FLEXIGROBOTS

D2.3 Requirements and platform architecture specifications. Final

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List of Acronyms

Abbreviation / acronym	Description
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
CAS	Common Application Services
CLI	Command Line Interface
CPU	Central Processing Unit
CRUD	Create, Read, Update, Delete
ELSE	Ethical, Legal, Social, Economic
FMS	Farm Management System
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GPU	Graphics Processing Unit
GUI	Graphical User Interface
HLEG AI	High-Level Expert Group on Artificial Intelligence
HPC	High-Performance Computing
IDS	International Data Spaces
IDSA	International Data Spaces Association
IEC	International Electrotechnical Commission
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MCC	Mission Control Centre
MLOps	Machine Learning Operations
MQTT	Message Queue Telemetry Transport
NAS	Neural Architecture Search
NDVI	Normalized difference vegetation index
NFR	Non-functional requirements
NIR	Near Infrared
ODC	Open Data Cube
OGC	Open Geospatial Consortium

Abbreviation / acronym	Description
PDF	Portable Document Format
RAM	Random Access Memory
RCS	Robot Control Software
REST	Representational State Transfer
RFMS	Robot Fleet Management System
ROS	Robot Operating System
SDK	Software Development Kit
TIFF	Tagged Image File Format
UAV	Unmanned aerial vehicle
UGV	Unmanned ground vehicle
UML	Unified Modelling Language
YAML	Yet Another Markup Language

Executive Summary

Deliverable D2.3 presents the final version of the FlexiGroBots platform requirements and specifications, which have been conceived to allow automating precision agriculture services through the usage of heterogeneous multi-robot systems and exploiting diverse data sources with advanced Artificial Intelligence techniques. It is the final result of task *T2.2 - Platform requirements and architecture* and has been produced leveraging the initial vision described in deliverable D2.2, which was released in December 2021, corresponding to month twelve of the project.

FlexiGroBots platform architecture is composed of a set of modules that provide an integrated solution to i) extract value from the information collected from different devices, robots and platforms using Machine Learning and Deep Learning following Machine Learning Operations (MLOps) and Automatic Machine Learning (AutoML) paradigms, ii) enable information to be managed by several stakeholders and exchanged between one another in a secure and sovereign manner embracing the Data Spaces concept, iii) process drone and satellite remote sensing products and expose the results with standard Open Geospatial Consortium (OGC) interfaces, iv) use "off the shelf" services for general precision agriculture in an “AI as a Service (AIaaS)” approach, v) plan and execute complex missions that require fleets of heterogeneous robots thanks to a powerful Mission Control Centre (MCC).

The previous version of the document included an exhaustive analysis of existing reference architectures and other European initiatives that were selected to influence and drive the definition of the FlexiGroBots platform architecture. From the initial set of specifications for the three pilots’ use-cases, a consolidated view of the needs of the target stakeholders was described following a Value Proposition Canvas methodology. Finally, functional requirements were derived in the form of user stories to populate the backlogs for the implementation of the platform. They were complemented by non-functional requirements, e.g., best practices, domain expertise and inputs provided by T2.4 with respect to ethical, legal and trust aspects. Then, the platform specifications and architecture were described following IEC 62559-2:2015 and the 4+1 architectural view model covering uses-cases, logic, development, process and physical diagrams.

The present document constitutes the final version of the FlexiGroBots platform requirements and architecture specification, being a refinement of the previous deliverable (D2.2). It has been updated with new requirements extracted during the progress in the implementation of the platform prototypes within the scope of WP3 and its application and integration in the three project’s pilots in WP4, WP5 and WP6. A major part of the initial vision is still relevant and only fine-tuning has been required for most of the components of the platform and therefore the present document is focused on the changes introduced from D2.2.

1 Introduction

1.1 Purpose of the document

FlexiGroBots project is an Innovation Action aiming to build a platform for flexible heterogeneous multi-robot systems for intelligent automation of precision agriculture operations, providing multiple benefits to farmers around the world. In this vision, fleets of heterogeneous robots will be able to execute complex missions in an orchestrated and coordinated way overcoming some of the main barriers that currently limit the adoption of unmanned vehicles and robotics technologies in the agriculture domain.

FlexiGroBots architecture was designed to enable the secure and sovereign exchange of information following the principles proposed by the International Data Spaces Association (IDSA), which breaks the data silos and opens the door to new business models for the farmers and other stakeholders. The embracement of IDSA's vision and guidelines [1] allows creating more powerful robotics systems, which can interact with other digital systems deployed in the field, having access to real-time or near real-time information and historic datasets.

Models powered by Artificial Intelligence techniques will be embedded in the robots for perception, navigation and decision making. They will be also used "as a service" or integrated into Farm Management Systems (FMSs) to analyse the information gathered by the robots and by other data sources and to create powerful applications and services to support the farmer's needs. Storage, access and analysis of geospatial information are also considered in FlexiGroBots architecture.

The project will pay special attention to comply with the requirements established by the European Commission in terms of trustworthy AI [2] [3], also providing guidelines about their specification application in the agriculture domain. FlexiGroBots AI methods will consider ethical, legal and socio-economic issues, in order to ensure scalable human oversight and intervention and compliance with trustworthy requirements.

The goal of this document is to identify the complete and final list of requirements that should be satisfied by the platform, considering the needs and expectations of the diverse actors that participate in the precision agriculture value chain. **From them, FlexiGroBots technical architecture has been designed, describing the main functionalities that are provided by each one of its components.** The analysis of previous and ongoing projects and initiatives that are related to FlexiGroBots, which either ' goal and which results will serve as a baseline or will be interoperable with the project's results, was part of the previous version of the deliverable, *D2.2 - Requirements and platform architecture specifications 1* [4], published in M12 of the project.

It must be noted that FlexiGroBots' architecture will be used as the main reference for the implementation of the respective WP3 modules and to guide the integration, execution and validation activities of the three pilots of WP4, WP5 and WP6.

FlexiGroBots architecture has been designed using an incremental approach with two main stages: D2.2 presented the first version of the requirements and architecture, while the present document contains the final, consolidated and refined specification incorporating the feedback and insights received from the work package focused on the implementation of the platform (WP3) and the three pilots (WP4, WP5 and WP6). For the sake of readability and clarity of the document, the parts of the original deliverable (D2.2) that were not changed are omitted here. Some texts have been maintained without modifications to preserve the comprehensibility of the present deliverable. The reader is strongly recommended to go through D2.2 in order to have a complete view of the FlexiGroBots platform architecture.

The finalisation and publication of D2.3 signals the consecution of a key milestone of the project, namely *MS4 - Mid-project platform*.

1.2 Relation to other project activities

A graphical representation of the relation between deliverable D2.3 and other tasks' outcomes is shown in Figure 1.

Deliverable D2.3 is the second and final outcome of *T2.2 - Platform requirements and architecture* and the third document produced by *WP2 - Requirements, architecture and standardization*, after the release in M9 of the project of D2.1 [5], which was devoted to describing the stakeholders' view to FlexiGroBots system scenarios, and D2.2, previous version of the present document.

The content of D2.3 has been generated through the refinement, distilment and extension of the initial specifications presented in D2.2, which were derived from D2.1, D4.1 [6], D5.1 [7] and D6.1 [8]. The discussion and alignment with the partners participating in the three pilots have been coordinated thanks to the efforts of *T2.5 – Pilots' methodology, follow-up and alignment*, which will have also a second outcome in M24 with D2.8, describing the methodology and conclusions of the process, updating the mapping of the project architecture to the different use-cases and including the results for the validation KPIs. At the same time, the work done for D2.3 has also a strong bidirectional influence on the rest of the tasks of WP2: with T2.3 to evaluate the standards that must be taken into account for the implementation activities or to which the project shall contribute (D2.4), with T2.4 for the assessment of the ethical, legal and socio-economic (ELSE) issues (D2.6). The integration of inputs from this task is especially visible in the non-functional requirements included in section 2.

The usage and integration of the FlexiGroBots platform in the three pilots will be reported exhaustively in March 2023 (M27 of the project) as part of D4.2, D5.2 and D6.2

Finally, WP3 is in charge of the development of the platform and all the specified functionalities. The implementation is being done following the agile methodology and the source code of the prototypes is available in the project GitHub repository [9] as described in D3.1 [10]. A new major release will be published with D3.2 in M24 (December of 2022).

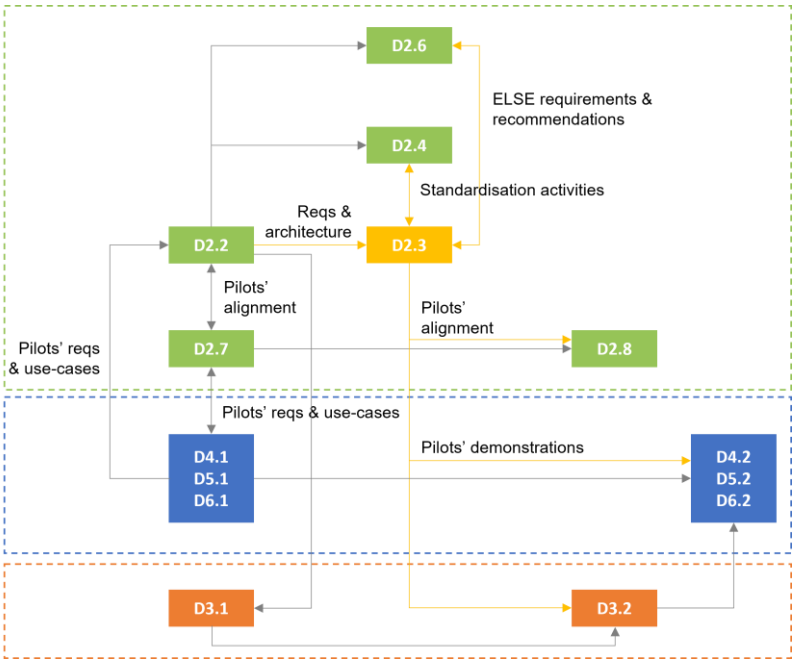


Figure 1 Deliverables linked to D2.3

1.3 Structure of the document

This document is structured in six major sections:

- **Section 1** introduces the purpose of the deliverable, its relation to other tasks and documents and the structure of the content. It also highlights the changes introduced with respect to the previous version.
- **Section 2** contains the final version of the functional and non-functional requirements.
- In **section 3**, D2.3 presents the needed updates in the FlexiGroBots platform architecture, covering IEC 62559 use-cases descriptions and the views of the 4+1 architectural view model (logical, developments, process and physical). Unified Modelling Language (UML) diagrams have been used as modelling language.
- **Section 4** explains the conclusions of the deliverable.

