

Deliverable 1.3

Description of relevant and current software workflows for the respective use cases

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Executive Summary

In the context of the DILAPRO project's ambitious goal to revolutionize European manufacturing through digital and sustainable laser-based technologies, Deliverable 1.3 occupies a crucial role. This deliverable provides an in-depth examination of the existing software workflows that underpin the project's various laser manufacturing use cases, which include different technologies such as Powder Bed Fusion Laser Beam (PBF-LB), Directed Energy Deposition Laser Beam (DED-LB), and Laser Texturing processes.

The primary objective of Deliverable 1.3 is to comprehensively map these workflows, detailing how they support current manufacturing practices and pinpointing opportunities for integration with the project's innovative software platforms, DILAFACT and DILACERT. These platforms are designed to bring a step change in process planning, certification, and standardization efforts in the field of laser-based manufacturing.

The deliverable's findings are the result of collaborative analysis among the project's partners, focusing on areas such as data processing, real-time monitoring and quality control. The insights gained not only underscore the heterogeneity of current workflows but also highlight the critical integration points for DILAFACT and DILACERT, promising improved efficiency, reliability, and compliance in laser manufacturing.

Through Deliverable 1.3, the DILAPRO project lays the groundwork for the transformative integration of advanced software solutions into established manufacturing environments. This step is pivotal in achieving the project's overarching vision of a digitized, sustainable, and competitive European manufacturing sector.

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Introduction

The primary aim of Deliverable D1.3, "Description of relevant and current software workflows for the respective use cases," is to outline the software architecture specifications required by the laser process planning platform through Digital Twinning - DILAFACT ("Digital Laser Factory").

The DILAFACT's platform is designed to help end-users in the manufacturing sector to plan and optimize their production processes, taking into account available technologies, material properties, economic factors, and environmental impacts. A strong emphasis is placed on laser-material interaction, leading to the development of several digital twins to assess the microstructure of materials. In the short term, the project aims to enable end-users to swiftly and easily process and format their production data, whether through DILAFACT input or online monitoring systems. In the long term, DILACERT ("Digital Laser Certification") aims to pioneer the development of remote, (semi-)automated "digital certification" of manufactured parts.

D1.3 details the functional specifications and physical implementation of the DILAFACT platform across four levels:

- Level 1: Collects data from various sources, enabling automatic data streaming.
- Level 2: Integrates and secures data storage within a cloud environment.
- Level 3: Uses machine learning algorithms for online predictive modelling and generates recommended workflows for multi-purpose laser processing. This level also includes an interface for different modules to effectively manage different data flows.
- Level 4: Enables the user to interact with the software.

The document is divided into two parts. The first part provides a comprehensive overview of the DATAmaestro platform infrastructure, an in-house solution that forms the backbone of the DILAFACT platform. DATAmaestro is responsible for the entire data analytics pipeline, from collecting data from multiple sources to storing, analysing and dashboarding. An architectural configuration tailored to the needs of the DILAFACT platform is proposed in the second part of the section. This configuration is designed to present use case information to users (as outlined in WP1) and to monitor various data sources identified in WP2 ("Optimization and Modelling of Laser Technologies") and WP3 ("Monitoring and Quality Control"). The types of data to be collected and analysed are determined in collaboration with the Digital Twin module development team.

Finally, the document thoroughly explains in detail the process for collecting and publishing these datasets.

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Software workflow description

Introduction: DATAmaestro platform

The purpose of this chapter is to provide an overview of the DATAmaestro full stack Platform, which offers a full suite of web services designed to implement a complete analytics workflow within the manufacturing industry. It consists of up to four software components, each with distinct features, as shown in Table 1 below:

DATA maestro COLLECTORS	To automate data collection from various sources, including time-series databases, relational databases, and real-time data.
DATA maestro LAKE	To store, consolidate, centralize data streams, resample, and prepare clean data tables for Advanced Analytics.
DATA maestro ANALYTICS	To provide Advanced Analytics services, including visualization and statistical tools, artificial intelligence, and machine learning methods to describe and troubleshoot asset or process behaviour, and to build predictive and prescriptive models.
DATA maestro DASHBOARD	To deploy and visualize real-time outputs of Advanced Analytics models through a web user interface.

Table 1: Full stack of DATAmaestro

Infrastructure configuration

The data infrastructure provides the support for data management, storage, processing, analysis and usage. It provides a centralized repository which enables the data integration from different sources and the process and the analysis of large amounts of data. It supplies security protocols to protect data from unauthorized access, loss or misuse. It can also provide an automatic collection of data.

Therefore, the DATAmaestro stack can offer, on demand, different services to the customers. A distinction is made between two types of services nominated as: the DATAmaestro platform (DM) and the DATAmaestro Collectors (DmC). The DM consists of DATAmaestro Lake (DmL), DATAmaestro Analytics (DmA) and DATAmaestro Dashboard (DMD), and it can also contain the DmC. However, the DmC is considered as a separate service since not all customers have available

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data for automatic collection. The customer can therefore either have access to the full stack, which comprises the use of a data server (DmC) and the services of storage, analysis and deployment (DM). Or only have access to the services of storage, analytics and dashboarding services, in case, there is no data collection accessible. The infrastructure can be placed or located in different instances on-premises (on site) or in the cloud. There are different possibilities to configure the infrastructure and they can be characterized as follows:

- **Cloud** vs. **On-Premises**: the service is either hosted on a cloud provider or deployed inside the customer's premises.
- **PEPITe** vs. **Customer**: the system is provided by PEPITe or the customer (i.e., server or cloud virtual machine).

These configurations can be applied separately to the DM and DmC services. For example, a classic configuration is a DmC installed on a customer's on-premises server and the DM installed on a PEPITe cloud virtual machine.

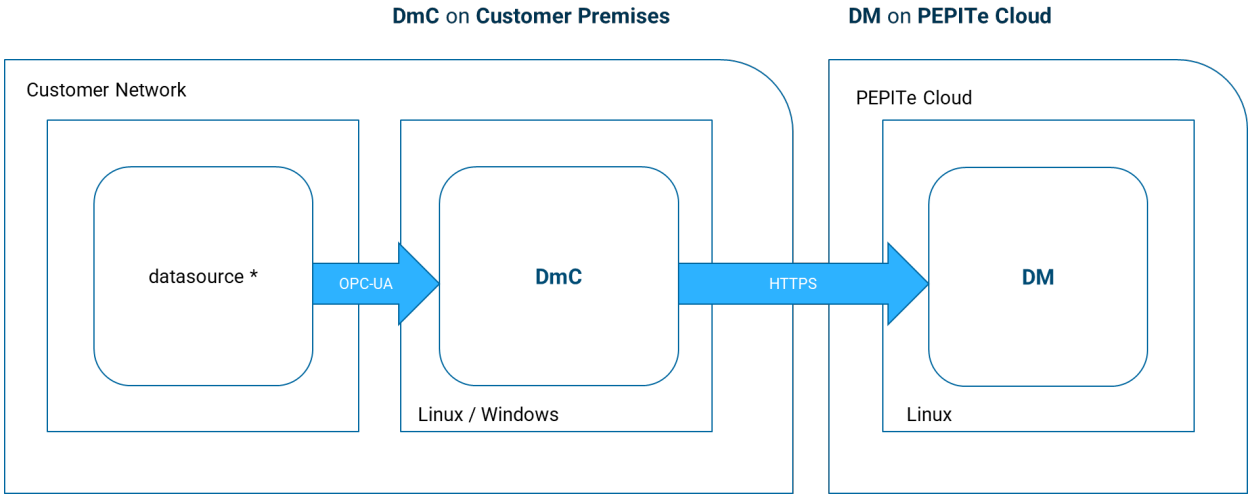


Figure 1: Collector on-premises and DM on cloud

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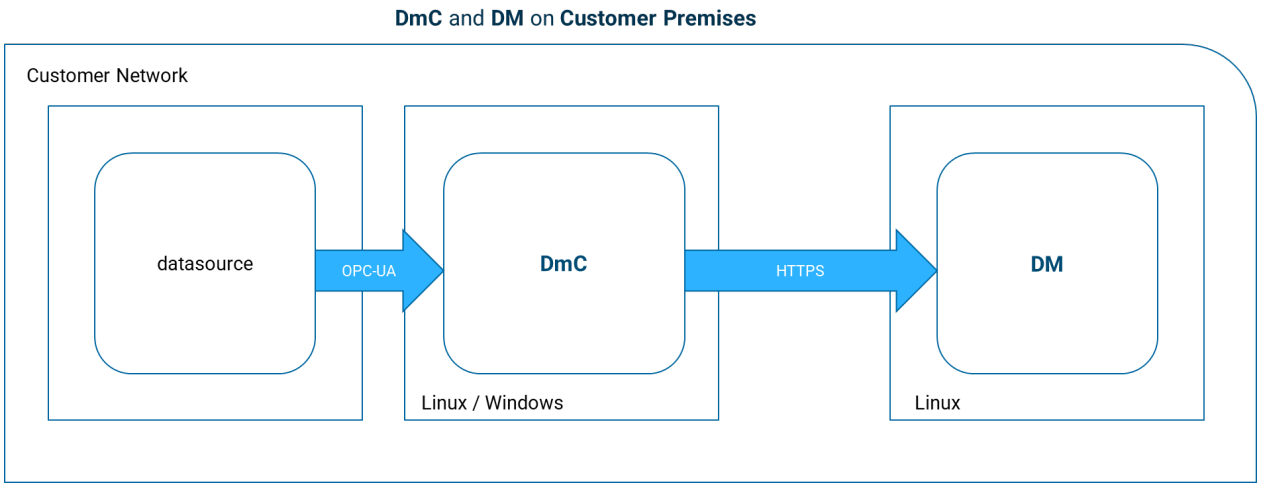


Figure 2: Collector and DM on premises

The two services can also be deployed inside the same system, as in Figure 3.

