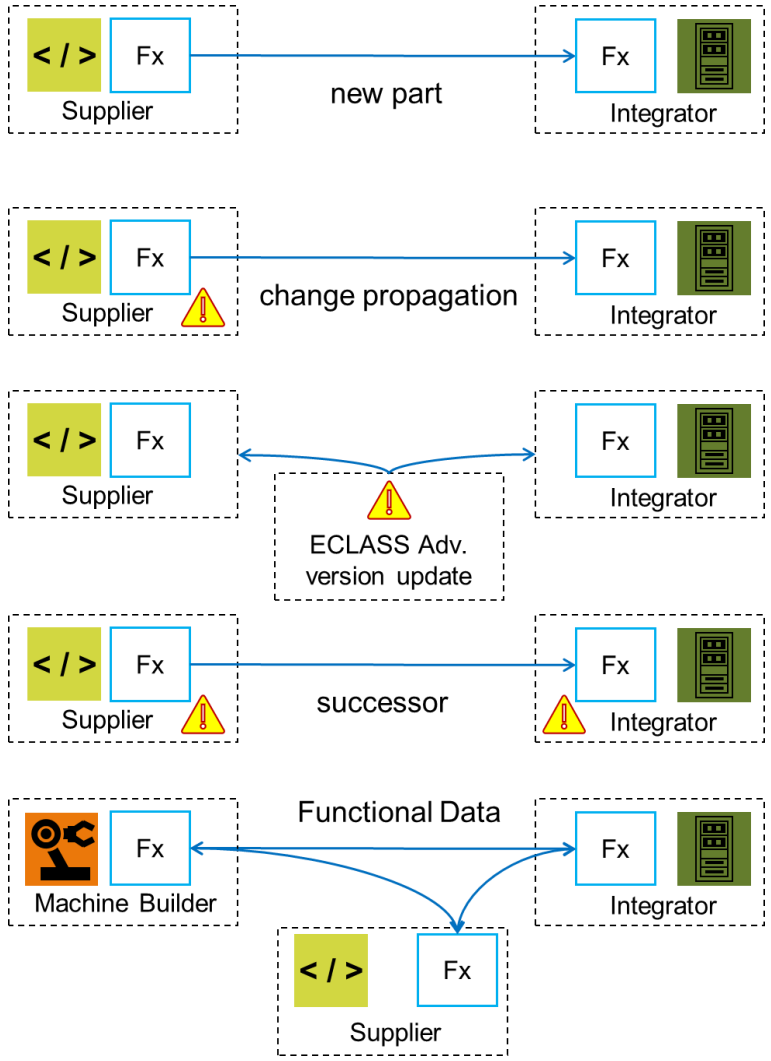
- based on real world user stories in electrical engineering, as-is analysis are made and the necessary target-state is derived
- clear focus on productivity raise by data continuity

What?

- representing the user in an engineering toolchain along different companies and different (engineering) software tools given
- What is needed in the daily life of an electrical engineer and which comfort needs a new solution to be accepted from the market?

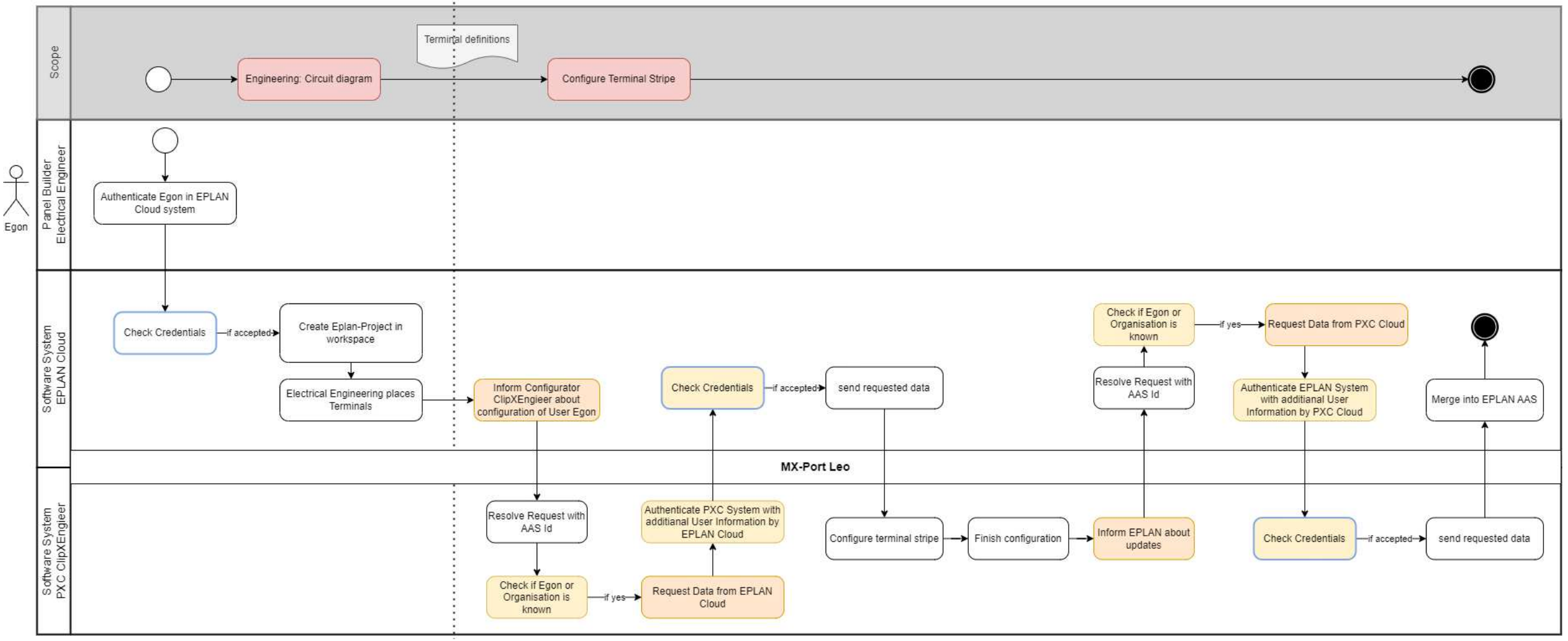
Workstream 2 (ELK)
Our User Stories

1. I have a new part in my project and need technical data.
2. Changes?!? A known component has been changed by supplier, wholesaler or software provider. How am I informed?
3. Semantics, e.g. ECLASS Advanced, is updated. How to handle different versions?
4. A used product will be outdated and replaced by a new one. How do I handle this?
5. I'm part of a supplier network and need to exchange functional data between eCAD systems and/or configuration tools in different legal entities. How to?



Workstream 2 (ELK)

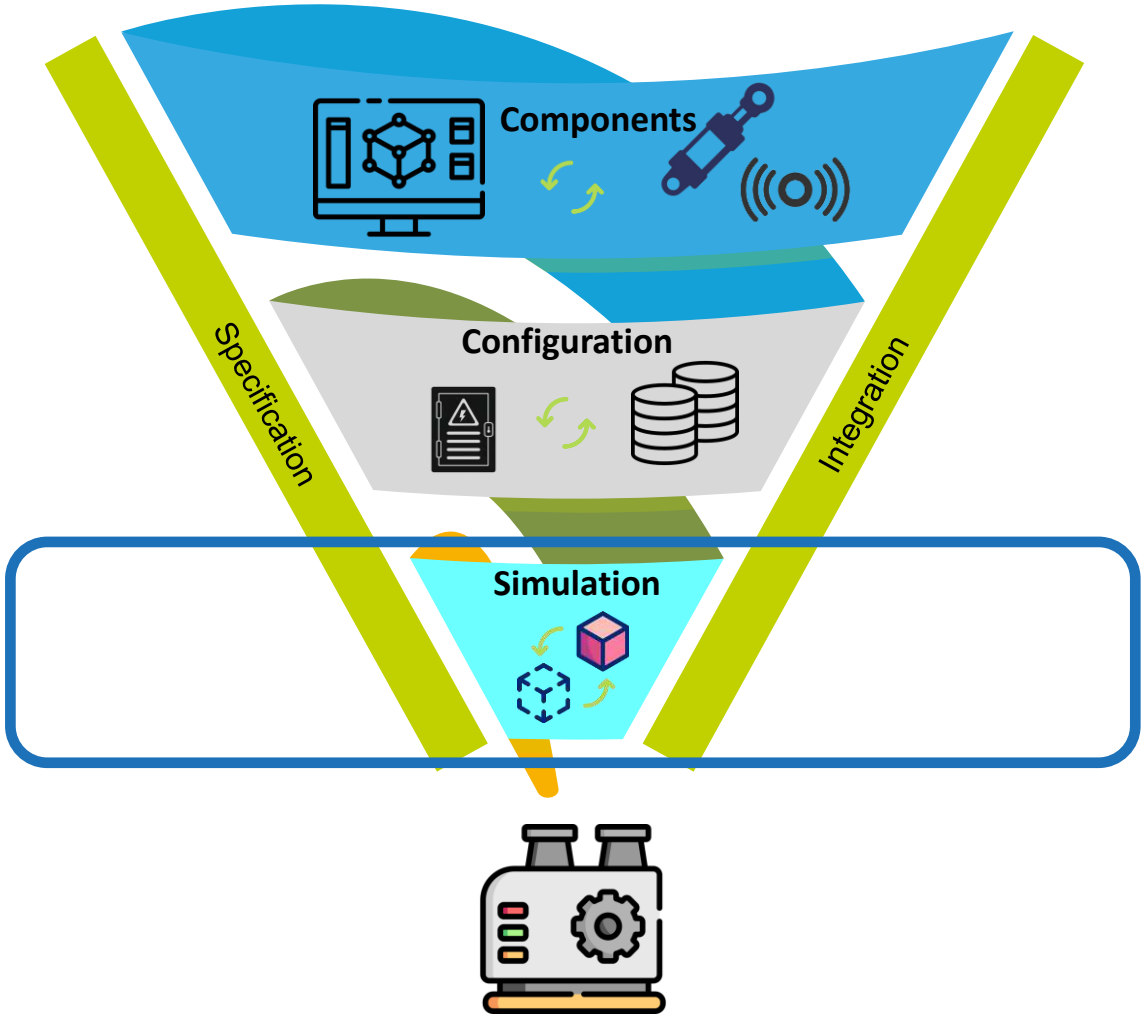
Swimlane Diagram – from Integrator to Supplier via EPLAN using MX-Port LEO



Workstream 3
Virtual Commissioning and Simulation (SIM)

Integrated Toolchains & Collaborative Engineering

Productivity by Engineering Data Continuity



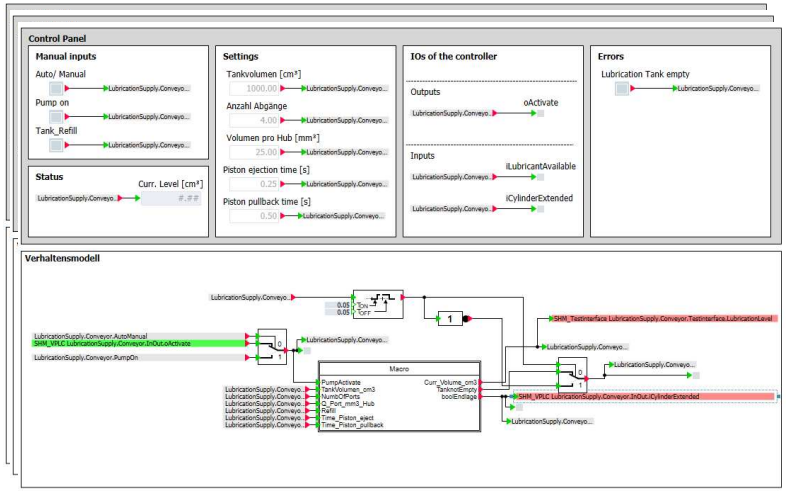
Workstream 3: Virtual Commissioning and Simulation (SIM)

Introduction
Software-in-the-Loop Simulation for Virtual Commissioning

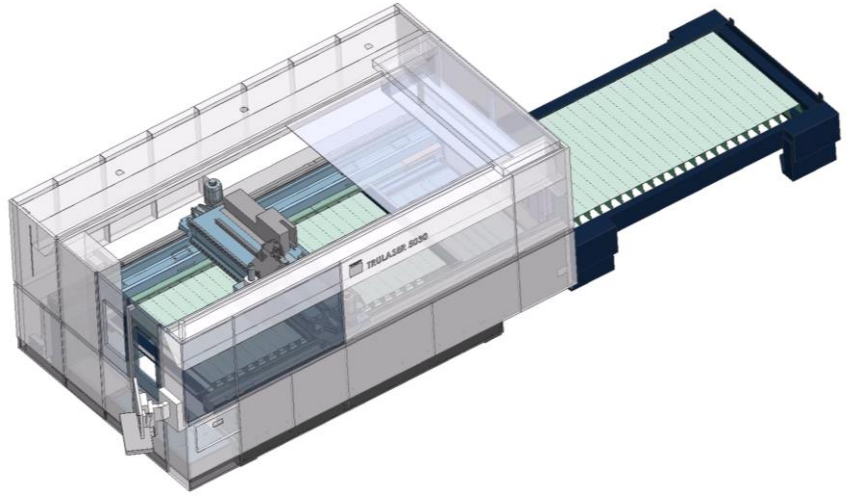
Virtual Control

Simulation Model

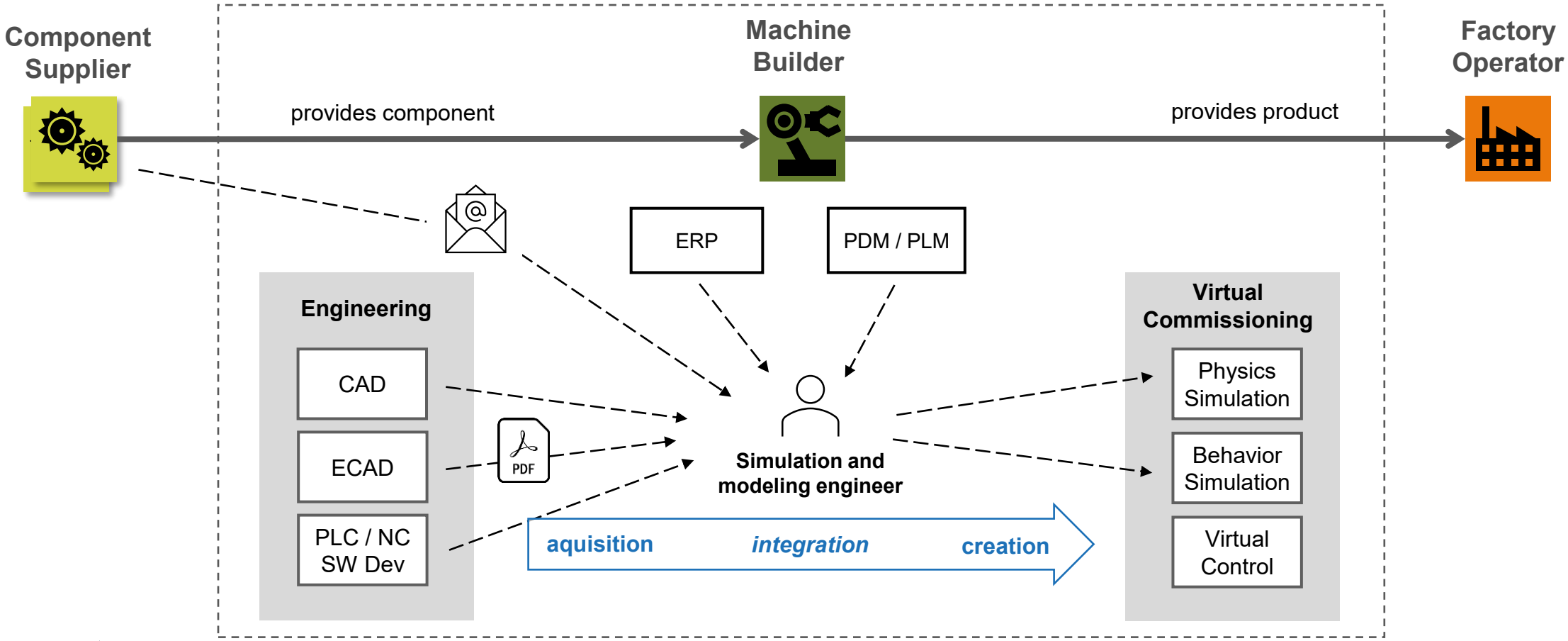
Behavior Simulation Model



Physics Simulation Model

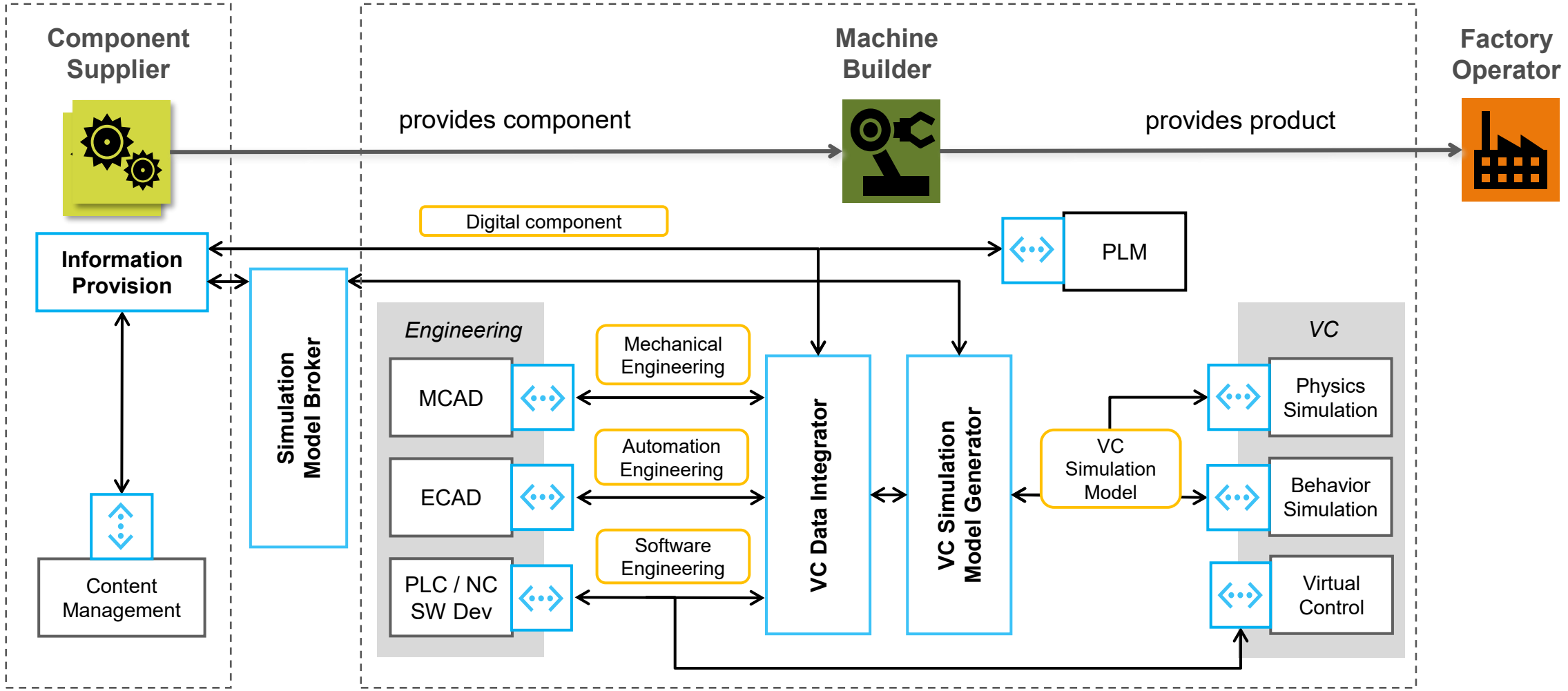


Introduction
Missing interoperability in the engineering toolchain

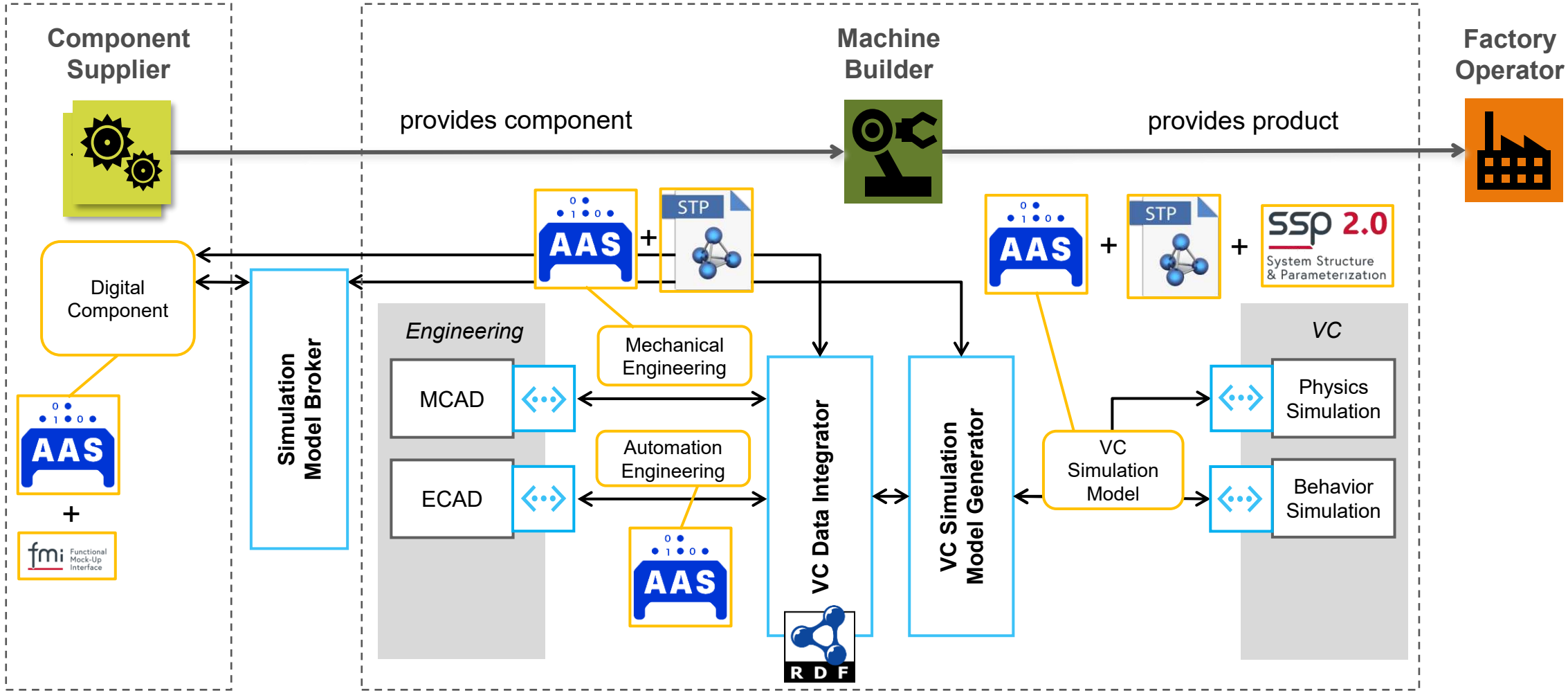


Elaborate effort for simulation model creation limits the potential of virtual commissioning

Concept for behavior simulation model generation
Integrated engineering toolchain



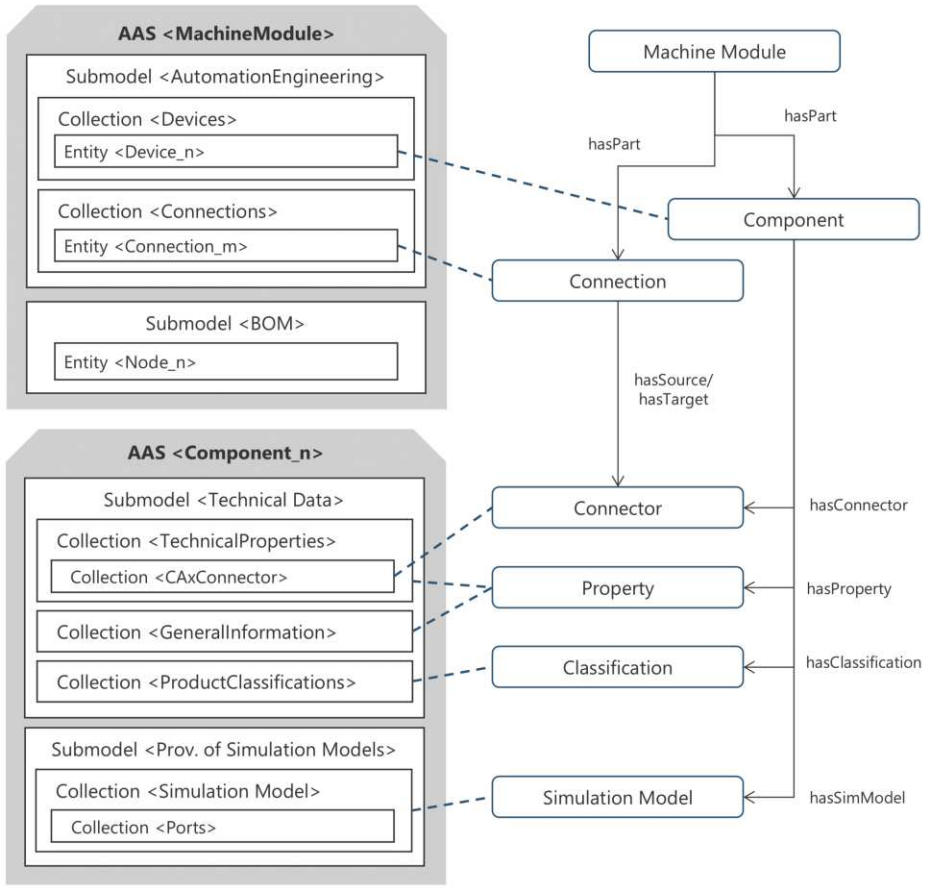
Concept for behavior simulation model generation
Selected technologies, formats and standards



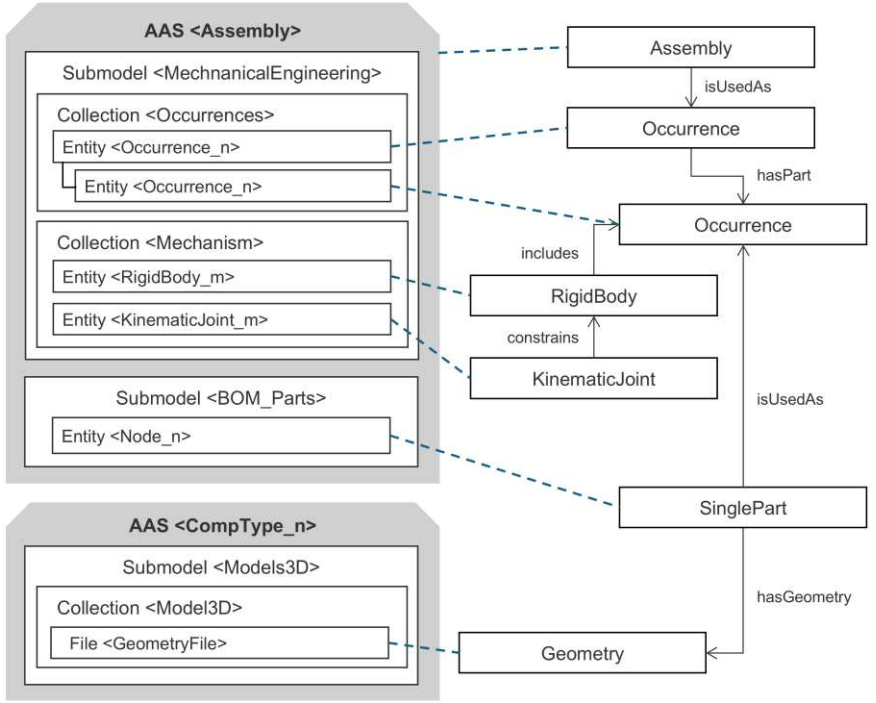
Concept for behavior simulation model generation
Ontology-based integration of mechanical and electrical engineering

FACTORY-X

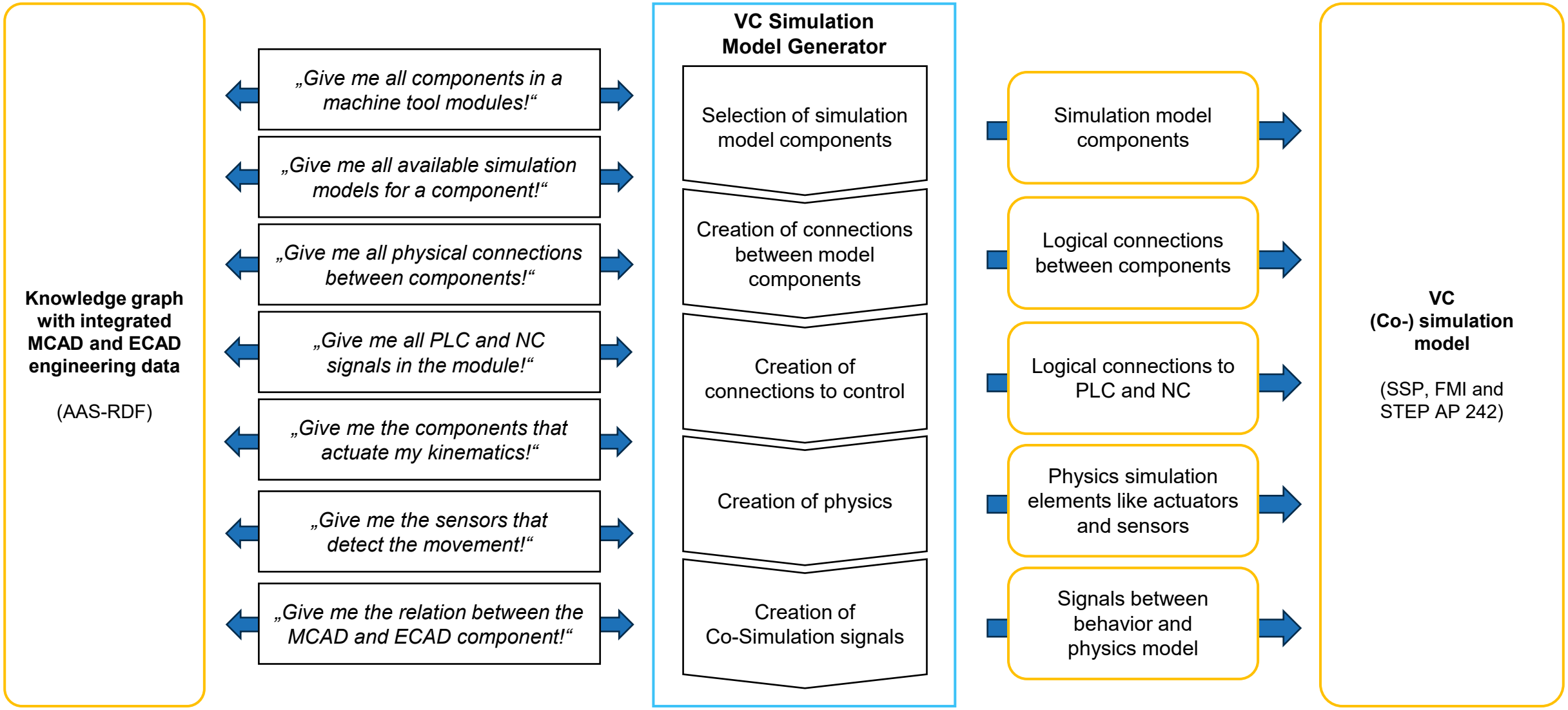
Automation Engineering (ECAD)



Mechanical Engineering (MCAD)



Concept for behavior simulation model generation
Simulation Model Generator



Information Update and Change Service

Information Update and Change Service

Instant Update – Fast Changes!

From cloud to factory shopfloor – updates are instant!

The Challenge

Highly complex intelligent production systems are networked with each other.

- Regular updates across suppliers are important to ensure the factory equipment is up to date and secure.
- Updates currently need to be searched for and retrieved manually from various sources, which takes a lot of time.

The FX-Solution and Offering

Factory-X dataspace with AAS-based MX-Port "Leo" enables seamless sharing of data incl. updates.

- Retrieval of asset (AAS) information and updates (product change notifications) via the MX-Port "Leo"
- Common Device Management System for the management of assets

Information Update and Change Service

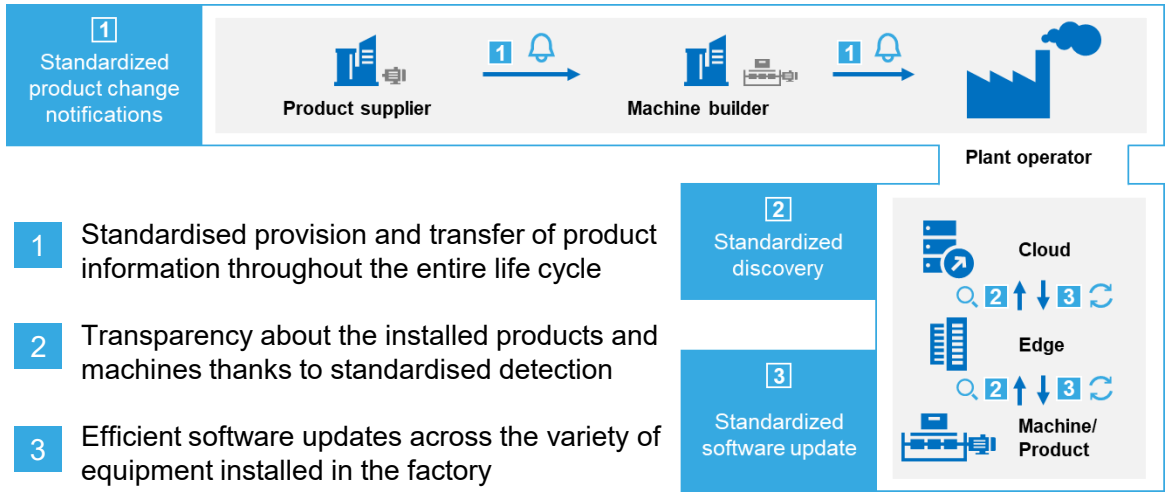
Instant Update – Fast Changes!