2 Requirements from stakeholders and pilots

This section is devoted to presenting the final list of requirements for the FlexiGroBots platform. The three project pilots have been used as the main instrument to derive the functional and non-functional requirements. It must be noted that no changes have been made to the stakeholders' characterization included in section 4.2 of D2.2 and therefore this content is not included again in the present document. The only point that must be mentioned is that *Robot Operators* (see subsection 4.2.4 of D2.2) are called *Mission operators* in the present document to have a broader meaning better aligned with the goals of FlexiGroBots project. This change supposes an amendment of the content of D2.2. Typical jobs, pains and gains are not modified.

With respect to the functional and non-functional requirements, additional ones have been added due to the progress in the execution of the three pilots and a better understanding of the needs of involved stakeholders. Also, due to the advances done in tasks T2.3, T2.4 and WP3. In order to increase the level of detail, for each requirement the following information was added:

- Component: which components of the FlexiGroBots platform must satisfy or are affected by the corresponding requirement. Multiple options are possible.
- Priority following the MoSCoW (Must Have, Should Have, Could Have, Won't Have this time) method [1].

As can be seen, 18 new functional requirements and 4 non-functional requirements have been added.

2.1 Functional requirements

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
US_01	Farmers	Automatically detect pests and/or diseases from UAVs and/or UGVs images	Costs associated with the human inspection are reduced and precision treatments can be applied early	AI Platform, Common application services	1, 2, 3	MUST

[1] https://www.projectmanagement.com/contentPages/wiki.cfm?ID=483405&thisPageURL=/wikis/483405/MoSCoW-Requirements#_=_

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
US_02	Farmers	Visualise occurrences and intensity of pests and/or diseases in an interactive map	Facilitate analysis and decision-making	Common application services	1,2	MUST
US_03	Farmers	Automatically apply pesticides using UAVs and/or UGVs with precision	Costs associated with the human application are reduced and environmental impact is minimised	Mission Control Centre	1, 2	MUST
US_04	Farmers / Farm workers	UGVs carry out detailed explorations of risk areas	Farm workers do not have to perform a visual inspection	Mission Control Centre	1	MUST
US_05	Farmers	Have an estimation of the production of the crop	To have better preparation for the harvest and the next processes	AI Platform, Common application services	1	COULD
US_06	Farm workers	UGVs follow farm workers safely	Products can be deposited, and the efficiency of the process is maximised	Common application services Mission Control Centre	1	MUST
US_07	Farmers / Farm workers	UGVs autonomously transport products to the established collecting places	Workers will be more comfortable and faster The efficiency of the harvesting process is maximised. Less damage to the product.	Common application services, Mission Control Centre	1	MUST

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
US_08	Farmers	UGVs control the weight of the products that are transported	Yield information for each area can be automatically obtained	Mission Control Centre	1	MUST
US_09	Farmers	Obtain maps with digestibility values from satellite imagery	Perform digestibility analysis	Data Cube	2	SHOULD
US_10	Farmers	Obtain ranking of fields according to relevant indices using satellite images and information from robots	Plan harvesting operations	AI Platform, Common Application Services, Data Cube, Mission Control Centre	2	SHOULD
US_11	Farmers	To define tasks in the FMS that are translated to goals and constraints for the MCC	Robotics missions are aligned with farms operations	Mission Control Centre	1, 2	MUST
US_12	Mission Operators	Plan UAVs and/or UGVs missions considering field maps and the type of mission	The mission file can be uploaded to the UAVs and/or UGVs	Mission Control Centre	1, 2	MUST
US_13	Mission Operators	Create mission plans that include control of cameras and/or sprayers	UAVs and/or UGVs require a low level of supervision by the operator	Mission Control Centre	1, 2	MUST
US_14	Mission Operators	Execute and monitor missions without intervention	Reduce the complexity and skills needed to operate robotics missions	Mission Control Centre	1, 2	SHOULD

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
			Allow controlling several missions simultaneously			
US_15	Mission Operators	Receive alerts about incidents and unexpected events during the mission execution	Ensure that the mission is executed safely and successfully	Mission Control Centre	1, 2, 3	MUST
US_16	Mission Operators	Manually control robots in case of exceptional situations	Ensure that the mission is executed safely and successfully	Mission Control Centre	1, 2, 3	MUST
US_17	Mission Operators	Images and data collected by the robots are automatically transferred to the FMS and FlexiGroBots platform	Automate the process and reduce the time/effort needed for data transfer Reduce the complexity and skills needed to operate robotics missions	Data Space, Common Application Services, Mission Control Centre	1, 2	COULD
US_18	Mission Operators	Missions updated dynamically	Robots may need to adjust their routes in real-time according to current data or to the positions and actions of other robots.	Mission Control Centre	2	COULD
US_19	Farmers / Mission Operators	UGV are able to autonomously locate weeds or areas infected by pests or diseases in an area	Precision treatment or appropriate actions can be autonomously and efficiently executed	Common Application Services, Mission Control Centre	1, 2	MUST

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
		covered by the mission plan				
US_20	Farmers/farm workers	UGVs are able to perform weeding and do the transportation	Increase the efficiency of weeding tasks	Mission Control Centre	2	MUST
US_21	Farmers / farm workers / Mission Operators	UGVs are able to detect real-time obstacles and people using onboard cameras and sensors	Safety requirements are satisfied	Common Application Services, Mission Control Centre	1, 2, 3	MUST
US_22	Farmers/Mission Operators	Supervise and coordinate several missions simultaneously	Increase the efficiency of robotics operations	Mission Control Centre	2	COULD
US_23	Farmers/Mission Operators	Detect in real-time or near real-time hazards and possible collisions	Ensure that the mission is executed safely and successfully	Common Application Services, Mission Control Centre	1, 2, 3	MUST
US_24	Farmers / Mission Operators	Implement appropriate actions in case of hazards, e.g., stopping one or more robots.	Ensure that the mission is executed safely and successfully	Mission Control Centre	1, 2, 3	MUST
US_25	Mission Operators	Visualise classified anomalies in a map	Mission situation can be easily understood and evaluated	Mission Control Centre, FMS	1, 2, 3	SHOULD
US_26	Farmers	Control the usage of the data collected by intelligent machinery and	Preserve private or confidential information and avoid data exploitation or	DataSpace	1, 2, 3	MUST

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
		robots by digital companies	commercialisation without consent			
US_27	Farmers	Publish and commercialise data so that it can be consumed by third parties, receiving some incentives.	Find alternative business models thanks to high-quality data	DataSpace	1, 2, 3	COULD
US_28	Farmers	Have the freedom to select digital services providers while keeping historical data (data portability)	Avoid situations of unfair negotiation with big digital companies	DataSpace	1, 2, 3	WON'T
US_29	Robots manufacturers / FMS developers / AI developers	Develop systems that are interoperable by design without spending high effort to develop custom interfaces.	Open new business opportunities through the creation of digital agriculture systems composed of heterogeneous components.	DataSpace	1, 2, 3	COULD
US_30	Farmers/ FMS developers	Receive new AI-powered services seamlessly.	Operations and features can be continuously improved.	AI Platform, Data Space	1, 2, 3	SHOULD
US_31	Farmers / FMS developers	Use AI as a service (AIaaS).	Reduce the resources and complexity	AI Platform, Common Application Services	1, 2, 3	MUST

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
US_32	Farmers	Obtain NDVI images.	Understand the density and health of the vegetation	AI Platform, Common, Data Cube, Application Services	1, 2, 3	MUST
UC_33	Farmers	Delineate zones according to the data / images obtained from satellites and robots.	Map problematic areas, make decisions or plan interventions.	AI Platform, Common, Data Cube, Application Services	1, 2, 3	MUST
US_34	Mission Operators	Orthophotos are automatically generated from UAVs images.	Reduce effort and time for processing images.	Common Application Services	1, 2, 3	MUST
US_35	AI developers	Manage and version big datasets coming from diverse sources.	Guarantee traceability, reproducibility of Machine Learning (ML) experiments.	AI Platform	1, 2, 3	SHOULD
US_36	AI developers	Train ML and Deep Learning (DL) models.	Information can be processed for precision agriculture services.	AI Platform	1, 2, 3	MUST
US_37	AI developers	Use interactive development environments.	Reduce the effort and time needed for prototyping and data analysis.	AI Platform	1, 2, 3	MUST
US_38	AI developers	Assign specialised hardware accelerators (i.e., Graphics Processing Unit (GPUs)) for training the models.	Accelerate the training process and be able to use large neural networks.	AI Platform	1, 2, 3	MUST

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
US_39	AI developers	Automatise the creation of Machine Learning Operations (MLOps) pipelines.	Experiments can be easily reproduced and replicated in new scenarios.	AI Platform	1, 2, 3	MUST
US_40	AI developers	Share workspaces with other members of the teams.	Work collaboratively in the development of AI services	AI Platform	1, 2, 3	COULD
US_41	AI developers	Manage and version ML/DL models.	Ensure correct governance and change mechanisms	AI Platform, Common Application Services	1, 2, 3	COULD
US_42	AI developers	Deploy and serve models.	They can be used to create new AI-powered services.	AI Platform, Common Application Services	1, 2, 3	MUST
US_43	AI developers	Apply Automated Machine Learning (AutoML) techniques (e.g., Neural architecture search (NAS), hyperparameter optimisation).	Reduce time and effort to train an ML model.	AI Platform	1, 2, 3	SHOULD
US_44	AI developers	Monitor the training process.	Debug and optimise ML models.	AI Platform	1, 2, 3	SHOULD
US_45	AI developers	Retrain already existing models by applying	Reduce the needs for available information and	AI Platform, Common	1, 2, 3	SHOULD