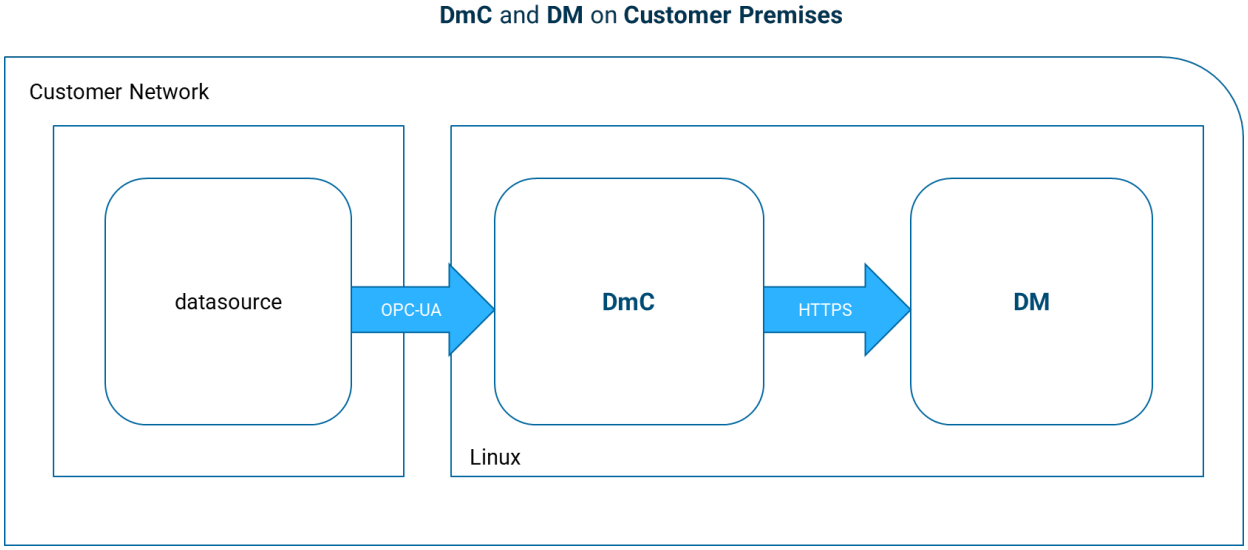


Figure 3: Services deployed inside the same system

The infrastructure diagram shows how the elements are connected to each other. Basically, the idea is to have a continuous data flow starting from collecting this data from different sources, storing all this information in a centralized lake, analysing the data with advanced artificial intelligence and machine learning algorithms to finally, monitoring this gathered knowledge in dashboarding systems. The infrastructure setup choice depends on the data sources, the security requirements, and easy access for maintenance. But in addition to that, it is also important to have all the information needed to understand the role of the network components and how they will communicate with each other, this should include:

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- **Source** of data: the component related to the data extraction, e.g. DATAmaestro Collectors (DmC). The database can also be extracted manually, as for example, one or more CSV files can be manually uploaded to the Lake or directly to Analytics.
- **Destination** of data: the component that is used to centralize the data storage, e.g. DATAmaestro Lake (DmL). Data can also be directly uploaded to Analytics component to be analysed.
- **Protocol** used for communication, e.g. OPC-UA, HTTP(s), MQTT.
- **Port** number assigned to identify a connection endpoint and direct data to a network service, e.g. transmission control protocol (tcp) 80.
- **Description** of the network service, e.g. access to the DmL service via HTTP.

A detailed example of a network access table information required is provided in the Annex A.

For a pure real-time (no history) data source, the collectors should be located close to the data, usually on-premises. Moreover, for on-premises deployment, a remote access should be provided by the customer. Additional efforts of connectivity can be required depending on the access to be provided. Figure 4 below can show a solution to an infrastructure diagram.

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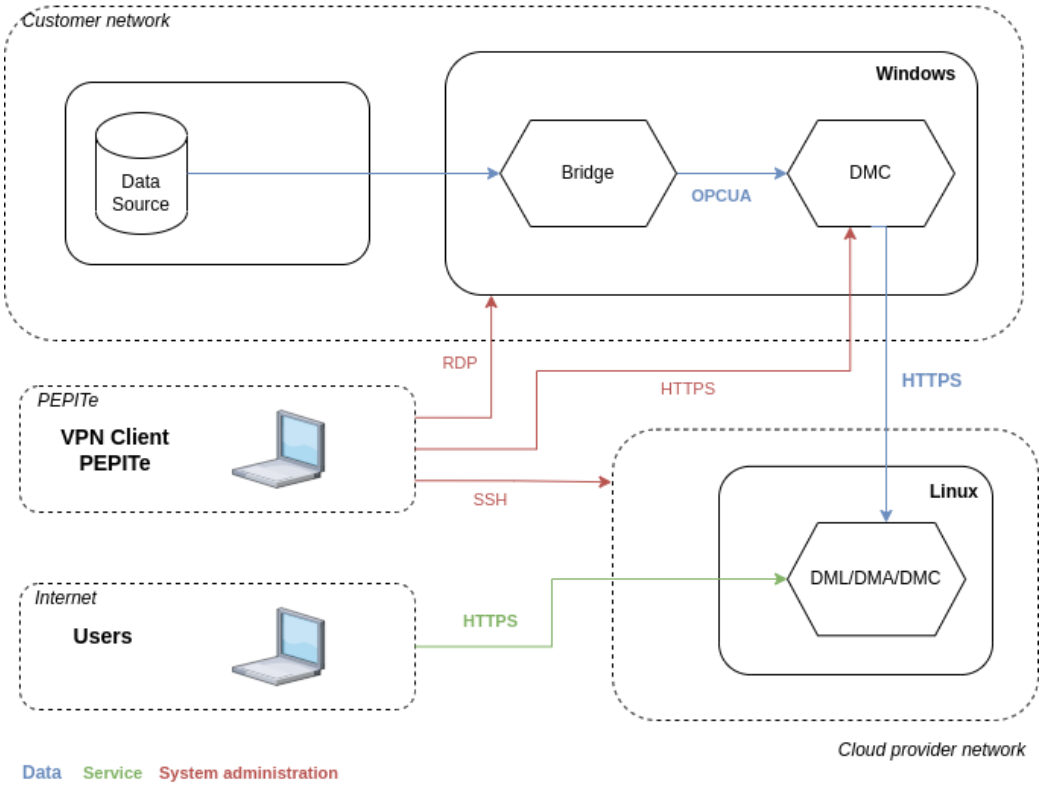


Figure 4: Example of infrastructure diagram

DM Collectors

Introduction to DATAmaestro Collectors (DmC)

The DATAmaestro Collectors component automates data collection from multiple data sources, retrieving data from the customer's data source and storing it in a storage component, the DATAmaestro Lake (DmL).

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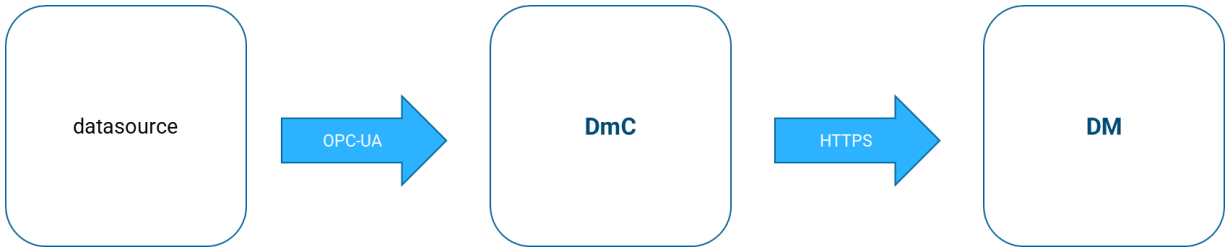


Figure 5: Collector component retrieving data automatically from source.

One of the most important communication standards for the industry and IoT is the Open Platform Communication (OPC). This communication protocol of data exchange allows collectors to access machines and other systems of the manufacturing environment in a standardized way. The latest specification standard is the OPC-UA which stands for Unified Architecture. The difference is that it is platform-independent, which opens up greater possibilities for data exchange.

Currently, the DmC collects data via the OPC-UA protocol and sends it to the DmL via Hypertext Transfer Protocol Secure (HTTPS). This collection has two main modes: history and subscription. History is used to retrieve historical data from a database and Subscription is used to collect from a real-time source. The History mode stores the data as they are stored in the original data source. The Subscription mode offers additional sub-modes regarding for data storage:

- Sampling mode: the values can be sampled at fixed intervals.
- Write On Change: the values are only written if they have changed.

In case the data source does not support OPC-UA, an additional component is set up to translate the source's available protocol to OPC-UA. This component is called a bridge. The bridge can be either from third-party software or from PEPITe (in-house).

