RE4DY

MANUFACTURING DATA NETWORKS

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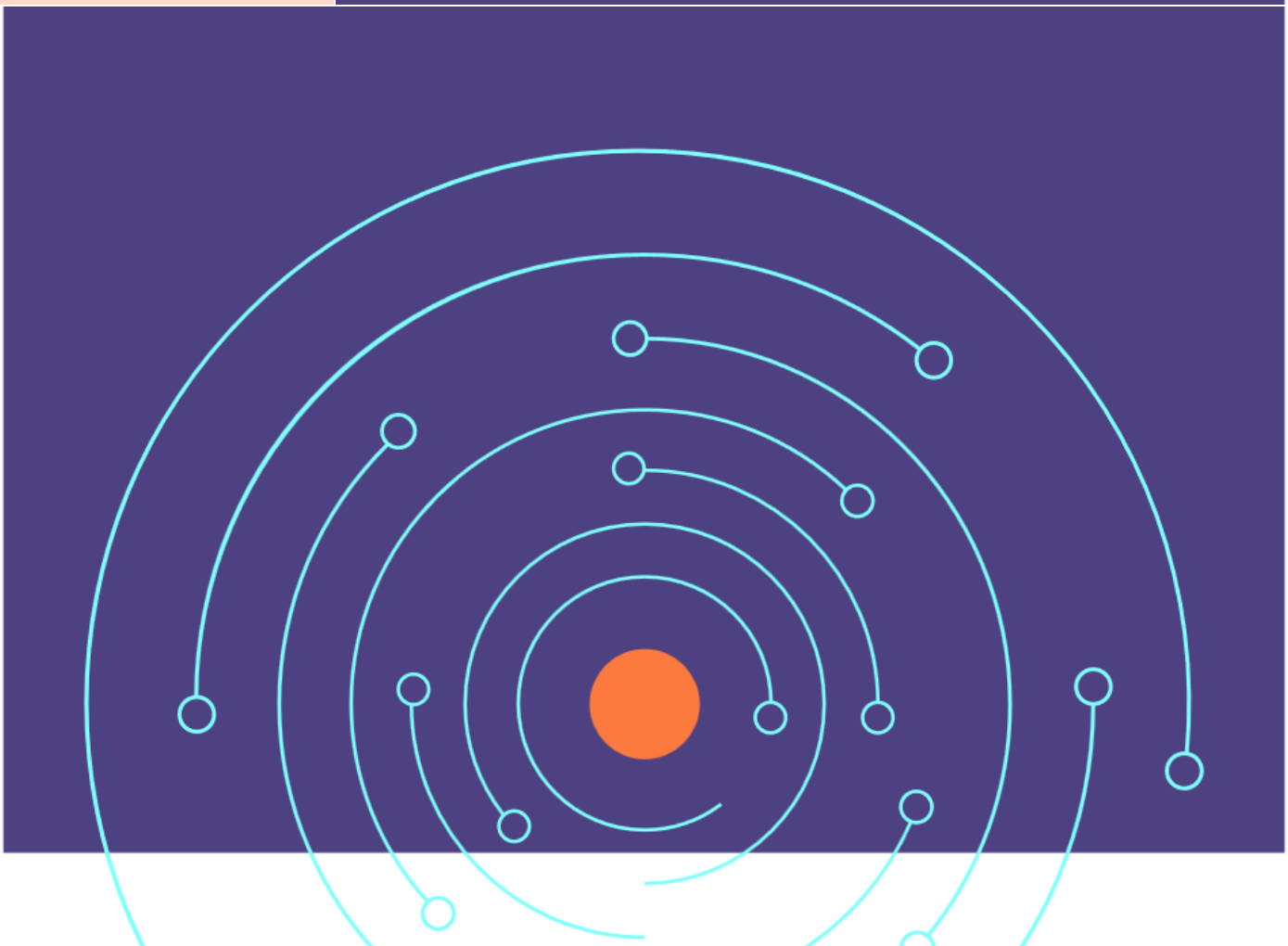

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Further Information

More information about the project could be found on project website: https://re4dy.eu/

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Project Partners

Number	Participant organisation name	Acronym
1	ASOCIACIÓN DE EMPRESAS TECNOLÓGICAS INNOVALIA	INNO
2	CHALMERS TEKNISKA HOGSKOLA AB	Chalmers
3	INTERNATIONAL DATA SPACES EV	IDSA
4	VOLKSWAGEN AUTOEUROPA, LDA	VWAE
5	ASSECO CEIT AS	CEIT
6	UNINOVA-INSTITUTO DE DESENVOLVIMENTO DE NOVAS TECNOLOGIAS-ASSOSIACAO	UNI
7	FILL GESELLSCHAFT MBH	FILL
8	AVL LIST GMBH	AVL
9	VISUAL COMPONENTS OY	VIS
10	UNIVERSIDAD MIGUEL HERNANDEZ DE ELCHE	UMH
11	ATLANTIS ENGINEERING AE	ATLANTIS
12	DATAPIXEL SL	DATA
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21	NOVA ID FCT - ASSOCIACAO PARA A INOVACAO E DESENVOLVIMENTO DA FCT	NOVA
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24	GRUPO S 21SEC GESTION SA	S21SEC
25	UNIVERSITAT POLITECNICA DE VALENCIA	UPV
26	CONSIGLIO NAZIONALE DELLE RICERCHE	CNR
27	SOCIEDAD ANDALUZA PARA EL DESARROLLO DE LAS TELECOMUNICACIONES SA	SANDETEL
28	SWITZERLAND INNOVATION PARK BIEL/BIENNE AG	SSF
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30	FRAISA SA	Fraisa SA
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Executive Summary

Deliverable 3.1, Resilient & Sustainable "Data as a Product" Computing and Data Space', is the first deliverable of work package 3. The main scope of WP3 ("Continuity Management Toolkit for Industrial Digital Thread & Cognitive Twin Fabrics") is to establish a network of Testing and Experimentation Facilities (TEFs) and European Data Spaces for qualifying digital 4.0 continuum open systems & OSS tools. The task 3.1, "TEF network set-up & experimentation plan", as the first task of WP3, enabled in the establishment of a TEF network. This task is set to reach two main objectives, firstly, to establish a network of TEFs for qualification of open systems and OSS tools and secondly, to support the design of a robust experimentation plan for qualification of technical assets in task T3.8.

Consequently, this document represents the steps to form a network of TEFs benefiting from "DR-BEST" methodology to analyse the service portfolio of each TEF to have a detailed perspective on the services which can be provided to the potential stakeholders. In addition, focusing on "REMOTIZATION" aspect of "DR-BEST" framework which enables the interoperability of the TEF network giving the opportunity to provide services remotely or collaborating remotely among the TEF network members, in this regard, several tools and actions have been described both in conceptual and practical point of view implemented at each TEF. After establishing the TEF network, the second goal, facilitating the design of a robust experimentation plan for task 3.8, has been considered. To that end, and based on the findings of previous chapters, the opportunities and challenges have been briefly discussed, and possible scenarios have been explained in order to provide added value to potential customers or stakeholders who rely on the collaborative services that the TEF network can provide. The recommended scenarios lay the groundwork for asset deployment and qualification, which will be carried out in task 3.8, without limiting their future ideas and initiatives.

Finally, in order to deal with RE4ADY goal of providing suitable data value ecosystems to facilitate trusted sharing and effective distributed data processing over common data spaces, the deliverable briefly introduces, on the hand, the concept of RE4DY "Data as a Product" (DAP) and Data Connection Profile (DCP) – aimed at offering the data consumers access to the data from the use cases following the Data as a Product principles. On the other hand, it also introduces the initial description of the different tools (commercial and open source) brought to the project by partners and their mapping to the IDSA building blocks to understand what aspects of the data space concept (and more particularly, the RE4DY data space) could be fulfilled with the available tools.

List of Acronyms/Abbreviations

Acronym/Abbreviation	Description
API	Application Programming Interface
AWS	Amazon Web Services
B	Business
CA	Consortium Agreement
CFD	Computational Fluid Dynamics
CIDM	Common Industrial Data Model
CPPS	Cyber-Physical Production System
CPS	Cyber-Physical System
CRUD	Create, Read, Update, Delete
D	Data
DAAP	Data as a Product
D-BEST	Data-Business-Ecosystem-Skill-Technology
DC	Data Containers
DCP	Data Connection Profile
DES	Discrete Event Simulation
DIH	Digital Innovation Hub
DoA	Description of Action
DR-BEST	Data-Remotization-Business-Ecosystem-Skill-Technology
DT	Digital Twin
E	Ecosystem
E2E	End to End
EC	European Commission
EDIH	European Digital Innovation Hub
ETB	Ecosystem-Technology-Business
ETL	Extract, Transform, Load
FEM	Finite Element Method
GA	General Assembly
GDPR	General Data Protection Regulation
I4.0	Industry 4.0
I4MS	ICT Innovation for Manufacturing SMEs
ICT	Information and Communication Technologies
IDSA	International Data Spaces Association
IOF	Industry Ontology Foundry
IoT	Internet of Things
IPR	Intellectual Property Rights
IT	Information Technology
KPI	Key Performance Indicator
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
OGC	Open Geospatial Consortium
OPC UA	Open Platform Communications Unified Architecture

PoC	Proof of Concept
R	Remotization
R&D	Research & Development
RAM	Reference Architecture Model
RAMI 4.0	Reference Architectural Model Industrie 4.0
REI	Responsible Exploitation & Innovation Board
S	Skills
SME	Small and Medium Enterprise
T	Technology
TEF	Testing and Experimentation Facility
TRL	Technology Readiness Level
WP	Work Package

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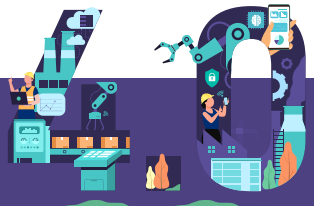


1 Introduction

1.1 Deliverable purpose and scope

The main scope of WP3 ("Continuity Management Toolkit for Industrial Digital Thread & Cognitive Twin Fabrics") is to establish a network of Testing and Experimentation Facilities (TEFs) and European Data Spaces for qualifying digital 4.0 continuum open systems & OSS tools.

Being the first task of WP3, the T3.1 "TEF network set-up & experimentation plan" assisted in the establishment of a network of TEFs. The TEF network will be configured as a result of this task in order to validate open systems and OSS tools. To make it easier for future integrations and to support the creation of a solid experimentation plan for the qualification of technical assets in T3.8, the DIMOFAC (Digital Intelligent Modular FActory) didactic and learning factories provided by INNO, SSF, and POLIMI will be set up and connected. A first instantiation of the existing assets brought by partners will also be carried out. Consequently, the aim of this deliverable is to present the process of TEF network establishment as well as benefiting from this network in order to foster reaching a resilient and sustainable "Data as a Product" computing and data space. Furthermore, the document is expected to aid in the preparation of an experimentation plan for the project's facilities and technical assets mentioned in task 3.8 by exploiting concepts and tools from DIMOFAC, another European project (Grant Agreement n° 870092) and applying these concepts and tools for a small-scale experiment among different TEFs of the established network.

Finally, the deliverable briefly introduces, on the hand, the concept of RE4DY "Data as a Product" (DAP) and Data Connection Profile (DCP) – aimed at offering the data consumers access to the data from the use cases following the Data as a Product principles – and which is also discussed in further detail in WP2 architecture documents. On the other hand, it provides the initial description of the different tools (commercial and open source) brought to the project by partners and their mapping to the IDSA building blocks to understand what aspects of the data space concept (and more particularly, the RE4DY data space) could be fulfilled with the available tools. These tools will also participate and collaborate in the various experiments to be carried out within the context of WP3 and the pilots use cases.

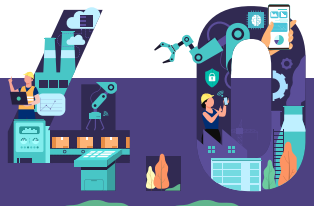
1.2 Structure of the deliverable

The document is structured in seven main sections.

Section 1 is dedicated at introducing the purpose and scope, structure, and the relation of WP3 with other work packages of the project.

Section 2 presents the context, explaining the reference framework adopted to analyse service portfolio of TEFs while mentioning the contribution taken from DIMOFAC detailing the adopted tools and concepts.

Section 3 presents the network formation and service portfolio analysis of contributing TEFs.



Section 4 provides information for preparation of an experimentation plan using a first installation of assets.

Section 5 introduces the concept of RE4DY "Data as a Product" (DAP) and Data Connection Profile (DCP)– aimed at offering the data consumers access to the data from the use cases following the Data as a Product principles.

Section 6 presents the initial description of the different tools (commercial and open source) brought to the project by partners and their mapping to the IDSA building blocks.

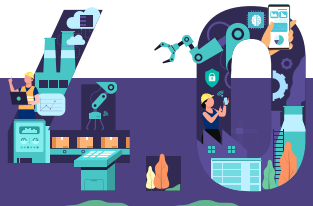
Finally, Section 7 summarizes the deliverable and provides the final conclusions.

1.3 Document status

The current version of the deliverable is the result of the revision after second round of internal review.

1.4 Relation with other work packages

As the initial task of WP3, it receives general guidelines and requirements for data connection profiles and "Data as a Product" containers from WP2 ("Digital 4.0 Continuum Reference Architecture for Active Resiliency") as well as data-driven experimentation requirements while defining the TEFs network which is essential for qualification of digital 4.0 continuum open systems and OSS tools. Additionally, it lays the groundwork for asset deployment and qualification in the Testing & Experimental Facility (TEF), as described in project task T3.8.



2 RE4DY Testing and Experimentation Facility (TEF): Context

2.1 The DR-BEST reference model for Service Portfolio configuration

"The large-scale reference testing and experimentation facilities (TEFs) will offer a combination of physical and virtual facilities, in which technology providers can get primarily technical support to test their latest AI-based software and hardware technologies (including AI-powered robotics) in real-world environments. This will include support for full integration, testing and experimentation of latest AI-based technologies to solve issues/improve solutions in a given application sector, including validation and demonstration. They will focus on testing mature AI-based technologies and solutions that have already been tested in the labs and have to be tested in real-world environments. TEFs seek to support technology providers with the necessary expertise to integrate and validate their solutions in the TEFs, but we also expect TEFs to involve end-users of the technologies to maximise its impact (in particular end-users can be involved in defining testing scenarios, protocols and metrics, most relevant and impactful to their sectors)"[1].

A preliminary service portfolio analysis is expected to be carried out in order to fully comprehend the capabilities and services offered by each TEF in the network with the goal of establishing a network of TEFs that can efficiently contribute. The Data-Remotization-Business-Ecosystem-Skills-Technology (DR-BEST) reference model is proposed with the main goal of configuring DIHs service portfolios in a systematic manner.

The work of multiple projects from the third and fourth waves of I4MS led to the creation of the D-BEST reference model (Sassanelli and Terzi 2022a).

"The evolution of the D-BEST Reference Model grounds on the threefold Ecosystem Technology-Business (ETB) I4MS service model developed in the context of the Access to I4MS (XS2I4MS) proposal (a support action to advance the I4M ecosystem) and actually used in all the DIHNET.eu projects. The three categories composing the ETB model have been elaborated based on the experience of DIH stakeholders and also from the past experimented research in the frame of several projects from the EC's I4MS calls. the D-BEST reference model is grounded on five main macro-classes (Ecosystem, Technology, Business, Skills, Data), representing the main contexts in which the DIH can operate delivering services to its stakeholders, and is aimed at configuring the services composing the service portfolio of DIHs" (Sassanelli and Terzi 2022a).

The identification of the group of services that a DIH offers is known as the service portfolio (Sassanelli and Terzi 2022a). The following is the distinction between TEFs and European Digital Innovation Hubs (EDIHs). EDIHs bring together local economy actors to support local

[1] https://digital-strategy.ec.europa.eu/en/faqs/testing-and-experimentation-facilities-tefs-questions-and-answers

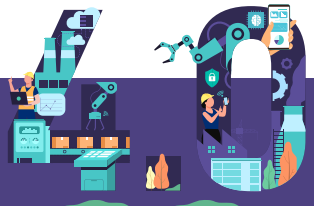
actors' digital transformation (build local ecosystems) and connect to other EDIHs across Europe. They also serve as the primary point of contact for all EU-funded AI activities in Europe, such as the TEFs. There are plenty of EDIHs. Their main goal is to "test before invest," or to assist users of digital technology in determining whether they can benefit from the technology in their environment before they buy it. One such technology has been developed enough to be used. This is different from the technologies tested in TEFs, which have not yet reached maturity to that point and require substantial testing and validation in real environments prior to deployment. For instance, a robot should perform extensive testing in a real environment before being deployed in hospitals. On the other hand, the TEFs are centralized shared resources that are available to all EDIHs and users of AI-solutions in general. TEFs are fewer in number. By validating them in actual settings, TEFs assist technology providers in creating new technological solutions and take a step them closer to the market. Results from this "centralised toolbox" should ideally be distributed (distribution channel) via the EDIHs to the local level once validated, if sufficiently mature, in order to empower all local businesses and users. A given technology should, in fact, be prepared (or have increased readiness level) to be deployed at an end-user site, for example via the "test before invest" activities of an EDIH, after successful validation in TEFs[2].

Given the differences and links between DIHs and TEFs, the DR-BEST reference model can also be applied to TEFs service portfolio analysis.

The DR-BEST reference model is divided into three levels: macro-classes, types, and classes. Each of the model's six macro-classes can be deduced in (second level) service types. The types of services represent the various groups of services provided by the TEF to its stakeholders in each of the six distinct macro-classes (first level). Furthermore, each type of service is subdivided into (third level) classes of services provided by the TEF (Sassanelli and Terzi 2022b).

To better present the DR-BEST methodology used in this deliverable, a detailed description of macro-classes, types, and their related services will be provided in the following pages.

[2] https://digital-strategy.ec.europa.eu/en/faqs/testing-and-experimentation-facilities-tefs-questions-and-answers



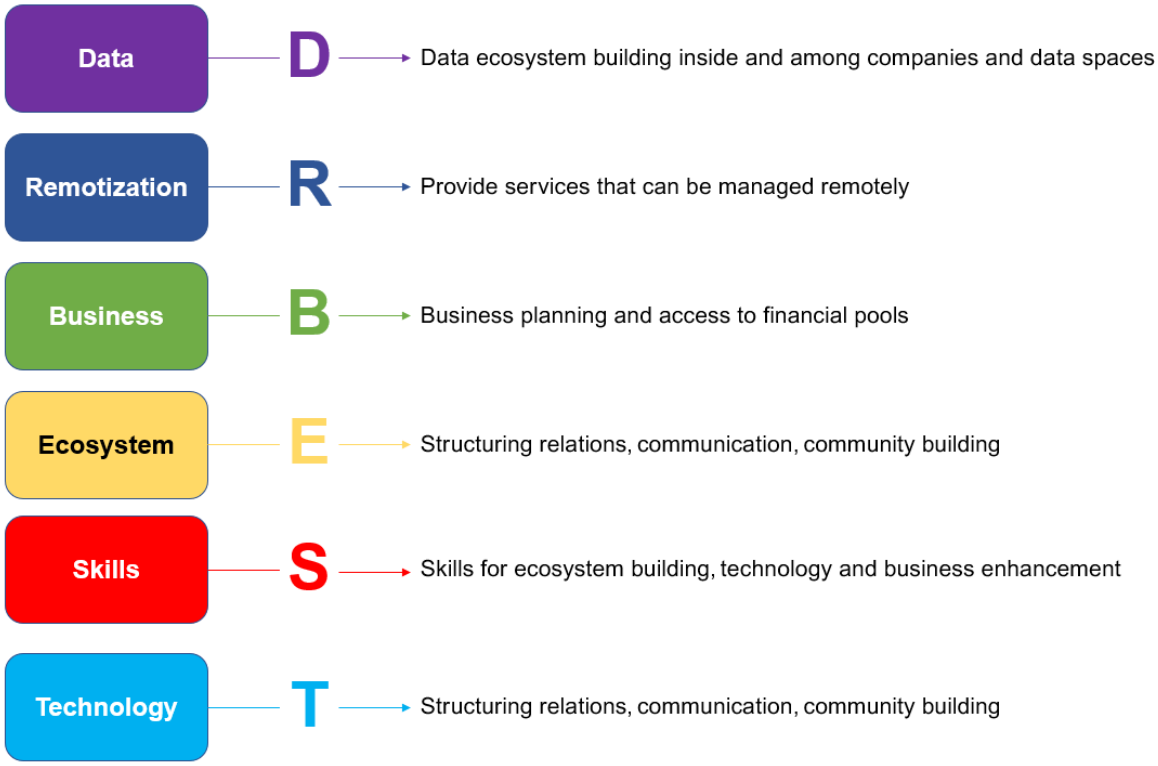
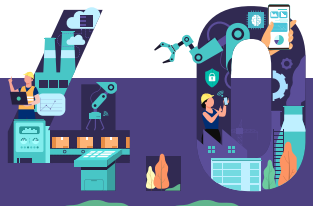


Figure 1- Extension of D-BEST to DR-BEST

Table 1- Definition of DR-BEST macro-classes

SERVICE MACRO-CLASS	DEFINITION
ECOSYSTEM	Ecosystem services aim at creating, nurturing, expanding and connecting the local SME constituency, involving in the SME digital transformation process different stakeholders as technology providers, technology users, competence centres, education and training hubs, business and market development experts, regional development agencies and associations,
TECHNOLOGY	Technology services aim at following the whole lifecycle of digital technologies from conception and idea generation, through design and proof of concept, up to minimum viable product prototyping to commercialization. They can be interpreted from the technology providers viewpoint and from the technology user's viewpoint, through the steps of access-experiment-experience spiral model.
BUSINESS	Business services intervene in more advanced scenarios (with higher TRL solutions), identifying, modelling and sustaining viable business models, including also fund-raising services (e.g. private matchmaking or access to public funding opportunities).
SKILLS	Skills services have a twofold aim. The first is to assess the status quo of the companies who want to approach digitization, in terms of both process/organization and skills maturity, and to set an adequate roadmap to empower it. The second is to actually support the skill empowerment through not only educational programs, up-skilling and re-skilling training but also sharing channels, structure contacts and collaborations for scouting and brokerage aimed at knowledge-transfer.



DATA	Data services are pivotal for adequately exploit digital technologies potentialities. The TEF should provide services dealing with different phases of the data lifecycle: from data acquisition and sensing, through data processing & analysis, up to decision-making and data sharing, not neglecting aspects as physical-human action & interaction.
REMOTIZATION	"This class contains all the services that a DIH/DF may provide from remote to enable experimentation and that don't require the physical interaction with the customer. The sub-classes identified cover different degrees of DF-customer interaction, including four type of assets that can be put at disposal: data space (Real Time Industrial Data Platform, Assets Administration Shell, Assets Data Marketplace), ICT as a Service (Software as a Service, Platform as a Service, Infrastructure as a Service), Digital Twin (FEM/CFD/FSI simulation, Discrete event simulation, Ambient virtualization), Assets as a Service (Teleoperation, Monitoring platform, Avatar)" (Razzetti et al. 2022).

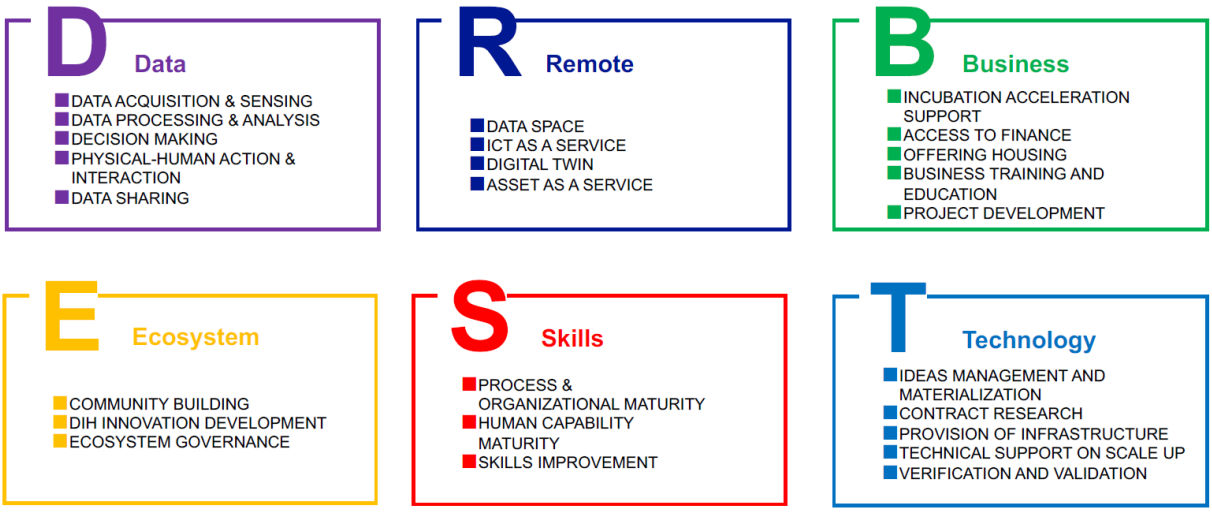


Figure 2- DR-BEST taxonomy - level 1 and 2 (Razzetti et al. 2022)

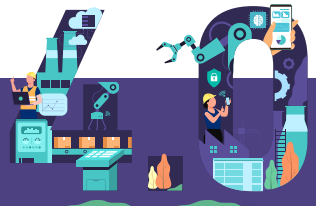
Data macro-class

The *Data* macro-class is critical for taking full advantage the capabilities of digital technologies through services that deal with various stages of the data lifecycle, such as data acquisition and sensing, data processing and analysis, decision-making, and data sharing, without dismissing aspects such as physical-human action and interaction. It presents five different types of services.

The first is *Data acquisition and sensing*, splits in two classes of services:

1. *Data acquisition*: Data in motion models and services for Industrial Internet of Things (IOT).
2. *Data protection*: Data anonymization, confidentiality, encryption and privacy preservation services.

The second type of services related to *Data* macro-class is *Data processing & analysis*. It is divided in two classes of services:



1. *Data storage*: Data Spaces, Data Lake, Linked Data, Distributed Storage, Knowledge representation services.

2. *Data analytics*: Semantic analysis, Data discovery, Advanced Data Analytics (Edge Analytics, Cloud Analytics) services.

Decision-making is the third type of service. In this case, there are two types of services:

1. *Cognitive big data architectures*: configuration and deployment architectures for Big Data.

2. *Decision support and development*: Cognition, Prediction and prescription, Simulation, Machine Learning, Reinforcement, DNNs, Formal Logics.

The fourth type of services is *Physical-human action & interaction.* It is declined in three classes of services:

1. *Collaborative intelligence*: services aimed at supporting for improving human-machine interface and interaction.

2. *User experience*: Navigation, User Experience, Exploration.

3. *Feedbacks loop*: Control/Actuation, Cognitive Mechatronics, Question Answering.

The last type of service is *Data sharing*. It can be split in three classes of services:

1. *General Data Protection Regulation (GDPR) and data sovereignty compliance*: these are consultancy services for personal and non-personal data sharing and exchange business processes modelling, rules of governance and contracts.

2. *Data spaces*: supporting the creation and development of data models and ontologies for trusted and secure data exchange.

3. *Data platform*: supporting in developing and providing hardware and software architectures and components and providing connectors services.

Remotization macro-class

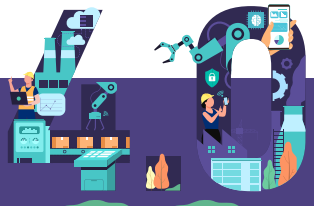
Remotization macro-class focuses on the aspects of the digitisation services which enable the assets or services to be interoperable while being accessible to network of TEFs regardless of their current physical location and limitations. Data space, ICT as a Service, Digital Twin and Asset as a Service are four types of this macro-class each of them composed of various services.

The first type is called *Data space* including three services:

1. *Real time industrial data platform*: how to access data generated in real time by industrial IoT systems.

2. *Assets Administration Shell (AAS)*: how to access structural data of the facility and assets.

3. *Open data repository*: collection of historical Findable Accessible Interoperable Reusable open data sets.



4. *Assets data marketplace*: collection of high value data sets with associated value and monetisation.

ICT as a service has been classified as the second type consisting of three services:

1. *Software as a service*: applicative Software components and resources licensed on a subscription basis and centrally hosted.
2. *Platform as a service*: cloud computing services that provide a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure.
3. *Infrastructure as a service*: online services that provide high-level APIs used to dereference various low-level details of underlying network infrastructure like physical computing resources, location, data partitioning, scaling, security, backup, etc.

Third type would be *Digital Twin* divided in three services:

1. *FEM/CFD/FSI simulation*: Simulation of the physical behaviour of the system.
2. *Discrete event simulation*: Simulation of the temporal behaviour of the process.
3. *Ambient virtualization*: Digital representation of the environment to create immersive reality.

Last type of this macro-class is *Asset as a service*:

1. *Teleoperation*: usage of tools to operate on the assets in remote and to transfer skills and expertise to remote place without physically presence.
2. *Monitoring platform*: usage of tools for the assessment of the status of the assets and for evaluation of production working progress.
3. *Avatar*: a physical system capable of replacing a person in the working environment to transfer his ability anywhere.

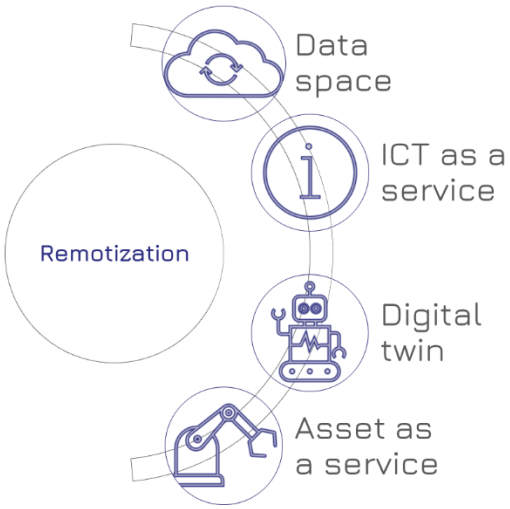


Figure 3- A graphical representation of Remotization macro-class types.

Business macro-class

Business, the third macro-class, intervenes in more advanced scenarios (with higher TRL solutions), identifying, modelling, and sustaining viable business models, along with providing fund-raising services (e.g., private matchmaking or access to public funding opportunities). It can be divided into five different types of services, which are further subdivided into several service classes.

The first type of services is *Incubation acceleration support* and can be divided in four classes of services:

1. *Basic facilities*: providing access to physical infrastructure (offices, café, meeting rooms, laboratories, co-working areas, libraries, etc.)

2. *Specialized facilities*: Providing access to telecommunication infrastructure, high powered computing, video conferencing, labs and data ecosystem.

3. *Business development*: coaches and mentors, entrepreneurs in residence, dedicated programmes to assist entrepreneurs in the process of business development (funnel, use case communication and assessment of SMEs), helping to adjust their organization and actions to the market and the changes brought by digitization, by adopting AI solutions.

4. *Guidance*: offering technical, fiscal, and legal advice where necessary, and regulatory assistance.

The second type of service, *Access to finance*, is split in two classes of services:

1. *Financial engineering*: providing support in addressing financial issues and/or advise on innovative financial products, value of AI legislation.

2. *Connection to funding sources*: facilitating access to different funding sources (EU, national, regional, and private) aiming at achieving an effective mix of funds (conversation, lobbying, projects).

The third type of service, *Offering housing* consists of one service:

1. *Innovation spaces*: Offering innovation spaces to encourage innovators and other ecosystem members to interact and share ideas as well as spaces for experimentation and pilot manufacturing (including data ecosystem and spaces).

The fourth type of services is *Business training and education*. It is composed of two classes of services:

1. *Methods and tools, business operations modelling*: providing training and development in business skills and entrepreneurship (e.g., formal courses, workshops, seminars) and influence academia.

2. *Secondment*: facilitating the exchange of personnel (e.g., researchers) and core competences among organisations, including IPR.

