Technical Guide

DIH^2 Second Open Call

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1 Technical requirements

To ensure its alignment with the DIH² Program, applicants are requested to propose Technology Transfer Experiments (TTEs) in compliance with a set of technical requirements that are grouped in two main categories:

- **(Hard) Relevance Requirements** are aimed at allowing applicants to understand the type of proposals that are considered in or out of scope for this open call. That is, based on the compliance with these requirements, the evaluators will make binary (yes/no) decisions on the relevance of the proposal for the purpose of this open call. On the one hand, proposals with significant weaknesses in any of the aspects associated with them will be considered non-relevant for the purpose of this open call (i.e., rejected). On the other hand, proposals that achieve correctness on these aspects will be considered relevant and conveniently scored according to a secondary set of criteria derived from the soft/quality requirements defined for this open call.

- **(Soft) Excellence Requirements** are aimed at allowing applicants to understand the key aspects that will be considered to score and rank the relevant proposals. It is important to mention that a generalised weakness in the set of requirements for excellence can lead to the rejection of a proposal. Therefore, the excellence requirements mainly focus on i) the quality of the proposed experimental methodology, ii) the ambition and value of the agile production KPIs to be validated, iii) the quality of the innovation that the proposed solution intends to contribute, and iv) the soundness of the ideas that the consortium describes for the life of the solution to be developed and the particular deployment under discussion after the experimental period.

The sections below elaborate a bit more on the specifics of these requirements and the "Short Proposal Template" in the attachments of this Guide for Applicants includes the necessary templates, background materials and explanations to prepare a successful TTE Application from the technical perspective.

1.1 (Hard) Relevance Requirements I - Problem Requirements "H-PRs"

Overall Description

The TTE clearly describes a relevant agile production problem that is being faced by a Manufacturing Company. The agile production problem must be described through a set of limitations/needs of a Manufacturing Company that aims to respond faster to changing customer demands and turbulent market trends (e.g., by producing smaller lot sizes and/or highly customised orders) while preserving when not improving the current production costs and quality control parameters. The successful proposal should describe this specific problem as a particularisation of a more generalised one which is well-known within the application domain and, therefore, applicable to a wide number of factories. For instance, the generalised product sorting problem in a flexible packaging line may be particularised and broken down into specific subproblems for the industrial robotics system that this TTE aims to develop (e.g., a system with convenient vision-based robotic grasping).

Specific Requirements

- **Application Domain (H-PR-01):** A valid application domain for this open call is a general area of work in a factory that specifies the required inputs (i.e., raw materials and/or product parts), equipment, and human resources as well as the sequence of manufacturing processes to convert the inputs into intermediate or finished goods. This also includes stages of the production cycle that emphasise on intralogistics problems in which the logistical flow of materials and goods is to be optimised for warehousing and distribution tasks. Despite multiple domains may fit with the previous description, the ones that this program prioritises are electronics assembly, automotive and aerospace, parts manufacture and assembly, and general production of metal, rubber, or plastic parts.

- **Generalised Problem and Agile Production KPIs (H-PR-02):** This requirement emphasises on the need of defining the core problem that will be faced in the proposed TTE. This core problem must be generalised as much as needed to match the definition of well-known problem that a wide number of factories face in similar application domains and/or area(s) of work. As for any well-known problem, there must be some KPIs that are common to almost any proposed solution. This requirement also aims to capture what those KPIs are and why they are relevant to produce with greater agility. Remember that the relevant KPIs in agile production are intended to assess the factory's ability to vary its production without impacting the efficiency and quality of its processes and products.

- **TTE Scenario – Specific Problems and Agile Production KPIs (H-PR-03):** This section of the requirements extends the definition of the general problem and the KPIs defined in the previous requirements to specify the particular characteristics of the problem that the proposed TTE as to cope with. Therefore, this requirement emphasises on the definition of the current factory scenario, which is determined by i) the current manufacturing infrastructure, ii) the base successful case for its production cycle, iii) the alternate successful cases in which the variation on production requirements can be efficiently absorbed with low impact on cost and quality, and iv) the variations production targeted by the manufacturing company that are currently unfeasible, costly, or risky. To characterize these details of the TTE scenario, the KPIs generated for the generalised problem need to be extended and/or complemented with new ones. This set of requirements is also intended to capture these customised KPIs.