FACTORY-X

Customer satisfaction due to efficient, interoperable data exchange for fast updates.

Organizational benefits

- Factory operators and component suppliers can easily access information from each other and about assets in the shopfloor



1. Standardised provision and transfer of product information throughout the entire life cycle
2. Transparency about the installed products and machines thanks to standardised detection
3. Efficient software updates across the variety of equipment installed in the factory

Economic benefits

- cybersecurity in a factory is improved due to standardised and fast updates
- no breaches, no down-time

Technical benefits

- Every actor can rely on the same standardised solution

Information Update and Change Service

Consistent, smart, interoperable: MX-Port "Leo" for AAS-based data exchange

FACTORY-X

Description

The demonstrator shows how the AAS-based MX-port "Leo" can be used to realize **continuity and interoperability in data exchange** in the areas of Smart Products, Smart Engineering, Smart Production, Smart Operation, Smart Services, and Smart End of Life

- Experience the demonstrator virtually: Factory-X Demonstrator

Benefit

Data exchange along the entire product life cycle improves transparency, efficiency, and value for products and services.

- AAS data can be retrieved through scan of QR-Codes on devices
- Videos of software demonstrations showcase several use cases in Factory-X

Information Update and Change Service

Software Demonstrator

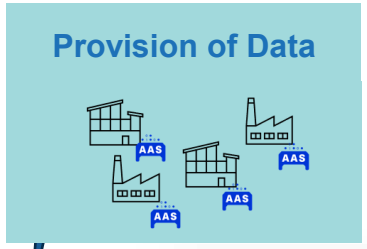
FACTORY-X

Description

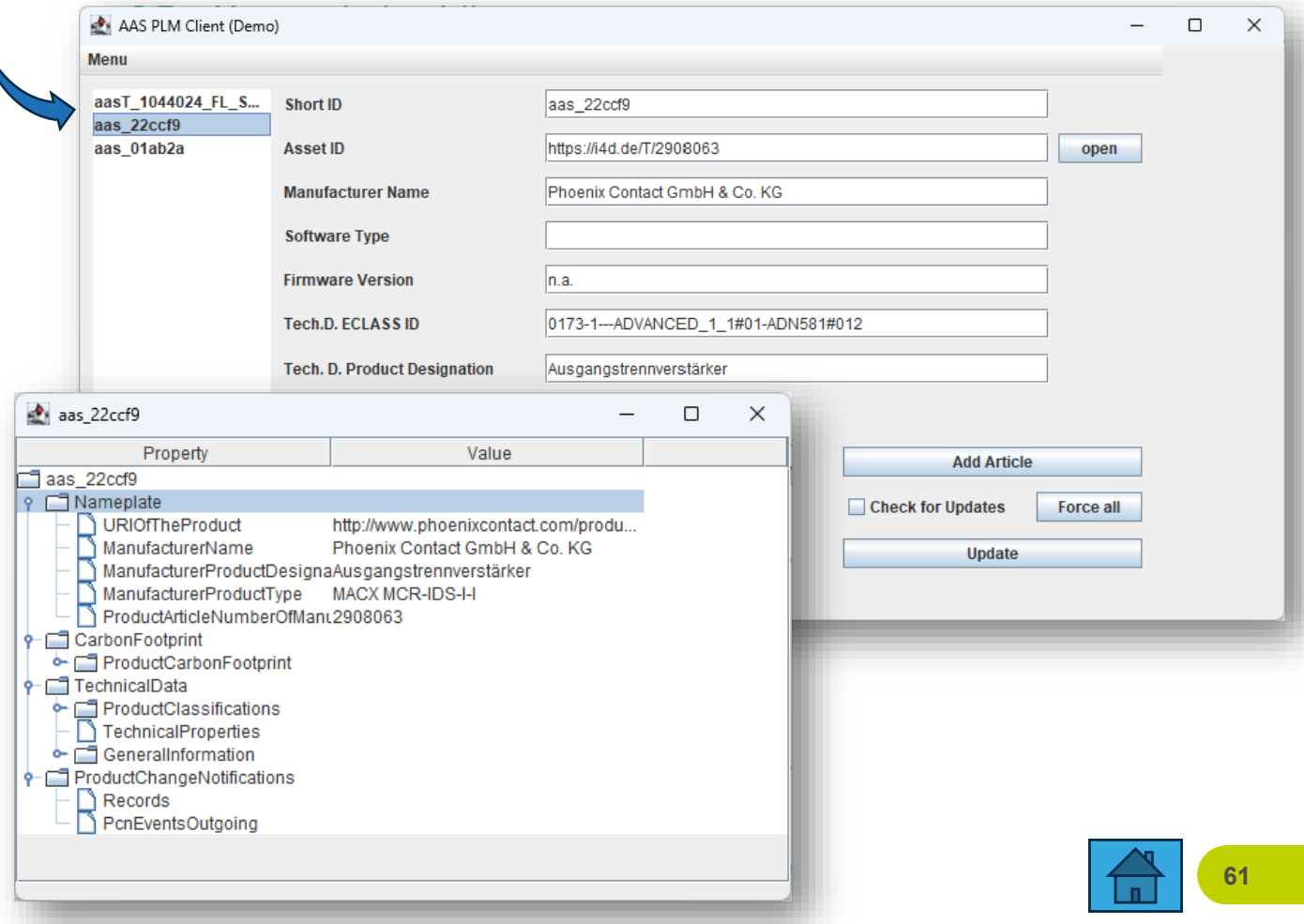
The demonstrator represents a Product Lifecycle Management (PLM) system which can import product information based on Asset Administration Shells (AAS)

Benefit

The automated notification and provision of product information between manufacturers and users (PLM systems), which makes it possible to reliably manage changes in the life cycle. Examples include notifications about product changes and software updates.



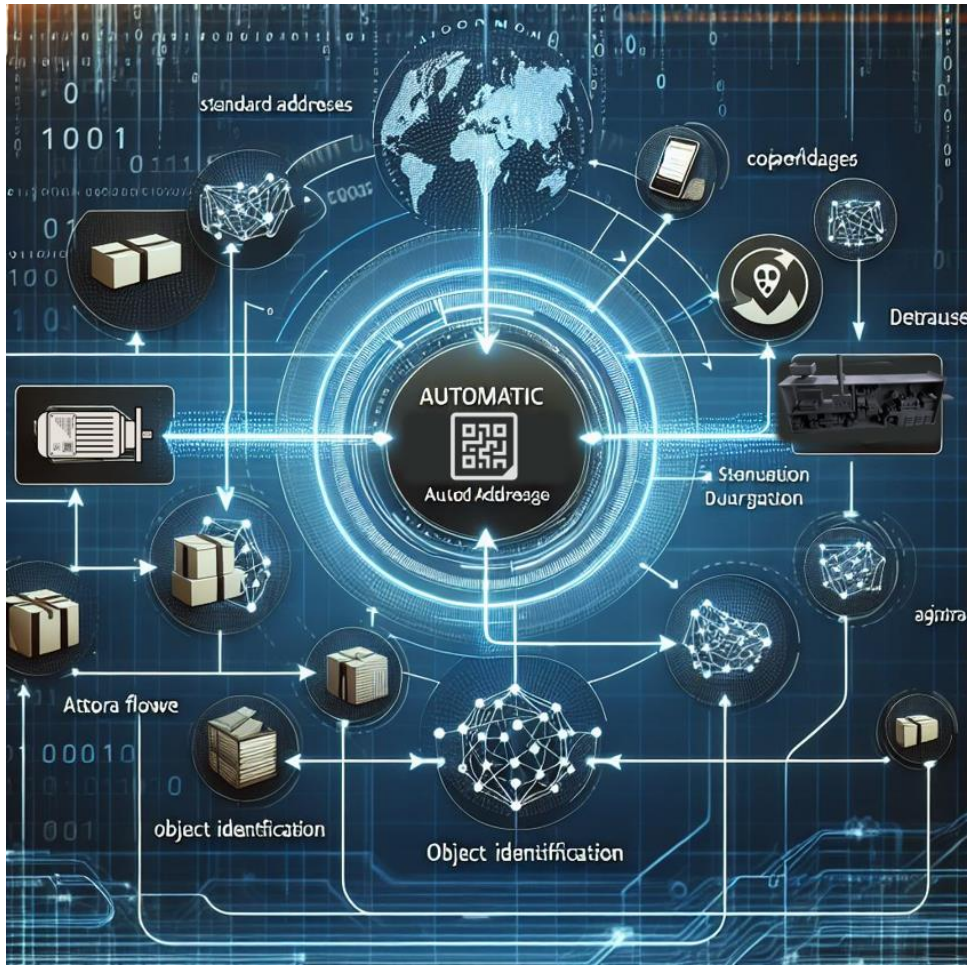
AAS PLM Client (Demonstrator)



Collaborative Information Logistics

Collaborative Information Logistics

Standardize Smart, Exchange Fast!



Information exchange across business partners and applications: Standardize Smart, Exchange Fast!

The Challenge

When information about assets is exchanged between business partners, there are high efforts required to add the information to applications and make them available to end users.

The FX-Solution and Offering

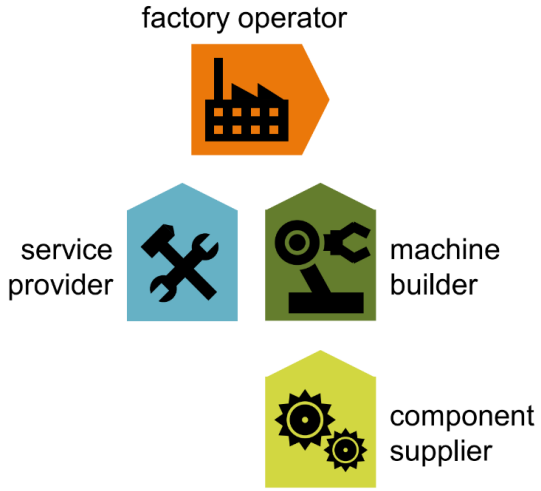
For specific user journeys like handover documentation, inspection reports, and IT/OT there are processes described, technologies selected and validated in demonstrators. Using the MX-Port Leo we show how information can be transferred standardized and automated.

Collaborative Information Logistics

Standardize Smart, Exchange Fast!

FACTORY-X

Information exchange about assets across partners and applications without manual efforts



Organizational benefits

- Standard use cases describe processes and data models which can be implemented in organizations
- Same understanding about process and data models across organizations

Economic benefits

- Reduced manual efforts for information transfer
- Reduced search times
- Better information quality

Technical benefits

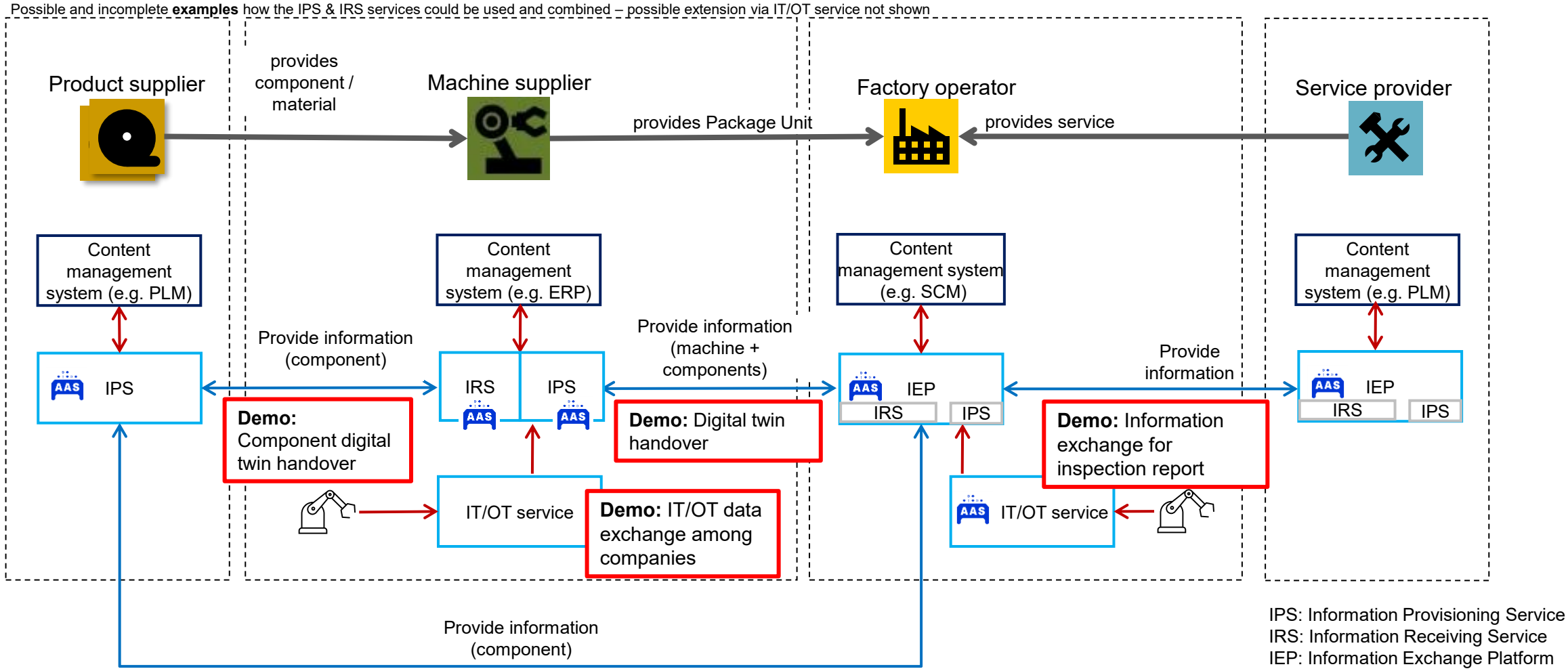
- Software using standards can be easily implemented and used.

Collaborative Information Logistics

Standardize Smart, Exchange Fast!

FACTORY-X

Usage View



Collaborative Information Logistics

Digital twin handover - paperless documentation

FACTORY-X

Description

The factory operator is ordering an automation system at a machine builder. After manufacturing he automatically receives a simple interoperable digital twin. The digital twin can be used in asset management processes.

Benefit

Simplicity, standardization and scalability is important.

- Automate the process of information handover for ordered assets.
- Reduced manual efforts.
- Reduced search times
- Better information quality

For Details, please visit the Demonstrator!

Collaborative Information Logistics
Inspection Report

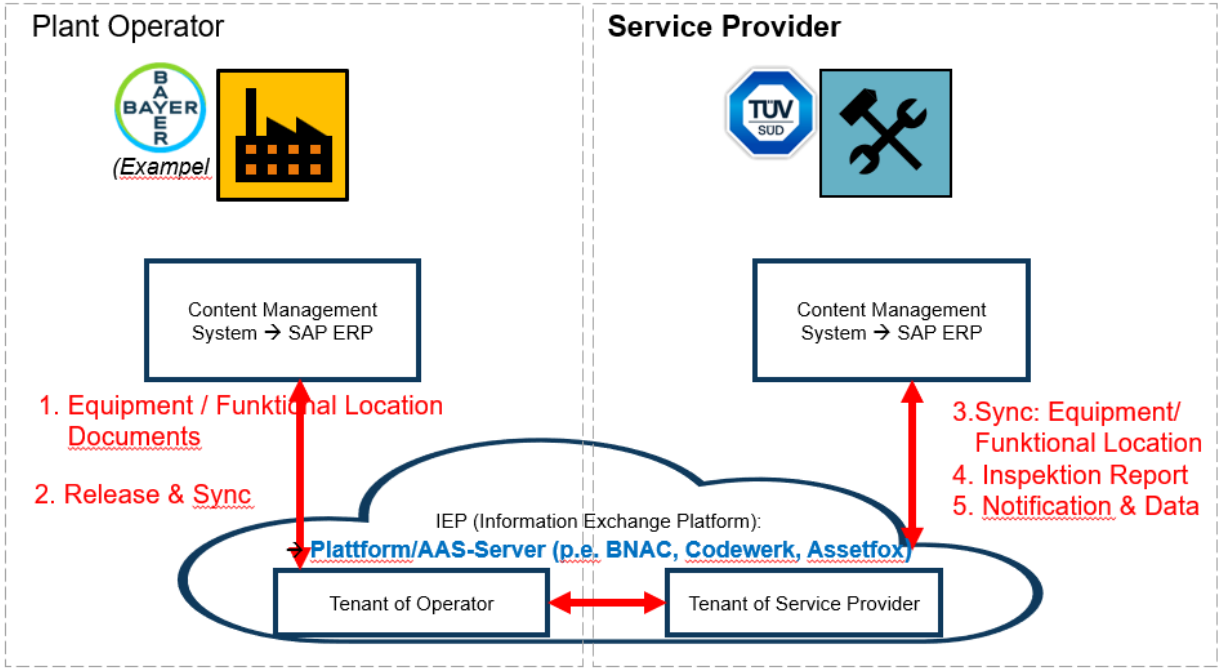
FACTORY-X

Description

The demonstrator shows the digital information exchange between the plant operator and a service provider (e.g. TÜV) across the entire inspection process. Master data and inspection documents are prepared by the operator, enriched during the inspection, and returned as a structured inspection report. All information is clearly assigned to the technical asset and available in a standardized, interoperable way.

Benefit

The operator benefits most: inspections can be prepared and tracked more efficiently, while coordination effort and rework with TÜV are reduced. Structured data exchange saves time and resources, increases transparency on findings and deadlines, and improves safety through clear asset identification and up-to-date limit values. Standardized digital data strengthens compliance and reduces risk.



Condition Monitoring led Services

Condition Monitoring Led Services

Enable new digital services to increase equipment availability cost-efficiently

Image generated by ideogram.ai

The Challenge

Technical, economic, and organizational barriers associated with cross-stakeholder data sharing have limited the widespread adoption of condition monitoring as a foundation for a new generation of proactive, automated, and remotely delivered services.

The FX-Solution and Offering

- Simplified and trustworthy data sharing through standardized mechanisms and models
- Industry-aligned integration increases trust in implementation and fosters adoption
- Basis for data-driven, proactive, and automated services

Condition Monitoring Led Services

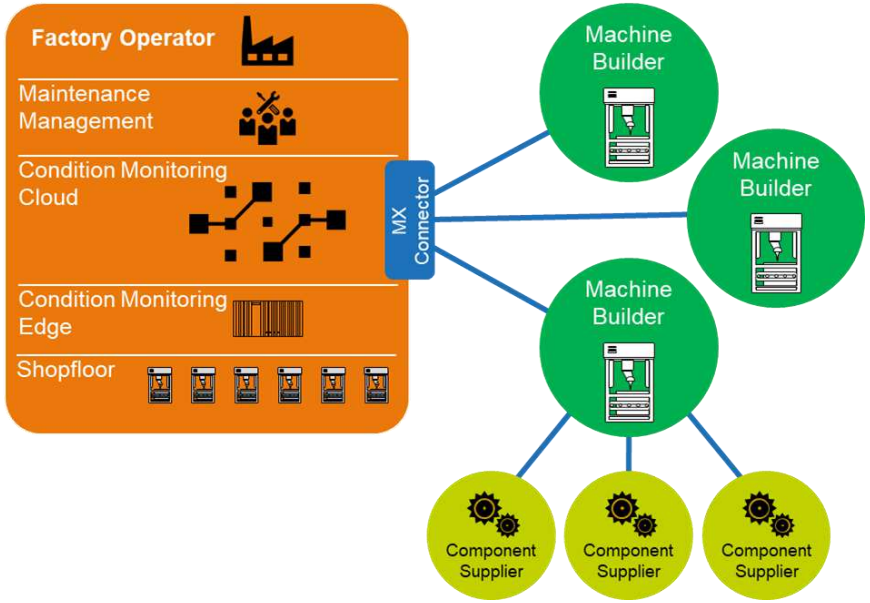
Enable new digital services to increase equipment availability cost-efficiently

FACTORY-X

Industry-compliant data sharing mechanisms and standards

Organizational benefits

- Improved cross-company collaboration through standardized data governance.
- Faster service workflows by replacing escalation chains with parallel, data-driven support.



Economic benefits

- Lower maintenance costs through early detection and reduced downtime.
- New revenue streams from scalable digital and remote services.

Technical benefits

- Standardized data exchange across heterogeneous equipment.
- More accurate diagnostics via shared real-time condition data.

Condition Monitoring Led Services
Demonstrator Ditzingen

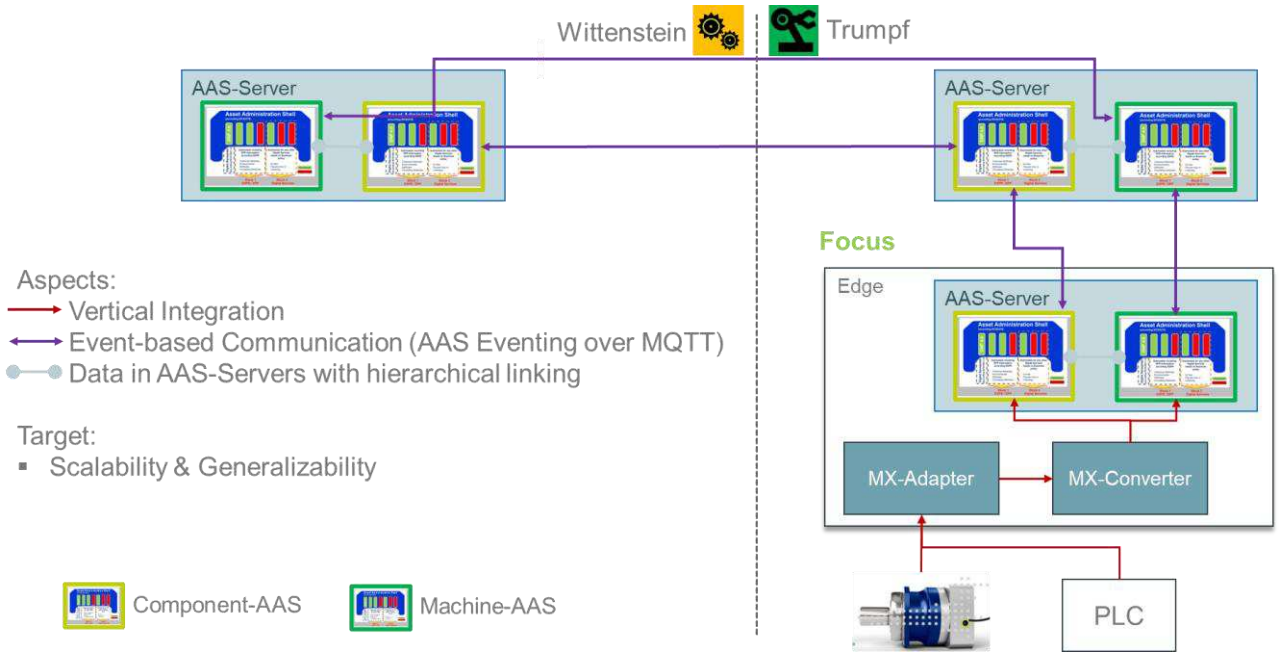
FACTORY-X

Description

This demonstrator evaluates key AAS submodels (Digital Nameplate, Contact Info, BOM, Time Series) and cloud-to-cloud communication between component manufacturers and machine builders via the MX-Port. It also tests asynchronous data exchange using MQTT and validates the setup with TP4's Hercules artifacts.

Benefit

The demonstrator shows how standardized AAS-based and asynchronous cloud communication enables seamless, interoperable data exchange. It reduces integration effort, improves cross-company collaboration, and supports scalable, data-driven services.



Condition Monitoring Led Services
Demonstrator Bad Neustadt

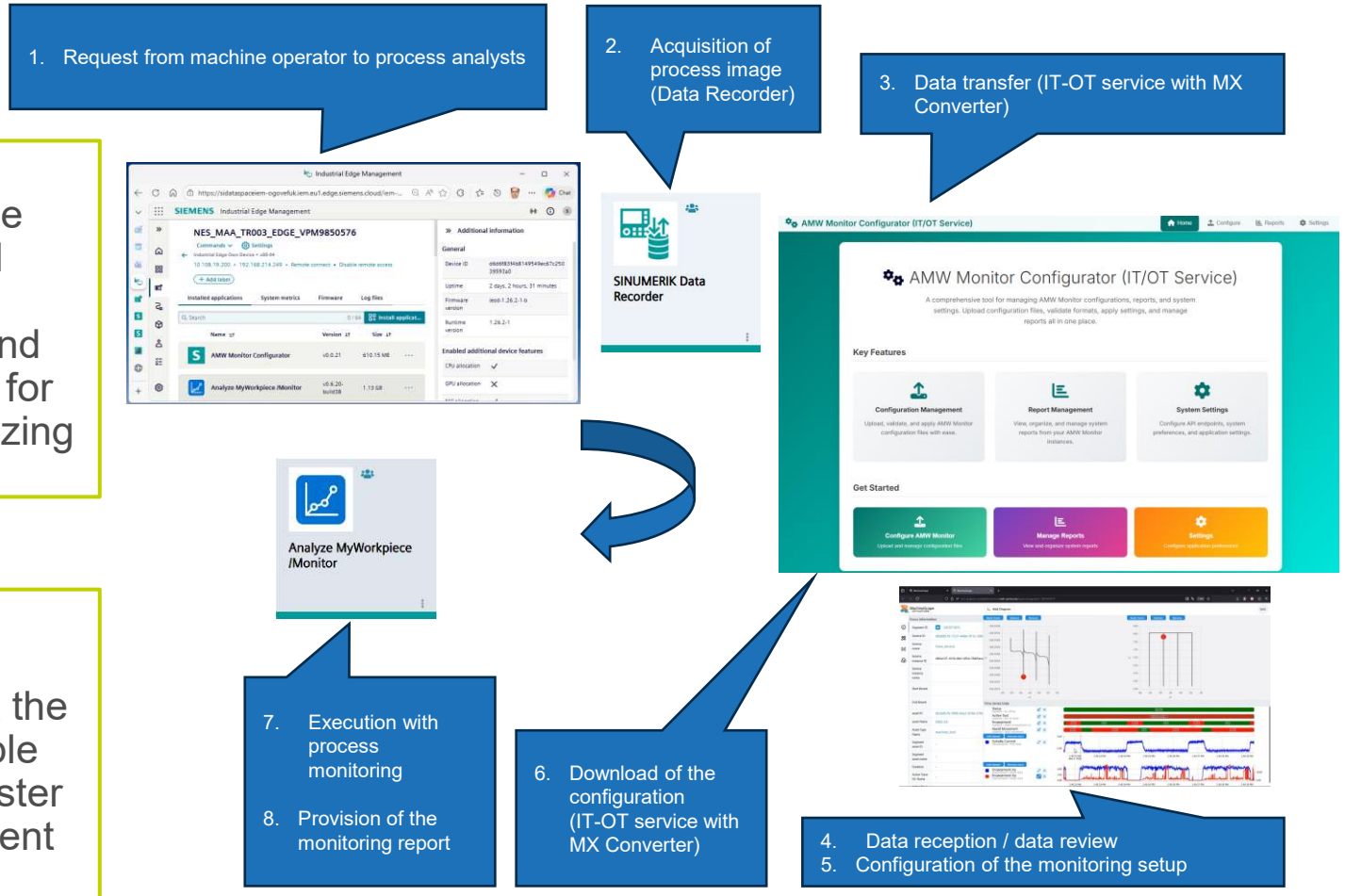
FACTORY-X

Description

This demonstrator evaluates the Asset Administration Shell as a central data hub for the factory operator, with a focus on monitoring and analyzing machining process data via an AAS server. It was developed together with TP-2.3 and validates the practical use of the MX-Port “Leo” for configuring process-monitoring apps and optimizing machining processes.

Benefit

The setup demonstrates how AAS-based integration simplifies process-monitoring and enables seamless data exchange. It shows that the MX-Port “Leo” supports reliable and interoperable communication for improved diagnostics and faster system integration. A key benefit is the transparent and fully traceable data-exchange process.



Use Case Details

Condition Monitoring Led Services
Demonstrator Rosenheim

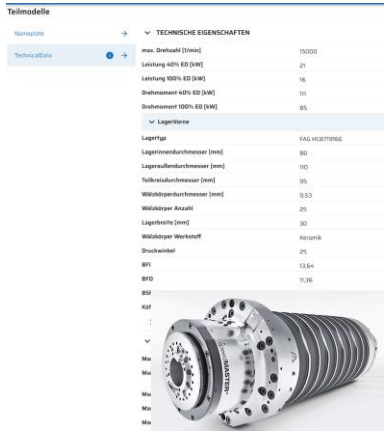
FACTORY-X

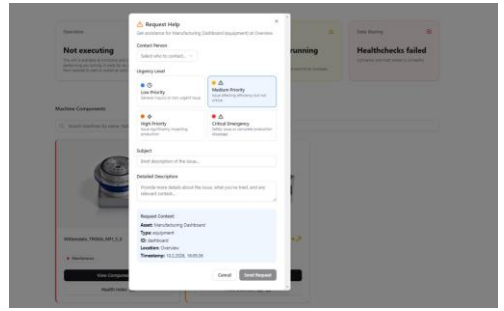
Description

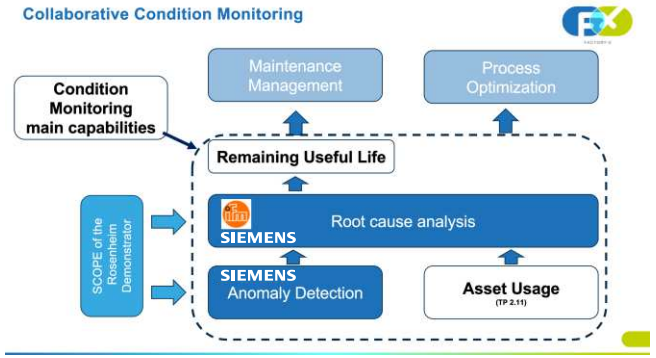
This demonstrator validates end-to-end data exchange: data is captured via an adapter, passed through PLC and gateway, and transferred to the operator's cloud. There, it is processed using predictive maintenance algorithms. All required components were installed and put into operation.

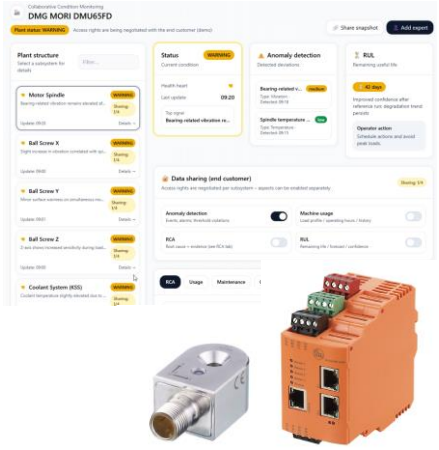
Benefit

The demonstrator proves seamless E2E data flow from machine to cloud. It enables automated analysis for predictive maintenance, improving reliability and providing a validated reference architecture for future Factory-X implementations.









Condition Monitoring Led Services

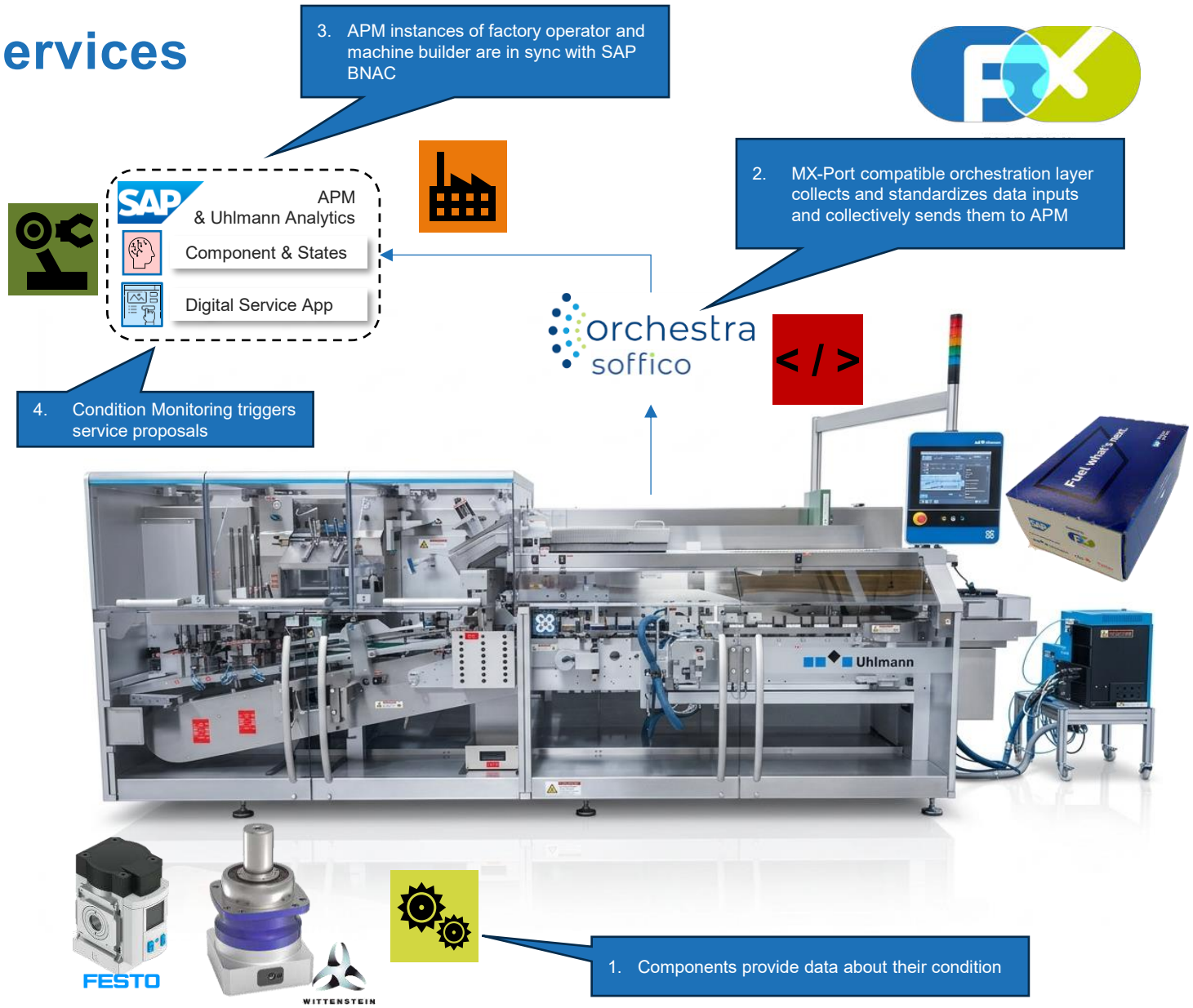
Demonstrator “PacXplorer”

Description

This demonstrator shows cross-company interoperability in a CMLS process. A packaging machine is integrated via OPC UA to evaluate machine and gearbox condition data. When limits are exceeded, an automated maintenance workflow is triggered and digitally documented.

