# DIGITbrain

## 1st OPEN CALL

## Short Technical Description

*DIGITbrain project has received funding from the European Union's H2020 research and innovation programme under grant agreement no. 952071*

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# 1. Introduction

This document is part of the technical information package prepared for participants to the 1st Open Call of the DIGITbrain project. It is intended to give an overview and insight to technical staff of the consortium proposing an application experiment to DIGITbrain.

It is important to note that the DIGITbrain Solution is being developed while experiments are run, i.e. different version of the DIGITbrain Solution will be available at different stages of the project. Thus, this document is structured into three main parts:

1. The DIGITbrain testbed as of February 2021
2. The first version of the DIGITbrain Solution with which the experiments selected in the 1st Open Call shall integrate
3. An Outlook to the envisaged final DIGITbrain Solution and its benefits for different experiment participants.

Before going into technical details, some principles have to be stated.

## 1.1. The DIGITbrain Vision

Enabling customised **Industrial Products** and facilitating cost-effective distributed and localised production for manufacturing SMEs, by means of leveraging edge-, cloud- and HPC-based modelling, simulation, optimisation, analytics, and machine learning tools and by means of augmenting the concept of **Digital Twin** with a memorising capacity towards:

a) recording the provenance and boosting the cognition of the Industrial Product over its full lifecycle, and
b) empowering the network of DIHs to implement the smart business model "Manufacturing as a Service" (hereafter MaaS).

Thus, three key concepts are of paramount importance for experiments within DIGITbrain:

- Industrial Products,
- Digital Twins and,
- Product Life Cycle (hereafter PLC)

Application experiments shall help manufacturing SMEs that produce or use **Industrial Products**, i.e. products that support the production of other products – consumer products are not in the scope of DIGITbrain experiments. Industrial Products are considered being mechatronic systems that can communicate over the Internet and can send and receive data by their own means or by means of attached networked devices (e.g. IIoT devices); such networked mechatronic systems are also referred to as Cyber-Physical Production Systems (hereafter CPPS). CPPS contain sensing, actuating, and controlling capabilities.

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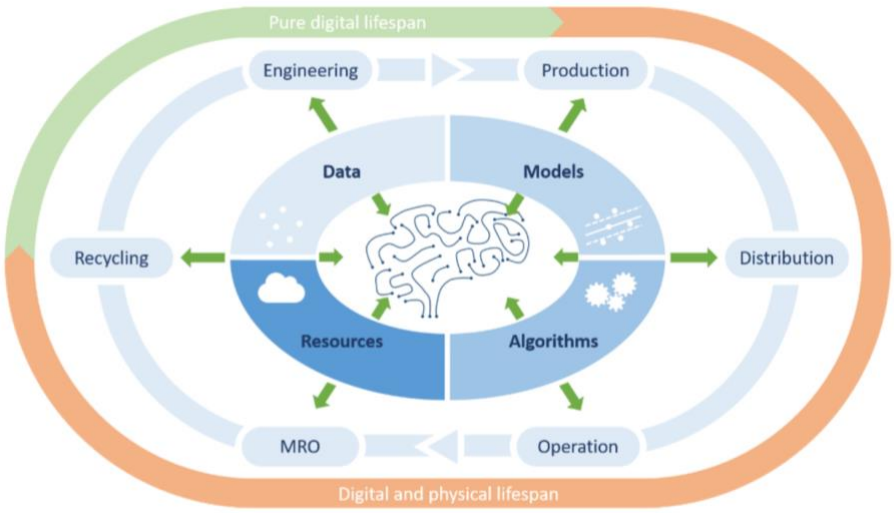
Application experiments shall do so by developing, using, exploiting **Digital Twins**. In DIGITbrain Digital Twins are conceived being formal digital representations of some asset, process or system that captures attributes and behaviours of that entity, and suitable for communication, storage, interpretation or processing within a certain context. The Digital Twin information includes, but is not limited to, combinations of the following categories:

- Physics-based model and data,
- Analytical models and data,
- Time-series data and historians,
- Transactional data, master data, visual data and
- Computations performed by executing implementations of algorithms which evaluate models.

