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QU4LITY

DIGITAL MANUFACTURING PLATFORMS FOR CONNECTED SMART FACTORIES

D6.8 Community Support Services

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Abstract: A report about the experimentation-related support services that will be offered to the communities that will engage with the project's results, including open call participants.

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Contents

HISTORY

0.1	25/04/2022	First draft of IMECH description template.	Alissa Zaccaria (IMECH)
0.2	26/04/2022	Internal review of the work.	Valerio Pesenti (IMECH), Stefano Ierace (IMECH)
1.0	17/05/2022	First review and final version.	Alissa Zaccaria (IMECH), Valerio Pesenti (IMECH), Lukas Schulte (TUDO), Christian Bolzmacher (CEA)

Executive summary

This deliverable follows the deliverable D6.7, which deals with the methodology used to identify the potential services that each Technological Experimental Facility (TEF) can offer to the communities.

This deliverable is a report on the experimentation-related support services that have been offered to the communities that have been engaged with the project's results. In particular, the D6.8 deals with the description of the methodology used to provide support services to experimenters to implement the testing of their technologies. In particular, it consists of 3 phases:

1- Integration of the TEFs' service portfolio with the remotization category due to the COVID-19 situation;
2- Structuring of the operative methodology for experimenters' requirements identification and definition of support services
3- Implementation of the operative methodology and TEF experimentation

Going into more detail, the deliverable consists of four chapters:

- The first chapter is an introduction to the objectives and scope of the document;
- The second chapter is dedicated to the presentation of the remotization services;
- The third chapter is dedicated to the integration of the remotization services with the service portfolio provided by each partner;
- The fourth chapter describes the operative methodology to connect experimenters and TEFs as well as the process of support services identification;
- The fifth chapter illustrates the results of the implementation of the TEFs' experimentation;
- The sixth chapter is dedicated to conclusions and lessons learned.

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1. Introduction

Objectives and scope of the document

One of the main goals of the QU4LITY project is to adopt a practical, experimentation based approach to ensuring standards compliance for its development. However, European manufacturers, solution providers and innovators are not offered access to experimental facilities and testbeds, which could allow them to conduct experimentations and certify innovative Zero-Defect Manufacturing (ZDM) technologies. To address this challenge, the QU4LITY project will set up testbeds and experimental facilities based on the standards-based reference architecture of the project and on top of the world-class facilities that will be contributed by the project partners (e.g., CEA, Fraunhofer, JSI). Accordingly, it will enhance these facilities with tools, techniques, processes and other complementary assets (such as training and support). The testbeds will become accessible to all stakeholders of the QU4LITY digital manufacturing ecosystem, in order to facilitate manufacturers and providers of industrial solutions to learn, experiment and innovate in ZDM/Autonomous Quality (AQ), but most important to facilitate testing of compliance to standards and relevant certification processes. Therefore, the main objective of WP6 is to establish and provide the ZDM experimental facilities of the project, which will support all work packages that deal with digital enablers and enhancements for ZDM (i.e. WP3, WP4 and WP5) to test, certify and ensure the standards compliance of their developments. In particular, the task T6.6 deals with Testbeds Support Services and Integration of Open Calls Result: this means providing continuous support to experimenters that will use the testbed facilities and provide support to open call winners in the process of testing and validating their solutions against the QU4LITY reference architecture and technical specifications.

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2. Methodology for TEF Analysis: Remotization Services

Background information

This deliverable follows the deliverable D6.7, which outlines:

- TEF Service Portfolio Analysis: that aims to classify the TEF services and provide a reference framework where individual services can be ideated, developed and provided;
- TEF Customer Journeys, that aims to identify typical Digital Transformation processes for Technology Users and Technology Providers and to define the main barriers to the implementation of digital transformation projects.

TEF Service Portfolio Analysis

The TEF Service Portfolio Analysis illustrated in D6.7 is based on the **D BEST** methodology (Figure 1). This methodology was defined for the formalization of the support services provided by TEFs. In particular, it classifies the TEF services into 5 main classes:

- The D *class*, **Data**, including five *types* of services, following the life cycle of Data assets:
  - Acquisition and Sensing,
  - Processing and Analysis,
  - Decision Support,
  - Human Data Interaction,
  - Data Sharing Spaces.
- The B *class*, **Business**, declined in five *types* of services:
  - Incubation/Acceleration,
  - Access to finance,
  - Innovation Housing,
  - Business Development,
  - Project Management.
- The E *class*, **Ecosystem**, involves three main *types* of services:
  - Community Building,
  - Innovation Development
  - Ecosystem Management and Governance Services.
- The S *class*, **Skill,** can also be declined in three *types* of services:
  - Process & Organizational Maturity,
  - Human Capabilities Maturity
  - Skills Improvement and Development.
- In the T class, **Technology**, five main *types* of services have been detected:
  - Ideas Management,
  - Contract Research,
  - Infrastructure (TEF) provision,
  - Technical Support
  - Verification / Validation.

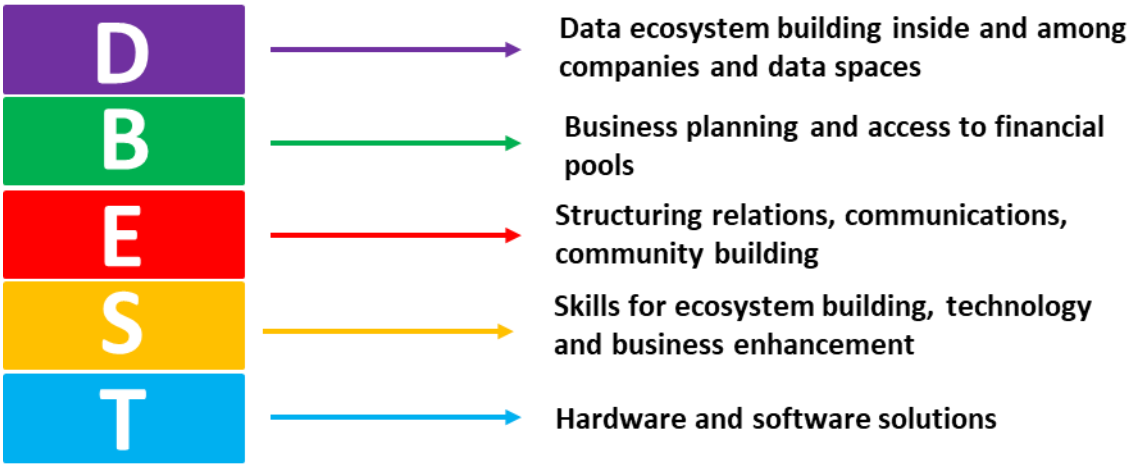

Figure 1 D BEST methodology for the formalization of the support services provided by TEFs.