Benefit

The demonstrator proves seamless cross-company workflows: automated fault detection, automatic technician dispatching, and fully digital maintenance documentation. It highlights how Factory-X enables efficient, end-to-end service processes across all stakeholders.



See this demonstrator live at SAP booth F08 H15!

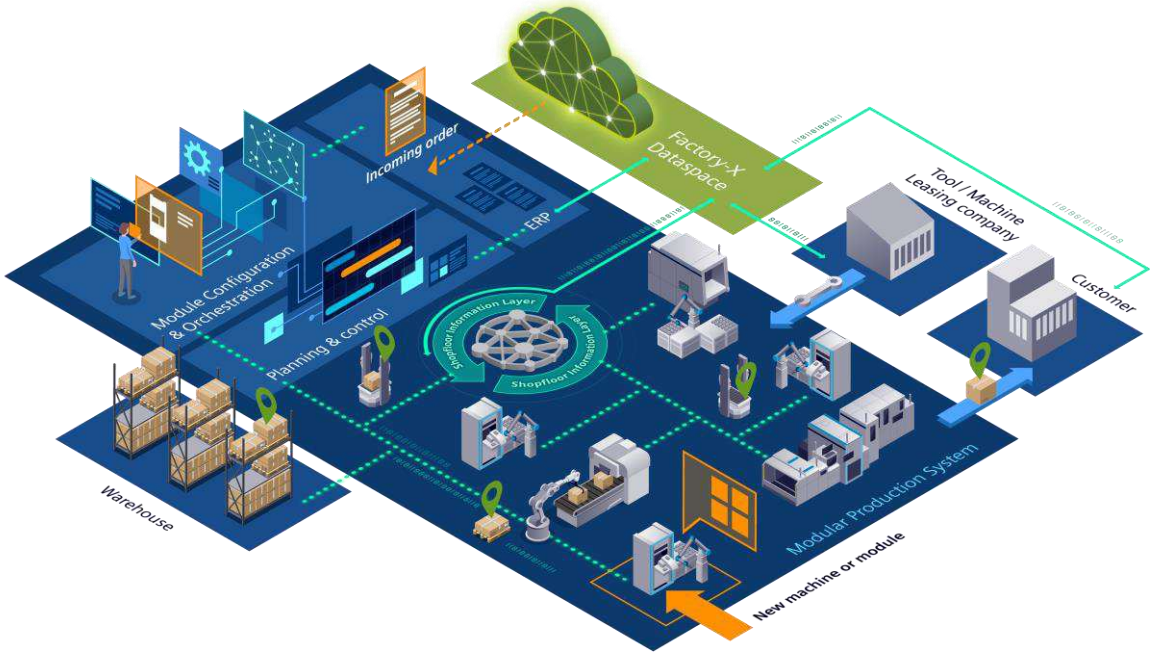
FACTORY-X

Modular Production

Modular Production

Build Smart. Adapt Fast!

FACTORY-X



The Challenge

- High costs for data integration and IT/OT convergence limit production flexibility
- Missing flexibility during re-scheduling in the case of unforeseen events and no insights of the implications
- Commissioning, maintenance and change-over are time-consuming and require a high level of technical expertise

The FX-Solution and Offering

- Modular solutions at machine level with semantic self-description and interfaces to the shopfloor
- Analysis of the current machine configuration and proposals for optimized reconfiguration
- Modular and adaptive production control to ensure an optimized orchestration of process steps and (re-)scheduling based on feedback from the shopfloor

Modular Production

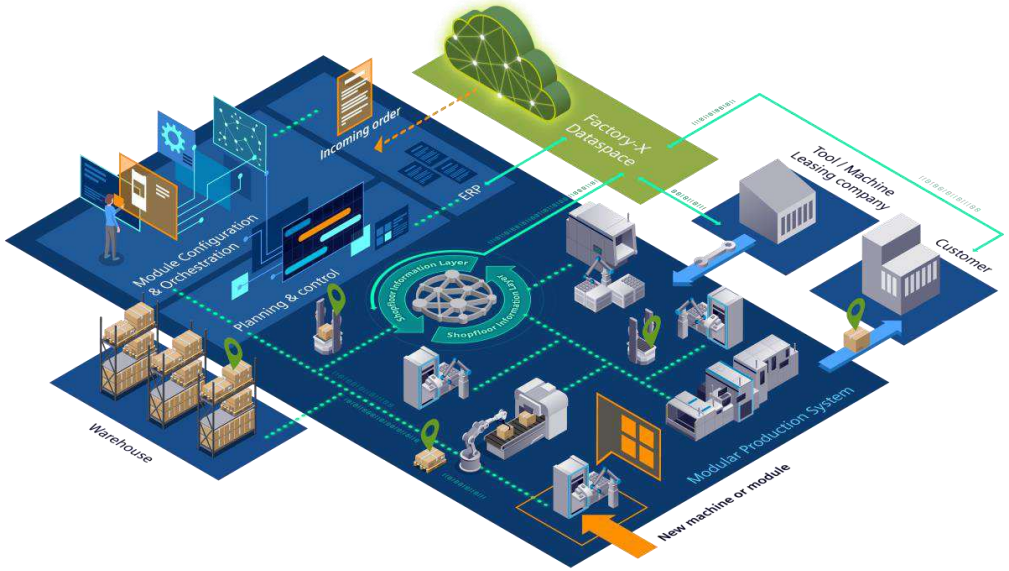
Build Smart. Adapt Fast!

FACTORY-X

Increase production capacity and flexibility

Organizational benefits

- Reduce machine setup time
- Use the existing system more flexibly
- Preliminary stage for cross-company demand and capacity planning
- Standardized capability descriptions enable interoperability



Economic benefits

- Reduced machine setup time
- Use the existing system more flexibly
- Fast response to market demands (through adaptive production planning)
- Standardized capability descriptions enable interoperability

Technical benefits

- Standardized interfaces for orders and resources
- Semantic mapping, automated integration process
- Fast response to market demands (through adaptive production planning)

Modular Production

Cross-company data-exchange of shopfloor data via MX-Port Leo

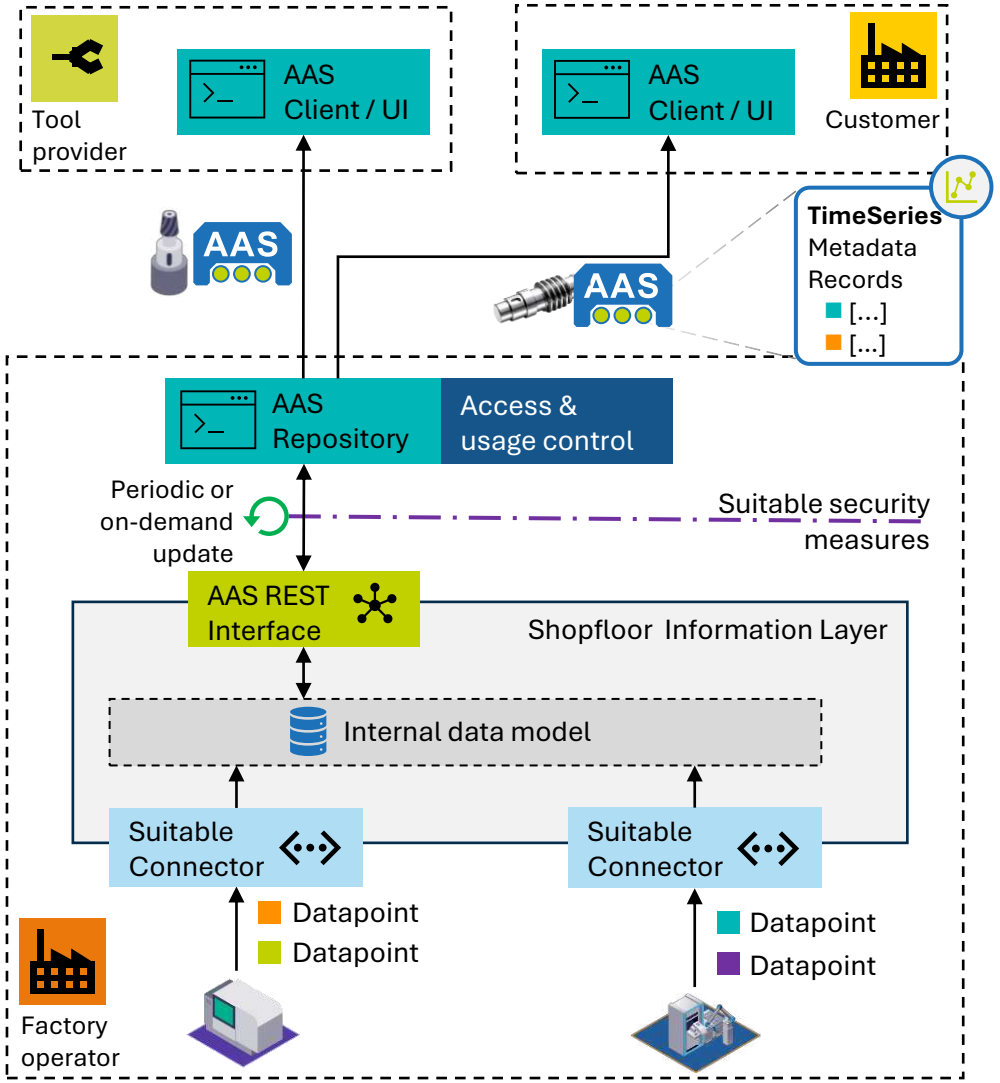
FACTORY-X

Description

- Share machine and process information as part of product or tool-specific AAS via MX-Dataspace
- Record relevant time-series data, attach it to selected AAS and transfer the information from the shopfloor to external AAS clients
- Limit access based on the need-to-know principle and define user access for individual AAS and submodels

Benefit

- Share relevant shopfloor data in a sovereign and interoperable manner
- Enable data provision for future applications of the Digital Product Passport (DPP)
- Cross-company data exchange based on common standards and protocols via MX-Dataspace



Modular Production

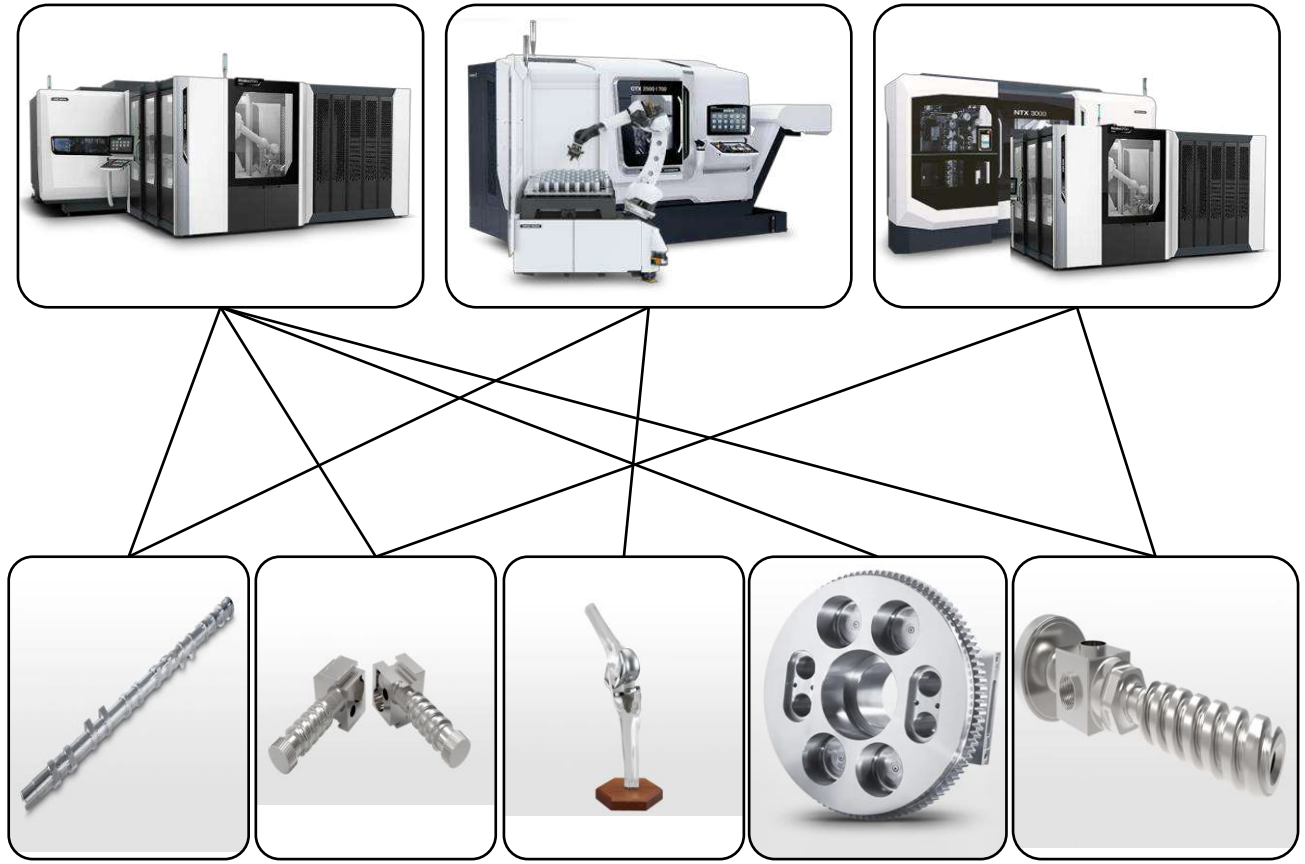
Interaction Scenario:
Production order scheduling with automated changeover processes

FACTORY-X

Description

Modular production of various products on flexible manufacturing systems

- Assignment based on system **capabilities**
- **Scheduling** of different production orders
- Modular setup by **changeover assistant**



Benefit

- **Automated** production order scheduling
- **Optimized utilization** of manufacturing systems
- **Fast and safe** changeover processes through operator assistance

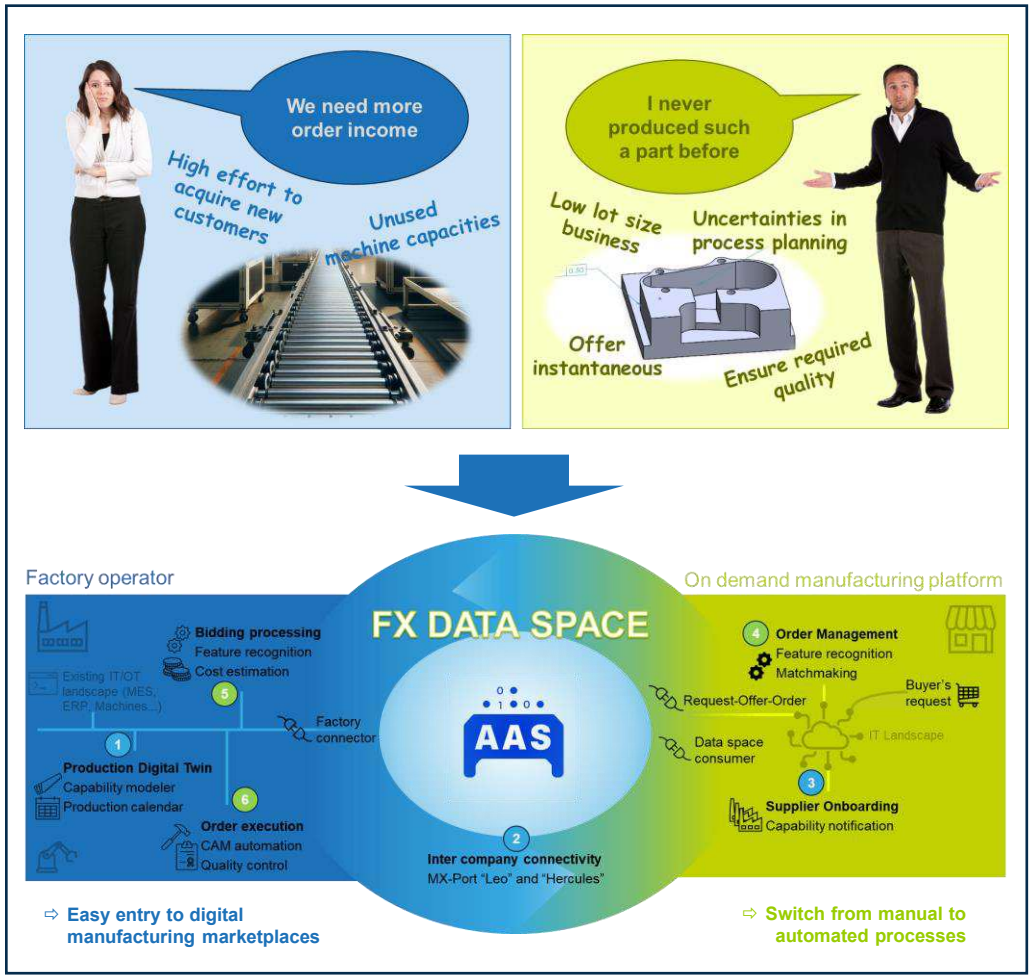
FACTORY-X

Manufacturing as a Service – On Demand Manufacturing

Manufacturing as a Service

Shared skills – matching orders

FACTORY-X



The Challenge

Handelsblatt INDUSTRIE GIPFEL 2023

Veröffentlicht am 08. Dezember 2023

Mit der smarten Fabrik in die Zukunft

Flexibilität und Resilienz sind das A und O in Zeiten des Umbruchs. Industrieunternehmen müssen daher konsequent auf digitale Technologien und Automatisierung in ihren Fertigungen setzen, um nachhaltig Wachstum und Arbeitsplätze auch in Deutschland sichern zu können.

Gastbeitrag von Philip Harting, Vorstandsvorsitzender, HARTING Technologiegruppe

Handelsblatt, 08.12.2024

Handelsblatt

Transformation

Digitaler Mittelstand – wie KMUs ihr Geschäft einfach digitalisieren

Handelsblatt, 11.12.2024

Handelsblatt

DIGITALE TRANSFORMATION MITTELSTAND

Warum die digitale Transformation im Mittelstand heute wichtiger ist denn je

Handelsblatt, 05.06.2025

The FX-Solution and Offering

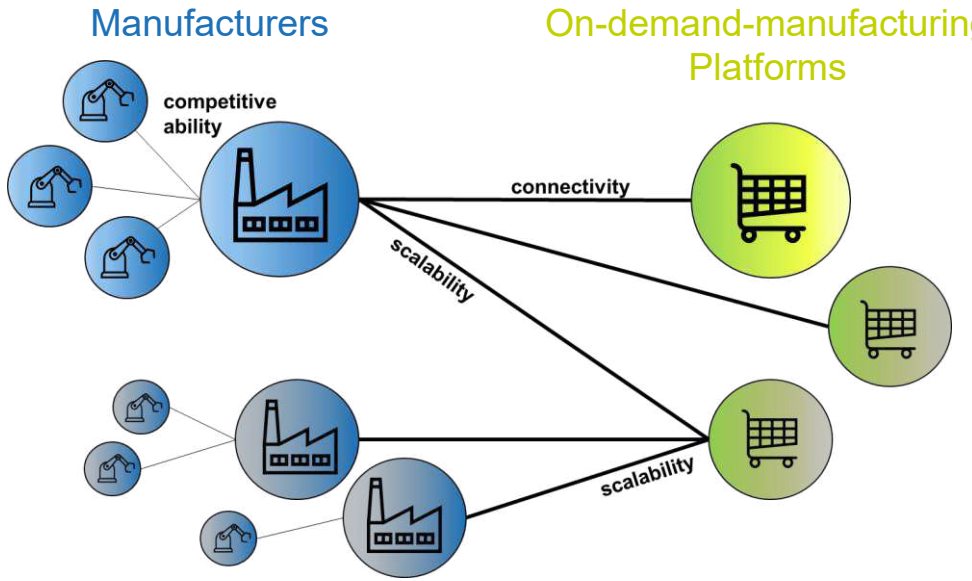
Digital transformation for on-demand manufacturing

- Easy entry to digital manufacturing marketplaces
  - ➢ From heterogeneous to homogenous connectivity
- Switch form manual to automated processes
  - ➢ With semantic data models

Manufacturing as a Service

Shared skills – matching orders

digitally fast



Organizational benefits

- Scalable visibility on digital manufacturing marketplaces
- Competitive also for low-lot-size business

Economic benefits

- Additional order income
- Reduced effort in bidding, planning and controlling processes

Technical benefits

- Automation of acquisition
- Automation of order execution

Manufacturing as a Service
Supplier Capability Notification

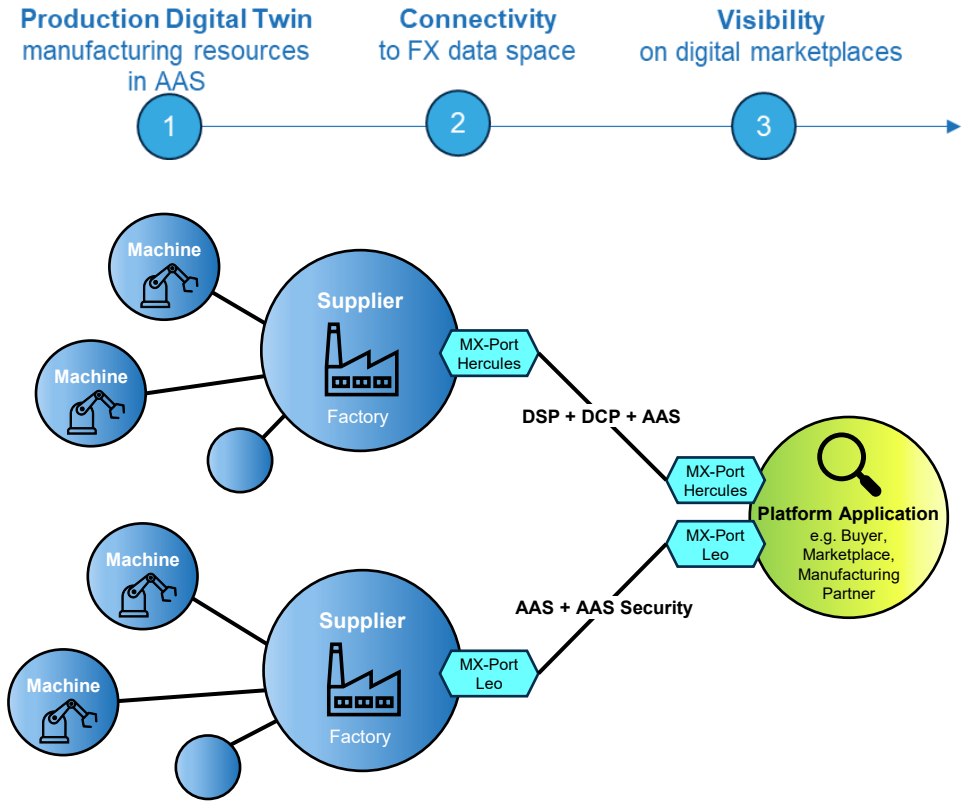
FACTORY-X

Description

Manufacturers provide their manufacturing capabilities

- Information needs to be captured and structured
- Information needs to be accessible and processible

⇨ **Easy entry to digital manufacturing marketplaces**



Benefit

Manufacturers are visible on digital manufacturing marketplaces

- Only one-time effort to provide harmonized data
- Multiple connectivity to different platforms

Manufacturing as a Service
Request-Offer-Order and Quality Control

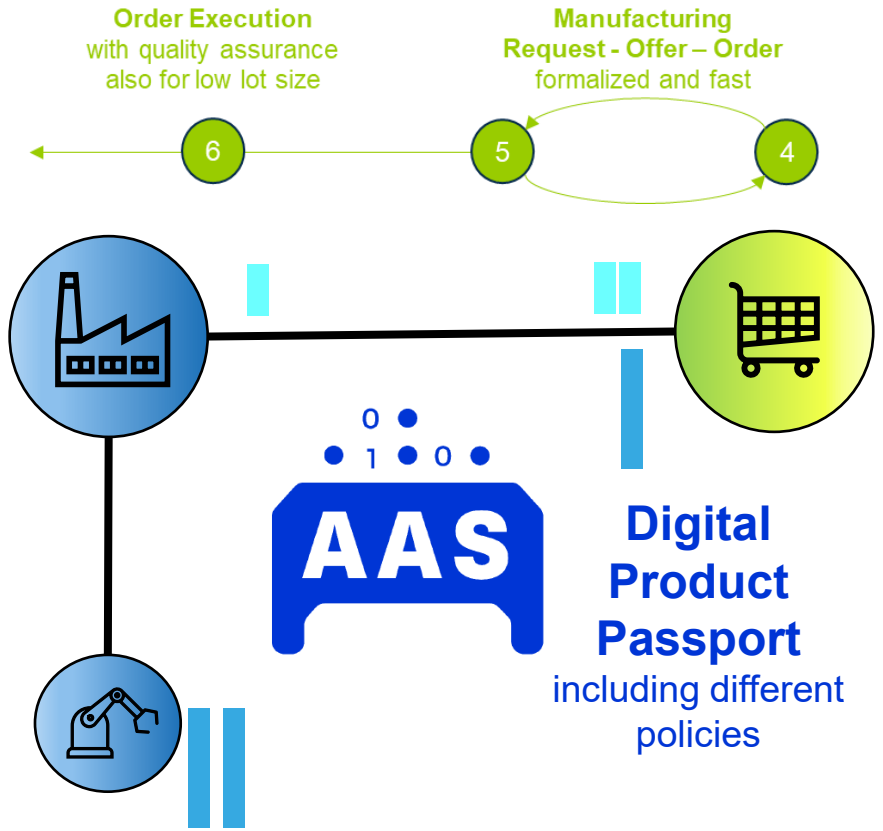
FACTORY-X

Description

Find the right manufacturer for high quality delivery

- Formalized request, offer and order
- Automated processes to support search, bidding, and quality control

⇨ **Switch from manual to automated processes**



Benefit

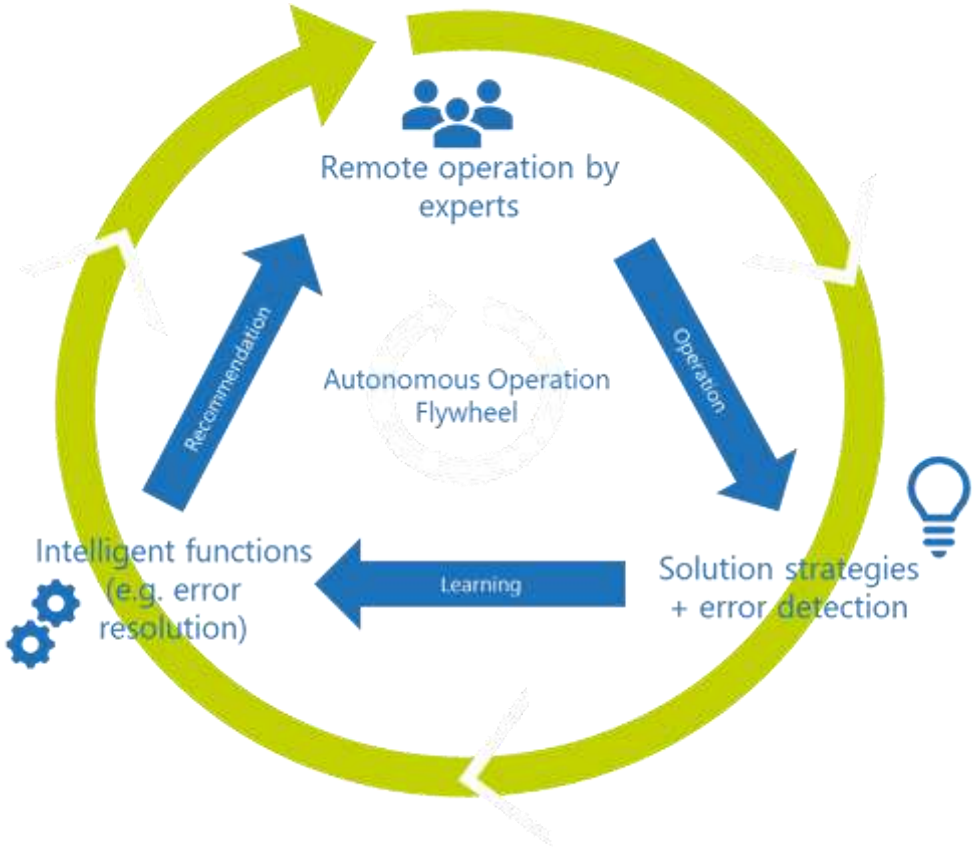
Being competitive on volatile markets

- Fast in quoting
- Competitive in execution

Autonomous Operation as a Service

Autonomous Operation as a Service - AOaaS

Remote Shopfloor automated – Service improved!



The Challenge

Recruiting qualified machine operators is becoming increasingly difficult. At the same time, machine owners are faced with the challenge of increasing machine productivity despite order fluctuations, while at the same time minimizing the use of resources.

The FX-Solution and Offering

- Provide a remote monitoring and operations platform that allows manufacturers to maintain high productivity and efficiency without relying on on-site specialists.
- Autonomous Manufacturing: Despite a shortage of skilled workers, you can also manufacture productively at the highest level.
- Productive unmanned shift: Reduce downtime processing time by a factor of five – for maximum efficiency during the unmanned shift

Summary and Benefits

Autonomous operation

Summary

- Urgent need for increased transparency and optimization of energy demand in manufacturing
- Data-driven solutions will support transformation towards autonomous production as well as performance based business models
- Use-case „Autonomous Operation as a Service“ in Factory-X provides solutions for seamless acquisition and usage of multiple data sources, enabling remote operations and adaptive control of machine tools

Your Benefits

- Solution for **interoperable remote operations** of machine tools
- Innovative approach to remotely control machine tools via Standards
- Despite a shortage of skilled workers, you can also manufacture productively at the highest level
- **Enable productive unmanned shift**: Reduce downtime processing time by a factor of five – for maximum efficiency during the unmanned shift

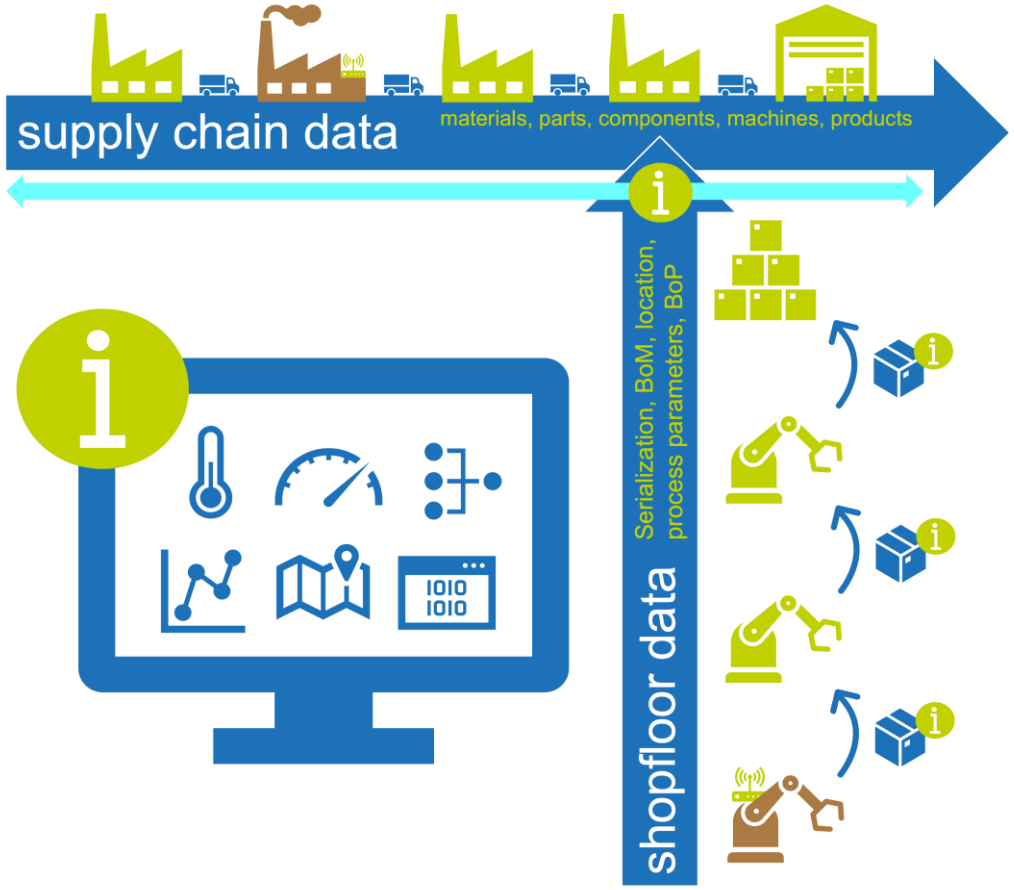
From Downtime to Uptime – Remotely and Intelligently

FACTORY-X

Traceability

Use Case TP2.8: Traceability

Trace Today, Trust Tomorrow



The Challenge

Late detection of quality issues drives **high costs, delays, and recalls**.