The DIGITbrain project aims to extend the traditional Digital Twin concept towards the **Digital Product Brain** (hereafter DPB): it is a coordinating entity that guides the behaviour and performance of the industrial product by coalescing its physical and digital dimensions and by memorising the occurred (physical and digital) events over a significant part of its lifecycle. The DPB is intended to be created as early as possible during the lifecycle of the industrial product (ideally during the conceptual design phase) and to accompany the downstream lifecycle phases. From the point of creation onwards, the DPB starts memorising events and its **Assets** (**Data**, **Models**, **Algorithms**, **Resources**) start evolving.

**Six** stages in the PLC have been identified to which DIGITbrain relates to:




1. **Engineering covering**
    a. Design
        i. Design a new Industrial Product (IP)
        ii. Adapt it based on insights derived from the DIGITbrain
        iii. Re-design and evolve an IP to a next-gen version
    b. Engineering
        i. virtual testing/simulating

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ii. physical testing/simulating

2. **Production covering**
   a. Production engineering / Production planning
   b. Producing and monitoring
   c. Quality assurance

3. **Distribution**

   This relates to the "distribution" of production capacity.

4. **Operation**

   This is the operation of an Industrial Product in/on a manufacturing facility. The manufacturing facility can be a factory building, plant, even a farmer's field where IPs are used to harvest natural goods.

   Improvements in the operation phase aim for faster adaptation of operation to changing requirements. The idea is to use knowledge represented in DIGITbrain and the Digital Twins to facilitate changing faster and easing the virtual testing phase before applying the change on an IP.

5. **Maintain, repair, overhaul (hereafter MRO)**

   Provided the corresponding Digital Twins, DIGITbrain can help to identify maintenance needs and be used for predictive maintenance measures. Digital Twins may help to prevent damages to IPs.

6. **Recycling**

   The Life-Cycle Assessment (LCA) activities and models within DIGITbrain are addressing recycling and support to evolution of ever more environment-friendly IP design and operation of IPs.

The outcome of the project is the DIGITbrain Solution that incorporates a platform and an associated Digital Marketplace that manufacturing and technology companies and Digital Innovation Hubs (hereafter DIHs) can utilise to implement the smart business model of Manufacturing as a Service. MaaS aims to democratise the access of advanced digital technologies and advanced manufacturing technologies to manufacturing SMEs.

In order to implement the technical solution and the application experiments, the project starts with a testbed infrastructure that will be gradually extended with new components from core partners and experiment partners (Third Parties) as they become available during the lifetime of the project, finally incorporating all components into the DIGITbrain Solution. The final version is expected to be a close-to-production-quality DIGITbrain Solution that is ready for commercialisation and wider exploitation.

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# 2. DIGITbrain testbed – overview (optional read for experiments of wave 2)

The DIGITbrain testbed provides a development, testing and execution environment for the application experiments of wave 1 (and also for developers of the DIGITbrain Solution). This section describes the initial version of the testbed.

A high-level architecture of the initial DIGITbrain testbed is shown in Figure 1. The initial version of the DIGITbrain Testbed is a CloudiFacturing Solution installation – CloudiFacturing being another EC project on which DIGITbrain builds.