ID	As a «type of user»	I want «some goal»	so that «some reason»	Component	Pilot(s)	Priority
		Transfer Learning	reduce the time to train models	Application Services		
US_46	AI developers	Publish resources (e.g., datasets, models) in the European AI On-Demand Platform	They can be shared and reused by other data scientists and developers	AI Platform, Common Application Services	-	SHOULD
US_47	AI developers	Publish detailed information about datasets and models using a cards format	Recommendations from the High-Level Expert Group on Artificial Intelligence (HLEG AI) [11] are applied	AI Platform, Common Application Services	-	SHOULD

Table 1 FlexiGroBots functional requirements in the form of user stories

2.2 Non-functional requirements

ID	Description	Source	Component	Priority
NFR.01	FlexiGroBots components must expose well-documented and standard REST interfaces.	State of the art / best practices	ALL	MUST
NFR.02	FlexiGroBots components must implement IDSA connectors.	Data Spaces reference architectures	AI Platform, Data Space, Mission Control Centre	SHOULD
NFR.03	FlexiGroBots components must be designed for high availability scenarios (e.g., relying on the Docker containers and Kubernetes manifests for the deployment)	State of the art / best practices	ALL	MUST
NFR.04	FlexiGroBots components must support deployment on main cloud platforms and on-premises infrastructures.	State of the art / best practices	ALL	SHOULD

ID	Description	Source	Component	Priority
NFR.05	FlexiGroBots common applications services must be deployable on robotics systems and edge computing devices.	State of the art / best practices	AI Platform, Common Application Services	MUST
NFR.06	FlexiGroBots platform must adopt secure by design principles, integrating authentication, authorization and access control.	State of the art / best practices	ALL	MUST
NFR.07	FlexiGroBots platform must support multi-tenant scenarios.	State of the art / best practices	ALL	COULD
NFR.08	FlexiGroBots platform must consider hardware infrastructures including GPUs and High-Performance Computing (HPC) resources.	State of the art / best practices	AI Platform, Common Application Services	MUST
NFR.09	FlexiGroBots data space must support structured and non-structured data formats. Data space components are data agnostic, except regarding metadata.	State of the art / best practices	Data Space	SHOULD
NFR.10	FlexiGroBots data space must support the exchange of big data between involved systems.	Domain expertise	Data Space	SHOULD
NFR.11	FlexiGroBots AI Platform must support the development of AI models in most common libraries and frameworks (e.g., TensorFlow [12], PyTorch [13] and Scikit-learn [14]).	Domain expertise	AI Platform	MUST
NFR.12	FlexiGroBots AI Platform must package and optimise ML models for heterogeneous architectures such as x86 and ARM.	Domain expertise	AI Platform	SHOULD
NFR.13	FlexiGroBots AI Platform should maintain essential information about the models and datasets for informative purposes, including accuracy metrics and training descriptions.	Ethical, legal, trust (T2.4)	AI Platform	MUST

ID	Description	Source	Component	Priority
NFR.14	FlexiGroBots Data Space must be able to work with streaming data.	Domain expertise	Data Space	SHOULD
NFR.15	FlexiGroBots MCC must provide an easy-to-use graphical user interface	Domain expertise	Mission Control Centre	MUST
NFR.16	FlexiGroBots MCC must be extensible to support easily new robots and robotics platforms.	Domain expertise	Mission Control Centre	MUST
NFR.17	FlexiGroBots MCC must be compatible with ROS operating system.	State of the art / best practices	Mission Control Centre	MUST
NFR.18	FlexiGroBots platform must be applicable to a wide range of use-cases and types of crops beyond the project's pilots. This applies specifically to Common Application Services.	Domain expertise	ALL	MUST
NFR.19	FlexiGroBots platform should be compliant with the terms of the General Data Protection Regulation (GDPR).	Ethical, legal, trust (T2.4)	ALL	MUST
NFR.20	FlexiGroBots platform, especially the MCC, should be compliant with applicable legal frameworks regarding autonomous vehicles.	Ethical, legal, trust (T2.4)	ALL	MUST
NFR.21	FlexiGroBots platform should guarantee the safety of human workers by performing a risk assessment. For instance, a stop-button should be implemented in the MCC.	Ethical, legal, trust (T2.4)	Mission Control Centre	MUST
NFR.22	FlexiGroBots platform should establish a mechanism for users to flag issues related to technical problems, data protection, biases, etc.	Ethical, legal, trust (T2.4)	AI Platform, Mission Control Centre	COULD
NFR.23	FlexiGroBots platform should incorporate advanced logging capabilities. Logs should be stored and preserved for later analysis.	Ethical, legal, trust (T2.4)	ALL	MUST

ID	Description	Source	Component	Priority
NFR.24	FlexiGroBots platform should log robots' activities for traceability and auditability in case of incidents or external audits.	Ethical, legal, trust (T2.4)	Mission Control Centre	MUST
NFR.25	Common application services should be developed to avoid potential biases and discrimination. For instance, services based on computer vision should work independently of the colour of the worker's skin.	Ethical, legal, trust (T2.4)	AI Platform, Common Application Services	MUST
NFR.26	FlexiGroBots platform should incorporate mechanisms to track the energy consumption and equivalent CO2 footprint.	Ethical, legal, trust (T2.4)	AI Platform	COULD
NFR.27	Training materials should be implemented. Also, documentation for components destined for end-users.	Ethical, legal, trust (T2.4)	ALL	MUST
NFR.28	Communication between platform components and FMS must be possible through message brokers (e.g., Message Queue Telemetry Transport (MQTT), Advanced Message Queuing Protocol (AMQP)) in case data is not shared between several stakeholders.	Business requirements	Mission Control Centre	MUST
NFR.29	Information exchanged between different components must follow well-known standards and common data models.	State of the art / best practices	ALL	SHOULD
NFR.30	Platform components must be based on widely supported open-source technologies, if available.	Business requirements	ALL	SHOULD
NFR.31	Platform components must be developed using modern DevOps practices, e.g., Continuous Integration, Continuous Testing, Continuous Deployment, microservices-based design pattern.	State of the art / best practices	ALL	SHOULD

Table 2 FlexiGroBots non-functional requirements

3 FlexiGroBots Reference Architecture

The main goal of section 3 is to revisit and update the initial reference architecture specified in D2.2 according to the changes that have been agreed in the last six months during the implementation of the platform prototype and the execution of the three pilots. The content is limited to the aspects that were changed, whereas the rest can be found in D2.2.

3.1 Description of the use cases for FlexiGroBots platform

3.1.1 AI Platform

In the case of the AI Platform, the following changes were introduced with respect to the use-cases described in D2.2:

- Data management: no changes needed.
- Experiments management: the scope of the use-case was refined and further elaborated in order to be better aligned with a modern MLOps vision. D2.3 introduced a complete and updated description in 3.1.1.1.
- Trainings management: it was also revisited and modified following the lessons learnt during the implementation of the AI Platform prototype and aligned with the management of experiments. The scope of the use-case was changed to pipelines management, and it is described in 3.1.1.2.
- Models management: a minor update was needed to reflect the publication of models' cards, which is one of the inputs coming from T2.4. The use-case is described in 3.1.1.3. The analysis of the actors, scenarios and consequent steps was omitted since the content is almost the same as in D2.2.

3.1.1.1 Experiments management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC2	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Experiments management

Scope and objectives of use case

Scope and objectives of use case

Scope	Management of AI experiments to support precision agriculture services.
Objective (s)	During the experimentation phase, data scientists analyse available datasets considering the target service and KPIs, applying feature engineering and exploring several algorithms.

Narrative of the use case

Narrative of use case
Short description
AI Experiments are loaded and managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs). The experimentation phase includes the usage of Jupyter Notebooks as a way to easily start the development phase and the definition of the jobs and pipelines that compose a complete MLOps workflow.
Complete description
Machine Learning engineers, data scientists or Mission Operators have the possibility to perform CRUD operations (Create, Read, Update and Delete) for experiments, which are stored in the FlexiGroBots AI Platform to enable subsequent MLOps workflows. The experiments cover the definition of the complete workflows and the corresponding ML models. They have associated metadata and version information so that it is possible to update them over time. The experiments include the possibility to create Jupyter Notebooks [15] for interactive programming in a web user interface using already existing and standard Docker images or custom ones, where specific libraries and tools can be loaded. During the configuration of the notebooks, preferences can be established in terms of needed hardware resources and specialised accelerators.

Use case conditions

Use case conditions
Assumptions
An account is created in the AI Platform for the ML engineer or data scientist.
Prerequisites

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Experiments management is required for executing pipelines on the AI Platform following AI_UC3.

Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case

Actors

Actors

Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
Data scientist / ML engineer	Human	Person in charge of the development of the ML model. He/she manages the experiments.	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Manages notebooks	Notebooks are managed for interactive prototyping and data analysis.	Data scientist	N/A	None	Data scientists are able to use Jupyter Notebooks.
2	Experiments with data	ML pipelines are defined to analyse data and train ML models.	Data scientist / ML engineer	N/A	None	A new pipeline is ready to be uploaded to the platform
3	Manages experiments	Experiments are managed by the data scientist in the AI Platform.	Data scientist / ML engineer	N/A	None	Data scientists are able to manage experiments.