The fifth type of services is *Project development*, divided in four classes of services:

1. *Strategic analysis and alignment of EU vs regional RDI investments*:

A. Matchmaking in order to favouring the encounter between regional supply and demand interested in AI solutions, including universities and research institutes as providers, or less frequently between companies with similar needs or complementary solutions. DIHs help regions to build on the strengths identified in their smart specialisation strategies and align their efforts with the capabilities of companies to use AI and the support structures they have available.

B. Research of different calls and public funding opportunities. Helping SMEs and suppliers to orientate among EU projects, coordinating different support mechanisms, integrating regional, national, and EU-level programmes and initiatives, and attracting forefront companies. Avoiding the risk of duplicating efforts, that is, that some innovation projects are running in parallel among companies who are not aware one of the other's activities.

2. *Identification of opportunities*: support in the identification of new market/business opportunities through strategic analysis of the ecosystem and trend watching.

3. *Creating consortia*: encouraging cooperation and collaboration among organisations for exploiting common opportunities (e.g. business, research, funding, match-making, open innovation).

4. *Development of proposals*: providing technical assistance in the proposal development process in order to comply with specific proposal requirements (e.g. for project funding).

Ecosystem macro-class

The type of services *Community Building* is divided in four classes:

1. *SME and people engagement:*

A. Mapping and analysis of the ecosystem requirements in order to enable the identification of consortium partners (or partnership) for establishing the DIH or TEF network, with a specific focus on AI technology providers.

B. Creating a community at the core of which is the DIH or TEF, which connects all members of the innovation ecosystem, with the goal to identify key stakeholders and potential partners with which to develop structured relationships.

2. *Brokerage, Awards, Challenges*:

A. Connecting suppliers with customers, business support services, collaborators, capital providers and others (Academic institutions, HR).

B. Stimulating and rewarding collaborative innovation and problem solving.

3. Technology scouting: For companies seeking innovative technologies to incorporate into their portfolio (define customer, needs and ecosystem)

4. *Communication*:

A. Raising awareness about DIH's activities as well as innovative AI technologies and solutions across the community including the organisation of events in order to disseminate information and knowledge.

B. Sharing best practices experiences and promoting and marketing themselves in EU landscape.

C. Inviting experts in business and entrepreneurship, or industry sectors to give talks and interact with (potential) customers and partners (study visits and roadshows)

The type of services *DIH Innovation Development* is divided in two classes:

1. *Trend-watching*: providing up to date information on the trends in the market, assessment of market potential (business model).

2. *Visioning and strategy development*: supporting both start-ups and SMEs in shaping their vision and strategies as well as large corporates that require fresh thinking to remain relevant and competitive in the marketplace.

The type of services *Ecosystem Governance* is divided in two classes:

1. *Services Impact assessment*: they are aimed at the assessment of the services provided to the ecosystem through KPIs.

2. *Ecosystem strategy management*: engagement rules, statute, governance structure. Facilitation of relationships both within the DIHs ecosystems and between DIHs of the network.

Skills macro-class

The *Skill* macro-class has two objectives. The first step is to evaluate the present situation for organizations that want to approach digitization, in terms of both process/organizational and skills maturity, and to set an appropriate path to empower it. The second is to support the empowerment of skills through sharing channels, structured contacts, and collaborations for knowledge-transfer scouting and brokerage in addition to educational programs, up-skilling, and re-skilling training. Three main *types* of services have been declined in the following *classes* of services:

The first type of services is *Process & organizational maturity* declined in two classes of services:

1. *Maturity assessment*: Assessment of company readiness for Industry 4.0 (tech, organizational, and ecosystem readiness). It can be also in the shape of a self-assessment to prepare themselves before proceeding to work with the DIH.

2. *Maturity strategy development*: Definition of a roadmap starting from the characteristics of the single enterprise or part of it. The roadmap design is based on the outcome of the assessment, and it proposes possible technologies, new solutions or new business models to be adopted.

The second type of services is *Human capabilities maturity*. It is declined in two classes:

1. *Human skill repository*: making available an online repository containing catalogue for AI resource, documentations, training material, papers, etc.

2. *Human skills maturity*: support in capabilities screening through on-site visit(s), interviews, etc. and definition of the actual level of skills maturity in Industry 4.0.

3. *Skills strategy development*: gap analysis between the AS IS and the desired level of AI skills, action plan definition and support to implementation.

The third type of services is *Skills improvement*. It is declined in three classes of services:

    1. *Human up-skilling, re-skilling training*: Life-long training on technical and soft skills focused on AI at corporate level, operational and technology specific level. Training are addressed: to the workforce, to be able to deal efficiently with the newly digitized products, processes or business models; to management, in order to overcome the cultural barriers; to trainers ("train to trainers"), to keep them constantly updated regarding new AI solutions.

    2. *Educational programs*: attracting and forming next generation talents, forming Industry 4.0 employees and workers.

    3. *Scouting and brokerage*: support in identifying channels, structure contacts and collaborations intended to knowledge-transfer, etc. with the aim to provide examples of existing (European) hubs and their approach to AI topics, and to combine new trainings with already existing capacity building materials developed by previous projects and from other reputable sources.

    4. *Standardization and certification*: standard methods and tool for standard certifications.

Technology macro-class

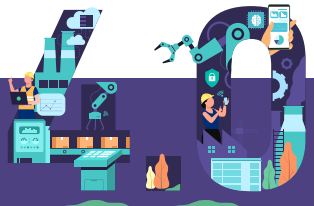
Yet another objective of the Technology macro-class is to track the entire lifecycle of digital technologies, from conception and idea generation through design and proof of concept to minimum viable product prototyping and commercialization.

The first type is *Ideas management and materialization*, divided in two classes:

1. *Ideas generation, assessment, feasibility study*: collecting innovation ideas, refining and targeting them in a collaboration environment. Preliminary feasibility analysis. Support companies on solution implementation, ensuring they targeted the right combination of technologies and services in their products.

2. *Technology readiness assessment*: through these services, DIHs conduct Technology Readiness assessments on products/solutions developed by start-ups and SMEs.

The second type of services, *Contract research*, is divided in two classes:



1. *Strategic and Specific R&D*: it includes collaborative R&D projects to support the translation of innovative ideas into demonstrable concepts, applying technological innovation to develop new products/services or improving existing ones.

2. *Technology concept development/Proof of Concept (PoC)*: it aims at planning and defining new business services solutions as well as demonstrating the feasibility of an idea or project through its temporary or provisional realisation.

The third type of services *Provision of infrastructure* consists of one class:

1. *Access to infrastructure and technological platforms*: provision of a large range of services such as renting equipment, providing platform technology infrastructure, lab facilities as well as support to low-rate production.

The fourth type of services is *Technical support on scale up*, declinable in two classes:

1. *Concept validation*: these services are aimed at developing minimum viable products (MVPs) that can be validated with real customers and/or in an industrially relevant setting.

2. *Prototyping*: they are aimed to design prototypes to explore ideas and emerging technologies before going into production by also considering potential opportunities offered by small series production.

The fifth type of services related to the *Technology* macro-class is *Verification, validation and demonstration*, declinable in two classes of services:

1. *Product qualification and certification*: support in certifying that the product has passed functional, performance and quality assurance tests.

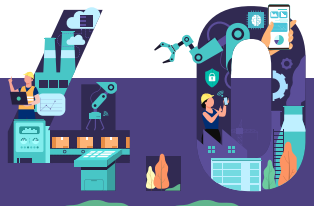
2. *Product demonstration*: promotion showrooms and demo cases in which a product is demonstrated in front of clients.

2.1.1 A special emphasize on Remotization services

All of the services that a DIH/DF (also TEF) may offer remotely to enable experimentation and that do not request for direct physical contact with the customer are included in the "Remotization" class. The four asset types that can be used are: data space (Real Time Industrial Data Platform, Assets Administration Shell, and Assets Data Marketplace), ICT as a Service (Software as a Service, Platform as a Service, Infrastructure as a Service), Digital Twin (FEM/CFD/FSI simulation, Discrete event simulation, Ambient virtualization), and Assets as a Service. The sub-classes identified cover various degrees of DF customer interaction (Teleoperation, Monitoring platform, Avatar) (Razzetti et al. 2022).

The timely and economical implementation of business workflows and processes is the ultimate goal of data-driven industrial value networks. Implementing measures to apply Remotization services seems to be crucial for enabling interoperability and accessibility of various services offered by different TEFs of the network to all network members and performing tasks.

When it comes to data, making it accessible or even integrable across the network, as well as using it for analysis and simulation of the physical environment, would be beneficial in



achieving the goal of interoperability. Creating an inventory for each TEF could also be beneficial to the aforementioned goal.

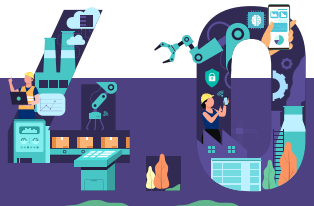
Concerning *ICT as a Service*, through three service models, cloud computing technology has introduced the notion of computing over the internet. Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS), and Infrastructure as a Service (IaaS) (SaaS). Cloud computing, which is primarily used by end users, enables active user collaboration while offering flexible and affordable access to information and software through the use of online servers (Rahman and Pribadi Subriadi 2022). "IaaS provides developers with infrastructures such as unlimited storage and computing power without the need for on-site physical hardware. PaaS provides a computing platform that primarily includes resources such as operating systems, programming languages, databases, and web servers that automatically scale to meet the needs of user applications. SaaS is the highest layer and most basic form of cloud computing. It follows a multi-tenant architecture where all users share a common infrastructure. The software and related data will be available and hosted on the internet, which users can access through a web browser" (Rahman and Pribadi Subriadi 2022).

As far as *Digital Twin* is concerned, "the Digital Twin technology, which has a bright future in many fields of study and many studies and research activities continue to be carried out, can be expressed as a digitally modelled copy of an object/system that physically exists in the real world. Digital Twins consist of three basic components: the physical state of the system in the real environment, the state of the system in the digital environment, and the data that connects these two states. While sensors and Internet of Things (IoT) technologies are actively used in the transfer of physical assets to the digital environment, artificial intelligence and advanced machine learning techniques are used to learn the behaviour of the physical entity from the created Digital Twin and to produce future predictions. The foresight helps manufacturers determine their roadmap for predicting future failures and process improvement" (Erol, Mendi, and Dogan 2020). The focus here could be on sharing and integration of various Digital Twins among TEFs of the network.

Considering *Asset as a Service*, teleoperation system allows an operator to carry out a task without physically being present where the machines are. Teleoperation eliminates the risks associated with jobs such as space exploration, toxic substance handling, and so forth because the operator is not physically present at the site of task execution. Simultaneously, in order for the operator to work efficiently, it is necessary to provide him with all of the information that he will require to carry out his task, while also keeping in mind that communication between the user and the teleoperation system must be fluid, with information that is easy to interpret. To achieve these requirements, a teleoperation system is a complex system, formed by divers subsystems such as interaction devices, acting devices, control modules, event handling, communications, graphics user interfaces and computer facilities to support computations (Rodriguez, Jessel, and Torguet 2001).

With respect to given definitions of Remotization services and descriptions, following points can briefly summarize the acts that can be expected for services to be provided remotely:

- Data (accessible or even integrable, to be analysed or simulate a physical environment), Set-up inventory for each TEF.



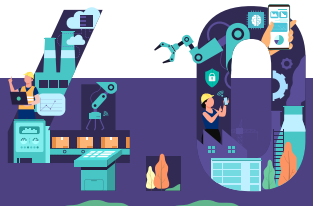
- Software (accessible from other TEFs, e.g., AAS explorer).
- Digital Twin (to be shared/integrated with other TEFs)
- Teleoperation (Assets teleoperation (A/V/XR) such as equipment can be teleoperated remotely)

2.2 Contributions from Digital Intelligent Modular Factory (DIMOFAC) concepts

2.2.1 Asset Administration Shell (AAS)

"The Asset Administration Shell (AAS), developed under the Industry 4.0 umbrella, aims to provide a common digital representation of each factory asset. It plays a major role in the goals of enabling data sharing between value chain partners, standardizing data security, and providing technology-neutral semantic standards. The role of the AAS specifically is to provide communication among assets within a single factory and cross-company, and to cover the complete asset life cycle from requirements until decommissioning. Industry 4.0 adopts a broad definition of what constitutes an asset: anything of value in the factory such as machines, raw materials, services, and human personnel. Moreover, immaterial assets such as processes and plans are explicitly included as well. The asset information is stored on the AAS in standardized Submodels, which are data models each pertaining to a specific functionality" (Bouter et al. 2021).

"The normative AAS documentation (Bader et al. 2018) has been published by Platform Industry 4.0 in co-operation with ZVEI, the German Electrical and Electronic Manufacturers' Association. The document formally describes the contents of an AAS and its components" (Bouter et al. 2021).



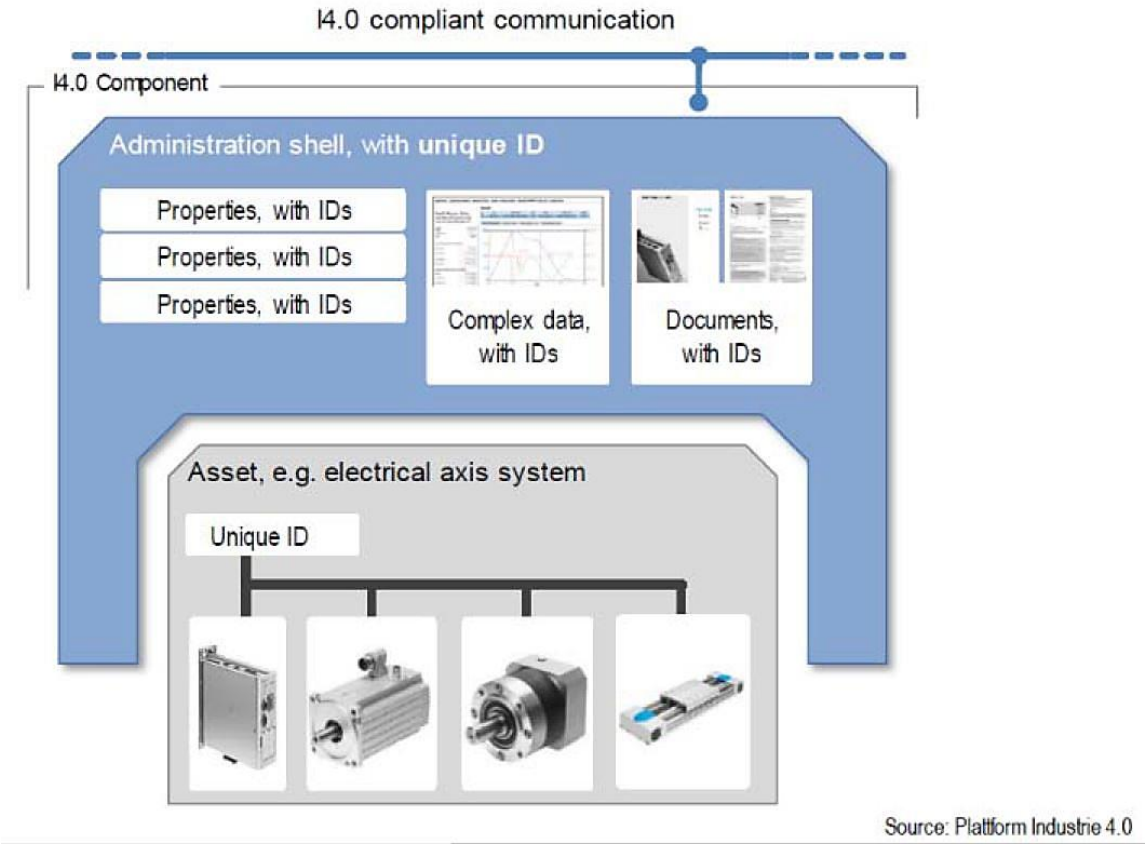
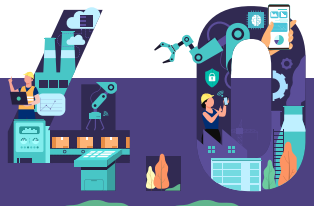


Figure 4- Structure of an AAS (Bader et al. 2018; Bouter et al. 2021).

Figure 4 "shows the basic AAS structure: Each asset (grey box) has a unique Administration Shell (blue box) that serves as an interface to the asset information. The AAS functions as a digital communication shell that exposes the asset data to other Industry 4.0-comliant components. The actual data is stored into various Submodels, each covering a separate asset functionality" (Bouter et al. 2021).

"The AAS equivalents of attributes are called SubmodelElements (Bader et al. 2018). For example, a Property contains a literal value of a specified datatype; a ReferenceElement contains a reference to a Referable (e.g., an AAS, Submodel, or SubmodelElement); a Document contains an actual file or a link; and a SubmodelElementCollection contains a set of SubmodelElements. The AAS requires SubmodelElements and the Submodel itself to be identifiable through a globally unique identifier for standardization and semantic integration. An International Registration Data Identifier (IRDI) can be used to refer to standardized dictionaries such as eClass or another relevant standard, as is done in the example Submodels. An Internationalized Resource Identifier (IRI) can refer to a (semantic) web resource. An important design principle of the AAS is that Submodels should be separated by functionality such that all assets that share a specific function have the same Submodel implemented on their AAS. Interoperability is then achieved by defining for each aspect a standard Submodel that should be used cross-company" (Bouter et al. 2021).



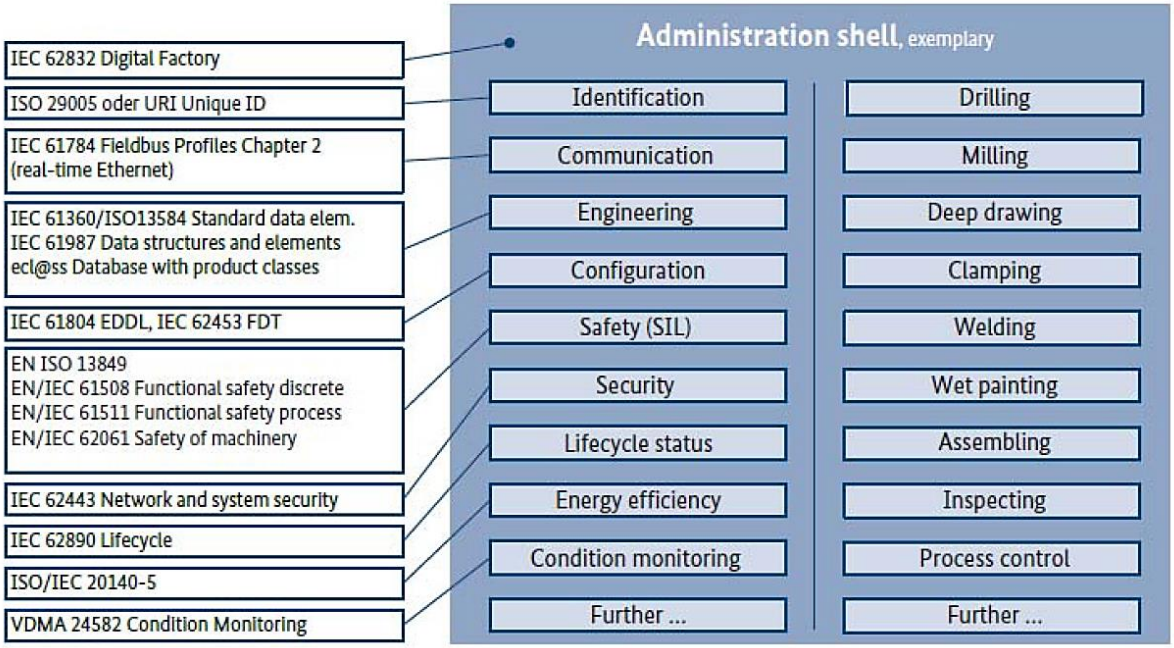
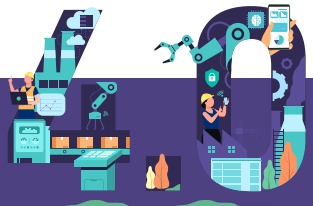


Figure 5- Potential Administration Shell Submodels (Bouter et al. 2021)



3 RE4DY DR-BEST based Testing and Experimentation Facility (TEF) Network Set-up

3.1 How to apply DR-BEST framework to set up a TEF network

Configuring a service portfolio is a key step in establishing a network of Testing and Experimentation Facilities (TEFs). This service portfolio gathers and, in some cases, enhances a broad, diverse, and complementary range of services from different providers that are chosen and arranged in accordance with the mission and value proposition of the networked enterprises. With the aim of collecting services provided by the partners in the task 3.1 of the project (TEFs), following steps has been taken to collect service portfolio configuration of each partner in this task:

i. Preparation of latest "DR-BEST" methodology questionnaire in order to meet the requirements of the project.

ii. Providing the instructions and guidelines for each TEF for how to fill the questionnaire.

iii. Holding online meetings with each TEF to clarify methodology concepts and address concerns.

iv. Compiling the final questionnaire that each TEF completed.

The "DR-BEST" questionnaire was created in an Excel file format and distributed to each TEF. Each service is described in the questionnaire, and each TEF is asked whether they currently provide or plan to provide that service, or if they do not currently provide that service (*Figure 6*). The results gathered from each partner are discussed and analysed on the following pages.

Services which are planned to be provided (To-Be)

Services which currently are being provided (Yes)

Services which have been withdrawn from service portfolio (No)

Figure 6-Services provision types

3.2 The POLIMI Service Portfolio

The POLIMI Industry 4.0 laboratory is fully equipped with industrial assets in order to create a realistic environment for testing research findings and developing customized solutions based on cutting-edge equipment and technological solutions. The core of the Lab is constituted by the fully automated assembly and manufacturing line with a robotic cell with a high precision 7 axis articulated robot. An AGV and a co-bot, controlled by open and independent informative systems, complete the industrial-like scenario with several vertical-integration solutions. The high flexibility of the system and the modularity of the configuration allows to test and replicate virtually any variety of discrete manufacturing/assembly systems.

Figure 7- Assembly line of Industry 4.0 Lab of POLIMI

Table 2 represents the service portfolio of POLIMI testing and experimentation facility according to "DR-BEST" framework:

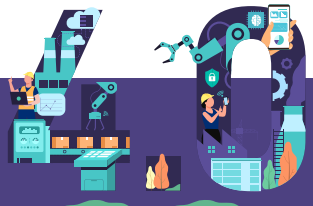


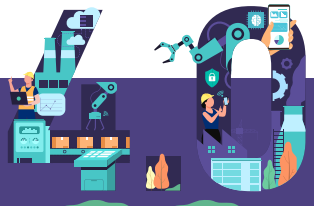
Table 2-POLIMI Service Portfolio based on "DR-BEST" questionnaire

CLASS	TYPE	SERVICE	Description	Provided? YES and/or TO-BE	Service description and details • Name of the service, reference, link • Specific characteristics of the services offered • Main target customers • Business model (freemium, premium) • Comments To fill only if P4=YES
DATA SPACES & DATA SHARING	Data acquisition and sensing	Data acquisition	Data in Motion Models and Services for Industrial Internet of Things	Yes	Technical consultancy for data acquisition Technical consultancy for software architectures for industrial data acquisition
		Data protection	Data anonymization, confidentiality, encryption, and privacy preservation services	TO-BE	
	Data processing & analysis	Data storage	Data Spaces, Data Lake, Linked Data, Distributed Storage, Knowledge representation services	No	
		Data analytics	Semantic analysis, Data discovery, Advanced Data Analytics (Edge Analytics, Cloud Analytics) services	No	
	Decision-making	Cognitive Big Data architectures	Configuration and deployment architectures for Big Data	Yes	Middleware-based architecture deployment for data acquisition and analysis from heterogeneous sources
		Decision support and development	Cognition, Prediction and prescription, Simulation, Machine Learning, Reinforcement, DNNs, Formal Logics	Yes	Simulation services for virtual commissioning and prediction-based decision making
	Physical-human action & interaction	Collaborative intelligence	Human-Machine Interface, Human-Robot Interaction, Human-Data Interaction, Multi-lingual AI	Yes	Dashboard development Formal modelling of human behaviour Human-meaningful KPI representation
		User experience	Navigation, User Experience, Exploration	No	
		Feedback loop	Control/Actuation, Cognitive Mechatronics, Question Answering	No	
	Data sharing	GDPR and Data Sovereignty compliance	Consultancy services for personal and non-personal data sharing and exchange business processes modelling, rules of governance and contracts	No	
		Data Spaces	Data models and ontologies for Trusted and Secure Data Exchange	TO-BE	

		Data Platform	Hardware and Software architectures and components, Connectors services	Yes	Hardware integration in industrial software architecture Software development for integration Software development for data uniformity Roadmaps towards full digitalisation
Remotization	Data Space	Real Time Industrial Data Platform	How to access data generated in real time by Industrial IoT Systems	Yes	Experimental Training Program Direct consultancy Testbed
		Assets Administration Shell	How to access structural data of the facility and assets	Yes	Direct consultancy Experimental Training Program
		Open Data Repository	Collection of historical Findable Accessible Interoperable Reusable open data sets	Yes	Direct Consultancy
		Assets Data Marketplace	Collection of high value data sets with associated value and monetisation	TO-BE	
	ICT as a Service	Software as a Service	Applicative Software components and resources licensed on a subscription basis and centrally hosted	No	
		Platform as a Service	Cloud computing services that provide a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure	Yes	Direct consultancy
		Infrastructure as a Service	Online services that provide high-level APIs used to dereference various low-level details of underlying network infrastructure like physical computing resources, location, data partitioning, scaling, security, backup etc	Yes	Experimental Training Program Direct consultancy Testbed
	Digital Twin	FEM/CFD/FSI simulation	Simulation of the physical behaviour of the system	Yes	Direct consultancy Experimental Training Program
		Discrete event simulation	Simulation of the temporal behaviour of the process	Yes	Direct consultancy Experimental Training Program
		Ambient virtualization	Digital representation of the environment to create immersive reality	Yes	Direct consultancy
	Asset as a Service	Teleoperation	Usage of tools to operate on the assets in remote and to transfer skills and expertise to remote place without physically presence.	Yes	Direct consultancy Experimental Training Program
		Monitoring platform	Usage of tools for the assessment of the status of the assets and for evaluation of production working progress.	Yes	Experimental Training Program Direct consultancy Testbed

		Avatar	A physical system capable of replacing a person in the working environment to transfer his ability anywhere	No	
BUSINESS DEVELOPMENT	Incubation acceleration support	Basic facilities	Providing access to physical infrastructure (offices, café, meeting rooms, laboratories, co-working areas, libraries, etc.)	No	
		Specialised facilities	Providing access to telecommunication infrastructure, high powered computing, video conferencing, labs and data ecosystem	Yes	Upon request, access to the technological assets and staff of Industry4.0Lab
		Business development	Coaches and mentors, entrepreneurs in residence, dedicated programmes to assist entrepreneurs in the process of business development (funnel, use case communication and assessment of SMEs), helping to adjust their organization and actions to the market and the changes brought by digitization, by adopting AI solutions	Yes	Direct Consultancy
		Guidance	Offering technical, fiscal, and legal advice where necessary, and regulatory assistance	Yes	Direct technical consultancy
	Access to finance	Financial engineering	Providing support in addressing financial issues and/or advise on innovative financial products, value of AI legislation	No	
		Connection to funding sources	Facilitating access to different funding sources (EU, national, regional, and private) aiming at achieving an effective mix of funds (conversation, lobbying, projects)	Yes	Direct consultancy Consortia building for accessing financed R&D programmes
	Offering housing	Innovation spaces	Offering innovation spaces to encourage innovators and other ecosystem members to interact and share ideas as well as spaces for experimentation and pilot manufacturing (including data ecosystem and spaces)	Yes	The service offered is through testbed.
	Business training and education	Methods and Tools, Business Operations Modelling	Providing training and development in business skills and entrepreneurship (e.g., formal courses, workshops, seminars) and influence academia	Yes	Business Model evolution for digital transformation
		Secondment	Facilitating the exchange of personnel (e.g., researchers) and core competences among organisations, including IPR	Yes	Researchers' exchange programmes (e.g., IDEA League)

	Project development	Strategic analysis and alignment of EU vs regional RDI investments	A. Matchmaking In order to favouring the encounter between regional supply and demand interested in AI solutions, including universities and research institutes as providers, or less frequently between companies with similar needs or complementary solutions DIHs help regions to build on the strengths identified in their smart specialisation strategies, and align their efforts with the capabilities of companies to use AI and the support structures they have available	No	
			B. Research of different calls and public funding opportunities. Helping SMEs and suppliers to orientate among EU projects, coordinating different support mechanisms, integrating regional, national and EU-level programmes and initiatives, and attracting forefront companies. Avoiding the risk of duplicating efforts, that is, that some innovation projects are running in parallel among companies who are not aware one of the other's activities	Yes	Consortia organisation for public initiatives Consortia organisation for cascade funding
		Identification of opportunities	Support in the identification of new market/business opportunities through strategic analysis of the ecosystem and trend watching	Yes	Direct Consultancy
		Creating consortia	Encouraging cooperation and collaboration among organisations for exploiting common opportunities (e.g. business, research, funding, match-making, open innovation)	Yes	Consortia organisation for public initiatives Consortia organisation for cascade funding
		Development of proposals	Providing technical assistance in the proposal development process in order to comply with specific proposal requirements (e.g., for project funding)	Yes	Consortia organisation and participation
ECOSYSTEM BUILDING	Community building	SME and People Engagement	A. Mapping and analysis of the ecosystem requirements in order to enable the identification of consortium partners (or partnership) for establishing the DIH network, with a specific focus on AI technology providers	Yes	The service offered is through direct consultancy
			B. Creating a community at the core of which is the DIH, which connects all members of the innovation ecosystem, with the goal to identify key stakeholders and potential partners with which to develop structured relationships	Yes	The service offered is through direct consultancy



		Brokerage, Awards, Challenges	A. Connecting suppliers with customers, business support services, collaborators, capital providers and others (Academic institutions, HR)		
			B. Stimulating and Rewarding collaborative innovation and problem solving	Yes	Contest and hackathon organisation
		Technology scouting	For companies seeking innovative technologies to incorporate into their portfolio (define customer + needs + ecosystem)	Yes	The service offered is through direct consultancy, and occasionally through research initiatives
		Communication	A. Raising awareness about DIH's activities as well as innovative AI technologies and solutions across the community including the organisation of events in order to disseminate information and knowledge.	Yes	Meetings, events, workshops, open days organisation and promotion
			B. Sharing best practices experiences and promoting and marketing themselves in EU landscape	Yes	Dissemination events organisation, paper publishing, press releases
			C. Inviting experts in business and entrepreneurship, or industry sectors to give talks and interact with (potential) customers and partners (study visits and roadshows)	Yes	Researchers' exchange programmes, forum organisation (i.e., World Manufacturing Forum), Teaching Talks, Lunch Seminars
	DIH Innovation Development	Trend watching	Providing up to date information on the trends in the market, assessment of market potential (business model)	Yes	Research outcome analysis and synthesis Direct consultancy
		Visioning and strategy development	Supporting both start-ups and SMEs in shaping their vision and strategies as well as large corporates that require fresh thinking to remain relevant and competitive in the marketplace	Yes	Direct consultancy
	Ecosystem Governance	Services Impact assessment	Assessment of performed services (KPIs)	Yes	Design, validation, and collection of KPIs. The service offered is through direct consultancy or participation in research initiatives.
		Ecosystem strategy management	Engagement rules, statute, governance structure. Facilitation of relationships both within the DIHs ecosystems and between DIHs of the network.	Yes	Consortia building for research initiatives

SKILLS & MATURITY ASSESSMENT	Process & Organizational Maturity	Maturity Assessment	Assessment of company readiness for Industry 4.0 (tech, organizational, and ecosystem readiness). It can be also in the shape of a self-assessment to prepare themselves before proceeding to work with the DIH	Yes	Digital transformation assessment (e.g., DREAMY, 6P)
		Maturity Strategy Development	Definition of a roadmap starting from the characteristics of the single enterprise or part of it. The roadmap design is based on the outcome of the assessment, and it proposes possible technologies, new solutions or new business models to be adopted	Yes	Digital transformation road mapping (e.g., DREAMY, 6P)
	Human Capabilities Maturity	Human Skill Repository	Making available an online repository containing catalogue for AI resource, documentations, training material, papers…		Skills assessment (e.g., CLIMB, 6P)
		Human skills maturity	Support in capabilities screening through on-site visit(s), interviews, etc. and definition of the actual level of skills maturity in Industry 4.0	Yes	Digital skills improvement (e.g., CLIMB, DREAMY, 6P)
		Skills strategy development	Gap analysis between the AS IS and the desired level of AI skills, action plan definition and support to implementation	Yes	Digital Skills road mapping (e.g., CLIMB, DREAMY, Road mapping)
	Skills Improvement	Human up-skilling, re-skilling training	Life-long training on technical and soft skills focused on AI at corporate level, operational and technology specific level. Training is addressed: to the workforce, to be able to deal efficiently with the newly digitized products, processes, or business models; to management, in order to overcome the cultural barriers; to trainers ("train to trainers"), to keep them constantly updated regarding new AI solutions. EU training course are also delivered	Yes	Experiential training programme about digital technologies, including hands on activities, frontal lessons, MOOC (e.g., POK, Skills-Move)
		Educational Programs	Attracting and forming next generation talents, forming Industry 4.0 employees and workers	Yes	BSc, MSc, PhD training, post-graduate innovation activities (e.g., YML)
		Scouting and Brokerage	Support in identifying channels, structure contacts and collaborations intended to knowledge-transfer, etc. with the aim to provide examples of existing (European) hubs and their approach to AI topics, and to combine new trainings with already existing capacity building materials developed by previous		

			projects and from other reputable sources		
		Standardization and certification	Standard methods and tool for standard certifications	Yes	BSc, MSc, PhD training, post-graduate innovation activities (e.g., YML) certifications.
TECHNOLOGY PROVISION	Ideas Management and Materialisation	Ideas Generation, Assessment. Feasibility study	Collecting new innovation ideas, refining and targeting them in a collaboration environment. Preliminary feasibility analysis. Support companies on solution implementation, ensuring they targeted the right combination of technologies and services in their products.	Yes	Requirements and feasibility analysis, offered through direct consultancy and participation to joined research initiatives.
		Technology Readiness assessment	DIHs conduct Technology Readiness assessments on products / solutions developed by start-ups and SMEs	Yes	Name: Technology Readiness assessment for manufacturing (e.g., DREAMY, 6P)
	Contract research	Strategic and Specific R&D	Strategic perspective: collaborative R&D projects to support the translation of innovative ideas into demonstrable concepts, applying technological innovation to develop new products/services or improving existing ones	Yes	The service offered is through testbed and direct consultancy.
		Technology concept development/ Proof of Concept (PoC)	Planning and defining new business services solutions as well as demonstrating the feasibility of an idea or project through its temporary or provisional realisation. Practical demonstration and technology testing in available infrastructures and demo lab.	Yes	Pilot and PoC design and deployment.
	Provision of Infrastructure	Access to infrastructure and technological platforms	Provision of a large range of services such as renting equipment, providing platform technology infrastructure, lab facilities as well as support to low-rate production	Yes	Testbed/sandbox usage.
	Technical support on scale up	Concept validation	Developing minimum viable products that can be validated with real customers and/ or in an industrially relevant setting	Yes	Testbed or sandbox usage, deployment, and industrialisation of research outcomes.
		Prototyping	Designing prototypes to explore ideas and emerging technologies before going into production by also considering potential opportunities offered by small series production	Yes	Software implementation for manufacturing application.