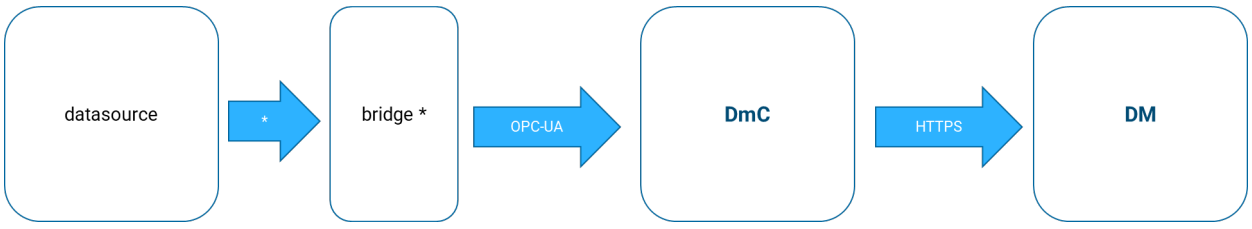


Figure 6: Collector with bridge

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The third-party bridges are Kepware (100+ available drivers): Honeywell, Siemens, Yokogawa, Allen-Bradley, etc. However there are also in-house embedded bridges supported, mainly data management solutions for plant information of the industry environment, some of examples are:

- OSIsoft PI
- CSV files
- Wonderware
- IP21 (soap)
- Edna
- InfluxDB v1
- Kairosdb
- Relational database (SQL Server, Postgres, MySQL, MariaDB, etc.).
- Kafka

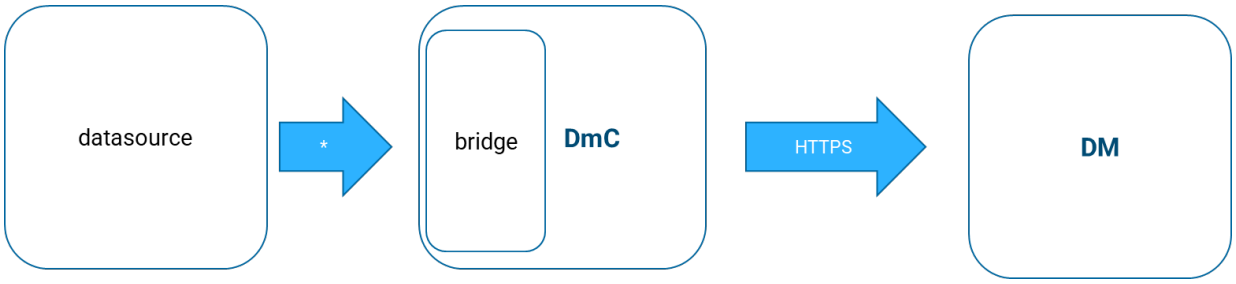


Figure 7: Bridge in an OPC-UA server node

The collectors can also write back to an OPC-UA server node the last value available in the Lake but not all bridges available offer this possibility.

Server Sizing of DmC

The data collected by the Collectors is buffered in memory (Random-Access Memory - RAM) before being sent to the DATAmaestro Lake. The buffer can hold a certain amount of data while the connection to the DATAmaestro Lake is down. The maximum size of the DATAmaestro Collectors is limited by the Java Virtual Machine (JVM) allocated memory.

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The maximum buffer size is calculated as:

Number of variables multiplied by the number of *Hours on hold* multiplied by the *Collection period* multiplied by the *Number of bytes*.

If the data source has 2000 measurement points to be collected every second and held in memory for 2 hours, more or less 250 MB of RAM will be required (2000 * 2 * 60 * 60 * 16 bytes + Java overhead).

The table below shows the basic recommended server size.

RAM	8 GiB
CPU	2 cores
DISK (HDD)	OS + 10 GB

Table 2: Recommended server size

Additional space may be required if third party software is needed to connect to the data sources (e.g. KEPserverEX which is an OPC server, a connectivity platform for industrial automation and IoT).

DmC Operating System

The DmC component can be installed on any Windows/Linux operating system with a Java environment (Java 8).

Dependencies

DmC runs on Java 8. Normally a Java Development Kit (JDK 8 - Adoptium.net) is installed as part of the installation phase. The DmC Windows service is installed via the Non-Sucking Service Manager (NSSM) which is a service helper that handles failure of the application running as a service. Third party OPC-UA clients such as UaExpert can be installed for troubleshooting purposes.

Remote access to DmC

Remote access to the DmC operating system for the system administrator must be provided by the partners or companies outside the consortium. For practical reasons, remote access is preferable to physical access.

There are different ways for system administrator to remotely access a Linux or Windows system. For Linux, the remote access is mainly via Secure Shell (SSH), for Windows via Remote Desktop (RDP). Other remote access clients can also be used (Teamviewer, Anydesk, Vmware Horizon, …).

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By adding a Virtual Private Network (VPN) or an intermediate Jump server, this access can be further secured. The options available for Linux and Windows, in order of preference, are shown in the table below.

Linux	Windows
SSH	RDP
SSH + VPN	RDP + VPN
Third-party remote access client (Teamviewer, Anydesk, Vmware, …)	Third-party remote access client (Teamviewer, Anydesk, Vmware, …)
Third-party client + hop (jump server)	Third-party client + hop (jump server)
Third-party client with on-ask access	Third-party client with on-ask access
Physical access	Physical access

Table 3: Access possibilities

System Network Access required

For each data source, it is necessary to have data source provider information. This data source information is important for extracting the data. (All the required information is presented in Annex A)

The access points should include the following information:

- Remote access for PEPITe system administrator to the DmC operating system (cf. Operating System Access)
- Access for the PEPITe system administrator to the DmC web services (HTTP/S)
- Access for the DmC to the data sources
- Access for the DmC to the DmL (HTTP/S)
- Access for the DmC users to the DmC web service (HTTP/S)

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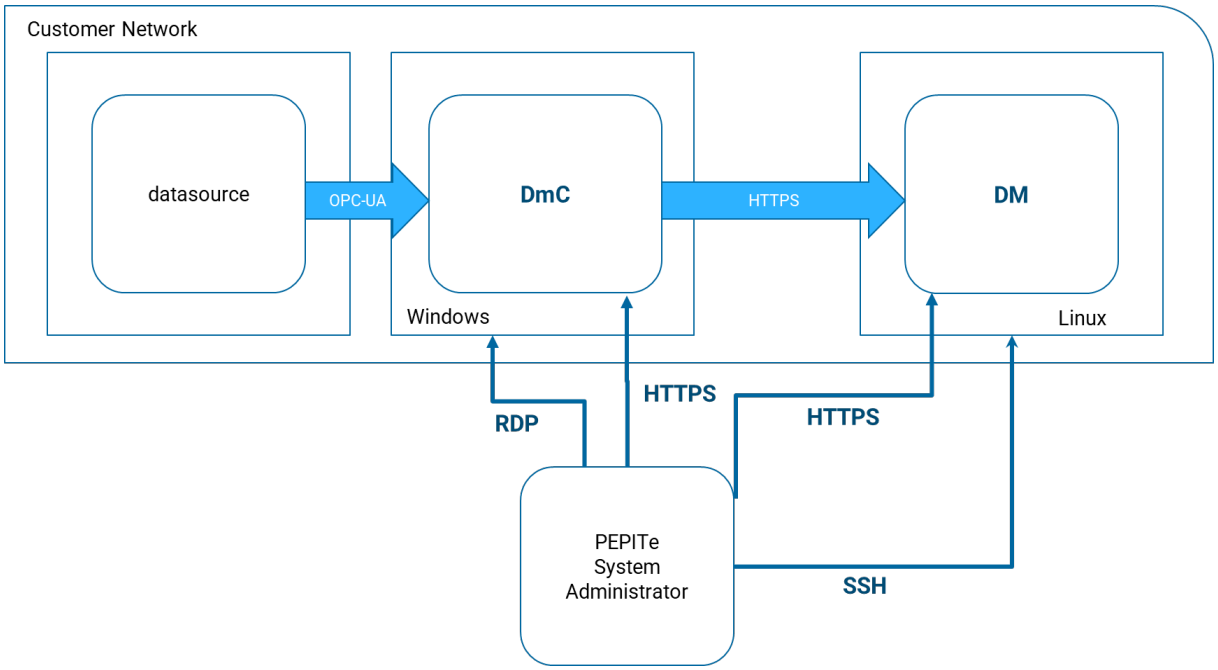


Figure 8: Example of system network access

DATAmaestro platform

The DATAmaestro platform (DM) consists of the Storage (DmL), Analytics (DmA) and Dashboarding (DmD) components and can be deployed in different configurations:

- **Dedicated PEPITe cloud**: a cloud server managed by PEPITe dedicated to the customer (no other customer on the server).
- **Shared PEPITe cloud:** a cloud server managed by PEPITe where the hardware is shared with other customers.
- **Customer cloud:** a cloud server managed by the customer.
- **On-premise**: an on premise server managed by the customer
- **On-premise PEPITe:** an on premise server managed by PEPITe

Furthermore, DmL can also be installed on a separate machine than the DmA and DmD part. There can also be redundant servers synced for failing over and backup.

Required size of DM platform

The size of the DM platform depends on the size of the site (multi-size region). It can be small, medium or large. The Table 4 below shows an example of a small site. The list of the detailed information on the size per site and per geographical (multi-site) region instance is available in Appendix A.

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RAM	16 GiB
CPU	4 cores
DISK (SSD)	OS + application data (cf. storage)

Table 4: Example for a small site

Storage needed for DM platform

The storage size depends on the number of variables, i.e. how long the data will be available, the sampling period and the number of bytes per data point. An evaluation is required to understand the storage needed for the data. Some examples below can show how the storage size can be calculated and it only concerns the data application, other factors such as, operating system, backup, monitoring, raid or other infrastructure related data is not taken into account.

Example 1: Evaluation for DATAmaestro Lake: DATAmaestro Lake storage is calculated based on the following hypothesis, 16 bytes per datapoint. For 2000 tags every 15 seconds for 1 year.

The storage size is calculated as: *Number of variables* multiplied by the *number of hours to be stored* multiplied by the *sampling period* multiplied by the *Number of bytes per datapoint: 2000 * 365 * 24 * 60 * (60 / 15) * 16 bytes = 67.3 GiB / year.*

Example 2: Evaluation for DATAmaestro Analytics: DATAmaestro Analytics storage is calculated based on the following assumption, 8 bytes per data point. Each time a user creates a resampled data file for analysis in DATAmaestro Analytics, a new file is created and therefore sufficient storage must be provided. If ten users each extract a file with 2000 tags sampled every hour for 1 year: 10 * 2000 * 365 * 24 * 60 * 8 bytes = 78.3 GiB / year.

It is recommended that the operating system is on a separate partition/disk from the application data. For example:

```
NAME            SIZE    RO TYPE MOUNTPOINT
sda             228.9G  0  disk
|-sda1          512M    0  part /boot
|-sda2          30G     0  part /
|-sda3          197.4G  0  part /data
```

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- The following operating systems are supported: Debian 11 (EOL August, 2026)
- Ubuntu 22.04 (EOL April, 2027)

Remote Access to DM platform

The access to the network for the system includes the Remote administrator access to the DmL/DmA/DMD operating system:

- Access to the DmL/DmA/DMD web services (HTTP/S) for the administrator's premises
- DmL/DmA/DMD user access to the DmL/DmA/DMD web services (HTTP/S)

User rights

User permissions are the means by which users are granted access to specific resources. Depending on their DATAmaestro access rights, users can perform tasks in the different components, Lake, Analytics and Dashboards. The user's permissions can specify:

- Type of access: for example, user can read and write data (Guest User) or read data without modifying it (Read Only).
- Functions user can access: for example, change configurations or assign permissions to other users (Administrator role).