Manufacturers struggle with **fragmented data** across materials, components, processes, and partners — limiting **end-to-end transparency** and fast **root-cause analysis**.

The FX-Solution and Offering

FX-Traceability enables **secure, standardized data exchange** along the supply chain, connecting partners and shopfloor for **full lifecycle transparency –** from materials and BoM variants to product and process traceability.

Use Case TP2.8: Traceability

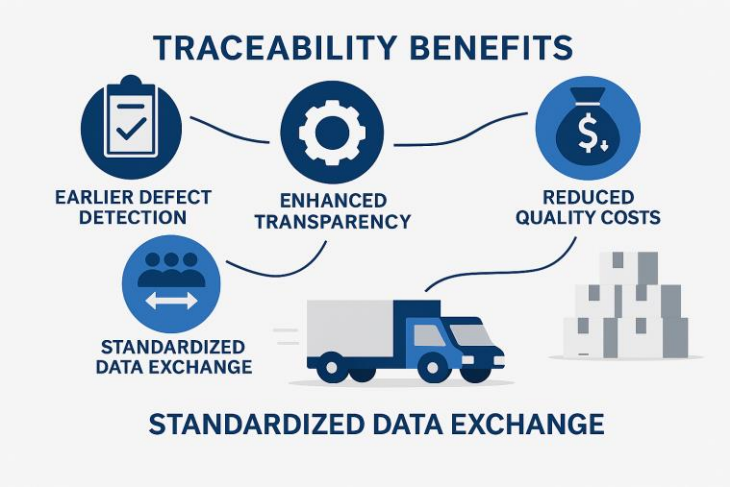
Trace Today, Trust Tomorrow

FACTORY-X

Quality | Transparency | Cost Efficiency | Trust | Standardization

Organizational benefits

- Regulatory compliance
- End-to-end transparency
- Increased customer trust
- Trusted partner collaboration



Economic benefits

- Faster root-cause analysis
- Reduced failures and waste
- New digital business models

Technical benefits

- Standardized data exchange
- Single data transformation
- Searchable production data

TP 2.08 Traceability

Shopfloor Data Transparency and Traceability

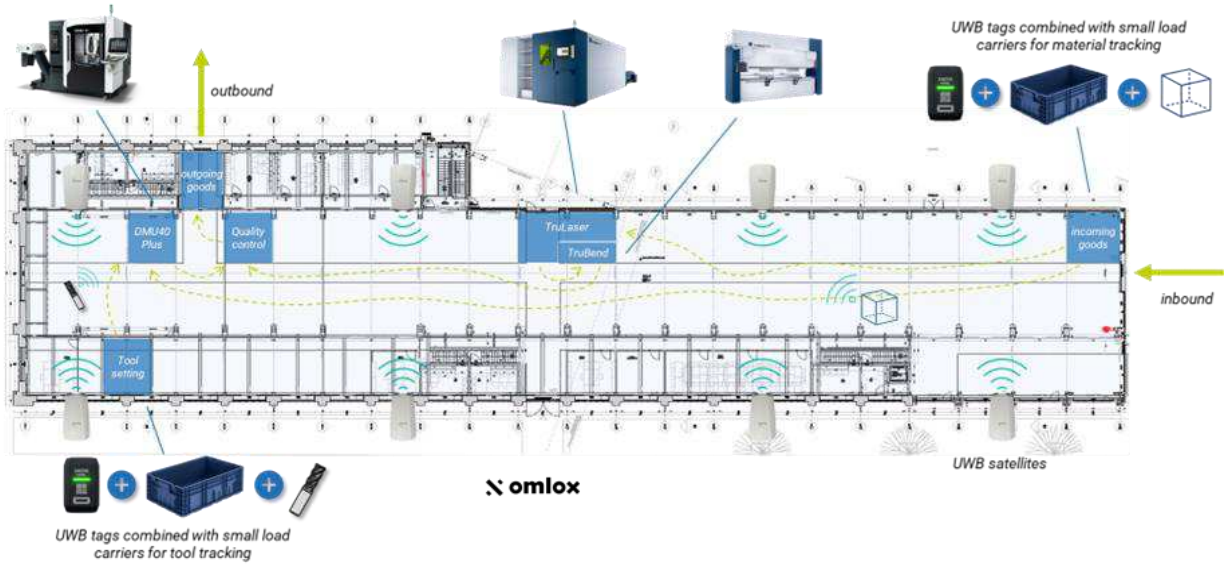
FACTORY-X

Description

- Shopfloor Data Visualization in Digital Twin of the Production (=Virtual Factory)
- Gathering information on shopfloor level (vertically) to prepare for exchange in the right format later **across supply chain**

Benefit

- Building foundation for quality notification exchange workflow based on Catena-X principles



TP 2.08 Traceability

Quality Investigation and Data Exchange across the Supply Chain using MX-Port Hercules

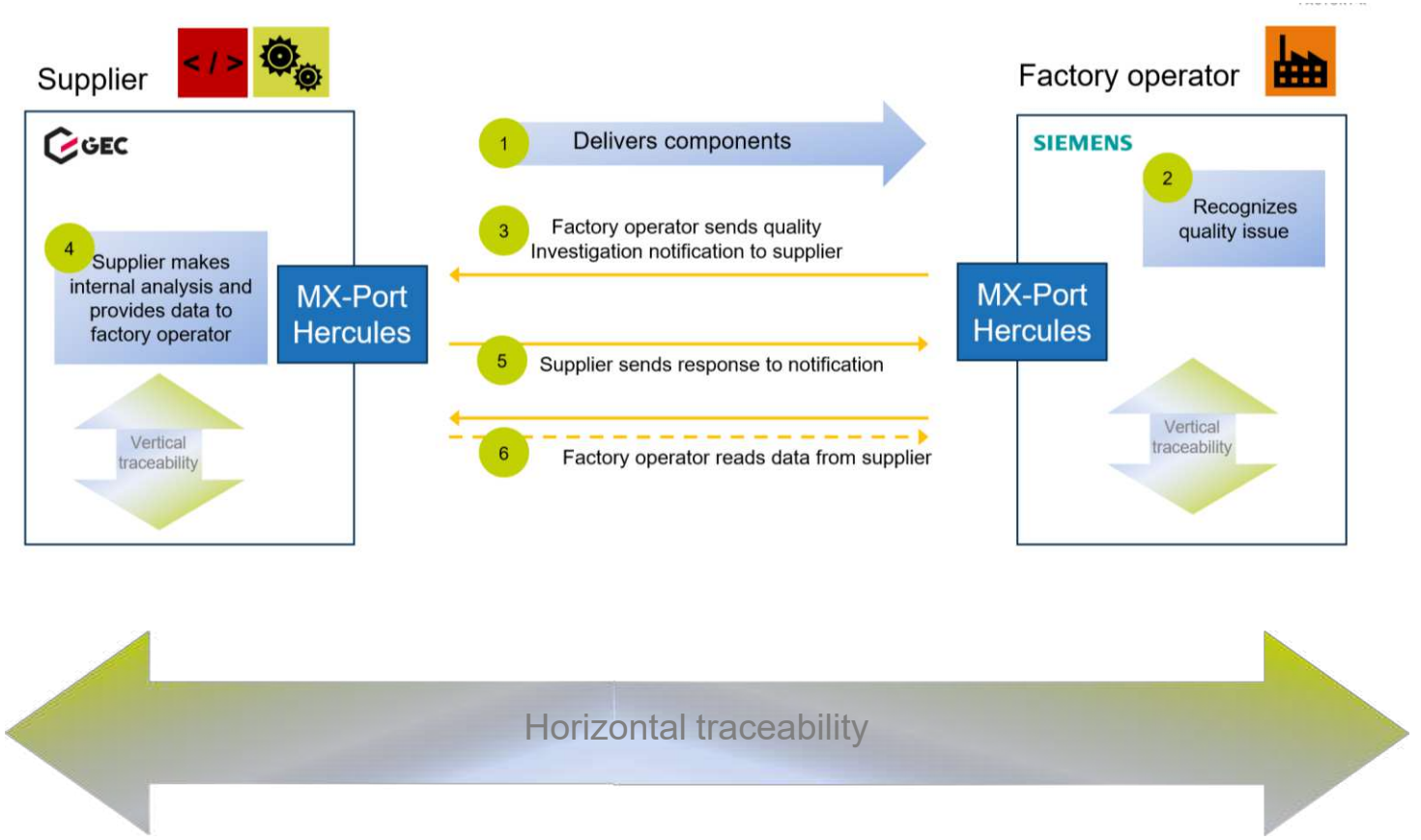
Description

- Communication between different partners in the supply chain using MX-Port Hercules
- Exchange of Quality Notifications based on Catena-X standards
- Provisioning and exchange of additional traceability related data between the partners

Benefit

By enabling secure and structured sharing of quality notifications and traceability data, partners can

- identify issues faster
- collaborate more effectively,
- and reduce the time and effort required for root-cause analysis.



TP 2.08 Traceability

From Machine Data to Cross-Factory Quality Exchange with MX Port Leo

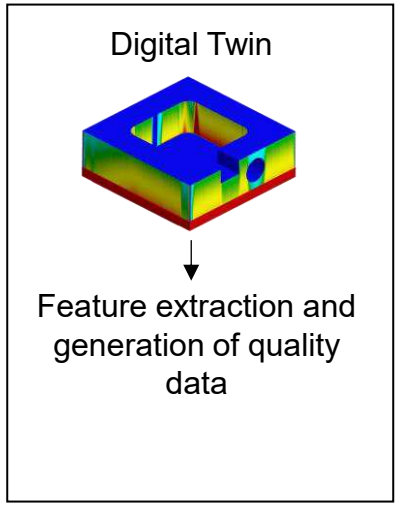
FACTORY-X

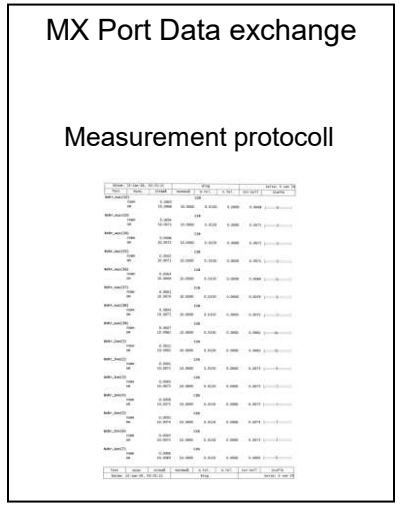
Description

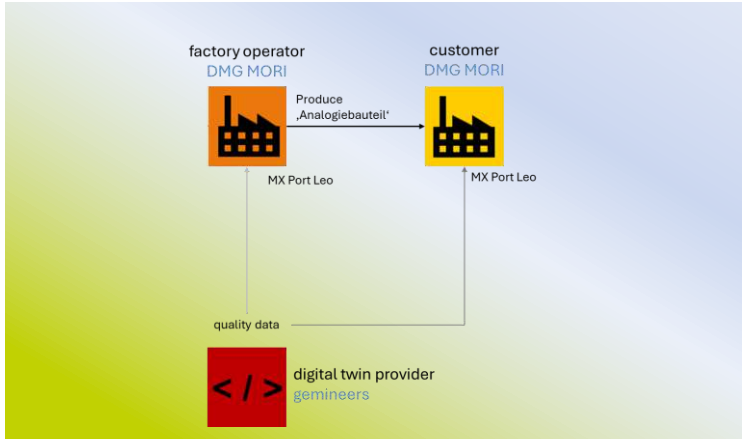
- Tracing of process data during part manufacturing
- Generating quality data from process data
- Connecting quality data to part and exchange information with customer

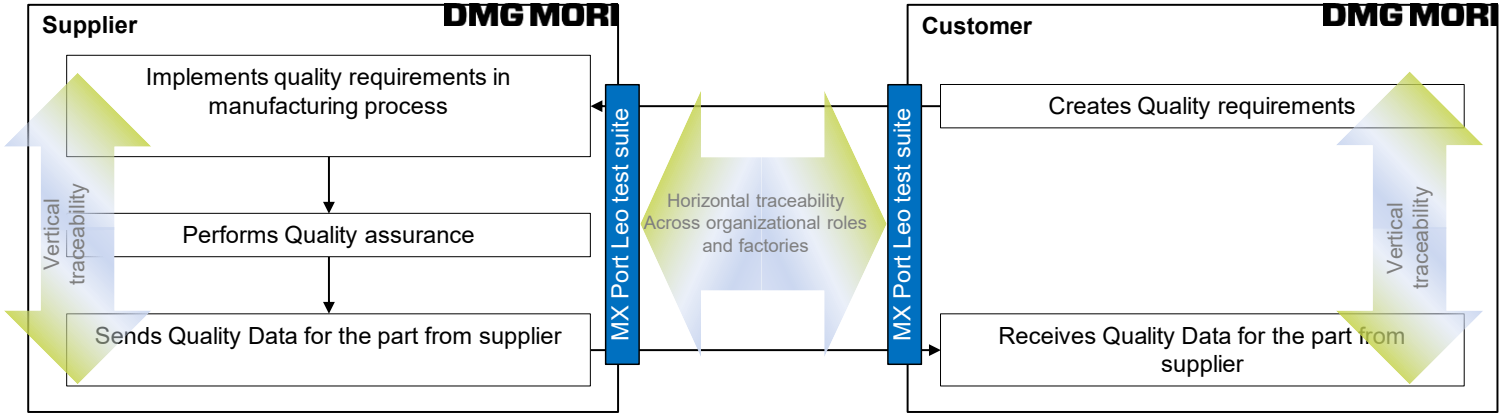
Benefit

- Reducing quality assurance effort
- Validating data exchange platform between factories and connecting quality data to part









TP 2.08 Traceability

XR Demonstrator von LNI 4.0

FACTORY-X

Description

An intuitive, haptic and immersive experience brings the use case closer to the user.

Benefit

The user gets a lasting result through the personal interactive experience using human interfaces and the gamification approach.

Energy Demand and Load Management

Energy Demand and Load Management

Data-driven solutions for energy-efficient manufacturing

The Challenge

Energy-efficient manufacturing requires transparency, monitoring, and levelling of energy demand

- Monitoring makes energy use visible and enables targeted reduction.
- Adjusting machine loads to renewable availability and on-site generation cuts cost

The FX-Solution and Offering

Data-driven solutions for monitoring and optimization of energy demand and flexibility management

Energy Demand and Load Management

Data-driven solutions for energy-efficient manufacturing

FACTORY-X

Data-based solutions for less energy consumption and improved load management

Organizational benefits

- Solutions for interoperable energy monitoring & load management

Economic benefits

- Reduced energy costs
- Novel business models with grid operators

Technical benefits

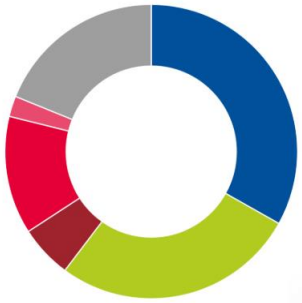
- Energy monitoring & demand-based operation of units
- Digital-twin-based energy modeling
- Energy forecasting & optimized production control
- Active load management & energy flexibility

Picture source: Generated by MS Copilot

Energy Demand and Load Management
Energy Monitoring & Energetic Digital Twin

The issue
Users require energy usage transparency

- Monitoring makes energy use visible and enables data-driven energy reduction
- Challenge: Data is only available locally



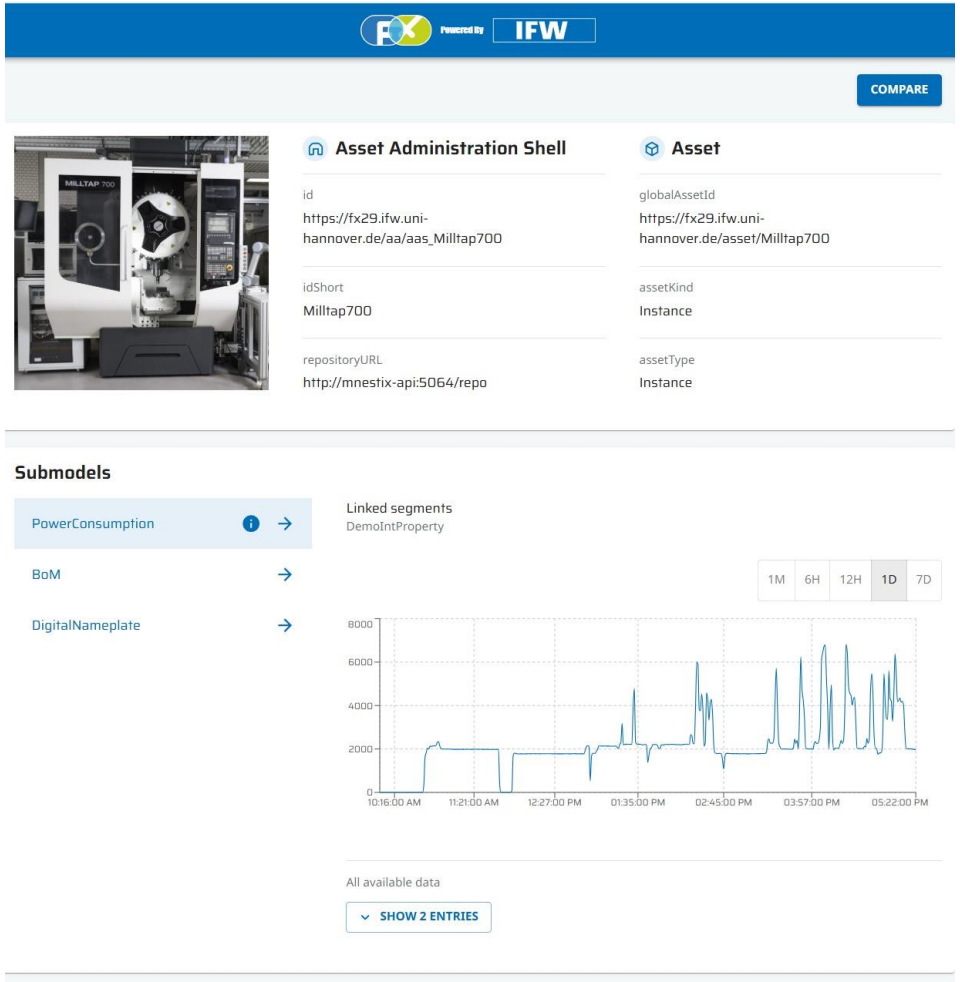
The FX-Solution
- Monitoring at the component level and collection of data in an edge database
- Data is transferred through the federated dataspace (MX-Port concept): Measurements > database > AAS (visualization and reporting layer)

Energy Demand and Load Management

Energy Monitoring & Energetic Digital Twin

Description

- Measurement of electrical energy demand and pressurized air
- Component-wise visualization of energy demand
- Data is made accessible via Asset Administration Shell (AAS)



Benefit

- Energy demand of machine tools becomes transparent on component-level
- Energy-data can be easily transferred to other stakeholders
- Data can be integrated into calculation of product carbon footprint (PCF)

Energy Demand and Load Management
Components-specific energy monitoring

FACTORY-X

Benefits and Insights

- Display of total **machine energy consumption** and calculation of **CO_2 emissions** can be realized
- Visualization of electrical and pneumatic energy demand linked to machine status leads to identification of **status-dependent energy reduction potentials**. Therefore, energy savings through standby modes and targeted status-based adjustments can be achieved
- Component-specific view to **identify main energy consumers**
- **Order-specific energy data can be generated** through linkage of energy consumption with machine status

Further Implications

- **Improved eco-designs** can be implemented during development of the machine based on the data
- Extended and **enhanced service offerings** are enabled

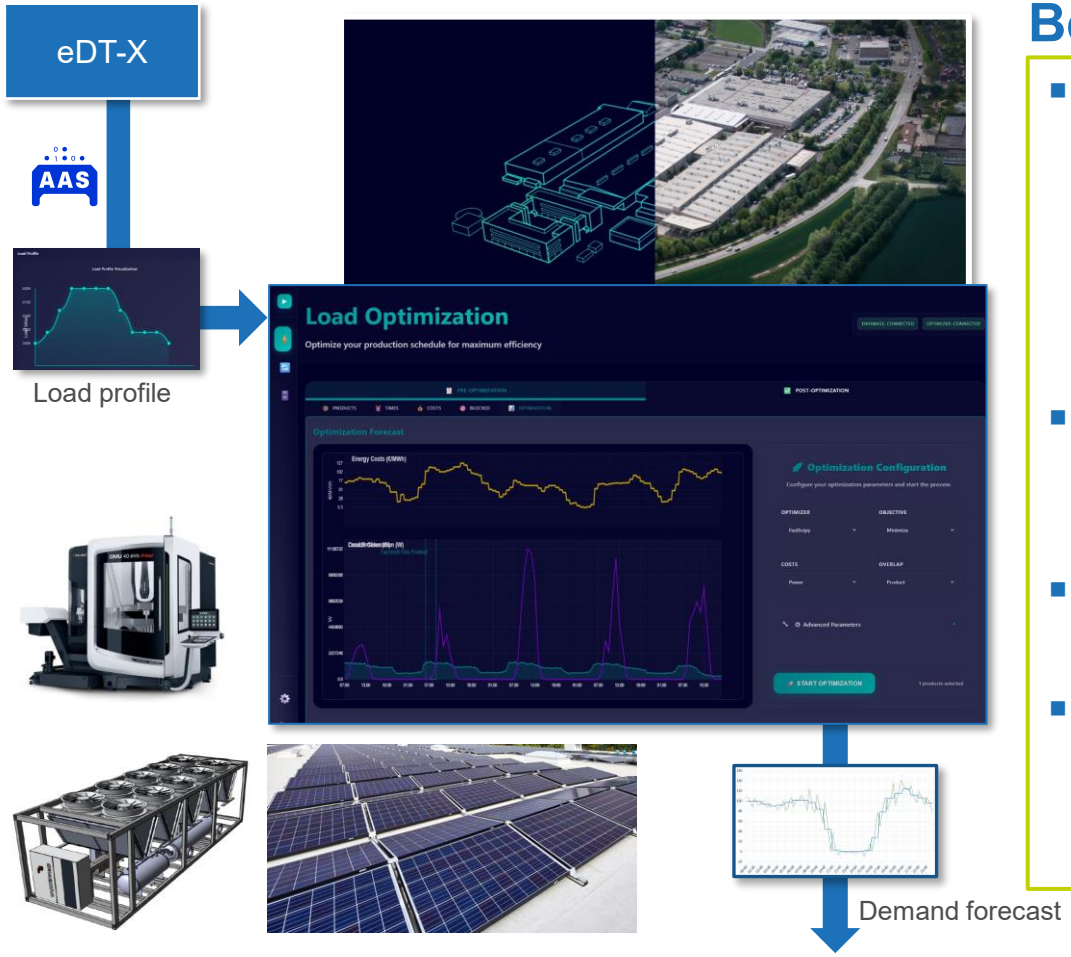
Energy Demand and Load Management

Enflex - optimization of flexible loads

FACTORY-X

Description

- Renewables drastically increase volatility of electricity price
- Flexibility is needed to take advantage of the cheaper prices
- eDT-X provides load profiles for machines / processes to optimize
- Enflex generate cost optimal schedule for different types of flexible industrial loads by providing optimized operating times and operating modes



Benefit

- Reduction of energy cost through optimal schedule of production processes and adapted operation of systems with high energy demand
- More efficient use of production facilities and reduction of peak load
- Evaluation of CO2 saving generated by load shifting
- Offer power demand forecast for energy supplier & grid operator

Energy Demand and Load Management

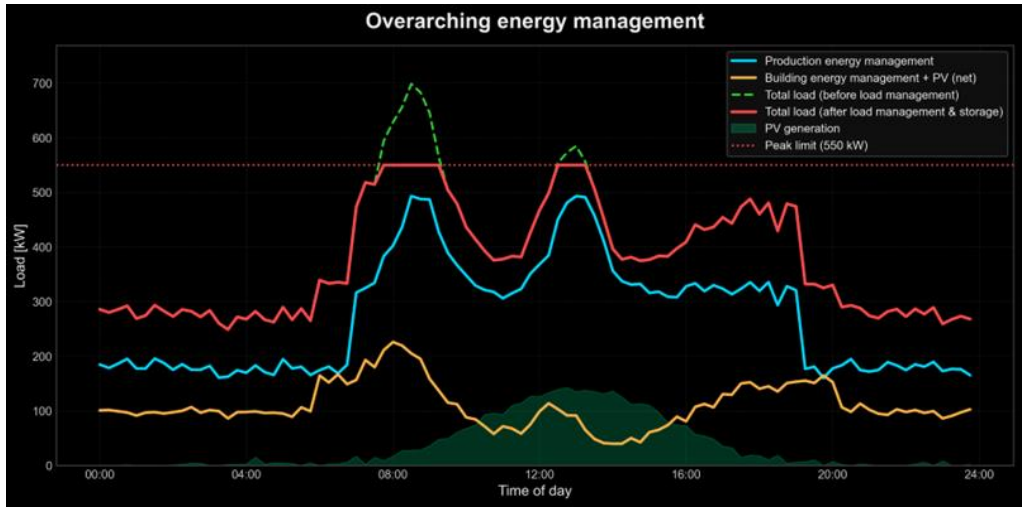
Overarching energy management

Description

- Energy prices become an increasingly important factor for production
- Companies must optimize their energy consumption to the point that accesses the grid
- Overarching energy management optimizes energy resources within companies as well as the flexibility from production processes
- Enables communication with energy companies

Production Energy Management

Facility Energy Management



Energy Management (Energy Company)

Benefit

- reduced costs for energy due to
  - smaller spikes in loads
  - Higher utilization of locally produced energy
- Offer power demand forecast for energy supplier & grid operator
- Communication with energy companies enables
  - better energy contracts
  - Better grid utilization

  → due to better data exchange

Carbon Footprint Management

Carbon Footprint Management

Comparable & Automated Product Carbon Footprint Calculation

The Challenge

- Factory Operators are missing detailed guidance on Product Carbon Footprint (PCF) calculation
- Calculating PCFs is complex and resource-intensive
- Our Goal is to provide calculation guidance and business applications, that enable companies to measure and calculate their PCF with less effort, higher comparability, and higher granularity

The FX-Solution and Offering

We will deliver Business Applications for:

- Calculation of logistics share of PCFs
- Calculation of manufacturing share of PCFs
- Management and sharing of PCFs

The Factory-X ecosystem will enable the reliable sharing of comparable PCF data between companies.

We additionally provide guidance for PCF calculation to lower the entry hurdle for KMUs.

Carbon Footprint Management

Comparable & Automated Product Carbon Footprint Calculation

Comparable & Automated Product Carbon Footprint Calculation & Sharing

Organizational benefits

- Standardized PCF sharing & calculation
- Guidance for the PCF Rulebook

Economic benefits

Competitive advantage by being able to share standardized PCFs

Technical benefits

- Standardized data exchange via M-X Port Hercules
- Data models & schemas for shopfloor & logistics integration

Carbon Footprint Management

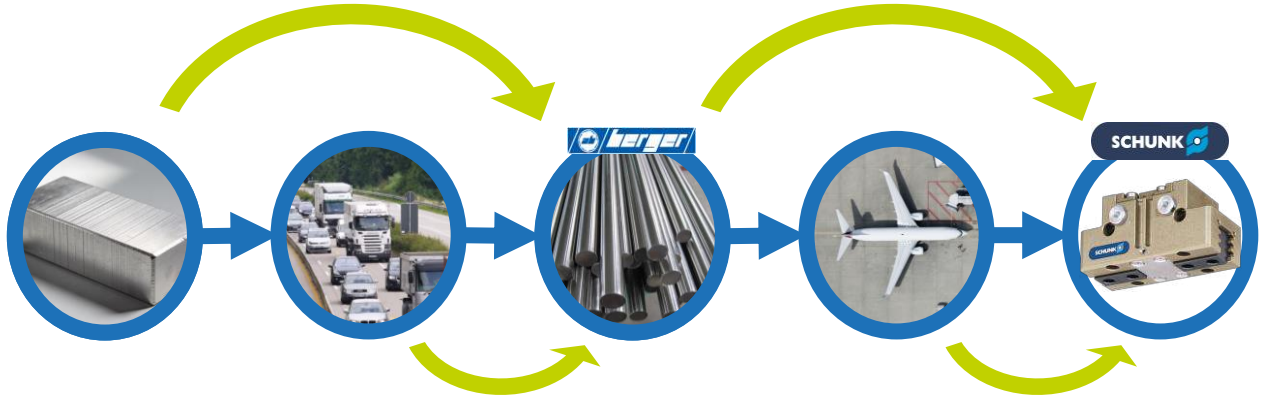
Comparable & Automated Product Carbon Footprint Calculation

FACTORY-X

Description

We demonstrate the calculation of a PCF across the supply chain, including:

- Logistics
- Own Manufacturing
- Cross-Company PCF exchange



Benefit

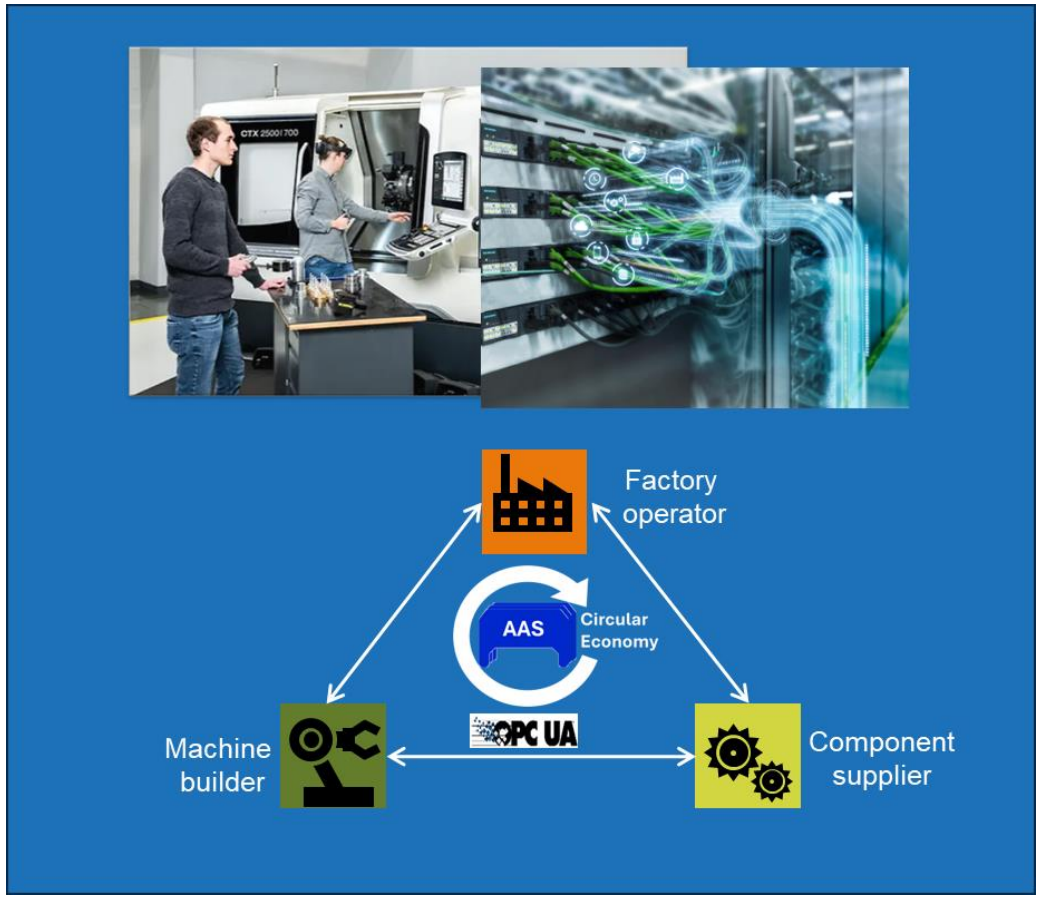
We demonstrate:

- integration of a logistics platform and the automatic logistics CF calculation,
- integration of shopfloor systems for own-manufacturing CF share calculation
- M-X Port Hercules for PCF exchange

Circular Economy

Circular Economy

Close the Loop – for a Second Life!



Close the Loop – for a Second Life!