	Verification and Validation	Product Qualification and Certification	Support in certifying that the product has passed functional, performance and quality assurance tests	Yes	Laboratory testing, on-site testing
		Product demonstration	Promotion showrooms and demo cases in which a product is demonstrated in front of clients	Yes	Public demos, scientific paper publications, open days, press releases.

3.2.1 Remotization at POLIMI TEF

Concerning "Remotization" macro-class services implemented by POLIMI Industry 4.0 lab, for each type of this macro-class following actions have been implemented and are briefly depicted:

3.2.1.1 Level 1- Data Space

Asset Administration Shell

- ✓ Entire assembly line (1 line)
- ✓ Each station (7 stations)
- ✓ For work orders (1 order)
- ✓ For products (3 types of products)
- ✓ For each AAS (.aasx package & .xlsx database)
- ✓ .aasx packages are accessible through AASX Package Explorer

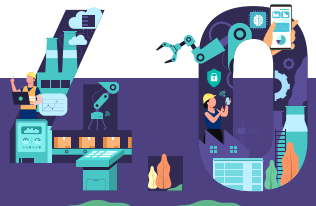


Table 3-AAS modelling descriptive details of each station

AssetName	id_short	asset id	aas id
Manual_Station	ManualStation	as:ManualStation	aas:ManualStation
Frontcover_Station	FrontcoverStation	as:FrontcoverStation	aas:FrontcoverStation
Drilling_Station	DrillingStation	as:DrillingStation	aas:DrillingStation
Robot_Station	RobotStation	as:RobotStation	aas:RobotStation
Camera_Inspection_Station	CameraInspectionStation	as:CameraInspectionStation	aas:CameraInspectionStation
Press_Station	PressStation	as:PressStation	aas:PressStation
Back_cover_Station	BackcoverStation	as:BackcoverStation	aas:BackcoverStation

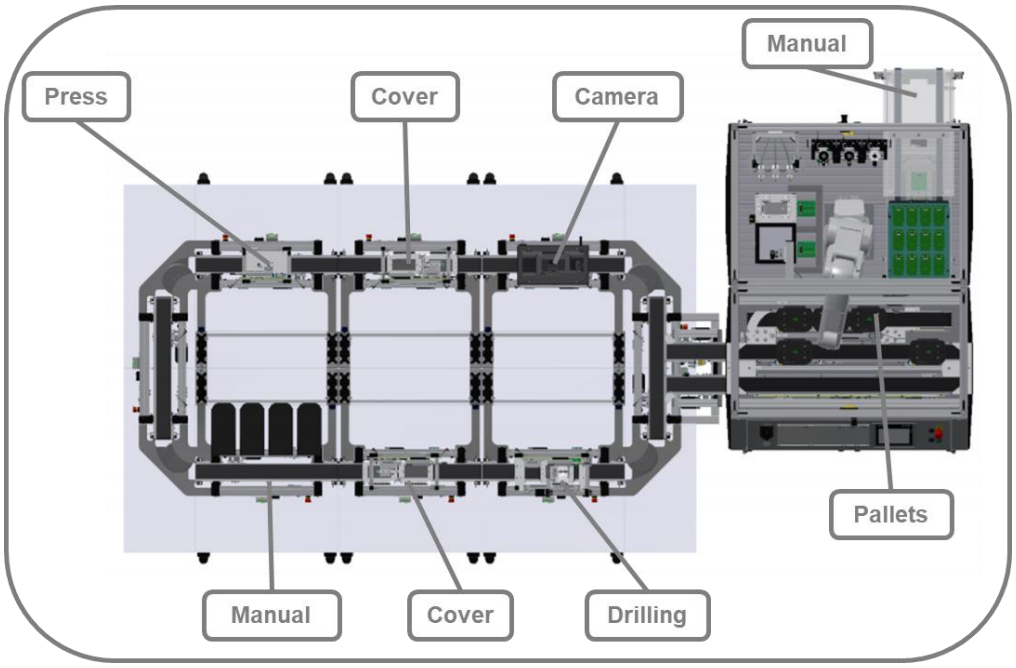
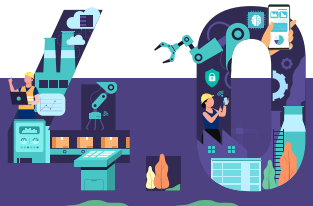


Figure 8- Schematic representation of Industry4.0 Lab assembly line with 7 stations



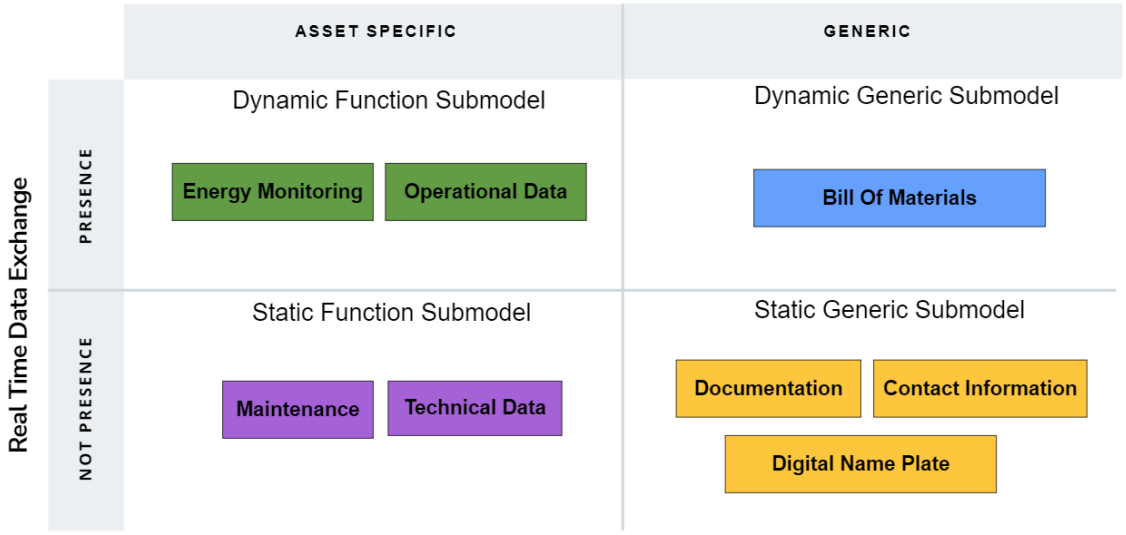


Figure 9-Generic and assets specific submodels for each station

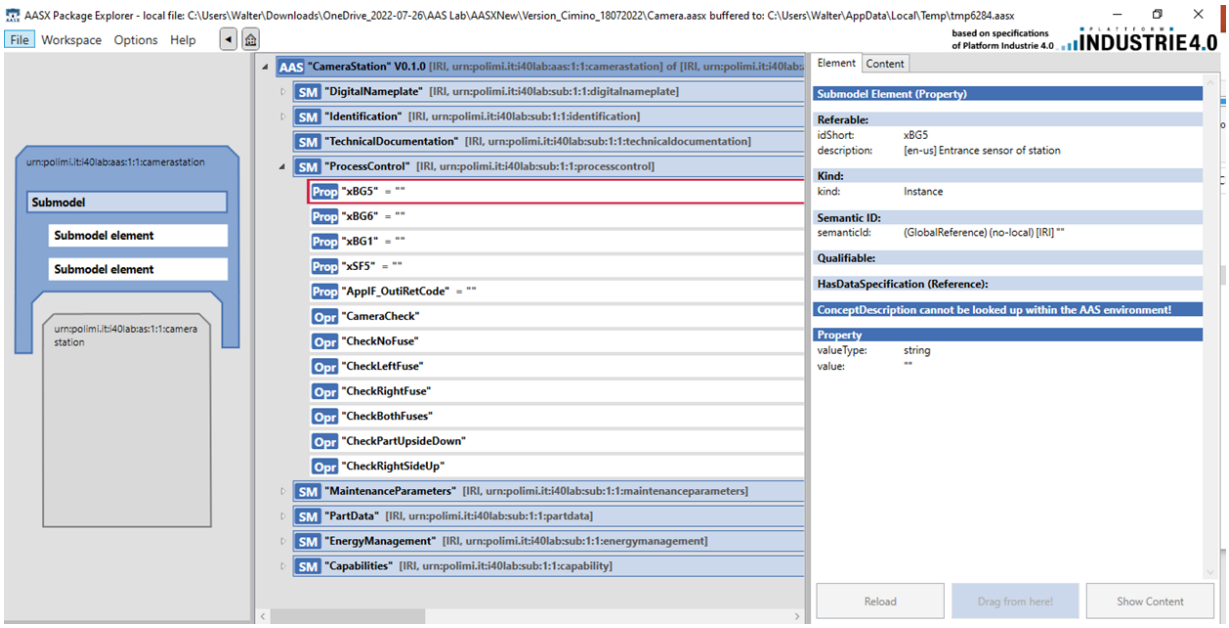
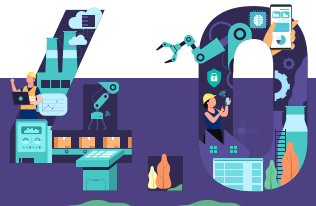


Figure 10-A frame of ASSX Package Explorer for AAS modelling

Figure 8 represents a schematic of the assembly line located at Industry 4.0 laboratory. The production line assembles a prototypical mobile phone, with the following assembly steps: the "Manual Station", is the load station where the production starts when an operator adds the carrier within a pallet, in the "Front Cover Station" the front cover of the phone is positioned on the pallet, in the "Drilling Station" the drilling operation is simulated on the cover, in the "Robotic Cell" the Printed Circuit Board (PCB) and the fuses are placed inside the front cover, in the "Camera Station" a camera controls that the pieces inside the front cover are positioned in the right way, in the "Back Cover Station" the back cover is placed on the front cover, finally in the "Press Station" a press close the two covers together. The finished assembled part returns to the "Manual Station" where the operator unloads it. All those steps are customisable for different types of products, i.e., it is



possible to have a product with or without a PCB and a product with a PCB with one or two fuses.

Figure 9 shows the idea to form submodels whether they are generic or specific while *Figure 10* is the picture of an example of implemented ASS model using AAS Package Explorer environment.

3.2.1.2 Level 2- ICT as a Service:

Software as a Service

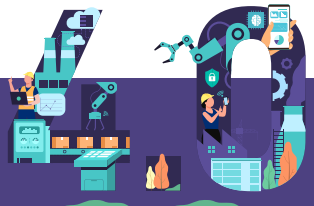
- ✓ AAS integrated development environment (IDE) alternatives:
  - BaSyx/Papyrus - provides various modules to cover a broad scope of Industry 4.0 (including AAS). Hence its substantially more complex architecture.
  - PyI40AAS - is a Python module for manipulating and validating AAS.
  - SAP AAS Service - provides a system based on Docker images implementing the RAMI 4.0 reference architecture (including AAS).
  - NOVAAS - provides an implementation of the AAS concept by using JavaScript and Low-code development platform (LCDP) Node-Red.
  - RACAS Wizard[3]

3.2.1.3 Level 3-Digital Twin

DES

- ✓ Before AAS
  - For line monitoring/production virtual commissioning
    - Data (sensors, CAD files, OPC UA tree, addresses) obtained through interviews (~weeks)
    - Manual data entry into Digital Twin simulation core
    - Product represented with a file periodically updated after each operation
- ✓ After AAS
  - For line monitoring/production virtual commissioning
    - Data structure retrieved from AAS (~hours)
    - Self-ingestion into Digital Twin simulation core
    - Product represented with a AAS file, as per every order, as per every simulation output

[3] Arm, J., et al. (2021). Automated Design and Integration of Asset Administration Shells in Components of Industry 4.0. Sensors, 21(6). https://doi.org/10.3390/s21062004



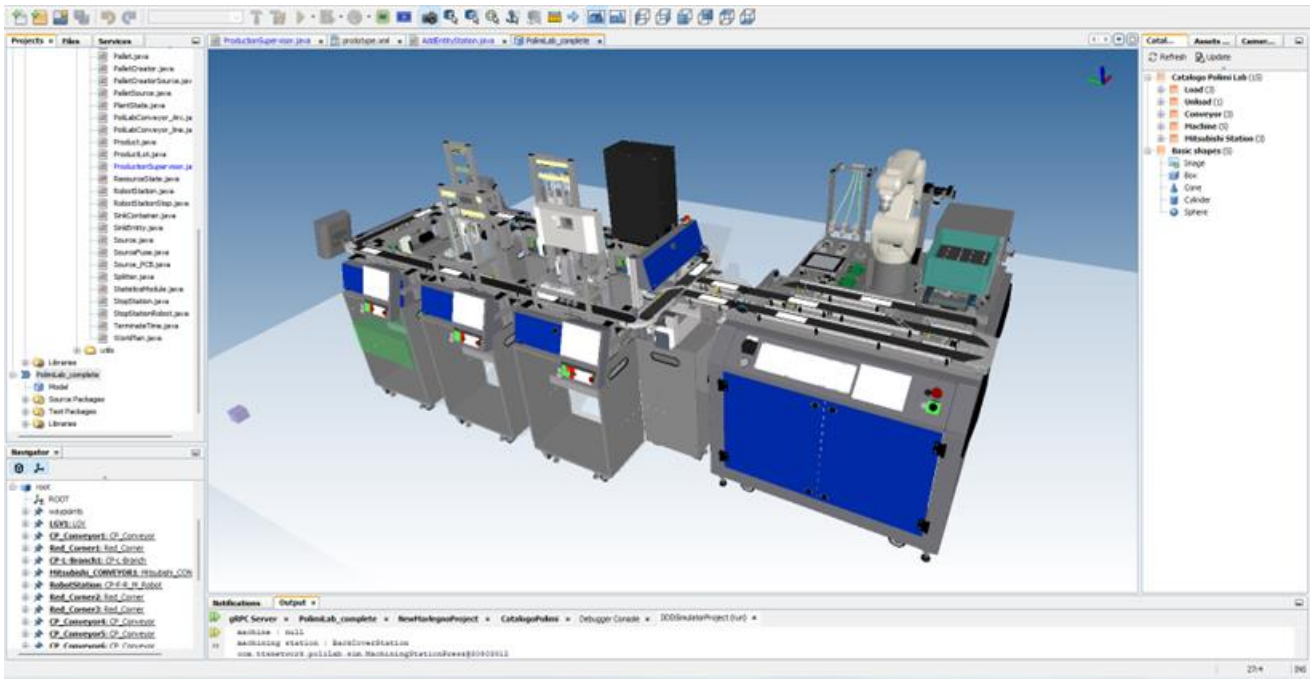


Figure 11-3D model of assembly line for DES

Simulation result AAS

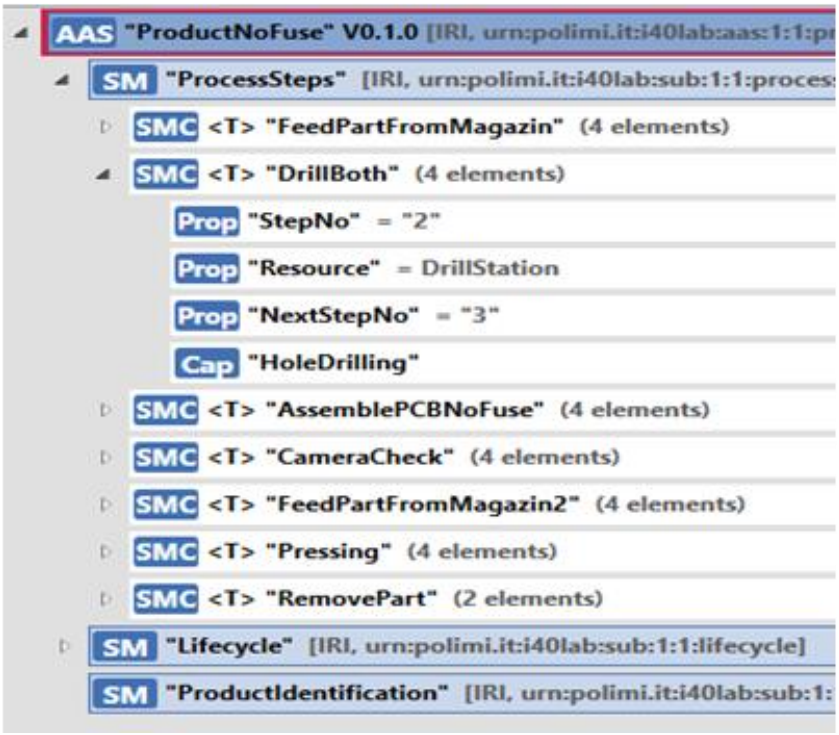


Figure 12-Simulation result after AAS

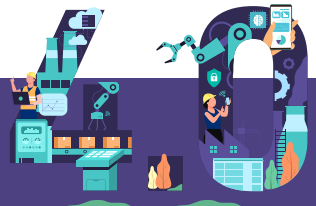


Figure 11 is the 3D modelling of the assembly line exploited for DES purposes while *Figure 12* depicts an example of simulation result implementing the concept and modeming of AAS.

3.2.1.4 Level 4-Asset as a Service

Teleoperation/Monitoring Platform

- ✓ Remotization of Augmented Reality (AR) modules to instruct maintenance/line operators (*Figure 13*, *Figure 14* and *Figure 15*)

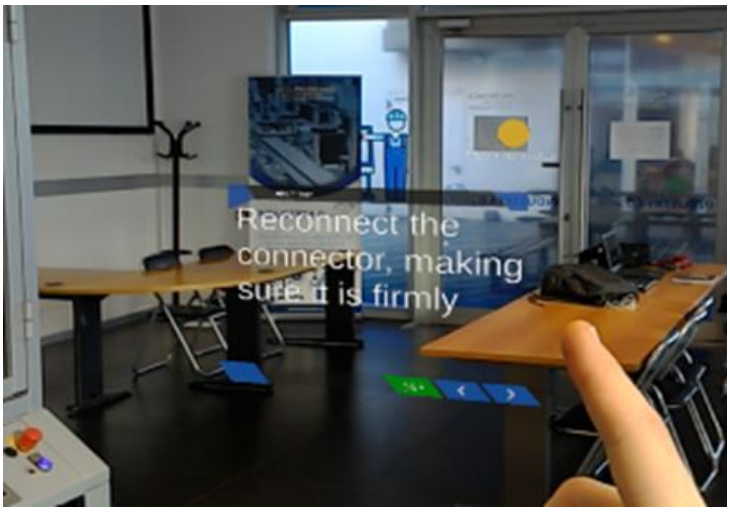


Figure 13-Instructions on floating screen

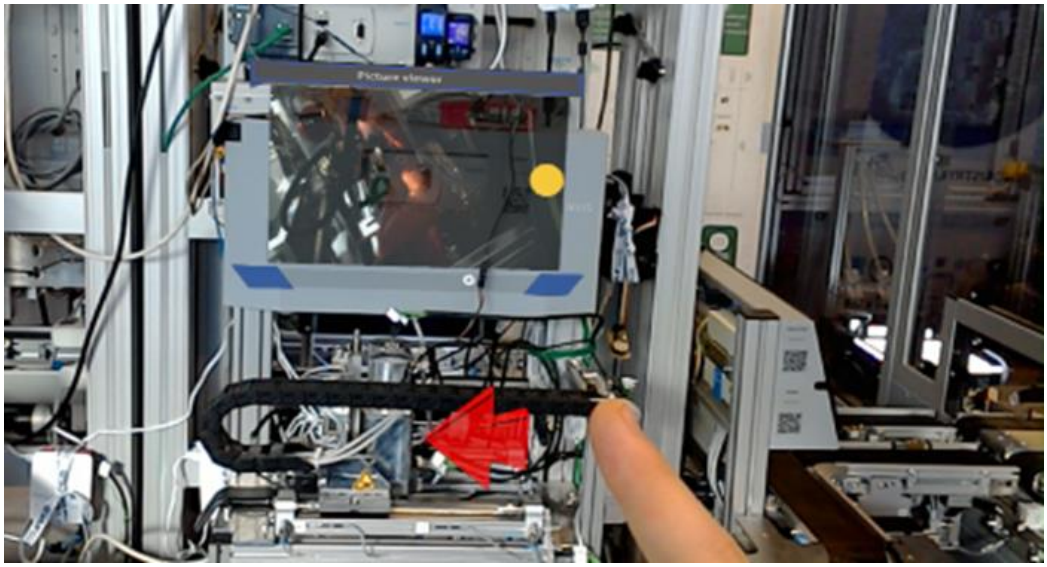


Figure 14-IoT real time data

Figure 15-AR tools application

3.3 The INNO Service Portfolio

Table 4 represents the service portfolio of INNO testing and experimentation facility according to "DR-BEST" framework:

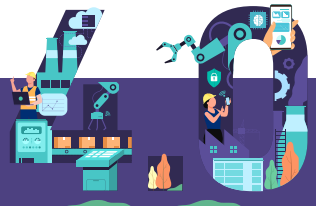
Table 4-INNO Service Portfolio based on "DR-BEST" questionnaire

CLASS	TYPE	SERVICE	Description	Provided?	Service description and details
				YES and/or TO-BE	• Name of the service, reference, link • Specific characteristics of the services offered • Main target customers • Business model (freemium, premium) • Comments
					To fill only if P4=YES
DATA SPACES & DATA SHARING	Data acquisition and sensing	Data acquisition	Data in Motion Models and Services for Industrial Internet of Things		
		Data protection	Data anonymization, confidentiality, encryption and privacy preservation services		
	Data processing & analysis	Data storage	Data Spaces, Data Lake, Linked Data, Distributed Storage, Knowledge representation services		
		Data analytics	Semantic analysis, Data discovery, Advanced Data Analytics (Edge Analytics, Cloud Analytics) services		
	Decision-making	Cognitive Big Data architectures	Configuration and deployment architectures for Big Data		
		Decision support and development	Cognition, Prediction and prescription, Simulation, Machine Learning, Reinforcement, DNNs, Formal Logics		
	Physical-human action & interaction	Collaborative intelligence	Human-Machine Interface, Human-Robot Interaction, Human-Data Interaction, Multi-lingual AI		
		User experience	Navigation, User Experience, Exploration	YES	Requirements capture
		Feedback loop	Control/Actuation, Cognitive Mechatronics, Question Answering	YES	Requirements capture
	Data sharing	GDPR and Data Sovereignty compliance	Consultancy services for personal and non-personal data sharing and exchange business processes modelling, rules of governance and contracts	YES	We comply with national requirements

		Data Spaces	Data models and ontologies for Trusted and Secure Data Exchange		
		Data Platform	Hardware and Software architectures and components, Connectors services		
Remotization	Data Space	Real Time Industrial Data Platform	How to access data generated in real time by Industrial IoT Systems	YES	Equipment and services provided by different suppliers to connect with the whole value chain
		Assets Administration Shell	How to access structural data of the facility and assets	YES	Algorithms developed for Big Data Analysis, Predictive maintenance, image analysis and applications for reverse engineering
		Open Data Repository	Collection of historical Findable Accessible Interoperable Reusable open data sets		
		Assets Data Marketplace	Collection of high value data sets with associated value and monetisation		
	ICT as a Service	Software as a Service	Applicative Software components and resources licensed on a subscription basis and centrally hosted		
		Platform as a Service	Cloud computing services that provide a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure		
		Infrastructure as a Service	Online services that provide high-level APIs used to dereference various low-level details of underlying network infrastructure like physical computing resources, location, data partitioning, scaling, security, backup etc		
	Digital Twin	FEM/CFD/FSI simulation	Simulation of the physical behaviour of the system		
		Discrete event simulation	Simulation of the temporal behaviour of the process		
		Ambient virtualization	Digital representation of the environment to create immersive reality		
	Asset as a Service	Teleoperation	Usage of tools to operate on the assets in remote and to transfer skills and expertise to remote place without physically presence.		
		Monitoring platform	Usage of tools for the assessment of the status of the	YES	Metrology equipment dedicated for production control

			assets and for evaluation of production working progress.		
		Avatar	A physical system capable of replacing a person in the working environment to transfer his ability anywhere		
BUSINESS DEVELOPMENT	Incubation acceleration support	Basic facilities	Providing access to physical infrastructure (offices, café, meeting rooms, laboratories, co-working areas, libraries, etc.)	YES	AIC (Automotive Intelligence Centre) R&D Facilities
		Specialised facilities	Providing access to telecommunication infrastructure, high powered computing, video conferencing, labs and data ecosystem	YES	Full conference infrastructure
		Business development	Coaches and mentors, entrepreneurs in residence, dedicated programmes to assist entrepreneurs in the process of business development (funnel, use case communication and assessment of SMEs), helping to adjust their organization and actions to the market and the changes brought by digitization, by adopting AI solutions		
		Guidance	Offering technical, fiscal and legal advice where necessary, and regulatory assistance	YES	IDSA
	Access to finance	Financial engineering	Providing support in addressing financial issues and/or advise on innovative financial products, value of AI legislation		
		Connection to funding sources	Facilitating access to different funding sources (EU, national, regional, and private) aiming at achieving an effective mix of funds (conversation, lobbying, projects)	YES	We provide support to SMEs in the identification and access to national and EU funds
	Offering housing	Innovation spaces	Offering innovation spaces to encourage innovators and other ecosystem members to interact and share ideas as well as spaces for experimentation and pilot manufacturing (including data ecosystem and spaces)		
	Business training and education	Methods and Tools, Business Operations Modelling	Providing training and development in business skills and entrepreneurship (e.g., formal courses, workshops, seminars) and influence academia		

		Secondment	Facilitating the exchange of personnel (e.g., researchers) and core competences among organisations, including IPR		
	Project development	Strategic analysis and alignment of EU vs regional RDI investments	A. Matchmaking in order to favouring the encounter between regional supply and demand interested in AI solutions, including universities and research institutes as providers, or less frequently between companies with similar needs or complementary solutions DIHs help regions to build on the strengths identified in their smart specialisation strategies, and align their efforts with the capabilities of companies to use AI and the support structures they have available		
			B. Research of different calls and public funding opportunities. Helping SMEs and suppliers to orientate among EU projects, coordinating different support mechanisms, integrating regional, national and EU-level programmes and initiatives, and attracting forefront companies. Avoiding the risk of duplicating efforts, that is, that some innovation projects are running in parallel among companies who are not aware one of the other's activities		
		Identification of opportunities	Support in the identification of new market/business opportunities through strategic analysis of the ecosystem and trend watching		
		Creating consortia	Encouraging cooperation and collaboration among organisations for exploiting common opportunities (e.g., business, research, funding, matchmaking, open innovation)	YES	For different type of projects or innovation projects solutions integration
		Development of proposals	Providing technical assistance in the proposal development process in order to comply with specific proposal requirements (e.g., for project funding)	YES	Full support
ECOSYSTEM BUILDING	Community building	SME and People Engagement	A. Mapping and analysis of the ecosystem requirements in order to enable the identification of consortium partners (or partnership) for establishing the		

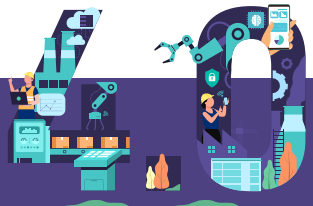


			DIH network, with a specific focus on AI technology providers		
			B. Creating a community at the core of which is the DIH, which connects all members of the innovation ecosystem, with the goal to identify key stakeholders and potential partners with which to develop structured relationships	YES	Innovalia organized the 1st European DIH conference and has since then participated in this and other events related to DIHs
		Brokerage, Awards, Challenges	A. Connecting suppliers with customers, business support services, collaborators, capital providers and others (Academic institutions, HR)	YES	Experiments carried out in collaborative European projects: SERENA, Z-BRE4K, BOOST 4.0, BEinCPPS, L4MS, CAXMAN, QU4LITY
			B. Stimulating and Rewarding collaborative innovation and problem solving		
		Technology scouting	For companies seeking innovative technologies to incorporate into their portfolio (define customer + needs + ecosystem)		
		Communication	A. Raising awareness about DIH's activities as well as innovative AI technologies and solutions across the community including the organisation of events in order to disseminate information and knowledge.		
			B. Sharing best practices experiences and promoting and marketing themselves in EU landscape		
			C. Inviting experts in business and entrepreneurship, or industry sectors to give talks and interact with (potential) customers and partners (study visits and roadshows)	YES	eBooks, Conferences, Reports, articles, whitepapers
	DIH Innovation Development	Trend watching	Providing up to date information on the trends in the market, assessment of market potential (business model)	YES	Work performed in this concern for our DIH
		Visioning and strategy development	Supporting both start-ups and SMEs in shaping their vision and strategies as well as large corporates that require fresh thinking to remain relevant and competitive in the marketplace	YES	Supporting SMEs with digital diagnosis, strategic and innovation planning assessments
	Ecosystem Cover	Services Impact assessment	Assessment of performed services (KPIs)	YES	Linked to client objectives

