FLEXIGROBOTS

D5.1 Pilot 2 objectives, requirements and design

Document Identification			
Status	Final	**Due Date**	31/12/2021
Version	1.0	**Submission Date**	23/12/2021

Related WP	WP5	**Document Reference**	D5.1
Related Deliverable(s)	D2.2, D2.7, D3.2, D5.2, D5.3	**Dissemination Level (*)**	PU
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Co-funded by the Horizon 2020 Programme of the European Union

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Document History			
Version	Date	Change editors	Changes
0.1	10/05/2021	Juha-Pekka Soininen (VTT)	Initial document created
0.2	31/05/2021	Juha-Pekka Soininen (VTT)	Use cases tables added to the document
0.4	15/06/2021	Jere Kaivosoja (LUKE)	Updates
0.6	05/11/2021	Jere Kaivosoja (LUKE)	Updates
0.7	19/11/2021	Jere Kaivosoja (LUKE)	All inputs
0.8	02/12/2021	Jere Kaivosoja (LUKE)	Updated version for the internal review
0.9	20/12/2021	Jere Kaivosoja (LUKE)	Reviewed full version
1.0	23/12/2021	Jere Kaivosoja (LUKE)	FINAL VERSION TO BE SUBMITTED

Quality Control		
Role	Who	Approval Date
Deliverable leader	Jere Kaivosoja (LUKE)	15/12/2021
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List of Acronyms

Abbreviation / acronym	Description
AI	Artificial Intelligence
D5.1	Deliverable number 1 belonging to WP 5
ECU	Electronic controller unit
EFDI	Extended farm management Information systems data interface
FMS	Farm Management System
IPM	Integrated pest management
KPI	Key performance indicator
MAVLink	Micro Air Vehicle Link
ML	Machine Learning
NDVI	Normalized difference vegetation index
SDK	Software development kit
TC	Task Controller
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
WP	Work Package

Executive Summary

This document is a deliverable of the FlexiGroBots project, funded by the European Commission under its Horizon 2020 Framework Programme (H2020). It is the resulting work carried out by the partners involved in the development of Pilot 2 (WP5) in terms of analysis, objectives definition, requirements gathering and design. This document also collects all functional and non-functional requirements of the pilot for all the components involved. The document provides an overview of the system to be developed in the next phases to achieve the objectives marked for WP5. The main outcome of this document is the pilot specific implementation architectures and the detailed definition of the use case plan. This document provided an overview of the systems to be developed within the FlexiGroBots-project.

1 Introduction

1.1 Purpose of the document

The purpose of the document is to present the objectives, specifications, and design of the Finnish pilot, i.e., pilot 2 in the FlexiGroBots project. FlexiGroBots project aims at developing the use of multi-robot fleets, artificial intelligence, and data spaces concepts in agricultural environments. The Finnish pilot will focus on three main use cases related to silage harvesting, pest management, and Rumex weeding that further divide into seven sub-use cases. This document presents the current understanding of the Pilot design, and that may be iteratively updated during the project execution to meet the objectives in the best manner.

1.2 Structure of the document

This document is structured in 6 major sections:

- Section 1: is the introduction.
- Section 2: presents the objectives of Pilot 2.
- Section 3: describes the specification of the seven identified use cases of Pilot 2 to be developed.
- Section 4: describes the identified datasets that will be shared in the scope of the FlexiGroBots project.
- Section 5: describes the involved robots, devices and platforms.
- Section 6: includes conclusions related to this deliverable.

2 Pilot objectives

The integrated pest management (IPM) of oil crops is challenging. It would require up to daily visits to the field and often include excess pesticide control to ensure being on the safe side. Silage harvesting is a timely intensive process where heavy machinery and human labour is needed. Silage, oil crops and cereals are commonly farmed on the same farm with the same machinery. The objectives of WP5 are to specify, implement, execute and assess Pilot 2 that focuses on piloting FlexiGroBots solutions in pest management of oil crops and harvesting of silage by integration of unmanned ground vehicles to the typical farm practices, which can reduce the work payload and perform tasks with higher accuracy decreasing amount of needed time and resources.

This Pilot 2 will demonstrate how robotics and information technologies can change the way of farm management by automatization of the farm tasks, optimal usage of resources, active preventing the possible difficulties in the growing instead of treatment the consequences. These advantages can be achieved by organizing existing and affordable farmers technologies (tractor driving system, drones, ground robotic vehicles with robotic arms and data processing methods) in a new high-level control system. This system will help to advance agriculture to the next technological level fitting the Industrial revolution 4.0 and response to the climatic challenges.

WP5 pilot objectives include:

- Demonstrating the performance of automated tasks related to the specific crops such as silage harvesting missions, pest identification and extermination mission.
- Automated robot/drone collaboration, where joint mission is created by the FlexiGroBots platform and executed automatically and/or with limited participation of humans.
- Demonstrating the use of agriculture data space and its services in robot mission creation, execution and reporting.

To enable the above pilot objectives, the project also fulfils the following sub-objectives:

- Specifying, designing, and implementing the pilot systems and components and providing actual ICT solutions supported by AI-driven robotics state of the art technologies that can be reused by other solutions (e.g., demonstrators) even beyond the project lifetime.
- Collection and assessment of key performance indicators.
- Developing and applying methods according to personal data protection.

Five project partners are contributing to this work package. VTT leads the WP and focuses on the ICT design, system architecture and piloting. LUKE's focus is the agricultural context including farm machinery, data collection and practical piloting while having a research approach. MTECH company as a Farm management system (FMS) provider clarifies and demonstrates the role of an essential FMS in relation to Pilot robotics. Probot company brings the best know-how of robotics and demonstrates the UGV applicability with prototype systems. Finally, the partner CEPS participates in the Pilot assessment from an international point of view.

3 Description of use cases

This chapter gives a detailed description of Pilot 2 use cases. It consists of two parts. The first subsection is the overview of Pilot 2 scenarios that shows relationships between the use cases. The second subsection gives the descriptions of seven use cases of Pilot 2 in a form of IEC 62559 (use case methodology) tables [1].

3.1 High-level description

Pilot 2 consists of three main use cases: silage harvesting, rumex weeding from silage fields and pest management of rapeseeds. Pilot 2 takes place in Finland, where the growing season is a short period of time between May and September. Rapeseed and silage are crops that can be grown at the same farm and in the same fields.

A high-level overview of pilot 2 is presented in Figure 1. The main components are farm management system (FMS), IoT platform, multi-robot control system, and FlexiGroBots platform services. The core of the pilot is the FMS that is a tool by which the farmer interacts with other services that are tested. FMS also delivers the results to the farmer in visualized form or reports. The multi-robot control system controls the autonomous missions executed by tractors, UGVs or drones and their payload tools depending on the use case. The IoT platform collects the data during mission performance. The FlexiGroBots services are the identification and analysis services based on AI and geolocation data. All system parts are connected through IDSA based agriculture data space.

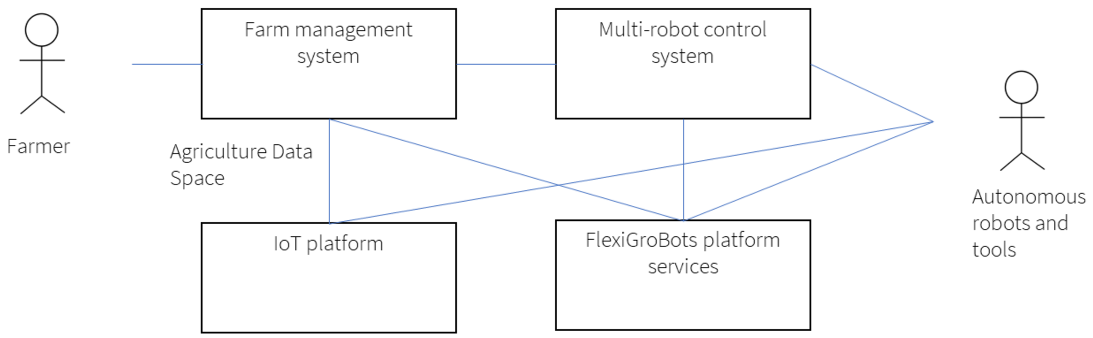


Figure 1. Overview of the main components in Pilot 2

These main use cases are divided into sub-use cases that are described in more detail in Chapter 2.3. Table 1 describes the main motivations of each sub-use case and Figure 2 gives the workflow of sub-use cases later called as use cases A to G.

Use case	Description of the main problems and the role of robots and AI in them
Silage harvesting use case: Silage harvesting is a resource-demanding task with a narrow time frame as silage is typically maturing simultaneously. The use case focuses on improving the predictability of resource demand, more accurate timing of harvesting itself and more efficient resource utilization by using robots.	
Harvesting planning	The timing of harvesting is critical in silage production. The optimal time depends on the digestibility of silage and resource constraints. All fields in the area typically get ready at the same time leading to complex logistics problems. The digestibility is analysed from crop samples at laboratory and from satellite images. The project aim is to perform the imaging mission using drones and to analyse the digestibility using hyper/multispectral images.
Multi-tractor harvesting mission	Silage harvesting is a complex process that requires seven tractors with different tools at the same time in the field. Modern tractors have ISOBUS control systems that can be used for autonomous execution of harvesting tasks. The project aim is to test at least one tractor totally autonomously collaborating with other tractors.
Situation monitoring	Silage fields are open spaces, and autonomous devices introduce safety threats. Since the monitoring capabilities of tractors are limited, the use case extends the situation monitoring with separate drone/camera system that can create a bird-eye view of the field and simplify the threat and hazard detection.
Pest management use case: The pests cause major loss of rapeseed crops. The main objective is reducing the amount of used pesticides by having early detection of pests and using the precision spraying done by autonomous robots.	
Rapeseed mapping survey mission	Precision spraying is the target of the use case. It requires that we know the growth stage of the rapeseed in the field. The rapeseed field is monitored during autonomous aerial imaging missions based on a fixed flight plan.
Pest detection	The main challenge in pest detection is the small size of the pest. The parameters that are needed to be studied before the actual choices for pest detection can be made. The alternatives are the detection of actual insects or damages caused by the insects. The accuracy of images needed is another parameter to be considered. For pest detection and localization, an AI service will be developed in WP3.
Pest spraying mission	The plan is to demonstrate autonomous spraying missions using a spraying drone or ISOBUS-tractor spraying, depending on the

Use case	Description of the main problems and the role of robots and AI in them
	required spraying amount. The spraying mission plan will be based on previously created pest location maps.
Rumex weeding use case: Rumex is a typical weed in Finnish grass fields. The main issue with Rumex is that animals do not want to eat, and they even try to avoid the surroundings of the Rumex. It contaminates silage and repeals animals. The weeding of Rumex as early as possible would improve the efficiency of silage production.	
Rumex mapping mission	Rumex mapping will be based on aerial imaging made by drones monitoring on a pre-planned flight path.
Rumex detection	The Rumex detection with exact location in the field and position of each plant will be done using developed AI service detecting and locating the Rumex plants from aerial images.
Rumex weeding mission	The Rumex will be weeded by UGV equipped with a weeding tool. The UGV mission will be planned based on pre-recorded driving routes and detected locations.

Table 1. Overview of the Pilot 2 use cases

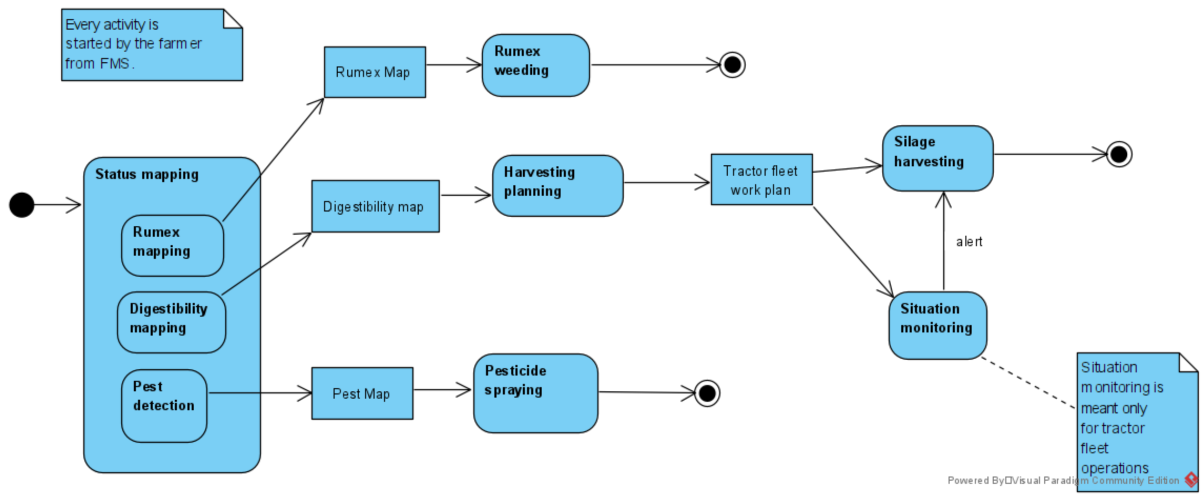


Figure 2. The main workflow of use cases. Rumex mapping includes both mapping and detection parts. Pest detection included both pest mapping and detection parts. Digestibility mapping is separated from harvesting planning as it is similar to other status mapping activities

3.2 Use case descriptions

This chapter will present the detailed use cases descriptions in a form of IEC 62559 standard tables. Seven use cases are described: A) Robotized tractor in silage fleet, B) Pesticide spraying with tractor or drone, C) Situation awareness of tractor fleets, D) Grass and rapeseed status mapping, E) Rapeseed pest detection, F) Rumex weeding, and G) Silage harvesting plan. Description, scope, narrative, key performance indicators, conditions and technical details are provided for each use case.

3.2.1 Use case A: Robotized tractor in silage fleet

3.2.1.1 Description of the use case

3.2.1.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2A		Robotized tractor in silage fleet

Table 2. Use case A identification

3.2.1.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	A robotized tractor capable of accomplishing complete raking tasks on a field as a part of an operating silage harvesting fleet.
Objective (s)	Autonomous operation under supervision during harvesting of an entire field
Related business case (s)	Silage harvesting

Table 3. Scope and objectives of the use case A

3.2.1.1.3 Narrative of use case

Narrative of use case
Short description
A robotized tractor in a silage harvesting fleet operates the windrower machine autonomously. The tractor-windrower combination drives along a planned route within the harvested field while other tractor-machine combinations are also working. A dedicated supervisor monitors the work of the robotized tractor.

Narrative of use case
Complete description
Silage harvesting is an intensive task where multiple tractors, machines and drivers are needed for a short period of time. A fleet may consist of for example a mover, a tedder/windrower, a windrower and a loader wagon or a baler. A robotized tractor in a silage fleet shall operate the windrower machine autonomously. The tractor-windrower combination drives along a pre-planned route within the mowed field in parallel with other tractor-machine combinations. A dedicated supervisor (person) will monitor the robotized tractor application. It is important that the robotized tractor does not restrict or limit the works of other tractors in the fleet (schedule, path). The robotized tractor consists of standardized ISOBUS communication to machinery, automatized GNSS-based navigation, throttle, steering and turnovers, remote control, and an integrated vision system for obstacle avoidance. The robotized tractor system manages the entire field operation autonomously based on the mover path. If sudden obstacles appear, the robotized tractor stops and waits for new instructions. The communication between the robotized tractor and the supervisor shall be ensured and the tractor stops if there are deviations in the wireless communication. The mission plan follows ISOBUS standardization.

Table 4. Narrative of the use case A

3.2.1.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2AKpi_01	Labour costs	The utilization of a robot tractor in silage fleet shall decrease the need for human labour when the robotized tractor supervisor can simultaneously operate additional working unit. The benefit is calculated based on the average labour needed for the tasks operated by a robotized tractor.	Labour costs

Table 5. Key performance indicators of the use case A

3.2.1.1.5 Use case conditions

Use case conditions
Assumptions
Additional supervision for the pilot execution safety.
Prerequisites
Regulations have to be captured completely before this kind of autonomous tractor driving can be implemented on wide scale. Infrastructure for autonomous tractor and mower is ready on farm.

Table 6. Use case A conditions

3.2.1.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Status mapping (include) / harvesting plan (include) / situation awareness (associate)
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
test

Table 7. Classification information of the use case A

3.2.1.1.7 General remarks

General remarks
This use case does not claim to be exhaustive regarding the functionality of a robotized tractor in a fleet operation

3.2.1.2 Diagrams of use case

Diagram(s) of use case

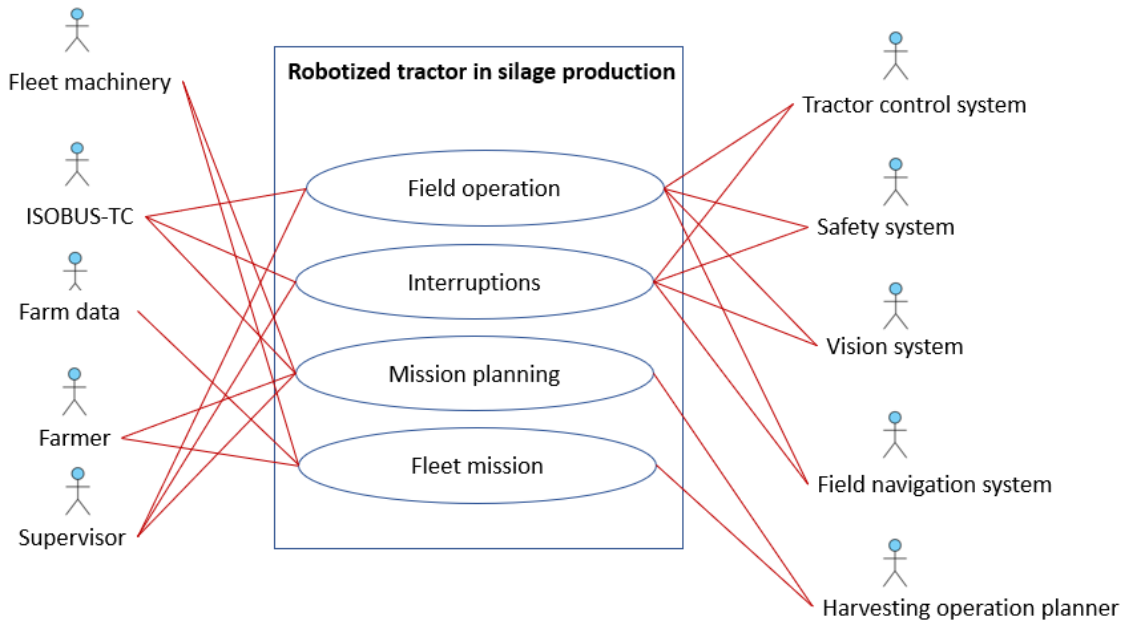


Figure 3. Use case diagram for robotized tractor in silage production

3.2.1.3 Technical details

3.2.1.3.1 Actors

Actors			
Grouping		Group description	
Safety system			
Actor name	Actor type	Actor description	Further information specific to this use case
Tractor safety systems	System	A tractor built-in safety systems	These need to be bypassed/managed in a controlled manner
Stop buttons	System	Emergency stop buttons	Stop buttons in each corner of the tractor
Controller handshake	System	Automatic system checking connection between the remote control and the tractor	Handshake between tractor and the remote controller
User interface	System	Interface for the supervisor	Tractor remote controller for the user

Actors			
Grouping		Group description	
Other actors			
Actor name	Actor type	Actor description	Further information specific to this use case
Tractor control system	System	A system controlling the tractor actions: steering, braking, gears, throttle.	Specific access is enabled by the manufacturer.
Vision system	System	A measurement system for the real-time environment detection	Zed2 stereo camera-based vision system
Field navigation system	System	A positioning and kinematics system.	Calculates navigation directions.
Harvesting planner	System	Plans the harvesting process for the whole fleet.	Specifically delivers navigation plan for the windrower.
Supervisor	Human	Describes the person who is responsible for the actions of the robotized tractor.	Dedicated person in the use case.

Actors			
Grouping		Group description	
Farmer	Human	Describes the person managing the fields.	Manager of the farming process at the field.
Farm data	System	Data repository for farming-related data.	Field-specific data.
ISOBUS-TC	System	Task Controller (TC) is the software that automates commands for the Electronic Controlled Unit (ECU).	Standard TC at the tractor.
Fleet machinery	External machinery	Mover, windrower and loader wagon	Other machines involved in the harvesting process

Table 8. Actors of the use case A

3.2.1.3.2 References

Actors						
No.	References type	Reference	Status	Impact on use case	Originator / organisation	Link
	Standard	ISOBUS, ISO 1783	Final	Medium	AEF	https://www.iso.org/standard/57556.html

Table 9. References of the use case A

3.2.1.4 Step by step analysis of use case

3.2.1.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
01	Fleet mission	The silage harvesting mission is prepared	Harvesting plan	Fields are ready for the harvest.	Farm management monitors the field status.	A general plan for the fleet in the fields is ready.
02	Mission planning	The mission for the robotized tractor is planned.	Fleet machinery	Fleet is operating and navigation data about harvestin	Grass cutting operation is recorded.	Mission for the robotized tractor is ready.