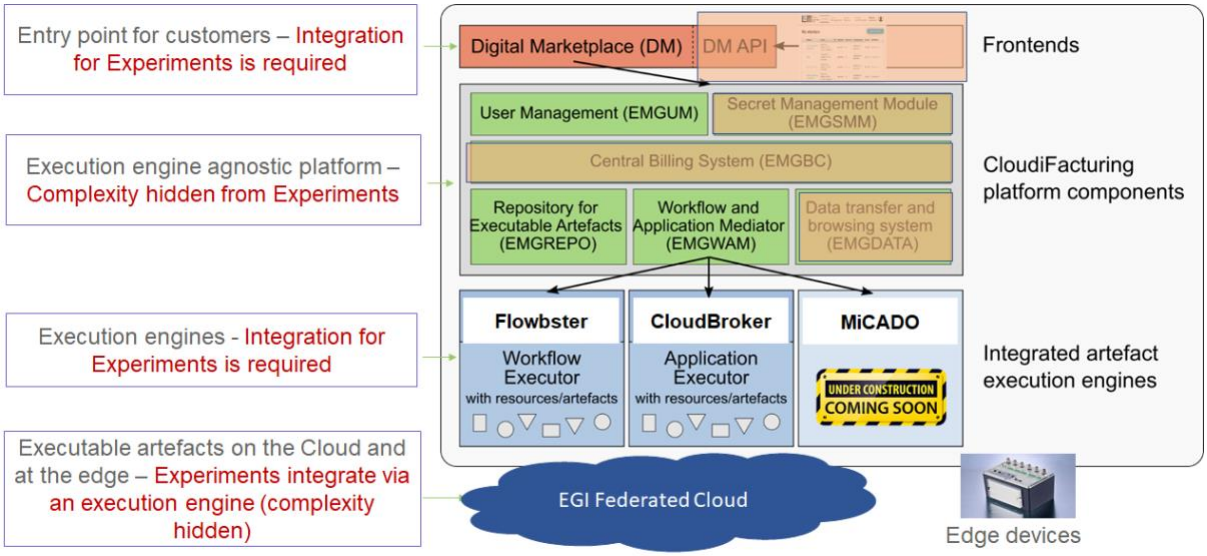


*Figure 1 High-level architecture of the initial DIGITbrain Testbed*

The topmost layer of the architecture is the Digital Marketplace (DM). It provides a web-based graphical user interface to access all lower-level services. Application experiments are expected to integrate with the DM and publish their applications there.

The second layer from the top is represented by some CloudiFacturing platform components. These components provide the basic and essential services to manage users and execute applications. In the initial version of the testbed contains the user management, repository and workflow/application executor services. Other components, such as those responsible for billing, data transfer and secret management are not part of the initial testbed, but are planned to be integrated later (these components are "greyed out" in the figure). The complexity of this second layer is fully hidden from the application experiments and conformance is guaranteed if one of the supported execution engines is utilised.

The execution engines layer includes three application/workflow executors: CloudBroker Platform (hereafter CBP), Flowbster and MiCADO. Two of these (CBP and Flowbster) are fully integrated yet, while the integration of MiCADO is ongoing. Application experiments are required to use either of them for their implementation.

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Finally, the lowest layer is represented by the EGI[1] Federated Cloud, the dedicated resource provider of the DIGITbrain project. Applications will be executed on cloud and edge computing resources. As the experiments will access the EGI cloud and edge devices via one of the execution engines, the lower level details of the cloud/edge will not be expressed towards the experiments.

In summary, an application experiment of wave 1 is expected to integrate with:

a) the execution engine layer, e.g. by providing a VM image or a Docker container and

b) the DM allowing the involved manufacturing SME users to use the corresponding application.

For end users, software deployed in the testbed will be accessible using the Digital Marketplace web application. More than that, the Digital Marketplace is aiming to be a commercialization hub and a space for community building around cloud-based engineering software for the manufacturing industry.

The testbed for experiments of wave 1 as described here, focuses on software packages, applications, and workflows, which are executed on cloud and/or HPC resources.

In the future, the DIGITbrain Solution will go a decisive step further: it will manage and deploy Digital Twins with their assets Data, Model, Algorithm as well as the link to the Industrial Products – the instances in the manufacturing facilities – and their evolution over the product's life cycle.

[1] For further information go to: https://www.egi.eu/federation/egi-federated-cloud/

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# 3. The DIGITbrain Solution: 1st version for experiments of 1st Open Call

In this section we describe the 1st version of the DIGITbrain Solution as it is being developed with which the experiments selected in the 1st Open Call need to integrate. More concepts are being introduced, such as Data, Model and Algorithm as well as its separation is motivated.

The DIGITbrain Solution extends the high-level architecture of the testbed considerably, first and foremost, with the component Publishing Interface and the Digital Product Brain. All the Asset (Data, Model, Algorithm) types as mentioned above can also be found in the figure below.