The user must prove their identity using one or more authentication factors such as, a security token or fingerprint, to gain access to the system. Depending on the user type, the user will then have access to certain resources. More detailed information can be found in the tables 5 and 6 below.

There are four main types of users of the system:

- Super Administrator: highly privileged accounts used primarily for the overall system administration. Examples of the account privileges include, full read/write of data; create, install and modify files; delete data and users.
- Local Administrator: privileged accounts used primarily for local system administration. Examples of the account privileges include, full read/write of data and create analytics projects within their own workspace.
- Standard User: this account limits the access to performing operations within a set of authorized functionalities. Examples of standard account include, check if a variable exists in the Lake and create tasks in analytics project within their own workspace.
- Read Only User: this least-privileged account is limited to read-only access.

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Role-based permissions require that the users access only the resources they need. The least privileged access ensures a minimal level of authorization is required. The roles and responsibilities of the users and a detailed description of the access levels must be specified to minimize security gaps.

- DmA & DmD

Analytics | Dashboard		**Super Administrator**	**Local Administrator**	**Standard User**	**Read Only User**
Create Analytics Project					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Delete Analytics Project					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Load Analytics Project					
	Owned Workspace	OK	OK	OK	OK
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Create Task					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Delete Task					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Edit Analytics Task					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Create Directory					
	Owned Workspace	OK	OK	DENIED	DENIED

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	Unknown Workspace	OK	DENIED	DENIED	DENIED
Delete Directory					
	Owned Workspace	OK	OK	DENIED	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED

Table 5: User's access rights for DmA and DmD.

- DmL

Lake		Super Administrator	Local Administrator	Standard user	Read Only user
Check Tag exist					
	Owned Workspace	OK	OK	OK	OK
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Read Tag data					
	Owned Workspace	OK	OK	OK	OK
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Write Tag data					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Create Tag					
	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
	ROOT	OK	DENIED	DENIED	DENIED
Delete Tag					
	Owned Workspace	OK	OK	DENIED	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
	ROOT	OK	DENIED	DENIED	DENIED
Create Directory					

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	Owned Workspace	OK	OK	OK	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Delete Directory					
	Owned Workspace	OK	OK	DENIED	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Lake **Jobs**					
Create, Edit, Delete, List Job					
	Owned Workspace	OK	OK	DENIED	DENIED
	Unknown Workspace	OK	DENIED	DENIED	DENIED
Manage					
	Create user	OK	DENIED	DENIED	DENIED
	Delete user	OK	DENIED	DENIED	DENIED

Table 6: User's access rights for DmL

Infrastructure configuration: DILAFACT

DILAPRO is developing modules that will allow users to better pre-qualify their desired material products compared to the laser processes they will use to produce them. This will allow users to anticipate problems in optimizing the conditions of their processes and the material quality of the parts they produce. In addition to that, quality control is needed to produce parts without defects, so that the system can work more efficiently. Simulations using multiple materials and factors can be used to assess the required knowledge of the properties and performance of the laser components. There is no easy way to tune a specific microstructure, although the number of studies focusing on this topic is continuously increasing.

Therefore, DILAPRO is focused on determining and monitoring the material properties and microstructures based on the processing conditions. The Digital Twins will focus on the material-laser interaction and it will be based on existing results in OPENFOAM and ANSYS software, where DILAPRO has experience and available data.

Finally, DILAFACT software will allow users to evaluate and combine multiple laser manufacturing technologies to achieve the best results in terms of quality, cost and environmental impact for their complex products. It will provide validated data to qualify the production in terms of material properties and user needs in terms of data monitoring across different technologies.

As far as the users of the platform are concerned, four groups of users will be targeted: researchers, developers, machine manufacturers and producers. For each of these groups, different types of access will be available under different licensing terms, using open source, open data access and commercial approaches to ensure the highest possible uptake and impact across Europe's photonics industrial and R&D pipelines.

The software will be built and demonstrated on 3 materials and 6 production facilities consisting of different machine types and monitoring. The adaptability of the software and its ability to incorporate future knowledge, materials and technologies will ensure the long-term sustainability of the results.

Therefore, the DILAFACT platform requires a specific architecture to automatically collect data from production machines and development modules. The data requirements are based on the general specifications of the use cases, in terms of the expected project outcome, as well as, technical specifications, quality control and certification requirements, number of parts required and required availability.

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In order to develop the online platform solution for the management and implementation of DILAFACT, which includes predictive models and the generation of recommended workflows for multi-purpose laser processing, it is important to map the software architecture requirements and to design and build the architecture itself for later implementation in WP7.

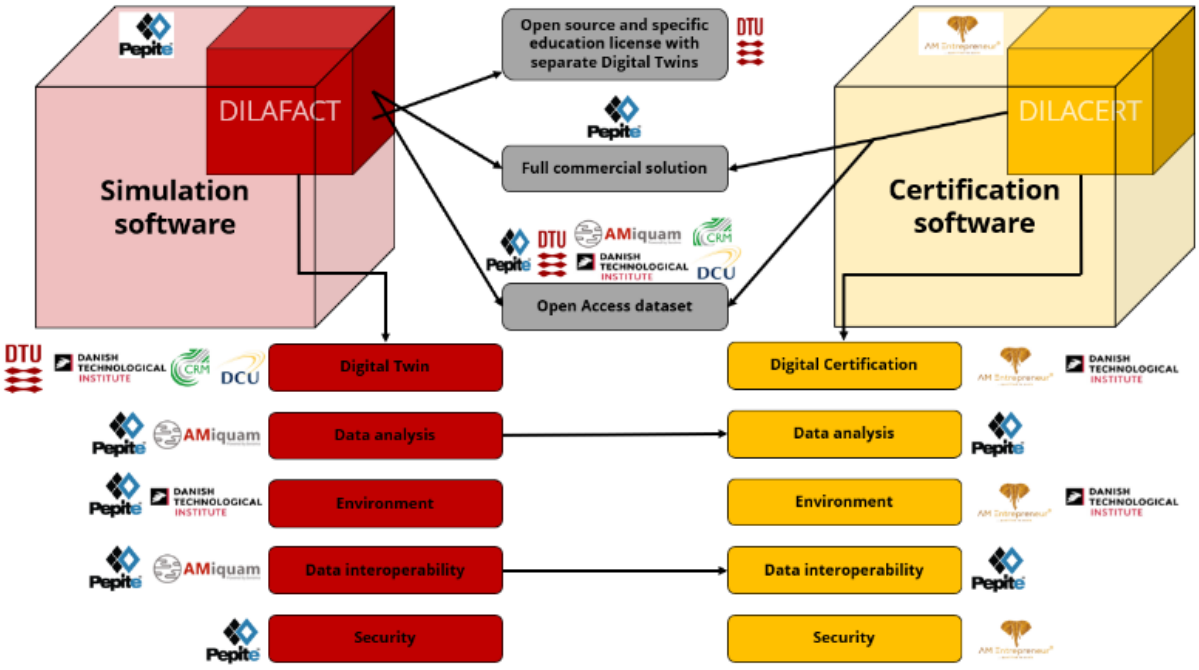


Figure 9: DILAFACT infrastructure

Given the description of the DILAFACT infrastructure in Figure 9 above, the proposed architecture is based on the backbone of the DATAmaestro architecture and should have the following levels:

- Level 1: Collects data from the different data sources. For non-members of the consortium, there should be the possibility of uploading data manually, using CSV files.
- Level 2: Integrates and stores data in a secure cloud environment.
- Level 3: Offers machine learning algorithms for online predictive models and the creation of recommended workflows for multi-purpose laser processing. The data analytics component should interface with the various modules and manage diverse data flows.
- Level 4: Facilitates interaction between users and the software. It is essential to establish different user types with segmented access to the information within the platform.

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Input requirements

The goal of DILAFACT is to provide in-process part certification using sensor data, particularly for additive manufacturing. DILAFACT needs to integrate data from different sensors, algorithms, and software components.

In order to produce qualified complex parts with laser processes, the expected results of the software include:

- Develop multiple Digital Twins to qualify the microstructure of materials based on use cases provided by the partners' production lines.
- Provide accurate data (online monitoring, sensors, and calibration).
- Apply current standards and certifications and define a methodology to qualify the parts that are produced based on data monitoring.
- Create software to pre-certify laser produced parts.
- Demonstrate the economic and environmental savings of the platform.