The Challenge

Cost and scaling of circular economy in machine businesses

- Linear industry: take, make, waste
- Time and resource intensive Manual processes
- Experienced based evaluation

The FX-Solution and Offering

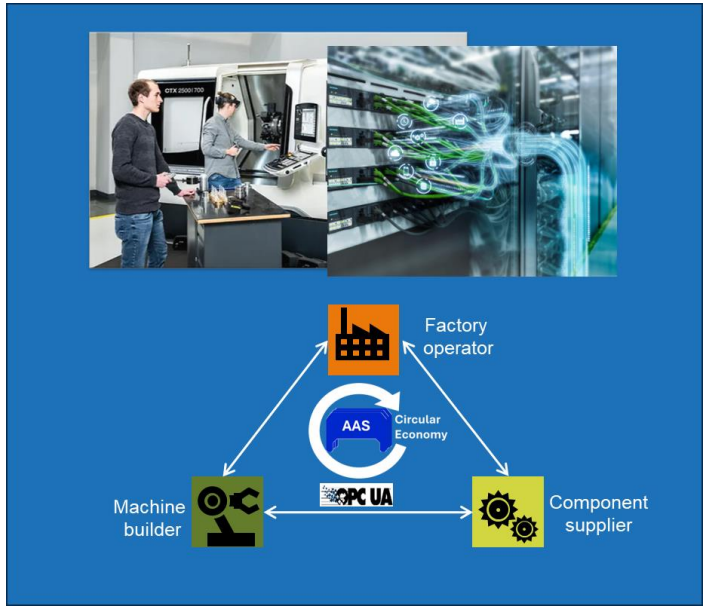
Extending the lifetime and value of machines

- Circular industry: take, make, R-decision
- Data-driven condition assessment and R-proposals

Scaling of Circular Economy for machine tools

Organizational benefits

- Avoiding silo thinking by sharing all available data
- Plannable reconditioning



Technical benefits

- Interoperability by AAS and MX Port
- Advancing data usage

Economic benefits

- Data-based situation assessment
- Transition from an experience-based to a data-based condition assessment
- Waste reduction
- Directly at the machine location of the factory operator
- Scaling potential due to low entry barriers and sharing of anonymized and bundled data

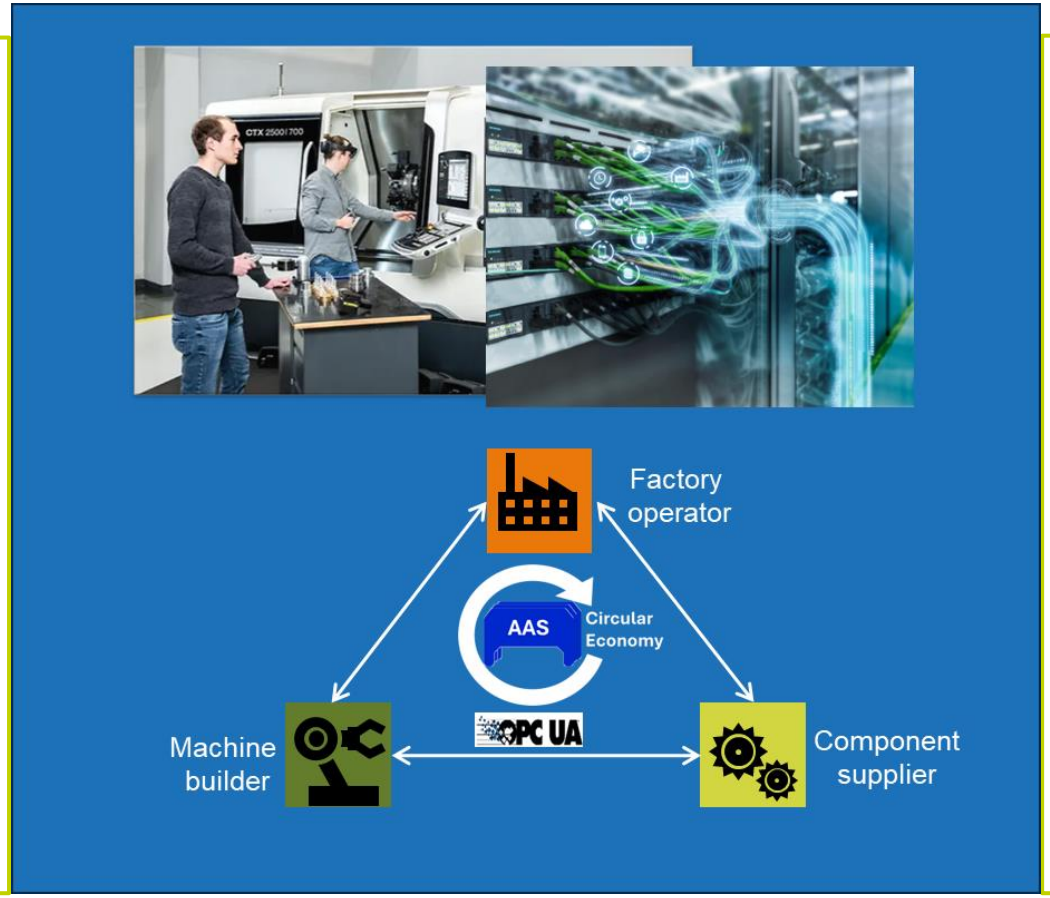
Circular Economy
DMG MORI productive machine in Dresden

FACTORY-X

Description

Productive machine with multiple processes for parts production

- Constant reconditioning of machines and components
- IT infrastructure available (AAS and OPC UA)
- Skilled process engineers
- Triggered high-frequency data acquisition by and condensated, anonymized interoperable data aggregation



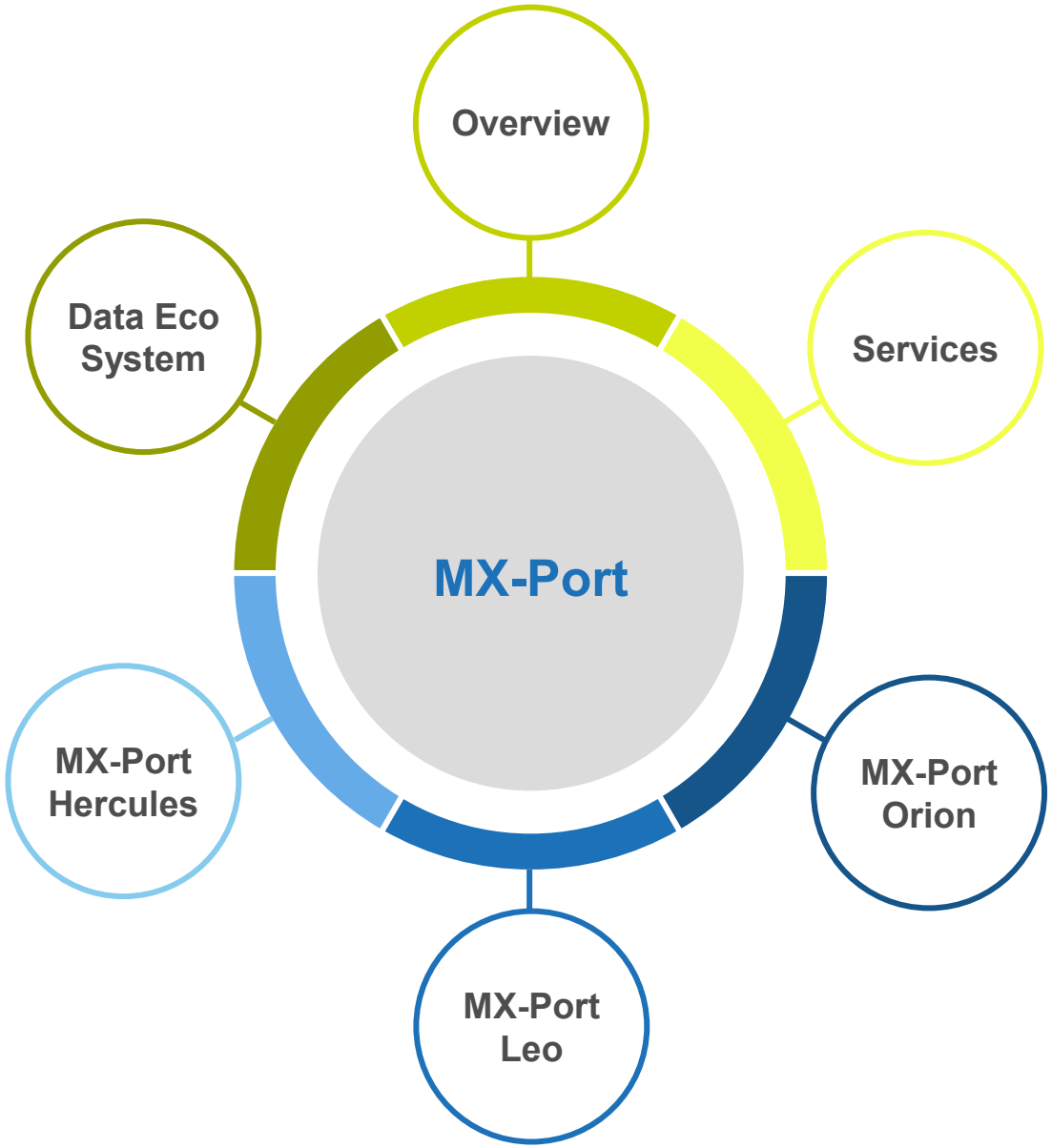
Benefit

Data-based situation assessment of machine and its components

- Data-based situation assessment of machine and its main components directly in Dresden
- Business triggered condition assessment of machines and main components
- Data transmission based on MX-Port Leo and standardized AAS sub models for Circular Economy

MX-Port

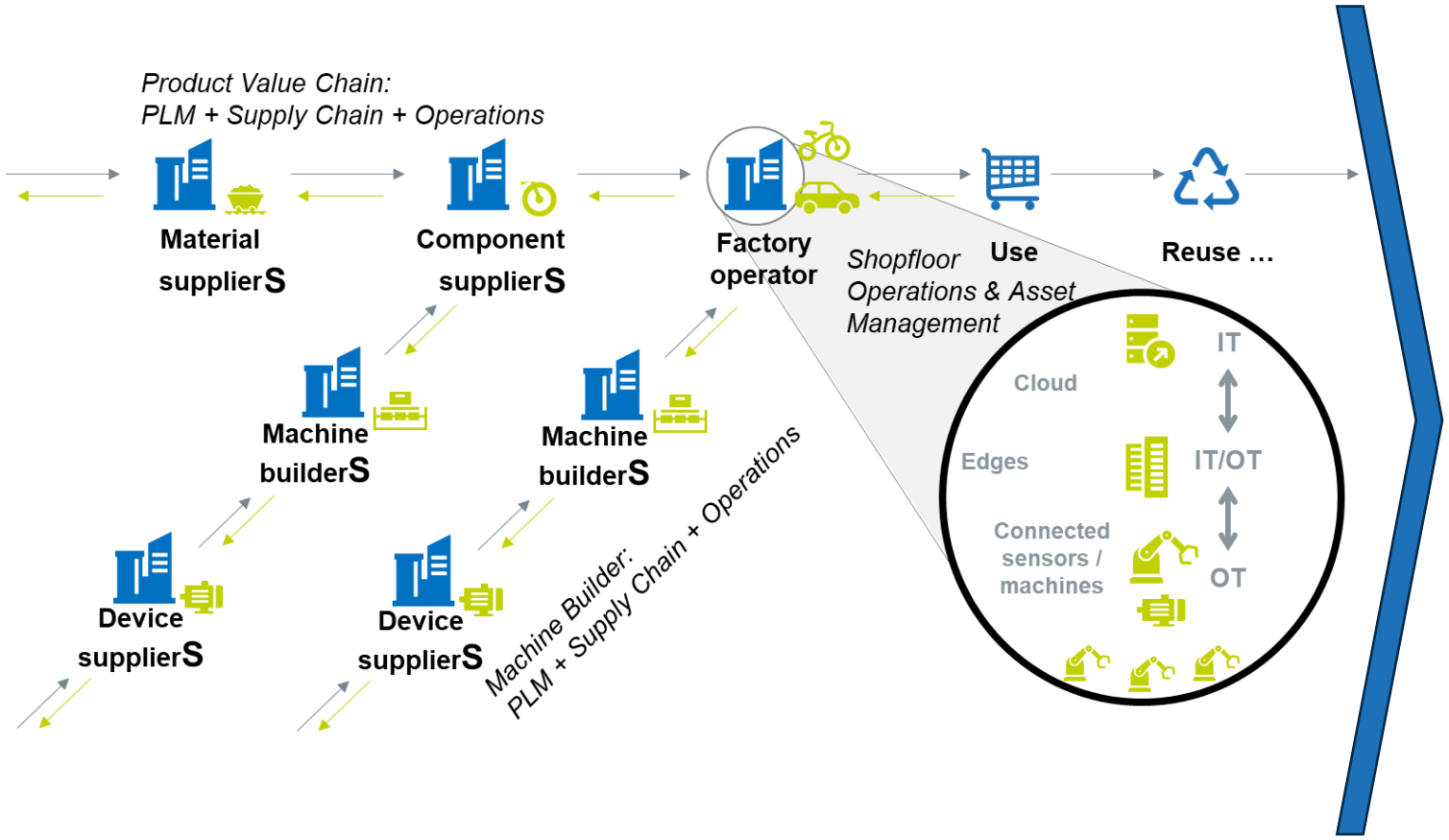
MX-Port and its configurations



MX-Port Overview

“One size fits all” does not work. We need a modular approach to achieve interoperable data spaces

The Factory-X Continuum



Generic structure of MX-Port

- Layered structure with different functional manifestations per layer
- Use case can configure specific MX-Port according to its needs

MX-Port Layer	Components for configurations
MX Discovery	A1 A2
MX Access & Usage Ctrl.	B1 B2
MX Gate	C1 C2
MX Converter	D1 D2 D3
MX Adapter	application specific

options

“One size fits all” does not work. We need a modular approach to achieve interoperable data spaces

Layer	Purpose
MX Discovery	. . . is used to find business partners, data assets (e.g. devices) or business applications.
MX Access & Usage Ctrl.	. . . is used to ensure that data providers can define the data access and usage as well as restrict the access and usage of the provided data.
MX Gate	. . . is used to exchange data in a uniform way.
MX Converter	. . . provides the semantic model for the data to be exchanged.
MX Adapter	. . . enables any business application to use the MX-Port.

Generic structure of MX-Port

- Layered structure with different functional manifestations per layer
- Use case can configure specific MX-Port according to its needs

MX-Port Layer	Components for configurations
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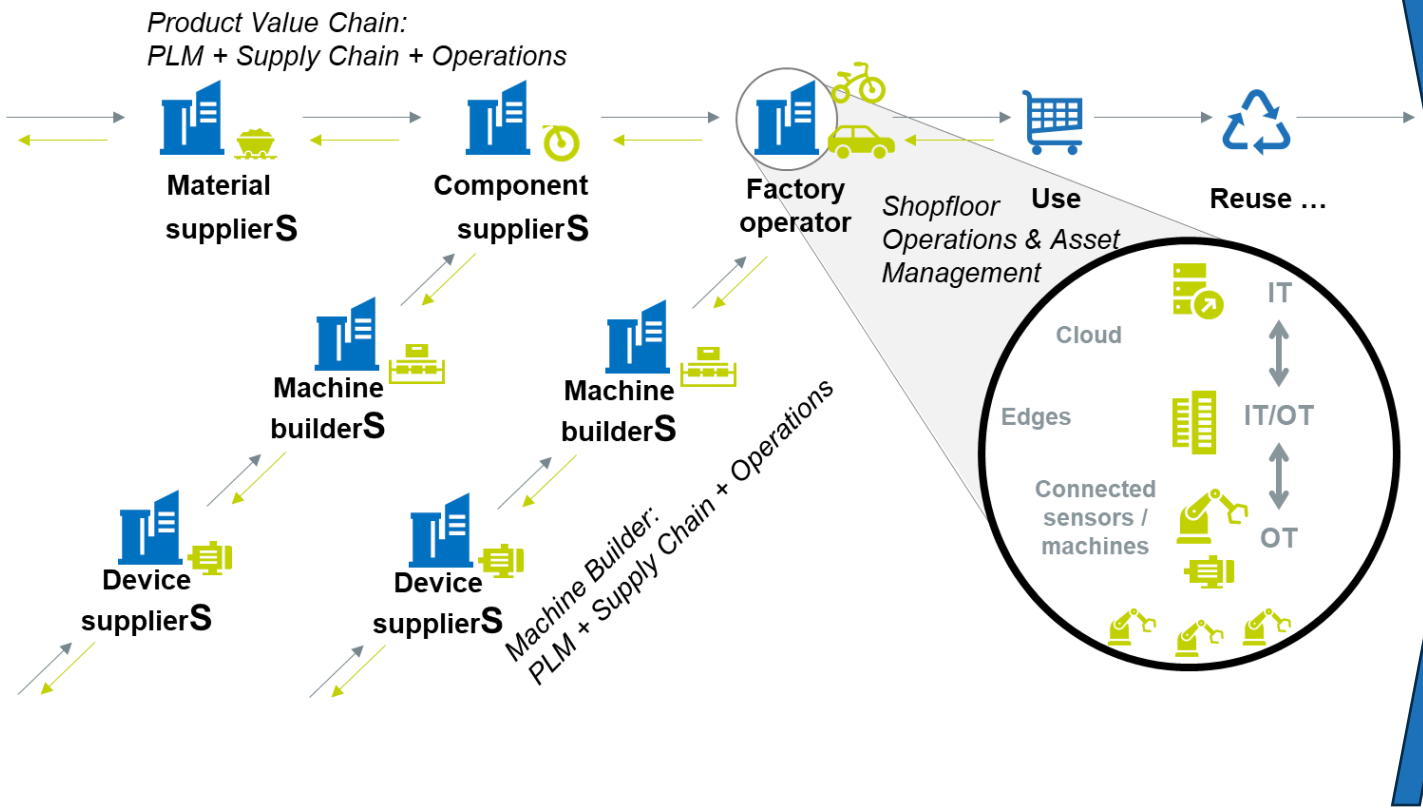
The Factory-X Continuum



Foci of MX-Port Configurations

Supply Chain oriented

“HERCULES”

PLM +
Operations Mgmt. for Production Equipment

“LEO”

Operations Mgmt. for Production Equipment

“ORION”

Our 11 Use Cases for horizontal and vertical data transfer use different MX-Port configurations

Usage of MX-Port configurations in our Use Cases			
Condition Monitoring led Services Hercules, Leo	Modular Production Leo	Manufacturing as a Service - On Demand Manufacturing Hercules, Leo	Autonomous Operation-as-a-Service Hercules, Orion
Traceability Hercules	Energy-Consumption and Load Management Hercules, Leo	Carbon Footprint Management Hercules	Circular Economy Leo

MX-Port: Concept and Configurations/Realizations

- **The MX-Port (concept) is framework for data exchange between participants of a value chain.**
- **MX-Port defines five functional groups (aka. “layers”) for different tasks/responsibilities:**
  - Discovery: find business partners
  - Access and usage control: restrict access to data to participants as defined by the data provider
  - Gate: provide a standardized interface using a standardized data model for exchanging data
  - Converter & Adapter: adapt “foreign” data models and interfaces to the standardized ones at Gate level (e.g., connectivity to machines on the shopfloor)
- **An MX-Port configuration is realized by selecting one or more technologies for each layer.**
- **Currently, three MX-Port configurations (i.e., Hercules, Leo, and Orion) are defined and realized, each of which addresses the needs of a specific group of use cases and application areas.**

Layer	Components for configurations
MX Discovery	A1 A2
MX Access & Usage Ctrl.	B1 B2
MX Gate	C1 C2
MX Converter	D1 D2 D3
MX Adapter	application specific

options

MX-Port configuration
= realization of MX-Port concept

Layer	Hercules	Leo	Orion
MX Discovery	DSP/DCP	AAS + Factory-X extensions	DSP/DCP
MX Access & Usage Ctrl.			
MX Gate	AAS	AAS	OPC UA
MX Converter			
MX Adapter	application specific		

MX-Port: Connector for cross-company data exchange
Different configurations to address different business needs

The MX-Port is a connector framework for secure data exchange in a data space.

- Currently, three MX-Port configurations defined
- Two options for data model and interface (i.e., API)
  - AAS, e.g., suitable for asset data
  - OPC UA, e.g., suitable for machine data and operations
- Two approaches for discovery (i.e., finding business partners) and authentication/authorization (i.e., secure data exchange)
  - AAS-based solution with low entry barrier and extensibility
  - DSP/DCP compatible with Catena-X/Tractus-X solution

MX-Port Leo (e.g., for PLM and system integration)

- AAS for standardized interface and data model as well as cross-company data sharing (using Factory-X extensions/services)

Layer	MX-Port Leo
MX Discovery	Company Lookup, ID-Link
MX Access & Usage Ctrl.	Trusted Partner List, AAS Security
MX Gate	AAS-REST, AAS-MQTT
MX Converter	AAS Submodels
MX Adapter	application specific

MX-Port Hercules (e.g., for supply chain)

- DSP/DCP for cross-company data sharing
- (Mainly) AAS for standardized interface and data model

Layer	MX-Port Hercules
MX Discovery	Dataspace Protocol
MX Access & Usage Ctrl.	Decentralized Claims Protocol
MX Gate	HTTPS (like AAS), MQTT (like OPC UA), BlobStorage
MX Converter	AAS Submodels, AAS Events, …
MX Adapter	application specific

MX-Port Orion (e.g., for shopfloor operation)

- DSP/DCP for cross-company data sharing
- OPC UA for standardized interface and data model

Layer	MX-Port Orion
MX Discovery	Dataspace Protocol
MX Access & Usage Ctrl.	Decentralized Claims Protocol (OPC UA Security)
MX Gate	OPC UA Binary, OPC UA MQTT (JSON)
MX Converter	OPC UA Information Model (w. Companion Spec.)
MX Adapter	application specific

Data Ecosystem

Factory-X Digital Ecosystem
What is our intention and goal?

Creating the fundament of an open and collaborative data space!

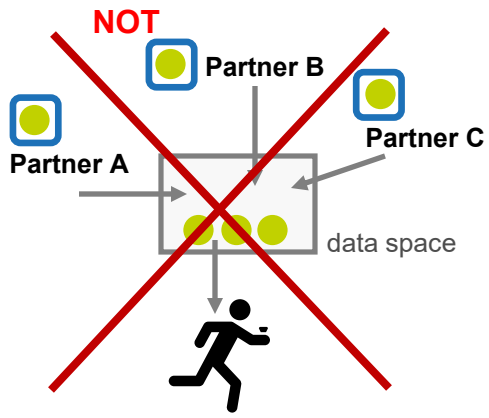
What is a data space?

… the scientific, academic answer

- "Interoperable framework, based on common governance principles, standards, practices and enabling services, that enables trusted data transactions between participants.",
  Source: glossary of Data Spaces Support Centre, https://dssc.eu/

… our motivation, philosophy and pragmatic understanding

- exchange of data between two partners in a partner network with purpose and mutual benefit, and of course in a data sovereign, trustful, secure etc. way.

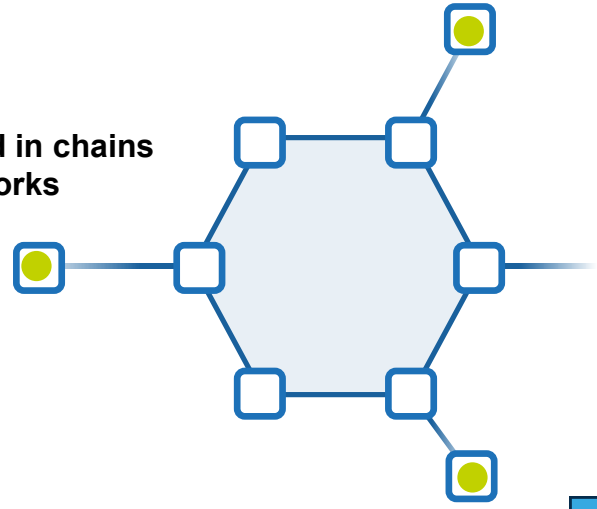


Principal exchange mechanism

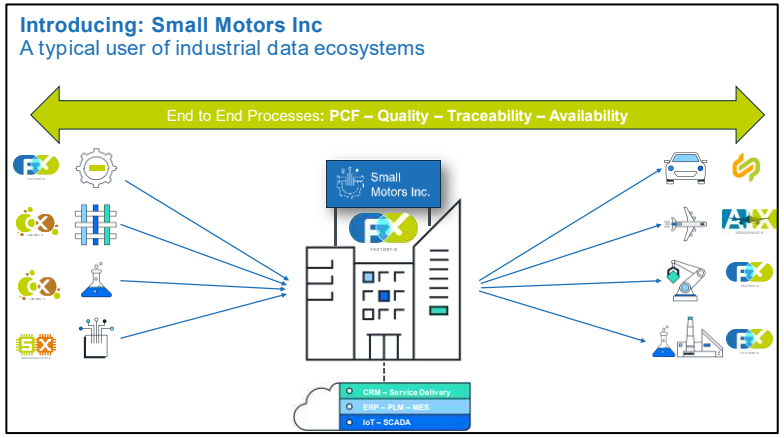
Legend:

- Partner A, B, C …
- Data (exchange)

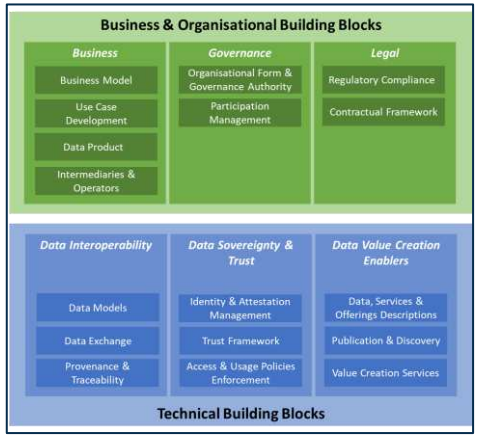
Illustrated in chains and networks



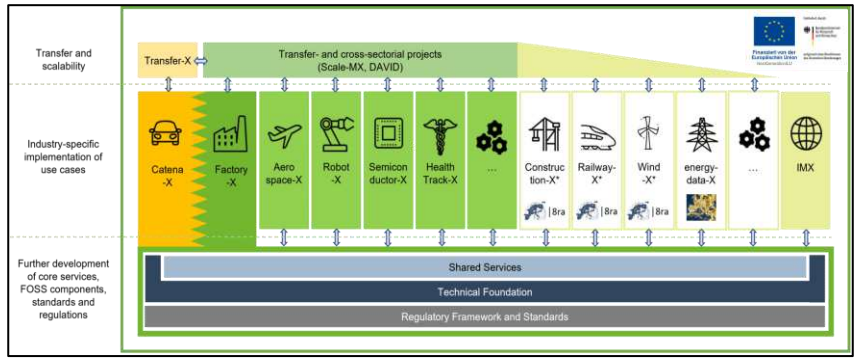
Business Requirements and Technology Building Blocks



Business Requirements

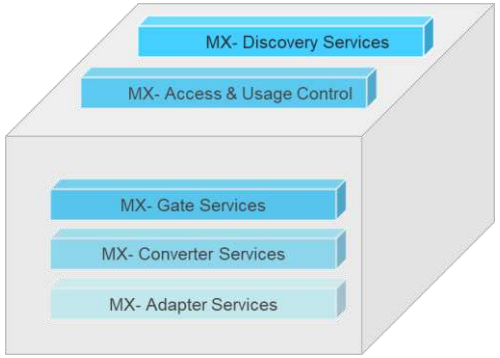


Technology Building Blocks
Standards and Legal Requirements



Manufacturing-X Framework

Interoperability, Trust & Security, Scalability, Data Sovereignty



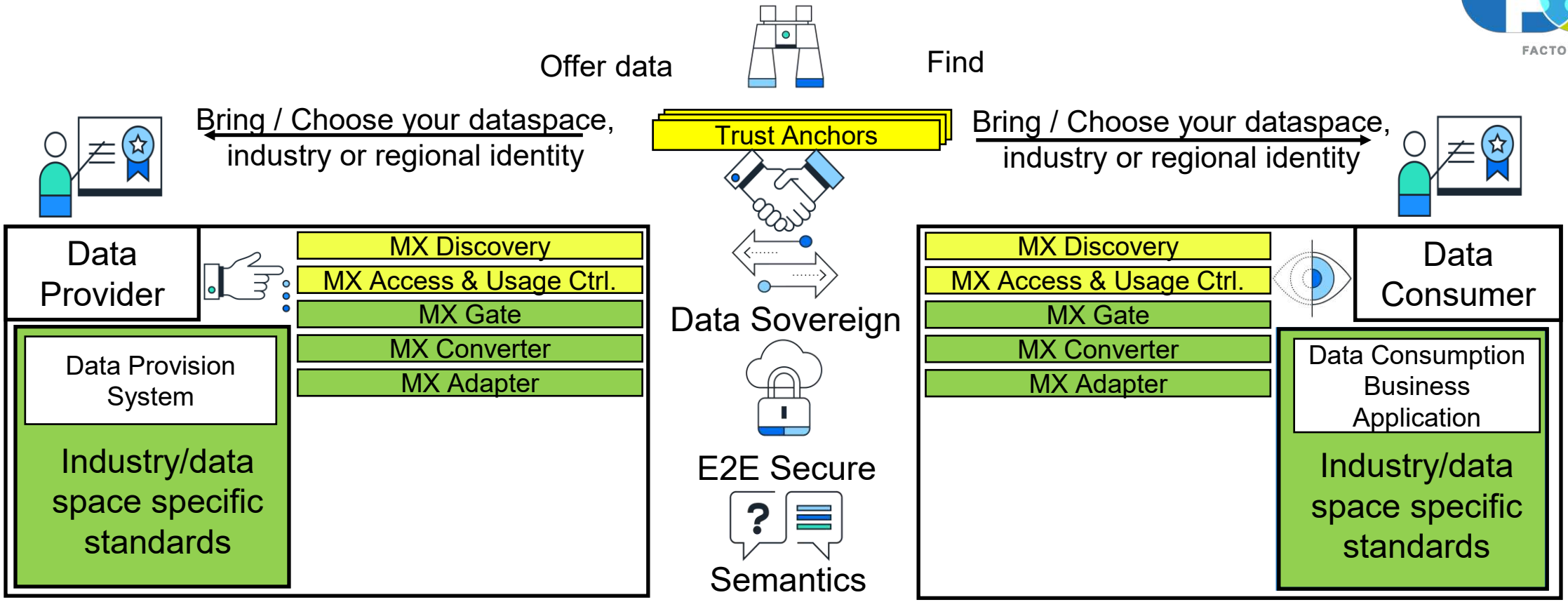
	Layer	Purpose
L5	Discovery	. . . is used to find business partners, data assets (e.g. devices) or business applications.
L4	Access & Usage Control	. . . is used to ensure that data providers can define the data access and usage as well as restrict the access and usage of the provided data.
L3	Gate	. . . is used to exchange data in a uniform way.
L2	Converter	. . . provides the semantic model for the data to be exchanged.
L1	Adapter	. . . enables any business application to use the MX-Port.

Interoperability in Data Spaces | IDS Knowledge Base
ISO/IEC 19941, ISO/IEC TS 10866:2024

Building Block Overview - Blueprint v1.5 - Data Spaces Support Centre

Manufacturing-X - Factory-X

MX-Port Mechanisms



- Baseline for industry, software and service community as KITs https://eclipse-tractusx.github.io/Kits/
- Work in standardization IEC
- Feedback internationally e.g. Japan Open Data Spaces
- Exchange on various events e.g. knowledge camp Events - Factory-X

Factory-X Guardrails
Participants and Rules

Participants:

A) We need one or more Operating Companies, which operates the Shared Services of all MX-Port Configurations.

B) Each legal entity only needs one set of identities (legal entities, human, machines etc.) to use all Shared Services. (Existing identities can be used further.)

C) Legal entities are free to choose the operating company.

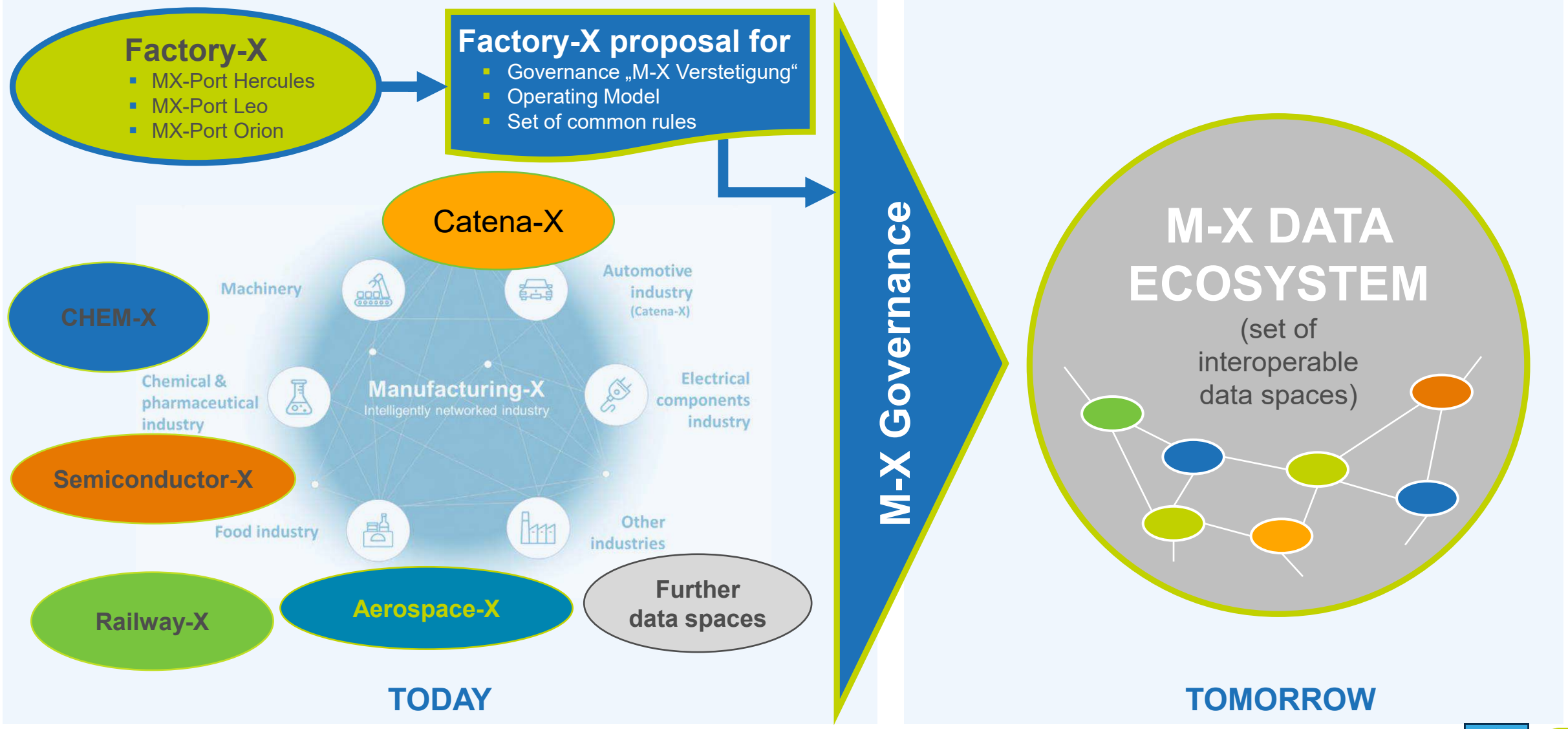
Rules:

The same problems are solved the same regardless of the use cases and selected MX-Port configuration.