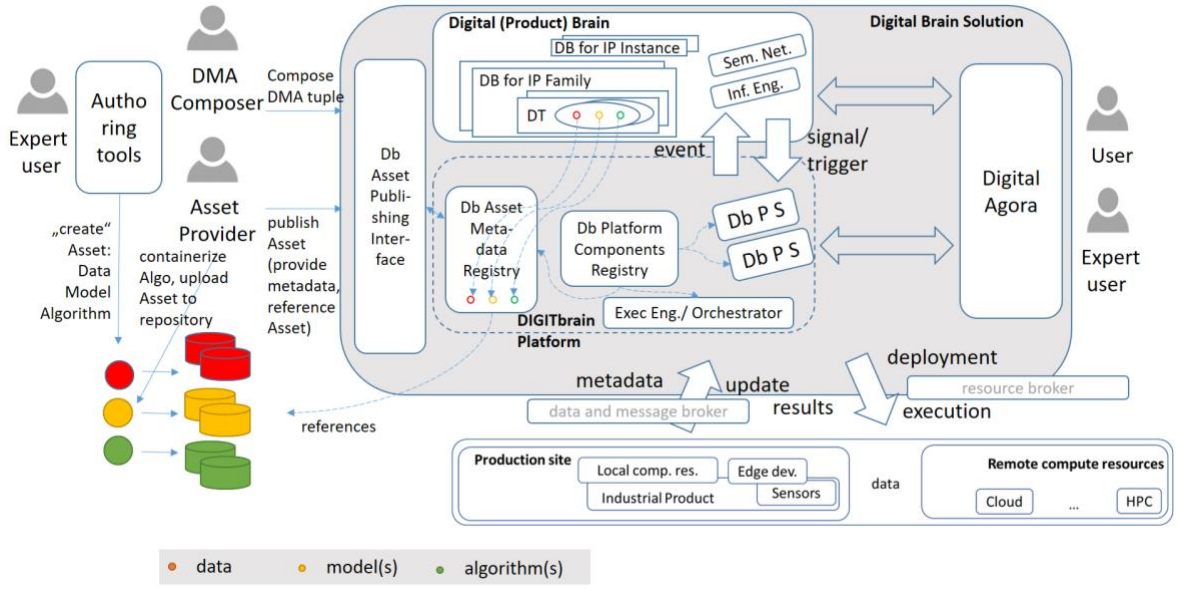


*Figure 2 High-level architecture of the 1st DIGITbrain Solution*

Although looking completely different in nature from Figure 1, Figure 2 depicts the DIGITbrain Solution high-level architecture and has many communalities with the testbed architecture:

- The Digital Marketplace has been moved from top to right and renamed to Digital Agora – it will be a further developed version of the Digital Marketplace from the testbed (for details see chapter 2)
- The CloudiFacturing Platform Components from Figure 1 are "condensed" into DIGTbrain Platform Services.
- MiCADO[2], Flowbser and CloudBroker are "anonymised" into Exec. Eng./Orchestrator in Figure 2 – MiCADO will be the main Exec. Engine / orchestrator being used for experiments of wave 2.

[2] For further information go to: https://micado-scale.eu/

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- New platform components are added: DIGITbrain Asset Metadata Registry and DIGITbrain Platform Components Registry.
- The Digital (Product) Brain has been added as a component to the DIGITbrain Solution.
- The DIGITbrain Asset Publishing Interface has been added to the DIGITbrain Solution as well.
- The lower part is similar to the one described in Figure 1: here the remote and local (compute) resources are depicted, either being Cloud resources provided via EGI or local ones residing in the production sites of the respective manufacturing SME. Note, here conceptually the Industrial Products can be found, too. They do not need to reside in a factory building, they can also be utilised "outdoors", e.g. being harvesting robots.
- In comparison to Figure 1, the left part is new. Here, persons acting in different roles are depicted using different tools as explained below. On the left, also the **Asset** types **Data**, **Model** and **Algorithm** are stylized.

DIGITbrain wants experiment partners to separate between **Algorithms, Models and Data**.

A **Model** in the context of DIGITbrain is a description of a certain behaviour for an Industrial Product according to the given characteristics and operation conditions. If instances of an Industrial Product share the same configuration and characteristics, a Model may be shared across these instances. A Model can be physics-based, or data-driven created via Machine Learning. Models shall be created as independent as possible from Algorithms so that different Algorithms may be used to evaluate a Model – for an experiment, it is sufficient to provide one Algorithm for Model evaluation.

An **Algorithm** in the context of DIGITbrain is an executable procedure capable of evaluating models (with the associated Data). Algorithms are agnostic w.r.t. instances of Industrial Products (e.g. their application field or the context in which a Model is being used). Multiple Models can use the same Algorithm. Algorithms can be deployed into different resources (e.g. edge, cloud, HPC) to be executed, depending on the needs of the Model.

**Data** in the context of DIGITbrain are actual data sources acting as inputs for Models and Algorithms. Data sources can contain Data from engineering, production, sensors, logistics/ distribution, environmental impact, etc.