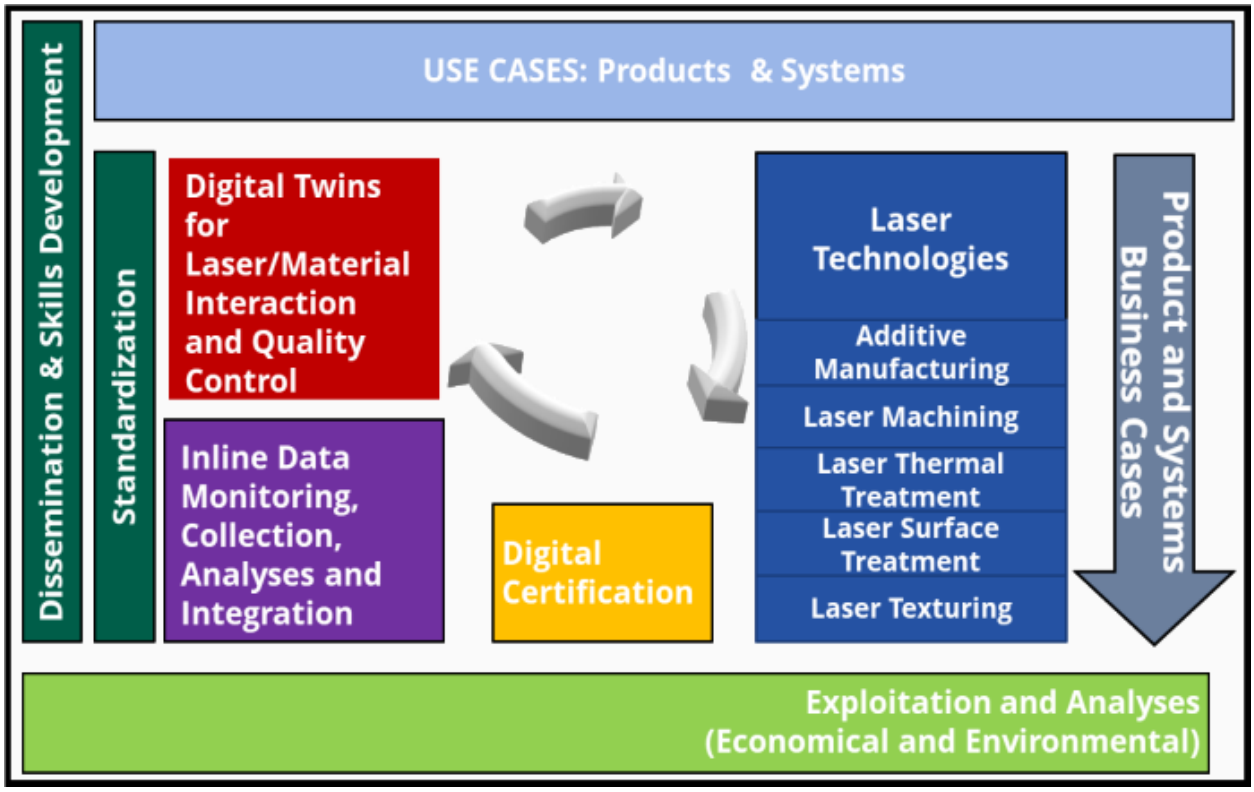


Figure 10: Workflows of DILAFACT

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The platform must integrate material behaviour databases and simulation models into a unified data platform, thereby providing access to virtual simulations. It merges metaphysical models with data-based material models to develop process optimization models and ultimately deploy them at production sites.

Use cases:

These use cases are selected based on the expected deliverables of the project, which include technical specifications, quality control and certification requirements. The table 7 below shows the input requirements for the DILAPRO platform, as provided by the project partners. The task 1.1 defines the use case definitions (pilot line and components) for the development and demonstration of DILAFACT and DILAPRO.

Metadata						
Component	**Partners**	**Contact persons**	**Use case name**	**Component name**	**Laser Technology**	**Industry / operating conditions**
C1	Fieldmade	Tobias	Valve indicator bracket switch	Valve bracket	PBF	Oil & Gas
C2	Fieldmade	Tobias	Valve wheel	Valve wheel	PBF	Oil & Gas
C3	Fieldmade	Tobias	NOMAD03 Spring Shoe	Spring Shoe	PBF	Transport
C4	Prima	Gaetano	Oil & Gas centrifugal impeller	Centrifugal impeller	DED	Oil & Gas
C5	Prima	Gaetano	Mold repair	Mold repair	DED repair	Automotive
C7	DCU	Dermot	Nammo	Truster bracket	Laser Texturing + PBF	Space (ESA)
C8	DCU	Dermot	Mincon	Rock drill chuck	Laser Texturing	Mining
C9	DCU	Dermot	Control Valve	Control Valve	Laser Texturing	Pharmaceutical
C10	CRM	Ahmed / Marine	Pump Diffuser	Pump diffuser	DED repair	Nuclear
C11	CRM	Ahmed / Marine	Launch Interface Ring	Interface Ring	DED	Space

Table 7: DILAPRO components use cases – Status (08/04/24)

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The table 8 below shows the general knowledge on each pilot line (Deliverable 1.2 - Identification and description of production lines).

Metadata				
Pilot line	**Contact**	**Laser Process / Machine**	**Partner / Location**	**Materials**
PL 1	Marine JB, Jurgen M	DED / HYMAX	CRM / Belgium	Stainless steel, Al, Ni, Ti
PL 2	Gaetano P	DED / Ianus Cell	Prima / Italy	Stainless steel
PL 3	Riccardo T, Daniel F	LPBF / SLM280	DTI / Denmark	316L, IN625, Cu, Al, Ti
PL 4	Tobias R	LPBF / NOMAD03	Fieldmade / Norway	316L, IN625
PL 5	Dermot B	LPBF / Aconity Mini	DCU / Ireland	316L, IN625, IN718
PL 6	Dermot B	Femtosecond and Fibre Dual Laser System	DCU / Ireland	316L, IN625, IN718

Table 8: DILAPRO Pilot Lines – Status (22/04/24)

Digital Twin: Specifications of the existing hardware and software infrastructures of the digital twins will be provided in the following work packages (WP2, WP3, WP4, WP5, and WP9). The digital twins will combine experimental capability development, simulation model development, and reduced models (using statistical modelling). An estimate of the data to be collected can be made based on the description of the physical twin, which includes database information as follows:

a) Material behaviour database based on simulations of thermomechanical conditions existing during laser-based processing (PFB, DED, and texturing).
b) Simulation models that use generic multi-scale, multi-physics (MSPM), and process-structure-property (PSP) models using generic software (OpenFOAM and ANSYS), and twin Stainless Steel materials (316L and IN718). Reduced models, i.e., models targeting a computational time of less than or equal to 1 hour, are created using fundamental MSPM models combined with machine learning models (surrogate models) that can easily be operated in real-time.

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Monitoring and Quality Control: Design and build an embedded system for online monitoring system that provides continuous quantitative or qualitative information about the process.

a) Evaluation of process parameters using optical, thermal, and electromagnetic sensors to achieve in-situ quality control for the two major Additive Manufacturing (AM) techniques – Laser Powder Bed Fusion (PBF-LB) and Direct Energy Deposition (DED-LB) – and Laser Texturing surface modification.
b) Development and validation of the feedback model sensor using a Bayesian-based machine learning technique to generate corrective actions and feedback for the PBF-LB, DED-LB, and Laser Texturing surface modification systems.

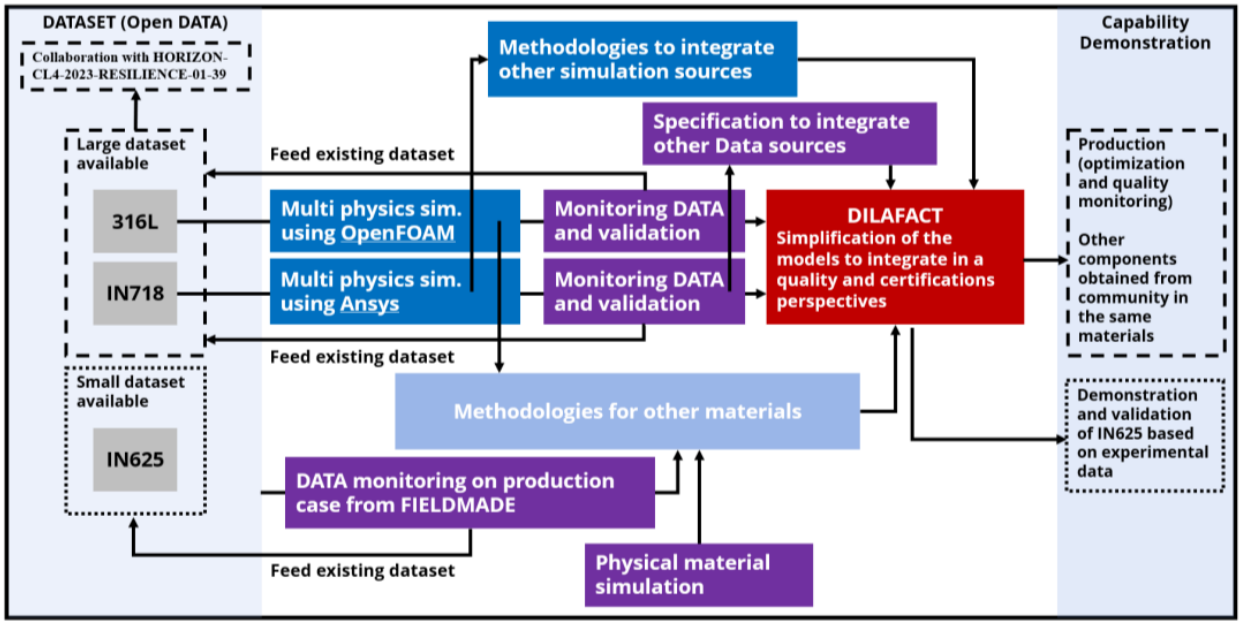


Figure 11: Architecture of DILAFACT

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Input	Comments
Data for Use cases	From the WP1 depiction, the identification and description of the production lines available within the consortium to carry out the experimental work will include the following information: • Manufacturer and current sensor integration • Hardware characteristics (manipulation, maximum volume, laser type, environments…) • Available sensors, data gathering and potential developments For the use cases, the data will be stored in a specified standard relational database management system (RDBMS). By the time of this deliverable, based on table 7, ten component use cases will be used in the development of DILAPRO. The use cases cover all three technologies required by the proposal, and the list of materials has been expanded to include tool steel, stainless steel 304L and aluminium alloy A20X, in addition to the three materials outlined in the proposal (316L, IN625 and IN718). Preferably this data must be time-series with good precision. • A strategy can be found to replace measurements if they are not available. The measurements should describe the point of installation. • Calibrations data, if required. • Provide a description of the scenario of the operating conditions. The following metadata information is required for the measurement: • Name of the variable • Title, optional • Data type • Units • Description • Sampling rates Date Time information must be provided, ideally, as a single variable. Different standards may provide the different levels of granularity (reference ISO 8601): • Date format should contain: year, month and day. • Hour format: should contain at least hour and minutes. Example of syntax required of Date Time: *2024/08/25 08:03*