Steps – Scenarios

Scenario							
Scenario name:	No. 1 – Manages notebooks						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)

01	User wants to use Jupyter notebooks in the AI Platform	Creates Jupyter notebook	The GUI is used to launch a new notebook	POST	Data scientist	AI Platform	Notebook information, e.g., name, description.
02	Step 01 initiated	Creates custom docker image	The user builds a new docker image including required libraries and tools	POST	Data scientist	AI Platform	Docker image
03	Step 02 completed	Selects docker image	User chooses a docker image from the available list	POST	Data scientist	AI Platform	Chosen docker image
04	Step 03 completed	Requests GPUs	User defines the number of GPUs and the vendor	POST	Data scientist	AI Platform	GPUs requested information
05	Steps 04 completed	Requests hardware resources	User defines requested number of CPUs and RAM memory	POST	Data scientist	AI Platform	Hardware resources requested
06	Step 05 completed	Attaches data volumes	User selects a volume to persist information	POST	Data scientist	AI Platform	Volume information
07	Step 06 completed	Starts Jupyter notebook	User uses the GUI to start the Jupyter	RUN	Data scientist	AI Platform	

			notebook session				
08	Step 07 completed	Deploys Kubernetes pods	Jupyter notebook session is launched in the underlying Kubernetes infrastructure	RUN	AI Platform	Kubernetes	
09	Step 08 completed	Interactive development	The data scientist uses Jupyter notebooks to interactively create an ML model	-	Data scientist	AI Platform	
10	User finishes the experimentation	Deletes Jupyter notebook	User removes the Jupyter notebook using the GUI	DELETE	Data scientist	AI Platform	
11	Step 10 completed	Deletes Kubernetes pods	AI Platform removes Kubernetes pods, releasing allocated resources	RUN	AI Platform	Kubernetes	

Scenario							
Scenario name:	No. 2 – Experiments with data						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)

01		Creates pipeline	Using an SDK, the user defines a new pipeline by composing several jobs and producing results	POST	Data scientist	N/A	Pipeline definition
02		Creates jobs	Users codes the script to execute a concrete step of the pipeline, e.g., downloads data, pre-process data, train model, etc.	-	Data scientist	N/A	Job definition
03	Steps 01 and 02 completed	Uploads pipeline	Pipeline definition is uploaded to the platform using SDK, CLI or GUI.	POST	Data scientist	AI Platform	Pipeline ID, pipeline

Scenario							
Scenario name:	No. 3 – Manages experiments						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)

01		Creates experiment	User uses the GUI to create a new experiment	POST	Data scientist	AI Platform	Experiment ID
02	Step 01 started	Defines metadata	User introduces experiment metadata	POST	Data scientist	AI Platform	Experiment ID, Experiment metadata
03	Steps 01 and 02 completed	Reads experiment	User lists available experiments in the platform	GET	Data scientist	AI Platform	Experiment s' list
04	Step 03 started	Reads metadata	Detailed information for a specific experiment is retrieved	GET	Data scientist	AI Platform	Experiment ID, experiment metadata
05		Deletes experiment	User removes an experiment from the platform	DELETE	Data scientist	AI Platform	Experiment ID

3.1.1.2 Pipelines management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC3	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Pipelines management

Scope and objectives of use case

Scope and objectives of use case	
Scope	Management of pipelines that will produce and put in productions ML models by applying experiments to datasets.
Objective (s)	Data Scientists or Machine Learning engineers will be able to execute MLOps pipelines including the training phase in order to produce and serve models.

	The datasets and experiments available in the platform will be referenced to trigger this use case.

Narrative of the use case

Narrative of use case
Short description
MLOps pipelines are launched and managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs).
Complete description
Machine Learning engineers or data scientists have the possibility to perform CRUD operations (Create, Read, Update and Delete) for MLOps pipelines, which are stored in the FlexiGroBots AI Platform. AutoML functionalities including algorithms for Neural architecture search (NAS) and hyperparameters optimisation are provided.

Use case conditions

Use case conditions
Assumptions
An account is created in the AI Platform for the ML engineer or data scientist.
The AI Platform has access to hardware resources suitable for running ML pipelines.
Prerequisites
Datasets and experiments are available in the AI Platform.

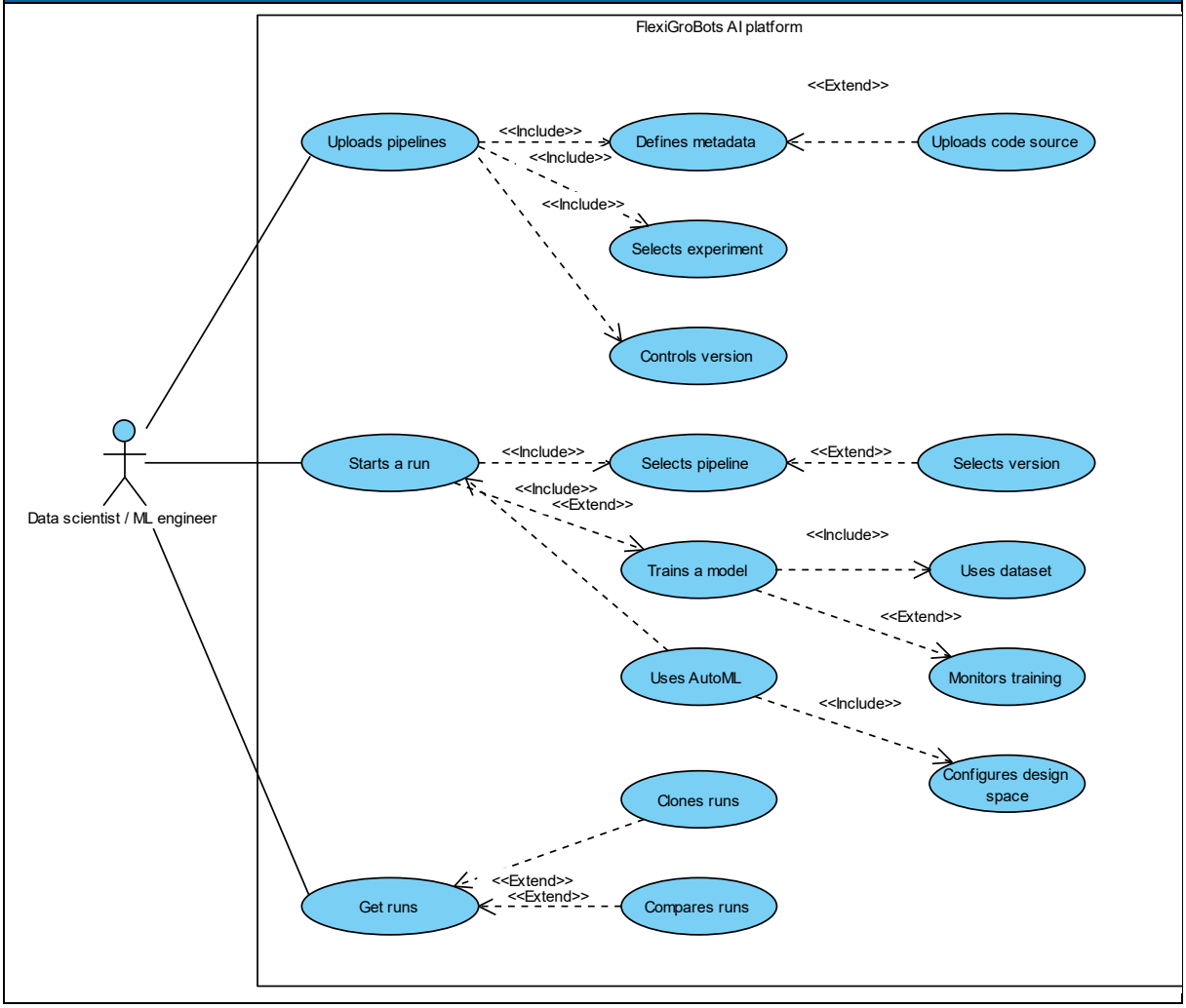
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Pipelines management is required for producing the models which are managed in AI_UC4.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case

Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
Data scientist / ML engineer	Human	Person in charge of the development of ML models	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Uploads pipelines	A training process is launched in the AI Platform.	Data scientist	N/A	Dataset is created Experiment is created	A new training is launched
2	Starts a run	A new session on Jupyter notebooks is opened for interactive experimentation which includes training a model.	Data scientist	N/A	None	A new Jupyter notebook session is launched
3	Get runs	Retrieves information about the trainings available on the platform.	Data scientist	N/A	A training is created	Trainings' information is retrieved

Steps – Scenarios

Scenario							
Scenario name:	No. 1 – Uploads a pipeline						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01		Defines metadata	User introduces metadata for the pipeline using the GUI	POST	Data scientist	AI Platform	Pipeline metadata
02		Uploads source code	Users uploads the YAML file describing the pipeline	POST	Data scientist	AI Platform	Pipeline YAML file

03		Selects experiment	From the list of available experiments, user selects the one that will contain the pipeline	POST	Data scientist	AI Platform	Experiment ID
04	Steps 01, 02 and 03 completed	Controls version	Pipeline version is controlled.	POST	Data scientist	AI Platform	Pipeline ID, pipeline version

Scenario							
Scenario name:	No. 2 – Starts a run						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Scenario 01 completed	Selects pipeline	From the list of available pipelines, the user selects the one that will be executed.	POST	Data scientist	AI Platform	Pipeline ID
02	Step 01 completed	Selects version	From available versions for a pipeline, user selects the one that will be executed.	POST	Data scientist	AI Platform	Pipeline ID, pipeline version
03	Steps 01 and 02 completed	Trains a model	A model is trained as part of the execution of the pilot	RUN	AI Platform	AI Platform	Model

04	Step 03 started	Uses dataset	An available dataset is consumed, processed and used to train the model	RUN	AI Platform	AI Platform	Dataset
05	Step 03 started	Monitors training	The platform obtains logs and metrics during the training process.	RUN	AI Platform	AI Platform	Training metrics and parameters
06	User executes AutoML instructions using the AI Platform library	Uses AutoML	AutoML libraries are used to automatically explore several architectures and configurations.	POST	Data scientist	AI Platform	
07	Step 06 started	Configures design space	User defines thresholds, objectives, search algorithms, early stopping, hyperparameters combinations, etc.	POST	Data scientist	AI Platform	AutoML parameters

Scenario							
Scenario name:	No. 3 – Get runs						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)

01	User wants to get information about runs executed on the platform	Lists runs	Available runs are listed	GET	Data scientist	AI Platform	List of runs with metadata
02	User wants to clone a run	Clones run	A run already executed in cloned and launched again	POST	Data scientist	AI Platform	Run ID, new run ID
03	User wants to understand differences between two runs	Compares run	The user compares information for two different runs	RUN	Data scientist	AI Platform	Run 1 ID, run 2 ID

3.1.1.3 Models management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC4	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Models management

Scope and objectives of use case

Scope and objectives of use case	
Scope	Management of AI models supporting precision agriculture tasks.
Objective (s)	Machine Learning models generated during MLOps workflows using the FlexiGroBots AI Platform will be integrated and used to build new applications and services supporting precision-agriculture tasks based on robotics systems.