The motivation for DIGITbrain to separate between these Assets is to maximize potential re-use of these Assets, i.e. deploy Algorithms on different compute infrastructures to evaluate different Models, feed Models with Data from different Industrial Products. A goal which seems obvious but not always supported in Cloud Computing and with Digital Twin technology.

The concepts Data, Model and Algorithm build a tuple where an Algorithm is evaluating a behaviour Model fed by some input Data. Since different kinds of Algorithms are needed to evaluate Models of different (physical) domains, and a Digital Twin shall represent all

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behavioural facets of an Industrial Product, Digital Twins consist of many tuples of Data, Model and Algorithm (short DMAtuple) in DIGITbrain.

Software to create Models representing a certain behaviour of an Industrial Product is considered to be an **Authoring Tool** in DIGITbrain. Experiments are encouraged to bring their own Authoring Tools to DIGITbrain. At the same time, Authoring Tools may contain functionality to evaluate the created Models, e.g. a numerical solver for a finite element model. Thus, the Authoring Tool can be an Algorithm in the sense described above.

All Assets need to be published in DIGITbrain. For this end, the DIGITbrain Publishing Interface will be used allowing to describe the Assets with metadata.

DIGITbrain offers automatic deployment which requires Algorithms to be containerized and provided as Docker containers. Experiment partners may need to containerize their Algorithm. In some cases, modularization of existing software may be required to facilitate the execution of some functionality on a remote compute resource (Cloud) and some other modules locally. An Algorithm in the context of DIGITbrain can consist of many (micro-) services, each being containerized.

Some Authoring tools already exists within DIGITbrain that can be used for realising experiments, however new Authoring tools are welcome in order to enrich the power of the DIGITbrain Solution and become part of the Digital Agora at the end of the experiment. Current DIGITbrain authoring tools include:

- Into-CPS App: an Authoring tool to compose co-simulation scenarios out of FMUs (provided by Aarhus University) – NB: the FMUs have to be provided by the experiment from Third party tools
- DDS Solution: an Authoring Tool for discrete event simulation of manufacturing lines (by Technology Transfer System)
- CAELLA: an Authoring Tool to create reduced-order models (ROMs) (by ITAINNOVA)
- PreSTRA: an Authoring Tool to create finite element models for structural analyses for the RISTRA solver (by Fraunhofer)

If an application experiment wants to make use of any of those Authoring tools, we highly encourage to get in touch with the respective experts and discuss the possibilities and limitations of these tools to be sure they deliver what the experiment requires in case of getting selected.

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# 4. The envisaged final DIGITbrain Solution and its expected benefits for the selected stakeholder

In this chapter, we sketch out the purpose of the Digital (Product) Brain – already mentioned in chapter 3, but not yet fully developed - and which benefits the final DIGITbrain Solution will provide to different stakeholders in different use scenarios along the product's life cycle.

As mentioned in the introduction (chapter 1 of this document), the **Digital Product Brain** is a coordinating entity that shall guide the behaviour and performance of an Industrial Product by coalescing its physical and digital dimensions. The physical dimension being the instance of an Industrial Product – the machine – itself, whereas the digital dimension being represented by a Digital Twin. The Digital Product Brain will memorise the occurred (physical and digital) events and all Assets related to the Digital Twin and Industrial Product (instance), respectively. For example, changes made to a Digital Twin, e.g. improvements made to Models, insights created from Model execution, are considered events that are memorised. The Digital Product Brain is intended to be created as early as possible during the lifecycle of an Industrial Product and to accompany the downstream lifecycle phases.

The final DIGITbrain Solution will have a user interface to the Digital Product Brain, where persons acting in the role of an Analyst of Industrial Products can configure Digital Twins, perform analysis based on rules triggered as well as navigate the provenance and evolution of IP published to the DIGITbrain Solution over their product's lifecycle. Provenance may be even available beyond the lifecycle of one IP comprising the impact of insights gained by analysis on improved versions and new generations of IPs.