	The Date Time formats supported by the system: • Excel Time • Text • Unix Time (ms) • Unix Time (s)
Digital twin	The digital twins will combine experimental capability development, simulation model development, and reduced models (using statistical modelling). Based on the specifications from WP1, all data will be made available in a specified standard RDBMS database. Automated pipelines for data preparation will be setup in order to generate a data frame that can be used directly in Advanced Analytics component. The requirements are to be defined in Task 1.2 and Task 2.3. They should contain the specifications for simulations results, simulation inputs, monitoring data, etc. Moreover, an automatic workflow of the system multiple simulation campaigns are needed for creating reduced order models. This is important so that the simulation/experimental data is provided in a useful format. At the time of this deliverable, the deliverable D1.2 contains the description of the current status of each pilot line and their certification, as well as, the information about current sensors/data available and those which will be implemented within DILAPRO project. In the current situation the output data can be .csv files, .xml or .doc, as well as, images. For .csv/.xls files, the upload to the storage system is straightforward. For images or .jpg files, further information will be required to be able to understand how this data can be integrated and handled in the platform. Although, so far, no specific requirements of the models are defined some propositions can be presented: 1. If only model's results will be used in the platform, they can be stored in the Lake component. In this case, if the result is numeric or symbolic variable, they will have the same requirements as a time-series data. Therefore, the following metadata information is required: • Name of the variable • Title, optional • Data type • Units • Description

	More information will be required if the result of the physical model provided is an equation. 2. If the physical model will be used to create a surrogate model (statistical model) in the Advanced Analytics component, therefore, the following information is required: • Physical model inputs, following the same requirements as a time-series data. Physical model output. More information will be required if the result of the physical model provided is an equation. Possibility of exploitation of the model via an API, further information may be necessary.
Quality and monitoring	For online monitoring of continuous quantitative or qualitative information about the processes. Development and validation of the feedback model and the sensors using Bayesian-based machine learning design of experiments approach and data from simple geometries, complex lattice structures, and impellers. The sensors' data will be analysed to identify patterns and develop algorithms to generate corrective actions and feedback for the PBF-LB, DED-LB and Laser Texturing surface modification systems information about the process. At the time of this deliverable, the requirements are still to be defined in WP3 (Task 3.1 and Task 3.2). In the description of the Task 3.1 it can be found that the details about the collection of data during the Additive Manufacturing (AM) using the sensor systems will be provided. This data should include information from all of the sensors, including melt pool temperature, melt pool shape, and input processing conditions (laser power, scanning strategy, powder properties etc.). This data will be used as input for the machine learning algorithms, the performance will be validated using additional data collected during the AM process. The description of Task 3.2 states that machine learning algorithms will be created using the Advanced Analytics component. No details of the models to be used are given. The models will analyse data recorded from the sensors and, in the event of defects during the part manufacturing by the partners, they should provide real-time recommendations for corrective actions to AconityMINI and P.ADD. The Additive Manufacturing Electronics (AME) maps

	the current implementation and monitors developments within each technology to guide and ensure digital certification opportunities. For this purpose, one or more templates of dashboards could be created. The dashboard can be customized for the monitoring of key measurements or performance indicators. Dashboard's widgets, presented in DM platform, can be used to create visual charts (temporal curves, histograms, scatter plots, etc.), process diagrams with real-time data, models, among others. if the user could have access to different templates or could be able to built their own dashboarding reports. For real-time dashboards data must be available in DmL and therefore, should be automatically from the DmC.

Specifications of data sources used by the partners

Depending on the data sources, different information is needed to be able to connect to data from the partners or future platform users. The advantage of implementing a collector is that data is streamed automatically from the different sources to the DILAFACT platform.

Therefore, for the implementation of an automatic data extraction, currently, the DmC collects data via the OPC-UA protocol and sends it to the DmL via Hypertext Transfer Protocol Secure (HTTPS). If the data source does not support OPC-UA a bridge will be necessary to translate the source's available protocol to the OPC-UA protocol. The bridge can be either from a third-party software or from PEPITe (in-house). In the Figure 13 below, the example shows an example of a relational database and a embedded bridge in DmC.

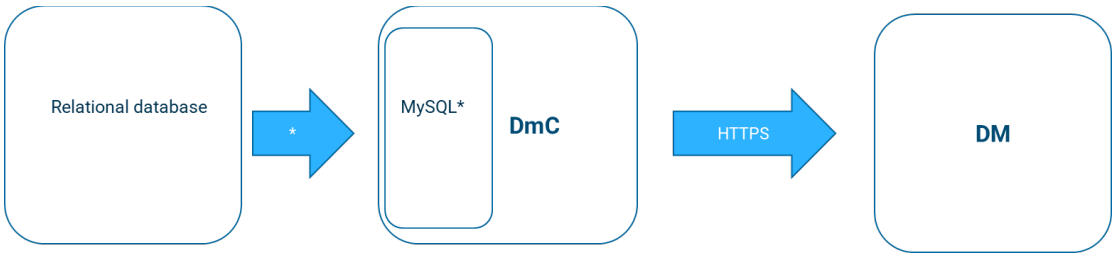


Figure 12: Example of data source with a embedded bridge

In addition to the type of communication protocol, it is necessary to define the collection mode. As mentioned in the previous chapters there are two collection modes, history and subscription. In case the partner or a non-member of the consortium has historical data to be uploaded to the DILAFACT platform, the history mode is used to retrieve this data. In the DILAFACT platform the user will also have the option of uploading their data manually, in this case, there is no need to install a DM Collector.

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In case of the different models or simulations within the platform or if the data need to be collected from a real-time source, the subscription mode could be a better option. The advantage is that this data can be directly published in the real-time dashboards. On that account, it would be necessary to define sub-modes for the collection, if data will be collected in a fixed interval (sampling mode) or only written if the value changed (write on change mode). More detailed information is presented in the chapter about the DM Collector and it contains the different propositions available.

Remote access to partners' systems

As mentioned in the previous chapters, a remote access to collectors operating system, when required, must be provided by the partners. There are different possibilities to remotely access Linux or Windows systems and this could be defined, case by case, as the WP1, WP2 and WP3 will provide more detailed information.

It is recommended to use for Linux, the remote access Secure Shell (SSH) and for Windows, the Remote Desktop (RDP). It is advisable to add a Virtual Private Network (VPN) or an intermediate Jump server therefore the access can be further secured.

For companies outside the consortium it is necessary to define if the access will be restrained to manual data uploading. Therefore, no remote access is required.

DILAFACT architecture

As explained in the previous chapters, DATAmaestro platform consists of 4 different levels which are: Collectors (DmC), Storage (DmL), Analytics (DmA) and Dashboarding (DmD). The components can be deployed in different configurations basically on a cloud or on premises.

For the DILAFACT platform, for the partners of the consortium, ideally, the configuration would be:

- DmC: on premises. There are two options available, that can be considered with each partner individually or have a standard defined for all partners.
    - On- premises server managed by the customer
    - On- premises server managed by PEPITe

  For non-members of the consortium it will be necessary to define if the third part could eventually have access to an automatic data collection or upload their data manually. This could be accounted for in the access rights.

- Storage (DmL), Analytics (DmA) and Dashboarding (DmD): on a cloud. The options available are:

- Dedicated PEPITe cloud: a cloud server managed by PEPITe dedicated to the customer (no other customer on the server).
- Shared PEPITe cloud: a cloud server managed by PEPITe where the hardware is shared with other customers.

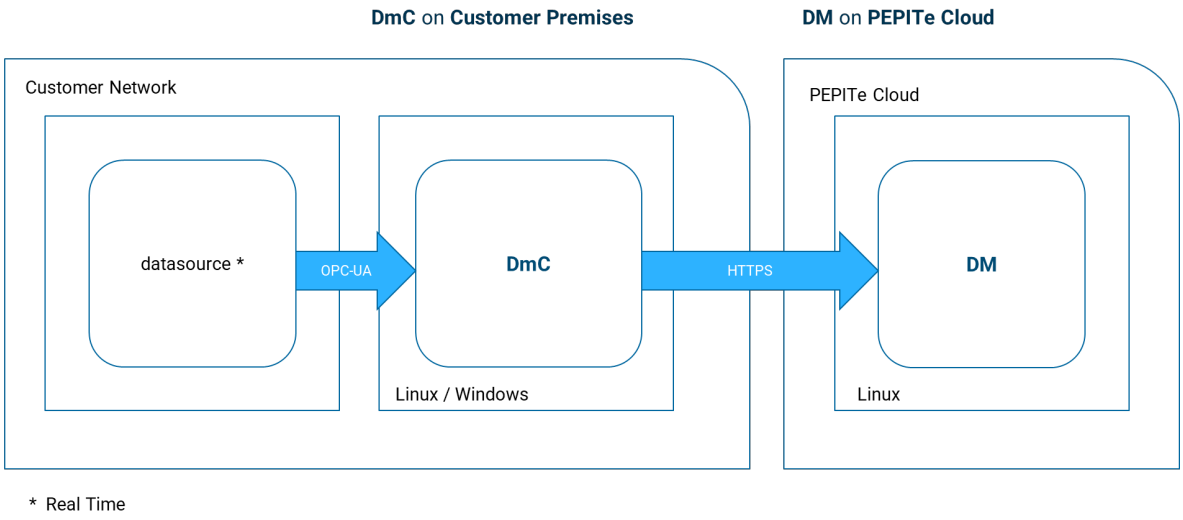


Figure 13: Recommended architecture DmC on-premises and Dm platform on cloud

Currently, the idea would be to have a DILAFACT dedicated cloud access to all members of the consortium. For non-members of the consortium, it will be necessary to define if they can have full or limited access to a shared or a dedicated cloud. This could be accounted for in the access rights.