Narrative of the use case

Narrative of use case
Short description

AI Models are managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs). The models can be downloaded in order to be integrated on-premises or consumed as a service through an API.
Complete description
The FlexiGroBots AI Platform will contain a repository with the Machin Learning models produced by the pipelines executed following AI_UC3. Data scientists will be able to handle their models from this repository and obtain detailed information about all the steps, resources and datasets which have been required to create each model, guaranteeing the traceability and reproducibility of the experiments. Two approaches are considered for the serving phase: • The models will be downloadable in several formats (i.e., original binary files, Docker images, Kubernetes manifests) for easy deployment and integration with FMS or other platforms. • It will be possible to launch an instance of the model directly on the platform and to consume the offered functionality following the "as a service" paradigm. Including this alternative as a one job of MLOps pipelines managed by AI_UC3 will be possible. During the publication step of the model, the data scientist will have functionalities to include a card describing its characteristics, addressing D2.6 recommendations.

Use case conditions

Use case conditions
Assumptions
An account is created in the AI Platform for the ML engineer or data scientist.
Prerequisites
An ML model has been generated using pipelines, experiments and datasets according to AI_UC1, AI_UC2 and AI_UC3.

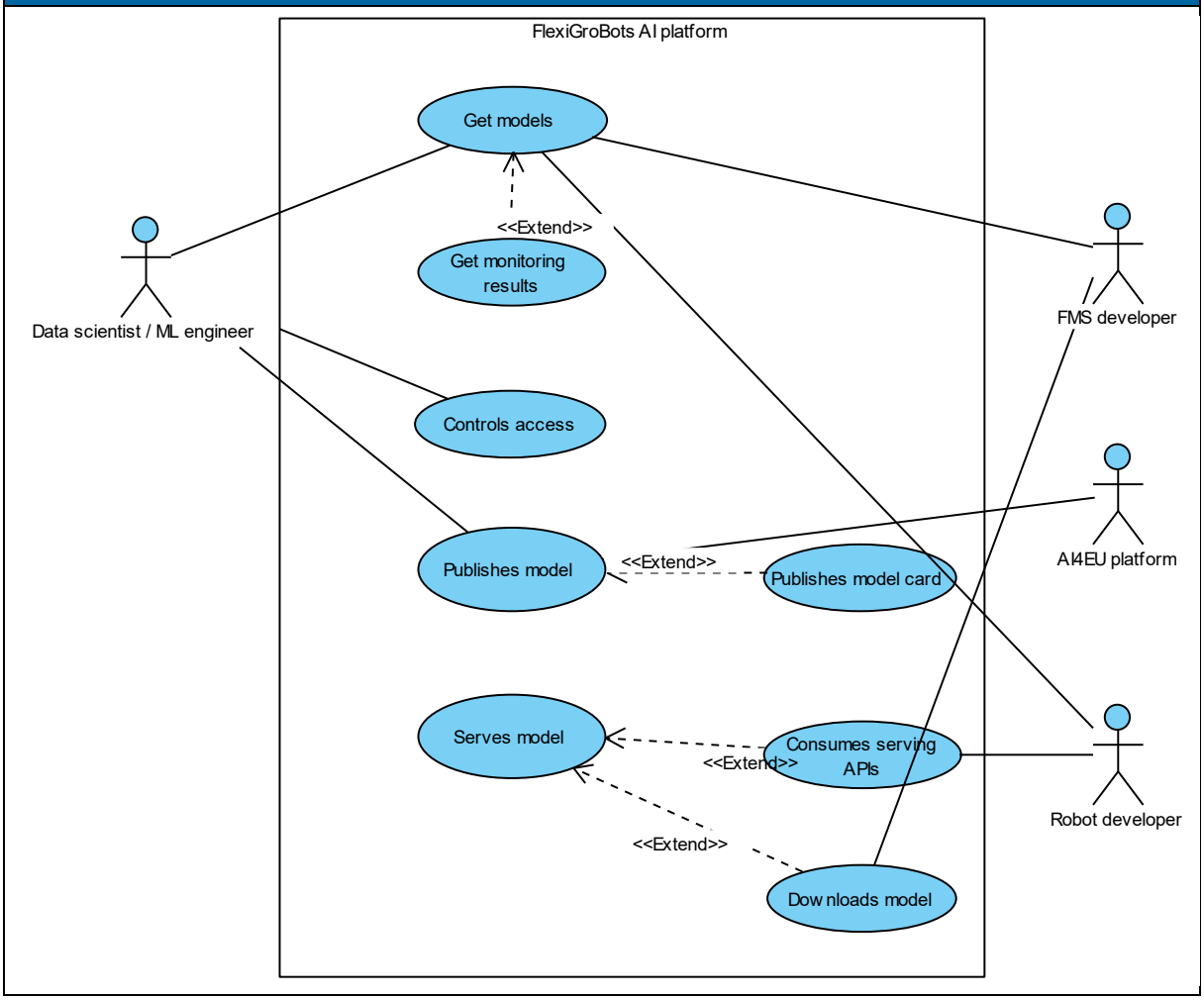
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Models management requires the previous execution of AI_UC1, AI_UC2 and AI_UC3.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation

Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



3.1.2 Common data services

No changes have been introduced with respect to the initial version of the architecture. The reader must refer to section 5.2.2 of D2.2.

3.1.3 Geospatial enablers and services

No changes have been introduced with respect to the initial version of the architecture. The reader must refer to section 5.2.3 of D2.2.

3.1.4 Common application services

Regarding the list of Common Application Services specified in section 5.2.4 of D2.2, the following changes have been done:

- The GIS (Geographic Information System) plug-in has been discarded some services will be able to get access to the features of the ODC through the standard and OGC compliant APIs.
- Two new services have been proposed:
  - An orthomosaic assessment tool, which is required by the three pilots.
  - An anonymisation tool to prevent including people's faces in the images collected by autonomous vehicles.

The specification of the two new services is included in the following subsections.

3.1.4.1 Orthomosaic Assessment Tool

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_OAT_UC5	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Orthomosaic Assessment Tool

Scope and objectives of use case

Scope and objectives of use case	
Scope	Acquire, process and evaluate high-resolution images of crop fields to generate orthomosaics and other products and develop an assessment report on potentially problematic areas in the field.
Objective (s)	1. Generate an assessment map for problematic areas.

Narrative of the use case

Narrative of use case
Short description
A common service for acquiring and processing aerial images to generate orthomosaics and other products of crop fields to create heatmaps showing a potential risk of pathology that should be checked.
Complete description

This is a common service for processing high-resolution UAV images of crop fields and evaluating derived orthomosaics generated with photogrammetry techniques. This service will use different mathematical methods to process the orthomosaic and generate an assessment report and a file including the coordinates of the potentially affected areas. The report will be in PDF and will include a heatmap showing a potential risk of pathology and therefore problematic zones in the field that should be checked. The output will consist of two documents: 1) A PDF, in which the user would find insightful information about the status of the crop. 2) A JSON file (or similar) including the coordinates of the areas potentially affected. The input should be UAV multispectral images (with the R, G, B, RedEdge, NIR and thermal channels) in GeoTiff format.

Use case conditions

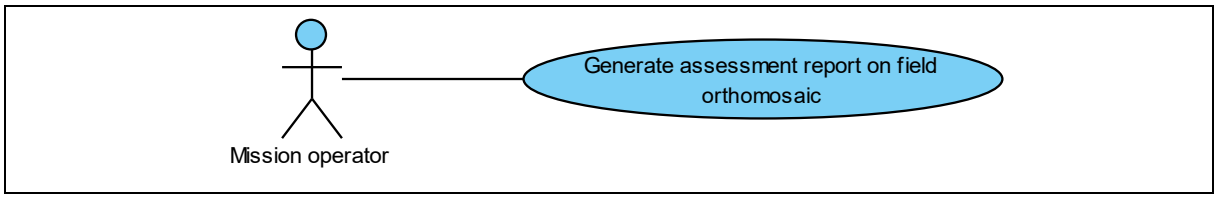
Use case conditions
Assumptions
Availability of accurate, well-rendered, high-resolution UAV images.
Prerequisites
Have adequate computer power to process such high-resolution images.
A UAV is equipped with a multispectral sensor.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Utility” category of common services.
Level of depth
Detailed
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Software module.

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Mission operator	Human	Captures and introduces UAV images to generate the orthomosaic, then consults information about the health of the crop field through the assessment report.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Generate assessment report on orthomosaic	The Mission Operator obtains UAV multispectral images and uses the tool to generate a report.	Mission Operator	N/A	Orthoimage has been already generated.	-

Steps – Scenarios

Scenario	
Scenario name:	No. 1 - Obtain assessment report on orthomosaic from the farm field.

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Assessment report request	Assessment report request	Mission Operator introduces aerial images in the system and requests an assessment report.	Orthomosaic assessment tool	-	Mission Operator		

3.1.4.2 Anonymization Tool

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_AT_UC6	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Anonymization Tool

Scope and objectives of use case

Scope and objectives of use case	
Scope	Software service to anonymize people's faces
Objective (s)	1. Anonymize people's faces in the image feed

Narrative of the use case

Narrative of use case
Short description
A software service to anonymize people's faces in images or video.
Complete description

This common service processes input images and video, detects human faces and alters the facial features beyond recognition. This modification effectively prevents for any observer to identify people by their facial features, ensuring anonymity. This service complies the with European GDPR.

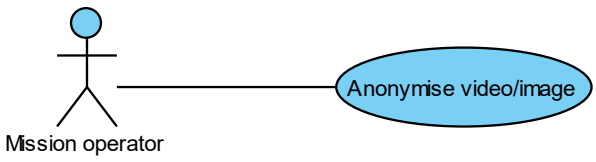
Use case conditions

Use case conditions
Assumptions
No assumptions are to be made.
Prerequisites
The service needs moderate computer power to run (low-tier GPU acceleration).

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Utility” category of common services.
Level of depth
Detailed
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Software module.

Diagrams of use case

Diagram(s) of use case


Actors

Actors	
Grouping	Group description

Actor name	Actor type	Actor description	Further information specific to this use case
Mission Operator	Human	Apply anonymization to video or image feed to ensure privacy.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Anonymize faces in video or image.	The operator modifies video or images to preserve privacy.	Mission Operator	N/A	Image or video feed is available.	-

Steps – Scenarios

Scenario								
Scenario name:	No. 1 – Request anonymization of input video/image.							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Anonymization request		Mission Operator requests visual data anonymization	Anonymization Tool	-	Mission Operator		

3.1.5 Mission Control Centre

In the case of the Mission Control Centre, a minor modification has been done in the MCC_UC4 use case to specify more explicitly the coordination capabilities that this component when several heterogeneous robotics systems are used together in the same mission. In order to maintain consistency with this change, MCC_UC4 has been renamed to Missions control and supervision.