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
				g is available.		
03	Field operatio n	The robotized tractor operates in the field according to the plan	Tractor control system	Superviso r accepts the mission planning results	The mission for the robotized tractor is planned, and the tractor is located in a correct position.	Field operation is accomplished, and the tractor stops.
04	Intercept ion	The operation is intercepted by internal or external factors. The tractor stops immediately if it is needed. Supervisor, farmer, ISOBUS-TC, fleet machinery, tractor control system, vision system, safety system feed data for the tractor for the decision. After interception, the system waits for the recovery command.	Safety system	Intercepti on for the mission occurs.	Field operation is carried out by the robotized tractor.	Field operation continues.

Table 10. Overview of scenarios in the use case A

3.2.1.4.2 Steps - Scenarios

Scenario name							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Informat ion produce r (actor)	Informati on receiver (actor)	Informat ion exchang ed (IDs)
01	Fleet mission preparati	Preparati on of data	Relevant data from farm data repository is	GET	Farm data	Harvestin g	AI-01

Scenario name							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
	on data is gathered		delivered for the harvesting planner			operation planner	
02	Fleet mission is prepared	Overall mission plan	Overall silage fleet mission is planned in the Harvesting planner, and the relevant machinery are informed (application tasks for ISOBUS-TC's)	CREATE	Harvesting operation planner	Fleet machinery	AI-02
03	Fleet mission is launched	Mission launch	Farmer approves the silage harvesting mission and starts the execution.	EXECUTE	Farmer	Fleet machinery	AI-03
04	Robot tractor mission is prepared	Robot tractor mission inputs	Relevant fleet machinery delivers mission navigation data to Harvesting planner	GET	Fleet machinery	Harvesting operation planner	AI-04
05	Robot tractor mission is planned	Robot tractor plan	Mission planning for the robot tractor	CREATE	Harvesting operation planner	ISOBUS-TC	AI-05
06	Mission execution	Mission starts	Task controller in the robotized tractor gets the mission and	EXECUTE	Supervisor	ISOBUS-TC, Safety system	AI-06

Scenario name							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
	permission		starts the operation				
07	Mission execution starts	Request to execute	The TC and the supervisor enable the mission to be executed	CREATE	ISOBUS-TC	Tractor control system, field navigation system	AI-07
08	Mission execution process	Robot tractor operating	The robot tractor is executing the farming operation and activates the sensors	REPEAT	Tractor control system	Vision system, safety system	AI-08
09	Mission continuation	Continuous mission surveillance	The safety systems are informing that operation is safe	CHANGE	Safety system	Tractor control system	AI-09
10	Mission execution reporting	Work data logging	The executed work is continuously reported	CHANGE	Tractor control system	ISOBUS-TC	AI-10
11	Mission interruption	Mission paused	Mission interruption is observed, and the tractor stops	CANCEL	Safety system, vision system, supervisor	Tractor control system	AI-11
12	System status	Mission status reporting to the supervisor	The tractor status is reported to the supervisor	REPORT	Tractor control system	Supervisor	AI-12

Scenario name							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
13	Mission update request	Request updated mission/task	A relevant actor delivers information that requires an updated mission (rain, low fuel, fleet interruptions)	CHANGE	Vision system, Supervisor, Farmer, ISOBUS-TC	Harvesting operation planner	AI-13
14	Mission update	Get new task	Harvesting planner delivers an updated mission	CHANGE	Harvesting operation planner	ISOBUS-TC	AI-14
15	Mission finishing	The field operation is done	Finish mission	CLOSE	ISOBUS-TC	Supervisor, tractor control system	AI-15

Table 11. Scenarios of the use case A

3.2.1.5 Information exchanged

Information exchanged, ID	Name of information	Description of information exchanged
2AI-01	Silage harvesting plan	The farm data repository sends a silage harvesting plan including fields ids and harvesting in order to the harvesting operation planner.
2AI-02	Harvesting operation plan	The harvesting operation planner sends the application ISOBUS-task or equivalent to each fleet machinery.
2AI-03	Fleet mission activation	The farmer accepts and activates mission execution in binary form for each machinery unit.
2AI-04	Robot mission preparation	Tractor navigation data including set of coordinates is sent to the harvesting operation planner.
2AI-05	Application task for raking	An ISOBUS-based application task for raking operation for the field under action.
2AI-06	Execution launch	Supervisor gives a confirmation including safety acceptance to start the field operation.
2AI-07	Mission execution	The ISOBUS-TC sends commands for field operation execution to the machinery including navigation coordinates, machinery settings and adjustments, steering commands, throttle commands, brakes, headland turns.
2AI-08	Internal monitoring system activation	Tractor control system sends its operational status to the vision system and to the safety system.
2AI-09	Work acceptance	The safety systems are enabling the operation, continuous binary status.
2AI-10	Work reporting	The tractor control system reports its real-time status to the ISOBUS-TC which records process data.
2AI-11	Stop mission	Safety system, vision system or supervisor send binary information for the tractor control system to stop the execution immediately.
2AI-12	Mission status information	Tractor control system reports the real-time status to the supervisor.
2AI-13	Request a mission update	Active sensors monitor the environment and fleet conditions including rain, low fuel, fleet interruptions for mission updates.

Information exchanged, ID	Name of information	Description of information exchanged
2AI-14	Mission update	Harvesting operational planner creates a new application task based on plans and executed work reports.
2AI-15	Mission finishing	ISOBUS-TC sends binary reports about the finished mission, to the supervisor and the tractor control system.

Table 12. Information exchanged in the use case A

3.2.1.6 Common terms and definitions

Common terms and definitions	
Term	Definition
ISOBUS	ISO 11783, known as Tractors and machinery for agriculture and forestry—Serial control and communications data network
EFDI	Extended farm management system data interface. The guidelines [1] provide an extensible communication system concept and define rules for adding new functionalities to cover specific use cases for the communication between ISOBUS machines and FMIS systems

Table 13. Common terms and definition of the use case A

3.2.2 Use case B: Pesticide spraying

3.2.2.1 Description of the use case

3.2.2.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2B		Pesticide spraying with tractor or drone

Table 14. Use case B identification

3.2.2.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	Conducting an application task for precision spraying by drone or tractor
Objective (s)	To enable spraying application for drone or tractor
Related business case (s)	Rapeseed farming

Table 15. Scope and objectives of the use case B

3.2.2.1.3 Narrative of use case

Narrative of use case
Short description
When pests on rapeseed are detected, a pesticide spraying application task is prepared. Depending on the task specification, a tractor sprayer combination or a spraying drone will operate the task.
Complete description
Flexible spraying tools can give better treatment when selective spraying of only invaded areas is needed. A spraying drone and a tractor-sprayer combination offer two different ways to spread pesticides. The drone can spray on-demand to the hotspots or specific areas without stamping the crops, while the tractor can spray the whole field efficiently. Based on the pest detection (use case E) and distribution, the FMS creates an ISOBUS-application task for the drone or for the tractor. The tractor can use the ISOBUS task as it is, but for the drone the ISOBUS task will be converted to a suitable format. The criteria for the spraying tool selection include the drone capacity (4*15 litres), total infected area, features of active substance, weather conditions, detected pests and estimated time criticality.

Table 16. Narrative of the use case B

3.2.2.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2BKpi_01		The usage of the same task for tractors and drone reduces the amount of applied pesticides: the drone acts when it is sufficient. The benefit is the difference between regular spraying to drone-based hotspot spraying.	
2BKpi_02		Better quality of the farm product	
2BKpi_03		Decrease of the environmental load.	

Table 17. Key performance indicators in the use case B

3.2.2.1.5 Use case conditions

Use case conditions
Assumptions
Pest species are identified
Prerequisites
Spraying system infrastructure is ready on farms. The detection rate of the pest detection system is high enough.

Table 18. B, use case conditions

3.2.2.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Use case E delivers information about pests
Level of depth
Generic/detailed Use Case
Prioritisation
Essential
Generic, regional or national relation
Generic
Nature of the use case
Pesticide spraying

Table 19. Classification of the use case B

3.2.2.2 Diagrams of use case

Diagram(s) of use case

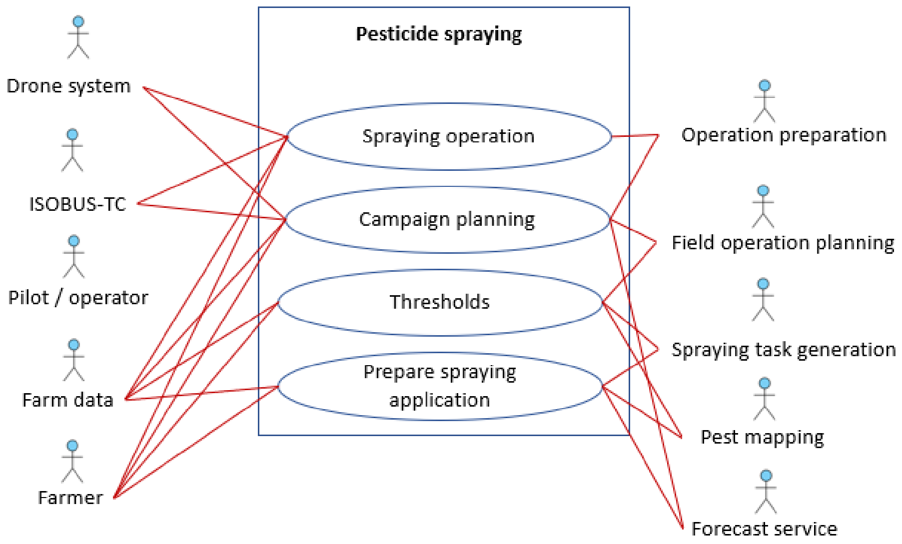


Figure 4. Use case diagram for pesticide spraying

3.2.2.3 Technical details

3.2.2.3.1 Actors

Actors			
Grouping		Group description	
Spraying task generation			
Actor name	Actor type	Actor description	Further information specific to this use case
ISOBUS-task generator	Service	Describes service calculating an ISOBUS-application task for precision spraying	Zones for different rates
Drone mission planner	Service	Describes service calculating an application task for spraying drone	This includes both the flying pattern and the application rate.

Actors			
Grouping		Group description	
Other actors			
Actor name	Actor type	Actor description	Further information specific to this use case
Pest mapping	Service	Method for definition of invaded areas by interpolation of the point pests' detections.	Including extrapolation to field corners. Practical thresholds are used.
Forecast service	Service	Providing a weather forecast related to relevant fields.	Monitoring all factors influencing the task performance.
Field operation planning	Service	Algorithm planning a detailed field task.	This combines the route/track/path and the task
Operation preparation	Service	Describes the service that prepares the operation for the machinery.	Navigation plan, operation timing.

Actors			
Grouping		Group description	
Farmer	Human	Describes the person managing the fields.	Responsible for robot activation and supervision.
Farm data	System	Repository with data related to the task.	Field boundaries and farming history from the current season.
Pilot / operator	Human	Person operating the drone.	Drone pilot.
Drone system	System	Spraying drone system.	Spraying and monitoring drones.
ISOBUS-TC	System	ISOBUS tractor task controller and user interface.	Task controller in the robotized tractor

Table 20. Actors, use case B

3.2.2.4 Step by step analysis of use case

3.2.2.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
01	Prepare spraying applicatio n	The spraying operation is planned	Pest mapping	Pest occurrence is mapped	Pest occurrence is mapped	Spraying map is created
02	Threshold s	The border conditions of the spraying are calculated	Spraying task generation	Spraying map is created	Spraying map is created	Pesticide usage and machinery are selected
03	Campaign planning	A detailed spraying task is combined and launched	Field operation planning	Border conditions are defined	Border conditions are defined	Field work is planned

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
04	Spraying operation	The spraying work is done at the field	Drone system / ISOBUS-TC	Field work is planned	Field work is planned	Spraying work is done

Table 21. Overview of the scenarios in the use case B

3.2.2.4.2 Steps - Scenarios

Scenario name:							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Data for campaign task design is gathered	Preparation of suitable data	Relevant data for the processing is selected	GET	Forecast service, Farmer, Farm data	Pest mapping	AI-01, AI02, AI-03
02	Pest mapping	Pest occurrence mapping	Pointwise data is processed to a map	CREATE	Pest mapping	Spraying task generation	AI-04
03	Triggering conditions	Data for spraying conditions	Data for relevant conditions are selected	GET	Farm data, farmer	Spraying task generator	AI-05, AI-06, AI-07
04	Threshold's determination	Thresholds	Thresholds for spraying are determined	CREATE	Farm data	Spraying task generation	AI-08, AI-09, AI-10
05	Pest-control map	Map for the pest-control	Mapping of pesticide usage	CREATE	Spraying task generator	Field operation planning	AI-11, AI-12

Scenario name:							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
06	Spraying campaign is planned	Overall spraying plan	The spraying campaign is planned, machinery is selected	CREATE	Field operation planning, Farmer, Forecast service	Operation preparation	AI-13, AI-14, AI-15
07	Spraying operation ready	Field operation preparation	The field operation including navigation is prepared	CREATE	Operation preparation	Drone system / ISOBUS-TC	AI-16
08	Spraying	Spraying operation	Field is sprayed with pesticides	REPORT	Drone system / ISOBUS-TC	Farm data	AI-17

Table 22. Scenarios in the use case B

3.2.2.5 Information exchanged

Information exchanged, ID	Name of information	Description of information exchanged
2BI-01	Farm data for campaign planning	Crop, seeding time, the timing of field operations
2BI-02	Farmer observations	Spatial observations: points or vectors or whole field-based notes about pests
2BI-03	Forecast service	Data about forecasted temperature and rain
2BI-04	Pest map	Interpolated raster map illustrating pest occurrence at the field
2BI-05	Total invaded area	Numbers illustrating hectares that need to be sprayed
2BI-06	Suitable substances	Suitable compounds and required amounts
2BI-07	Farmer observations	Manual changes to existing values
2BI-08	Selected compounds	Selected liquid
2BI-09	Restrictions	Restrictions related to compounds
2BI-10	Other restrictions	Other restrictions
2BI-11	Spraying map	Spraying map in vector format
2BI-12	Spraying conditions	Required conditions
2BI-13	Spraying map	Selected map
2BI-14	Forecast service	Rain forecast
2BI-15	Farmer observations	Manual changes
2BI-16	Work plan	Navigation data and spraying map
2BI-17	Work execution report	Work report as point data

Table 23. Information exchanged in the use case B

3.2.3 Use case C: Situation awareness of tractor fleets

3.2.3.1 Description of the use case

3.2.3.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2C		Situation awareness of tractor fleets

Table 24. Use case C identification

3.2.3.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	Implementation of a situation awareness service that supports multi-robot fleet management during the silage harvesting
Objective (s)	To increase the reliability and safety of the system, the situation awareness of the tractor fleet is strengthened by adding one or a number of drones taking bird-eye images during the harvesting operation. The objective is to detect tractors, UVGs, and possibly other objects, such as people or animals from the field, identify them, predict their trajectories, update the situation on the field map for viewing, and warn the system of possible hazards such as collisions. The aim is to increase the reliability and safety of the system.
Related business case (s)	Silage harvesting using multiple ISOBUS tractors.

Table 25. Scope and objectives of the use case C

3.2.3.1.3 Narrative of use case

Narrative of use case
Short description
A service for monitoring the situation at the field where tractors and robots are working. The service provides situation information to users and alerts users and autonomous systems when possible hazards are detected. Task recovery after alert is done by user.
Complete description
When a robotized tractor operates in a non-closed area together with other tractor units, a separate monitoring system can improve the situation awareness of the robot tractor, especially when the GNSS position of all the working units is not available. This tool uses drone images and/or other camera images from tractors/robots in real-time to calculate the position of the robotized tractor and the positions of other working units close by. The service also creates an alert in case of collisions or objects representing a possibility for colliding (animals, people, …) are detected. This information is transferred to the interface of the supervisor of the robotized tractor. The system tolerates switching of drones and interruptions of data stream and is independent of remote controlling of the tractor robot.

Table 26. Narrative of the use case C

3.2.3.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2CKpi-01	Labour cost	With the external and independent monitoring system, the robot tractor supervisor can simultaneously operate additional tasks, e.g., drive another tractor in the field. This KPI enables the KPI in use case A thus the benefit is the same.	Labour cost
2CKpi-02	Increased safety	Detection time is increased, and the total number of risks is decreased	Safety

Table 27. Key performance indicators in the use case C

3.2.3.1.5 Use case conditions

Use case conditions
Assumptions
Use case takes place when multi-tractor fleet is doing silage harvesting.
Prerequisites
Silage harvesting is started. Farm management system can visualise the situation to the user. All active machines must be connected to this service to be able to report their locations.
Drone with camera ready to fly.

Table 28. C, use case conditions

3.2.3.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Silage harvesting
Level of depth
Generic
Prioritisation
Mandatory/optional
Generic, regional, or national relation
National (because of drone legislation).
Nature of the use case
Service test

Table 29. Classification of the use case C

3.2.3.1.7 General remarks

General remarks
This is an idea of a service that could improve the safety and security of the operation of an autonomous fleet by providing an independent view of the system situation. Motivation is also to build external service that can be easily tailored to any kind of situation.

3.2.3.2 Diagrams of use case

Diagram(s) of use case

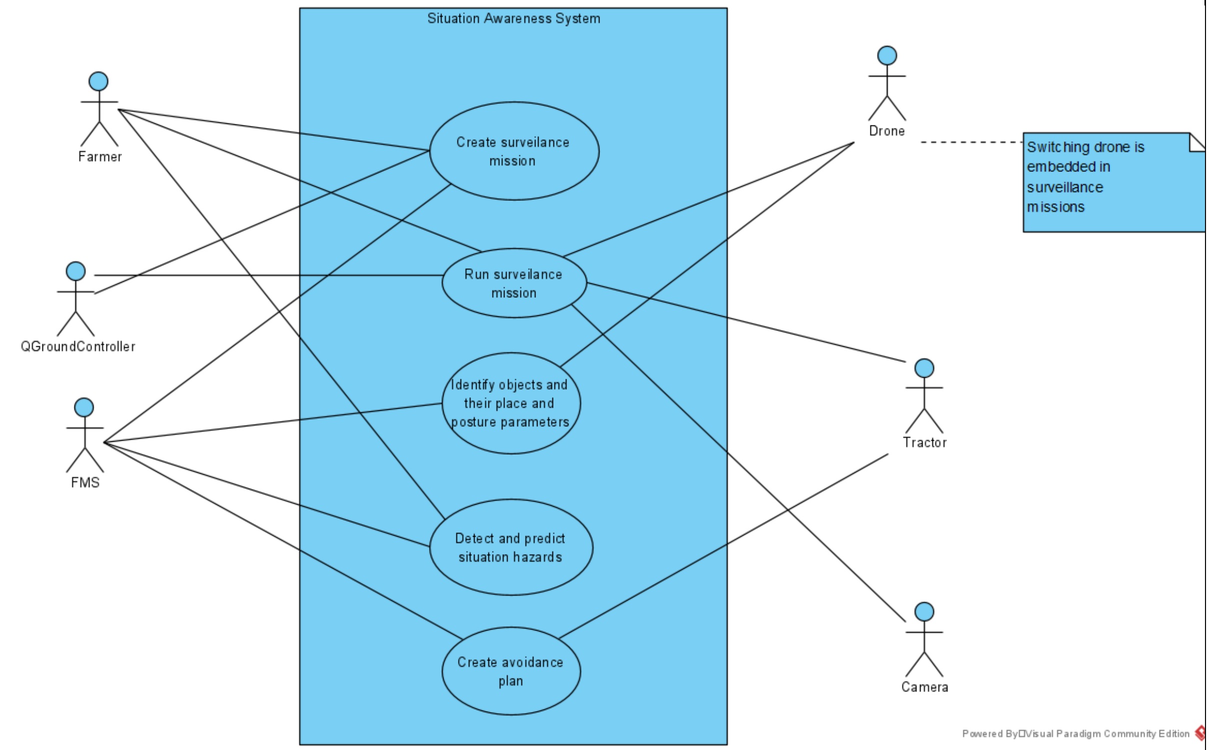


Figure 5. Use case diagram for situation awareness system

3.2.3.3 Technical details

3.2.3.3.1 Actors

Actors			
Grouping		Group description	
Robots		Autonomous systems	
Actor name	Actor type	Actor description	Further information specific to this use case
Tractor	Machine	Machine doing autonomous tasks during silage harvesting.	Robotized tractor with a windrower.
Drone	Machine	Drone with a camera payload during harvesting.	Imaging drone collecting real-time data.

Table 30. Actors, use case C

3.2.3.3.2 Overview of scenarios

Actors			
Grouping		Group description	
Other actors		Autonomous systems	
Actor name	Actor type	Actor description	Further information specific to this use case
Farm management system (FMS)	System	Software used for farm management, activating tasks, monitoring task execution and results.	Detailed farm data.
GroundController	System	System used for controlling drone.	Controls the imaging drone.
Camera	Device	Camera taking images or video for situation monitoring.	Camera system of the imaging drone.