		Ecosystem strategy management	Engagement rules, statute, governance structure. Facilitation of relationships both within the DIHs ecosystems and between DIHs of the network.	YES	Different methodologies. Actions performed include workshops, webinars, questionnaires, customer satisfaction analysis
SKILLS & MATURITY ASSESSMENT	Process & Organizational Maturity	Maturity Assessment	Assessment of company readiness for Industry 4.0 (tech, organizational, and ecosystem readiness). It can be also in the shape of a self-assessment to prepare themselves before proceeding to work with the DIH	YES	Digital Maturity Assessment tool
		Maturity Strategy Development	Definition of a roadmap starting from the characteristics of the single enterprise or part of it. The roadmap design is based on the outcome of the assessment, and it proposes possible technologies, new solutions or new business models to be adopted	YES	Digital maturity assessment tool. Methodologies for road mapping
	Human Capabilities Maturity	Human Skill Repository	Making available an online repository containing catalogue for AI resource, documentations, training material, papers…	YES	We can train / assess companies in terms of I4.0 management through our experts in metrology / design
		Human skills maturity	Support in capabilities screening through on-site visit(s), interviews, etc. and definition of the actual level of skills maturity in Industry 4.0		
		Skills strategy development	Gap analysis between the AS IS and the desired level of AI skills, action plan definition and support to implementation	YES	Based on our digitalization questionnaire and methodology
	Skills Improvement	Human up-skilling, re-skilling training	Life-long training on technical and soft skills focused on AI at corporate level, operational and technology specific level. Training are addressed: to the workforce, to be able to deal efficiently with the newly digitized products, processes or business models; to management, in order to overcome the cultural barriers; to trainers ("train to trainers"), to keep them constantly updated regarding new AI solutions. EU training course are also delivered	YES	Workshops
		Educational Programs	Attracting and forming next generation talents, forming Industry 4.0 employees and workers	YES	Client based training

		Scouting and Brokerage	Support in identifying channels, structure contacts and collaborations intended to knowledge-transfer, etc. with the aim to provide examples of existing (European) hubs and their approach to AI topics, and to combine new trainings with already existing capacity building materials developed by previous projects and from other reputable sources		
		Standardization and certification	Standard methods and tool for standard certifications		
TECHNOLOGY PROVISION	Ideas Management and Materialisation	Ideas Generation, Assessment. Feasibility study	Collecting new innovation ideas, refining and targeting them in a collaboration environment. Preliminary feasibility analysis. Support companies on solution implementation, ensuring they targeted the right combination of technologies and services in their products.	YES	Industry 4.0 and AI
		Technology Readiness assessment	DIHs conduct Technology Readiness assessments on products / solutions developed by start-ups and SMEs	YES	We have our internal tool to evaluate the innovation stage
	Contract research	Strategic and Specific R&D	Strategic perspective: collaborative R&D projects to support the translation of innovative ideas into demonstrable concepts Applying technological innovation to develop new products/services or improving existing ones	YES	Supporting SMEs: analysis of actual status and later implementation of needed technologies
		Technology concept development/ Proof of Concept (PoC)	Planning and defining new business services solutions as well as demonstrating the feasibility of an idea or project through its temporary or provisional realisation. Practical demonstration and technology testing in available infrastructures and demo lab.	YES	Based on demand per client: concept of bringing research results to market through workshops to connect research with industry
	Provision of Infrastructure	Access to infrastructure and technological platforms	Provision of a large range of services such as renting equipment, providing platform technology infrastructure, lab facilities as well as support to low-rate production	YES	Innovalia Metrology is within Automotive Smart Factory R&D Center, with lab equipment available to control small batches of production (prototypes, proof of concept validations…)
	Technical support on scale up	Concept validation	Developing minimum viable products that can be validated with real customers and/ or in an industrially relevant setting		

		Prototyping	Designing prototypes to explore ideas and emerging technologies before going into production by also considering potential opportunities offered by small series production		
	Verification and Validation	Product Qualification and Certification	Support in certifying that the product has passed functional, performance and quality assurance tests	YES	We provide metrological validations for quality assurance definition tests (dimensional status for instance)
		Product demonstration	Promotion showrooms and demo cases in which a product is demonstrated in front of clients	YES	We have our equipment and solutions in different labs and in house where we manage and support clients in getting know technology and the future use, life demos, workshops, and other online demonstrations



3.4 The SSF Service Portfolio

The SSF offers an excellent test and demonstration platform for advanced manufacturing technologies. The open factory lab covers currently an area 1000 m² and is located in a brand-new building of SIPBB at the heart of the city Biel. The SSF lab consists of a large-scale production line for the manufacturing of quadcopter and hexa-copter drones in batch size 1. The production line demonstrates innovative manufacturing concepts and is built and operated with more than 40 companies. The test and demonstration platform includes a wide variety of different industry 4.0 components. As an example, the following list shows a selection of components (list is not complete):

- Batch Size 1 product configurator integrated in ERP
- AR – and VR technologies and devices
- 3D-printer tower equipped with additional industry 4.0 components
- Several industrial robots for machining and quality control
- Several cobots for material handling and packaging
- Fully integrated conveyor belts for material movement
- AGV's for material transpiration between the stations
- Dashboarding tools for the production line
- Edge Gateways, Computing devices, Data storage software
- Etc.

In addition to the test and demonstration platform, a digital lean training system is located in the SSF. On this training system, people can experience the digital transformation on a real example by producing RC-Cars on prepared workstations. Within several rounds, the experience starts with a paper-based approach for manufacturing the cars. The last round of the training system is fully digitized and supported by I4.0-technologies for the manufacturing of the cars. Within the workshop the two different approaches are discussed and analysed.

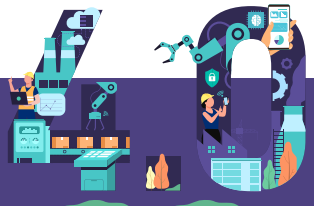


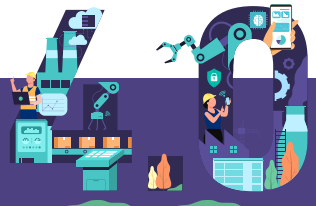
Figure 16- An instance of SSF facilities

Table 5 represents the service portfolio of SSF testing and experimentation facility according to "DR-BEST" framework:

Table 5-SSF Service Portfolio based on "DR-BEST" questionnaire

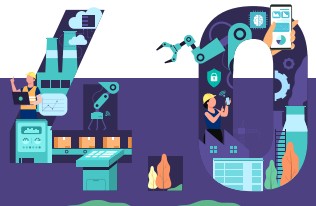
CLASS	TYPE	SERVICE	Description	Provided?	Service description and details
				YES and/or TO-BE	• Name of the service, reference, link • Specific characteristics of the services offered • Main target customers • Business model (freemium, premium) • Comments To fill only if P4=YES
DATA SPACES & DATA SHARING	Data acquisition and sensing	Data acquisition	Data in Motion Models and Services for Industrial Internet of Things	YES	Condition Monitoring of SSF-Hall and Lighthouse Project (Temperature, Humidity, Vibration, Power Consumption, Memory usage…), RFID Trace and Tracking over entire Lighthouse Project, Acquisition of production data along the Lighthouse production process
		Data protection	Data anonymization, confidentiality, encryption and privacy preservation services	NO	
	Data processing & analysis	Data storage	Data Spaces, Data Lake, Linked Data, Distributed Storage, Knowledge representation services	YES	Data Storage of Lighthouse production Data in MS Azure

		Data analytics	Semantic analysis, Data discovery, Advanced Data Analytics (Edge Analytics, Cloud Analytics) services	YES	Several Vision based quality and status systems, Dashboarding of e.g., Condition Monitoring, Speech Recognition for Logistics…
	Decision-making	Cognitive Big Data architectures	Configuration and deployment architectures for Big Data	NO	
		Decision support and development	Cognition, Prediction and prescription, Simulation, Machine Learning, Reinforcement, DNNs, Formal Logics	YES	Vision based quality control for tooling-machines, drone production, Digital Twin with Simulation
	Physical-human action & interaction	Collaborative intelligence	Human-Machine Interface, Human-Robot Interaction, Human-Data Interaction, Multi-lingual AI	YES	Several Robots, Co-bots, Supported assembly systems,
		User experience	Navigation, User Experience, Exploration	NO	
		Feedback loop	Control/Actuation, Cognitive Mechatronics, Question Answering	NO	
	Data sharing	GDPR and Data Sovereignty compliance	Consultancy services for personal and non-personal data sharing and exchange business processes modelling, rules of governance and contracts	NO	
		Data Spaces	Data models and ontologies for Trusted and Secure Data Exchange	YES	POC-Series with NTT and SIEMENS
		Data Platform	Hardware and Software architectures and components, Connectors services	YES	Edge-Gateways
Remotization	Data Space	Real Time Industrial Data Platform	How to access data generated in real time by Industrial IoT Systems	YES	Edge-Gateways
		Assets Administration Shell	How to access structural data of the facility and assets	YES	DIMOFAC Demonstrator
		Open Data Repository	Collection of historical Findable	NO	



			Accessible Interoperable Reusable open data sets		
		Assets Data Marketplace	Collection of high value data sets with associated value and monetisation	NO	
	ICT as a Service	Software as a Service	Applicative Software components and resources licensed on a subscription basis and centrally hosted	YES	3D-Expierence Platform from Dassault, SIEMENS NX, Schneider EcoStruxure™ Machine Advisor, Cloudbased ERP System from proAplha,…
		Platform as a Service	Cloud computing services that provide a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure	YES	MS Azure
		Infrastructure as a Service	Online services that provide high-level APIs used to dereference various low-level details of underlying network infrastructure like physical computing resources, location, data partitioning, scaling, security, backup etc	NO	
	Digital Twin	FEM/CFD/FSI simulation	Simulation of the physical behaviour of the system	YES	Digital Twin with SIEMENS Simulink and NX, Digital Twin built with the 3D-Experience Platform from Dassault, Digital Twins Solutions of Side Effects
		Discrete event simulation	Simulation of the temporal behaviour of the process	YES	Digital Twin built with the 3D-Experience Platform from Dassault
		Ambient virtualization	Digital representation of the environment to create immersive reality	YES	Schneider Electric EcoStruxure™ Augmented Operator Advisor
	Asset as a Service	Teleoperation	Usage of tools to operate on the assets in remote and to transfer skills and expertise to remote place without physically presence.	YES	Almer glasses, Holo-Lense, MyLifeZone

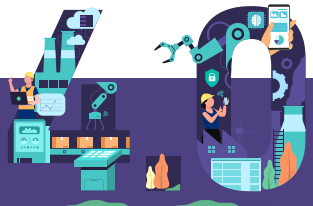
		Monitoring platform	Usage of tools for the assessment of the status of the assets and for evaluation of production working progress.	YES	Schneider Electric EcoStruxure™, Sigoor Asset Tracking, Power BI
		Avatar	A physical system capable of replacing a person in the working environment to transfer his ability anywhere	NO	
BUSINESS DEVELOPMENT	Incubation acceleration support	Basic facilities	Providing access to physical infrastructure (offices, café, meeting rooms, laboratories, co-working areas, libraries, etc.)	YES	With our brand-new Building in Biel (CH) we have very good basic facilities. All physical infrastructures mentioned in the bracelets are there
		Specialised facilities	Providing access to telecommunication infrastructure, high powered computing, video conferencing, labs and data ecosystem	YES	Several high-power computers and video conference systems. An extensive Industry 4.0 lab (Lighthouse Project)
		Business development	Coaches and mentors, entrepreneurs in residence, dedicated programmes to assist entrepreneurs in the process of business development (funnel, use case communication and assessment of SMEs), helping to adjust their organization and actions to the market and the changes brought by digitization, by adopting AI solutions	YES, TO-BE	Coaching, Mentoring and Consulting offered by the team of the Swiss Smart Factory. Several Trainings, Workshops and Tours offered and more will follow. Realization of Digital Transformation Projects with PoC's, Workshops and a clear Roadmap
		Guidance	Offering technical, fiscal and legal advice where necessary, and regulatory assistance	YES & NO	Focus on technical advice, fiscal and legal advice not



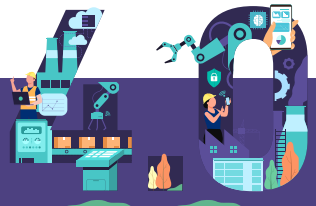
	Access to finance	Financial engineering	Providing support in addressing financial issues and/or advise on innovative financial products, value of AI legislation	NO	
		Connection to funding sources	Facilitating access to different funding sources (EU, national, regional, and private) aiming at achieving an effective mix of funds (conversation, lobbying, projects)	YES	Enabling the access to different funding sources with companies from Switzerland and abroad. SSF often the starting point of funded projects and support of SSF to companies, how process is going etc. Several national funded Projects ongoing together with companies from Switzerland and several EU funded Project together with Companies from all over the world.
	Offering housing	Innovation spaces	Offering innovation spaces to encourage innovators and other ecosystem members to interact and share ideas as well as spaces for experimentation and pilot manufacturing (including data ecosystem and spaces)	YES	Innovation-Space of 1000m2, SSF-membership for sharing ideas and starting PoC's and pilots in manufacturing. Within Lighthouse Project, several possibilities for PoC's, pilots, experiments etc. exists.
	Business training and education	Methods and Tools, Business Operations Modelling	Providing training and development in business skills and entrepreneurship (e.g., formal courses, workshops, seminars) and influence academia	YES	Currently offering two Workshops: Lean Manufacturing and Data Analytics, more will follow soon (AR, Chatbots, Low-Code etc.). We are offering The SSF Enabling Journey (Some kind of digital technology / AI Enabling) for companies. Working also together with local universities (BFH, HFTM) which are located in the same building.
		Secondment	Facilitating the exchange of personnel (e.g., researchers) and core competences among organisations, including IPR	YES	Strong relationship with local universities and other researchers. Supporting process of IPR in particular in finding potentials for patents in research projects
	Project development	Strategic analysis and alignment of EU vs regional RDI investments	A. Matchmaking in order to favouring the encounter between regional supply and demand interested in AI solutions, including universities and research institutes as providers, or less frequently between companies with similar needs or	YES	Together with our partners of the SSF-membership we are favouring the encounter between regional and national companies within the topics of industry 4.0. We are supporting the companies in their digitalisation strategy and are with them in innovative projects.

			complementary solutions DIHs help regions to build on the strengths identified in their smart specialisation strategies, and align their efforts with the capabilities of companies to use AI and the support structures they have available		
			B. Research of different calls and public funding opportunities. Helping SMEs and suppliers to orientate among EU projects, coordinating different support mechanisms, integrating regional, national and EU-level programmes and initiatives, and attracting forefront companies. Avoiding the risk of duplicating efforts, that is, that some innovation projects are running in parallel among companies who are not aware one of the other's activities	YES	We are supporting and encourage companies and organisations of our membership and beyond to participate in EU-Projects and we are coordinating and supporting the companies in coordinating withing the projects. We try to create synergies between several projects in order to avoid the risk of duplication.
		Identification of opportunities	Support in the identification of new market/business opportunities through strategic analysis of the ecosystem and trend watching	YES	We are supporting companies, which are looking for new market/business opportunities and showing them the actual trends in the appropriate business.
		Creating consortia	Encouraging cooperation and collaboration among organisations for exploiting common opportunities (e.g., business, research, funding, matchmaking, open innovation)	YES	We encourage companies and organisations of our membership and beyond to collaborate and cooperate among each other.

		Development of proposals	Providing technical assistance in the proposal development process in order to comply with specific proposal requirements (e.g., for project funding)	YES	We support companies and organisations in the writing of the proposal for national and international funded projects.
ECOSYSTEM BUILDING	Community building	SME and People Engagement	A. Mapping and analysis of the ecosystem requirements in order to enable the identification of consortium partners (or partnership) for establishing the DIH network, with a specific focus on AI technology providers	TO-BE	but planned
			B. Creating a community at the core of which is the DIH, which connects all members of the innovation ecosystem, with the goal to identify key stakeholders and potential partners with which to develop structured relationships	NO	
		Brokerage, Awards, Challenges	A. Connecting suppliers with customers, business support services, collaborators, capital providers and others (Academic institutions, HR)	YES	SSF-network for events and Projects like Lighthouse Factory 4.0, which has the goal to promote the know-how and technologies of the network.
			B. Stimulating and Rewarding collaborative innovation and problem solving	NO	
		Technology scouting	For companies seeking innovative technologies to incorporate into their portfolio (define customer + needs + ecosystem)	NO	

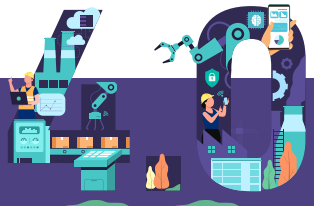


		Communication	A. Raising awareness about DIH's activities as well as innovative AI technologies and solutions across the community including the organisation of events in order to disseminate information and knowledge.	NO	
			B. Sharing best practices experiences and promoting and marketing themselves in EU landscape	YES	LinkedIn Channel and Website
			C. Inviting experts in business and entrepreneurship, or industry sectors to give talks and interact with (potential) customers and partners (study visits and roadshows)	YES	3x time a year Breakfast-Pitch in the SSF hold by partners of the SSF-network (15 partners in total every year). Partner-events to promote technologies, around 50 visits within total 3'000 visitors every year
	DIH Innovation Development	Trend watching	Providing up to date information on the trends in the market, assessment of market potential (business model)	NO	
		Visioning and strategy development	Supporting both start-ups and SMEs in shaping their vision and strategies as well as large corporates that require fresh thinking to remain relevant and competitive in the marketplace	YES	Within the SSF Enabling Journey, a roadmap is created to explore new solutions and technologies and how they can be transformed to business
	Ecosystem Governance	Services Impact assessment	Assessment of performed services (KPIs)	NO	
		Ecosystem strategy management	Engagement rules, statute, governance structure. Facilitation of relationships both within the DIHs ecosystems and between DIHs of the network.	NO	



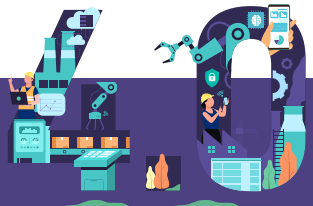
SKILLS & MATURITY ASSESSMENT	Process & Organizational Maturity	Maturity Assessment	Assessment of company readiness for Industry 4.0 (tech, organizational, and ecosystem readiness). It can be also in the shape of a self-assessment to prepare themselves before proceeding to work with the DIH	YES	In the context of the SSF enabling journey, we elaborate on a state analysis to assess the readiness of a company for industry 4.0. Afterwards we are looking for the future possibilities together with the company
		Maturity Strategy Development	Definition of a roadmap starting from the characteristics of the single enterprise or part of it. The roadmap design is based on the outcome of the assessment, and it proposes possible technologies, new solutions or new business models to be adopted	YES	Within the SSF Enabling Journey, a roadmap is created to explore new solutions and technologies and how they can be transformed to business
	Human Capabilities Maturity	Human Skill Repository	Making available an online repository containing catalogue for AI resource, documentations, training material, papers…	NO	
		Human skills maturity	Support in capabilities screening through on-site visit(s), interviews, etc. and definition of the actual level of skills maturity in Industry 4.0	YES	We went already to companies and organisation for on-site visits to discover opportunities and the actual level of skills maturity in Industry 4.0. Vice-versa a lot of companies and organizations visiting the Swiss Smart Factory for discovering new possibilities and opportunities in the context of industry 4.0
		Skills strategy development	Gap analysis between the AS IS and the desired level of AI skills, action plan definition and support to implementation	YES	We are supporting companies and organisations which in form PoC's.
	Skills Improvement	Human up-skilling, re-skilling training	Life-long training on technical and soft skills focused on AI at corporate level, operational and technology specific level. Training is addressed: to the workforce, to be able to deal efficiently with the newly	TO-BE	Within the SSF Enabling Journey, it is planned to support companies for life-long at corporate, operational and technology specific level.

			digitized products, processes or business models; to management, in order to overcome the cultural barriers; to trainers ("train to trainers"), to keep them constantly updated regarding new AI solutions. EU training course are also delivered		
		Educational Programs	Attracting and forming next generation talents, forming Industry 4.0 employees and workers	YES	To our strong relationship to the local universities, departing students can directly start in a very innovative and interesting environment for industry 4.0
		Scouting and Brokerage	Support in identifying channels, structure contacts and collaborations intended to knowledge-transfer, etc. with the aim to provide examples of existing (European) hubs and their approach to AI topics, and to combine new trainings with already existing capacity building materials developed by previous projects and from other reputable sources	NO	
		Standardization and certification	Standard methods and tool for standard certifications	NO	
TECHNOLOGY PROVISION	Ideas Management and Materialisation	Ideas Generation, Assessment. Feasibility study	Collecting new innovation ideas, refining and targeting them in a collaboration environment. Preliminary feasibility analysis. Support companies on solution implementation, ensuring they targeted the right combination of technologies and services in their products.	YES	Feasibility Analysis and POC's has been made with partners of the network and beyond



		Technology Readiness assessment	DIHs conduct Technology Readiness assessments on products / solutions developed by start-ups and SMEs	NO	
	Contract research	Strategic and Specific R&D	Strategic perspective: collaborative R&D projects to support the translation of innovative ideas into demonstrable concepts Applying technological innovation to develop new products/services or improving existing ones	YES	POC, MVP, Serial development with industrialisation partner
		Technology concept development/ Proof of Concept (PoC)	Planning and defining new business services solutions as well as demonstrating the feasibility of an idea or project through its temporary or provisional realisation. Practical demonstration and technology testing in available infrastructures and demo lab.	YES	Practical demonstration and technology testing has been made already several times on our lighthouse production
	Provision of Infrastructure	Access to infrastructure and technological platforms	Provision of a large range of services such as renting equipment, providing platform technology infrastructure, lab facilities as well as support to low-rate production	TO-BE	Most the technologies available at SSF are accessible for guest to test and experience
	Technical support on scale up	Concept validation	Developing minimum viable products that can be validated with real customers and/ or in an industrially relevant setting	YES	Starting with POC's and bringing it to the next level of an MVP. Especially in national funded projects is this the case or together with partners, when new demonstrators are created for the lighthouse project
		Prototyping	Designing prototypes to explore ideas and emerging technologies before going into production by also considering potential opportunities offered	TO-BE	Designing of Prototypes = Yes, but small series production of any products hast not been made within the SSF.

			by small series production		
	Verification and Validation	Product Qualification and Certification	Support in certifying that the product has passed functional, performance and quality assurance tests	YES	In some Med-Tech cases, we are able to support in certifying products for medical uses.
		Product demonstration	Promotion showrooms and demo cases in which a product is demonstrated in front of clients	YES	Lighthouse Project 4.0 with drone as demo product, Lean Manufacturing Training Environment with RC-car as demo product



3.5 Benchmarking of network services and possible collaborations

To get a quick overview of the potential complementary collaborations that can be carried out among the TEF network members, a comparison of the services offered by each "DR-BEST" macro-class has been provided in this subsection.

Table 6- Data macro-class comparison

Class	Type	Service[4]	POLIMI	SSF	INNO
DATA SPACES & DATA SHARING	Data acquisition and sensing	Data acquisition	✓	✓	×
		Data protection	☐	×	×
	Data processing & analysis	Data storage	×	✓	×
		Data analytics	×	✓	×
	Decision-making	Cognitive Big Data architectures	✓	×	×
		Decision support and development	✓	✓	×
	Physical-human action & interaction	Collaborative intelligence	✓	✓	×
		User experience	×	×	✓
		Feedback loop	×	×	✓
	Data sharing	GDPR and Data Sovereignty compliance	×	×	✓
		Data Spaces	☐	✓	×
		Data Platform	✓	✓	×

[4] ✓ If the service is provided (Yes)

☐ If the service is planned to be provided (To-Be)

× If the service is not provided (No)

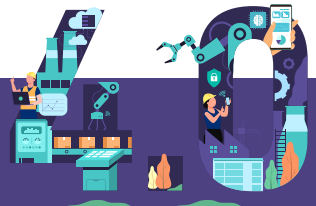


Table 7- Remotization macro-class comparison

Class	Type	Service	POLIMI	SSF	INNO
Remotization	Data Space	Real Time Industrial Data Platform	✓	✓	✓
		Assets Administration Shell	✓	✓	✓
		Open Data Repository	✓	✗	✗
		Assets Data Marketplace	☐	✗	✗
	ICT as a Service	Software as a Service	✗	✓	✗
		Platform as a Service	✓	✓	✗
		Infrastructure as a Service	✓	✗	✗
	Digital Twin	FEM/CFD/FSI simulation	✓	✓	✗
		Discrete event simulation	✓	✓	✗
		Ambient virtualization	✓	✓	✗
	Asset as a Service	Teleoperation	✓	✓	✗
		Monitoring platform	✓	✓	✓
		Avatar	✗	✗	✗

Table 8-Business macro-class comparison

Class	Type	Service	POLIMI	SSF	INNO
BUSINESS DEVELOPMENT	Incubation acceleration support	Basic facilities	✗	✓	✓
		Specialised facilities	✓	✓	✓
		Business development	✓	✓	✗
		Guidance	✓	✓	✓
	Access to finance	Financial engineering	✗	✗	✗
		Connection to funding sources	✓	✓	✓
	Offering housing	Innovation spaces	✓	✓	✗

	Business training and education	Methods and Tools, Business Operations Modelling	✓	✓	✗
		Secondment	✓	✓	✗
	Project development	Strategic analysis and alignment of EU vs regional RDI investments	✗	✓	✗
			✓	✓	✗
		Identification of opportunities	✓	✓	✗
		Creating consortia	✓	✓	✓
		Development of proposals	✓	✓	✓

Table 9-Eco-system macro-class comparison

Class	Type	Service	POLIMI	SSF	INNO
ECOSYSTEM BUILDING	Community building	SME and People Engagement	✓	☐	✗
			✓	✗	✓
		Brokerage, Awards, Challenges	✗	✓	✓
			✓	✗	✗
		Technology scouting	✓	✗	✗
		Communication	✓	✗	✗
			✓	✓	✗
			✓	✓	✓
	DIH Innovation Development	Trend watching	✓	✗	✓
		Visioning and strategy development	✓	✓	✓
	Ecosystem Governance	Services Impact assessment	✓	✗	✓
		Ecosystem strategy management	✓	✗	✓

Table 10-Skills macro-class comparison

Class	Type	Service	POLIMI	SSF	INNO
SKILLS & MATURITY ASSESSMENT	Process & Organizational Maturity	Maturity Assessment	✓	✓	✓
		Maturity Strategy Development	✓	✓	✓
	Human Capabilities Maturity	Human Skill Repository	✓	✗	✓
		Human skills maturity	✓	✓	✗
		Skills strategy development	✓	✓	✓
	Skills Improvement	Human up-skilling, re-skilling training	✓	□	✓
		Educational Programs	✓	✓	✓
		Scouting and Brokerage	✓	✗	✗
		Standardization and certification	✓	✗	✗

Table 11-Technology macro-class comparison

Class	Type	Service	POLIMI	SSF	INNO
TECHNOLOGY PROVISION	Ideas Management and Materialisation	Ideas Generation, Assessment. Feasibility study	✓	✓	✓
		Technology Readiness assessment	✓	✗	✓
	Contract research	Strategic and Specific R&D	✓	✓	✓
		Technology concept development/ Proof of Concept (PoC)	✓	✓	✓
	Provision of Infrastructure	Access to infrastructure and technological platforms	✓	□	✓
	Technical support on scale up	Concept validation	✓	✓	✗
		Prototyping	✓	□	✗
	Verification and Validation	Product Qualification and Certification	✓	✓	✓
		Product demonstration	✓	✓	✓

4 RE4DY Testing and Experimentation Facility (TEF): Experiment Plan

Data is being generated at a faster rate than ever before by businesses and organizations of all sizes. To function effectively and make informed decisions, they must exchange that data both internally and with one another. Data sharing between enterprises requires both interoperability and data sovereignty (Jacoby et al. 2021), Data can be combined and used together even when it comes from different sources and in different formats thanks to data interoperability, obtaining data interoperability enables a company to maximize the value of its data while overcoming the significant challenges posed by distributed data assets while data sovereignty ensure the authority and control of data while being exchanged.

The concept of a Digital Twin (DT) is a hot topic in all initiatives aimed at developing and implementing service and data infrastructures for networked industrial production. Due to the digitalization and subsequent virtualization of the physical assets in a production environment, it is becoming more prominent (Jacoby et al. 2021). The true power of a digital twin—and the reason it might matter so much—is that it can create a thorough linkage between the physical and digital worlds in near real-time (Parrott and Lane 2017). A single instance of such a digital representation is insufficient to support production environment use cases. Interactions between DT instances must be supported, as well as the aggregation of DT instances to represent complex physical assets. Furthermore, because these DT instances (and their physical counterparts) may be installed in different organizational units, supporting infrastructures for such networked DT instances must be considered. As a result, syntactical and semantic interoperability is not only a challenge for data exchange between physical entities, but also for data exchange between digital entities. This also includes aspects of data access and usage control, raising the issue of data sovereignty (Jacoby et al. 2021).

Having mentioned the importance of data exchange for networked industrial production and similarly for network of TEFs to offer their services or products more convenient and efficient to their potential customers or stakeholders as well as importance of Remotization aspect of the services among network, within the context of task 3.1 which aims to support the design of a robust experimentation plan for qualification of technical assets in task 3.8, in following subsections, an initial concept for the experimentation plan has been introduced.

4.1 Preparing an initial experimentation plan based on available services

Knowing the service portfolio of each TEF, which was compiled and examined in earlier sections, enables us to take advantage of the services offered either individually at each TEF or collectively among networks to provide innovative services or products to potential stakeholders or customers within the concept of RE4DY. "The READY concept advocates for adoption of modern distributed data management and integration architectures based on data fabric design principles and to extend those to value ecosystems and data spaces.

To address increasingly connected and autonomous manufacturing value networks, which are the principles for active resilience implementations, such principles need to be integrated with data space sovereignty principles and Asset Administration Shell (AAS) models" (European Commision 2021). Hence, based on the RE4DY concept and available service and/or existing assets which can be supported by TEF network while considering future requirements in task 3.8, here in this subsection first a brief description of tools that can be used for this initial experiment have been depicted and in the second part the possible scenarios for experiment have been explained.

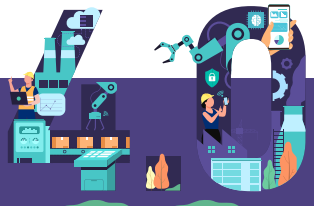
To meet the requirements and available services of TEF network, the development of a Digital Twin-supporting infrastructure makes use of and integrates Platform Industry 4.0 concepts, particularly the Asset Administration Shell (AAS), and International Data Spaces (IDS).

AAS engages several functions that are intended to make this technology a real interoperability enabler in the manufacturing domain. To ensure interoperability, each AAS entity can rely on a set of functions (Quadrini et al. 2023):

- *Reference*: an ordered list of keys which, key by key, defines the represented element.
- *Kind*: level of "embodiment" of an asset, which can identify the asset as a type (e.g., a specific tool part of a manufacturer's catalogue) and is named as type or can embody a type in specific object in the shopfloor and is named as instance.
- *Referability and Identifiability*: since "every physical thing" should be univocally identifiable and referable, AAS provides global identifiers that can unambiguously point to a certain asset type independently from the context, and other attributes (i.e., idShort, category, description, parent) which make the entity referable in a defined namespace and explicit its relations with eventual parent referable entities.
- *Semantics*: structured references to external entities.
- *Data Specification*: a set of additional attributes to the ones already defined in the default class. Thanks to the Semantics functionality, Data Specification can be referenced to existing global templates.
- *Asset Administration Shell*: is the main element of the metamodel and contains references to the Asset, eventual Submodel(s) and concept Dictionary.
- *Asset*: an identifiable entity containing all the metadata about the related asset.
- *Submodel*: an entity listing specific attributes of a subsystem of the metamodel.