In addition, Robot Fleet Management System (RFMS) concept is replaced by a more generic Robot Control Software (RCS). Thus, MCC_UC1 - Provisions robots, MCC_UC2 -Creates mission plan and MCC_UC3 – Executes mission is not included in the present document.

3.1.5.1 Missions control and supervision

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
MCC_UC4	Precision agriculture/ robotics system	Missions control and supervision

Scope and objectives of use case

Scope and objectives of use case	
Scope	Control, monitoring and supervision of mission execution.
Objective (s)	Ensures the safe and successful implementation of the mission plan according to the high-level goals and constraints, providing mechanisms so that the mission operator can manage and control multiple robots in parallel.

Narrative of the use case

Narrative of use case
Short description
Once the mission execution starts, the MCC collected detailed information from the robots. The data is analysed in order to detect potential failures and safety risks, launch appropriate alarms and unchaining needed corrective actions. If the mission requires the usage of diverse vehicles managed through diverse control systems, the MCC orchestrates and coordinates the different tasks.
Complete description

One of the main goals of the FlexiGroBots project is to enable the execution of complex agricultural missions by fleets of multiple heterogeneous robots with the capacity to interact between them, modifying dynamically their initial tasks according to new circumstances and events. In this sense, the role of the MCC is to obtain from the different members of the fleets (potentially through the robot control software) detailed data about telemetry and sensors' observations to assess the evolution of the mission according to the initial plan. The collected information will be analysed in order to detect real-time anomalies, incidents or potential risks. Depending on the level of criticality and the level of automation configured by the mission operator, the MCC will try to overcome the situation by enforcing appropriate actions. In all cases, notifications and alarms will be sent to the operator so that human intervention is guaranteed. The MCC is also in charge of the orchestration of the mission between the several involved vehicles.

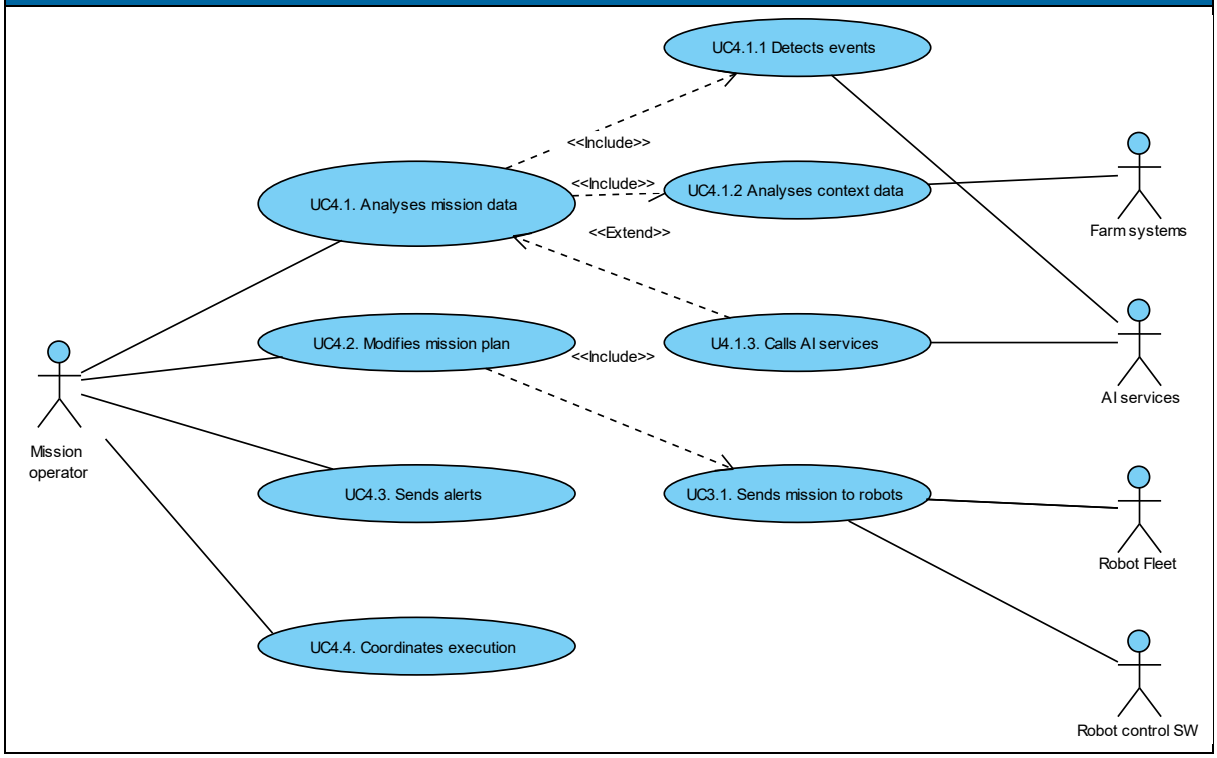
Use case conditions

Use case conditions
Assumptions
Mission operator has enough knowledge about the involved robots to safely execute the mission and monitor them.
Prerequisites
The mission plan is correct and takes into account the goals of the task and the characteristics of the field / farm.
Appropriate safety measures have been adopted taking into account potential risks.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Previous use-cases (MCC_UC1, MCC_UC2, MCC_UC3) are required for MCC_UC4.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case


Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Mission operator	Human	Responsible for the supervision and control of the mission execution.	
Robot Fleet	Device	Fleet of UAVs and UGVs in charge of implementing the mission.	
Farm systems (FMIS)	System	Digital systems are used as part of the farm operations.	
AI services	System	ML models and AI services were	

		developed using the FlexiGroBots AI Platform.	
Robot control software	System	System in charge of the low-level management of a set of robots.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Analyses mission data	Collected information from the execution of the mission is analysed and processed together with context data from other systems.	MCC	Mission is launched	Data from the mission is available	Events or failures are detected
2	Modifies mission plan	Considering unexpected situations and the evolution of the mission, the mission plan is adjusted automatically or with the intervention of the operator.	MCC	Detection of events during the mission	Data from the mission is available	Mission plan is updated
3	Coordinates execution	MCC takes care of the execution of the mission through supervision and sending actions to different	MCC	Mission is executed	The mission is started and sent to several RCSs	Multiple RCSs are coordinated

		Robot Control Software.				
4	Sends alerts	Alerts are sent to inform the mission operator about events or problems during the execution. Level of criticality is considered.	MCC	Detection of events during the mission	Data from the mission is available	Notifications are sent.

Steps – Scenarios

Scenario								
Scenario name:	No. 1 – Analyses mission data							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission is launched	Events detection	AI services are used by the MCC in order to detect issues in the data obtained from the robots.	POST	MCC	AI services	Mission data, events	
2	Mission is launched	Context data analysis	Context data from FMS, geospatial services	GET	MCC	Farm systems	Context data	

			or AI models are analysed.					

Scenario								
Scenario name:	No. 2 – Modifies mission plan							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Detection of incidents or unexpected situations during the mission	Mission plan update	The MCC introduces automatically changes in the mission plan according to the situation. In the case it is not possible, the person in charge of the robot and the automated systems built into the robot will adapt the mission plan to the new circumstances.	RUN	MCC	MCC	Updated mission plan	

2	MCC introduces changes in the mission	Plan update confirmation	The MCC requests confirmation of changes in the plan to the operator, who may add additional updates.	POST	MCC	Mission operator	Updated mission plan	
3	Mission operator confirms or introduces additional changes in the mission plan	Send mission plan	The MCC sends the updated mission plan to the robot fleet / RFMS	POST	MCC	Robot fleet / Robot control software	Updated mission plan	

Scenario								
Scenario name:	No. 3 – Coordinates execution							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	N/A	Mission status analysis	The MCC checks the progress of the mission according to the initial plan.	GET	MCC	MCC	N/A	

2	Unexpected situations are detected	Mission plan update	The MCC introduces automatically changes in the mission plan according to the situation.	RUN	MCC	MCC	Updated mission plan	
3	MCC introduces changes in the mission	Plan update confirmation	The MCC requests confirmation of changes in the plan to the operator, who may add additional updates.	POST	MCC	Mission operator	Updated mission plan	
4	Mission operator confirms or introduces additional changes in the mission plan	Send mission plan	The MCC sends the updated mission plan to the robot fleet / control software.	POST	MCC	Robot fleet / RFMS	Updated mission plan	

Scenario								
Scenario name:	No. 4 – Sends alerts							
Step No.	Event	Name of proce	Description of process / activity	Service	Information	Information	Information	Requirement, R-IDs

		ss / activity			producer (actor)	receiver (actor)	exchanged (IDs)	
1	Detection of events during the mission	Filter alerts	Considering mission configuration, MCC decides which alerts must be shown to the operator.	RUN	MCC	MCC	N/A	
2	Critical situations are detected	Show alerts	Critical alerts are shown in the MCC GUI.	POST	MCC	Mission operator	Alerts	