- **Challenging Production Cases (H-PR-04):** The challenging production use cases are the last and more specific level of problem requirements in a TTE proposal. They are in charge of defining concrete problems that will be faced during the TTE and they do so by fully describing a targeted variation of the production cycle that impacts in the quality and/or efficiency of the regular production cycle. Thus, each challenging production case must provide a clear description of the conditions that prevent the factory from efficiently handling the targeted production variations with its current infrastructure. This description will include i) the current factory capabilities related to the production cycle variation being pursued, ii) a preliminary assessment of the potential impact of this variation on the current production cycle, and iii) a new set of capabilities that are required to transform the challenging production case into a successful one. A TTE proposal can describe as many challenging use cases as it deems appropriate to establish a precise framework with the problems to be addressed during the experiment.

1.2 (Hard) Relevance Requirements II - Solution Requirements "H-SRs"

Overall Description

The TTE proposes the development of a fully functional robotics-based solution to deal with the challenging Agile Production Problem described by the Manufacturing Company. A successful proposal will describe a preliminary solution design for a turn-key solution that builds on three main pillars: i) a set of flexible automation capabilities, which must be enabled by an by industrial robots or robotics systems[1], ii) a set of digitisation capabilities for robotics-based agile production, which must be enabled by a standard-based and reusable Digital Platform[2], and iii) a set of custom capabilities enabled by systems and/or components that are highly tailored to the specific needs of the factory under discussion. The following list of specific requirements include the necessary details to successfully develop the requested preliminary design in compliance with the goals set for this Technology Transfer Program.

Specific Requirements

- **Industrial Robotic System (H-SR-01):** The proposed solution must consider at least one system that fits into one of the following categories.

[1] Since the boundaries between Cyber-Physical, robotics, and automation systems are often blurred, the requirement "H-SR-01" specifies the industrial robotics systems that this Technology Transfer Program prioritises.
[2] To maximise the openness, standardisation, and reusability of experiment contributions this Technology Transfer Program has selected FIWARE as the mandatory underlying technology for the proposed digital platforms. The requirement "H-SR-02" elaborates on the core concepts and requirements linked to the use of technology.

- Industrial Robot (ISO 10218) → "*an* automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications".
- Industrial Robot System (ISO8373)→ "a system comprising industrial robot, end effectors and any machinery, equipment, devices, external auxiliary axes or sensors supporting the robot performing its task".
- Transportation Robots →This third category includes Automated guided vehicles (AGVs) and Autonomous Mobile Robots (AMRs) for intralogistics as in scope robotics systems for the purposes of this open call.

- **Smart Factory Platform (H-SR-02):** Applicants must build on the "system-of-system" vision of FIWARE and its technology to propose the preliminary design of its Smart Factory Platform (see Figure 1.2.i). As the Figure illustrates, the essential element in this system of systems vision is a common CIM layer (Context Information Management layer) which breaks the information silos created by the several assets (i.e., connected devices, information systems and vertical solutions) that are in charge of heterogeneous factory processes. In practice, this CIM layer is enabled by a FIWARE NGSI Context Broker. The rest of the systems gravitate around this central component, making use of standard APIs (FIWARE NGSI APIs) to interact with context information. Proposed designs are expected to materialise this simple, yet powerful, idea in compliance with specific requirements of this Technology Transfer Program, which are summarised in the following three directives:
  - **(H-SR-02a) The proposed Smart Factory Platform must be "Powered by FIWARE".** The main and only mandatory requirement for any "Powered by FIWARE" platform is to rely on the FIWARE NGSI Context Broker for managing, enabling the update, and bringing access to context data[3]. In agile production, the main sources of context data are the IIoT enabled sensors, equipment, and factory information systems[4]. Therefore, the term context data in this application domain has a clear focus on the data representation in NGSI format of these devices and systems, the state of the processes involved, and the availability of factory resources. These data representations are called NGSI Entities and they all have a standardised format which consists of an ID (URI), a type (a data model that defines the structure of the entity as well as the semantics of its key-value attributes), and a set of key-value attributes (properties and relationships with well-defined semantics to define the state of the entity and its relevant links to other entities).
  - **(H-SR-02b) The industrial Robotic System proposed must be "FIWARE-Ready".** This directive adds a requirement that is particularly relevant for the purpose of this open call. The proposed robotic system must be conveniently modelled through an NGSI entity or a set of them and be able to access and update context information through the context broker[5]. The priorities of this program regarding the design of FIWARE-Ready interfaces and proposed digitisation capabilities are described in the next directive.