Customer Journeys Definition and Blocking Points Analysis

Following the TEF Service Portfolio analysis, in the deliverable D6.7, the main phases that experimenters are expected to pass through during the process of QU4LITY transformation, supported by TEFs, are extensively explained. This transformation process is described through the Customers' journey, subdivided into technology users (Figure 2) and technology providers (Figure 3). For each phase, the main challenges and barriers that companies are likely to encounter, namely Blocking Points, have been identified.

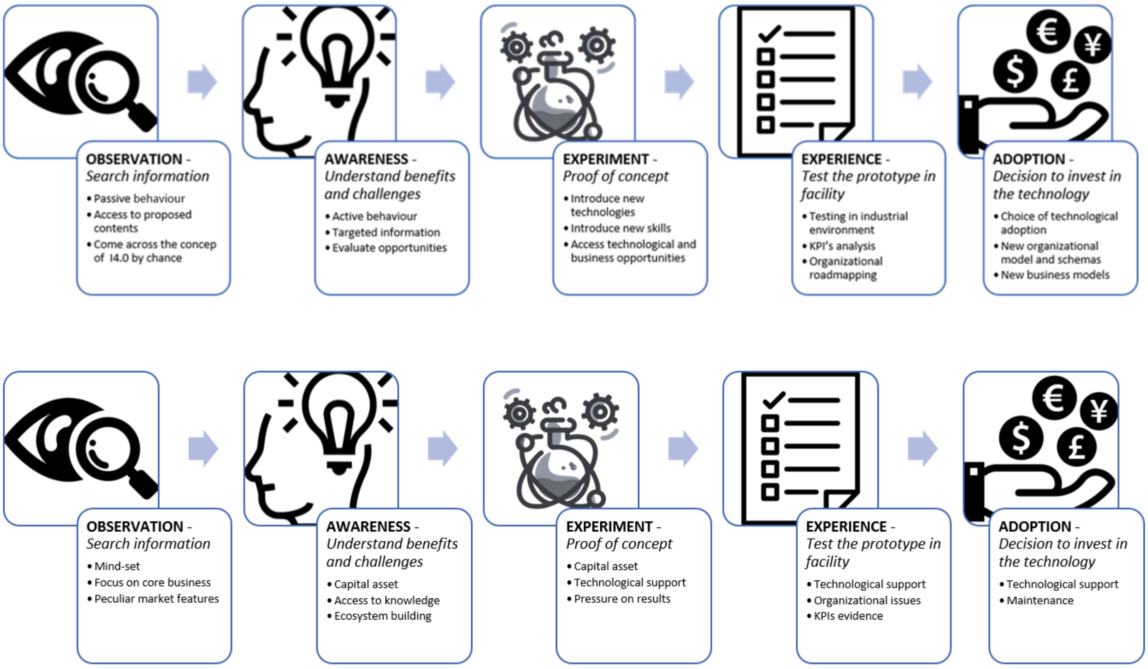

Figure 2: Technology Users Customer Journey (top); Technology Users Blocking Points (bottom).

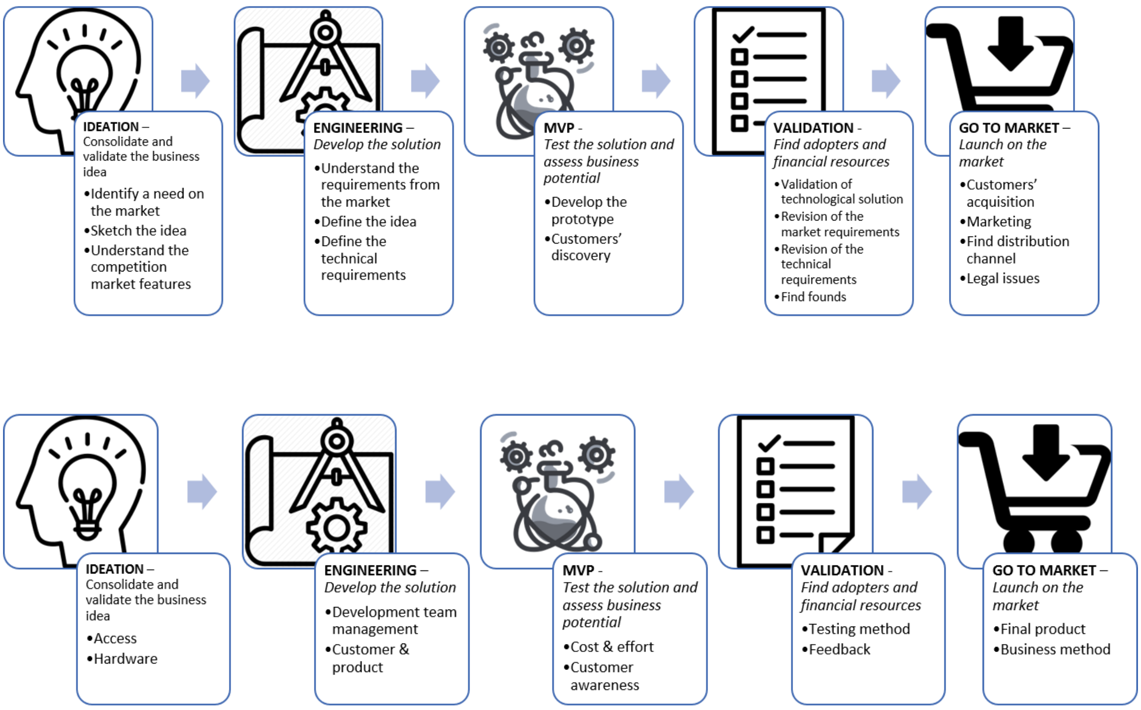

Figure 3: Technology Providers Customer Journey (top); Technology Providers Blocking Points (bottom).