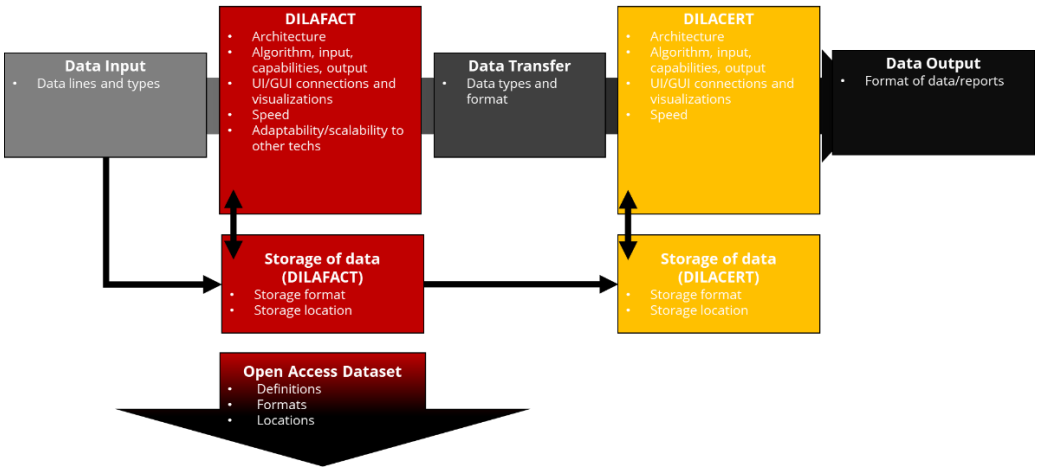


Figure 14: DILAFACT – DILACERT Data workflow

DILAFACT Server size:

As mentioned in the previous chapter related to DmC, the data collected by the DmC is buffered in memory (RAM) before being sent to the DATAmaestro Lake.

In case the connection with the DmL is down, it is advisable to hold a certain amount of data using a buffer. The size of the buffer depends basically on the number of variables by the numbers of hours on hold. The recommended server size for the collectors to be placed on-premises (per partner) is:

RAM	8 GiB
CPU	2 cores
DISK (HDD)	OS + 10 GB

Table 9: Recommended server size for collectors

Additional space may be required if third party software is needed to connect to the data sources (e.g. kepserverEx).

Size of the Lake, Analytics and Dashboards components (DM platform) and storage estimation:

The size of the DM platform depends on the size of the site. In this case, the DILAFACT platform could be considered as a large site or large multi-site region considering it is going to gather information from different sites.

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The Table 10 below shows an example of a large multi-site.

RAM	128 GiB
CPU	32 cores
DISK (SSD)	OS + application data (cf. storage)

Table 10: Recommended size for DM platform

The storage size depends on the number of variables, how long the data will be available, the sampling period and the number of bytes per data point.

An evaluation is required to understand the storage needed for the data and it could depend on the results of the WP1, WP2 and WP3. The Lake size depends on the number of variables per a period of time during a year and the number of bytes per data points. For the Analytics storage size it must be considered that each time a user creates a resampled data file for analysis in DATAmaestro Analytics, a new file is created and therefore sufficient storage must be provided. Considering the size of the platform based on the examples given the previous sections, and what it is known so far in terms of variables to be stored and models to be created it could be recommended to have more than 70 GiB / year for Lake storage and more than 80 GiB/year for Analytics.

For the quality monitoring, the idea could be to create dashboard's templates for the different groups that have access to the DILAFACT platform.

However, to have access to real-time dashboards, data must be available in DmL and therefore, be automatically collected. For instance, for companies outside the consortium, an access to the collectors would be necessary for them to be able to visualize their own data in real-time dashboards' templates. The editing of dashboards could be also envisioned, if necessary.

Access to the platform

As mentioned before, four user groups will be targeted to use the software: researchers, developers, machine manufacturers, and producers. For each of these groups, different types of access will be available under different licensing terms, using open source, open data access and commercial approaches.

As the platform is divided in different levels from collection to dashboarding, different types of user's accounts could be envisioned:

- Super Administrator: highly privileged account used primarily for the management of the DILAFACT platform. This user account could be exclusive to PEPITe and could include, among others, the following tasks:
    - Group users according to their needs and roles
    - Create user's accounts: provide login for end-users and allow users to set and reset passwords
    - Assign user rights to systems, services, and applications
    - Prevent unauthorized access to infrastructure, applications, and data
    - Store user details and credentials
    - Define access policies
    - Maintain the security of IT systems
    - Manage the platform
    - Maintain all the software components with updated versions
    - Manage user entitlements within services and applications
- Local Administrator: privileged accounts used primarily for local system administration and could be extended to all members of the consortium. Access would be available for Lake, Analytics and Dashboarding in a cloud. The Collectors would be on-premises.
- Standard User or Read only User: access to a set of authorized functionalities or read-only based on the different licencing terms and could be provided for the users that are not part of the consortium. The access could be limited to one or more components, as for example, a user could have access only to the final dashboarding.

Software sustainability

The development of DILAPRO is planned to increase the scalability of the software, increasing its ability to deal with other materials, new laser sources, or technologies. However, beforehand, the project is building its initial environment based on a selected of set of materials with realisable datasets, since data is the central point to create and validate a Digital Twin and materials simulations. The idea is also to keep DILAFACT and DILACERT separate rather than fully integrated to allow a faster certification of DILACERT, and to ensure impartiality between the software for analysis (DILAFACT) and another one for certification (DILACERT).

There is also a commitment to feed general data anonymously for future or parallel development around the same technologies using the Open Access/Open Data methodology. The Digital Twins will be kept in open source or educational licenses to allow the development of modules based on new materials and sensors. Specific agreements can be settled for the developers of the new modules. Digital twins and datasets will also be shared with projects stemming from 'Coordination and knowledge sharing across materials development communities' (HORIZON-CL4-2023-RESILIENCE-01-39).

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Figure 15: Commitments for future and parallel development

Updated risks

The primary risk currently is the potential for delays following the termination of the partner Welltec. Deliverable 1.3 is closely tied to the information necessary for the completion of Deliverable 1.1, which involves the "definition of use cases and requirements including business case definitions," as well as Deliverable 1.2, which requires the "identification and description of available production lines for use, including boundary conditions and requirements for Digital Twin integration." A delay in any of these deliverables could lead to a cascading effect, causing further delays. The status of other risks identified during the kick-off of Work Package 1 remains unchanged at this time.

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Example of implementation of DILAFACT in DATAmaestro

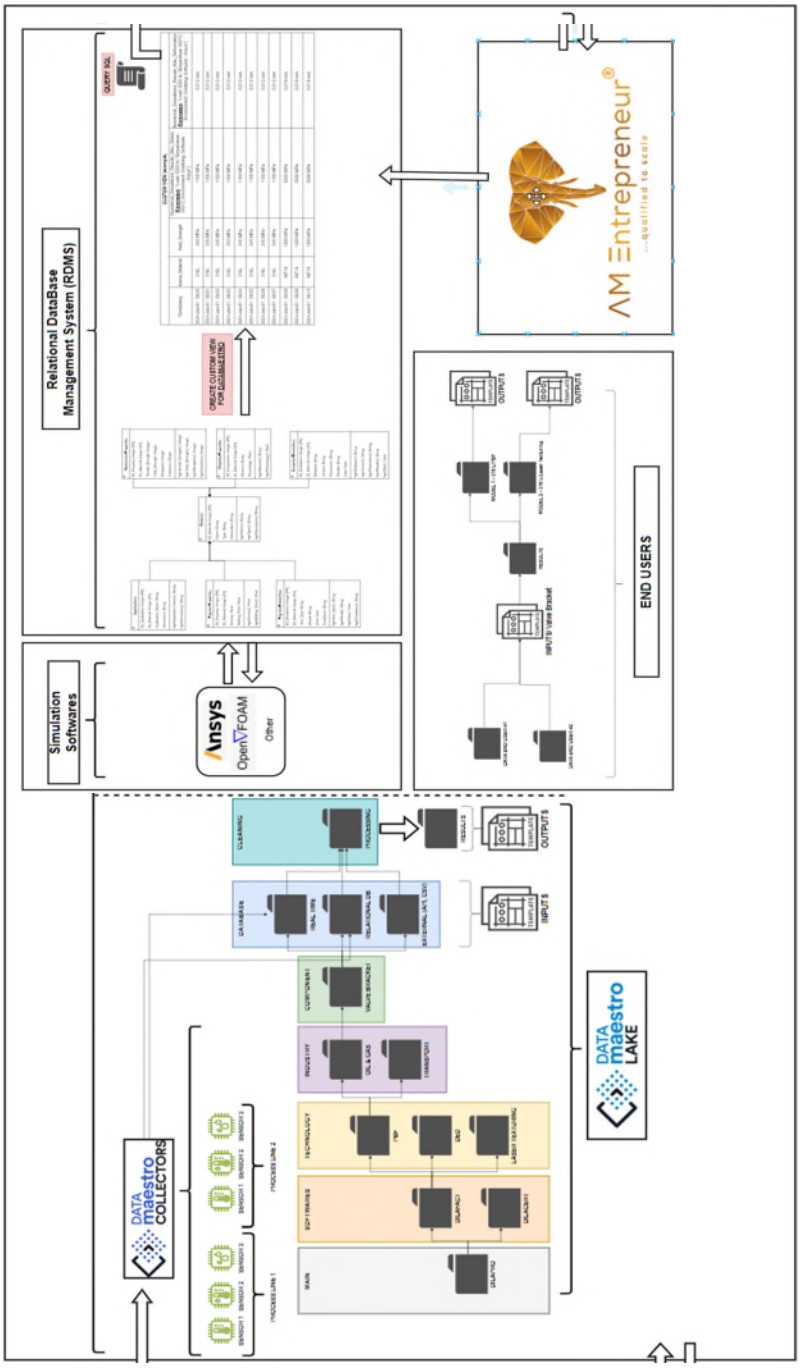


Figure 16: DILAFACT Architectural example of implementation

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To provide the project partners with a practical example as clearly as possible, an implementation of DILAFACT within DATAmaestro was completed. This illustrates in detail the various workflows between different components.