[3] Besides this core component, the FIWARE Catalogue contributes a curated framework of (optional) open source platform components which platform developers can assemble together as well as with other third-party platform components to create the platform of choice that best fits with their needs.
[4] Industrial PCs, SCADA, MES, ERPs and any vertical solution that copes with cross-cutting concerns of these systems
[5] This definition is slightly more restrictive than the generic definition of FIWARE-Ready as, for the latter, communications do not need to be bi-directional. That is, the ability of a system to either update or access context information are enough to be considered FIWARE-Ready.

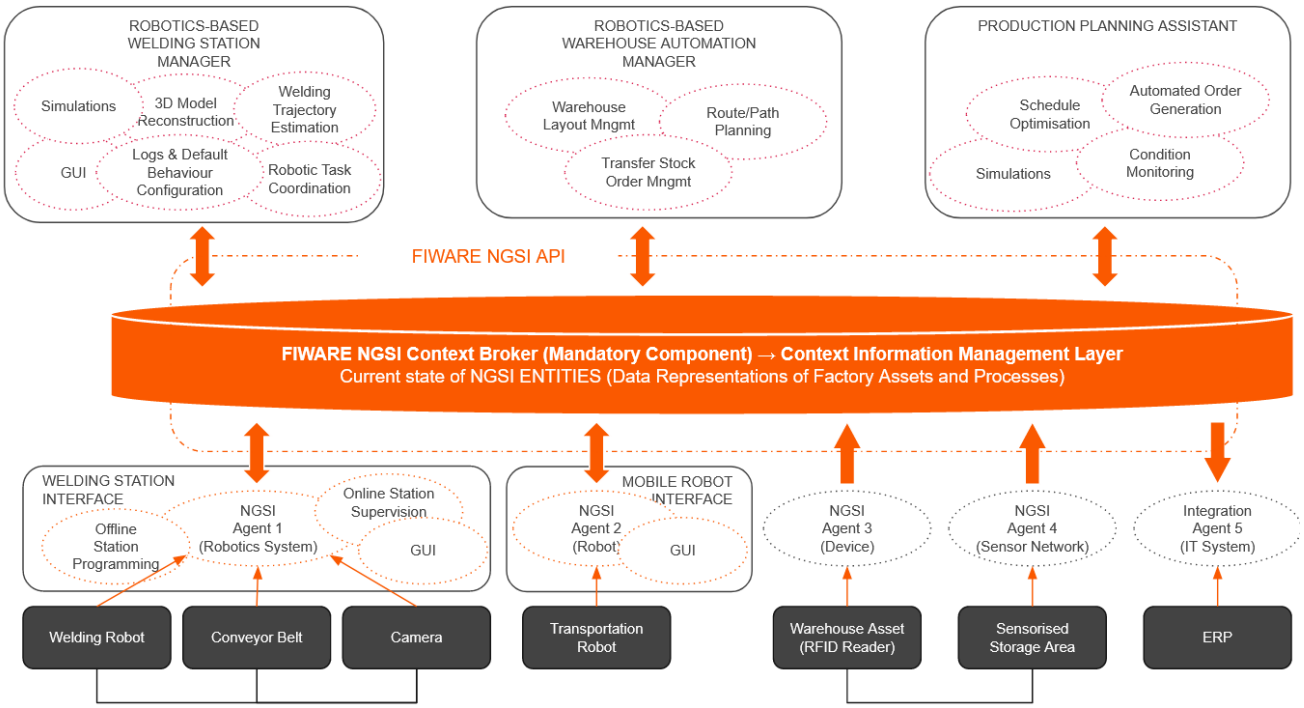

Figure 1.2.i. Example of a Powered by FIWARE system of system architecture for a robotised factory.