Remotization Class integration

Remotization Class - Definition

Recently, the COVID-19 pandemic has stressed the need for remotization of services due to the reduced mobility and variability of regulations in different countries. In this sense, it becomes clear the necessity for the integration of TEFs' service portfolio with a class that takes into account this innovation trend.

In this view, the R class, **Remotization**, has been introduced. Similarly to the other classes, the services related to remotization are classified based on a three levels taxonomy. In particular, in the R class, five main *types* of services have been detected: Data space, ICT as a service, Digital Twin, and Asset as a service. For each *type* of service, different subcategories have been identified as described in the following:

- **Data space**
  - *Real-Time Industrial Data Platform*
    How to access data generated in real-time by Industrial IoT Systems;
  - *Assets Administration Shell*
    How to access structural data of the facility and assets;
  - *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 monetization.

- **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 that can be 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.

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- **Asset as a Service**
  - *Teleoperation*: Usage of tools to operate on the assets in remote and to transfer skills and expertise to remote places without physical presence;
  - *Monitoring platform*: Usage of tools for the assessment of the status of the assets and evaluation of production working progress;
  - *Avatar*: A physical system capable of replacing a person in the working environment to transfer his ability anywhere.

The resulting service portfolio analysis methodology has been named **DR BEST**. A simplified representation is reported below (Figure 4).

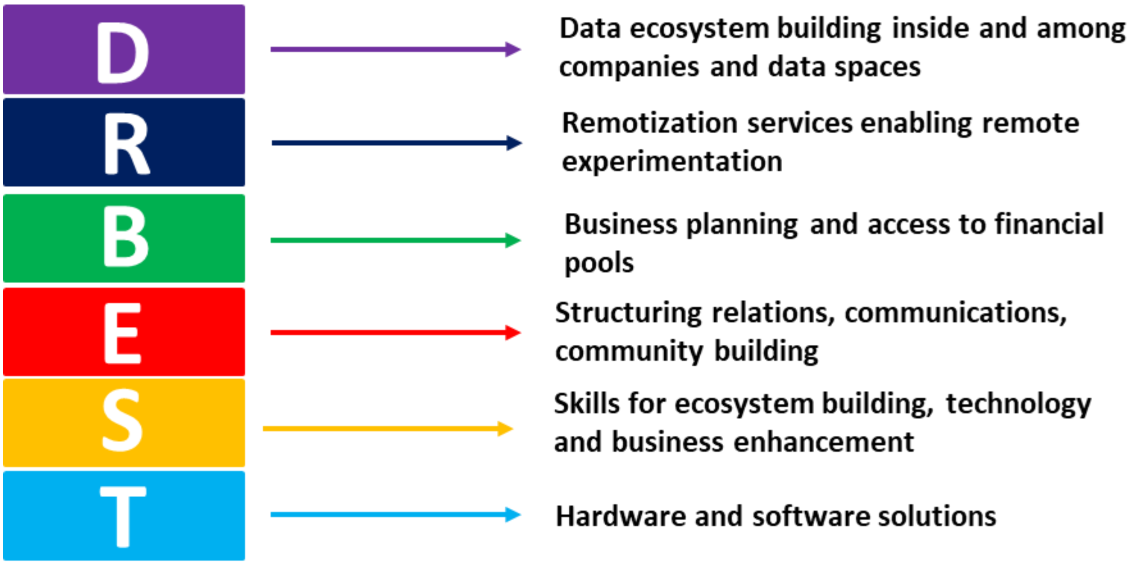

Figure 4 DR BEST methodology for the formalization of the support services provided by TEFs.

Remotization Class – Barriers and Challenges

As recalled in the previous section, in the deliverable D6.7, the main phases that experimenters are expected to pass through during the process of QU4LITY transformation, supported by TEFs, are extensively explained, as well as the analysis of the main challenges and barriers, namely Blocking Points, that companies are likely to encounter in each phase described.

Without repeating considerations available in D6.7, in this deliverable, the analysis will be limited to the identification, for each type of Remotization service, of the main barriers and challenges, which are reported in Table 1.

Table 1 Main barriers and challenges related to Remotization services

Remotization: Barriers and Challenges		
Data Space	Real-Time Industrial Data Platform	• Cybersecurity, • Ultra-low latency communication system, • Broadband communication system, • Data model standardization, • Model interoperability.
	Assets Administration Shell	• Cybersecurity, • Standard command interface, • Data model standardization, • Model interoperability.
	Open Data Repository	• Cybersecurity, • Data model standardization, • Model interoperability.
	Assets Data Marketplace	• Cybersecurity, • Data model standardization, • Model interoperability.
ICT as a Service	Software as a Service	• Cybersecurity, • broadband communication system, • software customization.
	Platform as a Service	• Cybersecurity, • Broadband communication system, • Platform customization.
	Infrastructure as a Service	• Cybersecurity, • Broadband communication system, • Infrastructure customization.
Digital Twin	FEM/CFD/FSI simulation	• High Performance Computing, • Model reliability, • Shared computing, • Data model standardization, • Customization,

		• Generative design, • Hybrid model.
	Discrete event simulation	• High Performance Computing, • Model reliability, • Shared computing, • Data model standardization, • Customization • Hybrid model.
	Ambient virtualization	• High Performance Computing, • Sensorial replication systems, • Model reliability, • Shared computing, • Data model standardization, • Customization, • Mixed reality, • User friendly modelling platform, • Model interoperability, • Model interface standardization.
Asset as a Service	**Teleoperation**	• Standardization, • Cybersecurity, • Safety, • Remote sensorial feedback, • Remote human in the loop, • Ultra-low latency communication system, • Broadband communication system, • M2M standard communication, • Data model standardization.
	Monitoring platform	• Standardization, • Cybersecurity, • HMI for visualization, • Ultra low latency communication system, • broadband communication system, • M2M standard communication, • Data model standardization.
	Avatar	• Standardization, • Cybersecurity, • Safety, • Remote sensorial feedback, • Remote human in the loop, • Ultra-low latency communication system, • Broadband communication system, • M2M standard communication, • Data model standardization.