Table 31. Overview of the scenarios in the use case C

3.2.3.3.3 References

Actors						
No.	References type	Reference	Status	Impact on use case	Originator / organisation	Link
1	Standard	ISOBUS	Final	Low	ISO 11783	iso.org
2	Software	OpenDroneMap	Final	Medium	Open Ecosystem Community	https://www.opendronemap.org/
3	Software	Drone control system (MAVLINK)	Final	High	MAVLink developer community	https://mavlink.io/en/
4	Format	Camera image formats (JPEG)	Final	Medium	ISO 10918	iso.org
5	Format	Video image format (H264)	Final	Medium	ITU	https://www.itu.int/en

Table 32. References of the use case C

3.2.3.4 Step by step analysis of use case

3.2.3.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Create surveillance mission	Farmer creates a drone flight mission.	Farmer, QGroundControl, FMS	Crop starts to get ready for harvesting	None	Surveillance mission plan in FMS database.
2	Run surveillance mission	Drone flies on top of the field where tractor fleet is operating. During the flight either images or videos are taken and forwarded to analysis.	Farmer/ QGroundControl/ FMS	Farmer starts the silage harvesting and the situation monitoring service.	Mission plan is available.	Drone landed after mission. Service is ended.
3	Identify objects and their place and posture parameters	The service receives image/video from the drone and analyses each frame to detect the objects such as tractors, and their positions.	Drone/ Camera	Image or video received.	Situation monitoring service started.	Situation map stored in the system.
4	Detect and predict situation hazards	The service detects possible collisions by analysing the sequences of situation maps.	FMS	New situation map available.	Situation monitoring service started.	If hazard is detected, robots and farmer are alerted.
5	Create avoidance plan	The functionality waits for farmers acceptance to continue mission.	Farmer FMS	Hazard detected.	Situation monitoring service running.	Mission continued or aborted.

Table 33. Overview of the scenarios in the use case C

3.2.3.4.2 Steps - Scenarios

Scenario							
Scenario name:	No. 1 – Create surveillance mission						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Farmer starts planning	Create mission	Open QGroundcontrol	CREATE	Farmer	QGC	
02	Farmer selects the field	Upload field	Upload the field map to planning SW	GET	FMS	QGC	7
03		Add point	Add starting point to plan	CREATE	Farmer	QGC	8
04		Add parameters	Add parameter describing image frequency to plan	CREATE	Farmer	QGC	9
05		Add drone change	Add parameter for drone change and change routine	CREATE	Farmer	QGC	10
06	Plan complete	Save plan	Save MAVLINK file to FMS	PUT	QGroundControl	FMS	1

Scenario							
Scenario name:	No. 2 – Run surveillance mission						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Farmer plans to execute mission	Select mission	Farmer selects and uploads mission to drone	GET	FMS	Drone	1
02	Farmer starts the mission	Fly to entry point	Drone flies the mission	EXECUTE	Drone	FMS	11
03	Point reached	Fly to next point	Drone flies the mission	EXECUTE	Drone	FMS	11
04	Time to take picture	Take picture	Camera takes an image and sends it to the analysis service	EXEC	Camera	FMS	2
05	Endpoint reached	Stop mission	Drone lands and stops	CLOSE	Drone	FMS	11
06	Battery minimum reached	Switch drones	Execute drone change routines	EXEC	Drones, FMS	Drones, FMS	1, 11

Scenario							
Scenario name:	No. 3 – Identify objects and their locations						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Farmer starts the mission	Activate service	Surveillance service activated; map created	CREATE	FMS	FMS	7
02	Picture available	Analyse picture	Service receives the pictures and analyses them	GET	Camera	FMS	4
03	Mission ends	End	Service stopped	CLOSE			

Scenario							
Scenario name:	No. 4 – Detect and predict situation hazards						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Image analysed	Detect collision analysis	Service estimates objects movement and detects possible hazard situations	EXEC		FMS	
02	Hazard detected	Alert	Service alters farmer, FMS and tractors about collision	EXEC	Service	Farmer, FMS, Tractor	5

Scenario							
Scenario name:	No. 5 – Create an avoidance plan						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Farmer gives permission to continue	Resume to mission	Tractor fleet continues to mission	EXEC	Farmer	Tractor	12
02	Farmer aborts the mission	Abort	Tractor fleet stops the missions. Drones return to the end point	EXEC	Farmer	Tractor, Drone	13

Table 34. Scenarios in the use case C

3.2.3.5 Information exchanged

Information exchanged		
Information exchanged, ID	Name of information	Description of information exchanged
2CI-1	Surveillance mission plan	Flight plan for the surveillance drone
2CI-2	Image/Video	Image taken by drone camera
2CI-3	Object information	Object type (or ID) and position from object detection
2CI-4	Situation map	Map of the field with detected objects and their movement vectors
2CI-5	Hazard alert event	Event for robots to stop and wait
2CI-6	Avoidance plan	Robot movement plan for farmer to accept and robot to execute after acceptance
2CI-7	Field Map	Map of the field where surveillance mission is executed
2CI-8	Point	Mission point coordinated (location + height)
2CI-9	Image parameter	Time between pictures taken
2CI-10	Drone Change	MAVLINK file and battery parameter for Drone change
2CI-11	Location point	Location of drone (same as point)
2CI-12	Resume	Command
2CI-13	Abort	Command

Table 35. Information exchanged in the use case C

3.2.4 Use case D: Grass and rapeseed status mapping

3.2.4.1 Description of the use case

3.2.4.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2D		Grass and rapeseed status mapping

Table 36. Use case D identification

3.2.4.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	Map the up-to-date field status
Objective (s)	To increase the situation awareness of the grass and rapeseed field growth status
Related business case (s)	Drone imaging service

Table 37. Scope and objectives of the use case D

3.2.4.1.3 Narrative of use case

Narrative of use case
Short description
Drone imaging campaigns on rapeseed fields and grasslands are carried out. The imaging data is processed as mapped, and the maps are classified for field anomalies, weeds, yield status and pests.
Complete description
Automated systems and AI solutions need up-to-date information about crops growth state, i.e., average, number of unfolded leaves, status of flowering or ripening. In addition, information about weeds, field heterogeneity and anomalies can improve AI models (use case G). These tools provide classified orthophotos from rapeseed fields and grasslands. Variable imaging tools and software tools are used, and the spatially oriented knowledge (classified maps with agreed themes) is delivered as a result. These results have an impact on the timing of the pest detection execution (use case E), silage harvesting (use case G) and Rumex weeding (use case F).

Table 38. Narrative of the use case D

3.2.4.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2DKpi_01	Decreasing labour needs	The up-to-date information about the grass and rapeseed fields is a key element when planning the timing of the field operations and inspections. It decreases the need for additional field visits and thus decreases the needed human labour. The impact is calculated based on the time saving of the additional up to daily field visits.	Decreasing labour needs
2DKpi_02	Rumex mapping	The detection of Rumex-weeds initializes targeted weeding operations thus decreasing manual labour needs and preventing spreading of weeds.	Decreasing labour needs and crop losses
2DKpi_03	Silage status mapping	The silage status mapping determines the grass growth status and makes it possible to optimize the harvesting time.	Increasing of digestible yield
2DKpi_04	Infestation status	Measuring the infestation status makes it possible to develop on-demand pesticide control.	Avoiding crop losses

Table 39. Key performance indicators in the use case D

3.2.4.1.5 Use case conditions

Use case conditions
Assumptions
Changing UAV regulations may affect the communication between UAVs and the systems.
Prerequisites
Up to date UAV regulations are considered.

Table 40. D, use case conditions

3.2.4.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Status mapping delivers information for the Use cases E (pest detection), F (rumex weeding) and G (harvesting plan). The pest detection use case also reports details for the Status Mapping –use case.
Level of depth
Generic/detailed Use Case
Prioritisation
Recommendable
Generic, regional or national relation
Generic
Nature of the use case
Status mapping, drone imaging, image classification

Table 41. Classification of the use case D

3.2.4.1.7 General remarks

General remarks
This use case does not claim to be exhaustive regarding the functionality of a Status Mapping of rapeseed and grass fields.

3.2.4.2 Diagrams of use case

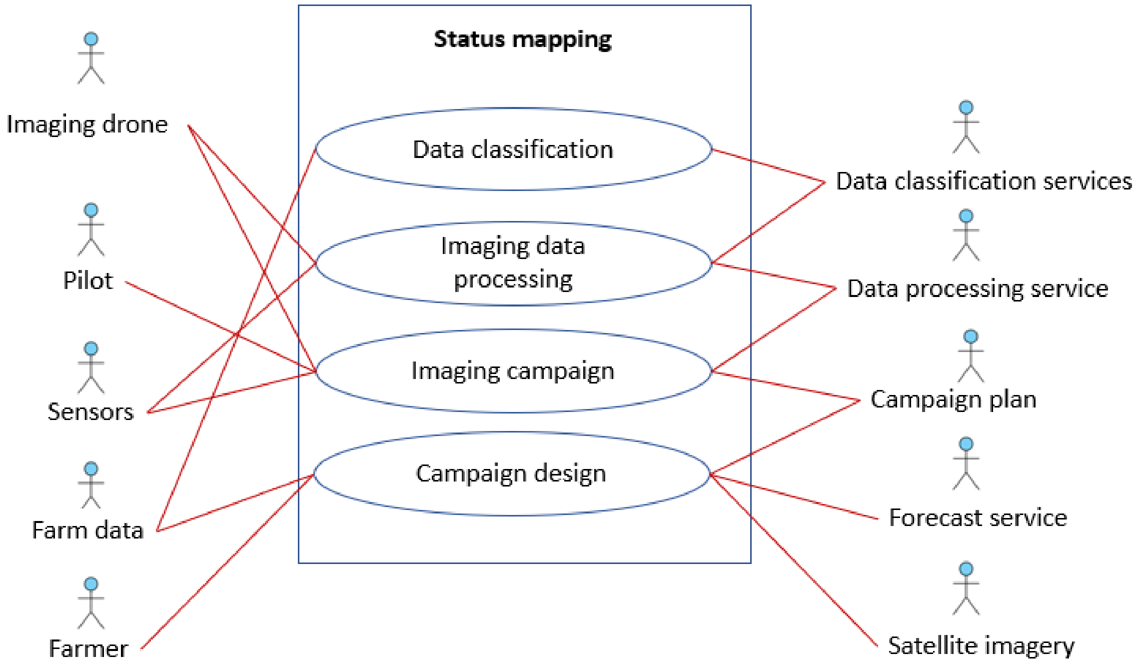
Diagram(s) of use case


Figure 6. Use case diagram for status mapping

3.2.4.3 Technical details

3.2.4.3.1 Actors

Actors			
Grouping		Group description	
Sensors		Measurement sensors	
Actor name	Actor type	Actor description	Further information specific to this use case
RGB-camera	Sensor	Acquiring images in visible spectrum.	Data for relative greenness and 3D models.
Multispectral camera	Sensor	Acquiring images with optimized wavelengths, including reference panels.	Practical camera solution for specific cases (yield and digestibility).
Hyperspectral camera	Sensor	Acquiring images with many spectral bands, including reference panels.	Setup for detecting small spectral differences.

Actors			
Grouping		Group description	
Data classification services		Services for data classification	
Actor name	Actor type	Actor description	Further information specific to this use case
Anomaly detection	Service	Classifying exceptional areas from a drone-based map.	Classes: normal field, anomaly, other.
Grass yield status	Service	Estimation of grass yield and digestibility from drone-based maps.	This service can use reference measurements from the field to ensure good quality data.
Rumex weeds	Service	Detects individual Rumex weeds from a pasture or grass field maps based on drone imaging.	Output is a binary raster map showing the potential spots of Rumex weeds.
Rapeseed flowering status	Service	Detects the status of flowering on a rapeseed field.	Pest invasion is related to flowering.

Actors			
Grouping		Group description	
Other actors		Other sensors	
Actor name	Actor type	Actor description	Further information specific to this use case
Campaign plan	Service	Planning the imaging campaigns.	The flying and imaging mission planning.
Forecast service	Service	Forecasting weather-related to relevant fields.	Forecasting weather factors influencing the task performance: rain, wind, etc.
Satellite imagery	Service	Providing access to classified satellite imagery data.	Sentinel-2 images
Farmer	Human	Person managing the fields.	Farm manager
Farm data	System	Data repository for farming-related data.	Relevant field-specific data
Pilot	Human	Person operating the drone.	The drone operator
Imaging drone	System	Imaging drone system.	Applied drone, DJI Phantom 4 RTK

Table 42. Actors, use case D

3.2.4.3.2 References

Actors						
No.	References type	Reference	Status	Impact on use case	Originator / organisation	Link
1	Regulation	EASA regulations		High	EASA	

Table 43. References of the use case D

3.2.4.4 Step by step analysis of use case

3.2.4.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
01	Campaign design	An imaging campaign is planned	Campaign plan	Field observations are needed	Growing season is progressing	Plans for specific imaging campaigns are made
02	Imaging campaign	A specific imaging campaign is carried out	Imaging drone	Time of the planned campaign is current	The relevant imaging campaign is planned	The imaging data is collected
03	Image data processing	The collected imaging data is processed as a map	Data processing service	The imaging data is collected	The imaging data is collected	The imaging data is processed as a map
04	Data classification	A relevant classification to the processed map	Data classification services	The imaging data is processed as a map	The imaging data is processed as a map	A classified map

Table 44. Overview of the scenarios in the use case D

3.2.4.4.2 Steps - Scenarios

Scenario							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
No. 1 – Task design							
01	Data for campaign designs are gathered	Preparation of data	Relevant data is delivered for the campaign plan	GET	Farm data Farmer Satellite imagery Forecast service	Campaign plan	AI-01, AI-02, AI-03, AI-04

Scenario							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
No. 1 – Task design							
02	Imaging campaign plan	Planning of imaging campaign	Data is used for accurate imaging campaign plan	CREATE	Campaign plan	Imaging drone, pilot	AI-05, AI-06
No. 2 – Imaging campaign							
03	Imaging	Drone imaging campaign	A relevant imaging campaign is carried out	EXECUTE	Imaging drone	Sensors	AI-07
04	Data capture	Imaging data capture	Onboard sensor collects data	CREATE	Sensors, imaging drone	Data processing service	AI-08, AI-09
No. 3 – Imaging data processing							
05	Map creation	Processing of imaging data	Processes from image data to maps	CREATE	Data processing service	Data classification services	AI-10
No. 4 – Data classification							
06	Map classification	Classification	Classification of mapped data	CREATE	Data classification services	Farm data	AI-11, AI-12, AI-13, AI-14

Table 45. Scenarios in the use case D

3.2.4.5 Information exchanged

Information exchanged

Information exchanged, ID	Name of information	Description of information exchanged
2DI-01	Farm data for campaign planning	Crop, seeding time, timing of field operations
2DI-02	Farmer observations	Spatial observations: points or vectors or whole field-based notes about mapping need
2DI-03	Classified satellite imagery data	Pre-classified satellite imagery such as NDVI-maps in raster/vector format
2DI-04	Weather and forecast data	Data about cumulative, current and forecasted temperature and rain
2DI-05	Imaging campaign plan	Flying patterns, such as KML-format and requested parameters (etc. Nadir, and altitude)
2DI-06	Imaging time and conditions	Requested date and time and setups
2DI-07	Request to take images	Request to take images based on coordinates, distance or time interval
2DI-08	Imaging dataset	Single images jpg/raw or other
2DI-09	Calibration values	Single predefined values for data processing
2DI-10	Processed multilayer map	Calibrated and georeferenced map in raster-format (etc. GeoTiff raster map)
2DI-11	Anomaly map	Detected anomalies as vector zones
2DI-12	Grass yield maps	Map illustrating the estimated grass yield and a map illustrating the estimated digestibility in raster formats
2DI-13	Rumex weed spots	Detected spots of Rumex weeds as point data
2DI-14	Rapeseed status	Illustrated relative growth status of rapeseed field as raster/vector map

Table 46. Information exchanged in the use case D

3.2.5 Use case E: Rapeseed pest detection

3.2.5.1 Description of the use case

3.2.5.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2E		Rapeseed pest detection

Table 47. Use case E identification

3.2.5.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	Implementation of a pest detection system based on imaging
Objective (s)	Mapping the extent of the rapeseed pests on a field
Related business case (s)	Rapeseed farming

Table 48. Scope and objectives of the use case E

3.2.5.1.3 Narrative of use case

Narrative of use case
Short description
A system where close-range low-altitude drone or a UGV will collect pointwise imaging data from the rapeseed field is developed. The occurrence of pests will be determined from the images and a pest map covering the field will be interpolated.
Complete description
The verification of existing pests and their distribution is a key in Integrated Pest Management. Data from IoT pest traps, imaging close range drones and UGV's with a vision system will be used to map the existence of pests within different locations in fields. The measurements provide pointwise data about the invasion which is then interpolated to cover the whole fields in FMIS. The imaging systems seek symptoms on leaves or pests themselves.

Table 49. Narrative of the use case E

3.2.5.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2EKpi_01	Pesticides only for the need	The pest detection and mapping its distribution on fields are essential for the Integrated Pest Management (IPM).	Decreasing pesticide usage and crop loss
2EKpi_02	Less applied pesticides	Early pests detection decreases the amount of needed pesticides carried out in the use case B.	Decreasing pesticide usage
2EKpi_03	Pest mapping	Early pests detection decreases laborious manual work.	Decreasing labour needs

Table 50. Key performance indicators in the use case E

3.2.5.1.5 Use case conditions

Use case conditions
Assumptions
Changing UAV regulations may affect the communication between UAV's and the systems
Prerequisites
Up to date UAV regulations are considered

Table 51. E, use case conditions

3.2.5.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
This use case is triggered by the use case D, when a possibility for pests is predicted. This use case is followed by the use case B: pesticide spraying.
Level of depth
Generic/detailed Use Case
Prioritisation
Recommendable
Generic, regional or national relation
Generic
Nature of the use case
Drone imaging, machine vision

Table 52. Classification of the use case E

3.2.5.1.7 General remarks

General remarks
This use case does not claim to be exhaustive regarding the functionality of a rapeseed pest detection

3.2.5.2 Diagrams of use case

Diagram(s) of use case

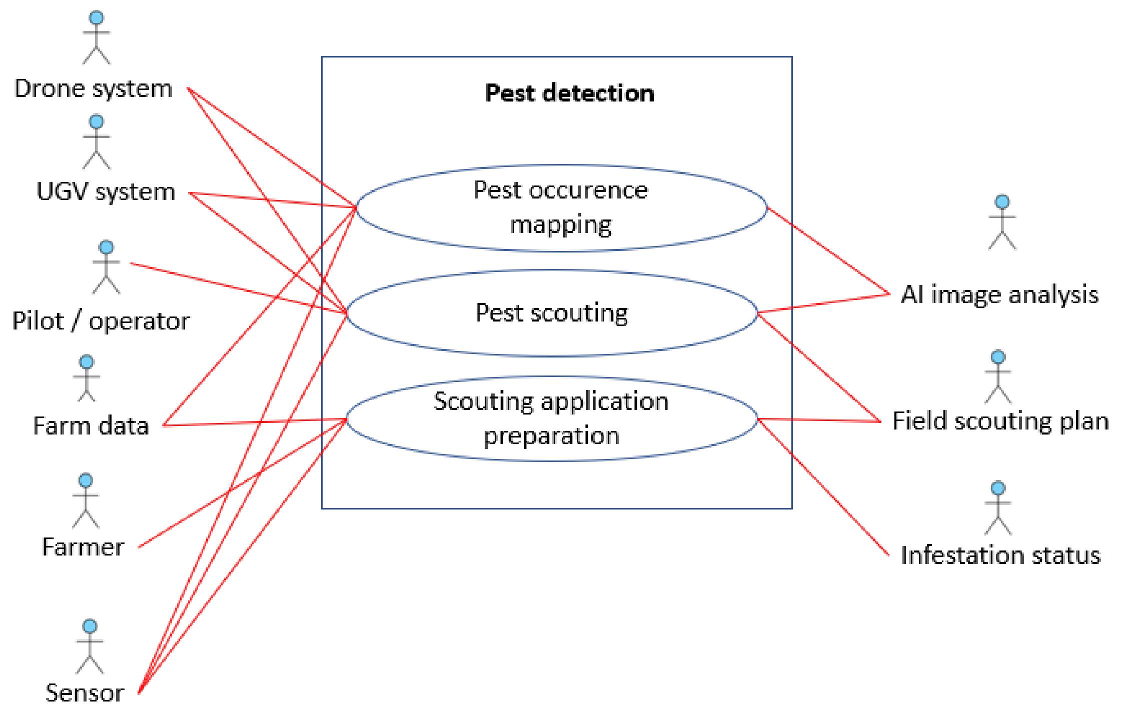



Figure 7. Use case diagram for pest detection

3.2.5.3 Technical details

3.2.5.3.1 Actors

Actors			
Grouping		Group description	
Sensors		Measurement sensors	
Actor name	Actor type	Actor description	Further information specific to this use case
RGB-camera	Sensor	Acquiring images in visible spectrum.	Data for relative greenness and 3D models.
Multispectral camera	Sensor	Acquiring images with optimized wavelengths, including reference panels.	Practical camera solution for specific cases (yield and digestibility).
Hyperspectral camera	Sensor	Acquiring images with many spectral bands, including reference panels.	Setup for detecting small spectral differences.
Pest trap	Sensor	Indication of occurrence of certain pests.	Manual backup, yellow trap.
Actors			
Grouping		Group description	
Other actors		Rest of the involved actors	
Actor name	Actor type	Actor description	Further information specific to this use case
Infestation status	Service	System providing a general infestation report.	General disease pressure service.
AI image analysis	Service	Detection of pests from the images.	Specifically developed AI tool for rapeseed pest detection.
Drone system	System	Imaging drone system.	The imaging drone, first summer DJI Mavic 2 zoom.