- One set of participants
- One set of rules

→ One Factory-X Dataspace

Way forward to M-X DATA ECOSYSTEM



MX-Port: Concept and Configurations/Realizations

- **The MX-Port (concept) is framework for data exchange between participants of a value chain.**
- **MX-Port defines five functional groups (aka. “layers”) for different tasks/responsibilities:**
  - Discovery: find business partners
  - Access and usage control: restrict access to data to participants as defined by the data provider
  - Gate: provide a standardized interface using a standardized data model for exchanging data
  - Converter & Adapter: adapt “foreign” data models and interfaces to the standardized ones at Gate level (e.g., connectivity to machines on the shopfloor)
- **An MX-Port configuration is realized by selecting one or more technologies for each layer.**
- **Currently, three MX-Port configurations (i.e., Hercules, Leo, and Orion) are defined and realized, each of which addresses the needs of a specific group of use cases and application areas.**

Layer	Components for configurations
MX Discovery	A1 A2
MX Access & Usage Ctrl.	B1 B2
MX Gate	C1 C2
MX Converter	D1 D2 D3
MX Adapter	application specific

options

MX-Port configuration
= realization of MX-Port concept

Layer	Hercules	Leo	Orion
MX Discovery	DSP/DCP	AAS + Factory-X extensions	DSP/DCP
MX Access & Usage Ctrl.			
MX Gate	AAS	AAS	OPC UA
MX Converter			
MX Adapter	application specific		

MX-Port: Connector for cross-company data exchange
Different configurations to address different business needs

The MX-Port is a connector framework for secure data exchange in a data space.

- Currently, three MX-Port configurations defined
- Two options for data model and interface (i.e., API)
  - AAS, e.g., suitable for asset data
  - OPC UA, e.g., suitable for machine data and operations
- Two approaches for discovery (i.e., finding business partners) and authentication/authorization (i.e., secure data exchange)
  - AAS-based solution with low entry barrier and extensibility
  - DSP/DCP compatible with Catena-X/Tractus-X solution

MX-Port Leo (e.g., for PLM and system integration)

- AAS for standardized interface and data model as well as cross-company data sharing (using Factory-X extensions/services)

Layer	MX-Port Leo
MX Discovery	Company Lookup, ID-Link
MX Access & Usage Ctrl.	Trusted Partner List, AAS Security
MX Gate	AAS-REST, AAS-MQTT
MX Converter	AAS Submodels
MX Adapter	application specific

MX-Port Hercules (e.g., for supply chain)

- DSP/DCP for cross-company data sharing
- (Mainly) AAS for standardized interface and data model

Layer	MX-Port Hercules
MX Discovery	Dataspace Protocol
MX Access & Usage Ctrl.	Decentralized Claims Protocol
MX Gate	HTTPS (like AAS), MQTT (like OPC UA), BlobStorage
MX Converter	AAS Submodels, AAS Events, …
MX Adapter	application specific

MX-Port Orion (e.g., for shopfloor operation)

- DSP/DCP for cross-company data sharing
- OPC UA for standardized interface and data model

Layer	MX-Port Orion
MX Discovery	Dataspace Protocol
MX Access & Usage Ctrl.	Decentralized Claims Protocol (OPC UA Security)
MX Gate	OPC UA Binary, OPC UA MQTT (JSON)
MX Converter	OPC UA Information Model (w. Companion Spec.)
MX Adapter	application specific

Service Maps

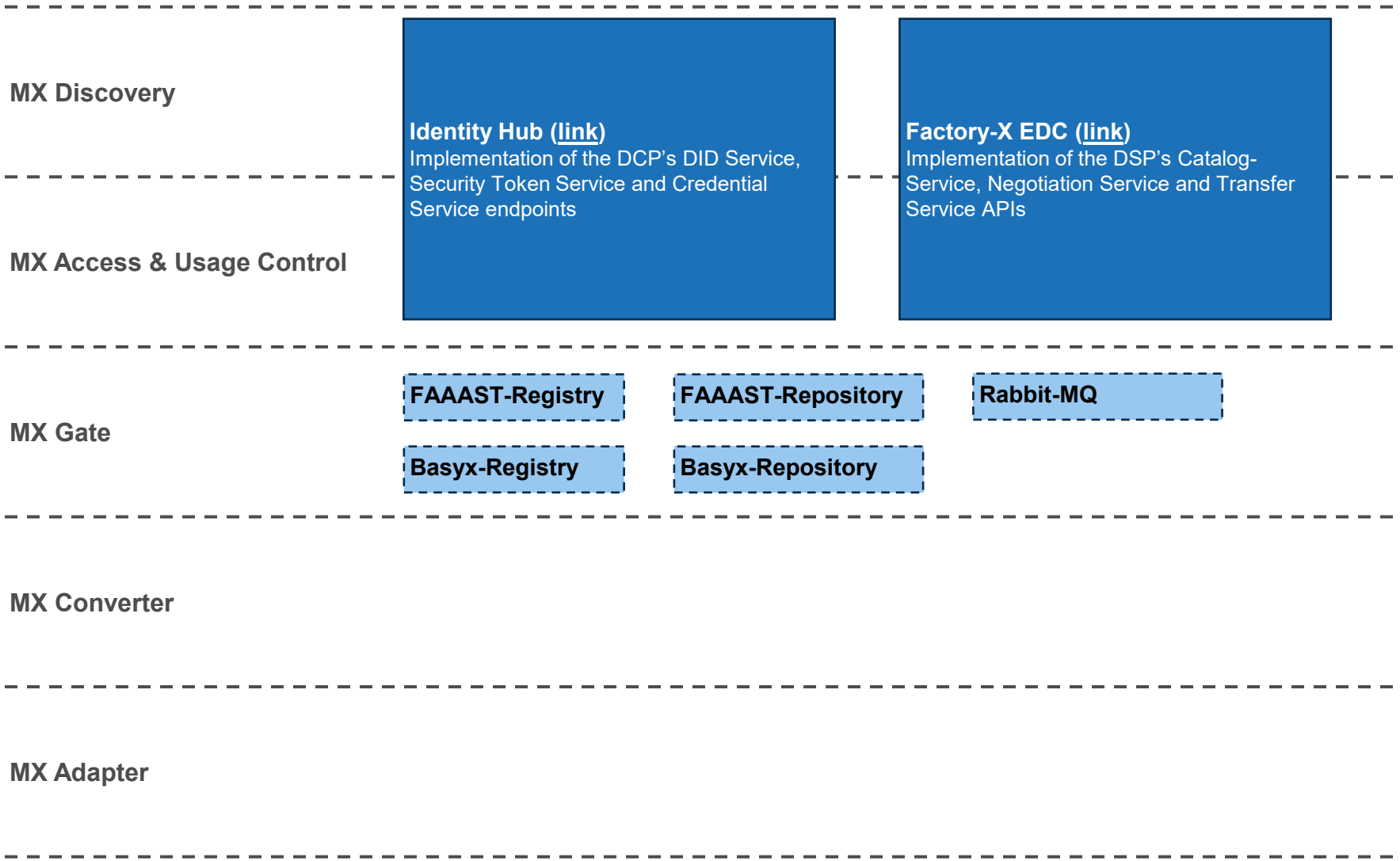
MX-Port Configuration Hercules
Conceptual Level

MX Discovery	**DID service** exposed by each participant as mandated by DCP. Maps a self-given id to a set of service endpoints	**Catalog Service** Exposed by each participant as mandated by DSP. Lists a Data Provider's offers.	
MX Access & Usage Control	**Credential Service** exposed by each participant as mandated by DCP. Grants a third-party's Negotiation and Transfer Service selective access to credentials	**Negotiation and Transfer Service** Exposed by each participant as mandated by DSP. Requests, validates, checks a third-party's credentials to grant access to MX-Gate-level.	
	Issuer Service exposed by a trust anchor as mandated by DCP. Creates, distributes and revokes long-living credentials to present in the dataspace.		
MX Gate	**HTTP Submodel Service** Exposes AAS Submodels according to ADR-008.	**Digital Twin Registry** Exposes Descriptors and AssetLinks according to ADR-008.	**Broker** Exposes an interface to subscribe to messages distributed via MQTT
MX Converter	use-case-specific		
MX Adapter	use-case-specific		

Notes & comments

- For specification of the mentioned services, please refer to the Factory-X Architecture Decision Records and the standards they rely on.

MX-Port Configuration Hercules
Implementation Level (concrete implemented & provided software services)



Notes & comments

- Please check the relevant repositories in the factory-x-contributions Github organization.
- All these services are deployed on the FX-Test Landscape and available for testing during the project.
- TP4.A has also contributed to the MX-Gate level implementations extensively during the project.

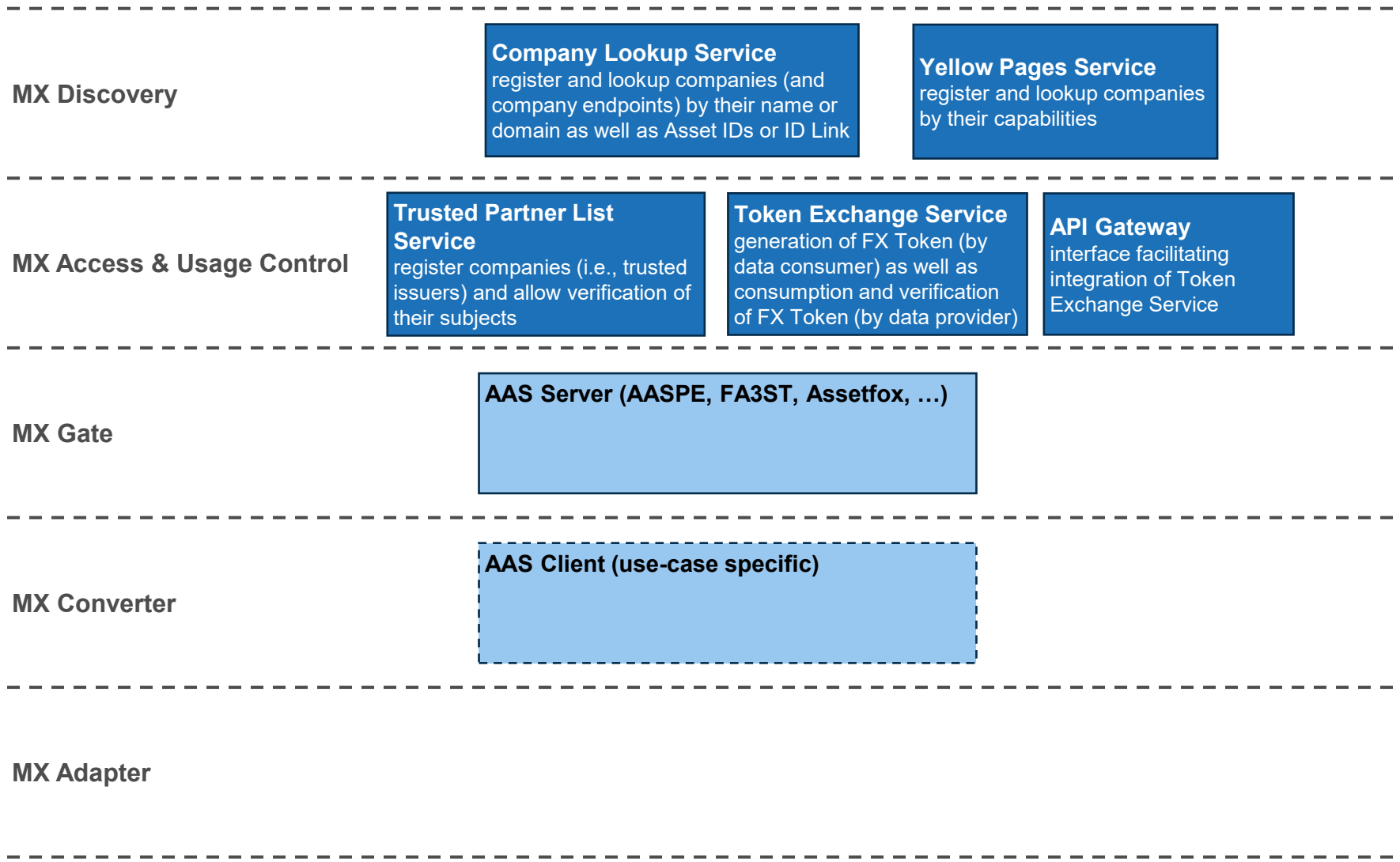
MX-Port Configuration Leo
Conceptual Level

MX Discovery	**company lookup service** abstract software service managing a list of company lookup information	
MX Access & Usage Control	**credential store service:** abstract software service managing credentials in a secure way	**gateway service** abstract software service which establishes a connection between several abstract software services
	identity and access management service abstract software service issuing and proving on request credentials and token	**trusted partner list management service** abstract software service managing a list of trusted partner entries
	token exchange service abstract software service receiving a token and providing another token	
MX Gate	**AAS server** abstract software service managing a set of AASs and providing the AAS interface	
MX Converter	**AAS client** abstract software application which accesses an AAS via its AAS interface for usage by humans or for automatic processing	
MX Adapter	no specific shared services	

Notes & comments

- For details see document MX-Port Configuration “Leo”

MX-Port Configuration Leo
Implementation Level (concrete implemented & provided software services)



Notes & comments

Roles in line with the definitions of the document "Governance MX-Port configuration "Leo""

Shared service operator:

- **Company Lookup Service**
- **Yellow Pages Service**
- **Trusted List Service**

Business application operator:

- **Token Exchange Service**
- **API Gateway**
- **AAS Server**
- **AAS Client**

Both roles can be assumed by the same operator.

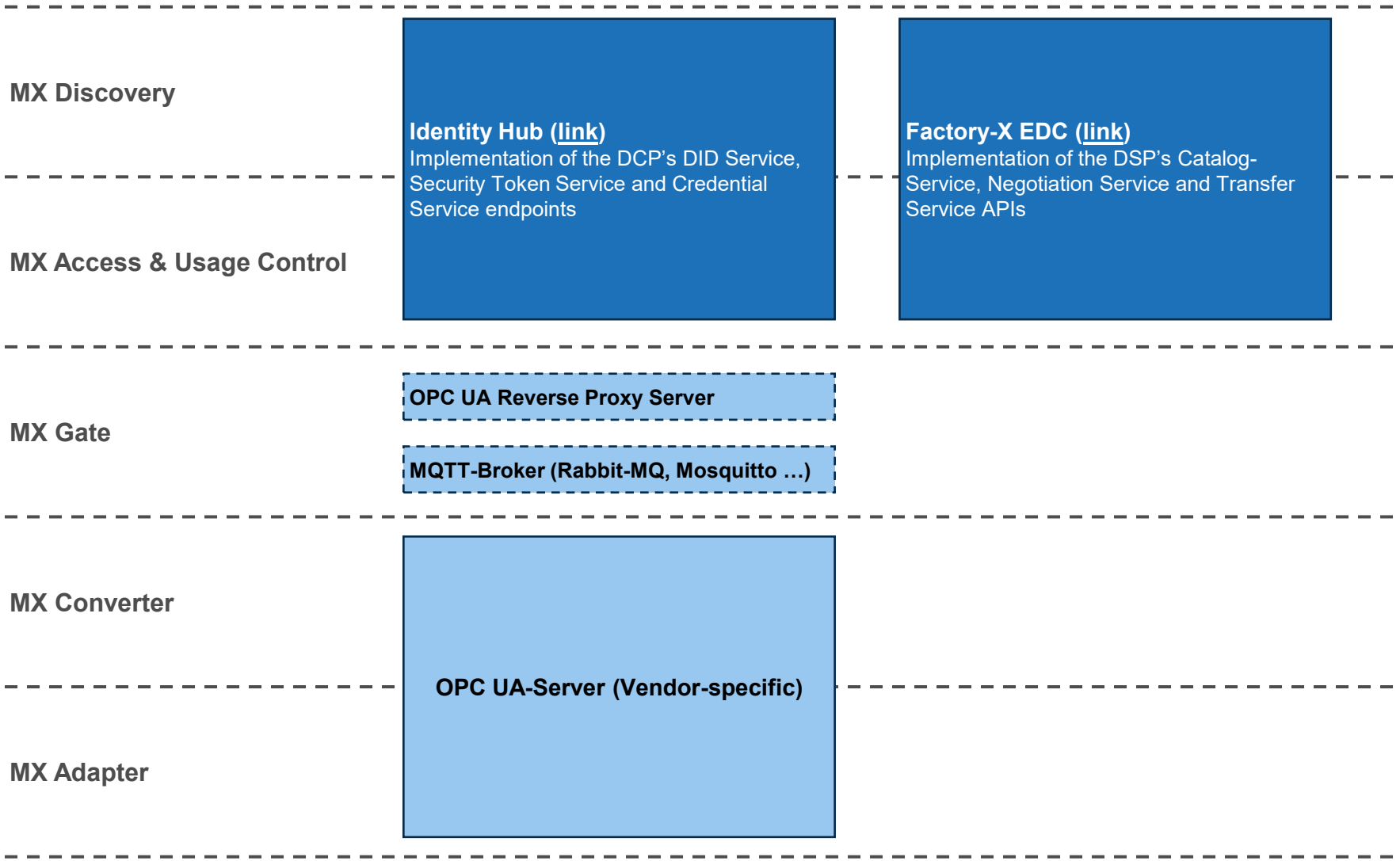
MX-Port Configuration Orion
Conceptual Level

MX Discovery	**DID service** exposed by each participant as mandated by DCP. Maps a self-given id to a set of service endpoints.	**Catalog Service** Exposed by each participant as mandated by DSP. Lists a Data Provider's offers.
MX Access & Usage Control	**Credential Service** exposed by each participant as mandated by DCP. Grants a third-party's Negotiation and Transfer Service selective access to credentials.	**Negotiation and Transfer Service** Exposed by each participant as mandated by DSP. Requests, validates, checks a third-party's credentials to grant access to MX-Gate-level.
	Issuer Service exposed by a trust anchor as mandated by DCP. Creates, distributes and revokes long-living credentials to present in the dataspace.	
MX Gate	**OPC UA Reverse Proxy Server** Exposes OPC UA Address Spaces of the assets.	**Broker** Exposes an interface to subscribe to messages distributed via MQTT.
MX Converter	use-case-specific	
MX Adapter	use-case-specific	

Notes & comments

- For specification of the mentioned services, please refer to the Factory-X Architecture Decision Records and the standards they rely on.

MX-Port Configuration Orion
Implementation Level



Notes & comments

- Please check the relevant repositories in the factory-x-contributions Github organization.
- All these services are deployed on the FX-Test Landscape and available for testing during the project.

Shared services:

- Identity Hub
- Factory-X EDC

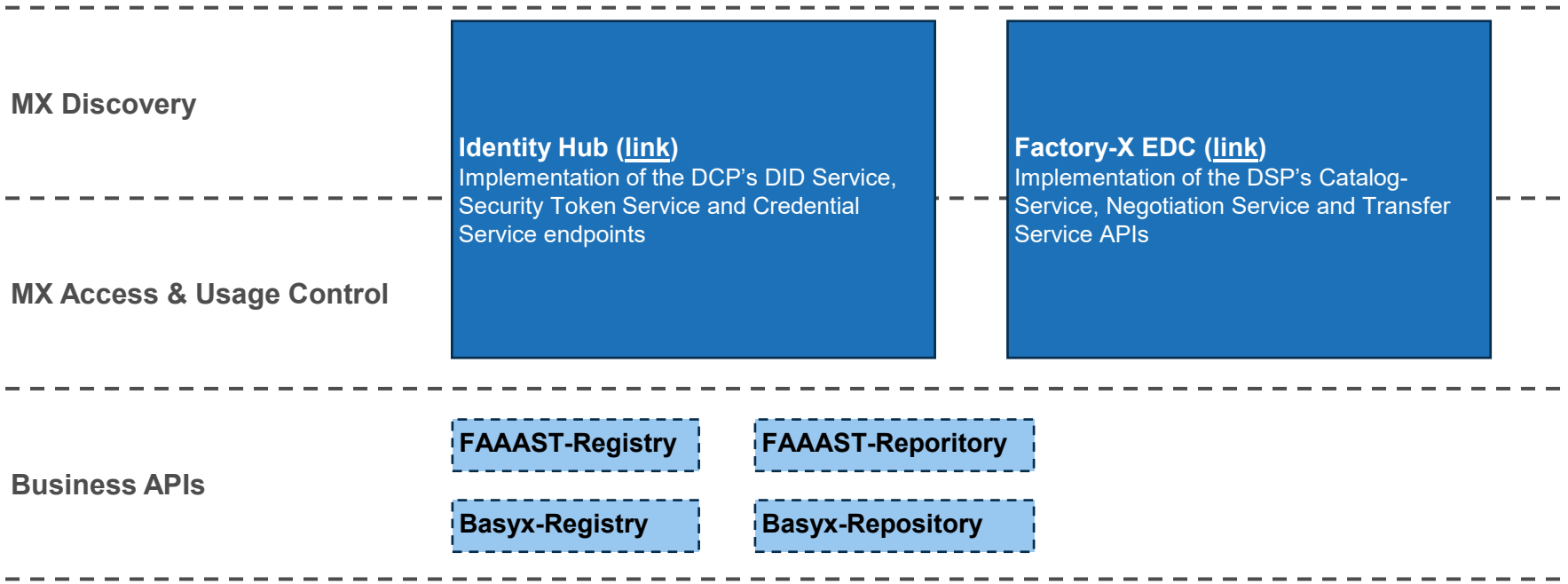
Business application

- OPC UA Reverse Proxy Server
- MQTT Broker
- OPC UA Server

MX-Port Hercules

Dataspace Connectivity

Extending the common Foundation for Dataspaces

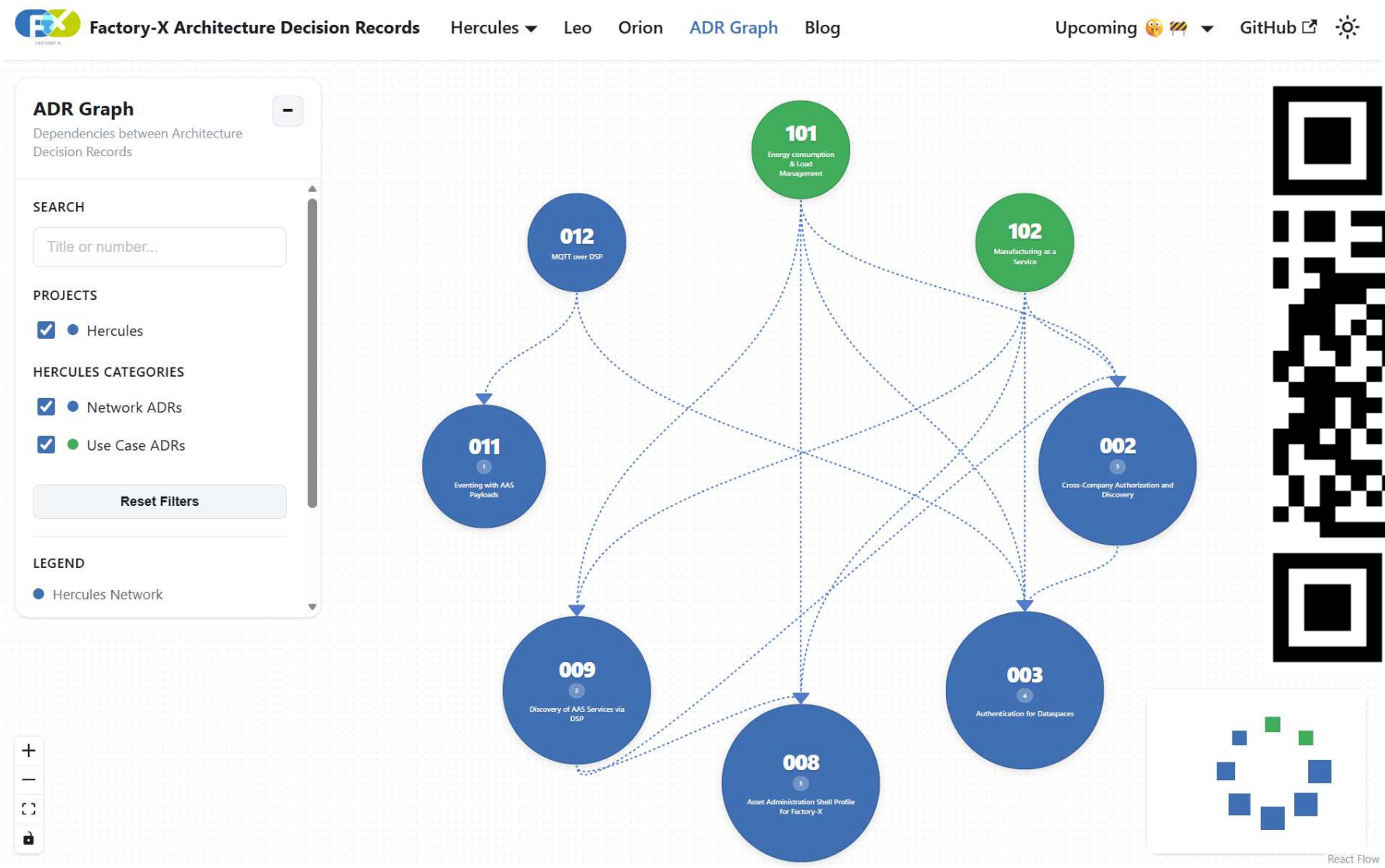


The Challenge

Build Specifications and Software for interoperable Data Exchange across industries. Especially with Catena-X.

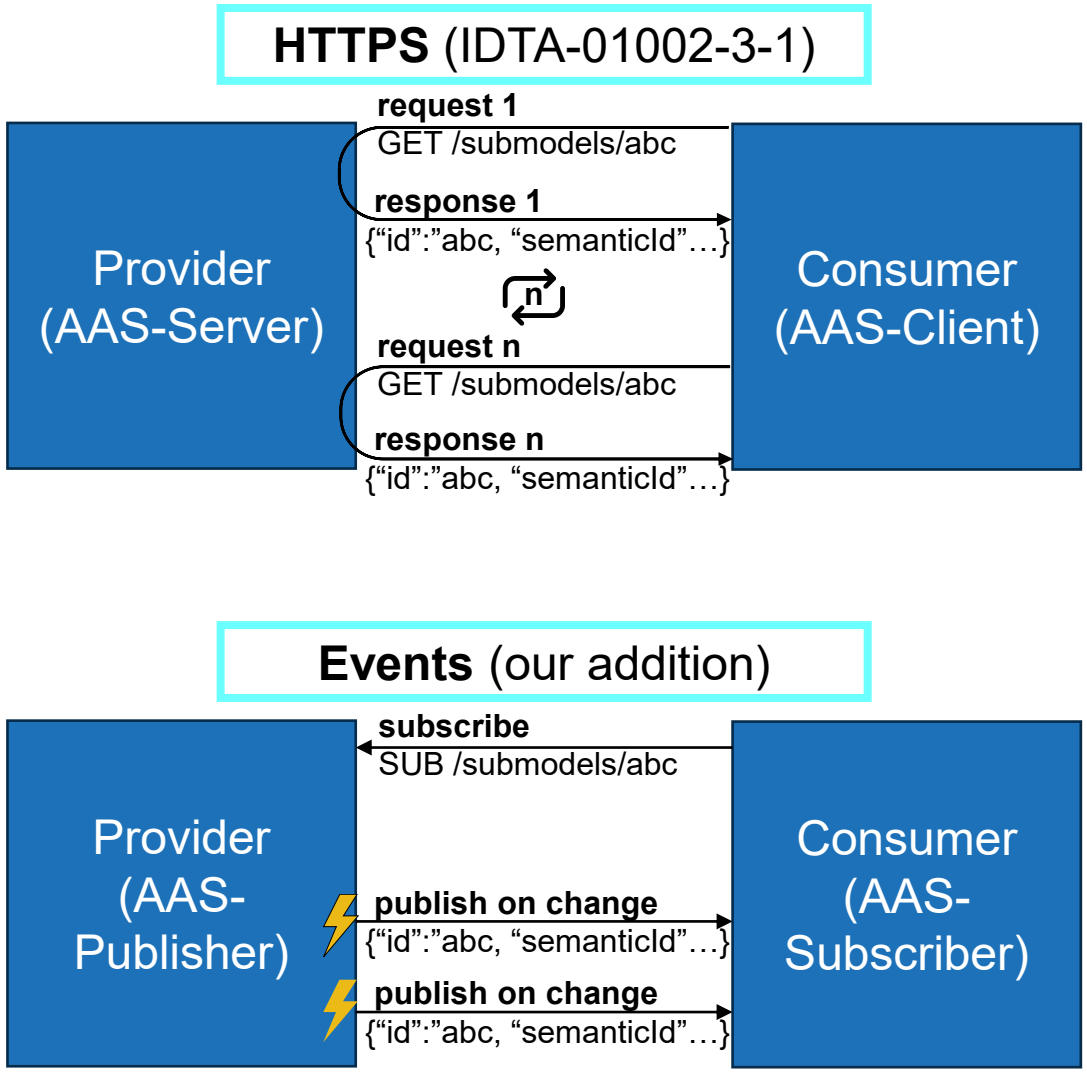
Dataspace Connectivity

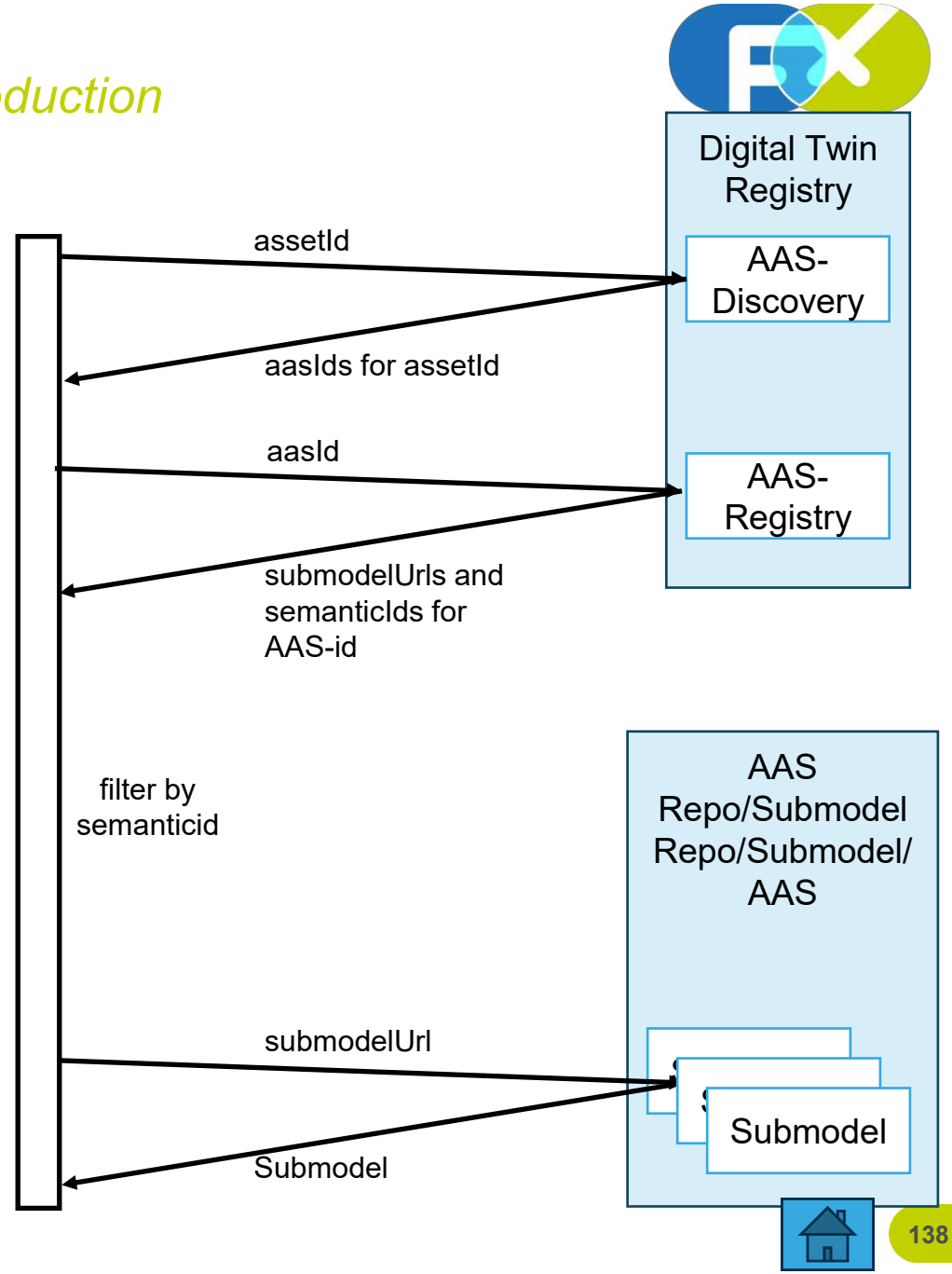
Read our Specification Documents!



Dataspace Connectivity

Profiling and Extending the AAS Specification to use it in production





Way forward

Global Standards and Implementations ready

- As digital twins evolve into a central asset for industrial value creation, the ability to securely exchange and use their data across organizations becomes essential. Today's fragmented approaches often limit scale, adoption, and the impact of AI-driven applications.

- IDTA and International Data Spaces Association (IDSA) have now formalized a cooperation to connect two foundational standards:
  - the Asset Administration Shell (AAS) as the global standard for industrial digital twins, and
  - the Dataspace Protocol as the standard for trusted data exchange in decentralized data spaces.