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As evident in Table 1, the main barriers and challenges are similar for subcategories belonging to the same *type* of services.

- **Data space**:
  Concerning the data space services, the main barriers are connected with:
  - *Cybersecurity*
    Identify appropriate means, technologies and procedures to protect information systems in terms of availability, confidentiality and integrity of information assets or property.
  - *Ultra-low latency communication system*
    Systems dealing with real-time operations need to process very high volumes of data with minimal delay (latency). Thus, near real-time access to rapidly changing data is fundamental to ensure the optimal functioning of such systems.
  - *Broadband communication system*
    Broadband technologies are required to enable communication over a wide frequency band, and especially over a range of frequencies divided into several independent channels for the simultaneous transmission of different signals.
  - *Data model standardization*
    Data standardization is a critical process consisting of modelling data based on a common format, so as to ensure data consistency. This standardization process is a key enabler for collaborative research, large-scale analytics and information sharing.
  - *Model interoperability*
    Simulations of real systems are becoming increasingly challenging. Thus, to achieve accurate results, it is necessary to subdivide the problem into its components of complexity. In this view, it becomes clear the significance of model interoperability.
  - *Standard command interface*
    In line with the three above mentioned points, focused on interoperability and standardization, standard common interfaces are needed to facilitate software usability and improve user experience.

- **ICT as a service**
  Concerning ICT as a service, the main barriers are connected with:
  - *Cybersecurity*
    As for Data space, it is necessary to protect information systems in terms of availability, confidentiality and integrity.

- *Broadband communication system*
  As for Data space, the broadband communication system is required for the simultaneous transmission of different signals.

- *Customization*
  For all the three subcategories, software, platform and infrastructure, customization represents a key feature, including the possibility to adapt standard features to a client's requirements, add or remove specific features, modify configurations and visualization.

- **Digital Twin**
  Concerning Digital Twin services, the main barriers are connected with:

  - *High Performance Computing (HPC)*
    HPC aims at facing the complexity and huge computational cost needed to solve advanced computation problems. Nowadays, the most popular computing systems which use HPC technologies are installations that require significant investment. Moreover, specialized personnel is required to manage this technology.

  - *Shared computing*
    Shared computing is a type of high-performance computing where a network of computers works together to accomplish a specific task. Thus, each computer provides some of its processing power to achieve a specific goal. However, these systems are complicated to design and administer and are currently poorly standardized.

  - *Model reliability*
    Models imply unavoidable errors and approximations compared to the real system. Thus, the reliability of the model should be verified and validated so as not to negatively impact the decision process by introducing dubious information.

  - *Data model standardization*
    As previously, data standardization is fundamental to building a common format on top of which collaborative research, large-scale analytics and information sharing can be performed.

  - *Customization*
    Customization is critical concerning digital twins. Indeed, to be representative of the real asset or process, a digital twin should be carefully tailored to the specific problem and take into account eventual peculiarities related to the specific business, company organization, environment and workforce.

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- *Generative design*
  Generative Design combines a wide variety of emerging technologies to create design solutions through the generative contribution of Artificial Intelligence. Its mission is to create increasingly advanced artefacts by interfacing relying on the connection between the physical and the digital worlds. One common example is shape optimization towards a functional target. Usually, generative design tools return very complex solutions which may require Additive Manufacturing (AM) technologies.

- *Hybrid model*
  Some phenomena are not yet fully understood or may require too high computational costs to be solved starting from analytical formulation and numerical solutions. Hybrid modelling aims at overcoming these limitations by integrating digital models with Artificial Intelligence (AI) capabilities able to infer predictions from data.

- *Model interoperability*
  As for data space, Digital Twins are becoming increasingly complex and commonly rely on the integration of different models able to simulate specific subproblems. Thus, model interoperability is, also in this case, of great significance.

- *Model interface standardization*
  Model interface standardization is a key enabler for model interoperability, collaborative research and information sharing. Indeed, similarly to the "Standard common interface" required in the Data Space field, standardization is crucial to facilitate software usability and improve user experience also concerning Digital Twin.

- *User friendly modelling platform*
  Modelling platforms are still commonly difficult to be used, requiring specialized skills to design a reliable model. Improving the user-friendliness of these platforms could significantly promote their wider application and consolidate the applicability of this technology.

- *Mixed reality (MR)*
  Mixed reality, also known as hybrid reality, is the blending of the digital and virtual worlds. This blending generates new environments and visualizations enabling intuitive interactions with both virtual and physical objects which coexist and interface with each other in real-time.

- *Sensorial replication systems*
  Starting from the mixed reality concept and aiming at proceeding in the evolution of these systems, one of the main challenges is connected with sensorial replication. Indeed, current commercial technologies are trained in environmental understanding, user position and interpretation of

actions and may be able to comprehend voice or textual inputs. However, the complete sensorial and experiential aspects of the real interaction are not yet replicable.

- **Asset as a Service**
  Concerning Asset as a service, the main barriers are connected with:

  - *Cybersecurity*
    As for Data space and ICT as a service, it is necessary to protect assets from eventual violations.

  - *Safety*
    The possibility of remotely controlling assets (teleoperation and avatar) introduces possible risks, which should be carefully evaluated and minimized. For instance, the risks related to the safety of the people physically present in the laboratory.

  - *Standardization*
    Similarly to the previous points, standardization is crucial to facilitate user interaction and enable integration.

  - *M2M standard communication*
    Standardization is a key enabler in this field also concerning M2M communication and in particular to makes it possible for networked devices to exchange information and perform actions, even in the absence of human physical assistance.