In the sense that the same metamodel, with a Kind defined as type, can be univocally represented in a different context, facilitating, for instance, the standardization of bill of materials for machines or the supply request for spare parts, all these characteristics, particularly the identifiability, contribute to the overall objective of interoperability (Quadrini et al. 2023).

The International Data Spaces (IDS) is a data network that concentrates on information sovereignty, or a data provider's ability to regulate who and how their data is used (Otto et al. 2019). The central component, the IDS connector, is a gateway to the network and different implementations are in development to ensure data security and sovereignty (Jacoby et al. 2021).



Hence, developing AAS concept in the assets of each TEF network could be essential in order to be shared and exploited among network members or customers while ensuring the security and sovereignty of the connection and data. Following the service portfolio analysis in the framework of "DR-BEST" methodology, the network of TEFs intends to offer potential stakeholders the opportunity of receiving services or products which were not being delivered by each single TEF due to some missing services while being now a member of the TEF network, it can provide the customer or potential stakeholders with this service or product. In order to implement this idea to an experimental plan, here, two general scenarios have been discussed which can be exploited or extended for the experiment and deployment of assets as required by task 3.8 of the project:

4.1.1 First scenario

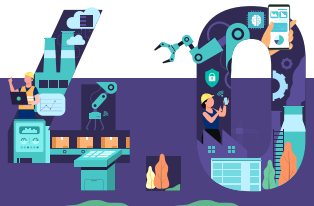
The first scenario deals mainly with the data exchanges stored and not being actively moving (data at rest):

i. Sharing AAS of same equipment/devices or process for validation: if there are similar equipment or devices or even processes among the network of TEFs, since AAS makes them to be interoperable, they can be used in different locations (with only a small amount of effort to be adopted for the new place) expecting the same behaviour and output for that device or process. For instance, exploiting two similar UR5 robots at two different TEFs to validate a machine learning or artificial intelligence algorithm to do a specific task by these same devices

ii. Sharing AAS of different equipment/devices to design a virtual factory: this sub-scenario benefits from the idea that AAS models of various assets originally located at various locations can be integrated and used in order to form a virtual factory that physically does not exist. Based on the needs of customers, several virtual assets from several TEFs or enterprises can be gathered so that after exchanging the AAS models and implementing simulations, results or services be delivered to the customer as a result of this virtual factory. For instance, using a 3D printer from one TEF network member to make the raw material which will be used by another TEF network member for its assembly line, this can be done by a simulation within this virtual factory

iii. Sharing AAS of various products/components to make a single modular product at the virtual factory: a similar idea could be also extended for producing a modular product consisting of several components each of them being supplied by the AAS representation of that component from different TEFs or organizations to be assembled to make the final single product at the virtual factory. For example, a mobile phone in which each of its components are supplied by AAS models from various companies to be collected and make a single AAS representation of mobile phone as the single asset in the virtual factory.

iv. Share the AAS with enabled students or customers to develop applications mining data directly from the hardware: here, the idea is to provide a repository of various AAS assets each one located and supported at one TEF or organization while granting access to external potential stakeholders or students or customers so that they can benefit from these assets to develop and use them for their needs or applications. For instance, providing a list of AAS assets including robots and mobile manipulators and obstacles so that they be used on a mobile manipulation challenge for educational purposes.



4.1.2 Second scenario

The second scenario relates to the signals and data in motion:

i. Comparison of different signals coming to the same type of hardware located at different TEFs: within this case, a collection and comparison of various signal emerging from various sources will be made for the same hardware existing at different TEFs or organizations. for example, robot with different end effectors

ii. IDS Connector to connect Digital Twins and AAS between TEF network members which requires a third party to host the centralised nodes: this idea exploits the IDS connector to make communication between two or several AAS-based digital twins possible. An example could be a coffee provider with an automatic sorting machine which sorts the preferred coffee beans ordered by the customers both represented by AAS and communicating via IDS connector (*Figure 17*).

iii. Real-time feeding: since AAS is a structured data representation of an asset, it can be fed by real-time data or info by a user to have the updated and realistic behaviour of the asset. An example could be the real-life cycle of a rotating shaft of a mechanical device which receives real time data for its remaining life before failure to prevent huge damages in the mechanical system.

iv. Feeding AAS asset by data coming from other pipeline: in this case, the user takes data references (e.g., data types) from the AAS, then use the data from another pipeline to feed it in the AAS structure.

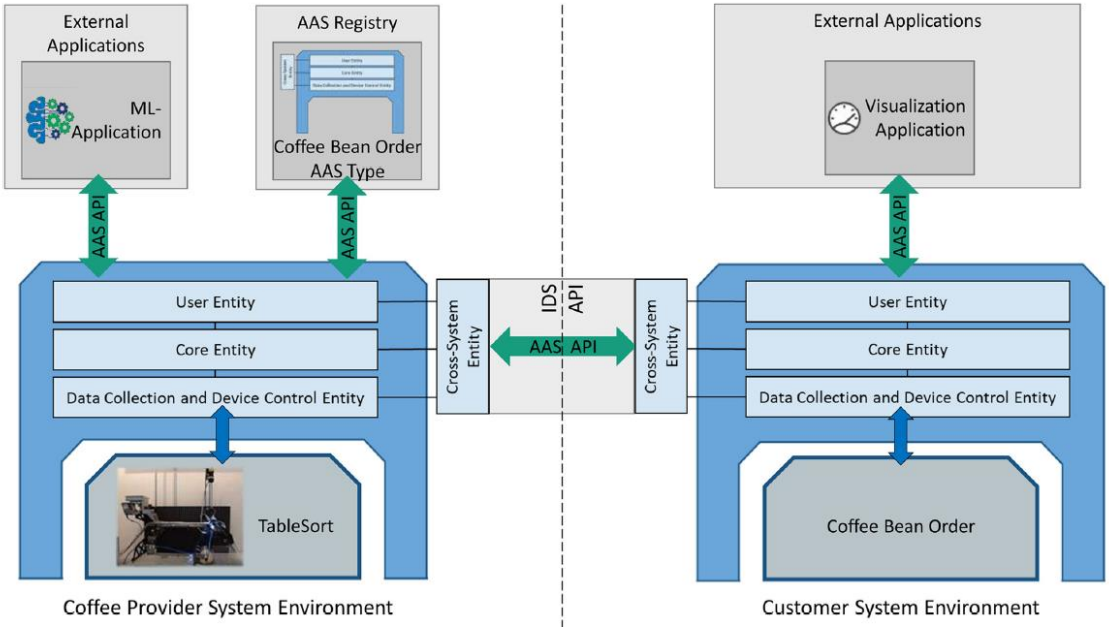
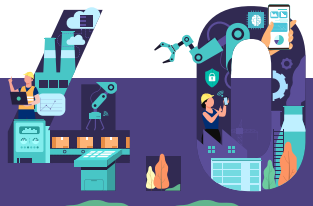


Figure 17- Second scenario- DTs communications via IDS connector (Jacoby et al. 2021)

Table 12-Table of scenarios and proposed added values

Scenario	Sub-Scenario	Proposed Added Value
First	Sharing AAS of same device/process	▪ Validation of ML/AI algorithms used to run the device or process ▪ Enhancing AAS structuring by experiences from these tests ▪ Supplying a service or product at a higher capacity since both outputs should be the same but at several organizations ▪ Improvement of services or products offered by these organizations benefiting from exchanging experiences
	Sharing AAS of different device/process	▪ Ability to make a virtual factory made of shared assets by various organizations ▪ Variety in types of services or products by exchanging assets ▪ Knowledge exchange as well as asset ▪ Eliminating physical limitations and costs for cross-collaborations ▪ Opportunity to have new customers and markets
	Sharing AAS of various products/components to make a single modular product at the virtual factory	▪ Variety in supplying services or products ▪ Ability to enter to new markets ▪ Eliminating the costs of buying new assets ▪ Integration among the network to reach one product or service
	Share the AAS with enabled students or customers to develop applications mining data directly from the hardware	▪ Sharing knowledge ▪ Opportunity to receive enhanced models of assets ▪ Opportunity to have new customers and markets ▪ Extending the interoperability of models by being used by several stakeholders
Second	Comparison of different signals coming to the same type of hardware located at different TEFs	▪ Resiliency of the model ▪ Lower cost of new asset purchases ▪ Useful for training data models and algorithms
	IDS Connector to connect Digital Twins and AAS between TEF network members	▪ Communication among DTs ▪ Facilitating the operations ▪ Improving efficiency of assets ▪ Time efficiency ▪ Shorter lead time of the service or product
	Real-time feeding	▪ Real representation of the asset ▪ More reliable asset modelling ▪ Applicable to various technical sectors like predictive maintenance
	Feeding AAS asset by data coming from another pipeline	▪ Ability to update asset models from various sources ▪ Opportunity to have new customers

These two scenarios result in the network user (or client) receiving metadata from AAS and using data streams for applications such as machine learning, artificial intelligence, or virtualization.



5 RE4DY "Data as a Product" (DAP) and Data Connection Profile (DCP)

5.1 RE4DY "Data as a Product" Containers and Open Toolware

Data as a Product[5] is an approach to distributed platforms based on the principle of treating data as a consumable product and anybody who needs to consume the data as customers. Thus, this approach includes the entire process of getting data to an adequate condition for the customers to consume, which considers aspects such as data quality and decreased lead time of data consumption.

In order to be able to treat the data as a consumable product, it must have the following qualities:

- Discoverable- to allow data consumers to find interesting datasets easily.
- Addressable- it must have a unique address to ensure that data consumers can access the data programmatically.
- Trustworthy and truthful- it must reflect the reality.
- Self-describing semantics and syntax- to make possible that the data consumers access and use the data without direct intervention of the data provider.
- Interoperable- to allow data sharing and correlation across different domains.
- Secure- with access control policies defined with the appropriate granularity.

The objective of the RE4DY "Data as a Product" Containers and Open Toolkit is to offer the data consumers access to the data from the use cases following the Data as a Product principles.

5.1.1 Data Containers

The Data Containers (DC) will define a trustworthy abstraction layer to make the data available for the RE4DY services and the different data consumers. DC will provide access the data from the different sources regardless of their type or specific features (such as structured or non-structured data, relational databases, NoSQL data stores or streaming), while supporting security, privacy, and data governance. This way, the data consumers will be able to access the data without having to deal with the technical complexity that can exist in the use cases. DC will provide an encapsulated and unified view of the data, allowing multiple applications to access the same data in a trusted and reliable way, as well as a link capability with other data containers, thus allowing the definition of complex DC as a composition of simpler DC.

[5] https://martinfowler.com/articles/data-monolith-to-mesh.html#DataAndProductThinkingConvergence

The Data Containers will provide predictability and trusted data-centric connections, enabling the creation of a data sharing framework based on data containers, with different profile access, considering the problem of moving from one system to another reliably. The initial definition of the Data Containers will be based on the outcomes of the H2020 projects DITAS[6] and DataPorts[7]. Both projects made use of the Virtual Data Container concept to define a middleware layer that delivers the data in a secure, consistent, and timely manner, and hides all the underlying complexity, thus allowing the application developers to focus only on the required data.

5.1.2 Data Management Toolkit

In addition to the use of DC, a toolkit for data management in decentralised networks (developed initially in AUTOWARE[8]) will be adapted and extended in RE4DY in order to support decentralised ML tools for target applications of the use cases, which could be for example anomaly detection. For instance, this toolkit could be integrated in a RE4DY use case to orchestrate data distribution across machines cooperating to detect rare anomaly events across different production sites (but homogeneous in terms of the detection task), so that rare anomalies can be spotted efficiently at one place and this knowledge can be immediately transferred to the other relevant locations.

5.1.3 Data Modelling and Ontologies as enablers of "Data as a Product"

One of RE4DY objectives regarding the delivery of "Data as a Product" is to extend RAMI4.0, OntoCommons and IOF frameworks with an open value network resiliency ontology library and common information model for increased semantic and technical interoperability and reusability.

At this early stage of the project (M9 - the related task T3.3 started on M6), the first step was to conduct research so to collect state-of-the-art ontologies and data model that are widely used in industry and academia for the description of manufacturing data, assets, and processes. RE4DY aims to use standardized data models that will enable platform's interoperability and adoption beyond the scope of the project. In ¡Error! No se encuentra el origen de la referencia., the most relevant ontologies, vocabularies and data models have been summarized that will be considered during actual data modelling and data transformation processes of the project.

[6] https://cordis.europa.eu/project/id/731945
[7] https://dataports-project.eu/
[8] http://www.autoware-eu.org/

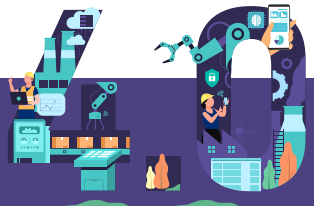
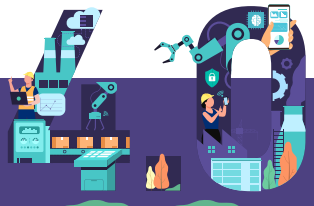


Table 13 - List of Ontologies/Data Models

Ontologies/ Data Models/ Vocabularies	Short Description
OntoCommons & IOF ONTO COMMONS	Ready-to-use Ontology Commons EcoSystem (OCES) for data documentation, including a set of ontologies and tools
OPC UA Information Model and Data Models	OPC is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries. It is platform independent and ensures the seamless flow of information among devices from multiple vendors
Cross-CPP - Standardized Cross Industrial Data Model CROSS-CPP CIDM	Provides a single point of access to data streams from multiple smart products in easily accessible non-proprietary data formats
OGC SensorThings Open Geospotial	It provides a common data model and services that allow IoT devices and applications to CREATE, READ, UPDATE, and DELETE IoT data and metadata. The data model is designed based on the ISO/OGC Observation and Measurement (O&M).
Asset Administration Shell Models and Sub-models INDUSTRIE4.0 DTA	Asset Administration Shell (AAS) is the digital representation of an asset. The AAS consists of a number of sub-models in which all the information and functionalities of a given asset - including its features, characteristics, properties, statuses, parameters, measurement data and capabilities - can be described.
QUALITY Ontologies, Data Models and Vocabularies from previous EU Boost Projects Nim34	Various data models and ontologies has been developed in EC-funded projects and they are related to manufacturing and supply-chain domains.

OntoCommons has gathered a wide list of ontologies[9] from Mechanical and Industrial Engineering, Materials Science and Processes alongside with ontology engineering tools[10]. Both are considered to be employed for the development or the extension of RE4DY common ontology library. OPC Foundation is working on the creation of OPC UA representations[11] for information from different domains. This approach could be considered as a reference point for the projects ontology library that should be support different domains based on the different pilot needs. Asset Administration Shell[12] includes sub-models that introduce an exchange format for the transport of information from one partner in the value chain to the next and would be considered in resilient scenarios of RE4DY. Another approach to be considered is the Common Industrial Data Model (CIDM)[13] by Cross-CPP. It is an open and scalable big data format, designed to harmonize IoT proprietary data into generic datasets. To the same aim, about the modelling of IoT devices

[9] https://zenodo.org/record/6504553#.ZBwnhXbMJPY
[10] https://zenodo.org/record/6504670#.ZBwntnbMJPY
[11] https://www.ascolab.com/technology-unified-architecture/meta-model.html?lang=en
[12] https://industrialdigitaltwin.org/wp-content/uploads/2021/09/07_details_of_the_asset_administration_shell_part1_v3_en_2020.pdf
[13] https://www.cross-cpp.eu/cidm



that are attached to manufacturing assets etc., OGC introduces SensorThings[14]. It is a common data model for IoT devices description alongside an API that enables CRUD operations to 'things' (devices/assets). Furthermore, EU-funded research projects such as Boost 4.0, and Quality has developed ontologies for manufacturing assets' representation and the relevant models will be employed for RE4DY processes as well. Other EC-funded projects' outcomes like COMPOSTION and NIMBLE will be considered as they propose some ontologies that connect manufacturing assets and capabilities with supply chain aspects based on e-class[15] data standard.

Beyond the research regarding the current state-of-the-art the modelling of manufacturing assets and services, RE4DY has also decide the usage of Facility Asset Information Modelling Framework (IMF) that is to enable transitions to information models of facility assets from current documentation practice. In order to achieve its purpose, the IMF framework is comprised of methods and resources designed to support incremental and scalable implementation.

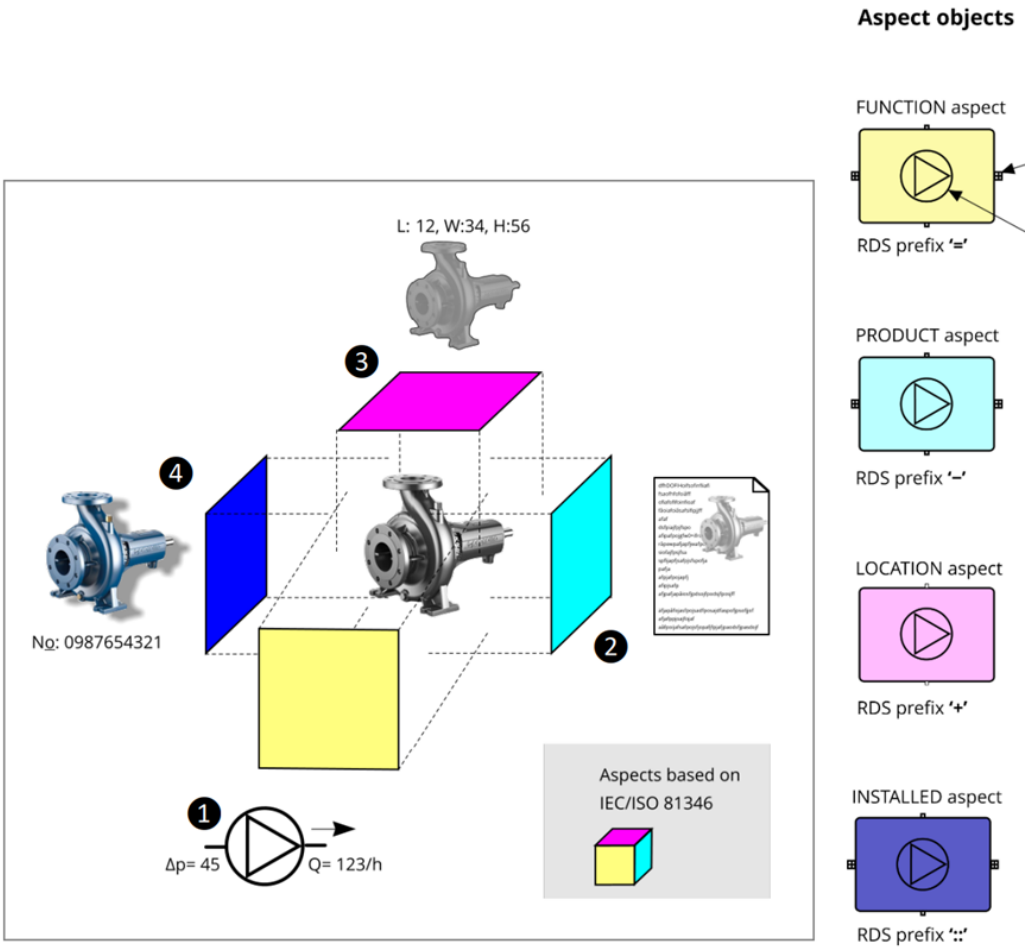


Figure 18- IMF Example Representation

In particular, IMF provides for incremental implementation where current ways of working are dominated by legacy systems, tools, and work processes, by creating value at each

[14] https://www.ogc.org/standard/sensorthings/
[15] https://eclass.eu/en

step of a gradual modelling exercise. Rather than aiming at developing one single model of an asset from the start, IMF identifies different types of models, where context models are the most basic ones. A context model is a model of a system, typically from one perspective, from one contributor in the value chain, and at one stage in the project lifecycle. A context model has clear interfaces to existing documentation, and thus provides incremental added value to the total body of documentation.

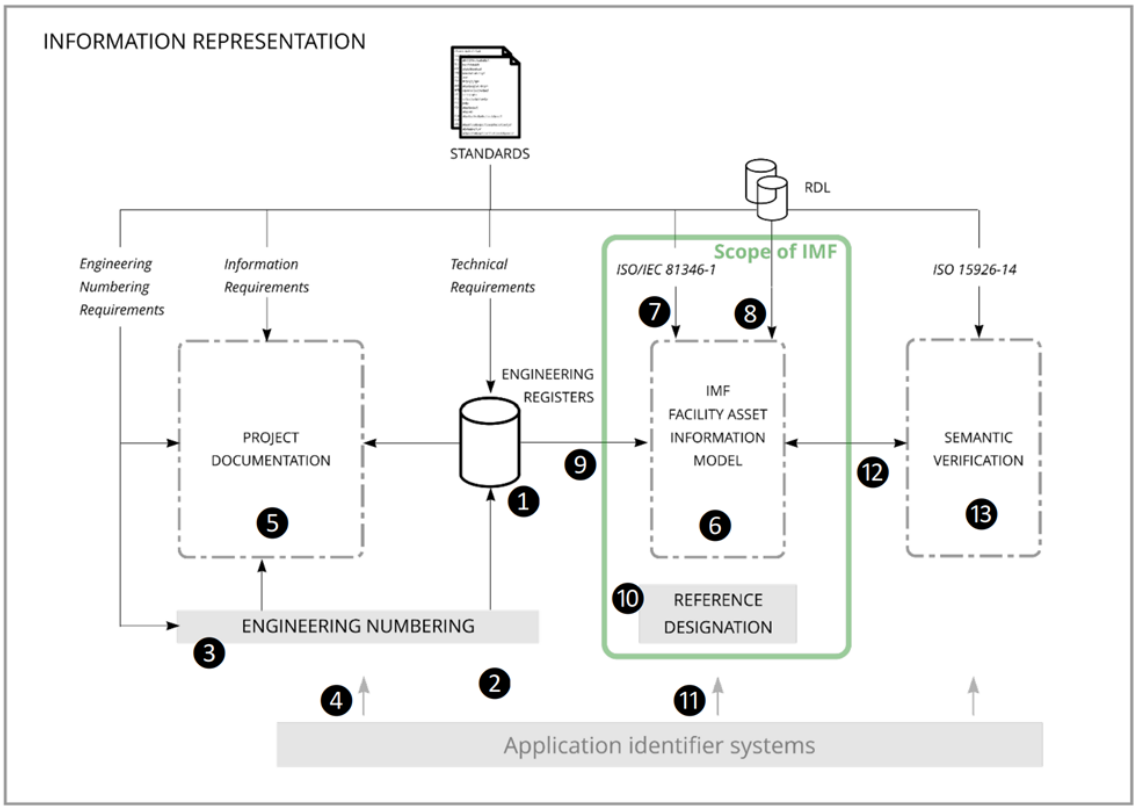


Figure 19- Information Representation Flow &Scope of IMF

5.1.4 Data Transformation and Sovereignty Services of RE4DY Data Fabric

Within the scope of WP3 and T3.3 RE4DY project aims to develop an open toolkit to enable industry to lift existing deep data sources and build "Data as Products" for self-service data consumption, active semantics and data engineering automation across value networks. Beyond the modelling approaches that are described in the previous section, the project will deliver services for Data Transformation and Data Virtualization as they are core technologies that enables a data fabric approach. Ideally, rather than physically moving the data from various on-premises and cloud sources using the standard ETL (extract, transform, load) processes, RE4DY aims to connect to the different sources, integrating only the metadata required and creating a virtual data layer. This allows users to leverage the source data in real-time.

Regarding secure and sovereign data exchange, the project is going to exploit IDSA RAM and relevant components through RE4DY Data Space as it is described in the previous chapter. However, for meeting the need for "Data as a Product" beyond these sovereignty services regarding the data transfer, the project should support some data transformation services as well that should work complimentary with the sovereignty ones. In this initial stage, research has conducted to this direction. World-leaders in ICT domain provide tools for ETL services, such as AWS Glue[16] than enables customers to prepare and load their data for AWS analytics. Microsoft Azure provides its Data Factory (ADF)[17] that allows developer to integrate disparate data sources with Azure data base services. IBM InfoSphere DataStage[18] is a leading ETL platform that integrates data across multiple enterprise systems, and it is available both on fog and cloud. Beyond these proprietary solutions, some examples of open-source available solution were detected. Jolt[19] provides a set of transforms for JSON-to-JSON transformation. It focuses on transforming the structure of JSON data, and not manipulating specific values. KETL[20] platform is a production ready ETL solution that is built upon an open, multi-threaded, XML-based architecture. KETL is designed to assist in the development and deployment of data integration efforts which require ETL. To the same direction, pygrametl[21] framework provides commonly used functionality for the development of ETL processes. In EFPF EU-funded project, the concept of an interoperable and open-source available Data Spine[22] was introduced.

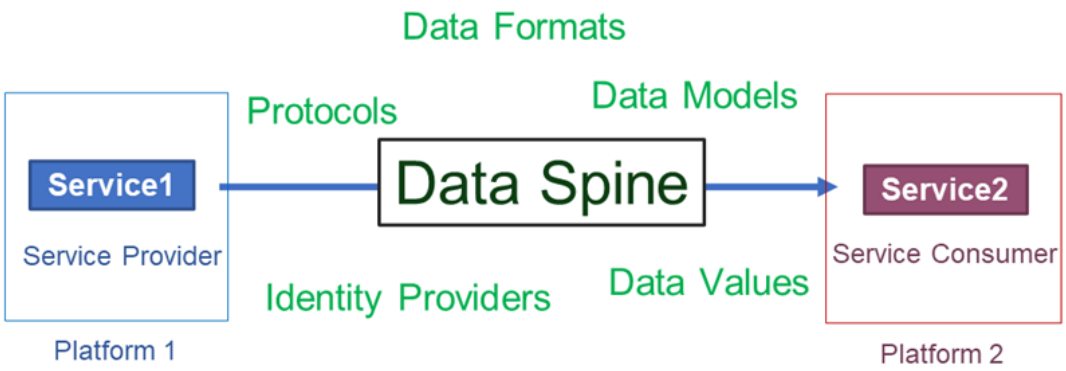


Figure 20- EFPF Data Spine Concept

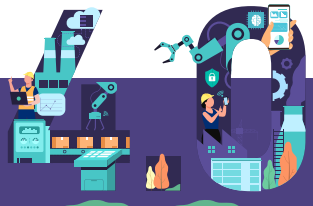
This artefact combines technologies for data and services integration and secure communication by surpassing protocols and data models limitation. It uses Apache NiFi[23] as the core integration engine, a MQTT broker as message bus, LinkSmart Service Catalog[24] as service registry and Keycloak[25] for authorized data access. Comparing these

[16] https://aws.amazon.com/glue/
[17] https://ms-adf.azure.com/en/
[18] https://www.ibm.com/products/datastage
[19] https://github.com/bazaarvoice/jolt
[20] https://www.linuxlinks.com/ketl/
[21] https://pypi.org/project/pygrametl/
[22] https://www.mdpi.com/1424-8220/21/12/4010
[23] https://nifi.apache.org/
[24] https://github.com/linksmart/service-catalog
[25] https://www.keycloak.org/

components from Data Spine with RE4DY approach and needs, it seems that this EFPF approach could be the starting and reference point that RE4DY would build its data sovereign and transformation services. Key elements from RE4DY data space such as IDS Connectors and IDS Broker could take the place of message bus and service registry. A Keycloak instance will be also employed for RE4DY purposes. The integration part regarding data sources could be based on Apache NiFi by combining it with ETL open-source tools such as Jolt.

Apache NiFi is an open-source data integration platform that enables users to automate the flow of data between different systems. With NiFi, users can create data pipelines to move, transform, and process data in real-time, making it an ideal tool for data streaming applications. It has a simple, drag-and-drop, user interface (UI), which allows users to create visual dataflows and manipulate the flows in real time and it provides the user with. It organises them as FlowFiles. NiFi, has as a core concept the processors. These processors provide capabilities to ingest data from numerous different systems and route, transform, process, split, aggregate and distribute them to many systems. All the processors are highly configured. Custom processors can also be built.

In RE4DY project, there is the need to meet the requirements of ETL services as explained before. So, data should be extracted, transformed and loaded across the RE4DY data fabric. Apache NiFi is considered as an ideal option, as it has processors that can enable these three services. NiFi can handle a large variety of file formats such as Json, csv, text etc. and for that reason it is effortlessly adopted in cases there are no restrictions regarding the file formats. Even if there would be a file format that it is not the ideal, NiFi will be able transform it. One of the key processors that can be used in NiFi to enable data transformation is the above-mentioned Jolt.



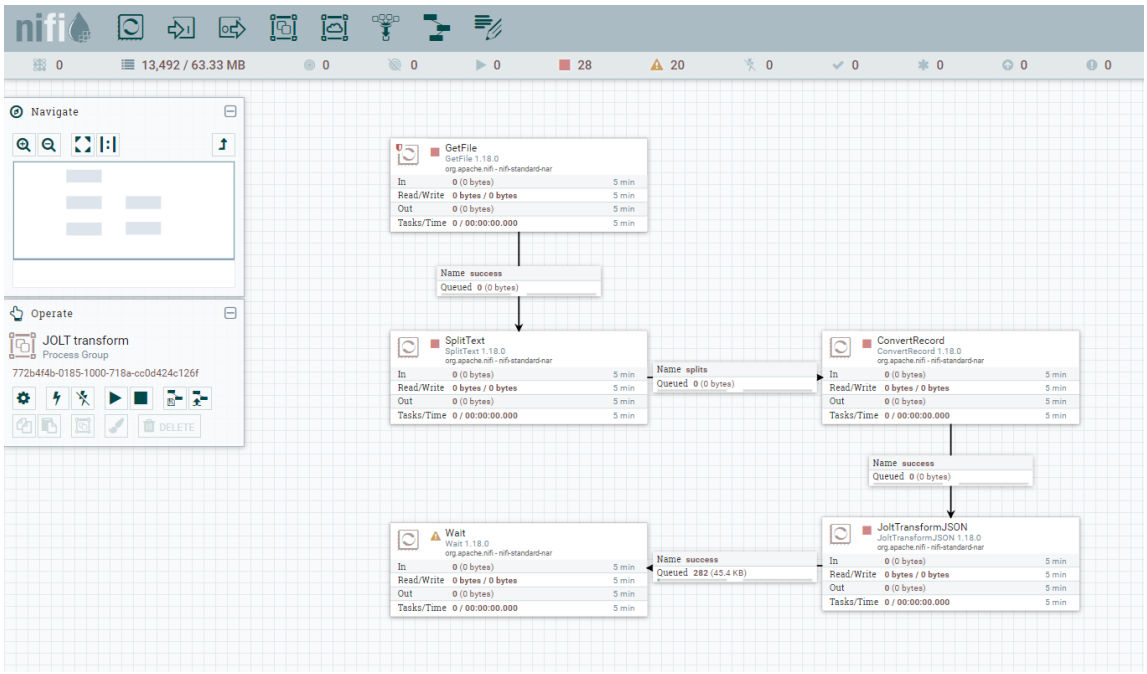


Figure 21- Apache NiFi Example regarding Data Transformation

For the purposes of T3.3, a testing environment for our instance of the NiFi platform has been set-up. Various processors have been tested so far:

- GetFile: Creates FlowFiles from files in a directory. Nifi will take the files from an input directory that the user will insert.
- SplitText: Splits a text file into multiple smaller text files online boundaries limited by maximum number of lines or total size of fragment. Each output split file will contain no more than the configured number of lines or bytes
- ConvertRecord: Converts records from one data format to another
- JoltTransforJSON: Applies a list of Jolt specifications to the Flowfile JSON payload. A new FlowFile is created with transformed content
- InvokeHTTP: An HTTP client processor which can interact with a configurable HTTP Endpoint. The destination URL and HTTP Method are configurable. FlowFile attributes are converted to HTTP headers and the FlowFile contents are included as the body of the request (if the HTTP Method is PUT, POST or PATCH).
- SplitJSON: Splits a JSON File into multiple, separate FlowFiles for an array element specified by a JsonPath expression
- UpdateAttribute: Updates the Attributes for a FlowFile by using the Attribute Expression Language and/or deletes the attributes based on a regular expression
- ReplaceText: Updates the content of a FlowFile by evaluating a Regular Expression (regex) against it and replacing the section of the content that matches the Regular Expression with some alternate value.