Actors			
Grouping		Group description	
Farmer	Human	Person managing the fields.	Farm manager.
Farm data	System	Repository for farming-related data.	Field-specific farming data.
UGV system	Human	Imaging UGV system.	Possible imaging UGV system as a backup.
Field scouting plan	Service	Describes the service that calculates the scouting plan.	Calculates the path for pest imaging.
Pilot / operator	Human	Person operating the drone or the UGV.	Drone pilot, or UGV pilot.

Table 53. Actors, use case E

3.2.5.3.2 References

Actors						
No.	References type	Reference	Status	Impact on use case	Originator / organisation	Link
1	Regulations	EASA regulations		High	EASA	

Table 54. References of the use case E

3.2.5.4 Step by step analysis of use case

3.2.5.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
01	Scouting application preparation	The scouting campaign is planned	Field scouting plan	Infestation status note	Assumed pests on the field	Scouting mission planned
02	Pest scouting	UGV or drone scouts the field	UGV system or Drone system	Scouting time	Scouting is planned	Scouting data is collected
03	Pest occurrence mapping	Collected data is analysed to reveal the occurrence of pests	AI image analysis	Scouting data is collected	Scouting data is collected	Scouting data is analysed

Table 55. Overview of the scenarios in the use case E

3.2.5.4.2 Steps - Scenarios

Scenario							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
No. 1 – Scouting application preparation							
01	Data for scouting planning is gathered	Preparation of data	Relevant data is delivered for the campaign plan	GET	Infestation status, Farmer, farm data, sensor data	Field scouting plan	AI-01, AI-02, AI-03, AI-04
02	Scouting is planned	Planning of scouting campaign	Data is used for accurate imaging campaign plan	CREATE	Field scouting plan	Done system, UGV system, pilot / operator	AI-05, AI-06, AI-07
No. 2 – Pest scouting							

Scenario							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
03	Scouting is performed by UGV	Imaging with the UGV	A relevant imaging campaign is carried out	EXECUTE	UGV system	Sensors	AI-08
04	Scouting is performed by Drone	Drone imaging campaign	A relevant imaging campaign is carried out	EXECUTE	Drone system	Sensors	AI-09
05	Data capture	Imaging data capture	Onboard sensor collects data	CREATE	Sensors	AI image analysis	AI-10
No. 3 – Pest occurrence mapping							
06	Pests are mapped	Classification	Classification of image data	CREATE	AI image analysis	Farm data	AI-11

Table 56. Scenarios in the use case E

3.2.5.5 Information exchanged

Information exchanged		
Information exchanged, ID	Name of information	Description of information exchanged
2EI-01	Farm data for campaign planning	Seeding time, timing of field operations
2EI-02	Farmer observations	Spatial observations: points or vectors or whole field-based notes about scouting need
2EI-03	Trap measurements	Trap system delivers pointwise invasion information
2EI-04	Infestation status observation	Pest pressure value for the field
2EI-05	Scouting campaign plan for UGV system	Flying pattern, such as KML-format and requested parameters (etc. Nadir, and altitude)
2EI-06	Scouting campaign plan for a Drone system	Requested date and time and setups
2EI-07	Campaign plan for the pilot/operator	Mission start
2EI-08	Request to take UGV images	Request to take images based on location and orientation
2EI-09	Request to take drone images	Request to take images based on coordinates, distance or time interval
2EI-10	Imaging dataset	Single images jpg/raw or other
2EI-11	Pest map	Detected pest spots on the map, vector/raster data

Table 57. Information exchanged in the use case E

3.2.6 Use case F: Rumex weeding

3.2.6.1 Description of the use case

3.2.6.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2F		Rumex weeding

Table 58. Use case F identification

3.2.6.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	Weeding of grazing and silage fields
Objective (s)	Autonomous weeding of Rumex plants from grass fields.
Related business case (s)	Animal husbandry

Table 59. Scope and objectives of the use case F

3.2.6.1.3 Narrative of use case

Narrative of use case
Short description
Rumex weeding from pastures and silage fields for more efficient use of the fields.
Complete description
The Rumex (Rumex longifolius) is a plant belonging to the buckwheat family (Polygonaceae) and grows well on pastures and grasslands. In grazing fields, the Rumex is typically handled as weeds. Typically, grazing cows avoid the weed as well as the grass nearby. This causes untapped spots on the field. The Rumex is typically a perennial plant, which spreads by producing seeds. The robotic system for performing the Rumex weeding navigates to the spotted weed locations (based on mapped spots, use case D), detects the actual weed location, cuts/tears the Rumex weeds and transports them off the field.

Table 60. Narrative of the use case F

3.2.6.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2FKPI_01	Increase of beneficial land area	Removing the Rumex-weeds from the pastures will increase the beneficial land area. The benefit can be calculated from the decrease of the effective area of the weeds (square meters per pasture field).	Autonomous weeding of Rumex plants from pastures and fields.
2FKPI_02	Plants removed per hour	The efficiency of the system can be measured by comparing the capacity to remove Rumex plants from the field in an hour. The comparison should be done against the work done manually by farmers.	Autonomous weeding of Rumex plants from pastures and fields.

Table 61. Key performance indicators in the use case F

3.2.6.1.5 Use case conditions

Use case conditions
Assumptions
An autonomous mobile robot or tractor can navigate in the fields.
An autonomous mobile robot or tractor has tools to rip up or cut the weeds, and storage to transport the weed remains out from the field.
Regulation of autonomous driving and remote monitoring are not considered.
Prerequisites
Weed map is available

Table 62. F, use case conditions

3.2.6.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Status mapping
Level of depth
Detailed use case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Test

Table 63. Classification of the use case F

3.2.6.1.7 General remarks

General remarks
The weeding task is challenging, especially concerning optimal ways to rip up the weed. Here the focus is on utilization of the weed map and usage of the autonomous mobile robot for navigating in the pasture to the weed and in weeding out the plant, we will content with weeding in one or two workable ways of the actual weeding procedure.

3.2.6.2 Diagrams of use case

Diagram(s) of use case

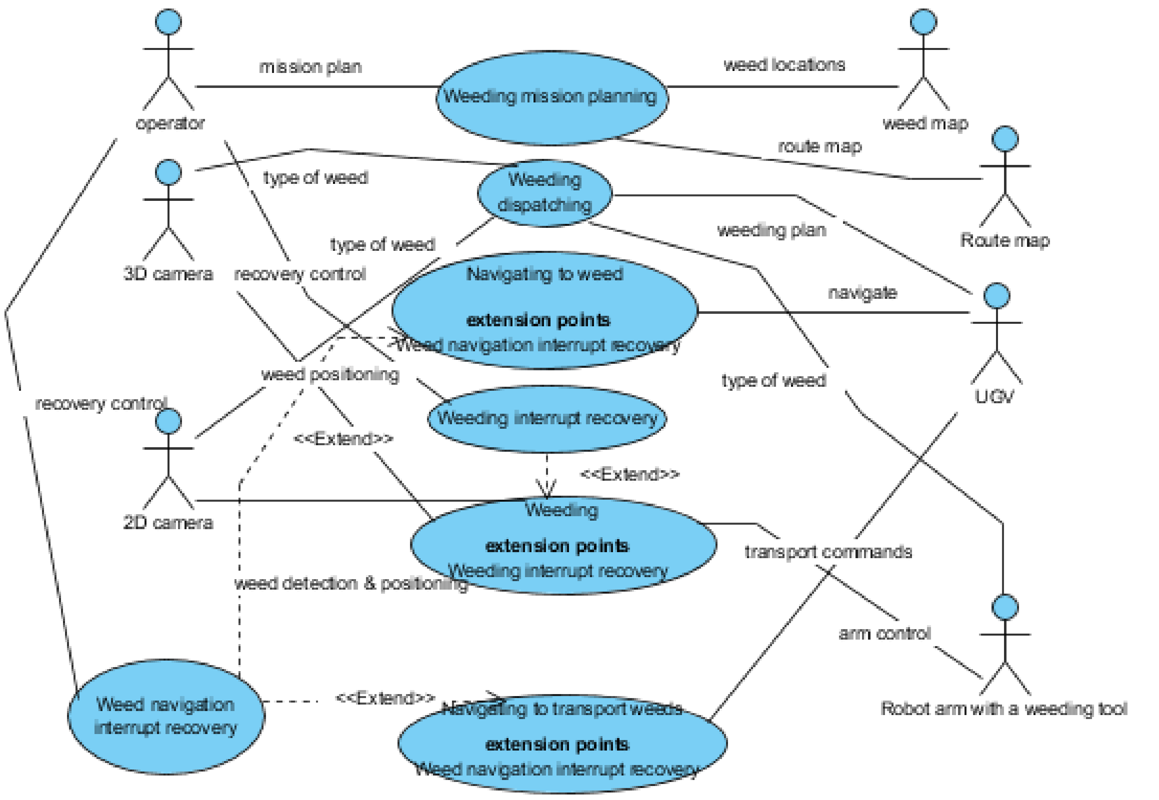


Figure 8. Use case diagram for Rumex weeding

3.2.6.3 Technical details

3.2.6.3.1 Actors

Actors			
Grouping		Group description	
Humans		Humans	
Actor name	Actor type	Actor description	Further information specific to this use case
Operator	Human	Person managing the fields.	A farmer decides to initiate the weeding operation.
Grouping		Group description	
Technology actors			
Actor name	Actor type	Actor description	Further information specific to this use case
UGV	Robot	Autonomous mobile robot or tractor.	Two platforms manufactured by Probot Oy (Probot, VTT)
Robot arm with a weeding tool	Robot	On-board robot arm or mechanism to carry out the weeding motions.	Schunk LWA 4 arm.
2D camera	Sensor	An RGB camera for weed detection and recognition.	
3D camera	Sensor	A 3D camera for weed detection, recognition and localization.	
Grouping		Group description	
SW system actors			
Actor name	Actor type	Actor description	Further information specific to this use case
Weed map	SW system	A map with locations of the weeds in the field.	
Route map	SW system	A map with UGV waypoints in the field.	Initially, MAVLink format.

Table 64. Actors, use case F

3.2.6.3.2 References

Actors						
No.	References type	Reference	Status	Impact on use case	Originator / organisation	Link
1	3D image (de-)facto standards	PCD, PLY		High		

Table 65. References of the use case F

3.2.6.4 Step by step analysis of use case

3.2.6.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
01	Weeding mission planning	A weeding mission is planned based on a weed map	Operator	Human operator observes the need for weeding	Weed map available	Weeding mission created
02	Weeding dispatching	Release a weeding task to the UGV	Operator	Human operator decides to start weeding	Weeding mission created	Weeding started
03	Navigating to weeds	The UGC navigates to the weeds one by one	UGV	Weeding mission started or a weeding operation completed	Weeds in the field	UGV near to a weed
04	Weeding	The weed is ripped up or cut by the robot arm	Robot arm	UGV near to a weed	UGV near to a weed	Weed removed, weed map updated
05	Weeding interrupt recovery	An error situation is managed by the operator	Operator	Error reported from the robot	Robot in an error state	Robot in an operable state
06	Navigating to transport weeds	The UGV navigates to the next weed or to the exit point of the pasture	UGV	Weeding operation completed	Weeding operation completed	UGV near to next weed or exited the pasture

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
07	Weed navigation interrupt recovery	An error situation is managed by the operator	Operator	Error created by the UGV	UGV in an error state	UGV in an operable state

Table 66. Overview of the scenarios in the use case F

3.2.6.4.2 Steps - Scenarios

Scenario							
Scenario name:	No. 1 – Weeding mission planning						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Get the weed list	Get the weed list	Acquiring weed list from the weed map	GET	Weed map		F1-01
02	Get the weed locations	Get weed locations	Acquiring weed locations from the weed map	GET	Weed map		F1-02
03	Get the route map	Get route map	Get the route map	GET	Route map		F1-03
04	Plan weeding routes	Plan routes	Plan the weeding routes to each weed	CREATE			

Scenario							
Scenario name:	No. 2 – Weeding dispatching						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Select weeding plan	Select weeding plan	Select the weeding plan (mission) and the UGV	CREATE			
02	Send weeding plan	Send weeding plan	Send the weeding plan (mission) data to the selected UGC and start the mission	EXEC.		UGV	F2-01

Scenario							
Scenario name:	No. 3 – Navigating to the weed						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Enter pasture	Navigate to pasture	Navigate to the entry point of the pasture	EXEC.		UGV	
02	Navigate to next location	Navigate to next weed	Set the location of the next weed as a target and navigate to it following the route map	EXEC.	UGV	Robot	F2-01
03	Wait for weeding	Weeding	Wait until the robot has ripped out the weed	EXEC.	Robot	UGV	F2-02
04	Navigate to next location	Navigate to next weed or exit point	Set the location of the next weed	EXEC.	UGV	Operator	

Scenario							
Scenario							
Scenario name:	No. 4 – Weeding						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Detect weed	Detect weed	Detect, recognize and localize the weed	EXEC.	2D and 3D cameras		2D and 3D images
02	Drive to weeding distance	Drive to weeding distance	Drive the UGV close to the weed, within the range of the robot arm	EXEC.	UGV		
03	Locate weed and move robot	Locate weed and move robot	Locate the weed in detail with the 2D and 3D cameras, and move the robot, with the tool in contact with the weed	EXEC.	ROBOT		
04	Weed	Weed	Rip out or grasp and cut the weed	EXEC.	ROBOT		
05	Lift the weed	Lift the weed	Move the weed to a storage cage of the UGV	EXEC.	ROBOT		
06	Drive a part from the weed	Drive a part from the weed	Drive back to the navigation route point	EXEC.	UGV		
Scenario name:	No. 5 – Weed transportation						

Scenario							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Weeding done	Go to the exit of the pasture	After the last weed, navigate to the exit point of the pasture	EXECUTE	UGV		
02	At the exit point	Leave the pasture	When exit point reached, leave the pasture	EXECUTE	UGV	Operator	

Scenario							
Scenario name:	No. 6 – Weed navigating interrupt recovery (extends “Weeding”)						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Navigation failure	Interrupting navigation	Stop weeding mission and report failure	EXECUTE	ROBOT	Operator	
02	Operator guidance	Operator guidance	Wait for operator guidance and recovery actions	EXECUTE	OPERATOR		

Scenario							
Scenario name:	No. 7 – Weeding interrupt recovery (extends "Weeding")						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Navigation failure	Interrupting navigation	Stop weeding mission and report failure	EXECUTE	UGV	Operator	
02	Operator guidance	Operator guidance	Wait for operator guidance and recovery actions	EXECUTE	OPERATOR		

Table 67. Scenarios in the use case F

3.2.6.5 Information exchanged

Information exchanged		
Information exchanged, ID	Name of information	Description of information exchanged
F1-01	Weed list	List of weeds found by drone
F1-02	Weed locations	List of weeds' global coordinates
F1-03	Route map	Ordered list of driving points to cover weed locations
F2-01	Weeding plan	Local manoeuvres at weed location after weed identification, robotic tool actions to remove weed
F2-02	Weeding result	Weeding action successful or unsuccessful at weed location

Table 68. Information exchanged in the use case F.

3.2.7 Use case G: Silage harvesting plan

3.2.7.1 Description of the use case

3.2.7.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
2G		Silage harvesting plan

Table 69. Use case G identification.

3.2.7.1.2 Narrative of use case

Narrative of use case
Short description
The grass harvesting for silage is a balance between digestibility and yield amount. The developed tool will collect information sufficient to optimize the moment of harvesting.
Complete description
The timing optimization of the silage grass harvesting depends on the yield increase and the grass digestibility decrease in a matter of about two days. Each field is harvested 2-3 times per year, depending on the weather of the season. On a large cattle farm, these grass fields are typically distributed in the area of several square kilometres. The optimization of harvesting order increases the quality and quantity of the harvested yield. Satellite imagery-based analysis supported with crop samples is used in FMS in order to detect the general harvesting order. Rather than calculating a full harvest order for the farm, the results of this tool can be used to trigger the harvest and to form a preliminary field order for harvesting fleet.

Table 70. Narrative of the use case G

3.2.7.1.3 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
2GKPI_01	Increased silage yield quality	The optimal harvesting time increases the silage quality due to better digestibility.	
2GKPI_02	Increased silage yield quantity	The optimal harvesting time increases the silage quantity. The benefit is calculated based on the total increase of digestible dry matter.	

Table 71. Key performance indicators in the use case G

3.2.7.1.4 Use case conditions

Use case conditions
Assumptions
Grass fields are known
Specie or species of cultivated crops are known
Prerequisites
Satellite data is available
Ability to collect and analyse site-specific samples of canopy

Table 72. G, use case conditions

3.2.7.1.5 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
A (tractor fleet), C (situation awareness) and D (status mapping)
Level of depth
Farm and crop-specific
Prioritisation
Required
Generic, regional or national relation
Regional and national
Nature of the use case
Predicting with commonly available datasets and specific production data

Table 73. Classification of the use case G

3.2.7.1.6 General remarks

General remarks
Optimization of silage production on farm level is season dependent task that affects animal production afterwards. Timing of harvest is currently made on a parcel level based on digestibility of crop canopy and estimated biomass yield. In this use case, the possibilities to improve current practices are outlined.

3.2.7.2 Diagrams of use case

Diagram(s) of use case

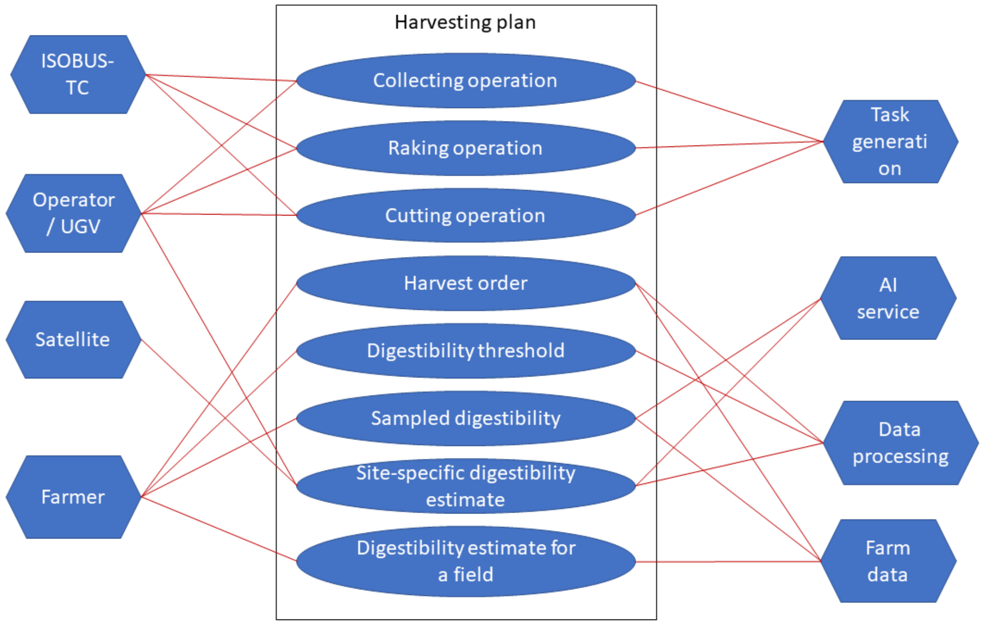


Figure 9. Use case diagram for harvesting planning

3.2.7.3 Technical details

3.2.7.3.1 Actors

Actors			
Grouping		Group description	
Humans		Humans	
Actor name	Actor type	Actor description	Further information specific to this use case
Farmer	Human	Farmer is the decision-maker for starting the harvest and controls the timing of different actions during harvest.	
Worker	Human	Executing tasks or timing of actions.	
Grouping		Group description	
Sensors		Sensors	
Actor name	Actor type	Actor description	Further information specific to this use case
Satellite imagery provider	Service	Regularly capturing data over wide areas or globally.	Data for predicting the digestibility in a site-specific manner.
Grouping		Group description	
Harvest plan			
Actor name	Actor type	Actor description	Further information specific to this use case
ISOBUS task generator	Service	Creating an ISOBUS task file for cutting a field.	Required information GI-01, GI-06
Mission planner	Service	Creating cutting missions for human operators or UGV.	