3.2 Development view

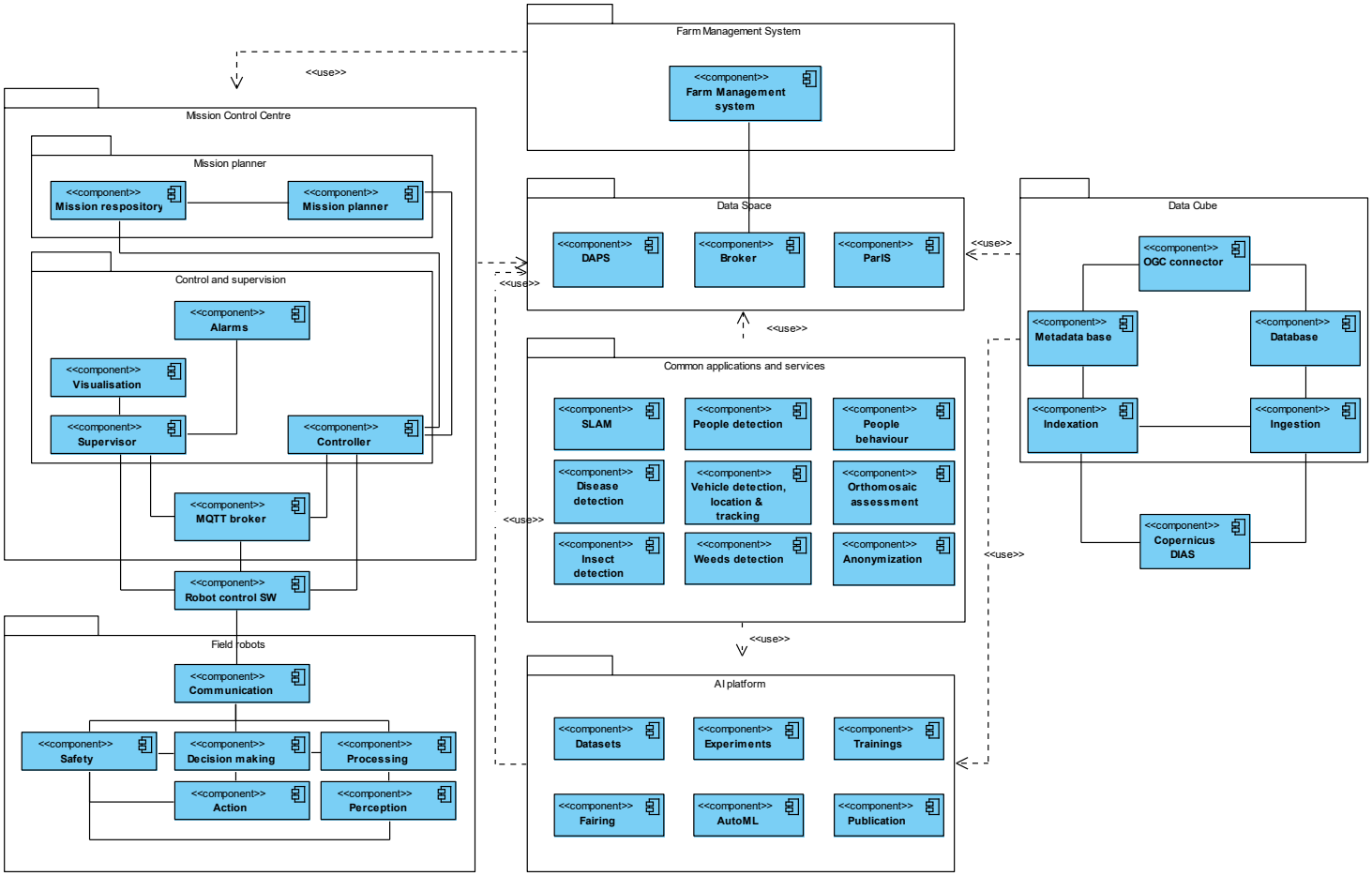


Figure 2 FlexiGroBots platform development view presented using a UML component model

Figure 2 presents the process view of FlexiGroBots platform technical architecture in the form of a UML component diagram. When compared to the initial vision included in section 5.4 of D2.2, the following aspects have changed:

- A direct connection between the FMS and the MCC is possible for those scenarios where a single stakeholder is managing the complete stack and there are no concerns in the sharing of information between the two components. In this way, the envisioned FlexiGroBots platform will be more flexible, and its application allowed for a broader set of scenarios.
- In the Common Application Services, the two new components specified in sections 3.1.4.1 and 3.1.4.2 have been added. GIS plug-in has been also removed as discussed at the beginning of this chapter.
- In the Mission Control Centre, major adaptions can be seen as a result of the discussions that have been maintained from the release of D2.2. Robotics platforms and Robot Fleet Management systems, which are out of the scope of the project, have been merged into a generic component named Robot Control Software. The communication with the MCC will be done directly to specific supervisor / controllers or through an MQTT broker depending on each specific implementation. The MCC has been also divided into two groups of components: on one hand, the planning and on the other hand the control and supervision.

3.3 Logical view

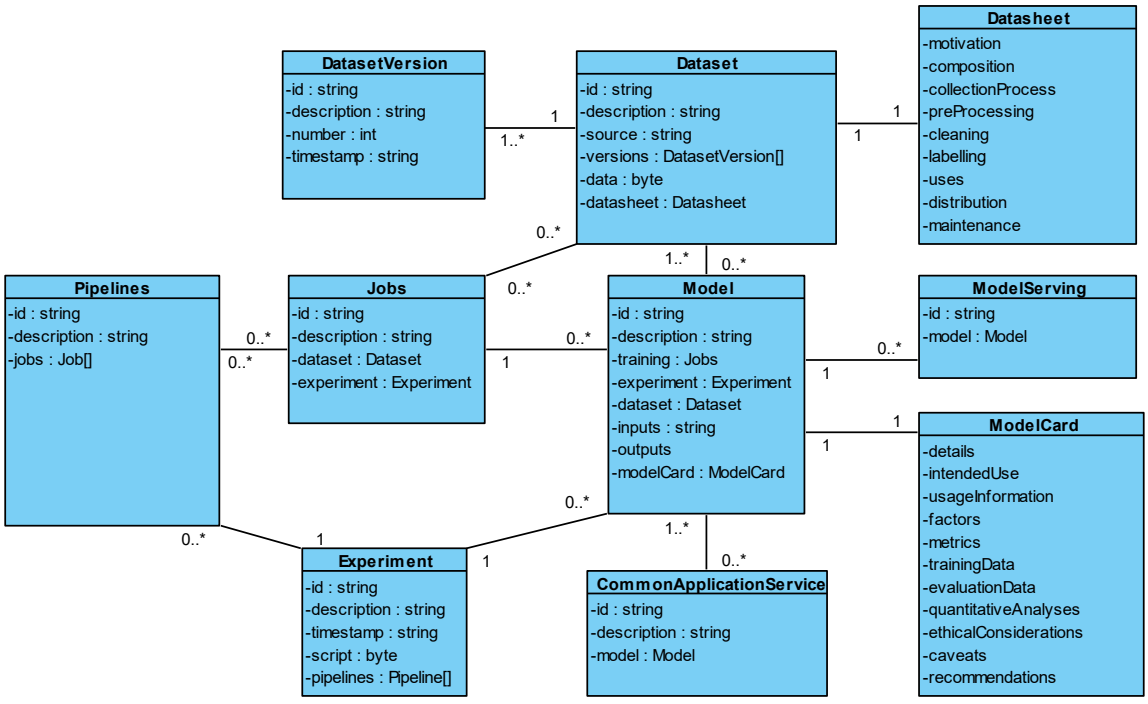


Figure 3 Logical view of FlexiGroBots AI Platform and Common Application Services

Figure 3 presents the new version of the logical view model for two FlexiGroBots subsystems: the AI Platform and the Common Application Services. The only relevant changes in the UML diagram are:

- Cards for both datasets and models following the recommendations of D2.6 has been added.
- The adaption of the diagram to better reflect the objects required to build MLOps workflows using *Pipelines* and *Jobs* as explained in section 3.1.1.

For the Mission Control Centre, a new class diagram is included in Figure 4.

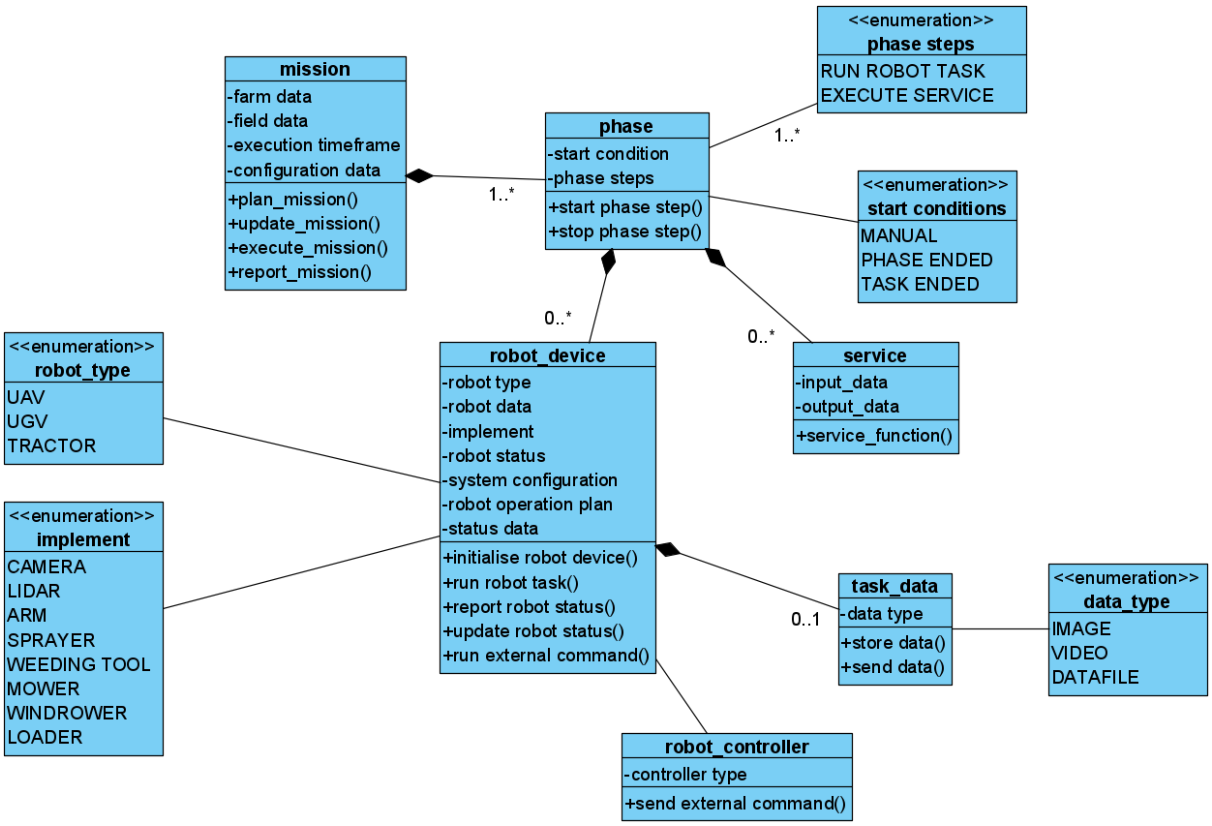


Figure 4 Logical view of FlexiGroBots MCC

The level of details has been increased from the previous version especially to illustrate the required information that will be needed to represent missions and their phases.