- Together, these frameworks enable structured digital-twin data to be shared reliably across companies, industries, and entire value networks — strengthening interoperability and data sovereignty in industrial environments. The agreement was officially signed 12 March 2026, during a joint community event in Frankfurt.

https://www.linkedin.com/posts/international-data-spaces-association_industrial-data-ecosystems-need-both-interoperability-activity-7437871689759223808-l8c7/

FACTORY-X

MX-Port Leo

MX-Port Leo
Key Messages

If a company uses today's IDTA standards, it is already participating in Data Space Leo Level 1

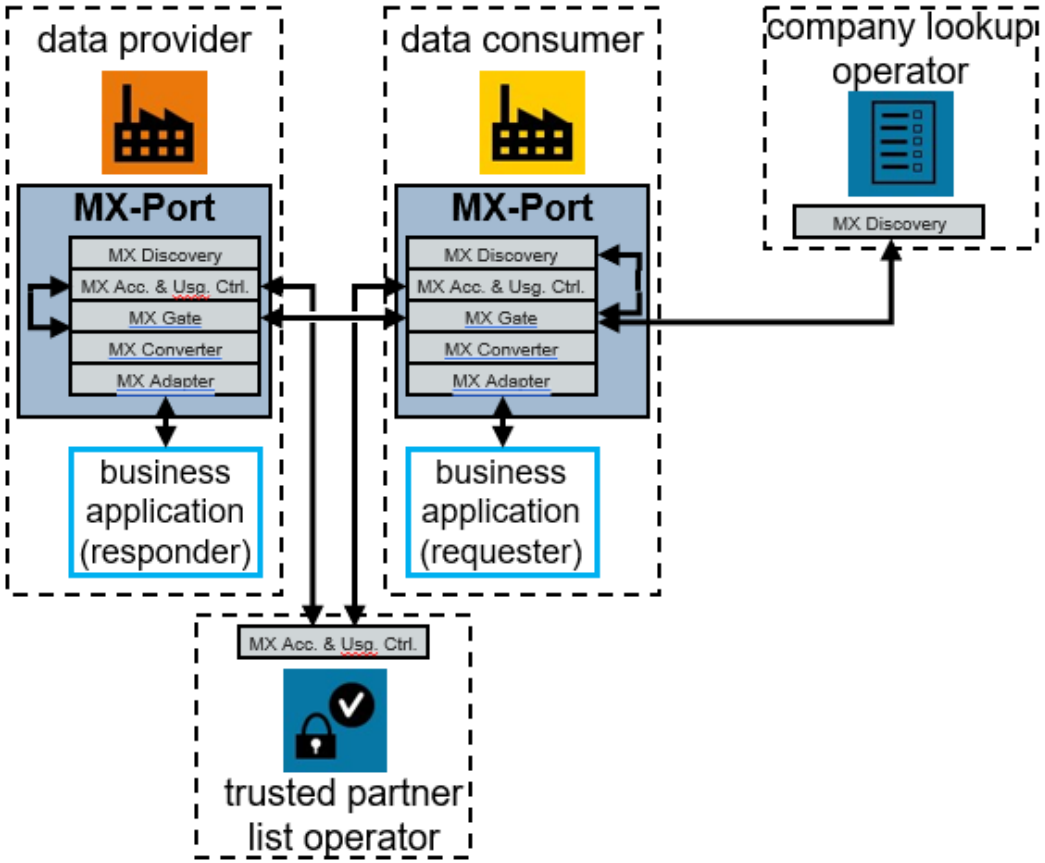
- Accordingly, all AAS activities involving automated data exchange contribute to Data Space Leo Level 1.
- Discovery and Access & Usage Control remain responsibilities that companies must solve individually at Leo Level 1.
- At Leo Level 1, no Shared Service Operator (Operating Company) is required.

Factory-X has developed extensions to IDTA standards with respect to Discovery and Access & Usage Control (i.e., for Leo Levels 2 and 3).

- IDTA e.V. plans to integrate these extensions into IDTA standards after completion of the Factory-X project (thus, IDTA e.V. will assume governance for the MX-Port Leo).
- For Leo Levels 2 and 3, a Shared Service Operator (Operating Company) is required.
- The role of the Shared Service Operator (Operating Company) can be taken over by an independent entity (e.g., IDTA GmbH) or by one or more companies participating in the data exchange.

MX-Port Leo

Secure AAS-based Data Exchange



Components of MX-Port Leo

The Challenge

- Low entry barriers to secure inter-company data exchange
- Scalability with regards to many participants in a data space
- Design (primarily) based on reuse of available technology

The FX-Solution and Offering

- Immediate entry possible for data providers and data consumers based on the Asset Administration Shell
- Gradual extensibility (with regards to many partners for data exchange) following the business needs and opportunities of a company
- Secure data exchange based on identities currently already managed by a company (no need for duplication of identities in another system)

MX-Port Leo

PCF Showcase realized with MX-Port Leo components

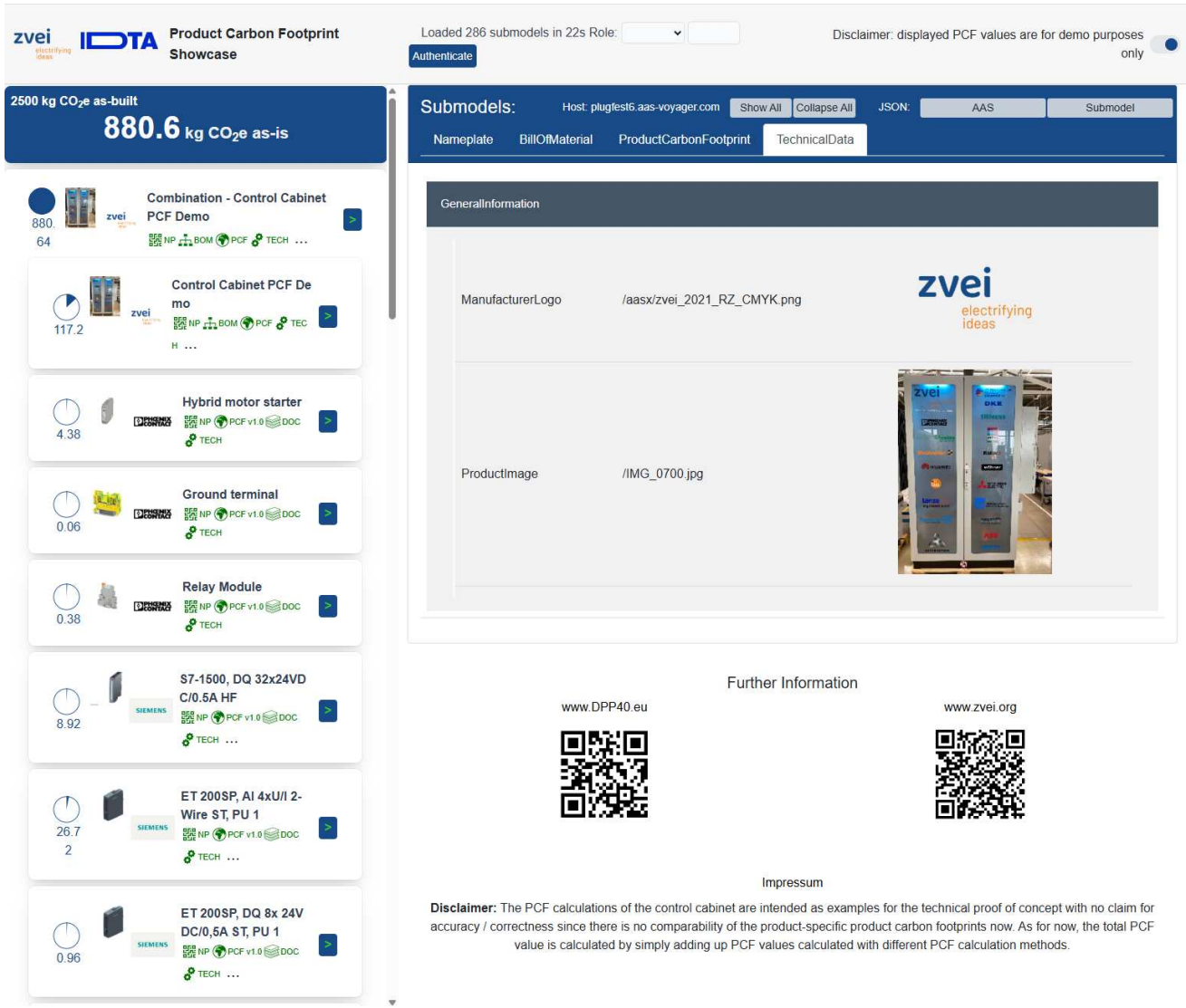
FACTORY-X

Description

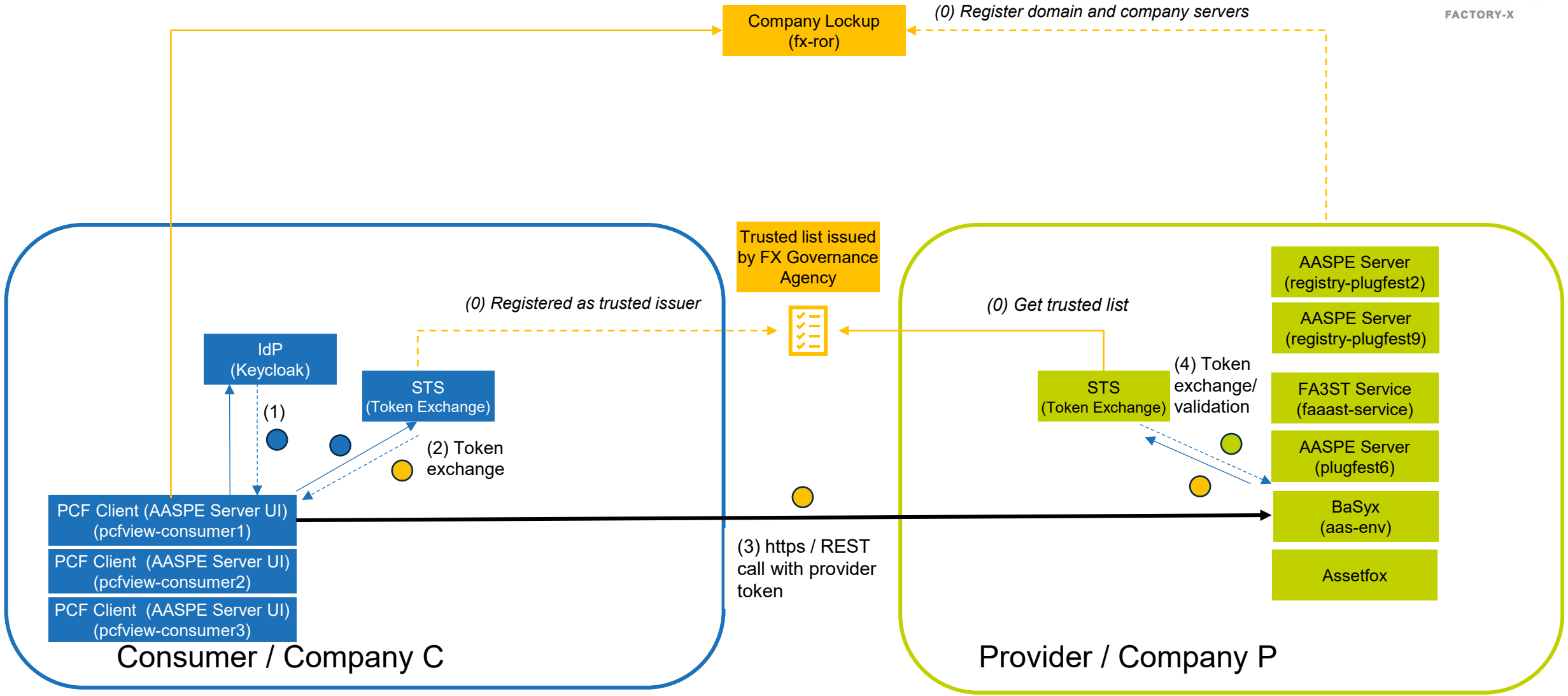
- Client application calculating the product carbon footprint (PCF) of a control cabinet
- Information retrieved from several component suppliers using MX-Port Leo's mechanisms for discovery and security
- Information in Submodel Templates (SMTs)

Benefit

- Unified data model provided by the Asset Administration Shell
- Unified discovery based on Company Lookup service
- Unified authentication and authorization based on FX Token and Trusted Partner List



MX-Port Leo: ZVEI PCF Showcase (Control Cabinet)



Token issued by Consumer IdP

Factory-X Identity Token (issued by Consumer)

Token issued by Provider

MX-Port Leo: Think Big, Start Small, Scale Up!*

FACTORY-X

Immediate entry possible for data providers and data consumers

- A data provider only needs to provide an AAS server in accordance with IDTA / IEC 63278
- No further requirements need to be met to provide data
- Data consumer can access data in accordance with IDTA / IEC 63278

Operation possible without 3rd party operating company

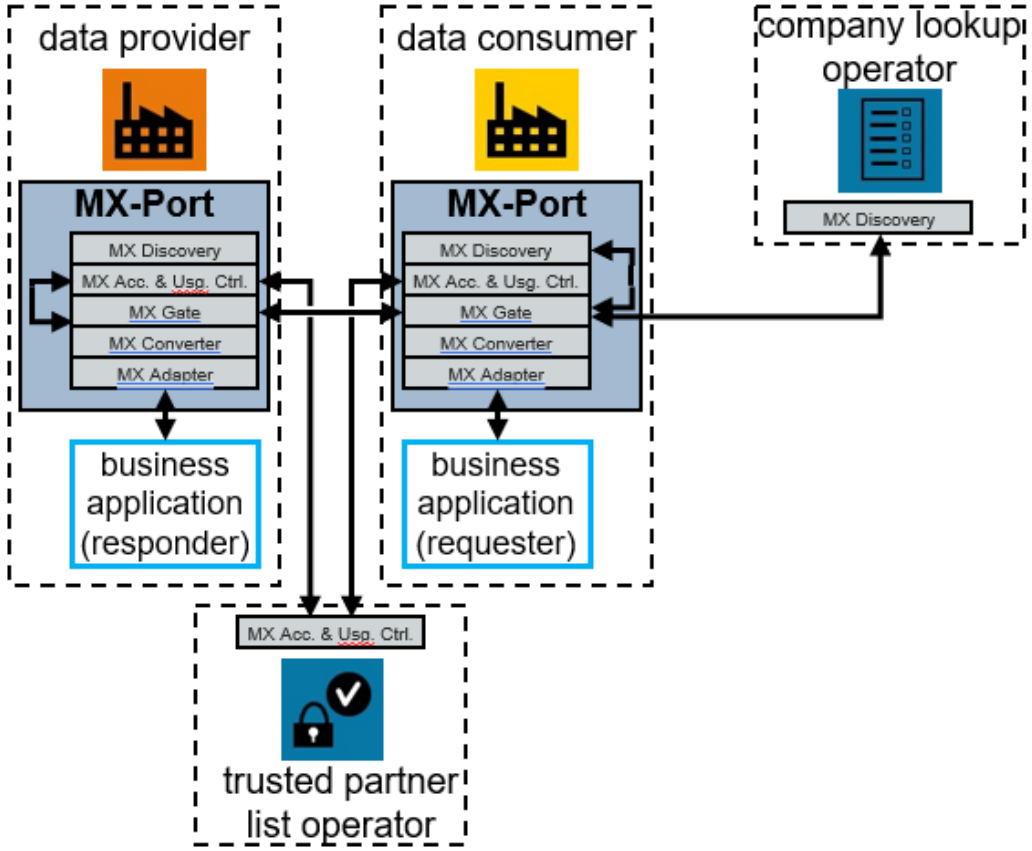
- Neither a data provider nor a data consumer needs to register at any 3rd party

Each company operates its own system to manage its identities

- Identities currently managed by a company do not need to be duplicated
- Identities extend down to the device/service and user level, not just the company level

Scalable regarding many partners for data exchange

- Gradually expandable following to business needs and opportunities of a company



*) Asset Administration Shell – Quick Start Guide

MX-Port Leo: Steps for Gradual Extension of Inter-Company Data Exchange

Leo is based on successive levels "$Step_n$"

- Companies submitting to the rules underlying "$Step_{n+1}$" can also share data with companies submitting to the rules of "$Step_n$" only
- For a company to progress to a higher Step, an investment is required
  - Regarding governance additional rules must be met
  - Regarding technology additional software services must be implemented

Main levels of MX-Port configuration "Leo"

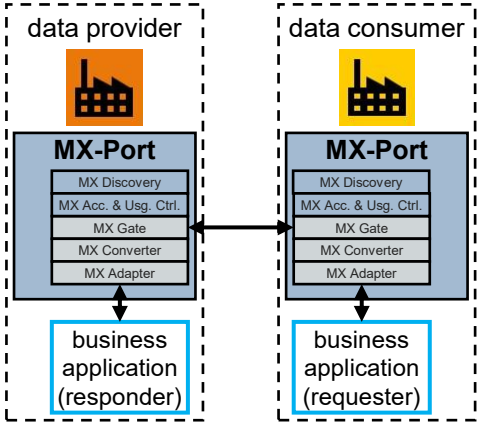
- **Step 1:** standardized internal data exchange based on MX Gate, MX Converter, and MX Adapter
  - Making the own data understandable and accessible is an essential prerequisite for any cross-company data exchange
  - Regarding MX Discovery and MX Access and Usage Control, the two partners agree individually at this stage
- **Step 2:** standardized MX Discovery
  - The basis is a list of standardized company lookup information through which a data consumer can find a data provider's AAS server
  - The data consumer can maintain the list entries itself or use a 3rd party operating company
- **Step 3:** standardized MX Access and Usage Control
  - The basis is a list of trusted partner entries
  - The data provider can maintain the list itself or use a 3rd party operating company
  - The use of a 3rd party simplifies the onboarding of new partners

MX-Port configuration “Leo” paves the way for companies to be able to share data with many partners in the future

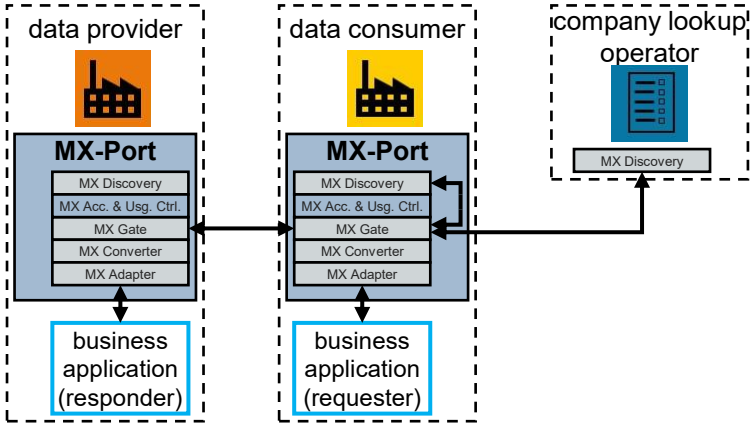
building on each other

building on each other

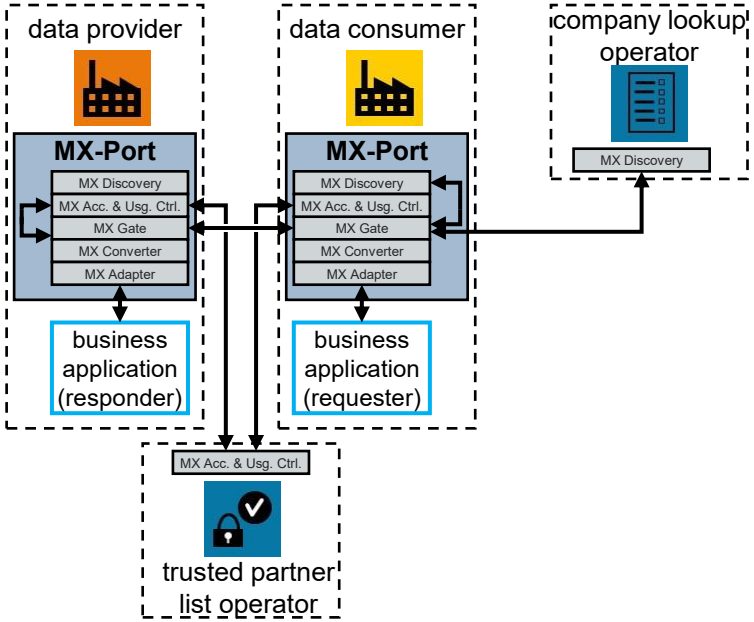
Step 1: standardized common data models and data access



Step 2: standardized discovery of the data provider



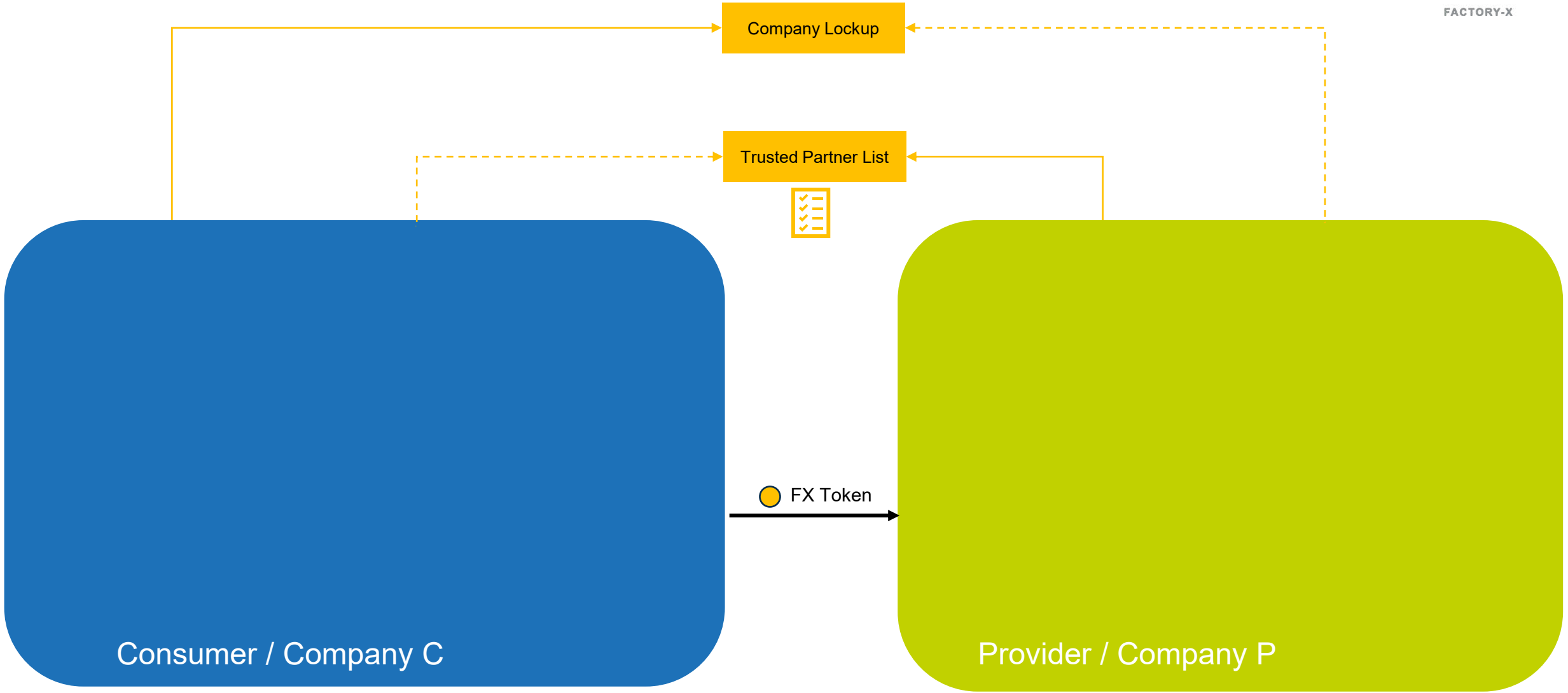
Step 3: standardized concepts for data sovereignty and trust



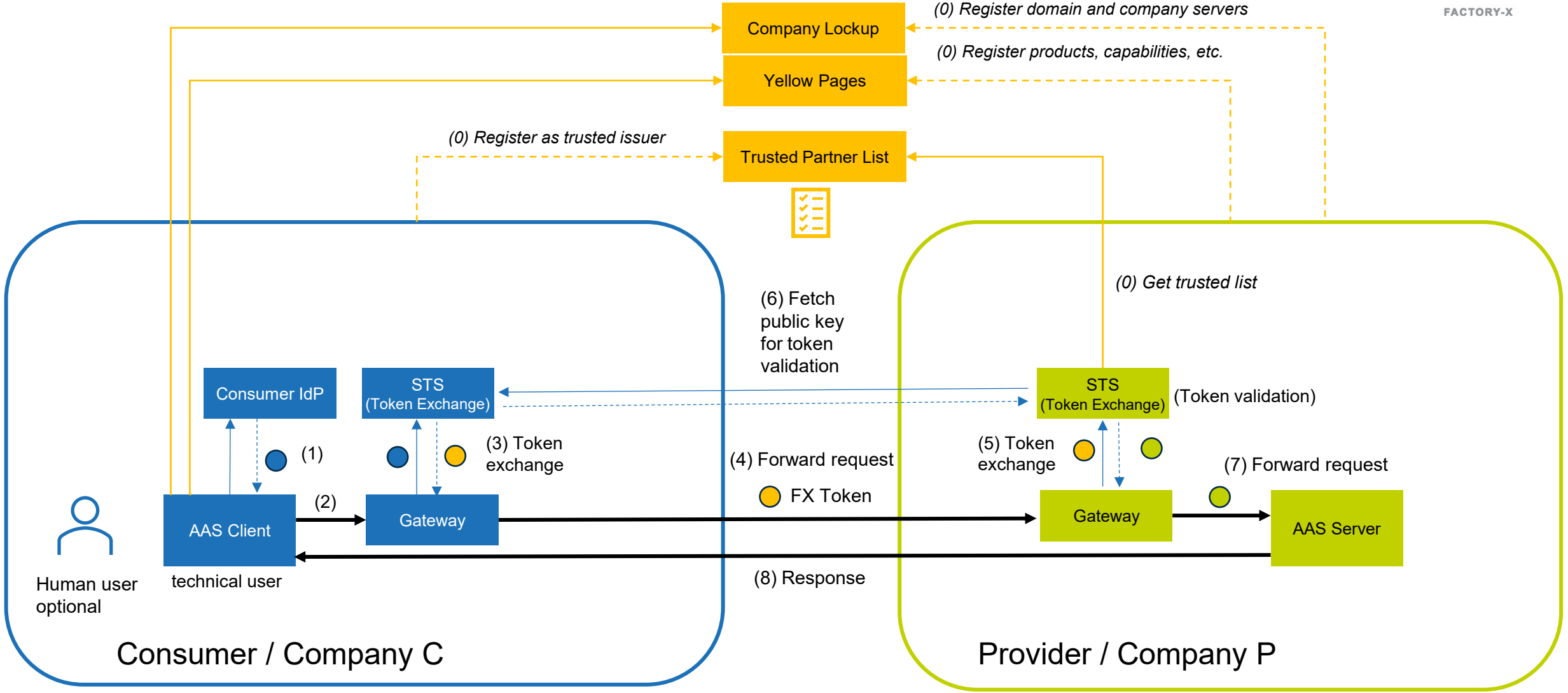
MX-Port configuration “Leo”

Note: Step 2 (additional discovery options) and Step 3 (additional security options) can be swapped

MX-Port Leo in a Nutshell



MX-Port Leo: Reference Architecture



Token issued by Consumer IdP

Factory-X Identity Token (issued by Consumer)

Token issued by Provider

MX-Port Leo: MX Discovery

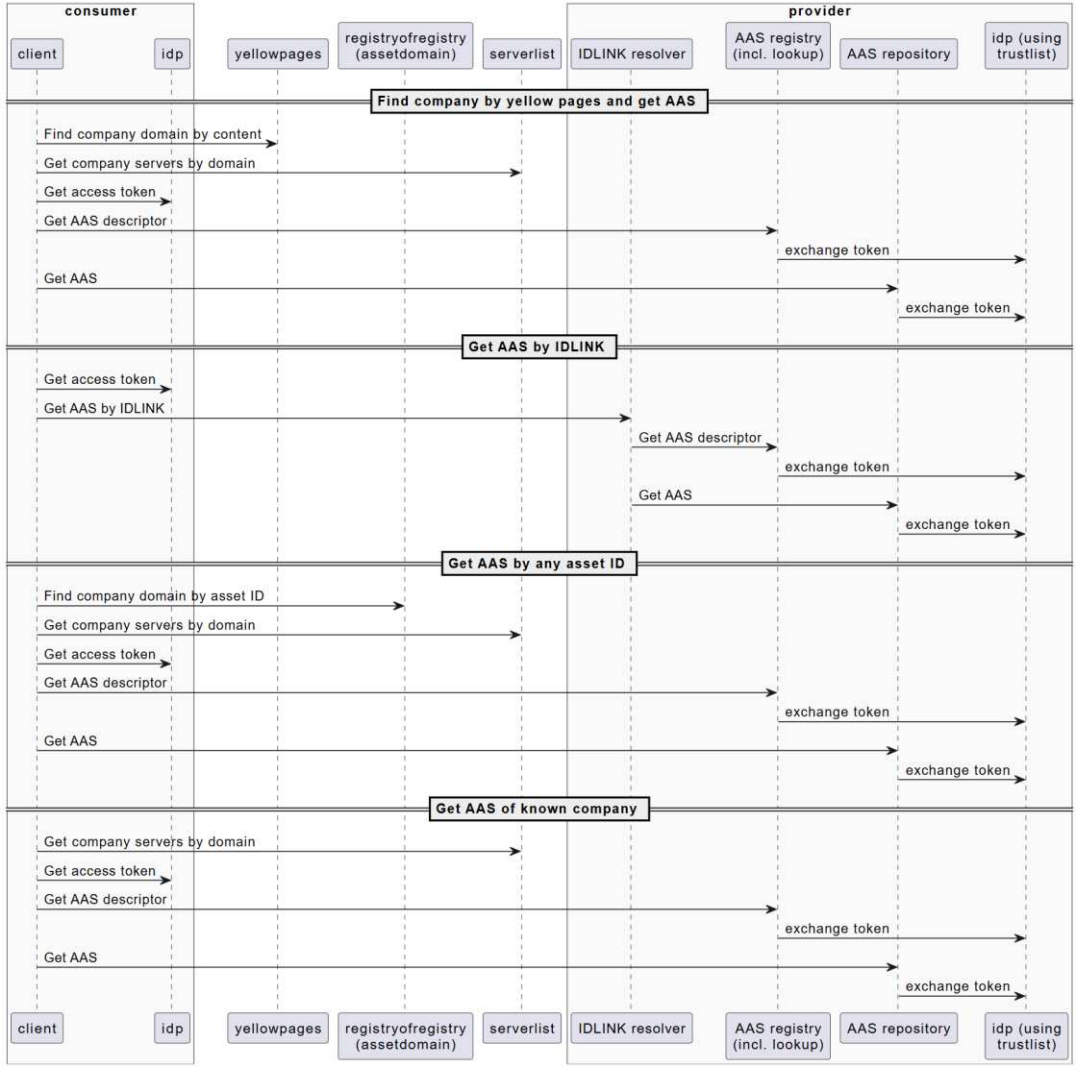
Two services facilitate the discovery of business partners

Main use cases

- Find company information (domain, endpoints, etc.) by company name, asset ID, and ID Link (REQ005)
  → **Company Lookup**
- Find company by content (query for products, capabilities, etc.) (REQ014)
  → **Yellow Pages**

General design: 2-step approach

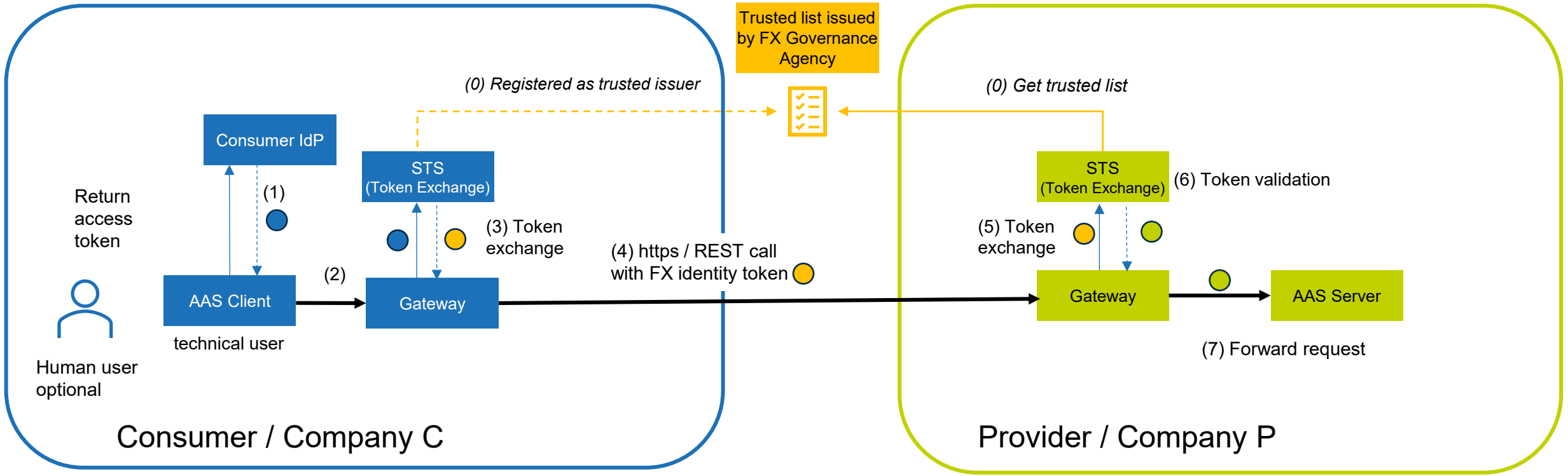
- First step: MX Discovery
  (MX-Port Leo shared service)
- Second step: AAS Discovery / AAS Registry
  (provider-side service at MX Gate level)



MX-Port Leo: MX Access and Usage Control

Consumer and Provider all trust a Factory-X Governance Body which onboards partners to Factory-X. This body issues/maintains a trusted list which includes public keys (and identities/names) of partner organizations. Token validation based on trusted lists is done on Provider side.