- PutFile: Writes the contents of a FlowFile to the local file system. The processor transfers the file from the nifi system to the local file system.

5.2 Data Connection Profiles (DCP)

Data Connection Profiles (DCP) enable simple, durable and context-sensitive integration between complex systems without wasteful custom development. Data Containers will be based on a defined set of common DCPs, which will be defined on a use case basis.

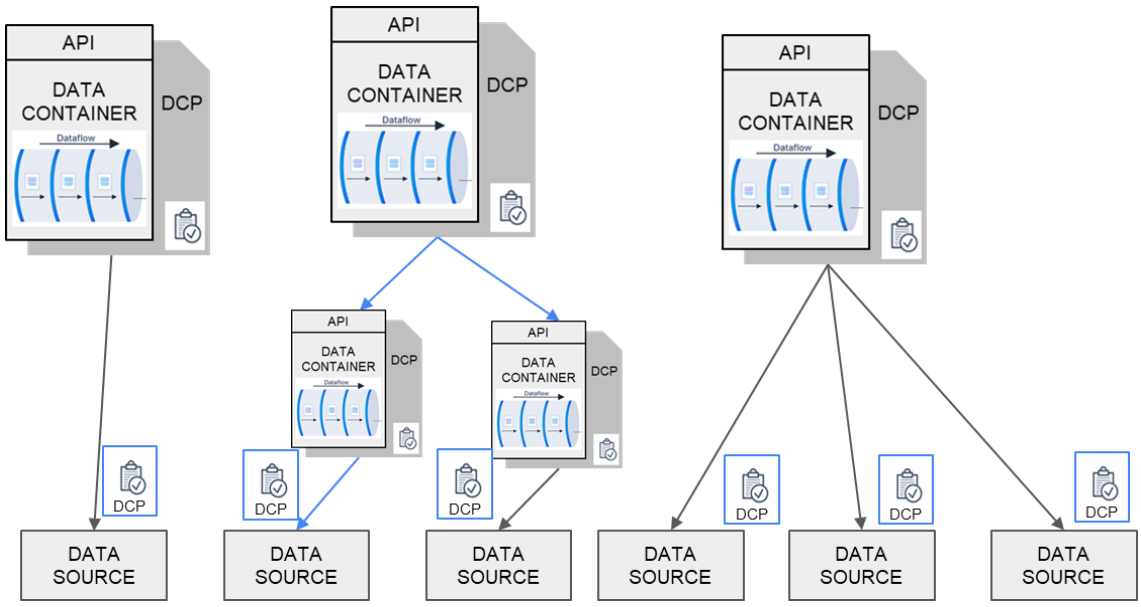
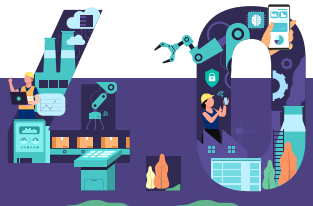


Figure 22- Data Connection Profiles and Data Containers

The Data Connection Profiles (DCP) are the fundamental element to harmonise, simplify and provide a well-known computing continuum that can be trusted and where data consumers and providers can deploy their data. The DCP will provide a standardized description of how the data from the use cases is going to be accessed to simplify the use of the data by other RE4DY components and to ease the integration. DCP will be the basis for accessing the data, providing the necessary information to access the data from the sources or from the DC. The Data Containers will make use of the DCP to communicate with the data sources in order to obtain the data (*Figure 22*). A DC could access data from one or more sources, which could be other Data Containers. Similarly, the components built on top of the DC will make use of the DCP to obtain data from the DC.



6 RE4DY Data Space and Toolware Catalogue

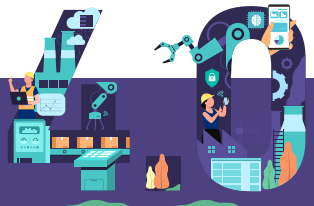
As described in RE4DY DoA, "*the ultimate goal of data-driven industrial value networks is to timely and cost-effectively implement their business processes and workflows. Industrial value networks are increasingly dependent on nurturing suitable data value ecosystems facilitating trusted sharing and effective distributed data processing over common data spaces.*"

In that regard, *RE4DY concept is fully aligned with the EU Data Space design principles: (1) Standardised data objects as a product and data platforms, providing support for effective data sharing and exchange as well as for data engineering automation and data quality and compliance assurance for clear and fair rules on access and the re-use of data; (2) Data marketplaces, for frictionless value network & deep data "prosuming"; (3) Data sovereignty, based on appropriate governance scheme and solid models for industrial value network agreements aligned with Gaia-X and IDSA data space specifications. RE4DY data value ecosystem and digital 4.0 continuity technologies for DaaP allows: (4) Open and qualified open software services and toolware that can be integrated as part of the digital thread and digital twin management fabric and supports E2E unified operation, governance, compliance and security of digital threads and digital twins fabrics; (5) Unification of data policy management, irrespective of the fact that data is provided or consumed from internal (deep) data sources or value network data sources. Unified digital thread fabric operations extend the toolset developed as part of the Boost 4.0, which already integrates and supports IoF (Industry Ontology Foundry), ProSTEP and NIST QIF3.0 digital thread and digital twins models. (6) Digital thread orchestration vs digital thread replacement. RE4DY concept does not attempt to force or predict how the data is to be used but to enable that type of decision to be made by today's user (and tomorrow's), while still maintaining appropriate access control and security at a value network level. It is important to remember that in an age where new technologies can go from cult usage to widespread adoption with astonishing rapidity that RE4DY aims to allowing orchestration of existing and future digital thread and cognitive digital twin data services rather than replace existing infrastructures.*

In order to realize RE4DY's data space, WP3 has first carried out an initial description of the different tools (commercial and open source) brought to the project by partners (section 6.1) and, identified their main features. Secondly, each of these tools have been mapped to the IDSA building blocks (section 6.2) to understand what aspects of the data space concept (and more particularly, the RE4DY data space) could be fulfilled with the available tools.

6.1 Initial identification and description of partners' tools and assets

In this section it is presented an initial list of partners' tools, services and components identified as part of the activities of task T3.2-T3.7. To that end, a survey was carried out,



using a template (see Annex I) for compiling partners' feedback, and describing – in a high-level manner - each of their assets/tools.

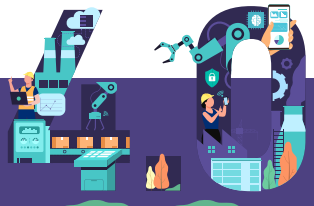
The template gathers relevant and comprehensive information of a specific technological asset. For that, it is organised into the following sections:

- (1) General Information: The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.
- (2) Features: The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
- (3) Dataset: The Dataset section should only be filled if the component belongs to this category, otherwise it must be left blank.
- (4) AI Model: The Machine Learning Model section should only be filled if your component belongs to this category, otherwise leave it blank.
- (5) Implementation: The Implementation section highlights the most technical aspects regarding the development of the component. It contains information such as the deployment requirements of the component, its communication capacities and other correlated components.
- (6) Distribution: The Distribution section describes the multiple ways in which the component can be accessed and used.
- (7) Reference: The Reference section provides useful documentation of the component, such as instructions manuals, datasheets, publications related to the component, training material, and so on.
- (8) Legal Aspects The Legal Aspects section contains the legal description of the component. Information like the associated license and the owner's contact information will be available here.
- (9) Project-related Information: The project-related Information section contains additional details about the component in the context of the project, including its evolution throughout the project.
- (10) Market: The Market sections contains the description of the component from the business perspective. This includes the target market, business model, the approach to develop the market, competitors, where you can buy the component and the SWOT analysis.
- (11) Comments / Notes: The Comments / Notes section contains additional information about the component that did not suit any other sections in the template.
- (12) Authorship: The Authorship section contains the version history of the current template, i.e., the current version, its author and the date of the last update.

tables

Given the exhaustive number of details, partners were asked to complete only sections (1), (2), - and depending on the nature of the asset, (3), (4), (5), (6) – and (12). In later stages of the project, other sections such as (8) and (10) which could be also of interest for the exploitation (WP6), will be completed.

The following is a short summary of the main features of the tools compiled, focusing mainly in sections (1) and (2). Tools were organized and listed by partner, given the fact that in some cases each tool could fit in one or more categories (e.g., data analysis and visualization).



6.1.1 ASSECO CEIT (CEIT)

Table 14 – General Information (Twiserion Design Manager)

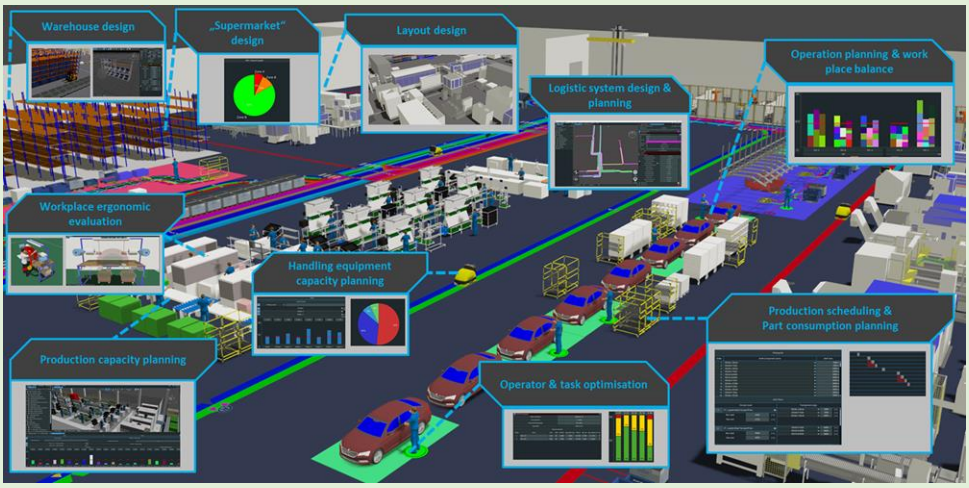
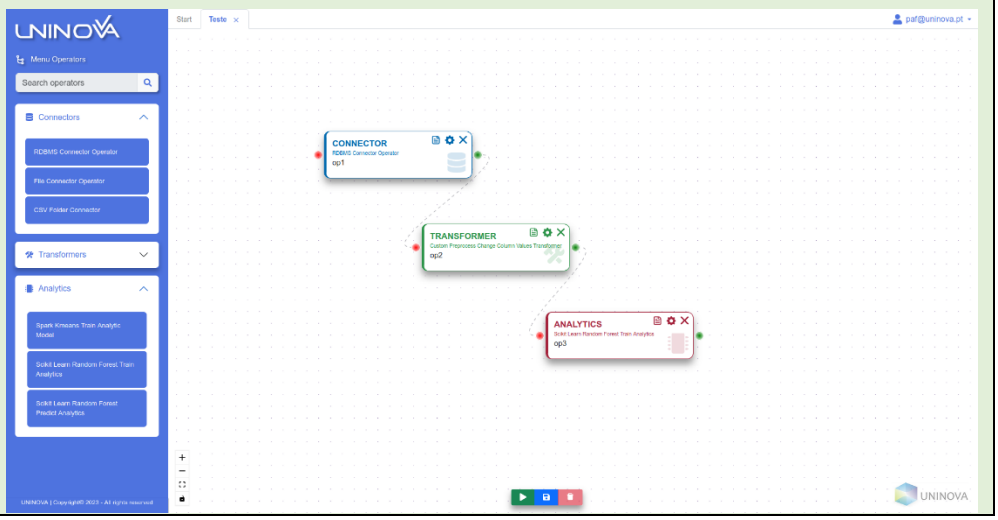
1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Twiserion Design Manager
Type	Other Software
Summary	SW solution for designing manufacturing and logistics systems.
Description	Twiserion Design Manager is an interactive tool for efficient manufacturing and logistics planning and design. Easily enables production or logistics concept planning using 3D models and select the best option via analysis. It represents an original and innovative approach to the planning and design of the production and/or logistics systems. During the workshops, project team members can use Twiserion Design Manager to change the production layout with a simple hand movement on the screen and see the immediate impact of their changes, as the system redraws material flows in real time and recalculates the monitored indicators. In the digital environment of Twiserion Design Manager, the three-dimensional layout is created by the parametric models that besides their 3D spatial interpretation in the manufacturing processes show their other behaviour and attributes (physical attributes, parameters etc.), based on which the system evaluates the monitored indicators. 
Technical Categories	Optimisation
Research Areas	-
Business Categories	-
Website	https://www.asseco-ceit.com/en/twiserion-design-manager-en/
Standards	
Data Space Building Block Categories	Data Analytics Engine (DAE)
Data Space Compatibility	N
TRL	TRL 9

Table 15 – Capabilities (Twiserion Design Manager)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
▪ Display 3D data (models of machines, vehicles etc.) in 3D world ▪ Design and display logistic map in 3D world ▪ Design and evaluate material flows of production ▪ Optimize production based on calculations of virtual production ▪ Usage of MTM and MOST analysis possible ▪ Possible export of 3D data in DWG, FBX, GLTF, GLB formats ▪ Possible export of text data in CSV, XSLX and PPTX formats

6.1.2 UNINOVA

Table 16 – General Information (Data Analytics Environment)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Data Analytics Environment
Type	As a Service
Summary	The Data Analytics Environment allows the creation of data analytics workflows in a dynamic way. This solution enables the creation of AI workflows in a simple and intuitive, code-free manner, building workflows using a visual programming environment to place the components through drag-and-drop interface.
Description	The Data Analytics Environment solution comprises four major components. The first one is the Apache Airflow platform, responsible for the orchestration of the workflows, meaning the scheduling, execution, monitoring and storage of the workflows. The second component is the set of supporting technologies, which encompasses all the necessary supporting technologies for workflow creation, as well as AI, Data Analytics and machine learning algorithms. The third component is the set of operators (connectors, transformers and analytics) used to create workflows, and finally, the last component is the User Interface (UI), which guides users through the dynamic definition of workflows, by enabling the creation of workflows that can connect to data sources (data source configuration, connection and storage), perform data preparation and pre-processing (data filtering, aggregation, harmonisation and semantic enrichment) and apply AI methods for AI model training, updating and serving and Data Analytics (selection and configuration of AI methods). 

Technical Categories	AI Services
Research Areas	-
Business Categories	-
Website	N/A
Standards	List of Standards supported by the Component
Data Space Building Block Categories	*Workflow Management Engine (WME), Data Analytics Engine (DAE)*
Data Space Compatibility	N
TRL	TRL 5

Table 17 - Capabilities (Data Analytics Environment)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
▪ Creation of Data Analytics Workflows: Visual programming of AI workflows, by using the drag and drop functionality to add operators and setting up dependencies between operators. ▪ Save and Load Workflows: Allows the saving of workflows in a database, so that it can be loaded and executed anytime, and allowing the user to make changes to previously done workflows. ▪ Creation and integration of new operators: The creation of user specific operators, through the help of guidelines, and integration of those specific on the workflow creation tool. ▪ Configuration of external tools and technologies: Full integration with tools and technologies, like Keras, Tensorflow, Sklearn, allowing an all-in-one box setting. ▪ Execution and orchestration of workflows: Easy plug'n'play of user created workflows directly on the Airflow interface, allowing the execution and orchestration of multiple workflows.

6.1.3 ATLANTIS ENGINEERING (ATLANTIS)

Table 18 – General Information (Federated Predictive Maintenance (FPdM))

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Federated Predictive Maintenance (FPdM)
Type	Platform, Machine Learning Model, , Software solution
Summary	FPdM will be a complete interoperable platform equipped with several predictive maintenance functionalities provided by a set of microservices/sub-components. The integrated platform will utilize federated learning and ML models to sufficiently predict machinery failures based on the current state of industrial equipment and provide with visual output of the analysis.
Description	The platform will offer multiple analytics services aiming to become an indispensable tool in the maintenance routine. It will provide insight concerning the life status of the machine as well as apply fault detection and identification of failures or defects. The analytic models will be trained and optimized via a federated learning mechanism and the results as well as the sensorial data will be available in friendly visualization panels. Simultaneously, the solution will be integrated with other components of the RE4DY data space, for communication, transformation, and training via different Federated Learning approaches.
Technical Categories	Machine Learning (ML)
Research Areas	Collaborative AI
Business Categories	AI for industry and manufacturing

Website	Not Available at this time
Standards	N/A
Data Space Building Block Categories	Data Analytics Engine (DAE)
Data Space Compatibility	NA
TRL	Aim to reach TRL 6 to 7.

Table 19 – Capabilities (Federated Predictive Maintenance (FPdM))

2 Features
The FPdM is expected to:
▪ Be able to communicate efficiently through APIs and access RE4DY maintenance data space. ▪ Utilize Federated Learning Services (e.g., ALIDA) for secure collaborative training. ▪ Develop a custom solution for Federated Learning functionalities. ▪ Perform predictions for the state of equipment in industrial facilities. ▪ Be able to perform tasks such as fault detection and identification of potential failures. ▪ Provide visualization features that will showcase the analysis results and sensorial data in a user friendly and intuitive way.

6.1.4 CORE KENTRO KAINOTOMIAS AMKE (CORE)

Table 20 – General Information (Decentralized Federated Learning)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Decentralized Federated Learning
Type	AI Model, As a Service, Other Software
Summary	Standalone component that is related to an end-to-end decentralized ML solution implementing an ML task (e.g., Predictive Maintenance/RUL, machine optimization). The federated approach will allow enable privacy preservation with device telemetry never leaving the factory premises, training time enhancement and contribution to a collaborative learning scheme.
Description	Federated Learning is an approach that needs a composition of heterogenous computation environments (edge, public & private clouds) in order to operate. Those environments contain heterogenous resource (edge devices, sensors, VM etc.) that need to be managed and utilized properly. In addition, because of the resource heterogenous we need to ensure that the system components can be isolated and be deployed while each one of those might vary in Hardware Specifications, Operating Systems, Network Connectivity etc. A great way to ensure that our applications can run independently of those specifications is containerization. Since containerization & resource orchestration between mixed environments are the requirements in this case, there is no better tool than Kubernetes. Kubernetes is an open-source resource & container orchestration platform that automates the deployment, scaling, and management of containerized applications & resources between heterogenous environments. It provides a framework for managing containerized workloads across a cluster of nodes (not necessary on the same physical location, as long as there is sufficient connectivity between the nodes) and can be used to simplify the management of complex distributed systems. Upon this computation platform a Federated Learning Framework will be deployed that will be managing the registered devices. This framework will provide all the essential components that a FL architecture requires such as: client registry, round definition, dynamic model retraining (ML/Ops) etc. In addition, K8S will allow the deployment of different services required by the system such as pre-process, post process, data validation etc. Another important aspect is communication with the factory's assets, to do so we can utilize OPC-UA standard since the factory machines are Industry 4.0 ready. Finally, a

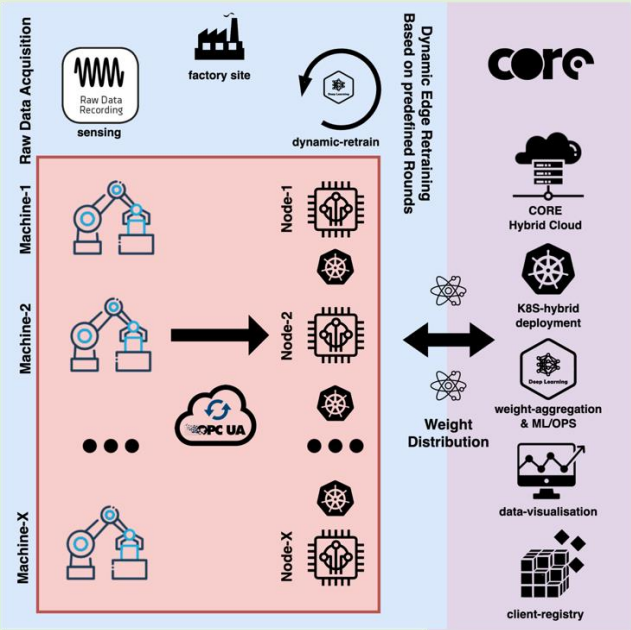
	data distribution (middleware) infrastructure is needed to distribute both the model-weights (at each round) as well as the inference outputs from the devices to the Federated Learning Cloud Server and vice versa. This infrastructure will be a composition of different well-established open-source data distribution tools and frameworks such as Apache Kafka, MQTT & Restful Webservices. The last piece of the component will be the persistence & visualization of these results and system Kip's. To persist the data, we need we will utilize different database management systems based on the type and variety of data such as Timeseries databases for time related data, document databases for Non-Relational Data and SQL databases for relational data strictures. Regarding visualization meaningful internal dashboards will be developed utilized well known data visualization tools such as Grafana & Superset. 
Technical Categories	Machine Learning
Research Areas	Collaborative AI
Business Categories	AI for Industry & Manufacturing
Website	Not applicable
Standards	List of Standards supported by the Component
Data Space Building Block Categories	Data Analytics
Data Space Compatibility	Not Applies
TRL	TRL 5-7 (start) -> 6-8 (end)

Table 21 – Capabilities (Decentralized Federated Learning)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
- Machine learning algorithms - Federating learning privacy preserving architecture More specific features depend on the use case

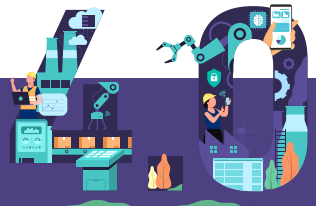


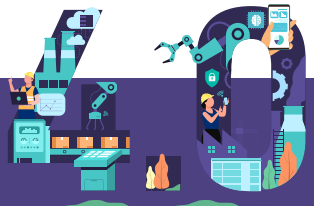
Table 22 – AI Model (Decentralized Federated Learning)

4	AI Model
The Machine Learning Model section should only be filled if your component belongs to this category, otherwise leave it blank.	
Machine Learning Type	The ML task depends on the use case and the available data. Typical examples include supervised or semi-supervised ML algorithms.
Machine Learning Technique(s)	Classification, Anomaly detection, Forecasting, Regression, etc.
Machine Learning Algorithm	Linear Regression, Decision Trees, Naive Bayes, Deep Neural Networks, SVM, etc.
AI-driven Application	Not applicable
Architecture	The ML algorithms will be based on a tailor-made architecture.
Training Dataset(s)	Custom
Model Format	TFLite, ONNX
Fine-tuneable	Y

6.1.5 ENGINEERING-INGENIERIA INFORMATICA (ENG)

Table 23 – General Information (ALIDA)

1	General Information
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	ALIDA
Type	Platform, As a Service
Summary	ALIDA is a micro-service-oriented platform for the composition, deployment and execution of Big Data Analytics (BDA) applications in several domains and scenarios.
Description	ALIDA is a unified platform catering for both core analytics developers and data analysts. Developers will be able to upload new BDA services (i.e., reusable analytics core logic) on ALIDA in the form of micro-services via the web user interface or the REST API - micro-services guarantee modularity and re-usability. After the upload, these services will be automatically registered into the integrated ALIDA catalogue, along with customisable, enriching metadata. Data analysts will then be able to compose their analytics pipelines (or BDA-applications) by using a Visual Pipeline Designer and the BDA services uploaded by the developers. Eventually, the resulting pipelines can be exported and deployed on other target infrastructures. ALIDA is designed and developed on top of the most cutting-edge Open-Source Big Data technologies and frameworks, and it is cloud-native, meaning it can scale computing and storage resources thanks to a pipeline orchestration engine that leverages Kubernetes capabilities for cloud resource management. OAuth2 is moreover used for user registration, authentication and profiling.



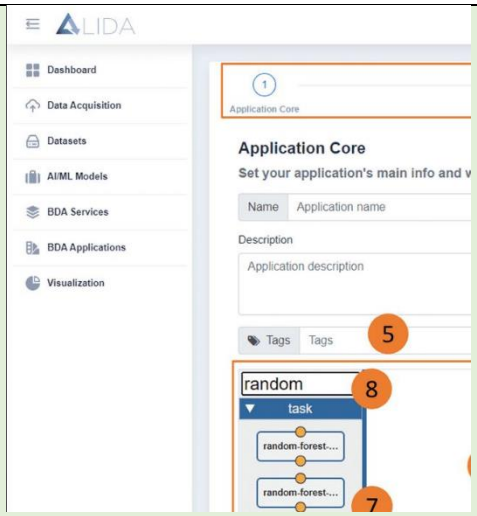
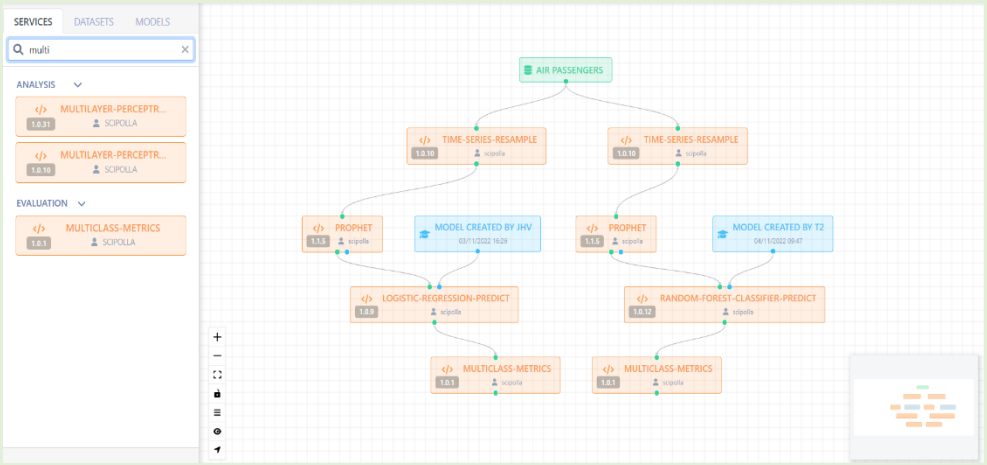
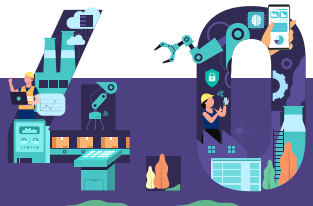
	 
Technical Categories	AI Services
Research Areas	-
Business Categories	*TBD*
Website	https://home.alidalab.it/
Standards	N/A
Data Space Building Block Categories	*Data Analytics Engine (DAE)*
Data Space Compatibility	N
TRL	TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

Table 24 – Capabilities (ALIDA)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
ALIDA offers the possibility to create BDA-applications (pipelines) by combining, through a Visual Pipeline Designer, a number of user-provided BDA-services available from the integrated catalogue. BDA-applications can also be exported for deployment on external target infrastructures. ALIDA functionalities include:



▪ Integrated catalogue of BDA-services and BDA-applications ▪ Visual Pipeline Designer ▪ Templates allowing the upload of user-provided machine learning or pre-processing code (with instructions to generate corresponding Docker images) ▪ RESTful API ▪ BDA-applications/pipelines export (in the form of docker-compose files) ▪ On-cloud execution engine ▪ On-board storage for tasks executed on-cloud ▪ Graphical User Interface ▪ Support to several Machine Learning framework

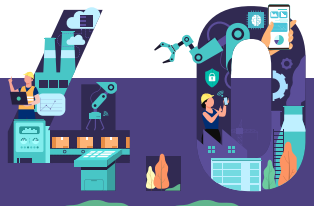
6.1.6 POLITECNICO DI MILANO (POLIMI)

Table 25 – General Information (POLIMI Lab 4.0 AAS)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	POLIMI Lab 4.0 AAS
Type	Dataset
Summary	AAS is a standardized digital representation of an asset to support Industry 4.0, which provides uniform access to information and functions and interoperability capability among the assets.
Description	The Asset Administration Shell (AAS) is the digital representation of an asset. The AAS consists of a number of submodels in which all the information and functionalities of a given asset – including its features, characteristics, properties, statuses, parameters, measurement data and capabilities – can be described. It allows for the use of different communication channels and applications and serves as the link between objects and the connected, digital and distributed world.
Technical Categories	Knowledge representation
Research Areas	N/A
Business Categories	Other
Website	https://www.industry40lab.org/
Standards	AAS
Data Space Building Block Categories	Data Interoperability
Data Space Compatibility	N
TRL	TRL 6

Table 26 – Capabilities (POLIMI Lab 4.0 AAS)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
▪ Common Information Model ▪ Data interoperability among different assets and factories ▪ Modularity, adaptability, and responsiveness ▪ Reconfigurable Manufacturing Systems (known as Plug & Produce) ▪ Self-locating, self-organizing production lines Lot size one production ▪ Customization, order-controlled production ▪ Scalable, upgradable production lines ▪ Faster integration, fast ramp-up and ramp-down of production lines ▪ Bidirectional persisting information flow among manufacturers to integrators to customers ▪ Fault / lifetime prognosis, predictive maintenance



▪ New business models ▪ Efficiency maximization

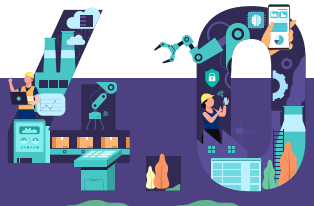
Table 27 – Dataset (POLIMI Lab 4.0 AAS)

3 Dataset	
The Dataset section should only be filled if your component belongs to this category, otherwise leave it blank.	
Dataset Type	AAS
Data Format	.aasx or JSON
Creation Date	N/A
Data Status	Preliminary
Time period	N/A
Data Frequency	N/A
Data Collection and Processing	N/A
Data Format	JSON, .aasx
Data Volume	~50 MB

6.1.7 ATOS

Table 28 – General Information (AGORA Data Marketplace)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	AGORA Data Marketplace
Type	As a Service
Summary	AGORA is an open platform that handles the brokering of brand-independent data from the different IoT devices allowing Services Providers to create new B2B and B2C data-based products and services.
Description	AGORA is a data-marketplace connecting Data Providers and Data Consumers for selling and acquiring Connected Vehicle and Home Building data under the standardized data model (CIDM, Common Industrial Data Model). It offers a secure and privacy preserving experience when selling or buying sharing big data, by having the full control over your data shared, to whom and for what purposes. Even though AGORA is targeted mainly to vehicles and home building information, it can be also an implemented in several environments such as smart health or smart energy. AGORA offers to cross-sectorial Data Consumers to combine, integrate and analyse all data at once – regardless of source, type, size, or format – to generate the insights needed to address a wide range of end-users and customers' needs and transform them into new business opportunities in the era of Data Economy. *Source: Atos, 2020, "AGORA Factsheet: "Unlocking data-driven business potentials for cross-sectorial industries"*
Technical Categories	Searching
Research Areas	N/A
Business Categories	Other
Website	N/A
Standards	List of Standards supported by the Component
Data Space Building Block Categories	Publication & Marketplace Services Metadata & Discovery Protocol Data Usage Accounting



Data Space Compatibility	NO
TRL	TRL 5

Table 29 – Capabilities (AGORA Data Marketplace)

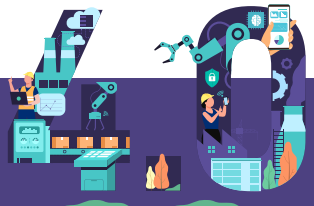
2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
AGORA offers to cross-sectorial Data Consumers, the possibility to search for more than 200 sensor signals, display advance visualization representations (Histograms, Geo-Histograms, Time Series) and retrieve those datasets in a seamless experience thanks to the open SDK-API created. Other AGORA functionalities include: • A wide data catalogue and delivery of statistics for Service Providers. • Discovery service of requested data and identification of data owners. • Management of permissions (future smart contract provision service) • Secure and reliable end-to-end communication (from the cloud to the Service Providers). • Transactions accounting. • Enabled through an open interface. *Source: Atos, 2020, "AGORA Factsheet: "Unlocking data-driven business potentials for cross-sectorial industries"*

6.1.8 INTRASOFT

6.1.8.1 eIDAS-Node

Table 30 – General Information (eIDAS-Node)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	eIDAS-Node
Type	As a Service
Summary	eIDAS-Node is an implementation of the eID eIDAS Profile able to communicate with other Nodes of the eIDAS Network in order to request or provide cross-border authentication.
Description	An electronic identification is a digital solution for proof of identity of citizens or organisations. It is one of the tools to ensure secure access to online services and to carry out electronic transactions in a safer way. The eIDAS solution allows citizens from Member States to prove and verify their identification when accessing on-line services in other Member States. It allows citizens to authenticate themselves by using their eIDs and connecting with their Identity Provider (IdP) from their country. The eIDAS Network consists of a series of eIDAS-Nodes implemented at the Member State level. An eIDAS-Node can act either as requester or as provider of cross-border authentication. The Member State requesting authentication is called the Receiving Member State while the Member State providing the authentication is called the Sending Member State.
Technical Categories	N/A
Research Areas	N/A
Business Categories	Other
Website	https://www.eid.as/
Standards	eIDAS Regulation



Data Space Building Block Categories	Identity Management (IM)
Data Space Compatibility	Not Applies
TRL	TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

Table 31 – Capabilities (eIDAS-Node)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
The eIDAS solution allows citizens to authenticate themselves by using their eIDs and connecting with their Identity Provider (IdP) from their country. eIDAS-Node functionalities include: ▪ Authorization with electronic identification (eID) ▪ Requesting a cross-border authentication ▪ Providing a cross-border authentication

6.1.8.2 F-UJI (FAIRsFAIR Research Data Object Assessment Service)

Table 32 – General Information (F-UJI (FAIRsFAIR Research Data Object Assessment Service))

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	F-UJI (FAIRsFAIR Research Data Object Assessment Service)
Type	As a Service
Summary	F-UJI is a web service to programmatically assess FAIRness of research data objects based on metrics developed by the FAIRsFAIR (https://www.fairsfair.eu/) project.
Description	FAIRsFAIR used the RDA FAIR Data Maturity Model Specification and Guidelines Recommendation of the FAIR Data Maturity Model Working Group as a basis to develop a set of seventeen minimum metrics for assessing the FAIRness of research data objects and tools to address researchers and data repositories (https://www.fairsfair.eu/fairsfair-data-object-assessment-metrics-request-comments). For each of the metrics, F-UJI, an open source tool, supports programmatic FAIR assessment of research data through practical tests based on existing standards and best practices.
Technical Categories	Knowledge representation
Research Areas	N/A
Business Categories	Other
Website	https://www.fairsfair.eu/f-uji-automated-fair-data-assessment-tool
Standards	N/A
Data Space Building Block Categories	Publication & Marketplace Services
Data Space Compatibility	YES
TRL	TRL 4 – technology validated in lab

Table 33 – Capabilities (F-UJI (FAIRsFAIR Research Data Object Assessment Service))

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
The F-UJI validation tool offers: ▪ The ability to enter an identifier (e.g., DOI, URL) of the data set one wishes to assess ▪ The ability to use a metadata service (OAI-PMH, SPARQL, CSW) endpoint URI to identify additional information about the data set ▪ Automated data set testing which depends on clear machine assessable criteria and is performed based on aggregated metadata. This includes metadata embedded in the data (landing) page, metadata retrieved from a PID provider (e.g., Datacite content negotiation) and other services (e.g., re3data) ▪ A JSON response with an evaluation score of the input data set as well as pass/fail statements for each test

6.1.8.3 Hyperledger Fabric

Table 34 – General Information (Hyperledger Fabric)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Hyperledger Fabric
Type	Platform
Summary	Hyperledger Fabric is an open-source permissioned distributed ledger with smart contract support and modular architecture that is specially designed for enterprise context only.
Description	Hyperledger Fabric is an open source blockchain which supports the use of smart contracts (also known as chaincode) to express logic with general-purpose scripting languages like Go, Java, and Node.js. It supports pluggable consensus algorithms (e.g., PBFT, Raft, and Kafka), allowing one to choose the consensus protocol that best suits their needs. Additionally, it offers privacy for communication via the design of channels, private data control via the access control list, and a membership mechanism to restrict channel access.
Technical Categories	N/A
Research Areas	N/A
Business Categories	Other
Website	https://www.hyperledger.org/
Standards	N/A
Data Space Building Block Categories	Data Provenance and Traceability, Access and Usage Control/Policies
Data Space Compatibility	YES
TRL	TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Table 35 – Capabilities (Hyperledger Fabric)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
Hyperledger Fabric features include: ▪ Low latency for finality ▪ Consensus modularity (allows pluggable consensus) ▪ Multi-language smart contract support (JavaScript, Go, Java)

- Support for JSON queries and key-based queries
- Privacy and confidentiality: access to the smart contract and transaction data is only provided to nodes which belong to the respective channel
- Chaincode trust flexibility: If some of the orderers misbehave or fail then this issue is being looked after by the endorsers' nodes which are different for each chaincode.
- Scalability: Every chaincode has a different endorser node to look after which helps the system to scale better than looking after all the functions by the same group of nodes.