3.4 Process view

No changes have been introduced with respect to the initial version of the architecture. The reader must refer to section 5.5 of D2.2.

3.5 Physical view

Figure 5 presents the UML deployment diagram for the FlexiGroBots platform, which corresponds to the UML component model or development view in Figure 2.

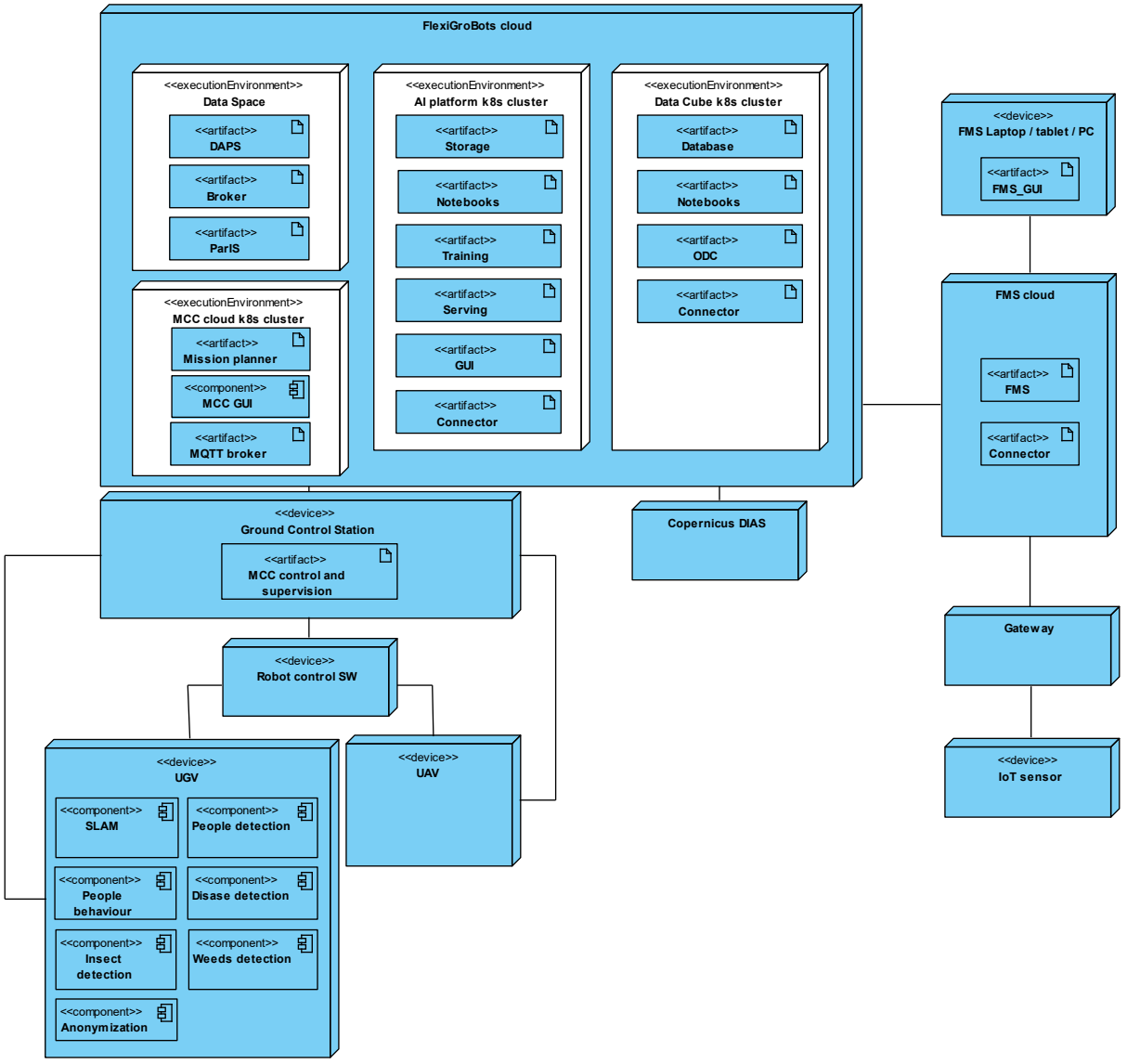


Figure 5 FlexiGroBots architecture physical view model

In this case, the diagram shows that the functionalities of the MCC for supervision and control will be deployed at the Ground Control Station, near the field vehicles in order to guarantee appropriate and secure operation. In the cloud realm, the MCC planner will be hosted.

4 Conclusions

This document presents the update of the FlexiGroBots platform architecture and technical specifications, providing a detailed description of the expected functionalities to be implemented and the main technical building blocks that will be developed in order to support the execution of missions by fleets of heterogeneous vehicles. FlexiGroBots platform architecture and technical specification have been derived from an exhaustive evaluation of the requirements imposed by the main stakeholders of the project and also leveraging the results and lessons learnt from multiple initiatives and projects.

The deliverable is built leveraging the content of the previous version of D2.2, which included a detailed analysis of the outcomes of some of the most prominent European initiatives in the area of emerging digital technologies and data spaces, i.e., International Data Spaces, GAIA-X, FIWARE and the Copernicus programme. In all the cases, FlexiGroBots will have a strong alignment with them through the adoption of IDSA concepts as a core element of the platform architecture and the implementation of specific connectors and the integration of the Open Data Cube.

The document provides the evaluation of functional and non-functional requirements that have been extracted thanks to the inputs provided by the three pilots and by the experience and knowledge of all the partners.

The core content of D2.3 is devoted to the introduction of FlexiGroBots' platform architecture. Its vision is completely aligned with the European Data Space concept, having the ambition to constitute one of the first agricultural embryonic data spaces. By embracing IDSA reference architecture and principles, FlexiGroBots will aim to achieve secure and safe data flows between several platforms and stakeholders, promoting interoperability and the creation of new business opportunities. The architecture introduces novel concepts, such as the presence of a specific AI Platform that should facilitate the seamless creation of powerful ML models, including access to powerful hardware and software technologies. It will include a set of off-the-shelf AI common services that will be directly applicable to multiple precision agriculture scenarios, some of them specific to robotics solutions. The exploitation of satellite images and remote sensing data will be also possible since an Open Data Cube system will be also part of the solution. Finally, the outputs of all these elements will be powerful inputs to guide the execution of complex missions by fleets of heterogeneous robots, under the planification, supervision and control of the Mission Control Centre.

The functionalities of each of the components of the FlexiGroBots platform are described in detail following the IEC 62559 standard, including use-cases diagrams, presentation of involved actors and expected exchanges of information. Following the 4+1 architectural view

model, logical, development, process and physical views have been also proposed for the introduced architecture.

The implementation of the different modules of the FlexiGroBots platform architecture will be done and reported in WP3 through deliverables D3.2 and D3.3.

With respect to the previous version of the FlexiGroBots platform architecture, changes have been introduced in all the layers of the specification in order to reflect the interactions with the project pilots and the evolution of the concepts achieved through the prototypes.

References

[1] "International Data Spaces Association," [Online]. Available: https://internationaldataspaces.org/.

[2] E. Parliament, "Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT) AND AMENDING CERTAIN UNION LEGISLATIVE ACTS," [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0206.

[3] H.-L. E. G. o. A. I. (. HLEG), "Ethics Guidelines for Trustworthy AI," [Online]. Available: https://ec.europa.eu/futurium/en/ai-alliance-consultation.1.html.

[4] "D2.2 - Requirements and platform architecture specifications 1," 2021. [Online]. Available: https://flexigrobots-h2020.eu/sites/flexig/files/public/content-files/deliverables/FLEXIGROBOTS_D2.2_Requirements%20and%20platform%20architecture%20specifications_v1.0.pdf.

[5] "D2.1 Stakeholder view to FlexiGroBots system scenarios," September 2021. [Online]. Available: https://flexigrobots-h2020.eu/sites/flexig/files/public/content-files/deliverables/FLEXIGROBOTS_D2.1_Stakeholder%20view%20to%20FlexiGroBots%20system%20scenarios_v1.0.pdf.

[6] "D4.1 Pilot 1 objectives, requirements and design," December 2021. [Online]. Available: https://flexigrobots-h2020.eu/sites/flexig/files/public/content-files/deliverables/FLEXIGROBOTS_D4.1.%20Pilot%201%20objectives%2C%20requirements%20and%20design_v1.0.pdf.

[7] "D5.1 Pilot 2 objectives, requirements and design," December 2021. [Online]. Available: https://flexigrobots-h2020.eu/sites/flexig/files/public/content-files/deliverables/FLEXIGROBOTS_D5.1_Pilot%202%20objectives%2C%20requirements%20and%20design_v1.0.pdf.

[8] "D6.1 Pilot 3 objectives, requirements and design," [Online]. Available: https://flexigrobots-h2020.eu/sites/flexig/files/public/content-files/deliverables/FLEXIGROBOTS_D6.1_Pilot%203%20objectives%2C%20requirements%20and%20design_v1.0.pdf.

[9] "FlexiGroBots GitHub repository," [Online]. Available: https://github.com/FlexiGroBots-H2020.

[10] "D3.1 FlexiGroBots Platform v1," December 2021. [Online]. Available: https://flexigrobots-h2020.eu/sites/flexig/files/public/content-files/deliverables/FLEXIGROBOTS_D3.1_FlexiGroBots%20platform_v1.0.pdf.

[11] "High-level expert group on artificial intelligence," [Online]. Available: https://digital-strategy.ec.europa.eu/en/policies/expert-group-ai.

[12] “TensorFlow,” [Online]. Available: https://www.tensorflow.org/.

[13] PyTorch. [Online]. Available: https://pytorch.org/.

[14] “Scikit-learn,” [Online]. Available: https://scikit-learn.org/stable/.

[15] “Jupyter Notebook,” [Online]. Available: https://jupyter.org/.