Table 74. Actors, use case G

3.2.7.3.2 References

Actors						
No.	References type	Reference	Status	Impact on use case	Originator / organisation	Link
ISOBUS	Standard	ISO11783:10	Final	Moderate	VDMA / AEF	https://www.iso.org/standard/61581.html

Table 75. References of the use case

3.2.7.4 Step by step analysis of use case

3.2.7.4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
01	Grass growth stage prediction	Average estimate over a field, digestibility of vegetation starts to decline	FMS	Heat summation	Growth season start is known	Request for an algorithm to detect sampling locations for fields with grass
02	Satellite data acquisition	Recent satellite data for grass fields	FMS	Request from farmer	Fields with grass are known, status of digestibility is known	Satellite imagery data exists over requested areas
03	Sample locations	Detecting suitable sampling locations based on variation in field	FMS	Availability of requested satellite imagery data	Field, crop varieties and satellite imagery dataset	3 sampling locations for each treated field
04	Sampling mission	Collecting crop samples for analysis	Human / UGV	Availability of coordinates for samples	Field and coordinates	Samples for requested locations

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
05	Crop status	Detailed prediction of crop status	FMS	Availability of sample data	Fields, crops, coordinates and sample data	Harvestability index
06	Selecting fields	Selection of fields for harvesting	FMS and farmer	Availability of harvestability index	Grass fields and harvestability index	Fields in harvesting order
07	Harvesting plan	Harvesting order for selected fields	FMS	Harvestability over threshold with certain number of fields	Fields, harvestability, order	Harvesting plan

Table 76. Overview of the scenarios in the use case G

3.2.7.4.2 Steps - Scenarios

Scenario							
Scenario name:	Harvesting planning						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Digestibility estimation, parcel	Average digestibility on parcel level	Calculating average status of a field	CREATE	FMIS	Human	GI-01, GI-02, GI-03
02	Defining fields for drone mission	Selecting fields	Selecting grass fields for detailed analysis	GET	Human	FMS	GI-01
03	Satellite data acquisition	Satellite data acquisition over requested field	Requesting data with known locations, downloading data from	GET	FMS	FMS	GI-01, GI-02

Scenario							
Scenario name:	Harvesting planning						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
			available dates				
04	Satellite data processing	Satellite data processing	Removing images covered with clouds, extracting wanted wavelengths	CREATE	FMS / Ai service	FMS	GI-04
05	Digestibility map	Creating digestibility maps	Creating digestibility maps	CREATE	Algorithm / AI Service	FMS	GI-01, GI-02, GI-03, GI-05, GI-06
06	Defining sampling locations	Defining sampling locations	Defining sampling locations for D-value samples	CREATE	Algorithm / AI Service	FMS	GI-01, GI-06, GI-07
07	Updating digestibility map	Updating digestibility map	Updating digestibility map based on analysis of collected samples	UPDATE	Algorithm / AI Service	FMS	GI-01, GI-02, GI-03, GI-05, GI-08
08	Harvesting order	Defining harvesting order	Defining harvesting order for grass fields	CREATE	Human	FMS	GI-01, GI-08

Table 77. Scenarios in the use case G

3.2.7.5 Information exchanged

Information exchanged		
Information exchanged, ID	Name of information	Description of information exchanged
2GI-01	Field data	Field Id, field borders
2GI-02	Crop data	Field Id, Crop Id
2GI-03	Weather data	Location, temperature, precipitation
2GI-04	Satellite dataset, raw	All existing dates over requested areas and with all wavelengths
2GI-05	Satellite dataset, cleaned	All existing valid data
2GI-06	Digestibility map	Digestibility values over captured area
2GI-07	Sampling locations	Field Id, field borders, target locations for samples, sample ids
2GI-08	Sampling results	Sample ids, analysis results
2GI-09	Harvest order	Field Id, harvest order
2GI-10	Harvest plan	Field Id, field location, planned harvest order
2GI-11	Raking definitions	Field Id, timing of raking

Table 78. Information exchanged in the use case G

4 Description of data sets

WP5 – Pilot 2 will use UGV, UAV and tractor robotics to carry out silage harvesting and oil crops pesticide management. During the execution of these activities, robots will gather different types of data, which, combined with Farm management data, will be used to implement the use cases.

4.1 Data set overview

4.1.1 Data summary

There are five types of datasets that will be generated or collected:

- Drone images: RGB, multispectral, hyperspectral
- UGV images/video (RGB)
- Satellite images
- Application tasks: machinery inputs, navigation routes
- Orthomosaics

Moreover, the use cases A-F each need specific datasets. Tractor system A requires UGV images for the vision system. The pesticide spraying B requires an application task originating from ISOBUS –task format and to be adjusted to machinery suitable format. Figure 12 left shows an example of the application task map for the spraying. The situation awareness requires nadir UAV video in real-time. Figure 12 right shows an example of the nadir image showing a windrower driving to the left and a mower heading to the right.

Figure 10. Left: use case B pesticide spraying example, application map in a vector format. Right: drone imaging for the situation awareness in use case C with windrower and mower driving

The use case D for general monitoring of silage and rapeseed fields require orthomosaics. Figure 11 shows a classified status map and a grass field with Rumex spots.

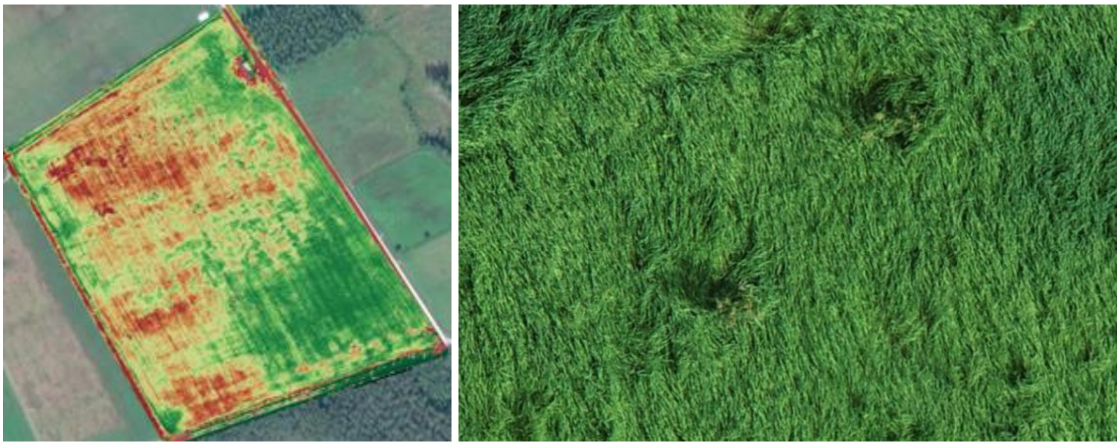


Figure 11. Status mapping examples for use case D. Classified grass field (left), and a grass field with two Rumex spots (right).

The pest detection use case E needs close range UAV images showing pests. Figure 14 left shows an example of that. The Rumex detection in use case F requires close range UGV images of Rumex weeds.

Figure 12. Left: pest detection example for use case E: rapeseed flowers and small black pests near leaves. Right: Rumex detection for use case F: Rumex plants on a grass field.

The fleet management use case G needs classified satellite images, and the work reports of fleet machinery in ISOBUS format.

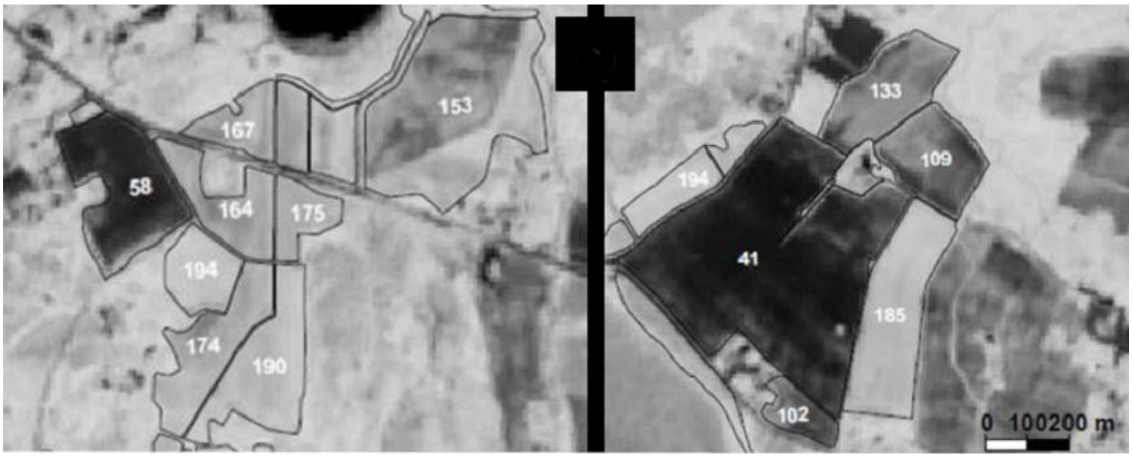


Figure 13. Harvesting plan example for use case G: comparable index values for different fields

4.1.2 Data acquisition

The following methods are used for data acquisition:

- Data will be logged with UAV system or with mission control system linked to the UAV in real-time. Images will be collected to SD cards.
- UGV data is logged onto a PC.
- New satellite images will be downloaded as a batch as soon as they are published through Sentinel Data Hub and its API, or by using Data Cube facilitating the access.
- Weather data will be assessed by web services.
- The ISOBUS-format and platform-specific navigation data will be produced in the mission planning.
- Relevant imagery data will be processed to orthomosaics with relevant software.
- Maps will be classified with additional relevant software.

The main imaging tasks during 2021 are listed in the following table. In addition, several other supportive tasks were made in co-operation with related projects collecting data from grasslands. The drones are presented later in section 5.4.3.

4.1.2.1 Format and structure of data

The acquired data will be in the following formats:

- Tiff format, jpg images
- jpg images
- GeoTiff format. Sentinel images come in 12 different bands, with a separate monochromatic image for each band. All images from one date will be located together in the same folder.
- csv format.
- ISOBUS binary format, KML format
- Tiff format
- Shapefile (*.shp), KML, GML (OGC)

4.1.2.2 Existing data

Will the task re-use any existing data and how? (See also Chapter 7 of the CESSDA guide)

Data for status mappings are available, but generally, we will collect new data. Only data for status mappings are available. For the other use cases, new data will be collected.

4.1.2.3 Origin of the existing data (if any)?

What is the origin of the data?

Existing data was collected by Luke in previous internally funded projects.

4.1.2.4 Size of data

What is the expected size of the data? (in Gb)

1. Drone images ~1TB.

2. UGV images ~100GB.

3. Satellite images ~100GB.

4. Application tasks ~100MB.

5. Orthomosaics ~10GB.

Usage of data

To whom it might be useful ("data utility")?

All data would be useful for the farmer to better understand the state of crops and the spatial variability within the field.

4.1.2.5 Where and how are data stored?

All data will be stored at VTT's servers.

4.1.2.6 What are the risks for data?

1. Drone images: change in sunlight/cloudiness during the drone flight (mission), sensor failures, calibration problems, windy conditions, data labelling.

2. UGV images: change in sunlight.

3. Satellite images: cloud occlusion (missing data).

4. Format transformation and loss of data.

5. Projections.

4.2 UAV images

The following Table 79 presents the UAV imaging missions during the first growing season.

Drone	dd.mm.yyyy	Time (min)	Location
DJI Phantom 4 RTK	25.5.2021	25	Jokioinen
DJI Phantom 4 RTK	3.6.2021	20	Jokioinen
DJI Phantom 4 RTK	3.6.2021	20	Jokioinen
DJI Phantom 4 RTK	7.6.2021	20	Mustiala
DJI Phantom 4 RTK	7.6.2021	25	Jokioinen
DJI Phantom 4 RTK	9.6.2021	40	Vihti
DJI Agras T-16	11.6.2021	10	Jokioinen
DJI Phantom 4 RTK	11.6.2021	10	Jokioinen
DJI Phantom 4 RTK	16.6.2021	35	Jokioinen
DJI Phantom 4 RTK	16.6.2021	15	Jokioinen
DJI Phantom 4 RTK	6.7.2021	20	Jokioinen
DJI Agras T-16	6.7.2021	15	Jokioinen
DJI Phantom 4 RTK	6.7.2021	10	Jokioinen
DJI Phantom 4 RTK	6.7.2021	20	Jokioinen
DJI Phantom 4 RTK	6.7.2021	15	Jokioinen
DJI Phantom 4 RTK	6.7.2021	45	Jokioinen
DJI Mavic 2 zoom	12.7.2021	30	Jokioinen
DJI Mavic 2 zoom	12.7.2021	30	Jokioinen
DJI Mavic 2 zoom	13.7.2021	20	Lempäälä
DJI Mavic 2 zoom	15.7.2021	60	jokioinen
DJI Mavic 2 zoom	15.7.2021	25	Jokioinen
DJI Phantom 4 RTK	15.7.2021	20	Jokioinen
DJI Mavic 2 zoom	20.7.2021	10	Jokioinen
DJI Agras T-16	21.7.2021	1	Juva

Table 79. Main drone missions during 2021

The updated list of collected imaging data is presented in the following Table 80.

Use case	Use case type	Imag e data	Maps	Videos	Sample data	Notes
C	Awareness	6	N/A	17	0	From various conditions
D	Mapping	N/A	12	N/A	54	Can be increased
E	Pests	300/ 1231	2	8	103	Sample data under preparation

Table 80. List of collected data during the first growing season

4.3 UGV, tractor and other datasets

Lidar and camera-based vision systems will be implemented to the tractor and UGV setups, but so far only preliminary tests are conducted. The planned system setups are presented later in the section 5. Data management related issues are presented next.

4.4 Data management

4.4.1 FAIR Data (Findability, Accessibility, Interoperability, Reusability)

The project level general guidelines are presented in the Deliverable 1.3 Data Management [3] Plan. The following paragraphs verify the Pilot 2 specific realizations.

4.4.1.1 Making data findable

(Chapter 2 of CESSDA Guide)

4.4.1.2 Metadata provision

Are the data produced and/or used in the Task discoverable with metadata?

Yes

4.4.1.3 Identification of data

Does the task plan to make use of persistent and unique identifiers such as Digital Object Identifiers?

Yes

4.4.1.4 Naming conventions

What naming conventions do you follow? (Folders and files conventions)

- Top-level - location name
- Middle level - Type of data
- Bottom level - Date of acquisition

4.4.1.5 Search keywords

Will search keywords be provided that optimize possibilities for re-use? If yes, please list the preliminary keywords e.g., Tagging items (i.e., datasets, documents, codes, etc.) with relevant keywords that are automatically indexed by the search

Yes rapeseed, silage, pasture, precision agriculture, image processing, deep learning, machine learning, UAVs, UGVs, robot tractor

4.4.1.6 Versioning

Do you provide clear version numbers?

e.g., Might be taken in charge by a tool, might only upload one version of each dataset

Yes. We are using _vX ending, where X is the number of the version

4.4.1.7 Standards for metadata creation

What metadata will be created? In case metadata standards do not exist in your specific discipline, please outline what type of metadata will be created and how.

e.g., Description, ownership, date etc.

e.g. Standard e.g. Dublin Core metadata standard

e.g., readme.txt file

1. Source
2. Region
3. Owner / producer
4. Licence
5. Sensitive / personal data
6. Frequency of acquisition
7. Date / time span
8. Spatial resolution
9. Total size

4.4.1.8 Making data ACCESSIBLE

See Chapter 4 and Chapter 6 of CESSDA Guide

4.4.1.8.1 Open available datasets

Which data produced and/or used in the Task will be made openly available as the default?

Follow the principle "as open as possible, as closed as necessary".

We will make the drone images used by the AI development available to the scientific community.

4.4.1.8.2 Closed datasets

If certain or parts of datasets cannot be shared (or need to be shared under restrictions), explain why, clearly separating legal and contractual reasons from voluntary restrictions (e.g., *ethical, rules of personal data, intellectual property, commercial, privacy-related, security-related, etc.).*

Any personal data if exists.

4.4.1.8.3 Repository

How will the data be made accessible (e.g., by deposition in a repository)?

Can you provide us with the link and D.O.I. (digital object identifier)?

e.g., Deposited in open access repository (e.g., OSF, Zenodo)

DOI for datasets differs from DOI for publications. You might find some useful information under: https://academia.stackexchange.com/questions/52032/how-do-i-get-a-doi-for-a-dataset

If you do not have/or will obtain a DOI, just mention that here.

Data will be deposited at a public repository and will be assigned a link and DOI.

4.4.1.8.4 Software tools for access

What methods or software tools are needed to access the data?

No tools, data will be downloaded directly.

Is documentation about the software needed to access the data included?

No need for the documentation

Is it possible to include the relevant software (e.g., in open-source code)?

-

4.4.1.8.5 Data depository

Where will the data and associated metadata, documentation and code be deposited? Preference should be given to certified repositories which support open access where possible.

e.g., Deposited in open access repository (e.g., OSF, Zenodo)

Different options are under consideration. Open data portal https://opendata.luke.fi/ is one option. Another is Zenodo.

Have you explored appropriate arrangements with the identified repository?

Yes

If there are restrictions on use, how will access be provided?

-

Is there a need for a data access committee?

-

4.4.1.9 Making data INTEROPERABLE

See Chapter 3 and Chapter 6 of the CESSDA Guide.

Due to the versatility of the pilots, a number of standards should be used to ensure interoperability and proper communication, protection, and reusability of the generated data. These include standards such as ROS, ISOXML (ISO 11783), ISO 50001, ISOBUS (ISO 11783), ISO 22000, DIN EN 1672-2:2009-07, Machinery Directive 2006/42/EC, FDA 21CFR 174-178, EHEDG Doc. 8 / 13 (+ more depending on the application), ISO 22166, ISO 18497, ISO 17757, ISO 25119, ISO 62443.

4.4.1.9.1 Interoperability of the data produced in the Task

Is the Task allowing data exchange and re-use between researchers, institutions, organizations, countries, etc. (i.e., adhering to standards for formats, as much as possible compliant with available (open) software applications, and in particular facilitating re-combinations with different datasets from different origins)?

Yes

What data and metadata vocabularies, standards or methodologies will the Task follow to make the data interoperable?

e.g., metadata format is compliant with standard formats (MARCXML, Dublin Core, and DataCite Metadata Schema)

Relevant standards for the involved data are applied

4.4.1.9.2 Vocabulary

Will your task use standard vocabularies for the data types present in the datasets to allow inter-disciplinary interoperability?

Yes

If not, will you provide mapping to more commonly used ontologies?

-

4.4.1.10 Making data RE-USABLE

See Chapter 3 of the CESSDA Guide

4.4.1.10.1 License

How will the data be licensed to permit the widest re-use possible?

e.g., Creative Commons license CC-BY or CC-0 (according to the H2020 guidelines)

Be aware there are different licenses for research data (in comparison with publications), depending on the nature of these data (origin).

Yes, Creative Common licenses are considered.

4.4.1.11 Availability

When will the data be made available for re-use?

e.g., after upload

Intentionally after upload, but in agreement with related scientific publication actions.

If applicable, specify why and for what period a data embargo is needed.

-

How long is it intended that the data remains re-usable?

e.g., at least 15 years, for the lifetime of the repository

For the lifetime of the repository

4.4.1.11.1 Third parties

Are the data produced and/or used in the Task usable by third parties, in particular after the end of the pilot/project? If the re-use of some data is restricted, explain why.

Yes

4.4.1.11.2 Data quality

How is the data quality assured? Are data quality assurance processes described?

Only relatively high-quality data can be applied within the project. Quality assurance will already be done for the project implementation according to our previous research experience.

Note: Please note that making data accessible should be the standard/default, but when, for some data, this is not possible, then it should be clearly explained; examples of restricted data could be personal information or consortium confidential data – the latter might be accessible to all the partners but kept within the project for exploitation during some time; this one, when published, normally is made available.

4.4.2 Allocation of resources

See Chapter 1 of the CESSDA Guide

4.4.2.1 Costs

What are the costs of making data FAIR in your project? And how will these be covered?

e.g., Long-term storage, journal open access costs etc.

e.g., project's budget

Additional costs are covered by the allocated project budget by the data authors.

4.4.2.2 Responsibility for data management

Who will be responsible for data management in the Task?

Jere Kaivosoja (LUKE) and Kari Kolehmainen (VTT).

4.4.2.3 Costs and potential value of long-term preservation

What are the costs of long-term preservation? And who decides how and what data will be kept and for how long?

No costs for long-term preservation. The decision concerning data sharing was made by the Pilot coordinator and fellow researchers.

4.4.3 Data security

Datasets must be preserved/stored during and beyond the lifetime of the Task. This means that each Task must provide a clear description of procedures for short-term and long-term preservation of the datasets.

See Chapter 4 of CESSDA Guide

4.4.3.1 Dataset security

What provisions are in place for data security (including data recovery as well as secure storage and transfer of sensitive data)?

e.g., data stored in the partners' networks with backups, firewall; in the project's SharePoint accessible with credentials; Basecamp; OwnCloud etc.

Data stored on the servers (VTT, LUKE, Probot) with backup and firewall.

4.4.3.2 Data storage

Is the data safely stored in certified repositories for long term preservation and curation?