- **(H-SR-02c) Prioritised Digitisation Capabilities and FIWARE Interfaces.** There are two additional aspects that this program considers of high priority to maximise the homogeneity and synergies across digital platform designs. The first one emphasises on the digitisation capabilities that this program prioritises for the Powered by FIWARE platform to be developed. The second one focused on a lower level, is associated with the need of defining convenient FIWARE interfaces for the factory assets involved. More specifically, this aspect is linked to the need of giving a right purpose to each of these interfaces at the right level of abstraction.

  Regarding the first aspect, digitisation capabilities, this guide for applicants contributes the list below with the aim of narrowing the scope of targeted platform capabilities. Since the possibilities to group and classify these digitisation capabilities are countless, the list should be considered by applicants as prioritised capabilities. In practice, the capabilities designed for the digital platform may fit into different categories of this list (or not exactly with any). Thus, proposals should classify each platform capability to be developed according to the category that best defines its purpose and the overlap with other categories should be described as a set of cross-cutting concerns. The list of prioritised digitisation capabilities includes the following categories:

  - Traceability and seamless interoperability of complex robotic systems
  - Easy robot configuration and operation
  - Fast development, programming, and simulation of complex robot behaviours
  - Distributed (edge) and/or Ubiquitous (cloud) extensions for the integrated planning and execution of robot tasks
  - Near real-time supervision of the robotised station
  - Efficient management, visualisation, and analysis of real-time and historical data
  - Distributed (edge) and/or ubiquitous (cloud) monitoring and optimisation features at multiple factory levels (i.e., Asset, Workstation, Plant, and/or Business levels)
  - Security mechanisms for identity management and data exchange/access control

  Regarding the second aspect, FIWARE NGSI interfaces, the key messages are:

- FIWARE NGSI interfaces aim to enhance and never collide with the current infrastructure of the factory.

- The purpose and the design of a standardised API for the FIWARE NGSI interfaces of sensors and typical factory systems like SCADA, MES, ERP and associated vertical solutions are usually easy to define and implement. The FIWARE catalogue contributes a variety of NGSI agents to translate most of the well-known IIoT protocols into NGSI.

- The most complicated situation for the design of FIWARE NGSI interfaces gravitates around robotic and cyber-physical systems, since their purpose goes beyond the acquisition, processing, and exchange of data, they act on the physical world. For these systems, the typical endpoints at which the FIWARE NGSI interface should run are PLC Servers and Industrial PCs that are connected to the main robot controller to export a high-level interface. In cases such as the cobots and mobile robots for intralogistics, the software embedded in the robotic platform directly exports a high-level interface and are therefore valid endpoints for the FIWARE NGSI interface. Regarding communication patterns, the interfaces defined by the well-known industrial connectivity frameworks like OPC UA and DDS as well as the specific interfaces defined by the ROS (Robot Operating System) framework are the easiest to integrate with FIWARE NGSI. Connecting to an endpoint that serves or consumes raw data via TCP or UDP requires the design of a specific adapter. This point contributes to the design of the communications. However, this is not sufficient to develop a good interface design. Thus, the next point elaborates on their purpose.

- The purpose of FIWRE NGSI interfaces for robotic and cyber-physical factory systems is to maintain an interactive and right-time synchronised data representation of them in the FIWARE NGSI Context Broker. By accessing to this data representation, FIWARE-Ready systems should be able to, for instance, get access to the system datasheet in which all the physical and mechatronic capabilities of the system are described. More ambitious aims include the near-real time monitoring of available resources and internal robot states or the simulation of jobs and robot behaviours form edge (distributed) and/or cloud (ubiquitous) enabled systems. Finally, and this is the big challenge that the proposals in this open call must address at some point, use cases for FIWARE NGSI interfaces aim to interact with actuation behaviours. For this purpose, it is essential to comply with the rule mentioned in the first point of this list. The FIWARE NGSI interfaces must not interfere with the factory's critical control loop, which has its own communication mechanisms and data space. Instead, the interaction will be done at higher levels which are typically focused on the optimisation of robot schedules and the online activation/deactivation of hardcoded robot behaviours. The most ambitious cases deal with the execution of recovery behaviours and/or the online reconfiguration of pre-set robot behaviours based on a list of predefined robot inputs.