6.1.8.4 Keycloak

Table 36 – General Information (Keycloak)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Keycloak
Type	Other Software
Summary	Keycloak is an open-source Identity and Access Management tool with features such as Single-Sign-On (SSO), Identity Brokering and Social Login, User Federation, Client Adapters, an Admin Console, and an Account Management Console.
Description	Keycloak is an open-source identity and access management solution which mainly aims at applications and services. Users can authenticate with Keycloak rather than individual applications. Therefore, the applications do not have to implement login forms, authenticate and store users. Once logged-in to Keycloak, users do not have to login again to access different applications. Signing-out operates similarly. Keycloak offers everything a sophisticated user management tool needs – without having to log on repeatedly with every login and into every system-as well as system security, social logins, support for mobile apps and integration into other solutions.
Technical Categories	N/A
Research Areas	N/A
Business Categories	Other
Website	https://www.keycloak.org/
Standards	OpenID Connect, OAuth 2.0, SAML 2.0
Data Space Building Block Categories	Identity Management (IM), Access and Usage Control/Policies
Data Space Compatibility	Not Applies
TRL	TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Table 37 – Capabilities (Keycloak)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
Keycloak features include: ▪ Admin Console: A centralised security and user management interface for administrators. ▪ Account Management Console, through which users can manage their own accounts. ▪ An easy integration of an existing directory system with LDAP protocol. ▪ Single Sign On (one login for multiple applications). ▪ Social Login (allows access to the applications through social networks accounts like Google, GitHub, Facebook, Twitter, etc.). ▪ Brokering (delegate the Platform security to an existing identity-management system through standard protocols such as OIDC or SAML2).

6.1.9 ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS (CERTH)

6.1.9.1 XAI and Active Learning Platform for Defect Detection

Table 38 – General Information (XAI and Active Learning Platform for Defect Detection)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	XAI and Active Learning Platform for Defect Detection
Type	Platform
Summary	The platform provides defect detection based on AI algorithms applied in images of manufacturing assets
Description	A defect detection & localization platform in hard metal Industry accommodated by AI explainability and human-AI in the loop mechanisms. The platform is built on a micro-service architecture to enable adaptation and extension over time, supports a variety of user types, including data scientists for building AI models and maintainers for monitoring conditions using previously trained models. The core engine of the platform is oiled with Machine Learning algorithms and Deep Learning models for defect detection and defects localization which are able to recognize the defects and locate them with high precision
Technical Categories	Machine Learning, AI Services and Machine Vision
Research Areas	Explainable and Collaborative AI
Business Categories	AI for industry and manufacturing, AI for IoT
Website	TBA
Standards	HTTP communication, JSON format, OpenID Connect, OAuth 2.0, IDS Compatibility is in progress
Data Space Building Block Categories	Data Processing Data Analysis Data Visualization
Data Space Compatibility	IDSA (in progress)
TRL	TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

Table 39 – Capabilities (XAI and Active Learning Platform for Defect Detection)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
Examples: ▪ Display in real time if an asset is defect or not ▪ Display localization of defect(s) ▪ Display XAI outcomes ▪ Enable users to provide feedback about defects or not ▪ AI and Machine Learning Engine

Table 40 – AI Model (XAI and Active Learning Platform for Defect Detection)

4 AI Model
The Machine Learning Model section should only be filled if your component belongs to this category, otherwise leave it blank.

Machine Learning Type	Supervised
Machine Learning Technique(s)	Classification, Object detection
Machine Learning Algorithm	Machine Learning Algorithm: XG-Boost, Random Forest
AI-driven Application	Defect Detection and Defect localization in hard metal industry
Architecture	ResNet, Deep CNN, XG-Boost, Random Forest, Yolov3, Yolov5
Training Dataset(s)	Dataset(s) used in the model's training: ImageNet, custom Dataset
Model Format	Format of the model: tf.h5, tflite
Fine-tuneable	Yes

6.1.9.2 Data Transformation Services

Table 41 – General Information (Data Transformation Services)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Data Transformation Services
Type	Software as a Service
Summary	The component/service is providing data transformation and integration services between different components. It is based on open-source software like Apache NiFI, Jolt etc.
Description	To meet the requirements of ETL services in RE4DY project some Data Transformation Services will be delivered. In order to extract, transform and load data across a data fabric these services must be based on widely used software artefacts. Apache NiFi is considered as an ideal option to be the base of Data Transformation Services, so to processors that can enable these three services. Our services can handle a large variety of file formats such as Json, csv, text etc. and for that reason will be effortlessly adopted in cases there are no restrictions regarding the file formats. Even if we have a file format that it is not the ideal, still we would be able transform it.
Technical Categories	Knowledge Representation
Research Areas	-
Business Categories	Other
Website	-
Standards	JSON, HTTP
Data Space Building Block Categories	Data Interoperability
Data Space Compatibility	N
TRL	TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling (targeted)

6.1.10 UNIVERSITAT POLITECNICA DE VALENCIA (UPV)

6.1.10.1 NGSI agents

Table 42 – General Information (NGSI agents)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	NGSI agents
Type	Other Software.
Summary	Set of software components that interact directly with the data sources, translate the data into a common format and send it to the Context Broker.
Description	An agent represents the smallest entity with the necessary logic to be able to access different data sources. Each agent shall have the ability to access the data sources for which it has been developed. Agents can be developed in python using the pyngsi library, although the use of other programming languages is also possible.
Technical Categories	Knowledge representation.
Research Areas	TBD
Business Categories	TBD
Website	N/A
Standards	FIWARE NGSI v2, NGSI-LD
Data Space Building Block Categories	Data Model & Formats, System Adaptation
Data Space Compatibility	N
TRL	TBD

Table 43 – Capabilities (NGSI agents)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
• Access to the data source. Access to the specific data source and recover the data. • Transform data to a valid data model. Convert the retrieved data into a data model that can be understood by the platform. • Send data to the rest of the components (via Orion Context Broker)

6.1.10.2 Pyngsi

Table 44 – General Information (pyngsi)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	pyngsi
Type	Library
Summary	pyngsi is a Python framework that allows to write a data-acquisition pipeline for Fiware.
Description	The framework enables developers to build custom NGSI Agents that: • process data using a common interface regardless of the type of the data source

	• convert custom data to NGSI entities based on Fiware data models • write NGSI entities to the Orion Context Broker
Technical Categories	Knowledge representation.
Research Areas	TBD
Business Categories	TBD
Website	https://github.com/pixel-ports/pyngsi
Standards	FIWARE NGSI v2, NGSI-LD
Data Space Building Block Categories	Data Model & Formats, System Adaptation
Data Space Compatibility	Not Applies
TRL	TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

Table 45 – Capabilities (pyngsi)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
• NGSI v2 support • Map Python-native data to NGSI entities • Write NGSI entities to Fiware Orion • Handle incoming data through a common interface • Compute statistics • Allow visualization/debugging facilities

6.1.11 CONSIGLIO NAZIONALE DELLE RICERCHE (CNR)

Table 46 – General Information (Data Distribution Toolkit)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Data Distribution Toolkit
Type	Other Software
Summary	The data distribution toolkit implements algorithms to dynamically move data across edge and beyond-edge devices, to comply with strict time-related requirements of applications and other related constraints.
Description	The component has been conceived to be run on far-edge devices, including IoT devices in manufacturing environments, which generate locally sensing data, for example. The toolkit, based on (i) the profile of data production; and (ii) the requirements of the application consuming them (such as, for example, freshness and real-time requirements) automatically moves data on the nodes of the network, so as to optimise resource usage while guaranteeing the application-level constraints. More details about the toolkit are presented in the listed scientific publications. In RE4DY, the toolkit will be extended to support decentralised ML algorithms, so as to optimise data distribution with respect to the requirements of the decentralised/distributed ML tasks.
Technical Categories	Optimisation.
Research Areas	N/A
Website	
Standards	List of Standards supported by the Component

Data Space Building Block Categories	*Data Exchange APIs*
Data Space Compatibility	N
TRL	TRL 4 – technology validated in lab

Table 47 – Capabilities (Data Distribution Toolkit)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
▪ Optimise data distribution ▪ Support various application-level requirements (real-time, sovereignty, …) ▪ Optimise edge-nodes resource usage ▪ Implement edge-centric data management ▪ Support optimised distributed ML

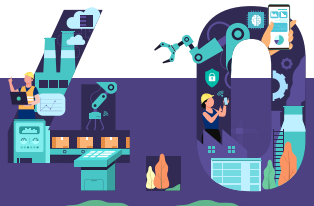
6.1.12SIEMENS SCHWEIZ (SIEMENS)

6.1.12.1 MindSphere

Table 48 – General Information (MindSphere)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	MindSphere
Type	Industrial IoT as a service / SaaS
Summary	MindSphere® is the leading industrial IoT as a service solution. Using advanced analytics and AI, MindSphere powers IoT solutions from the edge to the cloud with data from connected products, plants and systems to optimize operations, create better quality products and deploy new business models.
Description	MindSphere® is an industrial IoT as a service solution that uses advanced analytics and AI to power IoT solutions from the edge to the cloud. With MindSphere you can ingest and visualize immediate real-time data and analytic results in one centralized location with no development required to unleash your digital potential. The Anything as a Service (XaaS) approach enables Original Equipment Manufacturers to increase the business value of the offering.Turn your product into a service by connecting it to MindSphere. Your customer profits from increased efficiency, as initial investment and material waste decrease.
Technical Categories	Machine learning, Knowledge representation, Optimisation, AI Services
Research Areas	N/A
Business Categories	AI for industry and manufacturing
Website	https://siemens.mindsphere.io/en
Standards	-
Data Space Building Block Categories	Business Agreements, Operational Agreements, Organisational Agreements, Data Model & Formats, Data Exchange APIs, Data Provenance and Traceability, Identity Management (IM), Access and Usage Control/Policies, Trusted Exchange, Metadata & Discovery Protocol, Data Usage Accounting, Publication & Marketplace Services
Data Space Compatibility	IDSA, GAIA-X, NTT | Siemens | Switzerland Innovation Park Biel/Bienne - International Data Spaces
TRL	TRL 9

Table 49 – Capabilities (MindSphere)



2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
▪ capability packages ▪ asset attributes ▪ cloud resource packs ▪ add-ons (apps)

6.1.12.2 NX CAD/CAM

Table 50 – General Information (NX CAD/CAM)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	NX CAD/CAM
Type	SaaS
Summary	The NX software for mechanical design provides a comprehensive set of leading-edge CAD modelling tools that enable companies to design higher quality products faster and less expensively. The NX comprehensive mechanical design solution lets you choose the tools and methodologies that best suit your design challenge. Innovative technologies deliver breakthrough mechanical design capabilities that set new standards for speed, performance and ease-of-use.
Description	NX mechanical design capabilities are unmatched in terms of the power, versatility, flexibility and productivity they deliver to a digital product development environment. NX enables to establish a complete design solution for an environment, including leading-edge tools and methodologies for comprehensive high-performance modelling, which enables to seamlessly use the most productive modelling approaches – from explicit solid and surface modelling to parametric, process-specific and history-free direct modelling that works with models from any CAD system. As well it supports an active mock-up and assembly design, which enables to work interactively with massive multi-CAD assemblies while leveraging leading assembly management and engineering tools. Furthermore, NX is a standards-compliant drafting and 3D annotation, which streamlines the creation of product documentation by directly leveraging a 3D master model.
Technical Categories	N/A
Research Areas	N/A
Business Categories	Other
Website	https://www.plm.automation.siemens.com/global/en/products/nx/
Standards	N/A
Data Space Building Block Categories	N/A
Data Space Compatibility	N/A
TRL	TRL 9

Table 51 – Capabilities (NX CAD/CAM)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
• Comprehensive 3D design capabilities, including wireframe, surface, solid and direct modelling • Synchronous technology for uniting parametric and history-free modelling in the same design environment • Assembly modelling with full context, multi-CAD digital mock-up and validation tools • Interactive design of massive assemblies that improves the performance and capacity of your design environment • Process-specific, streamlined modelling tools for sheet metal routed systems and other applications • Configurable, intuitive interface that facilitates ease-of-use, user learning and accessibility to powerful modelling capabilities

• Associative integration with all NX product development solutions, including NX industrial design, electromechanical, simulation, tooling and machining solutions • Automated, real-time design validation checking to monitor functional requirements • Knowledge capture and automation tools • Seamlessly integrated, transparent engineering data and process management

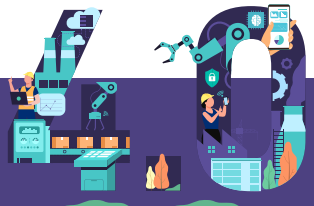
6.1.12.3 Plant Simulation, Tecnomatix, HEEDS

Table 52 – General Information (Plant Simulation, Tecnomatix, HEEDS)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Plant Simulation, Tecnomatix, HEEDS
Type	As a Service
Summary	Plant Simulation is a software to enable the simulation, visualization, analysis and optimization of production systems and logistics processes. Using Plant Simulation helps optimize material flow, resource utilization, and logistics for all levels of your plant planning, from global facilities and local plants to specific production lines.
Description	Plant Simulation helps to create digital models of logistics systems to explore system characteristics and optimize the performance. The digital model not only enables to run experiments and what-if scenarios without disturbing an existing production system, but it can be used in the planning process long before the real system is installed. Extensive analysis tools, statistics and charts help to evaluate different manufacturing scenarios and make fast, reliable decisions in the early stages of production planning. Plant Simulation helps to detect and eliminate problems that otherwise would require cost- and time-consuming corrective measures during production ramp-up. With Plant Simulation the investment cost of production lines can be minimized without jeopardizing required output. Furthermore, it is possible to optimize the performance and energy usage of existing production systems by taking measures that have been verified in a simulation environment prior to implementation
Technical Categories	Planning and scheduling, Optimisation, AI Services
Research Areas	N/A
Business Categories	Other
Website	https://plm.sw.siemens.com/en-US/tecnomatix/products/plant-simulation-software/
Standards	ActiveX, C, CAD, COM, JSON, MQTT, ODBC, OPCClassic, OPCUA, Oracle SQL, Socket and XML Siemens: NX Line Designer, Teamcenter, Simcenter HEEDS, Opcenter APS, TIA Portal, PLCSIM Advanced and SIMIT
Data Space Building Block Categories	Business Agreements, Operational Agreements, Organisational Agreements, Data Model & Formats, Data Exchange APIs, Data Provenance and Traceability, Identity Management (IM), Access and Usage Control/Policies, Trusted Exchange, Metadata & Discovery Protocol, Data Usage Accounting, Publication & Marketplace Services
Data Space Compatibility	N/A
TRL	TRL 9

Table 53 – Capabilities (Plant Simulation, Tecnomatix, HEEDS)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
• Object-oriented, hierarchical modelling based on dedicated object libraries for fast and efficient modelling of discrete and continuous processes • Graphical outputs for analysis of throughput, resource utilization, automatic bottleneck detection, Sankey diagrams and Gantt charts • Energy analysis tools for calculating and optimizing energy usage



• 3D online visualization and animation based on the ISO-standard JT format • Integrated neural networks for experiment handling and automated system optimization via genetic algorithms • Open system architecture supporting multiple interfaces and integration capacities (ActiveX, C, CAD, COM, JSON, MQTT, ODBC, OPCClassic, OPCUA, Oracle SQL, Socket, XML, etc.)

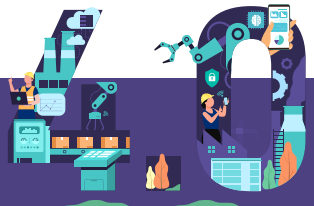
6.1.12.4 SiGREEN

Table 54 – General Information (SiGREEN (Product Carbon Footprint Management))

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	SiGREEN (Product Carbon Footprint Management)
Type	Other Software
Summary	SiGREEN provides industry leaders with the long-desired solution to effectively pursue their decarbonization goals on the product level.
Description	The most urgent task for achieving climate goals is the significant reduction of CO2 emissions. As the source of around one third of these global emissions, industry bears a major responsibility in this regard. To meet this responsibility, companies need reliable and verifiable data on materials, components, and processes to quantify the CO2 footprint for each of their products. SiGREEN provides this necessary basis for targeted emission management while preserving the data sovereignty of all participants in the supply chain. Peer-to-peer communication, whose trustworthiness is secured using cryptographic keys, enables companies to efficiently and securely identify improvement potential and reduce emissions faster.
Technical Categories	Automated reasoning, Common sense reasoning, Searching, Optimisation
Research Areas	Collaborative AI, Verifiable AI
Business Categories	Other
Website	https://marketplace.siemens.com/s/product/sigreen/01t7Q000002etSZQAY?language=en_US https://www.siemens.com/global/en/company/topic-areas/product-carbon-footprint.html
Standards	TSX technology
Data Space Building Block Categories	Business Agreements, Operational Agreements, Organisational Agreements, Data Model & Formats, Data Exchange APIs, Data Provenance and Traceability, Identity Management (IM), Access and Usage Control/Policies, Trusted Exchange, Metadata & Discovery Protocol, Data Usage Accounting, Publication & Marketplace Services
Data Space Compatibility	N/A
TRL	TRL 7

Table 55 – Capabilities (SiGREEN (Product Carbon Footprint Management))

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
• Web-based application for fast adaption and easy supplier onboarding • Aggregation of dynamic of dynamic Product Carbon Footprints from your supply chain • Optional shopfloor connectivity for automated quantification of own emissions • Verifiable credentials for third-party verification of exchange emission data



6.1.12.5 PLM Teamcenter

Table 56 – General Information (PLM Teamcenter)

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	PLM Teamcenter
Type	Other Software
Summary	Teamcenter powers innovation and improves productivity by connecting people with the product and process knowledge they need to effectively function in a globally oriented product lifecycle. Teamcenter's proven digital lifecycle management solutions are built on an open PLM foundation. Teamcenter is the world's most widely used PLM system. It is backed by Siemens PLM Software's leadership in delivering Global Innovation Networks that enable companies to make unified, information-driven decisions at every stage in the product lifecycle.
Description	Use digital twins to connect and optimize processes for designs, systems, software, simulation and visualization. Resolve problems before they become real. Connect people across your business. Automate and streamline product lifecycle processes. Provide visibility for everyone to make innovative product decisions. Invest in the future with modern PLM of unmatched breadth, depth and usability. Set the strategic direction and product definition to guide downstream decisions. Design and document the multi-discipline product to leverage the digital twin. Weave the digital thread to connect product development with manufacturing, service and suppliers. Adapt to business disruptions while driving product innovation. Teamcenter provides a single source of product information for every stakeholder across the business.
Technical Categories	Knowledge representation, Common sense reasoning, Planning and scheduling, Searching, Optimisation, Multi-agent systems
Research Areas	N/A
Business Categories	Other
Website	https://plm.sw.siemens.com/de-DE/teamcenter/ https://plm.sw.siemens.com/de-DE/teamcenter/solutions/
Standards	Multi CAD integration, open ERP interfaces, IoT Data interface and other platforms, Asset Administration Shell
Data Space Building Block Categories	Business Agreements, Operational Agreements, Organisational Agreements, Data Model & Formats, Data Exchange APIs, Data Provenance and Traceability, Identity Management (IM), Access and Usage Control/Policies, Trusted Exchange, Metadata & Discovery Protocol, Data Usage Accounting, Publication & Marketplace Services
Data Space Compatibility	IDSA, GAIA-X
TRL	TRL 9

Table 57 – Capabilities (PLM Teamcenter)

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
• Requirements engineering • Model based system engineering • Bill of material management • Product configuration • PLM process management • Product cost management • Mechanical design management • Electronics and electrical CAD management • Software design management • Product documentation management and technical publications • Product visualization and digital mock-up

- Simulation process and data management
- PLM analytics
- Sustainable product development
- Supplier management
- Quality and compliance management
- Manufacturing process planning
- Service lifecycle management

6.2 Relation with IDSA Building Blocks

According to IDSA, and its position paper 'Design principles for data spaces' (https://zenodo.org/record/5105744), *"the design and implementation of a data space comprises a number of building blocks, which fall under two types: the technical building blocks and the governance building blocks"*.

Thus, on the one hand, the Technical building blocks *"enable the implementation of the technical architecture of a data space. They include network protocols, middleware components, (standardized) APIs, and more, facilitating the sharing of data between different parties in a secure and trustworthy fashion". On the other hand,* Governance building blocks *"refer to business, operational and organizational agreements among data space participants. These agreements are enforced through legal frameworks participants have to adhere to, or via building blocks".*

Besides, "there are some guiding principles that need to be respected in the implementation of a data space, such as decentralisation, scalability, collaboration support, federation, interoperability, compatibility, trust management, and auditability".

The picture below, extracted also from the aforementioned position paper, identifies the building blocks classified by four categories: interoperability, trust, data value, governance.

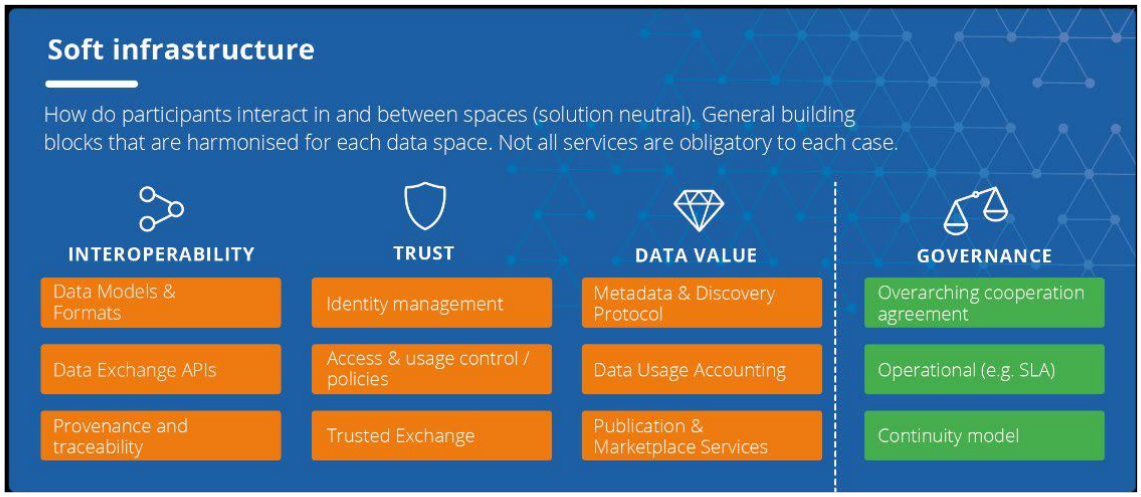
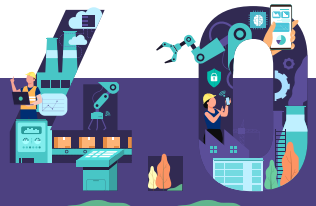


Figure 23 - Data spaces building blocks

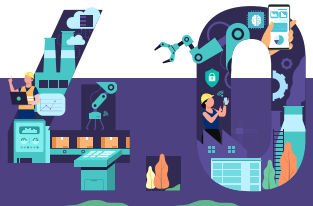


These four building blocks, which are further subcategorized and refined as described in the position paper 'Design principles for data spaces', are used for identifying the building blocks that comprehend a typical data space. For the sake of completeness within the deliverable, these have been summarized in the following two tables.

Table 58- Data Space Building Blocks

Data Space Building Block			Description
Business, Organization and Operational Building Blocks	*Governance [1,2,3,4]*	*Business Agreements [5,6,7,8]*	*Comprises service level agreements (SLAs), data usage and access control policies as well as accounting and pricing/billing/payment schemes, which data service providers may specify in connection with their offerings to govern their interaction with data consumers.*
		Operational Agreements [9,10,11,12]	*Regulates policies that need to be enforced during data space operation. E.g., terms and conditions dealing with the ever-growing importance of compliance with mandatory regulations like GDPR.*
		Organisational Agreements [9,10,11,12]	*Comprises terms and conditions regarding governance bodies and procedures established for a data space.*
Technical Building Blocks	*Data Interoperability [9]*	*Data Model & Formats*	*Establishes a common format for data model specifications and representation of data in data exchange payloads. Combined with the Data Exchange APIs building block, this ensures full interoperability among participants.*
		Data Exchange APIs	*Facilitates the sharing and exchange of data (i.e., data provision and data consumption/use) between data space participants. An example of a data interoperability building block providing a common data exchange API is the 'Context Broker'.*
		Data Provenance and Traceability	*Provides the means for tracing and tracking in the process of data provision and data consumption/use. It thereby provides the basis for a number of important functions, from identification of the lineage of data to audit-proof logging of transactions. It also enables implementation of a wide range of tracking use cases at application level, such as tracking of products or material flows in a supply chain.*
	Data Sovereignty and Trust [10,11,12]	*Identity Management (IM)*	*Allows identification, authentication, and authorisation of stakeholders operating in a data space.*
		Access and Usage Control/Policies	*Guarantees enforcement of data access and usage policies defined as part of the terms and conditions established when data resources or services are published (see 'Publication and Services Marketplace' building block below) or negotiated between providers and consumers. A data provider typically implements data access control mechanisms to prevent misuse of resources, while data usage control*

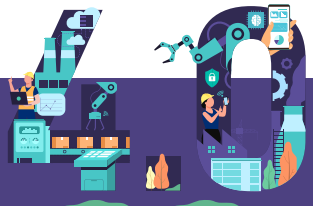
			mechanisms are typically implemented on the data consumer side to prevent misuse of data. In complex data value chains, both mechanisms are combined by prosumers. Access control and usage control rely on identification and authentication.
		Trusted Exchange	*Facilitates trusted data exchange among participants, reassuring participants in a data exchange transaction that other participants really are who they claim to be and that they comply with defined rules/agreements. This can be achieved by organisational measures (e.g., certification or verified credentials) or technical measures (e.g., remote attestation).*
	Data Value Creation	*Metadata & Discovery Protocol*	*Publishing and discovery mechanisms for data resources and services, making use of common descriptions of resources, services, and participants. Such descriptions can be both domain-agnostic and domain-specific. They should be enabled by semantic-web technologies and include linked-data principles.*
		Data Usage Accounting [5,6,7,8]	*Provides the basis for accounting access to and/or usage of data by different users. This in turn is supportive of important functions for clearing, payment, and billing (including data-sharing transactions without involvement of data marketplaces).*
		Publication & Marketplace Services	*Supports the offering of data resources and services under defined terms and conditions, marketplaces must be established. This building block supports publication of these offerings, management of processes linked to the creation and monitoring of smart contracts (which clearly describe the rights and obligations for data and service usage), and access to data and services.*
Additional Technical Building Blocks		*System Adaptation*	*Interfaces with the various data resources exported by the system and performs the necessary transformation of the data formats adopted for data exchange within the data space.*
		Data Processing	*Systems connected to data spaces via system adapters are able to process shared data to enforce data usage restrictions. In order to exert wider control, data spaces may incorporate different stages of usage control, as provided by the concept of the usage control onion, (e.g., for data accountability/traceability or access/usage control) with data-processing technologies.*
		Data Routing and Pre-processing (DR&P)	*There may be a need for dynamic routing of data to the proper data-processing node (as part of a dynamic data-routing function). For instance, stream-processing middleware platforms (e.g., Apache Kafka)*



			can be used to support the routing and pre-processing of streaming data.
		Data Analytics Engine (DAE)	*Many data space use cases allow analysis of multi-source, multi-stakeholder data based on methods like statistical analysis, machine learning, deep learning, and other data-mining techniques (e.g., for demand forecasting in an industrial use case, which must synthesise and analyse multiple data flows coming from different platforms the data space is comprised of).*
		Data Visualisation	*Data spaces should also provide data presentation and visualisation features. A building block offering these features can take various forms, from a simple dashboard to augmented analytics (e.g., implemented on the basis of frameworks like Kibana or Grafana).*
		Workflow Management Engine (WME)	*Data-processing use cases usually involve interaction of multiple data sources, data consumers, and data services. This interaction must be properly orchestrated by means of structured and acknowledged workflows (including data extraction, transformation, and analysis, as well as data presentation and visualization).*

Table 59-Data Space Transversal features/artifacts

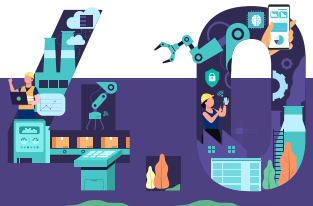
Transversal features/artifacts		Description
Data space Administration, Organisation, and Guidance	*[1] Data Space Boards:*	*Provide governance for data spaces in terms of decision-making, guidance, steering, and conflict resolution.*
	[2] Overarching cooperation Agreements	*All data space participants need to agree on certain functional, technical, operational and legal aspects. While some agreements are reusable in a generic or sector-specific way (e. g. rule books), others are use-case specific.*
	[3] Continuity Model	*Describes the processes for the management of changes, versions, and releases for standards and agreements. This also includes the governance body for decision-making and conflict resolution.*
	[4] Regulations	*Regulations refer to laws or administrative rules, issued by an organisation, used to guide or prescribe the conduct of the members of that organisation or countries.*
Operational Service Level Agreement (SLA)	*[5] Billing/Charging Scheme*	*This artifact specifies how billing/charging is to be performed. Commonly used billing/charging schemes are schemes relying on the data volume provided (i.e., volume-based), the number of requests for, or connections to, a service (i.e., I/O based) or the time period the service can be used (i.e., time-based). While in some cases flat billing/charging schemes may be an adequate solution (as they are simple to set up and use), it is also possible to combine the above-listed schemes into a hybrid scheme.*
	[6] Accounting Scheme	*Accounting practices and reports that should be produced as part of the operation of the data space and in line with the underlying business models. It specifies the parameters that should be logged and*



		reported for every business actor and transaction of the data space.
	[7] Data Valuation Method	*Data valuation is concerned with methods to estimate the value of data shared by organizations in the data space.*
	[8] Smart Contracts	*Provide a protocol for implementation of agreements between two or more parties (mainly the Data Provider and the Data Consumer). As such they specify data usage policies, legal aspects, SLAs and other agreements in a machine-readable and cryptographically signable manner.*
Interoperability	*[9] Domain Data Standard*	*The Domain Data Standard represents the language for data sharing in a specific sector or domain. To achieve specific goals, multiple such standards can be used in combination.*
Trust	*[10] Unique Identifiers*	*Unique and trusted identifiers enable reliable identification of legal and natural entities (including things) across domain specific or country specific identification schemes. Such identification has to be extended with value-adding attributes (e.g., commercial register number or tax identification number). Such additional information must be provided by trusted parties.*
	[11] Authorisation Registries	*To unambiguously identify each data space participant, special authentication registries must be in place. These registries need to be established in accordance with operational agreements (i.e., policies) concluded within the data space. These registries itself must be approved and monitored by a neutral body. Authentication of a participant requires a structured admission process including a compliance assessment to set up the trust anchor of each identity at the registry.*
	[12] Trusted Parties	*On the basis of authenticated identities, trusted parties can verify and validate participants' capabilities. This includes two aspects: 1) acquisition or evaluation of capabilities in a structured process and 2) verification of these claims against a digital identity. While the first aspect is typically covered by certifications or registrations, the second aspect is often carried out by commercial services. A trusted party therefore provides digital evidence of specified and measurable criteria. The content of those criteria is specified by regulations or by (sector-)specific agreements.*

RE4DY Data Space leverages on the vision of the International Data Spaces Association (IDSA) and its definition of the building blocks to realize a data-driven industrial value chain that maximizes synergies, collaboration, and economic trading around data, while ensuring data sovereignty, data governance and security in a data sharing / exchange environment across companies, domains, and international borders.