Yes

4.4.4 Ethical and legal aspects

In those cases where personal data (GDPR) is involved, detailed information is planned to be provided:

1. On what personal data is collected, stored and processed;
2. On the recruitment process, inclusion/exclusion criteria for participation;
3. On privacy/confidentiality and the procedures that are implemented for data collection, storage, access, sharing policies, protection, retention and destruction during and after the project;
4. On how informed consent is pursued;
5. if application/is needed to be filed with a local/institutional ethics review body (if personal data is being collected) and if yes, which bodies / where / when.

See Chapter 5 of CESSDA Guide.

4.4.4.1 Ethical or legal issues

Are there any ethical or legal issues that can have an impact on data sharing?

e.g., data from 3rd-party that didn't give explicit consent, data that need to comply with the GDPR etc.

In a project like FlexiGroBots, the following ethical issues might arise:

- *privacy and surveillance*
- *data ownership or the right to access data*
- *responsibility for decisions and their consequences (including accidents)*

GDPR related data (people in images) will be removed.

4.4.4.2 Data collection in non-EU countries

Does your task involve data collection in non-EU countries?

No

In case it does, please specify: Which data are collected in non-EU countries?

-

Is the research conducted legally in at least one EU Member State?

Yes

4.4.4.3 Data transfer to non-EU countries

Does your task involve a data transfer to non-EU countries?

No

In case it does, please specify which data are transferred to non-EU countries.

-

4.4.4.4 Personal data

Does your data collection involve collection of personal data or data that can be traced back to whom it is about? In case not, the remainder of section 5 can be skipped.

Ideally no, but possible images including persons are removed from the open datasets.

4.4.4.5 Personal data: Information provisions and access

Do you comply with the GDPR concerning information provisions and access to personal data (right to be informed, right to access and informed consent for data sharing and long-term preservation included in questionnaires is given by data providers)?

Yes

4.4.4.6 Personal data: Rectification and erasure

Do you comply with the GDPR concerning rectification and erasure of personal data (rights to rectification, erasure, restriction of processing, to be notified and data portability)?

Yes

4.4.4.7 Personal data: Right to object and automated individual decision-making

Do you comply with the GDPR concerning the right to object and automated individual decision-making?

Yes

4.4.4.8 Personal data: Data controllers and processors

Do you comply with the GDPR responsibilities for data controllers and processors (the controller and the processor have implemented appropriate technical and organizational measures to ensure a level of security appropriate to the risk and keep records of its processing activities)?

See Chapter 4 of CESSDA Guide.

Yes

4.4.5 Other issues

4.4.5.1 Other procedures for data management

Do you make use of other national/funder/sectorial/departmental procedures for data management? If yes, which ones?

See also Cessda guide.

No

4.4.5.2 Dissemination of research results

Indicate how the 'research results' of the Task are communicated/disseminated to relevant European and global channels such as OpenAIRE, CIARD, GODAN and Big Data Europe.

The research results will be published in scientific journals.

4.5 Dataset catalogue

Data Description

Work Package / Task / Pilot	Pilot 2: Rapeseeds and silage
Partners	VTT, LUKE, MTECH, PROBOT

1. Drone images

Name	Drone images
Source	UAVs
Region	Finland
Owner / producer	LUKE
Licence	Creative Commons Attribution
Sensitive / personal data	No
Frequency of acquisition	3 times per season
Date / time span	March - September (2021-2023)
Spatial resolution	0.5mm -5 cm
Total size	~1TB

2. UGV images

Name	UGV-images
Source	UGV and Tractor
Region	Finland
Owner / producer	Probot, Luke, VTT
Licence	Creative Commons Attribution
Sensitive / personal data	No
Frequency of acquisition	3 times per season
Date / time span	March - September (2021-2023)
Spatial resolution	0.5mm -5 cm
Total size	~1TB

3. Satellite images

Name	Satellite images
Source	ESA
Region	Finland
Owner / producer	ESA
Licence	
Sensitive / personal data	No
Frequency of acquisition	About 2-3 times per season
Date / time span	March - September (2021-2023)
Spatial resolution	10m
Total size	~1TB

4. Machinery data

Name	Machinery data
Source	ISOBUS-machinery

Region	Finland
Owner / producer	LUKE
Licence	Creative Commons Attribution
Sensitive / personal data	No
Frequency of acquisition	About 2 times per season
Date / time span	March - September (2022-2023)
Spatial resolution	- 10Hz
Total size	~1GB

5. Orthomosaics

Name	Orthomosaics
Source	Rapeseed and silage fields
Region	Finland
Owner / producer	LUKE
Licence	Creative Commons Attribution
Sensitive / personal data	No
Frequency of acquisition	About 3 times per season
Date / time span	March - September (2021-2023)
Spatial resolution	About 2cm
Total size	~50GB

Table 81. Dataset catalogue

5 Description of robots, devices, and platform

5.1 Pilot Implementation Architecture

The pilot 2 implementations are based on the idea that there are six different business partners involved in the use cases. The partners are the farmer, cloud storage provider, IoT solution provider, drone service provider (AgriDrone), field service provider (AgriRobot), and AI Enterprise. The high-level planning for the pilot components is detailed in D2.7.

Pilot 2 implementation architecture is presented in Figure 14. The architecture consists of six main cloud instances that are farm management system (FMS), farm data storage, IoT solution provider, AgriDrone, AgriRobot, and AI Enterprise. AgriDrone, AgriRobot and AI Enterprise represent the cloud systems of companies that provide the services to the farmer.

- AgriDrone services are responsible for detailed drone mission planning and execution.
- AgriRobot services are responsible for tractor and UGV detailed mission planning and executions.
- AI Enterprise provides FlexiGroBots platforms common services to customers via the Internet.
- The farm management system is a cloud-based application that the farmer uses for managing his farm. FMS also includes data storage capability for farm data and visualisation services for external data.
- Farm cloud storage is a cloud service operated by the different cloud service provider, where farmer stores the data coming from external service companies. Data is photos, videos and maps of analysis results.
- The IoT solution provider offers a cloud service for the farmers IoT devices and context-driven services such as FlexiGroBots platform's multi-robot mission controller and situational awareness services.

The seventh cloud instance represents other business entities that are connected to the same data space. This is reserved for possible changes or extensions that the pilot may have.

Farmer uses farms' PC for accessing all farmer's cloud services and for communication between farmer and other business entities. In the pilot, these communication parts are not implemented, but this is shown in the architecture because it is needed in real scenarios. Examples of communication are agreements with business entities and money transactions.

At the core of the architecture is IDSA data space consisting of infrastructure services implemented in the cloud. These services are DAPS (Dynamic attribute provision service), ParIS (Partnership information service), and Broker services. The communication between cloud instances takes place through the IDS data sharing service.

The physical devices: drones, tractors, and UGVs and their remote controllers are connected to respective companies' cloud services via dedicated communication channels.

The motivation for the proposed data management architecture based on six business entities is the demonstration of the need for the data space concept. It demonstrates the trend of going into distributed value co-creation models, where specialized companies provide optimized services and together make up a better composition. The data space concept gives agility and flexibility to implement various combinations of the value chains easily. In the case of the use of autonomous robots these are essential issues as the cost of robots need to be justified and efficiency in the use of expensive devices is obligatory.

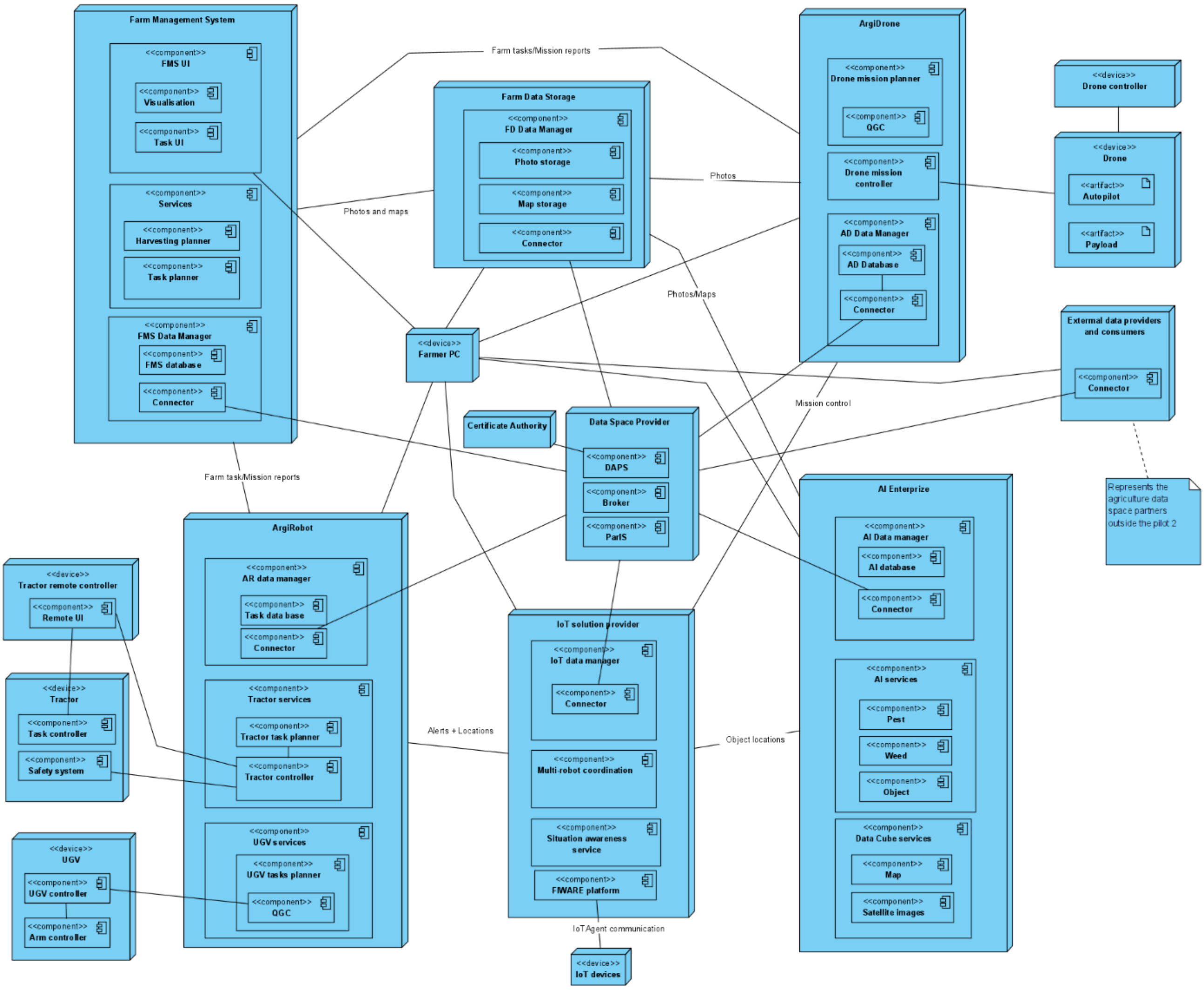


Figure 14. Pilot2 implementation architecture

5.2 Activity diagrams of main use cases

Pilot 2 has three main uses cases, i.e., pest management, silage harvesting, and Rumex weeding. These use cases are implemented by activities distributed between four different business entities. The sequences and distribution of activities are shown in the following figures.

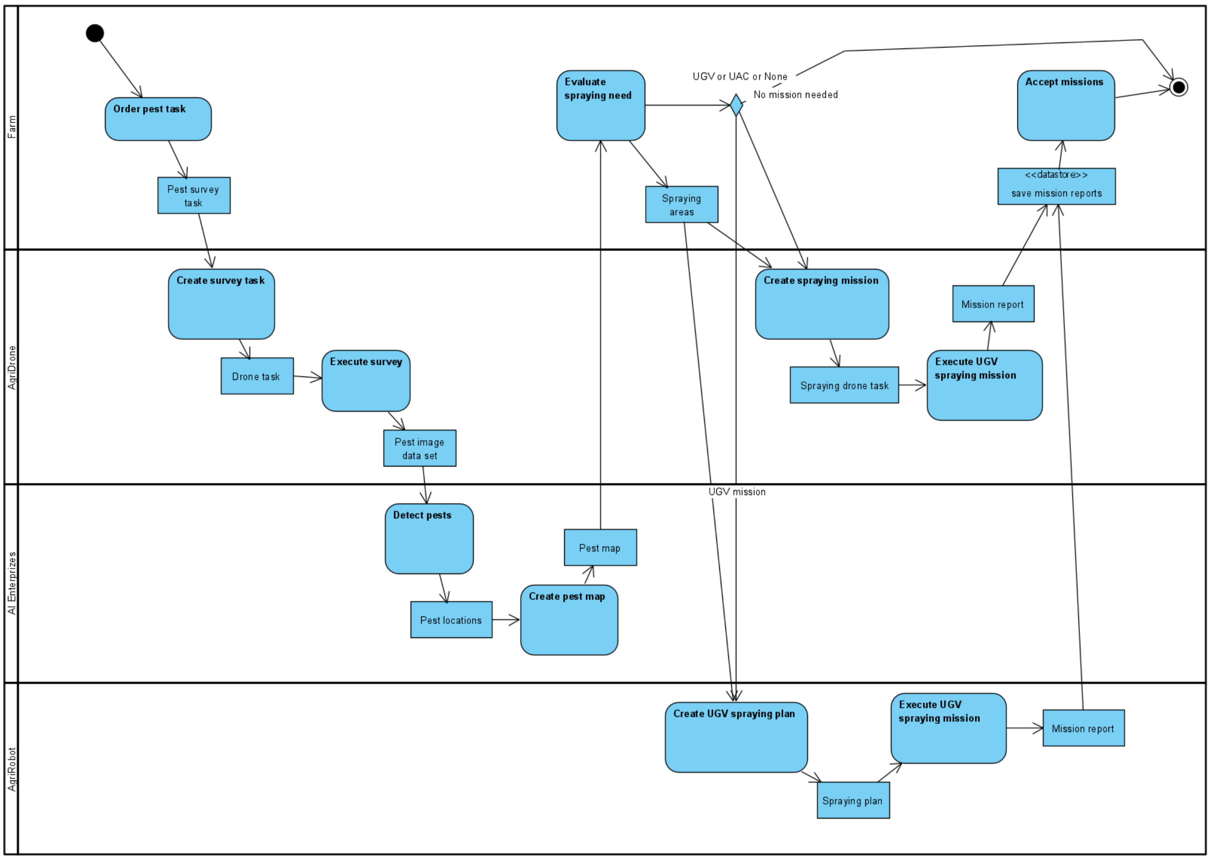


Figure 15. Activity diagram of pest management use case

As seen in Figure 15, the pest management use case starts with the creation of a request to analyse whether there are rapeseed pests in some fields. The request includes a farm task description that contains the details of the field in question. The description is shared with AgriDrone company that creates a detailed drone mission task and executes the autonomous imaging mission. The result is a set of photos of the rapeseed. These photos are shared with an AI service provider that analyses the images with FlexiGroBots pest detection algorithms and creates a pest map using Data Cubes maps of the locations of detected pests. These maps are shared with the farmer which confirms that spraying missions are needed. Depending on the situation, the farmer decides to do drone or UGV sprayings or to do nothing. In case of spraying, the farmer either shares the pest map with AgriDrone or AgriRobot company, who will make respective detailed plans, execute the missions and report the results. In the end, the farmer accepts the tasks, and the use case is performed.

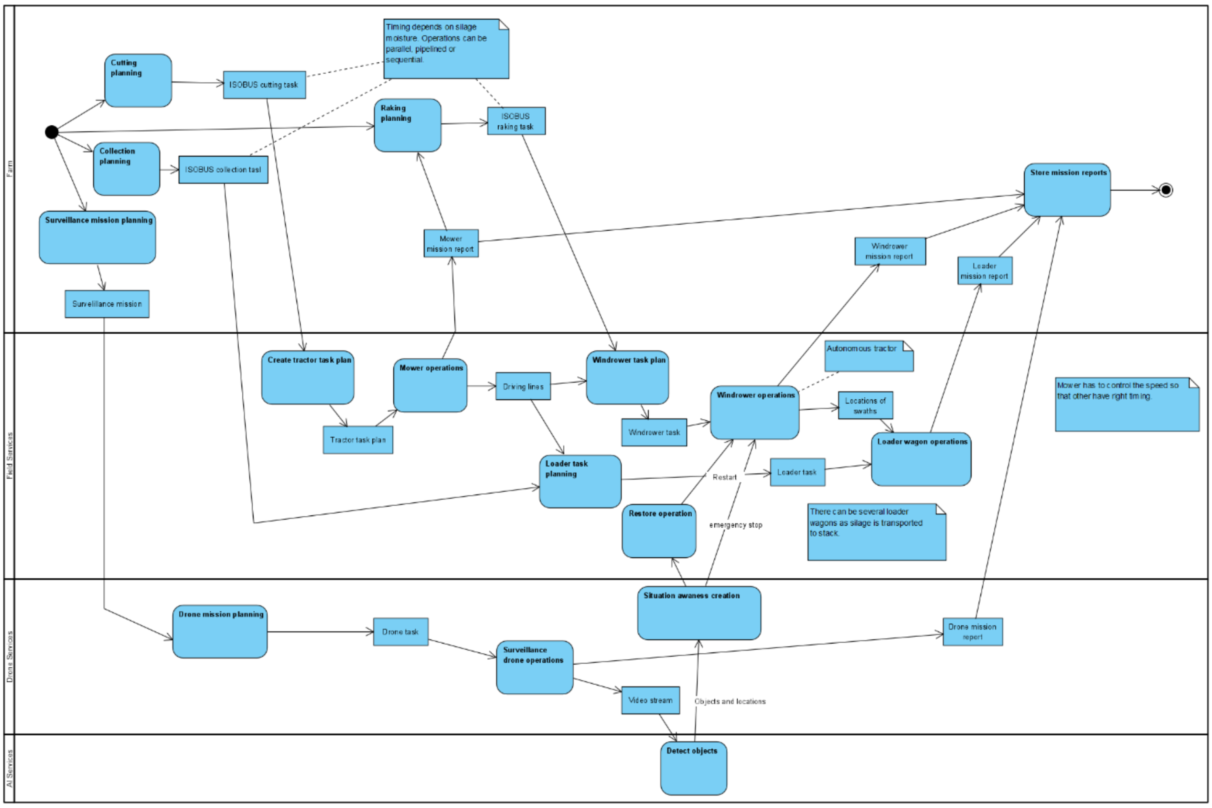


Figure 16. Activity diagram of silage harvesting use case

The silage use case involves the following companies: farm, AgriRobot, AgriDrone and AI services.

The use case in Figure 16 starts with silage harvesting planning which is not described in detail in the diagram. It produces three farm level tasks for different tools and activities in harvesting: cutting, raking and collection tasks. In addition, the surveillance drone task must be planned before actual field operations.

The harvesting process starts with the cutting of the silage. The ISOBUS task must be converted to a more detailed tractor task that is given to the mower operator, who drives the mower tractor in the use case. The data related to the driving lines at the field are used for planning the detailed windrower task that controls the autonomous windrower tractor and loader tractor plan that is driven by a human operator.

When the windrower starts its task, the surveillance drone mission is started as well. The surveillance drone hovers above the windrower and takes photos/video (to be defined later) that is transmitted to AI service for the object detection operations. Objects and locations are transferred to situation awareness creation and hazard detection. The exact operation of situation awareness functionality and its relation to the multi-robot mission controller will be defined later.

The final step in the use case is the generation of mission reports to the farmer and farm management system by all involved devices, and the farmer accepts the tasks completed.