1) Client (technical user – human optional) authenticates and acquires access token from the Consumer's Authorization server
2) Send request to Gateway on Consumer side
3) STS (secure token service): Token exchange to create FX (identity) token
4) Then, the Client starts an AAS request using the Factory-X token
5) On Provider side, the Gateway initiates a token exchange to exchange the Factory-X token to an access token of the Provider domain
6) STS validates token: (a) token format, (b) trusted issuer via trusted list
7) Gateway forwards the request to the AAS server



Token issued by Consumer IdP

Factory-X Identity Token (issued by Consumer)

Token issued by Provider

MX-Port Leo: MX Access and Usage Control: Trusted List & FX Token

FACTORY-X

Trusted List

- XML document listing trusted issuers in the dataspace
- Based on established (ETSI) standards

FX Token

- Lean design (no redundancies)
- Principle of need-to-know (few claims)
- Organization and domain derived via trusted list
- Limited attack surface (claim “aud”)
- Identification of user (claim “email”) or service/device (claim “client_id”)
- Based on established (IETF) standards

```xml
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<TrustServiceStatusList>
  ...
    <TrustServiceProviderList>
        <TrustServiceProvider>
          ...
          <TSPServices>
                <TSPService>
                    ...
                    <ServiceName>https://sts.consumer.com</ServiceName>
                    ...
                </TSPService>
            </TSPServices>
        </TrustServiceProvider>
    </TrustServiceProviderList>
</TrustServiceStatusList>
```

```json
{
  "alg": "RS256",
  "typ": "JWT",
  "kid": "NDE5QThGNDN...NQ"
}
{
  "iat": 1760369590,
  "exp": 1760405590,
  "jti": "8c2f99b1-58d6-11f0-89f4-08002704c1e9h11s3rtbfk7t",
  "iss": "https://sts.consumer.com",
  "aud": ["https://gw.provider.com:8443/aas"],
  "sub": "1dbfb58bb28fcecbc299898692aa47d4c88615d0bad0563b8c8f29bd7e82600d",
  "client_id": "aas_browser",
  "typ": "clientflow"
}
```

MX-Port Leo: Summary / Key Aspects

- “Start small”: AAS as starting point – MX-Port Leo integrates in today’s setups for (inter-company) data exchange
- “Scale up”: additional options (“Steps”) for discovery and security as needed – well integrating into existing AAS architectures

---

- **Discovery**: two services for finding business partners: **Company Lookup**, **Yellow Pages**
- **Identity**: no new identities issued – Data Provider & Data Consumer use their available identities
- **Authentication**: based on **F-X Token** and light-weight **Trusted Partner List**
- **Authorization**: using available mechanisms in AAS Registry and AAS Repository based on AAS Security (IDTA-01004)
- **Usage Control**: description of usage policies associated with provided data supported
- **Operation**: central and decentral operation of Leo’s discovery (Company Lookup) and security (Trusted Partner List) possible

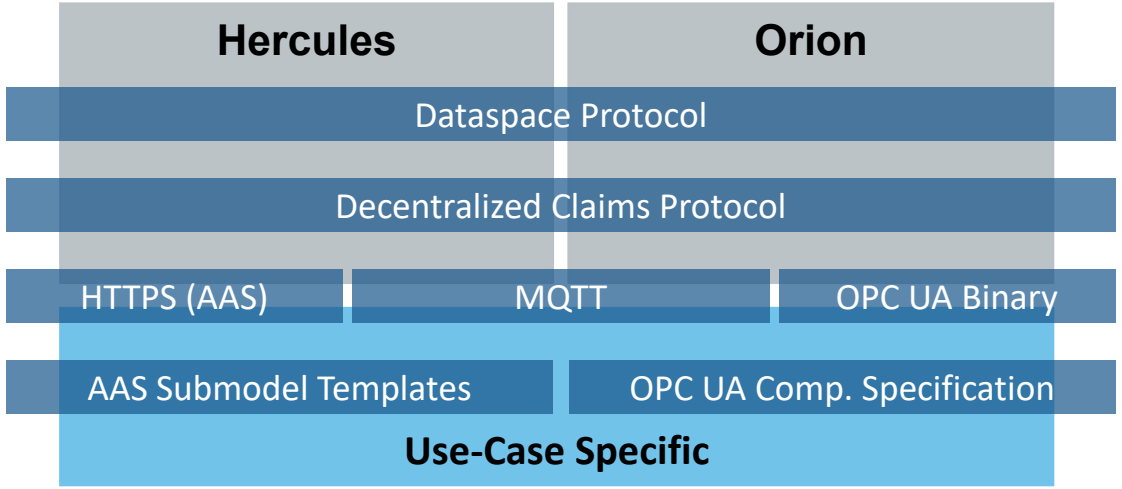
Low entry barrier, but individually and gradually expandable

FACTORY-X

MX-Port Orion

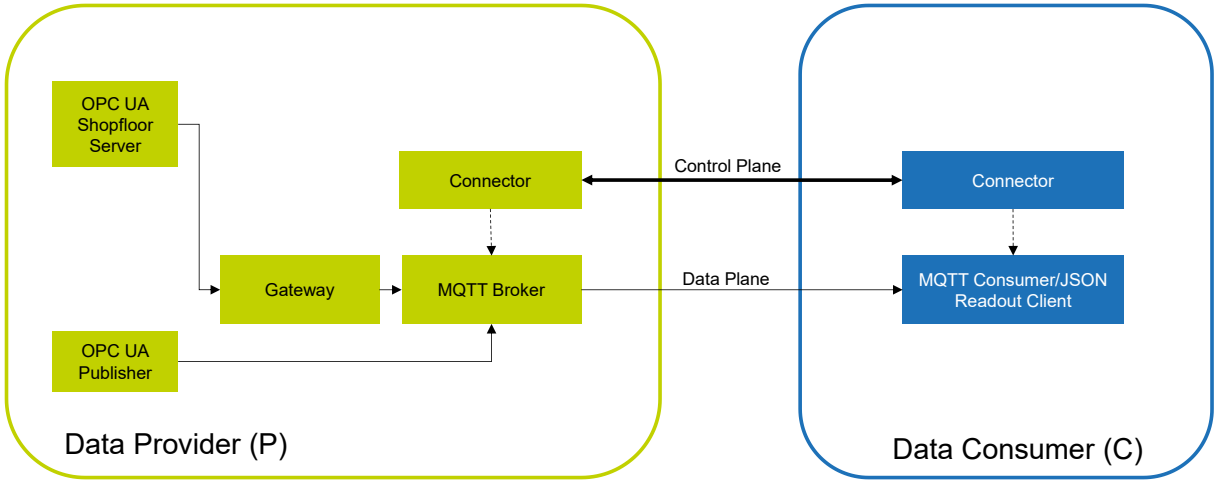
MX-Port Orion
Overview

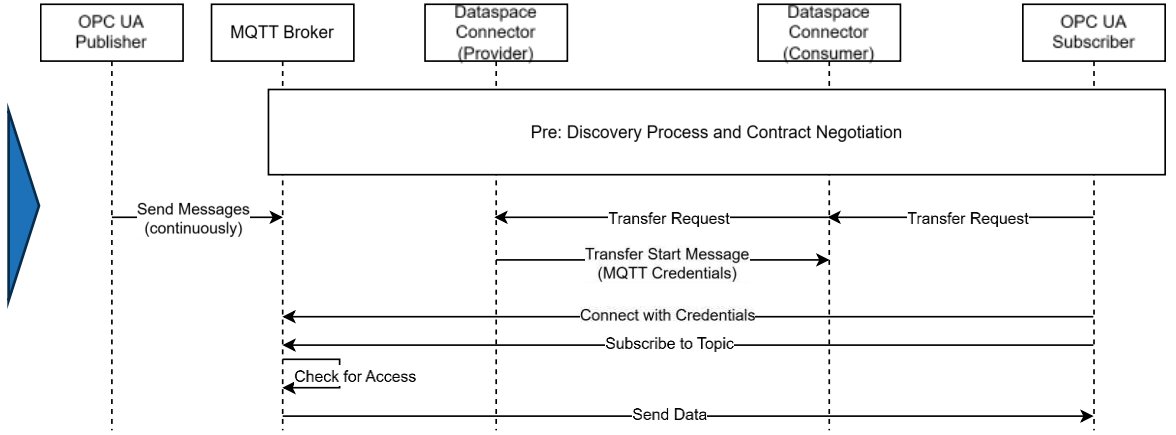
- **What is it?**
  - MX-Port concept based on OPC UA with Companion Specification and DSP / DCP
- **What can it do?**
  - Cross-company exchange of live shopfloor information
- **What is it for?**
  - Cross-company exchange of existing OPC UA information
  - (continuous) provision of machine-level data
  - External condition monitoring / analysis
  - Authorized and secure bidirectional communication with industrial equipment (e.g., remote control, remote maintenance)
- **Benefits**
  - OPC UA is an established and widely used technology
  - Semantic models / OPC UA Companion Specifications are available as freely accessible resources
  - Information models are developed and harmonized together with experts from machine and plant manufacturers
  - No additional effort caused by technology mismatches (conversion of information models)



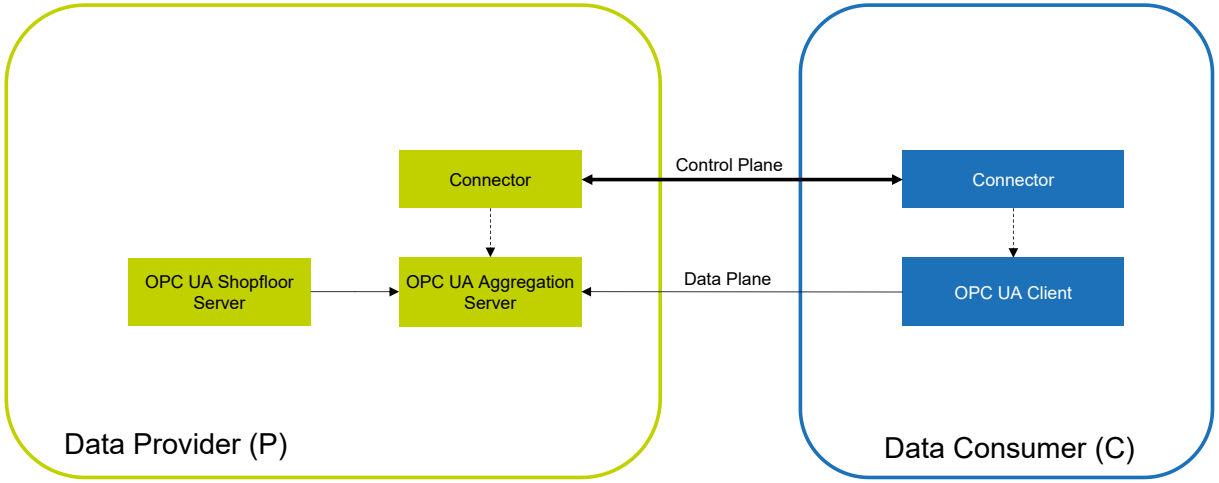
MX-Port Orion - Variants

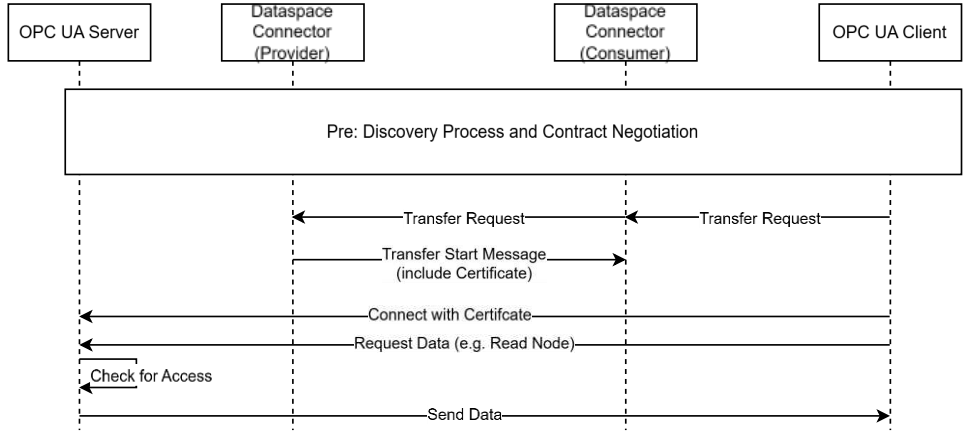
OPC UA over MQTT (Publish/Subscribe)





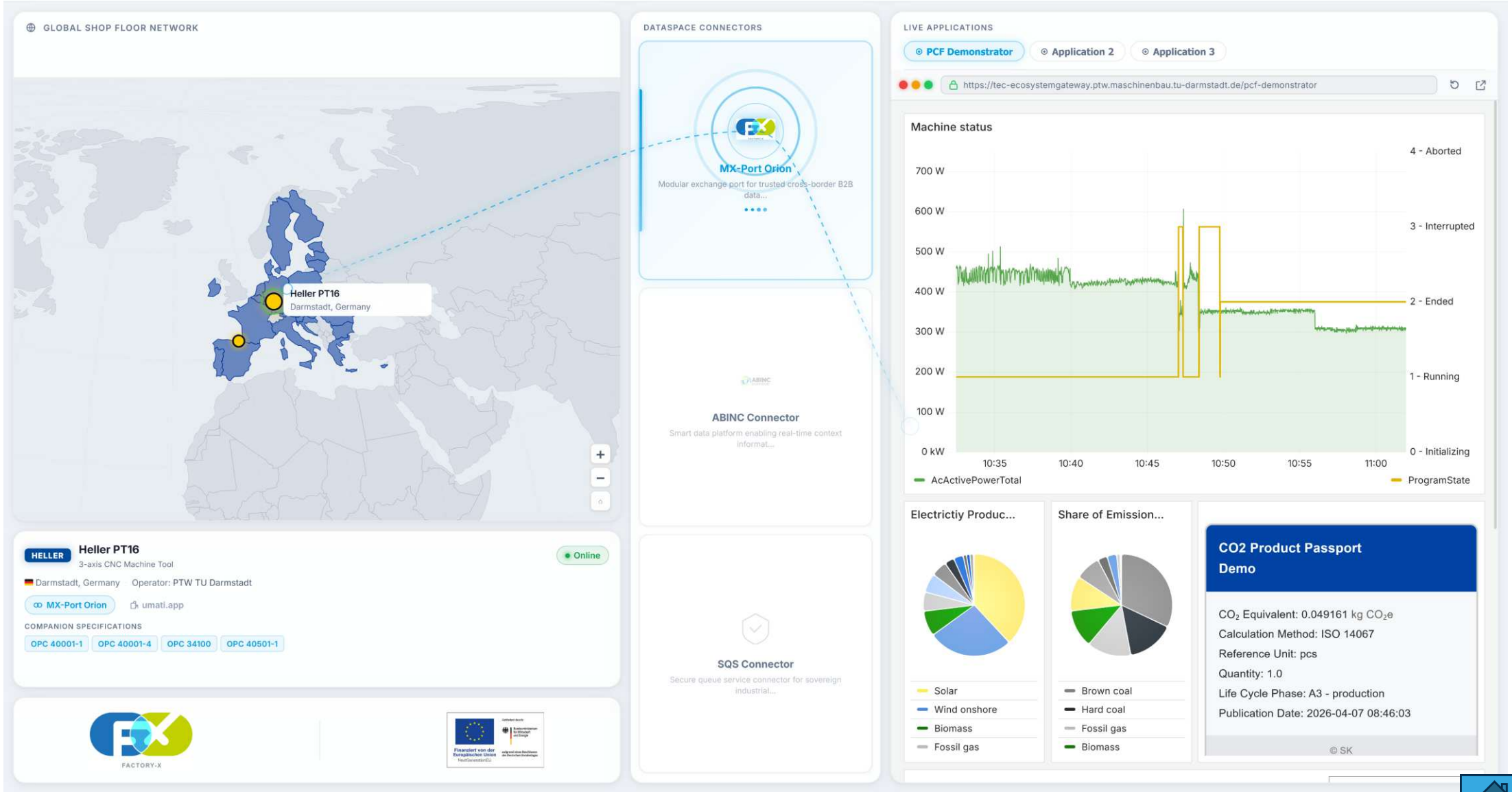
OPC UA Binary (Client/Server)





MX-Port Orion

Cross-Company Exchange of Shopfloor-Data in Action



Way forward Orion

Cooperation brings together two powerful ecosystems:

Catena-X, the first open, globally trusted collaborative data space for the automotive industry, offering multi-tier collaboration via sovereign, standardized data-sharing, based on interoperable infrastructure and semantic templates, and

OPC Foundation, the largest organization for industrial interoperability and the creator of OPC UA, the internationally recognized standard for secure and semantically enriched information exchange.

By aligning OPC UA's proven industrial modelling capabilities with the governance framework and cloud-based infrastructure of Catena-X, the two organizations aim to simplify data integration, reduce reporting errors, and enhance compliance with emerging regulatory demands like the DPP.

The parties agree to cooperate in the following four core areas:

Semantic Integration: Combine the OPC UA information modelling and Catena-X semantic templates to create the most comprehensive repository of interoperable, machine-readable models. This technology backbone will also support automated DPP generation from production data.

Open-Source Reference Implementations: Jointly develop and provide open-source reference implementations for key dataspace and interoperability components, enabling straightforward integration of OPC UA-based systems into the Catena-X data ecosystem.

Reference Architecture Alignment: Align the OPC Foundation's Cloud Initiative reference architecture with Catena-X's dataspace architecture to enable streamlined deployment from the shopfloor to the supply chain.

Industrial Ecosystem Enablement: Empower companies to leverage their existing OPC UA tools and infrastructure to meet emerging regulatory requirements, particularly the DPP, while reducing integration costs and accelerating time-to-compliance.

Catena-X and OPC Foundation Join Forces to Enable Seamless Industrial Data Exchange for the Digital Product Passport - Catena-X

FACTORY-X

Manufacturing-X

MX wide coordination

Our focus

- Collaboration with international stakeholders through meetings, conferences and workgroups to ensure that Manufacturing-X is well aligned internationally.
- Tight collaboration with all projects under the Manufacturing-X umbrella to identify gaps, overlaps and discrepancies, that need to be resolved in order to achieve interoperability.
- Working with all projects under the Manufacturing-X umbrella to understand specific requirements for governance and at the same time identify aspects that need to follow a joint governance

Goal

Ensure the interoperability of all projects under the Manufacturing-X umbrella both on a national as well as on an international level.

Key Results

- Launch of the International Manufacturing-X Council.
- Launch of the Manufacturing-X Guidance Board
- Launch of various Factory-X and Manufacturing-X web sites
- Proposal for a cross Manufacturing-X Governance

Motivation & Big Picture

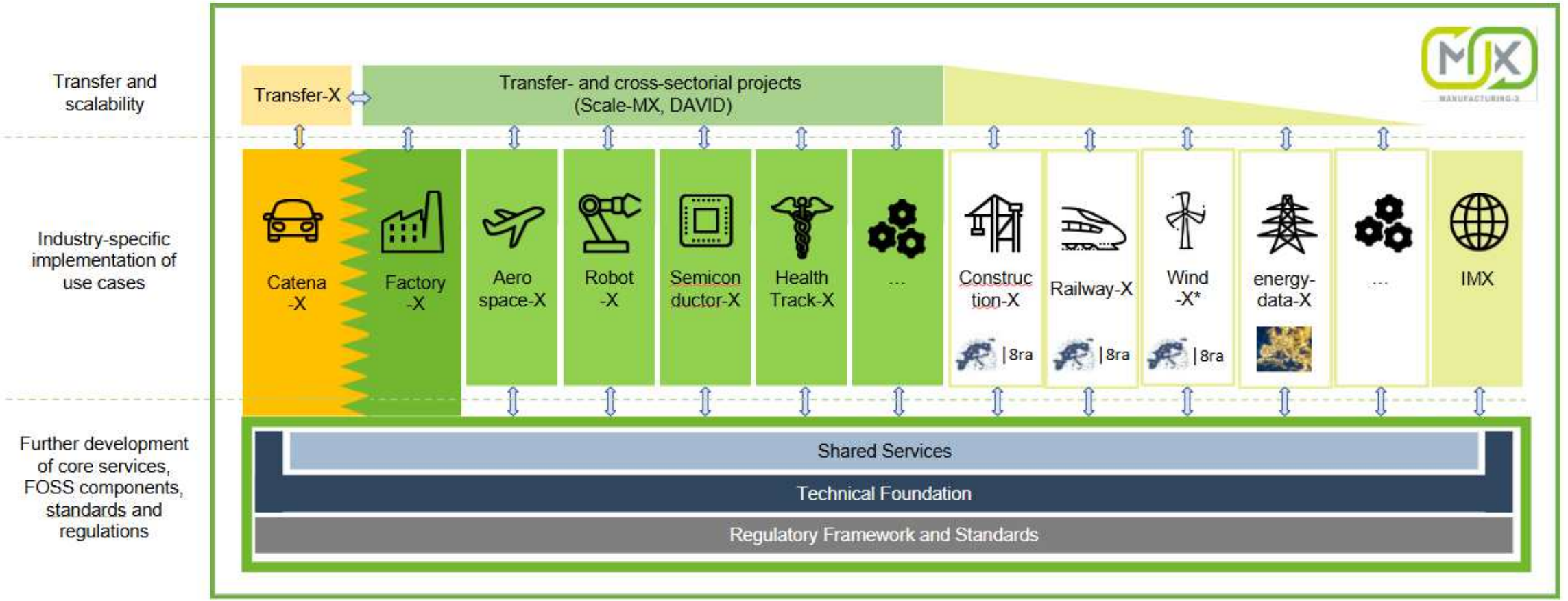
International Manufacturing-X (IMX): Make Data Work

IMX will implement a federated, decentralized and collaborative data ecosystem for smart manufacturing.
Open, global and cross-industry, following FAIR Data Principles.

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

Projects

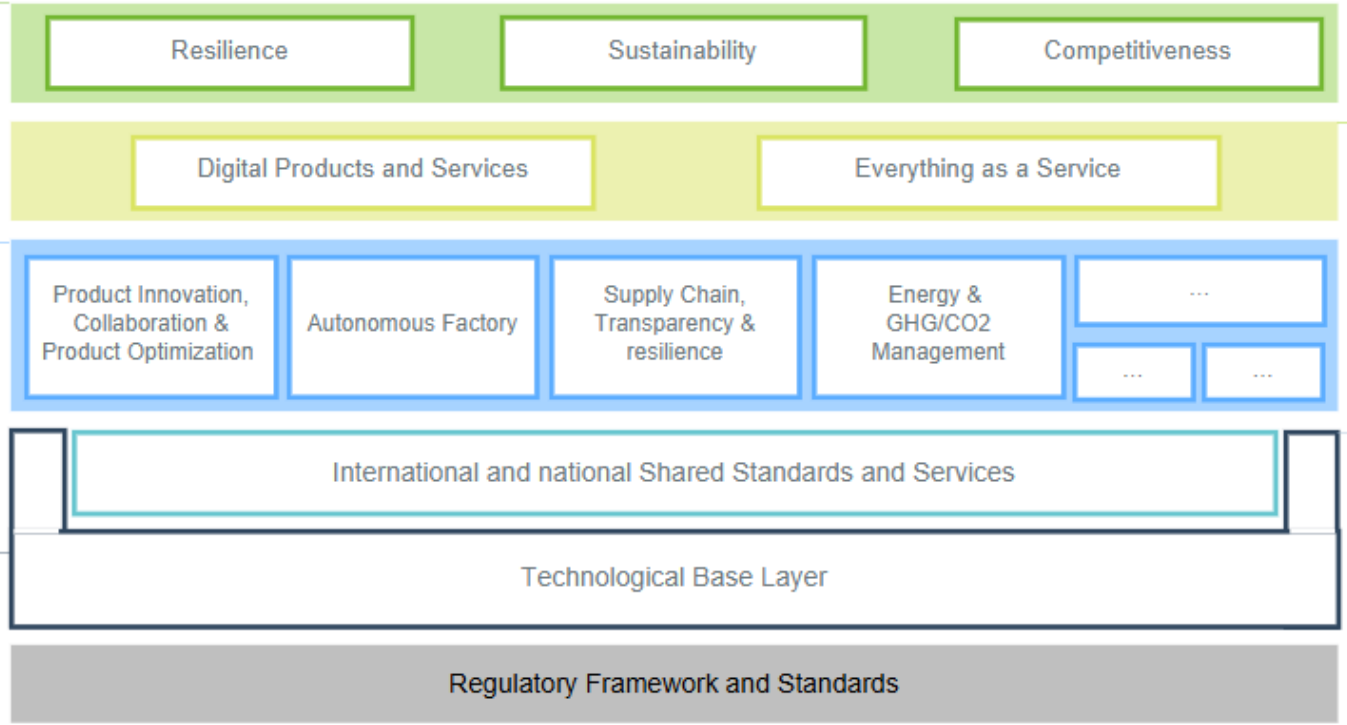
Landscape of Manufacturing-X projects in Germany



Motivation & Big Picture

Foundational Framework for IMX

A common guideline for IMX activities and international stakeholders.



Strategic Goals

International Manufacturing-X develops the foundations for a resilient and competitive industry in a sustainable society.

Exemplary Cross-Industry Use Cases

International Manufacturing-X addresses cross-industry use cases based on a collaborative use of data with high economic and ecological impact.

Foundation

International Manufacturing-X defines global standards and runs a basic technical infrastructure to guarantee interoperability and sovereignty.

Business Models

International Manufacturing-X enables innovative business models based on a interoperable data-ecosystems

Capabilities

International Manufacturing-X enables development and deployment of fundamental services driving the federated data ecosystem.

Requirements

International Manufacturing-X builds on a common technical, organizational and legal framework and contributes to the future development in cooperation with international law.

International Manufacturing-X

Make Data Work

FACTORY-X

What has happened so far:

2023 July Initiation Brussels, Belgium

2023 October Inauguration Tokio, Japan

2024 February Kick-off Paris, France

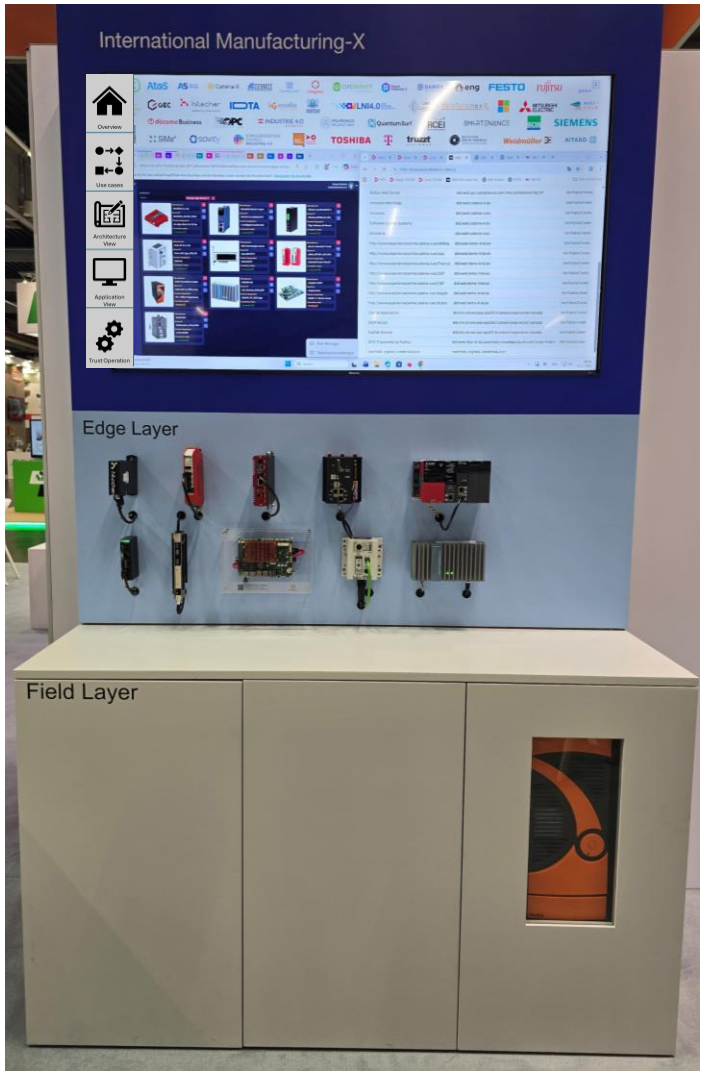
2024 Novem. USA/ CESMII

2025 May Athens/ Greece

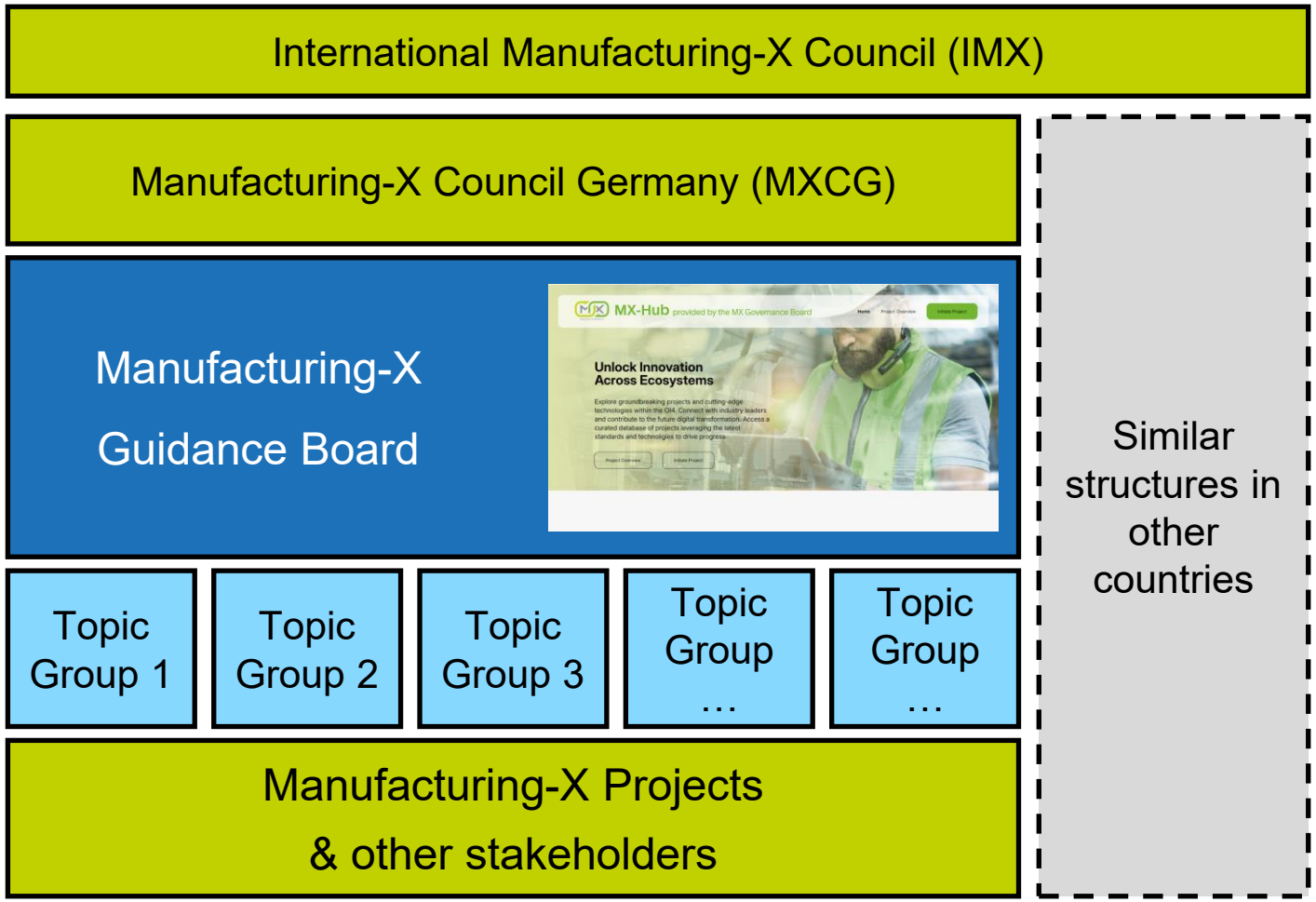
2025 Nov. Copenhagen/ Denmark

International Manufacturing-X Council Showcase

- **14** Countries participate
- **Two** use cases (DPP and Edge AI)
- **Joint** Understanding and Realization of **Trustworthiness**



Making Manufacturing-X successful nationally
Manufacturing-X Guidance Board



What we do:

- **Identify:** analyze the participating projects for overlap including risks of incompatibility and redundancy,
- **Prioritize:** identify alignment potentials and sort them for expected impact to reach the stated goal,
- **Evaluate:** structure and compare options for each alignment potential,
- **Decide:** draw up a joint way to move forward together across all alignment potentials,
- **Communicate:** create transparency about the degree of alignment of all M-X projects and all decisions taken by the M-X Guidance Board
- **Advocate:** create transparency about the technology, administrative and organizational approaches how to become M-X compliant interoperable to a broad audience to inform potential upcoming projects.
- **Cooperate:** with other standardization initiatives like Gaia-X, Catena-X, IDTA, ISO, IEC, … in order to reuse what is already established

Project Overview Guidance Board

Manufacturing-X Topic Groups
Results & Deliverables

Topic Group	Results / Deliverables (done & in progress)
M-X Data Exchange Technologies incl. Data Exchange via AAS	Whitepaper Data Exchange & Interoperability (incl. M-X Port concept)
Identification of Participants in & across Dataspaces	Whitepaper Identity Management in Dataspaces
e2e Security Architecture Industrial Dataspaces	Security-Concepts for secure implementable Architectures, Risk Management in Dataspaces, Control Catalogues etc
M-X Governance	M-X Governance Model and continuation topics
Product Carbon Footprint (PCF)	M-X PCF Rulebook Guidelines
Collaborative Engineering	Guidance Doc Collaborative Engineering
Circular Economy	R-Grading Whitepaper Circular Economy and Digital Product Passport (DPP)
Asset Data Modelling / DMP / DPP	Guidance Doc Asset Data Modelling
Modular Production	Reference-Architecture for Modular Production
Data Governance	Whitepaper Data Governance
Demo & Test Environment	M-X Demo Environment Set-Up Guideline M-X Test Environment Whitepaper

Thank you

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View our LinkedIn Profile