  - *Data model standardization*
    As outlined previously, data standardization is fundamental also to ensure remote monitoring and control.

  - *Remote sensorial feedback*
    This challenge refers to the previous one "*Sensorial replication systems*" and extends it further to the possibility of transmitting data and bringing experiential sensorial feedback remotely.

  - *Remote human in the loop*
    The human in the loop approach involves constant interaction between the system and the people in charge. In practice, automation is used for the collection and processing of data, and automatic management of the simple and standard operations, while humans provide the discretionary ability. Human operators should be able, also remotely, to provide feedback to the system to feed it with new data and/or make decisions based on the system outputs.

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- *Ultra-low latency communication system*
  As previously, ultra-low latency communication systems are fundamental to ensure real-time operations and the processing of very high volumes of data with minimal delay.

- *Broadband communication system*
  As previously, broadband communication systems are required for the simultaneous transmission of different signals.

- *HMI for visualization*
  Human Machine Interfaces are required for the proper visualization of the asset to be monitored and/or controlled as well as the environment in which this asset is operating.

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3. Remotization of services in the QU4LITY TEF Ecosystem

This chapter will analyse the information provided by each partner concerning the TEF accessibility and the availability of remote services outlined in the previous chapter.

TEF Accessibility

Due to the COVID-19 pandemic, commonly provided services may have had limited deliverability in the last two years. To define the possibility to perform experimentation at TEFs, despite the limiting situation, the accessibility of the TEFs has been evaluated.

Table 2 illustrates a summary of the identified situation concerning physical accessibility.

Table 2 Accessibility of TEFs

TEF	Owner	Contact	Physical Accessibility
Automotive Smart Factory	AIC	Irati Vizcarguenaga i.vizcarguenaga@aicenter.eu	Yes
FFLOR	CEA	HOCHARD Mathieu Mathieu.HOCHARD@cea.fr	Yes
Industry 4.0 Lab	POLIMI	Giacomo Tavola giacomo.tavola@polimi.it	Yes
ReconCell	JSI	Andrej Gams andrej.gams@ijs.si	Yes (maximum 2 people)
SMACC	VTT	Helin Kaj Kaj.Helin@vtt.fi	No
SmartLab	IMECH	Valerio Pesenti valerio.pesenti@intellimech.it	Yes

As visible, only one TEF have not repristinated the physical accessibility at the laboratory at the time of the interview, namely SMACC, the VTT’s TEF.

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It should be highlighted that, even if the majority of the TEFs still guarantee physical access to the experimental laboratory, some additional procedures have been commonly introduced to safeguard people's health and prevent the spread of the contagion. These temporary procedures may vary significantly among different countries based on the regulatory guidelines that national and local government entities have provided. However, we can summarize the most commonly adopted measures as follows:

- **Social distancing promotion**
  Minimized number of entrants (as highlighted in Table 2 for ReconCell, which has limited the number of people present concurrently at 2). In some cases, this measure required the layout modification or the extension of the available time slots.

- **Sanitizing of spaces**
  Shared locals, both concerning the TEF itself as, in some cases, the surrounding confined environment need to be periodically cleaned and sanitized to ensure the safety of the working areas.

- **Personal Protective Equipment (PPE)**
  People accessing the TEF spaces have been generally asked to wear gloves and masks or face shields, so as to minimize the probability of contagion.
  Moreover, given the critical role of individual behaviours in contagion prevention, usually, guidelines are provided to raise awareness among employees/researchers/visitors concerning good personal hygiene practices. Moreover, to this objective, commonly hand sanitiser dispensers are deployed.

- **Monitoring actions**
  Concerning monitoring actions, generally, body temperature measurement of the people accessing the facilities is performed. Moreover, COVID-19 documentation can be asked for (e.g., vaccine certification or serological test results). Finally, registration is usually required to enable contagion traceability.

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Besides the physical access to the laboratory, the possibility to use and interact with the experimental assets is commonly subject to specific conditions not derived from the COVID-19 pandemic but worth mentioning:

- **Specific training**
  Specific training is required to use the assets available in the TEF. Note that different trainings are needed based on the activities planned and related equipment.

- **Personnel assistance**
  Usually, personnel from the TEF is asked to assist in experimental activities. Indeed, TEF is aimed at supporting different entities whose activities within the laboratory are limited in time. Thus, the provision of basic training and constant assistance is usually considered more advantageous than delivering specialized long training to all external technicians and researchers.

- **Contract basis (ReconCell)**
  Access and work on the JSI TEF asset are on a contract basis only. This means that after initial discussion and negotiation, external users need to sign a contract with JSI. The contract will provide physical access, technical support and training that will enable the independent continuation of work.

TEF Services Remotization

Given the limited TEF accessibility outlined in the previous section, as well as the inability or unwillingness of experimenters to move to a different region or simply to a different environment due to the risks connected with the pandemic, the possibility to perform validation tests remotely is of great significance. Thus, the remote accessibility of the TEFs has been evaluated.

Table 3 illustrates a summary of the identified situation concerning virtual accessibility.

Table 3 Virtual accessibility of TEFs

TEF	Owner	Contact	Virtual Accessibility	Assets Remoting
Automotive Smart Factory	AIC	Irati Vizcarguenaga i.vizcarguenaga@aicenter.eu	Yes	Yes
FFLOR	CEA	HOCHARD Mathieu Mathieu.HOCHARD@cea.fr	-	No
Industry 4.0 Lab	POLIMI	Giacomo Tavola giacomo.tavola@polimi.it	No	No
ReconCell	JSI	Andrej Gams andrej.gams@ijs.si	No	No
SMACC	VTT	Helin Kaj Kaj.Helin@vtt.fi	Yes	No
SmartLab	IMECH	Valerio Pesenti valerio.pesenti@intellimech.it	No	No

Note that the only TEF that has not repristinated the physical accessibility at the laboratory at the time of the interview, namely SMACC, is one of the two TEFs, together with Automotive Smart Factory, to provide the possibility to virtually access the experimental facility.

Nevertheless, only Automotive Smart Factory allows accessing assets and infrastructure data.