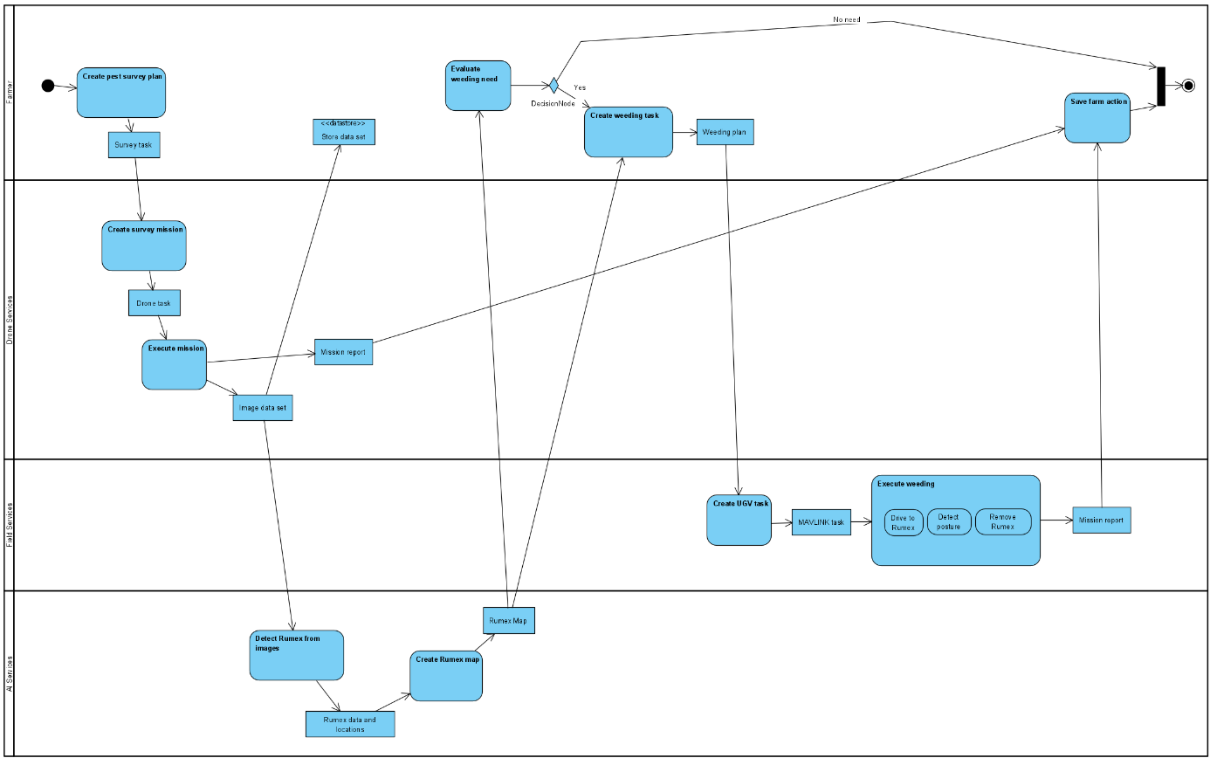


Figure 17. Activity diagram of Rumex weeding use case

The Rumex weeding use case in Figure 17 has a very similar structure to the pest management use case. The first phase is an aerial survey mission by drone. The images are analyzed by an AI service for the detection of Rumex locations. A weeding plan for the UGV weeding robot is created using those locations. The main difference is in the actual weeding process. From the location data has only an approximate location of plants. When the robot approaches the area, it has to detect the Rumex with its own 3D camera and analyze the exact posture of the plant, to posture the weeding tool to the right position. The posture calculation is an AI service integrated into the robot.

5.3 Pilot processes

The pilot processes define the control messages between the architecture artefacts and users needed to organize the services for the implementations of the use cases. In the following diagrams, we have divided the three main use cases into drone survey mission planning, drone survey mission execution, drone surveillance mission execution, harvesting planning, weeding, silage harvesting and pest spraying missions. The idea has been to make each process more clear and more independent from the others so that the diagrams would serve better in the actual service design.

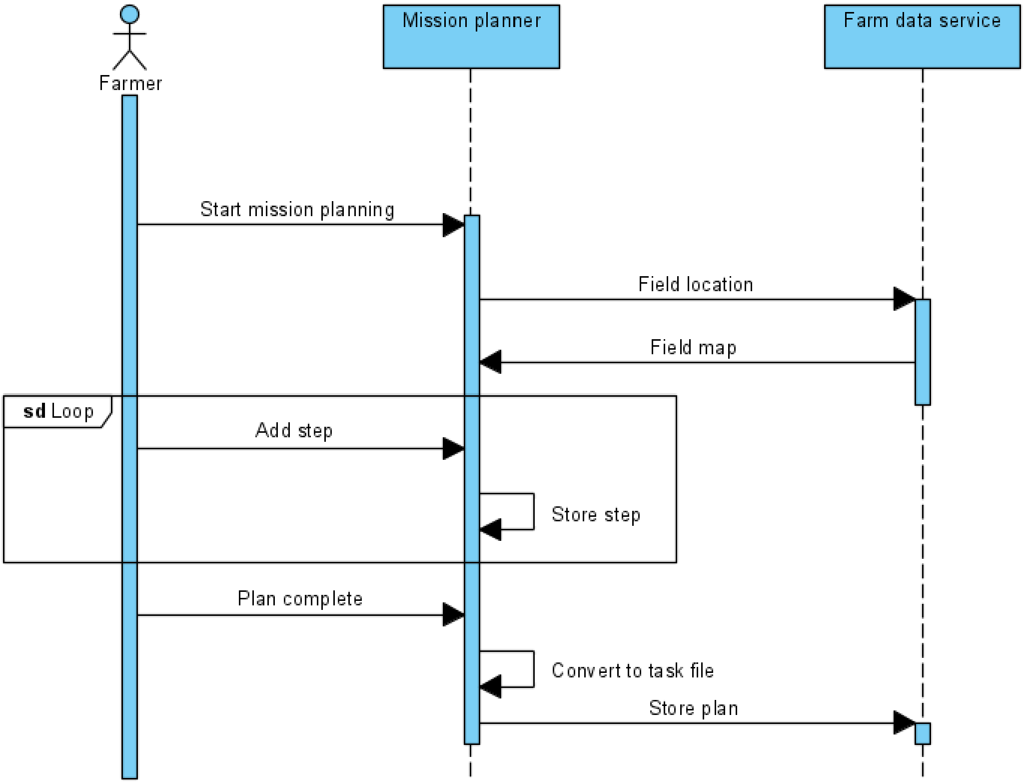


Figure 18. Drone survey mission planning process

Figure 18 presents a generic drone survey mission planning process that can be used in the planning of all drone missions in the Rapeseed pilot. In the diagram, the farmer is the actor planning the mission, but it could be the drone operator as well. It depends on how the actual overall process is organised on the farm.

Figure 19 describes the initial drone survey mission execution process that divides into activities started by the farmer and drone operator. The same process can be used both for pest and weed detection use cases in the Rapeseed pilot. The farmer initiates the survey mission and receives the final mission report. The drone operator uploads the farm level mission plan and updates it into a drone mission plan (as in Figure 18) and uploads it into a drone. After that, the mission is executed and resulting images are shared with the AI service doing the analysis service and mapping of results to field map. The resulting map is uploaded by the farmer for further steps.

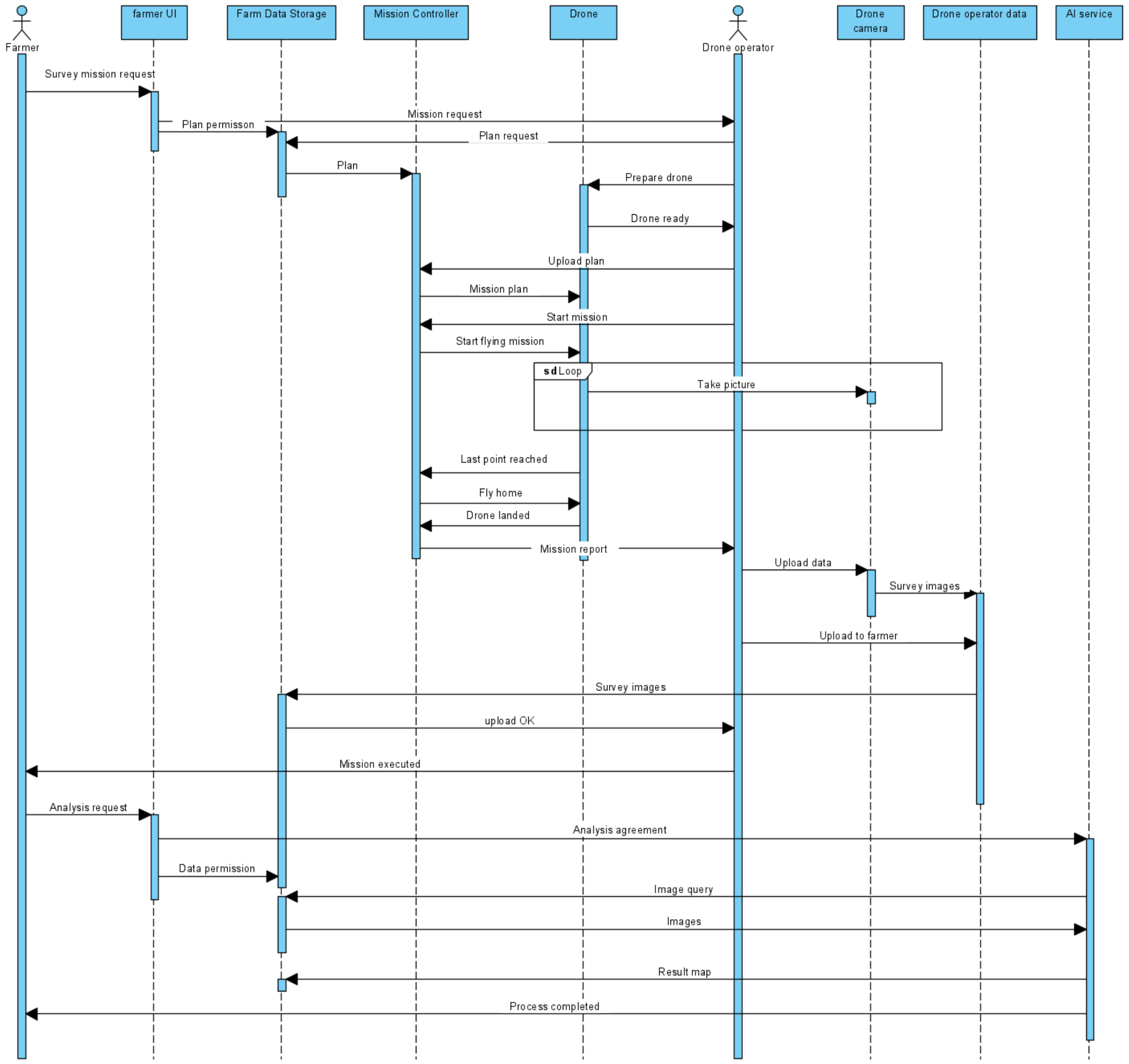


Figure 19. Drone survey mission execution process

Figure 20 describes the initial spraying mission execution process. The process starts when the farmer gives a request for drone operator to do the mission and gives permission to access the spraying mission task description. In this process, we assume that the drone spraying mission task is already existing and saved in the farm data storage. The drone mission is sketched like any other autonomous drone mission. In practice, the spraying of pesticides is currently prohibited by legislation in rapeseed pilot locations.

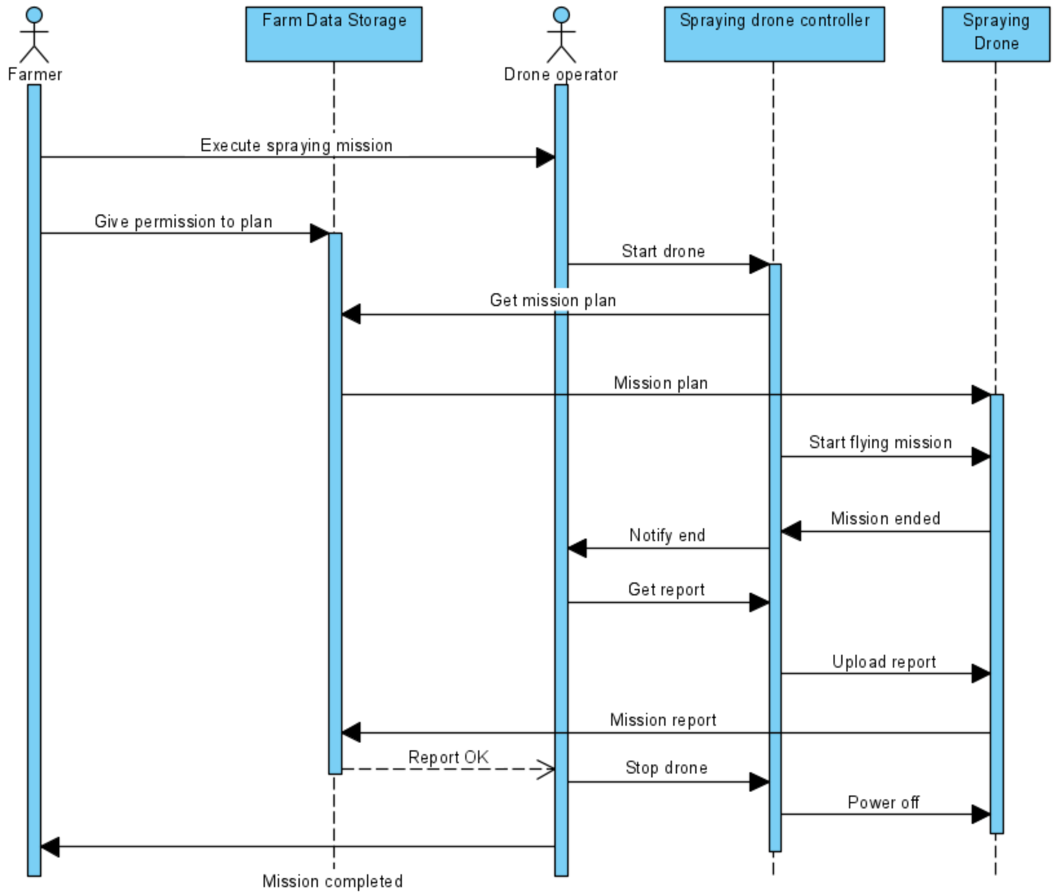


Figure 20. Spraying mission execution process

Figure 21 shows the initial surveillance mission execution process that is done in parallel with silage harvesting. The diagram shows the main messages between different actors. This process will be improved when the mission control centre is more mature, and interaction or integration of surveillance service is better understood.

The main challenge in the surveillance mission is interaction with the silage harvesting mission. The surveillance drone takes continuously images or videos and sends them to be analyzed. In case there are possible hazards, the system must report to both tractors and operators so that the situation can be resolved.

The situation awareness service and hazard detection are time-critical services. To decrease the system response time, we make physical implementation so that there are no unpredictable delays, and we increase the safety margins of hazard detection. These decisions will be done in the later phases of physical architecture design.

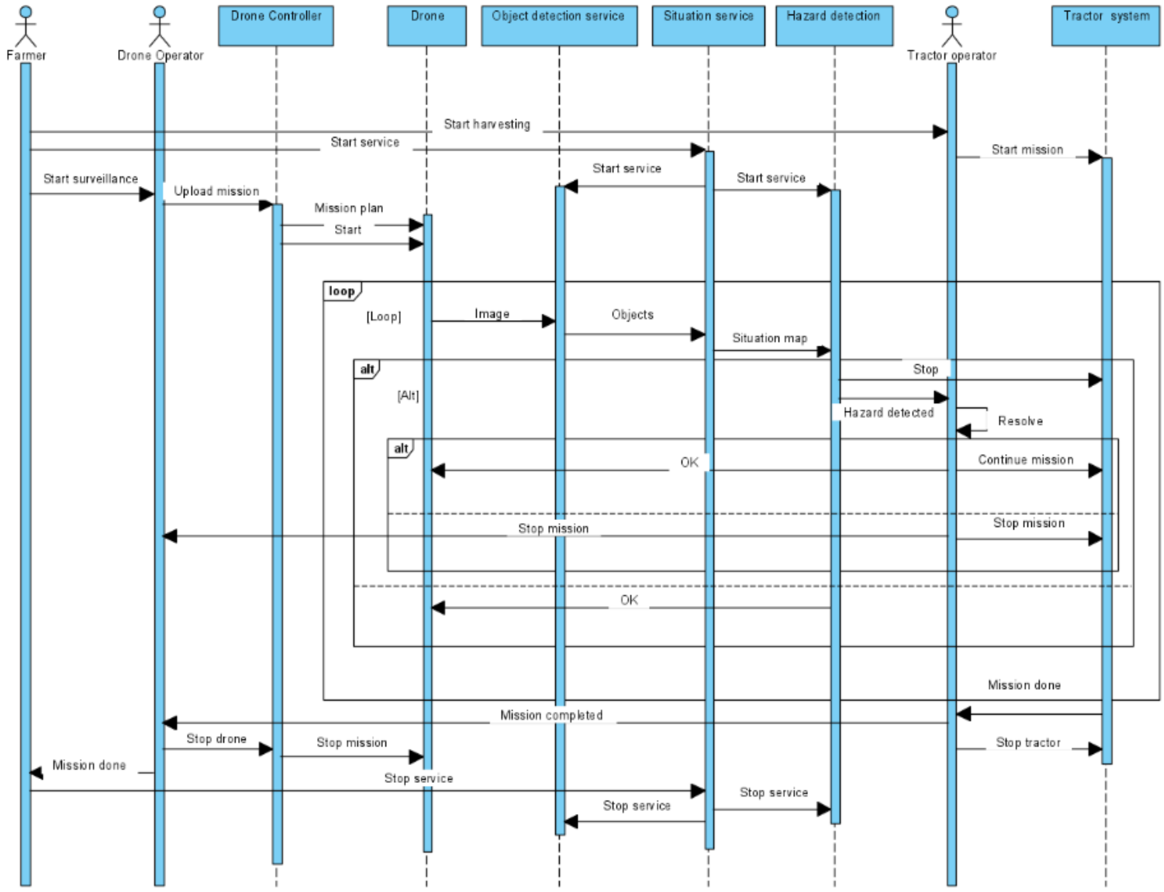


Figure 21. Surveillance mission execution process

Figure 22 describes the initial weeding mission execution process. The weeding process includes phases where the robot makes autonomous decisions on its movements. When the robot arrives at a weed, it needs to detect the exact locations and postures of the actual plants. The robot starts to scan the surroundings and when it detects a plant, it uses its 3D camera and posture detection services to find the exact location of the plant. Then the robot grabs the plant, removes it, and puts it into its bin for transportation. This process is continued until all weeds in the given area are removed. Then the robot continues to the next area and repeats this until the mission is completed.

Figure 23 describes the silage harvesting process. The process consists of four phases: the creation of a harvesting plan, the creation of ISOBUS tasks, the creation of tractor tasks, and actual mission execution.

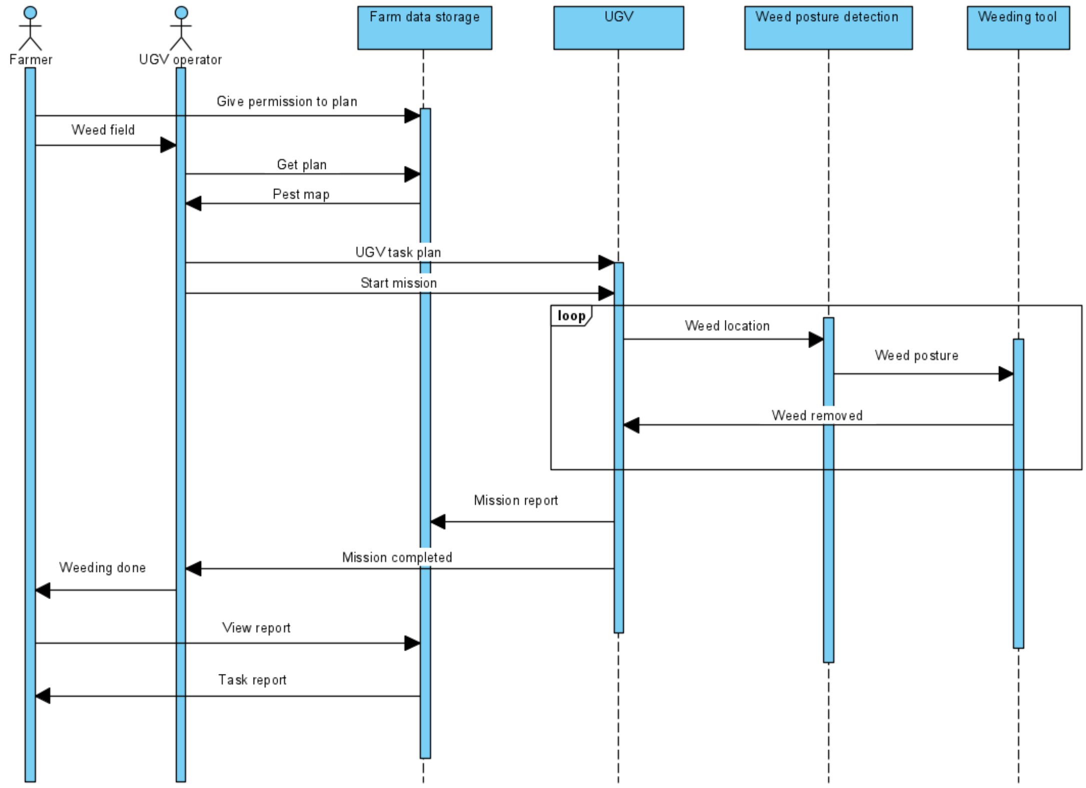


Figure 22. Weeding mission execution process

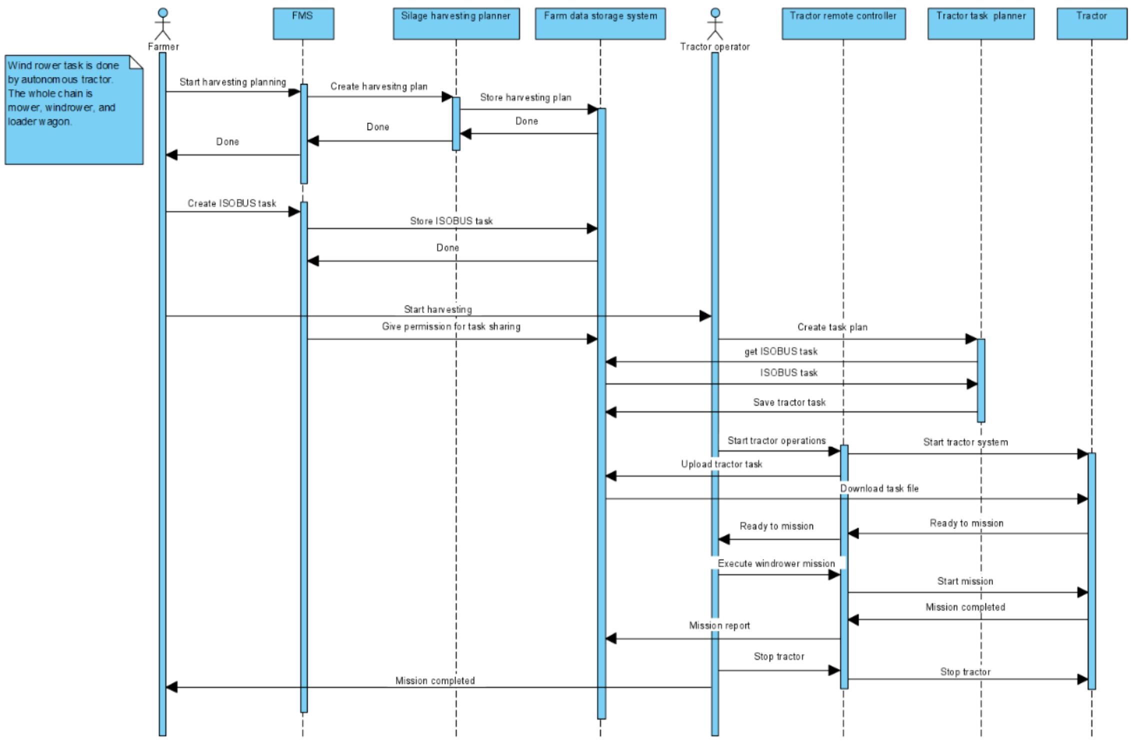


Figure 23. Silage harvesting process

5.4 Devices and Robots

This pilot 2 implements several different devices, drones, UGVs, a robot tractor. A general overview of this hardware is presented next.