The tables below summarize the envisaged benefits of the DIGITbrain Solution for stakeholders such as:

a) Manufacturers of Industrial Products (manufacturing machinery, CPS)
b) Manufacturing companies (users of Industrial Products)
c) Algorithm Providers/Suppliers (RTO / ISV / VAR)
d) Model Providers/Developers (RTO / ISV / VAR/ Consultants)

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### a) Manufacturers of Industrial Products (manufacturing machinery, CPS)

Manufactures of Industrial Products have clients that use their IP Instances to produce goods – the latter are manufacturing companies using Industrial Products.

| Who? | Manufacturers of Industrial Products (manufacturing machinery, CPS) |
|---|---|
| Which benefit? | DIGITbrain Solution as a central point of access to information on virtual IP Instances and families of Industrial Products<br>• Easier and faster creation of Digital Twins<br>• Flexible execution on different resources<br>• Documentation of evolution across engineering domains, data involved (consumed and generated)<br>• Comprehensible decision-making |
| How? | Manage and maintain information (Assets) related to virtual IP Instances and families of Industrial Products:<br>• Manage the Assets<br>• Create Digital Twins<br>• Evaluate Models and execute Algorithm on local and remote resources to perform virtual simulations<br>• Use simulation results to refine digital models<br>• Document and track the provenance of evolution |
| Where/when in PLC? | Engineering |
| Which benefit? | DIGITbrain Solution as a central point of access to information on physical Industrial Product Instances (hereafter IPIs) manufactured |
| How? | Document each IPI produced in DIGITbrain Solution:<br>• Its configuration<br>• QA results<br>• the client<br>• etc. |
| Where/when in PLC? | Production |
| Which benefit? | DIGITbrain Solution as a central point of access to information from Industrial Product Instances (IPIs) "working in the field", i.e. the ones delivered to customers in order to:<br>• Optimize settings for IPIs<br>  ○ Maximize output<br>  ○ Reduce energy consumption<br>  ○ Reduce wear and tear<br>• Minimize break-down times in a MaaS setting<br>• Learn from the data/insights to improve next product generation<br>• Improve customer experience (customer = IPI Operator) |
| How? | Collect and analyze information provided by IPIs (sold and/or rented ones - MaaS)<br>• monitor their status<br>• run simulations / evaluate models with data from the field (real conditions)<br>• create insight from data & results<br>• feedback insight to product development (Engineering stage)<br>• inform clients |

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| | |
|---|---|
| | ○ how to optimize settings for IPI for their conditions<br>○ to update the "firmware"<br>○ etc.<br><br>Analysis can be done across the multitude of IP instances independent from their location and the IPI Operator.<br><br>Behavior of individual IP instances can be compared with Digital Twins a family of IPs, e.g.<br>• to identify outliers,<br>• find cohorts (clusters) of IPs experiencing similar conditions,<br>• adjust Models for a family of IPs. |
| Where/when in PLC? | Operation |
| Which benefit? | DIGITbrain Solution as a central point of access to information from Industrial Product Instances (IPIs) "working in the field", i.e. the ones delivered to customers in order to:<br>• schedule maintenance events minimizing negative impact on production<br>• minimize maintenance duration / down-times<br>• postpone or avoid repair by adjusting IPI to actual load case / use scenario (cmp.: drive slower to burn less energy) |
| How? | Similar to the Operation phase above, but with different Models / Data. |
| Where/when in PLC? | Benefits in MRO |

NB: the benefits depend on the Models published to DIGITbrain Solution.

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### b) Manufacturing companies (users of Industrial Products)

Manufacturing companies, i.e. the operators of IP Instances, use instances of Industrial products to produce goods. The main product lifecycle stage they benefit in, thus, is operation.

However, they may also:

- pursue activities in the planning phase (production planning) how to best use the available IP Instance for their production – this is considered operation planning in the table below,
- plan how to distribute and deploy the IPIs for producing, esp. when the IPIs are mobile,
- run their own MRO activities as some actually do or
- even consider re-purposing (parts of) the IPIs and recycle others.