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In the following, further details for each TEF concerning the possibility of remotely accessing some of the assets in the TEF and the application of standard data modelling ontologies (e.g., RAMI 4.0 modelling) are reported.

Automotive Smart Factory (ASF) – AIC

The virtual layer and the infrastructure of the TEF can be accessed remotely (data, process and product information, equipment configuration.. etc). Note that for accessing the assets virtually, as well as for physical access, specific training is required and usually personnel from AIC should assist activities.

No standard data modelling ontologies are used within ASF.

FFLOR experimental facility – CEA

It is not possible to access the assets remotely. Assets are isolated into a dedicated VLAN.

FFLOR adopts a kind of TEF "self-designed" ontology. Indeed, FFLOR uses Tango, a free open source device-oriented controls toolkit for controlling hardware or software and building SCADA systems.

Industry 4.0 Lab [1] – POLIMI

For people outside the organization is not possible at the date to connect remotely. Following an agreement on specific activities/data collection to be performed, the TEF personnel can manage it remotely and, following, forward the resulting data to the experimenter.

Regarding ontology availability:

- The SHIELD architecture (developed in the Lab) is based on AAS (Asset Administration Shell), a German data model that is closely connected with RAMI 4.0;
- Ontology developed in the laboratory is based on ISO 21838 which defines a foundational ontology (BFO - Basic Formal Ontology) of reference to standardize the creation of ontologies in the industrial field;
- As a best practice in semantic modelling, Industry 4.0 Lab uses IOF (Industrial Ontologies Foundry) [2] as a repository of ready-to-use ontologies and CHAMP [3].

ReconCell - JSI

No remote access to the TEF is possible. Moreover, there is no plan to provide virtual access since the type of experiments usually conducted in ReconCell require the physical presence of the personnel.

Robot Operating System (ROS) provides the backbone of the TEF's software infrastructure. It enforces modular programming and provides standard tools for creating new robotics applications. The modules can easily be shared between different applications. As ROS is open source, there are no licensing charges when transferring the results from TEF to real production. While ROS does not provide standard data modelling ontologies, it does provide a standard framework to create and share robotic operations and functionalities.

SMACC – VTT

SMACC is accessible only virtually at the moment of the interview due to COVID-19 prevention measures.
However, the assets cannot be accessed remotely.

No standard data modelling ontologies are used within the TEF.

SmartLab – IMECH

For people outside the organization is not possible at the date to connect remotely. Following an agreement on specific activities/data collection to be performed, the TEF personnel can manage it remotely and, following, forward the resulting data to the experimenter.

No standard data modelling ontologies are used within the TEF.

4. Operative methodology to support TEFs and Experimenters connection

This chapter will illustrate the operative methodology to promote the connection between experimenters and TEFs and to support the validation process.

Operative Methodology

The overall methodology followed in task T6.6 can be subdivided into 6 steps.

The following 3 steps are focused on the definition and identification of services to be provided to the community. These services include the ones provided by each TEF to technology users and/or providers as well as the services that partners in charge of T6.6 have made available to support the testing and validation process within the QU4LITY ecosystem.

- **Definition of TEFs' Service Portfolio Analysis and Customer Journey (D6.7)**
  Description of the potential services that each TEF can offer to the community. In detail it's composed of TEF Service Portfolio Analysis, which aims to classify the TEF services and provide a reference framework where individual services can be ideated, developed and provided; and TEF Customer Journeys, which aims to identify typical Digital Transformation processes for Technology Users and Technology Providers and to define the main barriers in the implementation of digital transformation projects. Details about this step can be found in the deliverable D6.7.

- **Integration of TEFs' Service Portfolio with the remotization services**
  The remotization category (R) addresses the necessities highlighted during the recent COVID-19 pandemic due to the reduced mobility and variability of regulations in different countries. The R class of services has been introduced, similar to the other classes, based on a three levels taxonomy. Finally, the remote accessibility of the TEFs has been evaluated to identify whether it was possible or not to remotely perform validation tests overcoming the limitations due to restricted TEFs' accessibility and reduced mobility. Details about this step are reported in the previous chapters: "Methodology for TEF Analysis: Remotization Services" and "Remotization of services in the QU4LITY TEF Ecosystem".

- **Definition of support services for testing and validation**
  Starting from a critical analysis of the service portfolio (DR BEST), crucial support services have been defined. These services aim at providing continuous support to experimenters during the testing and validation process performed at the TEFs. More specifically, 4 types of services have been identified. A more detailed analysis of this step and the defined support services is reported in the following section "Definition of support services for testing and validation".

The following 3 steps describe the operative process, including the interaction with experimenters, the interaction with TEFs, and the support services implementation.

- **Contact experimenters for requirements identification**
  Contact experimenters, including technology providers and open call winners to understand needs and specific requirements so as to enable technologies validation. This step is crucial to define the priorities which will guide the TEF selection. The information provided by experimenters has been collected in a structured Technology Matrix described more in detail in the following section "Technology Matrix"

- **Contact TEFs for feasibility analysis**
  A preliminary selection of TEFs for technology validation has been performed starting from the inputs collected in the previous step. In particular, the geographical location of the reference partner, the TRL, the possibility for remote validation and the testing requirements have been used to select the most promising TEFs for the specific technology. Thus, the identified TEFs have been contacted to evaluate their availability, clarify eventual doubts, and identify the proper testing asset and conditions.

- **Support actions implementations**
  Starting from the requirements highlighted by experimenters and from the feedback collected by TEFs, the needed support services for testing and validation have been identified. These services are subdivided into: Procedure organization support; Travel organization support; Technical support; Skills support; Validation support. Further details on each service are provided in the following section "Definition of support services for testing and validation".

Definition of support services for testing and validation

The services to provide continuous support to experimenters during the testing and validation process performed at the TEFs have been defined starting from a critical analysis of the service portfolio (DR BEST). More specifically, 5 types of services have been identified:

- **Procedure organization support**
  Support in the testing and validation planning and management process. In particular, this service includes:
  - *Planning aspects,* such as the definition of the objectives and work plan, analysis of risks and mitigation actions, etc.
  - *Management aspects,* such as the definition of the timeline, effort estimation, maintaining contact between experimenters and TEF etc.