Initially, we begin with digital simulation software that needs to interact with one or more relational databases containing all necessary information about different materials (The relational database shown in Figure 13 is by no means a real relation database provided by a partner, is just an illustration, for the sake of the example). The first step to utilizing this data in DATAmaestro is to create a Custom View in the database that is timestamped and smartly structured for the creation of the digital twin. An example of such a custom view has been suggested. The data from "SQL" databases will be retrieved in DATAmaestro Collector via a query provided by the partners. As for the temporal data from different pilot lines, this will also be collected through the collector via various communication protocols used (OPC-UA, etc.). Once the data sources mapping with the collector is completed, the data will be stored in the lake in a tree-structured folder system. An example of this tree structure is also provided in the schema for the "Valve bracket" example. Data cleaning pipelines will also be defined in the lake. Once the data is cleaned and properly identified, it will serve as inputs for DATAmaestro Analytics. This is where AI models and digital twins will be developed. Once the models are created, key information will be displayed using various dashboards in DATAmaestro Dashboard.

Access rights to different folders will need to be defined with the partners.

A final user view was also proposed for the "Valve bracket" example. Templates for inputs and outputs must be defined for each use case to ensure validation for certification. This schema is, of course, a starting point and will need to evolve with the project's further developments.

To correctly visualize the details, the image "DILAPRO_ARCHTECTURE.jpg" is attached at the end of the report.

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Conclusion

This report outlines all the prerequisites for designing the DILAFACT software infrastructure. Currently, some critical questions, such as size of storage required or access rights, remain unresolved mostly due to the fact that the project is still in the beginning of its activities.

In conclusion, this report meticulously delineates the necessary prerequisites for the DILAFACT software infrastructure, spotlighting the pivotal role of comprehensive planning and precise specifications in navigating the complexities of digital transformation. Despite the challenges posed by current delays and unresolved questions, this document underscores the importance of a collaborative approach among all stakeholders to refine and address these pivotal considerations. By systematically addressing the enumerated aspects, ranging from data source specifications and access rights to architectural decisions and user interface designs, the path forward involves a strategic alignment of technological capabilities with the project's overarching goals.

The successful realization of the DILAFACT infrastructure hinges on our collective commitment to resolving these outstanding queries, thereby ensuring a robust, scalable, and user-centric platform. As we move forward, the focus must remain on fostering an adaptive framework that accommodates evolving requirements, ensuring DILAFACT not only meets current needs but is also poised to tackle future challenges. This collaborative endeavour is a cornerstone in the pursuit of innovation and excellence in digital infrastructure, setting a precedent for future projects within the European context and beyond.

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ANNEX A

Network access

Network access table example:

Source	Destination	Protocol	Port	Description
PEPITe	Jump	RDP	tcp 3389	Access to the jump for PEPITe
Jump	DmL/DmA/DMD	SSH	tcp 22	Remote access to the VM for system administration and services administration
Jump	DmC	SSH	tcp 22	Remote access to the VM for system administration and services administration
Jump	DmL/DmA/DMD	HTTP	tcp 80	Access to the DmL/DM/DMD services via http
Jump	DmC	HTTP	tcp 8180	Access to the DmC service via http
Jump	DmL/DmA/DMD	HTTPS	tcp 443	Access to the DmL/DmA/DMD services via https
DmC	DATASOURCE 1	OPC UA	tcp 49320	DM Collectors acts as client in order to retrieve data from the DATASOURCE 1
DmC	DATASOURCE 2	OPC UA	tcp 4840	DM Collectors acts as client in order to retrieve data from the DATASOURCE 2
DmC	DmL/DmA/DMD	HTTPS	tcp 443	DM Collectors sends the data to the DmL via the DmL API
User (laptop, workstation)	DmL/DmA/DMD	HTTP	tcp 80	Access to the DmL/DmA/DMD services via http

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User (laptop, workstation)	DmL/DmA/DMD	HTTPS	tcp 443	Access to the DmL/DmA/DMD services via https
User (laptop, workstation)	DmC	HTTP	tcp 8180	Access to the DmC service via http

Data sources information

At this stage, pending definition of data sources used for the use cases:

- OPC-UA real-time
- OPC-UA historized
- Relational- Database (SQL)
- OSISoft PI
- IP21
- CSV
- Wonderware
- WinCC

Estimation of size DATAmaestro Lake and Analytics

Small (per site)

RAM	16 GiB
CPU	4 cores
DISK (SSD)	OS + application data (cf. storage)

Medium (per site)

RAM	32 GiB
CPU	8 cores
DISK (SSD)	OS + application data (cf. storage)

Large (per site)

RAM	64 GiB
CPU	16 cores
DISK (SSD)	OS + application data (cf. storage)

Per geographical (multi-size region instance size):

Small (geo)

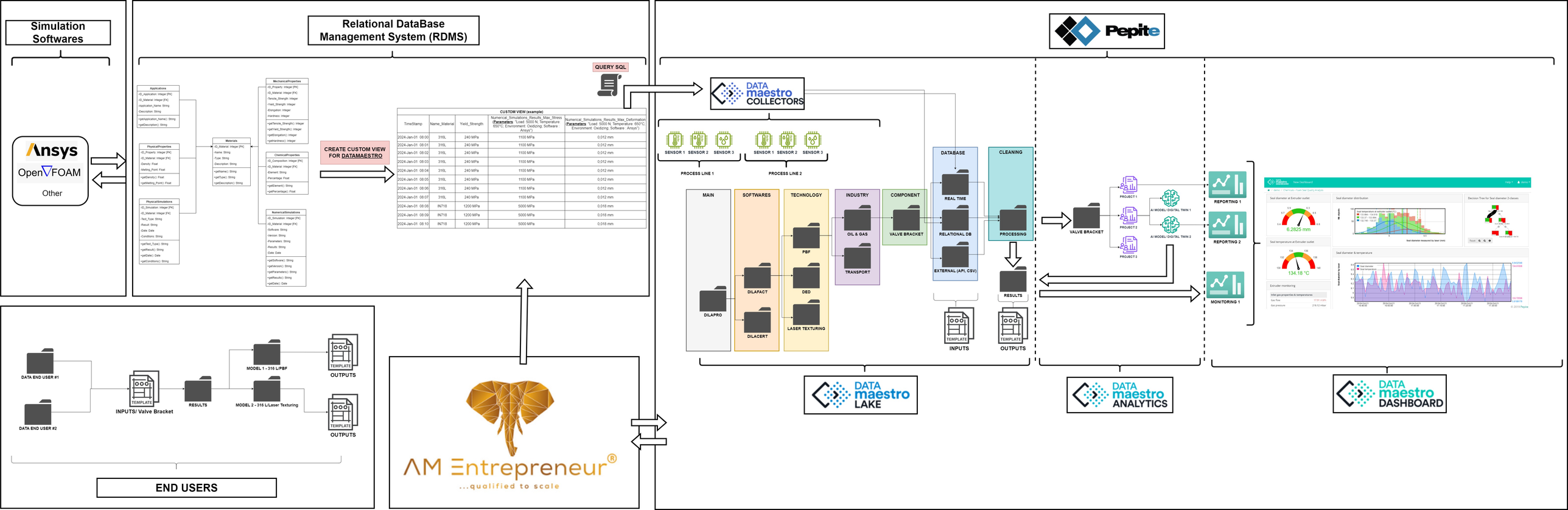
RAM	32 GiB
CPU	8 cores
DISK (SSD)	OS + application data (cf. storage)

Medium (geo)

RAM	64 GiB
CPU	16 cores
DISK (SSD)	OS + application data (cf. storage)

Large (geo)

RAM	128 GiB
CPU	32 cores
DISK (SSD)	OS + application data (cf. storage)


Simulation Softwares
Ansys
OpenFOAM
Other
Relational DataBase Management System (RDMS)
Applications
Materials
PhysicalProperties
PhysicalSimulations
MechanicalProperties
ChemicalProperties
NumericalSimulations
QUERY SQL
CUSTOM VIEW (example)
TimeStamp | Name_Material | Yield_Strength | Numerical_Simulations_Results_Max_Stress (Parameters "Load: 5000 N; Temperature: 650°C; Environment: Oxidizing; Software : Ansys") | Numerical_Simulations_Results_Max_Deformation (Parameters "Load: 5000 N; Temperature: 650°C; Environment: Oxidizing; Software : Ansys")
2024-Jan-01 08:00 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:01 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:02 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:03 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:04 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:05 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:06 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:07 | 316L | 240 MPa | 1100 MPa | 0.012 mm
2024-Jan-01 08:08 | IN718 | 1200 MPa | 5000 MPa | 0.018 mm
2024-Jan-01 08:09 | IN718 | 1200 MPa | 5000 MPa | 0.018 mm
2024-Jan-01 08:10 | IN718 | 1200 MPa | 5000 MPa | 0.018 mm
CREATE CUSTOM VIEW FOR DATAMAESTRO
Pepite
DATA maestro COLLECTORS
SENSOR 1
SENSOR 2
SENSOR 3
PROCESS LINE 1
PROCESS LINE 2
DATABASE
REAL TIME
RELATIONAL DB
EXTERNAL (API, CSV)
CLEANING
PROCESSING
RESULTS
TEMPLATE
INPUTS
OUTPUTS
MAIN
DILAPRO
SOFTWARES
DILAFACT
DILACERT
TECHNOLOGY
PBF
DED
LASER TEXTURING
INDUSTRY
OIL & GAS
TRANSPORT
COMPONENT
VALVE BRACKET
DATA maestro LAKE
VALVE BRACKET
PROJECT 1
PROJECT 2
PROJECT 3
AI MODEL/ DIGITAL TWIN 1
AI MODEL/ DIGITAL TWIN 2
DATA maestro ANALYTICS
REPORTING 1
REPORTING 2
MONITORING 1
DATA maestro DASHBOARD
DATA END USER #1
DATA END USER #2
INPUTS/ Valve Bracket
RESULTS
MODEL 1 - 316 L/PBF
MODEL 2 - 316 L/Laser Texturing
OUTPUTS
END USERS
AM Entrepreneur®
...qualified to scale