| Who? | Manufacturing companies (users of Industrial Products) |
|---|---|
| Which benefit? | Especially in case of mobile IP Instances:<br>• better planning of how and where to deploy the IPI to<br>  ○ maximize occupancy rate of IP Instances (maximizing through- and output)<br>  ○ faster react to changing conditions |
| How? | • Knowing demands and run production/operation planning simulations to optimize "distribution" of production capabilities represented by the (mobile) IP Instances |
| **Where/when in PLC?** | **Distribution** |
| Which benefit? | Manufacturing companies uses the Assets within DIGITbrain Solution (its installation – likely to differ to quite an extent from the one of the IP Manufacturer) to<br>• better plan their production of goods<br>• maximize occupancy rate of IPI (maximizing through- and output)<br>• gain agility in re-planning-faster re-planning<br>• detect issues quicker<br>• detect issues earlier<br>• explore alternatives solutions<br>• find optimal settings faster – optimizing IPIs to operation conditions<br>• improve quality of production |
| How? | Exploit information referenced, managed by DIGITbrain Solution as a central inventory of IP Instances and data/results provided by them to:<br>• monitor operation status and conditions<br>• get warnings if rules trigger<br>• analyze data, not just single sources but in conjunction<br>• exploit the Digital Twins of the IP Instances, ideally provided by the IP Manufacturer and accessible via DIGITbrain<br>• re-use, re-purpose, extend DTs<br>• create and integrate additional Digital Twins in DIGITbrain – easier/faster development of Digital Twins using the authoring tools |

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| | |
|---|---|
| | and search and browse functionality for Assets of DIGITbrain and DIGITbrain for deployment<br>• run and re-run Digital Twins - easy use and deployment of Digital Twins<br>• gain insights from data analytics and simulation results<br>• inform workers to change settings of IP Instance |
| Where/when in PLC? | Operation |
| Which benefit? | • Minimize maintenance work and efforts<br>• Predict maintenance necessities<br>• Minimize and schedule repair efforts<br>• Minimize wear and tear<br>• Better plan overhauling |
| How? | See IP Manufacturer |
| Where/when in PLC? | MRO |

NB: the benefits depend on the Models published to DIGITbrain Solution

### c) Algorithm Provider/Supplier (RTO / ISV / VAR)

An Algorithm Provider may be able to expand the use of its Algorithm and generate additional revenue e.g. based on pay-per-use models whenever the Algorithm is run as a part of a Digital Twin.

The Algorithm Provider is expected to present its profile and Algorithm also via the Digital Agora, part of the DIGITbrain Solution. The Digital Agora provides an additional marketing channel for the Algorithm provider to become better known in the manufacturing market sector on a European scale.

### d) Model Provider/Developers (RTO / ISV / VAR/ Consultants)

A Model Provider may be able to expand the use of its Model and generate additional revenue e.g. based on pay-per-use models whenever the Model is evaluated by an Algorithm run from a Digital Twin.

The Model Provider is expected to present its profile and Models also via the Digital Agora, part of the DIGITbrain Solution. The Digital Agora provides an additional marketing channel for the Model Provider to become better known in the manufacturing market sector on a European scale.

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## 5. What do technical experiment partners have to do?

There are two categories of technical activities for experiment partners to be performed:

a) Technical developments within the respective experiment
b) Technical integration with DIGITbrain Solution

**Regarding a)**

Technical development within an experiment typically comprises:

- Design, develop, apply, verify Digital Twins for instances of Industrial Products and selected behaviour.
- Provide / adapt corresponding software tools: simulation, optimisation, analytics, machine learning, etc.
- Leverage edge-, cloud- and HPC-based computing.
- Provide Assets: Model, Data, Algorithm, on repository.
- Provide connectors to factory data sources if experiment requires.
- Provide Apps for visualizing results of Model evaluation and human computer interaction
- Showcase benefits for:
    - Customisation of Industrial Products / Production Processes,
    - Cost-effective distributed and localised production,
    - Evolution and improvement of next generation Industrial Products

  by applying Digital Twins:
    - on one instance of Industrial Products.
    - on many instances of Industrial Products (cohort analysis).

**Regarding b)**

Technical integration with DIGITbrain Solution comprises (mandatory):

- Containerization of software tool(s) aka Microservices:
    - Docker and Linux preferred, deployment is automatic
    - Data connectors are considered Microservices and need to be developed/provided by the experiment
- Optional: modularization of existing software tool(s)
- Publishing Algorithm, Model and Data to the DIGITbrain Solution via DIGITbrain Asset Publishing Interface
- Defining rules and actions to be triggered via the Digital Product Brain (rules act on output of evaluated Models).
- Optional: providing visualisation app with specific functionality e.g. acting on data generated by the Digital Twin
- Registering Assets with the Digital Agora
- Publish profile in Digital Agora

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