- **Travel organization support**
  Support in the organization of personnel travel towards the testing facilities as well as devices and material shipping.
  Travel organization support plays a key role due to the pandemic restriction. Indeed, correct and updated information on current limitations may not be easily accessible. In this view, it is fundamental to get clear and detailed information from the local entity, namely the TEF, with which to support experimenters in the travel planning process.

- **Technical support**
  Partners involved in T6.6 will ensure that, for each experimenter, the selected TEF provides access to the required infrastructure and technological platforms. Moreover, access to documentation will be guaranteed at a preliminary stage to evaluate in advance the compliance with the technology to be tested. Then, support is provided in the design of testing and benchmarking procedures and, if needed, technical assistance is offered for on-site deployment.

- **Skills support**
  The involvement of the infrastructure and platforms of the TEF for technological tests requires the strengthening of human skills, as previously outlined in "TEF Accessibility". In this view, T6.6 acts as an intermediary of the network, enabling the association between specific expertise required and experimenters.

- **Validation support**
  Finally, T6.6 aims at supporting experimenters to test, certify and ensure the standards compliance of their developments. In particular, T6.6 will assist the validation of the technological solutions against the QU4LITY reference architecture and technical specifications. Besides the functionality, performance and quality tests, the validation support may include the promotion of showrooms and demo cases in which a product is demonstrated in front of clients.

Technology Matrix

The information provided by experimenters has been collected in a structured Technology Matrix. Note that, this matrix is a living document, meaning a dynamic document that is continually edited and updated. More specifically, the Technology Matrix includes for each technology the following fields:

- **Technology matrix:**
    - *Technology ID*
      The technology ID has been defined as the "number of the technology WP" + ". (dot)" + "a linearly increasing number".
      The final matrix collects:
        - 23 technologies from the WP3: 3.1, 3.2, …, 3.23;
        - 66 technologies from the WP4: 4.1, 4.2, …, 4.66;
        - 27 technologies from the WP5: 5.1, 5.2, …, 5.27.
    - *Technology name*
      Name defined by the technology provider.
    - *Deliverable*
      The deliverable which refers to the technology at issue.
    - *Partner*
      Reference partner for the technology at issue.
    - *Identified testing requirements*
      Constraints or requirements for the deployment, testing and validation. E.g., cloud infrastructure able to run docker images, datasets for testing, and specific hardware that could be provided by the experimental facility for validation.
    - *TRL*
      Technology Readiness Level (TRL), is a value scale from 1 to 9 for assessing the maturity level of a technology. Concerning the technologies involved in this project, the TRL ranges from 4 to 7:
        - TRL 4: Technology validated in a laboratory;
        - TRL 5: Technology validated in an industrially relevant environment;
        - TRL 6: Technology demonstrated in an industrially relevant environment;
        - TRL 7: Demonstration of a prototype system in an operational environment.
    - *Available implementation*
      This field specifies if the technologies can be implemented in a laboratory, in an industrially relevant environment or an operational environment, based on the addressed TRL.

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- *Remote validation possible*
  This field specifies if the testing/validation can be performed remotely. More specifically, this field indicates if the human presence requirement is very limited and validation can be done over the Internet.

- *Experimental facility/Pilot assignment*
  This field indicates where the technology will be validated, specifying if it will be tested in a pilot or an experimental facility.

- *In preparation*
  The assignment is done and the definition of the validation methodology is in preparation.

- *Deployed*
  State of the deployment process:
  done / expected date / not yet deployed

- *Tested*
  State of the testing process:
  done / under test / expected date / not yet tested

- *Validated*
  State of the validation process:
  done / under validation / expected date / not yet validated

5. Implementation of the TEFs' experimentation

Following the collection of information and requirements from experimenters, it was possible to highlight technologies, which require the selection of a suitable testing facility. Thus, TEFs have been contacted to evaluate the testing feasibility and identify the best option for experimenters. Finally, support has been provided for the testing implementation.

In this chapter, the applicative case concerning the FOOTPRINT technology is presented. Table 4 illustrates the Technology Matrix for the FOOTPRINT technology on the 15th of September 2021 and the 25th of April 2022. Indeed, as outlined in the previous chapter, the Technology Matrix is a living document, thus, the reference date is essential to contextualize the provided information.

In particular, the FOOTPRINT is an advanced technology for assets' health status monitoring. This device is designed to measure current on electric motors by applying direct actions on the production line in order to detect different patterns and behaviours.

The main features, extracted from the electrical signal, are visible through an appropriate dashboard, created by means of Grafana. The dashboard enables the monitoring of electric signature associated to the working conditions of the asset, allowing the anomaly detection and process optimization.

Figure 5: Web based dashboard

Table 4 Technology Matrix for the FOOTPRINT technology on the 15th September 2021 and 25th April 2022.

Technology Matrix: FOOTPRINT		
Reference Date	15/09/2021	25/04/2022
Technology ID	3.18	3.18
Technology name	D3.8	D3.8
Deliverable	FOOTPRINT	FOOTPRINT
Partner	UNP	UNP
Identified testing requirements	1. Access to power supply cables to install the electrical sensor device. 2. Internet access to transmit electrical data to a database. 3. Annotated dataset according to what's happening at each timestamp (both regular workflow, and manufacturing/machine defects that might happen during production). 4. The electrical configuration of the machine (number of motors, motors per phase, etc.)	1. Access to power supply cables to install the electrical sensor device. 2. Internet access to transmit electrical data to a database. 3. Annotated dataset according to what's happening at each timestamp (both regular workflow, and manufacturing/machine defects that might happen during production). 4. The electrical configuration of the machine (number of motors, motors per phase, etc.)
TRL	TRL 4	TRL 4
Available implementation	Yes	Yes
Remote validation possible	No, user interaction may be needed to emulate/identify events and produce annotated data	No, user interaction may be needed to emulate/identify events and produce annotated data
Experimental facility/Pilot assignment	EXPERIMENTAL FACILITY TBD	SmartLab – IMECH

In preparation	-	Already available and deployed at the SmartLab
Deployed	-	Done
Tested	-	not yet tested
Validated	-	not yet validated

Note that in the referred period, starting from the identified requirements for the FOOTPRINT validation, the most suitable TEF has been selected. Following, the shipping and deployment of the FOOTPRINT device have been assisted. However, testing and validation processes are still pending due to COVID-19 related delays.