- **Use Cases (H-SR-03):** In practice, designing a successful solution is practically unfeasible if it is not driven by a clear set of use cases. Therefore, the proposed design must elaborate a well-defined set of use cases (as much as necessary) in which the challenging case scenarios defined by the manufacturing company are considered and associated with the capabilities of the robotics-based solution to be developed. Each use case must provide clear ideas on how specific capabilities will help in solving the problem under discussion. Ad/hoc or highly customised capabilities which are essential to achieve the project objectives but either will not meet this condition or are unlikely to be reusable in another application will be also mentioned and briefly described in these use cases.

- **Technology Readiness Level, TRL (H-SR-04):** The **TTEs** to be carried out by the selected consortia, will be developed in research facilities of DIHs or in end-user's facilities and will get engineering support. The experiment should be deployed in the factory. Starting from at least TRL 5 (technology validated in a real environment), **the expected result of the TTE will be a Prototype (TRL 7) in this case deployed in the factory**. After the prototype solution is demonstrated in the factory, the Manufacturing SMEs/Slightly Bigger company will define its roadmap for implementing the full solution in its production and indicate the key steps for the next five to ten years. The Entrepreneur- in-Residence (EiR) will monitor the implementation even beyond the EU funded project.

1.3 (Soft) Excellence Requirements "S-ERs"

Overall Description

The TTE describes a preliminary setup in the manufacturing company along with an ambitious set of goals with meaningful KPIS and a coherent experimental methodology. Besides, based on the idea of a successful experiment, each participant in the consortium provides consistent preliminary ideas on the exploitation plan for the results of the experiment. A successful TTE proposal must show a high potential for the proposed solution to reach the TRL 7 and, therefore, the quality of the proposal highly depends on the maturity of the preliminary ideas presented for the manufacturing company setup. A second aspect with relevant impact on the quality of the proposal is the definition of clear and ambitious objectives for the flexible automation and digital platform capabilities proposed which, in turn, must be connected to the description of the mechanisms that aim to provide solid evidence on the experiment achievements. Finally, this open call sets the sustainability potential of the experiment results after the project as a decisive quality parameter. Thus, the proposition of ideas or developments that are cross-cutting to the strategic agenda of the consortium participants will be considered a clear indicator of weakness in a proposal.

Specific Requirements

- **Envisioned Factory Deployment (S-ER-01):** This requirement focuses on the collection of preliminary ideas regarding the selection of technologies and the envisioned factory setup. The equipment and the different systems already existing in the factory shall be specified together with the description of their main physical and/or technology related features. For equipment and systems that the experiment considers as new acquisitions/developments, a distinction will be made between cases where a final decision has been made on the selection of a particular equipment or technology and those cases in which only a preliminary idea of the required characteristics is available. In the former case, the main physical and/or technology related features will be specified. In the latter case, references shall be provided to existing equipment or systems that meet similar requirements to those proposed by the experiment. Besides, the key aspects that make this decision still an open decision as well as a set of alternatives to be considered will be given.
- **Experiment Goals, KPIs, and Experimental Methodology (S-ER-02):** The fulfilment of the objectives and the achievement of the KPIs in the factory should provide solid evidence that the capabilities described in the use cases of the proposed solution have been realised. Parts of the proposed deployment/solution without clear associated objectives and convenient means of validation will not contribute value to the proposal. These goals and KPIs must be presented along with an experimental methodology in which preliminary ideas on the execution plan and evaluation methods for the results achieved are given.
- **Ideas on the Exploitation plan - Manufacturing Companies (S-ER-03):** In successful proposals, manufacturing companies provide clear ideas on how the solution to be deployed aligns with and fits into the actual strategic roadmap of the factory. A poor justification for this aspect is a clear indicator of a weak proposal.
- **Ideas on the Exploitation plan - Technology Providers (S-ER-04):** In successful proposals, Technology Providers provide clear ideas on how the developments for the solution to be deployed align with and fit into their actual strategic roadmap of the factory. A poor justification for this aspect is a clear indicator of a weak proposal.

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