The realization of RE4DY Data Space will entail the use of several of these building blocks (not necessarily all of them), providing basic features such as identity management and data control usage as well as other more advanced like data processing, data analytics, data publication, etc. To that end, and as a first step, in this deliverable the previously presented partners' assets are mapped into the proposed IDSA building blocks, in order to better understand what the features and capabilities at hand are to build RE4DY Data Space.



These preliminary building blocks that will conform RE4DY Data Space will be extended and adapted in further iterations for the needs and requirements of the stakeholders and systems participating in the project pilot cases.

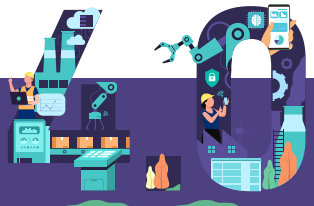
Other possible external solutions (either commercial or open source), such as IDSA Testbed components[26] and the overview of existing data connectors compiled by IDSA ("IDSA Data Connector Report"[27]) will be assessed in the future.

The following table presents the mapping of the aforementioned partners' assets to the Data Space Building Blocks as proposed by IDSA, indicating also the responsible partner and in which WP/task(s) the asset is involved in.

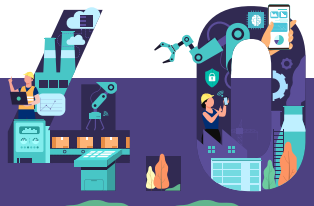
Table 60 - Mapping of partners' assets to IDSA Data Space Building Blocks

Data Space Building Block / Feature-Artificat	RE4DY Required Features	Identified Services/ Components	WP / Task	Partner(s)	Notes
Business Agreements	-	-	-	-	-
Operational Agreements	-	-	-	-	-
Organisational Agreements	-	-	-	-	-
Data Model & Formats	Data as Product, Semantic integration of heterogeneous data sources	POLIMI Lab 4.0 AAS	WP3/T3.2	POLIMI	Use AAS to exchange information among facilities. This is also linked with the "Data Exchange APIs" building block.
		Ontologies Facility Asset Information Modelling Framework (IMF)	WP3/T3.3	CERTH UiO	Ontologies from OntoCommons, OPC UA Data models and OGC Sensorthings models are expected to be used. *However, pilot data would enable us to be more concrete (still not available)
		Data Transformation Services	WP3/T3.3	CERTH	
		FIWARE Smart Data Models, NGSI-LD/JSON-	WP3/T3.2	UPV	

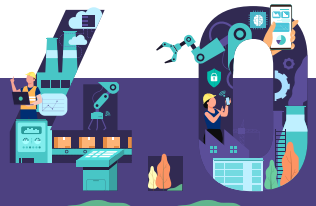
[26] https://github.com/International-Data-Spaces-Association/IDS-testbed
[27] https://internationaldataspaces.org/idsa-data-connector-report-published/



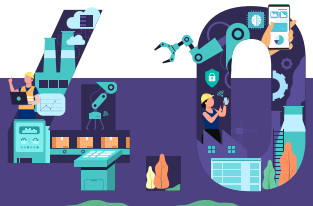
		LD, NGSI agents, pyngsi			
Data Exchange APIs		FIWARE Context Broker (Orion Context Broker/Orion-LD), NGSI agents, pyngsi	WP3/T3.2	UPV	
		Apache NiFi (part of EFF Data Spine)	WP3/ T3.3	CERTH	Data transformation based on ontologies (open-source tool)
		Data Distribution Toolkit	WP3/T3.2, WP5	CNR	In RE4DY, the toolkit will be extended to support decentralised ML algorithms, so as to optimise data distribution with respect to the requirements of the decentralised/ distributed ML tasks.
Data Provenance and Traceability	Data Provenance/Validation/Certification	Hyperledger	WP3/T3.4	INTRA	• A decentralized application based on blockchain to create decentralized identities of products, verifiable credentials, and presentations. • This decentralized application will enable us also to generate provenance records for each piece of data.
Identity Management (IM)	Identification/Authentication/Authorization	eIDAS-Node	WP3/T3.4	INTRA	To authenticate stakeholders
		Keycloak	WP3/T3.4	INTRA	To create access controls
Access and Usage Control/Policies	-	-	-	-	-
Trusted Exchange	-	-	-	-	-



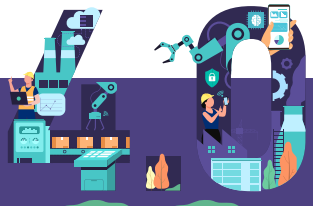
Metadata & Discovery Protocol	-	-	-	-	-
Data Usage Accounting	-	-	-	-	-
Publication & Marketplace Services	Cataloguing of "Data as Products", datasets, data apps and ML models; monetisation schemes; a sovereign data clearing house service in accordance with IDSA specifications	AGORA Data Marketplace	WP3/ (T3.3, T3.4, T3.5, T3.6)	ATOS	
	Data FAIRness Assessment Tools	Fairsfair	WP3/T3.5		https://www.fairsfair.eu/f-uji-automated-fair-data-assessment-tool
		SATIFYD	WP3/T3.5		From DANS: https://satifyd.dans.knaw.nl/
System Adaptation		NGSI agents, pyngsi	WP3/T3.2	UPV	Including Python library pyngsi (https://pypi.org/project/pyngsi/)
Data Processing		XAI and Active Learning Platform for Defect Detection		CERTH	
Data Routing and Pre-processing (DR&P)	Data Pipelines, Data Routing	Apache Airflow			Open-source
		Apache Nifi			Open-source
		Apache Kafka			Open-source
		RabbitMQ	WP3/T3.2	UPV	Open-source
		Apache StreamPipes	WP3/T3.2	UPV	Open-source
		Apache Spark	WP3/T3.2	UPV	Open-source
		Apache Flink	WP3/T3.2	UPV	Open-source
		Fiware Cygnus (Apache Flume)	WP3/T3.2	UPV	Open-source
		Fiware Cosmos	WP3/T3.2	UPV	Open-source
Data Analytics Engine (DAE)	Data Analytics; Machine Learning / Federated Machine Learning; AI/ML explanations; Trusted & Validated AI	Kubeflow			Kubeflow is open-source platform for machine learning and MLOps on Kubernetes. The different stages in a



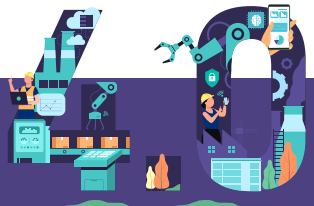
	Analytics (WP3/T3.4) AI and data pipeline delivery services; privacy-preserving federated learning environment (WP3/T??)				typical machine learning lifecycle are represented with different software components in Kubeflow, including model development, model training, model serving, and automated machine learning.
		ALIDA	WP3/T3.6	ENG	
		Decentralized Federated Learning component	WP3/T3.6, WP5	CORE	This is a standalone component that is related to an end-to-end decentralized ML solution implementing an ML task (e.g. Predictive Maintenance/RUL, machine optimization). The federated approach will allow enable privacy preservation with device telemetry never leaving the factory premises, training time enhancement and contribution to a collaborative learning scheme.
		Federated Predictive Maintenance (FPdM)	WP3 (T3.6, T3.7, T3.8), WP5 (T5.1, T5.2, T5.3)	ATLANTIS	The FPdM as a predictive maintenance platform, will provide predictive analytics (fault detection, prediction and identification to name a few), as well as several Graphical User Interfaces that



					will visualize the analysis results. The component's Federated Learning aspect will be satisfied both by connecting to ALIDA and as well as by implementing a custom solution for a federated learning functionality.
		XAI and Active Learning Platform for Defect Detection	WP3/T3.6	CERTH	The tool provides UIs and AI modules for defect detection based on visual inspection of assets in real-time. Human-AI collaboration mechanisms are used for AI modules retraining alongside XAI functionalities. (*the tool is planned to be used for AVIO use case)
Data Visualisation		XAI and Active Learning Platform for Defect Detection		CERTH	
Workflow Management Engine (WME)	Data Pipelines, Data Engineering (Data Cleansing, Data Pre-processing)	Apache Airflow			Open-source
		Apache Nifi			Open-source
		Apache Kafka			Open-source
		NodeRED	WP3/T3.2	UPV	Open-source
		RabbitMQ	WP3/T3.2	UPV	Open-source
		Wirecloud	WP3/T3.2	UPV	Open-source
		Apache StreamPipes	WP3/T3.2	UPV	Open-source
Data Space Boards	-	-	-	-	-
Overarching cooperation Agreements	-	-	-	-	-
Continuity Model	-	-	-	-	-
Regulations	-	-	-	-	-
Billing/Charging Scheme	-	-	-	-	-



Accounting Scheme	-	-	-	-	-
Data Valuation Method	-	-	-	-	-
Smart Contracts	-	-	-	-	-
Domain Data Standard	-	-	-	-	-
Unique Identifiers		Hyperledger	WP3/T3.4	INTRA	• A decentralized application based on blockchain to create decentralized identities of products, verifiable credentials, and presentations. • Decentralized identities of products (or product passports) will be based on standards like GS1 (https://www.gs1.org/standards)
Authorisation Registries	-	-	-	-	-
Trusted Parties	-	-	-	-	-



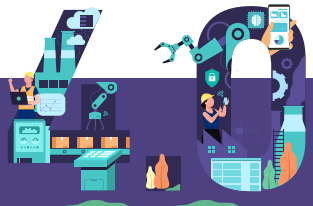
7 Conclusion

One of the main objectives of work package 3 is to set-up a network of TEFs and European data spaces for qualifying digital 4.0 continuum, the first step to reach this goal is formation of a network consisting of Testing and Experimentation Facilities (TEFs) following requirements and actions described in task 3.1. In this deliverable, a TEF network including POLIMI, INNO and SSF has been established to perform a first instantiation of existing assets to facilitate future integrations as well as focusing on Remotization services to prepare the foundation for experimentation plan for asset deployment in task T3.8.

Furthermore, the "DR-BEST" framework has been introduced for this network set-up which gives a better view of various and cross-collaborations among the network members by detailing the service configuration of each TEF. A specific concentration has been devoted here to Remotization services and tools which facilitate the integration of data sharing between enterprises as well as guaranteeing the interoperability of assets and data as a main requirement of RE4DY project. In addition, possibilities for offering added values to potential customers or stakeholders have been discussed which can be expanded for implementation of experiments required in task T3.8.

Considering following tasks of WP3, the concept and characteristics of "Data as a Product" has been defined as well as the data models and tools that can be used for data containers and data connection profiles. Finally, concerning RE4DY data space, chapter 6 has first managed to complete an initial description of the various tools (commercial and open source) brought to the project by partners and identified their key features in order to realize RE4DY's data space. To determine which aspects of the data space concept (and more specifically, the RE4DY data space) could be satisfied with the available tools, each of these tools has been mapped to the IDSA building blocks.

Next deliverable "D3.2 First generation digital continuum 4.0 open toolkit" will report on the development of the first generation of the digital 4.0 continuum open toolkit, including further information on the progress of the experiments carried out – within the context of the TEFs and the tools brought by partners - as well as the establishment of the RE4DY Data Space instance supporting them.



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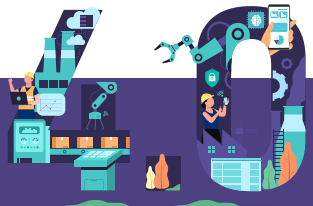


Annex I. Technological Asset Template

This template gathers relevant information of a specific technological asset, to be stored in the assets' repository. For that, it is organised into the following sections:

- General Information: The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.
- Features: The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
- Dataset: The Dataset section should only be filled if your component belongs to this category, otherwise leave it blank. Please, make sure to provide in table "Legal Aspects" the license of the dataset and, in table "Project-related Information" (under "Usage in Project") in which project pilot(s) is going to be used.
- AI Model: The Machine Learning Model section should only be filled if your component belongs to this category, otherwise leave it blank.
- Implementation: The Implementation section highlights the most technical aspects regarding the development of the component. It contains information such as the deployment requirements of the component, its communication capacities and other correlated components.
- Distribution: The Distribution section describes the multiple ways in which the component can be accessed and used.
- Reference: The Reference section will provide useful documentation of the component, such as instructions manuals, datasheets, publications related to the component, training material, and so on.
- Legal Aspects The Legal Aspects section contains the legal description of the component. Information like the associated license and the owner's contact information will be available here.
- Project-related Information: The project-related Information section contains additional details about the component in the context of the project, including its evolution throughout the project.
- Market: The Market sections contains the description of the component from the business perspective. This includes the target market, business model, the approach to develop the market, competitors, where you can buy the component and the SWOT analysis.
- Comments / Notes: The Comments / Notes section contains additional information about the component that did not suit any other sections in the template.
- Authorship: The Authorship section contains the version history of the current template, i.e., the current version, its author and the date of the last update. tables

Each section has a descriptive text and contains a variety of fields that may be mandatory. All fields have important explanations that must be carefully read. Before filling the template, please refer to the Annexes, for it will help you decide which type of component best suits your technological solution.

Annex Table 1- General information

1 General Information	
The General Information section intends to portray the general aspects of the component, namely its name, type and description, amongst many others.	
Component Name	Name of the Component
Type	Indicate the type of the Component: Platform, Sensor, Gateway, Dataset, Machine Learning Model, Library, Extension, As a Service or Other Software.
Summary	Short summary of the Component (with a maximum of 280 char).
Description	Extended description of the Component (text, images, etc.)
Technical Categories	Choose one from the list of Technical Categories, in the Annexes.
Research Areas	Choose one from the list of Research Areas, in the Annexes.
Business Categories	Choose one from the list of Business Categories, in the Annexes.
Website	The website of the Component
Version	Version of the Component
Standards	List of Standards supported by the Component
Data Space Building Block Categories	Choose one or more (if the component fits/overlaps more than one category) from the list of Data Space Building Blocks, in the Annexes. Please, use as category(-ies) the name(s) in the third column (e.g., 'Data Model & Formats', 'Data Exchange APIs', 'Data Provenance and Traceability', etc.)
Data Space Compatibility	Indicate whether the software component is already compatible with IDSA or GAIA-X (and therefore ready for deployment) Y/N/Not Applies
GDPR Requirements	Explain how you are impacted by GDPR requirement
Trustworthy AI	Explain how you are impacted by trustworthy AI requirement
TRL	Select the TRL of the Component according to European Commission H2020/HLG-KET Technology Readiness Level: ▪ TRL 1 – basic principles observed ▪ TRL 2 – technology concept formulated ▪ TRL 3 – experimental proof of concept ▪ TRL 4 – technology validated in lab ▪ TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies) ▪ TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies) ▪ TRL 7 – system prototype demonstration in operational environment ▪ TRL 8 – system complete and qualified ▪ TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)
Logo	Or main image of the Component.
Media Gallery	Media gallery of the Component. Create a folder that identifies that it is a component and the name of the Component (MediaGallery_Componet_[ComponentName]) and add the photos. In the videos case, add the link in this field.

Annex Table 2- Capabilities

2 Features
The Features section focuses on the asset's abilities, i.e., what the platform is able to do.
Examples: ▪ Display the graphical map and aerial views for the field mapping. ▪ Get all of the important weather data for the next few days. ▪ The field mapping contains your nutrient balance. The nutrient report for your fertilisation measures is displayed graphically. ▪ Data Storage ▪ Machine Learning Engine

Annex Table 3- Dataset

3	Dataset
The Dataset section should only be filled if your component belongs to this category, otherwise leave it blank.	
Dataset Type	Type of Dataset: Instruments and sensors, Database, API, document,…
Data Format	The format of the data (e.g., JSON, XML, CSV, JPEG, RDF, etc.)
Creation Date	Date of creation
Data Status	Preliminary or Final
Time period	Time period covered by the data
Data Frequency	Frequency of data collection (e.g., 5 minute, hourly, continuous, etc.).
Data Collection and Processing	Description of the Data Collection and Processing
Data Format	o Data file structure and file naming conventions (e.g., column delimited ASCII, GIF, JPEG, JSON, XML, RDF, etc.) o Data format and layout (i.e., description of header/data records, sample records) o List of parameters with units, sampling intervals, frequency, range o Description of flags, codes used in the data and definitions (i.e., good, questionable, missing, estimated, etc.)
Data Volume	Amount of data that exists (in MB, GB, TB, PB units)

Annex Table 4- AI Model

4	AI Model
The Machine Learning Model section should only be filled if your component belongs to this category, otherwise leave it blank.	
Machine Learning Type	Type of Machine Learning: Supervised, Unsupervised, Semi-supervised, Reinforced, Deep, …
Machine Learning Technique(s)	Machine Learning Technique(s) used: Classification, Regression, Clustering, …
Machine Learning Algorithm	Machine Learning Algorithm: Linear Regression, Logistic Regression, Decision Trees, Naive Bayes, K-Nearest Neighbours, …
AI-driven Application	The model's application from the AI standpoint (Data Processing Machine Learning, Machine Vision Image Processing Robotics, Media and Language Knowledge Extraction, Digital Assistant Chatbots, etc.) and its limitations (e.g., indicate the supported languages for text-related models)
Architecture	Architecture used: BERT, BiGAN, CNN, DAN, ELMo, etc.
Training Dataset(s)	Dataset(s) used in the model's training: ADE20K, BAIR, HRWSI, ImageNet, etc.
Model Format	Format of the model: TF.js, TFLite, Coral, …
Fine-tuneable	Does the model allow fine-tuning (Y/N)?

Annex Table 5- Implementation

5	Implementation
The Implementation section highlights the most technical aspects regarding the development of the component. It contains information such as the deployment requirements of the component, its communication capacities and other correlated components.	
Deployment requirements	System/Hosting requirements for the deployment of the Component - e.g., Hardware: Sensor needs Arduino / Software: Application needs Node.js; TensorFlow 2 must be installed in order to load the ML model

Communication capacities	Component communication capacities. For example, describe if the component connects to Wi-Fi, if it is input/output-configurable or if the platform connects to external services.
Interaction with external services	Can the component interact with external services (Y/N)?
Interoperability mechanisms	Describe which mechanisms were used to help at the interoperability level. This could be the use of data sources, visualisation interfaces, remote procedure calls (e.g., https://grpc.io) or other.
SDK(s)	Software Development Kit(s) associated to the Component.
Runs on	Indicate the Operating System (OS) required for the component to work (e.g., Linux, Windows, etc.).
Tested on	For example, Ubuntu 14.0. Specify the version, because from version to version can change the behaviour of the asset.

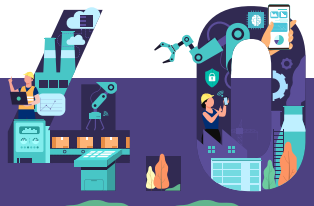
5.1 *Linked Components*		
Comp. 1	Comp. Name	Name of the Component
	Integration Type	How is the linked Component taking part of the main Component? (e.g., used as a library, integrated the source code, external service, part, etc.)
Comp. 2	Comp. Name	Name of the Component
	Integration Type	How is the linked Component taking part of the main Component? (e.g., used as a library, integrated the source code, external service, part, etc.)

Annex Table 6-Distribution

6 Distribution	
The Distribution section describes the multiple ways in which the component can be accessed and used.	
Source Code	Indicate the URL that gives access to the source code of the component. It can lead to GitHub, FTP or another download system and compilation will be necessary.
Binary	Indicate the URL that gives access to the component in the binary format. It can lead to GitHub, FTP or another download system.
Docker	Indicate the URL if the component is hosted in a docker hub or the docker-compose, if otherwise.
Package Manager	Indicate how the component can be accessed through a package manager (e.g., npm).
Other types of distribution	Indicate other formats through which the component is accessible (e.g., Jupyter Notebook) or describe it, if does not fit any of the previous options.
Execution Instructions	Indicate how the user can execute the asset. This could be a tutorial available through a URL, a GitHub repository or using, for example, a script hosted somewhere.

Annex Table 7-Reference

7 Reference	
The Reference section will provide useful documentation of the component, such as instructions manuals, datasheets, publications related to the component, training material, and so on.	
Documentation	Files (e.g., PDF guides) or URL where the Component is described
API(s)	Information related to the API of the Component (e.g., swagger)
Plug-ins, Apps, etc.	If available, reference to catalogue of Plug-ins, Apps, etc.
Publications	List of publications related to the Component
Training	Training material regarding the Component



Annex Table 8- Legal Aspects

8	Legal Aspects	
The Legal Aspects section contains the legal description of the component. Information like the associated license and the owner's contact information will be available here.		
Type of use / distribution		Open-source, closed-source, internal, etc.
Open-Source License		Open-source license (guide for open-source license[28])
8.1	*Owner(s)*	
Entity 1	Entity Name	Name of owner entity
	Logo	Logo (image + weblink) of the owner entity
	Website	Website of the owner entity
	Contact(s)	Name and email of the contact(s) person
	Entity Type	Type of entity: Higher or secondary education establishment; International Organisation; Non-governmental organization; Private for-profit organisation; Public organisation; Research organisation; Small or medium-size enterprise; Other.
Entity 2	Entity Name	Name of owner entity
	Logo	Logo (image + weblink) of the owner entity
	Website	Website of the owner entity
	Contact(s)	Name and email of the contact(s) person
	Entity Type	Type of entity: Higher or secondary education establishment; International Organisation; Non-governmental organization; Private for-profit organisation; Public organisation; Research organisation; Small or medium-size enterprise; Other.

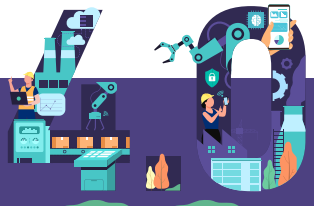
Annex Table 9-Project-related Information

9	Project-related Information	
The Project-related Information section contains additional details about the component in the context of the Project, including its evolution throughout the project.		
Usage in Project		How the Component was used in the project (e.g., use case)
WP(s) / Task(s)		Work package(s) or task(s) associated with the Component
Deliverable(s)		Deliverable(s) related to the Component in the project
Evolution	Technological	Advancements to the Component made during the project
	Business/Market	Business/Market development related to the Component
	TML Level	Evolved Technology Maturity Level during project
	TML Standard	Related Technology Maturity Level standard

Annex Table 10- Market

10	Market	
The Market sections contains the description of the component from the business perspective. This includes the target market, business model, the approach to develop the market, competitors, where you can buy the component and the SWOT analysis.		
Target Market(s)		Main target market(s) of the Component
Business Model		Business model for exploitation of the Component (e.g., subscription, buy, service, etc.)
Market Approach		Market development approach: how to approach the market(s)? with which instrument(s)?
Competition		Other Components that you consider competitive with this Component
Stores		List of stores where the Component is available (e.g., to purchase)
S W	Strengths	Characteristics of the Component that give it an advantage over others

[28] https://www.iot-catalogue.com/openSourceLicences



	Weaknesses	Characteristics of the Component that places it at a disadvantage relative to others
	Opportunities	Elements in the environment that the Component could exploit to its advantage
	Threats	Elements in the environment that could cause trouble for the Component

Annex Table 11- Comments/Notes

11	Comments / Notes
The Comments / Notes section contains additional information about the component that did not suit any other sections in the template.	
Additional notes about the Component.	

Annex Table 12- Authorship

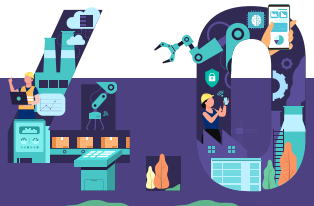
12	Authorship
The Authorship section contains the version history of the current template, i.e., the current version, its author and the date of the last update.	
Author	Name and contact(s) of the person who provided the information contained in this template
Date	Date when the information in this template was provided

Supporting annex tables

Annex Table 13 contains the types of components supported in this template.

Annex Table 13- Available types of components

Type	Description
Platform	Cloud service that provides Web-scale infrastructure capabilities to support digital solutions. For example, Ubidots (https://ubidots.com) allows users to connect their hardware and digital services to its cloud, in order to deliver customized Cloud solutions.
Sensor	Hardware component that detects events in its surroundings and translates them into electrical signals. Depending on the type of sensor, it can be able to detect changes in temperature, proximity to other objects, humidity, pressure, amongst many others (https://www.futureelectronics.com/c/semiconductors/analog--sensors).
Gateway	Piece of hardware that ensures the flow of data between two or more networks. For example, the ALTA Ethernet Gateway (https://www.monnit.com/products/gateways/ethernet-gateways) is used to receive data from Monnit Wireless Sensors and transmit it to the iMonnit Sensor Configuration and Management Software.
AI Model	Results from running a specific Machine Learning algorithm on some data and represents what the algorithm has learnt, i.e., the rules that will be applied the next time a prediction is asked for. For instance, the spice (https://tfhub.dev/google/spice/2) model recognises the dominant pitch of the raw audio waveform taken as input.
Library	Set of robust routines that allows users to perform complex tasks without rewriting many lines of source code. For instance, in Machine Learning, libraries may provide several models, which can be used without deep knowledge of their most technical aspects (e.g., TensorFlow Hub - https://www.tensorflow.org/hub).
Extension	Piece of software that adds on extra functionalities to an existing program. For instance, AdBlock Plus (https://adblockplus.org) provides browsers with the ability to block undesired advertisements.
As a Service	Multiple services can be available in external websites. For example, https://www.raffle.ai.
Other Software	Other types of software that do not fit any of the previous definitions.



Below, you can find the list of Technical Categories supported in this template:

Annex Table 14- Available Technical Categories

Technical Categories					
Knowledge representation	Automated reasoning	Common sense reasoning	Planning and scheduling	Searching	Optimisation
Machine learning	Natural language processing	Computer vision	Audio processing	Multi-agent systems	Robotics and automation
Connected and automated vehicles	AI Services	AI Ethics	Philosophy of AI	-	-

Below, you can find the list of Research Areas supported in this template:

Annex Table 15- Available research areas

Research Areas					
Collaborative AI	Explainable AI	Integrative AI	Physical AI	Verifiable AI	-

Below, you can find the list of Business Categories supported in this template:

Annex Table 16- Available business categories

Business Categories					
AI for agriculture	AI for air traffic management	AI for fashion	AI for space	AI in autonomous driving and mobility	AI for law
AI in retail and ecommerce	AI in Human Resources	AI in health	AI for telecommunication	AI for robotics	AI for media
AI for IoT	AI for ambient intelligence	AI for industry and manufacturing	AI for finance & insurance	AI for environment and sustainability	AI for cybersecurity
AI for citizen services & education	AI for art and music	AI in software engineering	Trusted and Privacy preserving AI	Other	-

Below, you can find the list of possible Data Space Building Blocks supported in this template. The position paper 'Design principles for data spaces', used for identifying the data space building blocks, can be found here: https://zenodo.org/record/5105744

Annex Table 17- Data Space Building Blocks

Building Block		
Business, Organization and Operational Building Blocks	*Governance [1,2,3,4]*	*Business Agreements [5,6,7,8]*
		Operational Agreements [9,10,11,12]
		Organisational Agreements [9,10,11,12]
Technical Building Blocks	*Data Interoperability [9]*	*Data Model & Formats*
		Data Exchange APIs
		Data Provenance and Traceability

	Data Sovereignty and Trust [10,11,12]	*Identity Management (IM)*
		Access and Usage Control/Policies
		Trusted Exchange
	Data Value Creation	*Metadata & Discovery Protocol*
		Data Usage Accounting [5,6,7,8]
		Publication & Marketplace Services
Additional Technical Building Blocks		*System Adaptation*
		Data Processing
		Data Routing and Pre-processing (DR&P)
		Data Analytics Engine (DAE)
		Data Visualisation
		Workflow Management Engine (WME)

Annex Table 18- Other information

Transversal features/artifacts	
Data space Administration, Organisation, and Guidance	*[1] Data Space Boards:*
	[2] Overarching cooperation Agreements
	[3] Continuity Model
	[4] Regulations
Operational Service Level Agreement (SLA)	*[5] Billing/Charging Scheme*
	[6] Accounting Scheme
	[7] Data Valuation Method
	[8] Smart Contracts
Interoperability	*[9] Domain Data Standard*
Trust	*[10] Unique Identifiers*
	[11] Authorisation Registries
	[12] Trusted Parties