Concerning the TEF selection, Table 5 illustrates the reasoning behind the SmartLab identification as the best option for the FOOTPRINT validation. Indeed, starting from the identification of the three most suitable TEFs, compliance with the requirements has been first evaluated. Due to this analysis, Industry 4.0 Lab (POLIMI) has been removed from the acceptable options, since it does not provide internet access. Moreover, ASF (AIC) has been discharged due to Limited efforts in consequence of the concurrent testing of other technologies.

Table 5 TEF selection starting from experimenter requirements

		Compliance		
#	**Requirements**	**Automotive Smart Factory (AIC)**	**Industry 4.0 Lab (POLIMI)**	**SmartLab (IMECH)**
1	Access to power supply cables to install the electrical sensor device.	X	X	X
2	Internet access to transmit electrical data to a database.	X	-	X

3	Annotated dataset according to what's happening at each timestamp (both regular workflow, and manufacturing/machine defects that might happen)	X	X	X
4	The electrical configuration of the machine (number of motors, motors per phase, etc.)	X	X	X
Additional notes		Limited efforts due to other technologies that are being tested and a use-case to be deployed in the following weeks		
Selected TEF				**X**

Once the SmartLab was selected, more detailed information was collected concerning the asset for the FOOTPRINT validation. More specifically, two options have been proposed:

- An automated assembly line composed of 5 stations and a transfer system;
- An industrial manipulator to facilitate the lifting of weights up to 80 kg (Figure 6).

Following the illustration of the detailed features of these two options, the second one, namely the industrial manipulator was selected for testing. Indeed, the actuation via pneumatic and hydraulic systems, which represents the main actuation mechanisms of the automated assembly line, may compromise the pattern detection capabilities. Thus, the industrial manipulator, which actuates only using electric motors, has been preferred.

Figure 6 SmartLab industrial manipulator

Given the COVID-19 restriction, no technician has been sent to the TEF so far to perform the validation tests. However, IMECH (SmartLab reference partner) and UNP (FOOTPRINT owner) coordinated to arrange appropriate FOOTPRINT delivery and deployment. In particular, the deployment has been performed by IMECH with the remote support of UNP technicians and following the preliminary provided manual and guidelines.

Finally, the test and validation processes have been postponed due to the current limitation. However, the testing procedure will consist mainly of two phases: (i) data related to "typical conditions" will be collected so as to train accurate AI models. (ii) process anomalies will be simulated to test the capability of the device in detecting irregularities.

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6. Conclusions

This deliverable provides information on the experimentation-related support services that have been offered to the communities engaged with the QU4LITY project's results.

In particular, the description of the methodology used to identify the potential services that each TEF can offer to the communities is summarized in the second chapter (D BEST Service Portfolio Analysis, customer journey and blocking points). Further details concerning this methodology can be found in the deliverable D6.7. Moreover, the methodology integration with the analysis of Remotization services is illustrated (DR BEST Service Portfolio Analysis and main barriers and challenges for the R class of services).

In the third chapter, the analysis of the Remotization of services in the QU4LITY TEF Ecosystem is outlined. In particular, the accessibility of each TEF is first evaluated, highlighting the general rules and the limitations related to the COVID-19 pandemic. Following, the possibility to access some services and/or TEF assets remotely has been investigated.

The fourth chapter illustrates the operative methodology followed to support TEFs and Experimenters connection. Indeed the overall methodology can be subdivided into 6 steps:

- 3 steps for the definition and identification of services to be provided to the community;
- 3 steps constituting the operative methodology, including the interaction with experimenters, the interaction with TEFs, and the support services implementation.

Finally, in the fifth chapter, the concrete application of the operative methodology and its implementation for a specific use case is reported. First, the preliminary process of requirements identification, TEF identification and feasibility evaluation is outlined. Subsequently, the steps needed to deploy the device at issue at the selected facility are summarized.

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References

[1] Industry40Lab - https://www.industry40lab.org/

[2] IOF: Industrial Ontologies Foundry - industrialontologies.org

[3] CHAMP - https://github.com/NCOR-US/CHAMP

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AAS	Asset Administration Shell
AI	Artificial Intelligence
AIC	Automotive Intelligence Center
AM	Additive Manufacturing
API	Application Programming Interface
AQ	Autonomous Quality
ASF	Automotive Smart Factory
BSO	Basic Formal Ontology
CEA	Commissariat à l'Energie Atomique et aux Energies Alternatives
CFD	Computational Fluid Dynamics
CHAMP	Coordinated Holistic Alignment of Manufacturing Processes
COVID-19	Coronavirus disease 2019
FEM	Finite Element Method
FFLOR	Future Factory LORraine

FSI	Fluid Structure Interaction
HMI	Human Machine Interface
HPC	High Performance Computing
ICT	Information and Communication Technologies
IMECH	Consorzio Intellimech
IOF	Industrial Ontologies Foundry
IOT	Internet of Things
ISO	International Organization for Standardization
JSI	Jožef Stefan Institute
LAN	Local Area Network
M2M	Machine to Machine
MR	Mixed Reality
POLIMI	Politecnico di Milano
PPE	Personal Protective Equipment
RAMI 4.0	Reference Architectural Model Industrie 4.0

ROS	Robot Operating System
SCADA	Supervisory Control And Data Acquisition
SMACC	Smart Machines and Manufacturing Competence Centre
TEF	Technological Experimental Facility
TRL	Technology Readiness Level
UNP	UNPARALLEL INNOVATION LDA
VLAN	Virtual LAN
VTT	VTT Technical Research Centre of Finland Ltd
ZDM	Zero Defect Manufacturing

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Partners