5.4.1 Tractor

Luke has developed a robot tractor together with Valtra. Mechanically the robot is based on the standard N-series tractor manufactured by Valtra. The electronic control units of the tractor are modified by Valtra such that the tractor facilities can be used from the robot software without driver actions. In addition, Luke has developed robot software for higher-level control and for external communication. Robot control software is run on Ubuntu Linux in a dedicated computer, Panasonic Toughbook CF-19.

The tractor is able to drive along predefined driving lines using a commercial Valtra Guide auto steering system. The driving lines and the information needed in precision farming operations can be transferred to the robot using EFDI communication. The EFDI is used also to transfer telemetry information and to give high-level remote commands to the tractor. The precision farming task file is transferred automatically to the commercial ISOBUS Task Controller before the autonomous operation is started. The ISOBUS Task Controller gives set-point commands for implementation based on GPS location. In turn, the implementation can command the hydraulic AUX-valves, PTO speed and hitch position. The remote control and emergency stop functionalities are added to ensure safety. In addition, for safety, machine vision system based on Zed2 stereo camera made by StereoLabs is developed to detect the obstacles in front of the tractor. The tractor control systems are described in more detail in chapter 5.5.5. Livox -based Lidar system is considered.

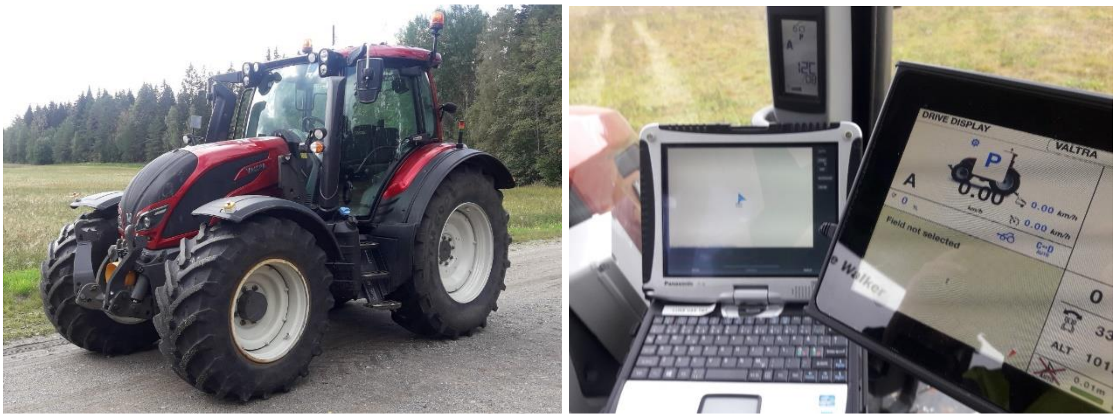


Figure 24. Robotized tractor (left), laptop giving commands to the robotized tractor (right)

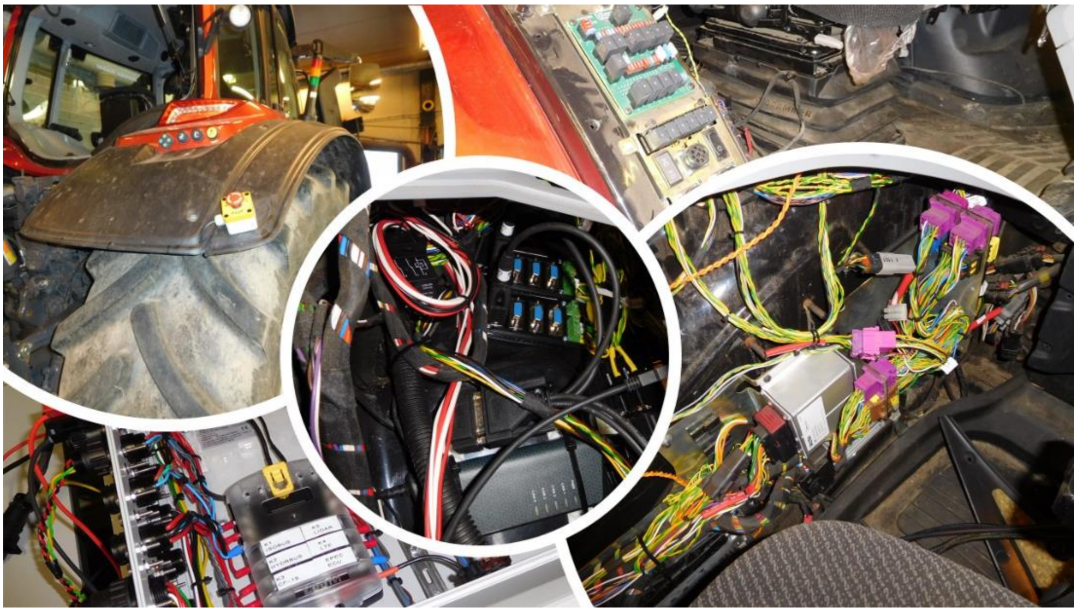


Figure 25. General view of cabling and implementations to the tractor

5.4.1.1 Tractor tools

The robotized tractor will be able to manage all types of common ISOBUS machinery, but the pilot focuses on windrower application within silage harvesting. In addition, the ISOBUS-compatible sprayer will be available for demonstration of the spraying application interface.

Figure 26. A windrower in a transportation setup

The ISOBUS compatible Hardi Mega 1500/21m VPZ sprayer is used for the spraying task demonstrations. For the windrower applications, Claas Liner 370 rake and ELHO V-Twin 750 swather will be used.

5.4.2 UGV (Unmanned Ground Vehicle)

5.4.2.1 Robot platform 1

Probot has designed its own mobile robot platforms for field operations. The platform is based on several lessons learned in earlier agricultural projects and use-cases and the robot has been built as modular as possible. In this project, the robot is used as a 5 to 7.5 m wide version, depending on the decisions made in the project before the final demonstration. The robot platform can be operated both manually and as automatically. In automatic mode, the robot navigates along predefined paths as well as directly to the desired GPS point. For short-range obstacle avoidance and navigation, a 2D LIDAR sensor is utilized (e.g., Slamtec, or URG). To demonstrate the Rumex weeding, the robot is implemented with 4G-based communication as well as on-board CAN-bus for communication between the Probots' robot platform and the VTTs' robot arm for the weeding. The final version of the robot is decided by the end of 2021 and the demonstration platform will be presented and tested first time during summer 2022.

The platform has stand-alone separate 36 V batteries for tool points and rovers. The communication between the tool point and the rovers is carried out by WLAN.

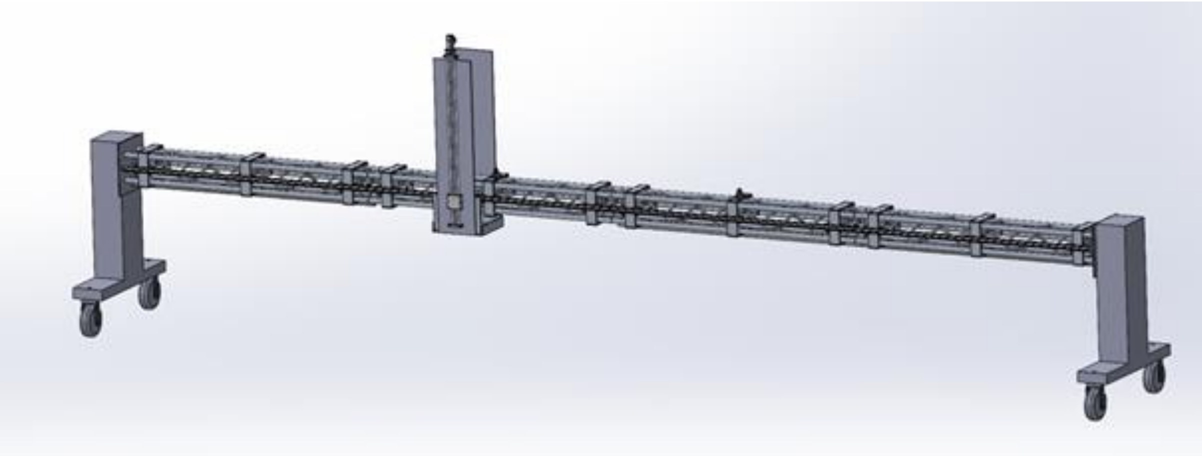


Figure 27. The robot platform by Probot Oy. The image shows a concept, the final version will be introduced in the summer 2022

5.4.2.2 Robot platform 2

Luke has also a small 1.5m x 1.5m sized electric ground vehicle. The driving components are based on electric bicycle components. Each wheel has its own 48V 3kW electric motor and all wheels can be turned independently. The capacity of the driving batteries is 2.2kWh. The operation voltage of all other electrical equipment is 24V and the capacity is 4.2kWh. The instructions to the robot can be given through EFDI communication similarly to the tractor. The robot control system is partially the same as in robot tractor, however, commercial components manufactured by the Valtra is not used in this platform. The robot is able to drive autonomously along predefined paths, move also sideways and rotate in place. Tools can be attached to the centre of the robot. Internal communication between the tool and the robot control unit can be realized using ZeroMQ communication or CAN-bus.

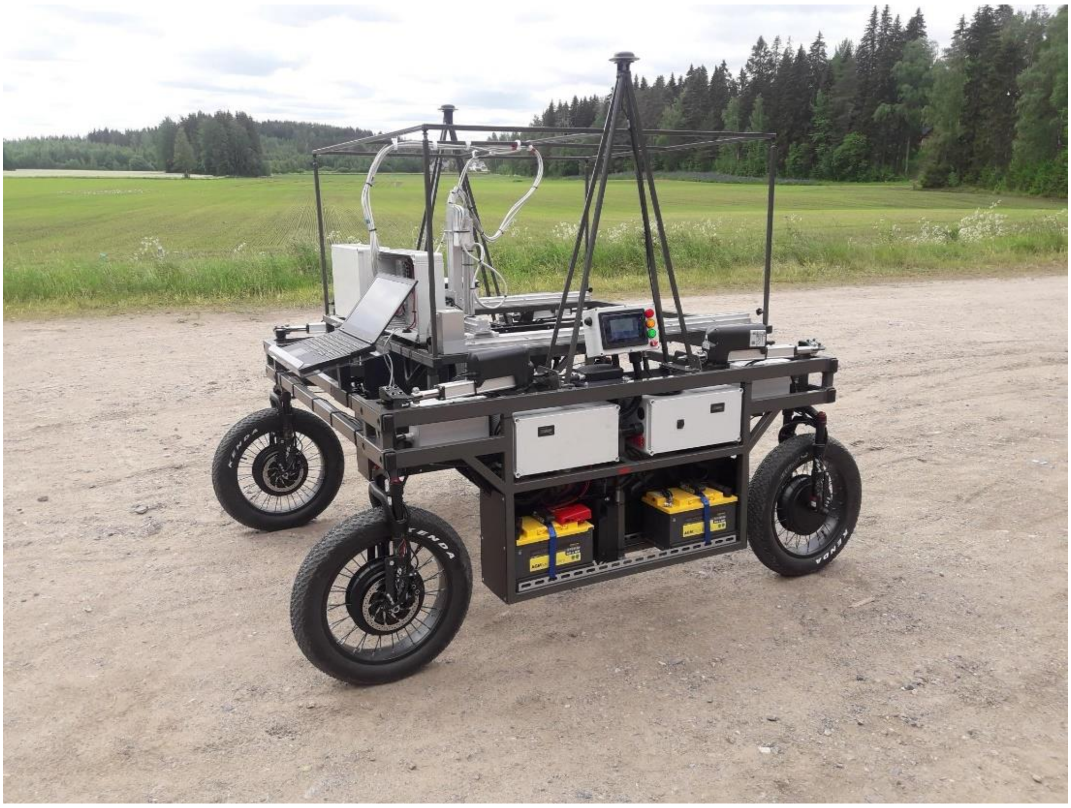


Figure 28. A backup UGV platform constructed by LUKE

5.4.2.3 Robot platform 3 (weeding tool)

VTT has a mobile robot test platform, which is used for developing and testing the weeding tools and functions. It consists of the following components and features:

- Autonomous Mobile Robot platform constructed by the Probot OY,
- SCHUNK LWA4p robotic arm with 6 kg payload,
- 6DOF Force/Torque Microelectronic MessSysteme Gmbh,
- On-board Intel NUC series embedded controller,
- GPS locating system (based on uBlox GPS receiver), 3D cameras (Intel RealSense; ZED),
- CAN-bus connectivity for the platform wheel motors, robot arm and F/T sensor,
- 2D/3D cameras (ZED, Intel RealSense 4x5).

The whole control stack has been developed by VTT and is using ROS in the vision sensor connectivity. For 3D shape detection, VTT's existing 3D vision software is used. For external connectivity, a 4G/5G modem is used. A mechanical weeding tool will be designed, planned to utilize mechanisms of currently commercially available fork-like weeding tools.

Figure 29. Test platform for weeding including a mobile robot platform (made by Probot Oy) with Schunk LWA 4 PB with force/torque sensor (ME MessSysteme Gmbh) and compliant motion control

5.4.3 Drones

The number of different drones is applied in imaging data collection. The main drones for imaging purposes are DJI Phantom 4 RTK (SDK-version, software development kit), DJI Mavic Zoom 2 and Parrot Anafi. In addition, DJI Phantom 4 Multispectral, Matrice 600 pro, Parrot

Disco and FreeFly Alta X provide a backup solution to provide multi- or hyperspectral information if needed in order to provide sufficient classification data.

Figure 30. Luke's' drones for project purposes. From the left: DJI Matrice 600 pro and Specim AFX10 & AFX17, Parrot Disco Fixed wing, DJI Agras T-16 spraying drone, three different DJI Phantom 4 drones

Figure 31. Backup drone: FreeFly AltaX drone with Specim AFX17 hyperspectral camera

The key specifications such as take-off weight, maximum flying speed, camera and lens type of the main drone setups are presented in the following Table 82.

	Phantom 4 RTK	Mavic Zoom2	Parrot Anafi	Phantom 4 multispectral	Agras T-16
Take-off weight	1391 g	905 g	320 g	1487 g	42000 g (full tank)
Max speed	58 km/h	72 km/h	55 km/h	50 km/h	36 km/h
Max flight time	30 min	31 min	25 min	27 min	10-18 min
Camera	1" CMOS; Effective pixels: 20 M	1/2.3" CMOS Effective Pixels: 12 M	Sony IMX230, 1/2.4'' CMOS, 21Mp	Six 1/2.9" CMOS, including one RGB and five monochrome sensors. Each Sensor: Effective pixels 2.08 MP	N/A
Lens specs	FOV: 84°. Focal length: 8.8 mm / 24 mm (35 mm format equivalent:24 mm). Aperture: f/2.8 - f/11. Depth: 1 m - ∞.	FOV: about 83° (24 mm); about 48° (48 mm), 35 mm format equivalent: 24-48 mm. Aperture: f/2.8 (24 mm)–f/3.8 (48 mm). Depth: 0.5 m to ∞.	ASPH (Low-dispersion aspherical lens) Focal length (35mm format equivalent): 23-69mm (photo), 26-78mm (video) Aperture: f/2.4. Depth: 1.5m - ∞.	FOV: 62.7°. Focal length: 5.74 mm (35 mm format equivalent: 40 mm). Aperture: f/2.2. Autofocus set at ∞.	N/A

Table 82. Key specifications of the involved drones

5.4.4 Drone payloads

5.4.4.1 Cameras

Four main types of cameras are used with drones: RGB (integrated DJI Phantom 4, RGB with zoom (integrated DJI Mavic 2 zoom), multispectral (integrated DJI Phantom 4 multispectral) and hyperspectral cameras (Specim AFX10 and Specim AFX17, Konica Minolta). The detailed information about cameras and lenses are presented earlier in Table 82.

5.4.4.2 Spraying drone

The pilot applies a commercial DJI Agras T-16 spraying drone for the aerial spraying operation demonstration. Due to legislation, the drone will only spray water. The Agras T-16 has 16 kg of operational payload and has eight spraying nozzles. The maximum take-off weight is 42 kg. A specific software DJI Terra Agriculture will be used for application task management.

Figure 32. Spraying drone DJI Agras T-16

5.4.5 Drone mission ground station / mobile depot

Luke has built a mobile ground station setup for drone mission operations. The setup holds drone-related accessories and additional batteries, backup disks (LaCie DJI co-pilot 2tb, LaCie Big Dock 16tb and a backup server), calibration panels, ground control points, integrated power source and Eco-Flow River MAX portable power source, laptops and tablets, 4G modem, DJI-RTK 2 base station, EMLID Reach RS RTK-GPS receiver, related laptops, tablets, cameras, cabling, weather station, water tanks for the sprayer, toolboxes and various additional reference measurement sensors such as CI-710 spectrometer. The mobile ground station is normally installed in VW Crafter or VW Transporter. This setup is used for data collection, and for pilot development and execution.

Figure 33. Mission ground station in stationary surveying setup with VW Crafter

The system is used in most of the drone missions carried out by Luke in various locations around Finland.

5.5 Platforms and Components

5.5.1 FlexiGroBots platform

The use of FlexiGroBots platform services in pilot 2 is summarized in Table 83.

Pilot's platform services	
FlexiGroBots platform	
AI platform	AI platform's development services will be used in development of services that are made available as common application services.
Common data services	Pilot will use open-source data space components from IDSA and possibly other providers. Pilot data space will have at least connectors, broker and DAPS. Connector components will be based on the IDSA Dataspace connector. As DAPS and certificate authority components the aim is to use IDSA test bed implementations.
Common application services	Pilot will use pest, Rumex and object detection services.
Geospatial services	The outcomes of pest, Rumex and object detections are locations of detected objects that could be used for creating respectively object, pest, and Rumex maps. These functionalities will be part of pilot 2. The mapping will be implemented using the service offered by the FlexiGroBots platform or maps provided by the pilot's farm management system.
Multi-robot mission controller	
QGroundControl (QGC)	QGroundControl will be used in drone mission planning and autonomous mission control tool and weeding robot mission planning. QGC will be adopted also for monitoring multiple robots using MAVLink protocol as well as open drone ID as the identifier for separate drones. MAVLink message that this central for identifying drones is called OPEN_DRONE_ID_BASIC_ID. The protocol is in the development stage and is not supported by a stable release of QGC. Open Drone ID is related to legislation work that is under development in USA and EU concerning drone operation. Protocol is defined so that it is compliant with EU regulations (EN 4709-002). Regulation is still not final, hence, it might be changed.

Pilot's platform services	
	QGC is related to MAV link protocol that is the basis of Dronecode foundation, which is a successor for ArduPilot and Pixhawk, which is, actually, standard in other than DJI drones. DJI is commercial market leader with substantial margin in both consumer and professional drones, and it is using its proprietary protocol and software ecosystem. To make QGC able to communicate and control DJI drones, an adapter for DJI drones must be developed. This is possible with DJI SDK that is available for most higher-end DJI products. Preliminary work for this is existing in open-source domain.
IoT platform	
FIWARE	FIWARE instance will be implemented on VTT server. It will serve as a basis for situation awareness services and multi-robot coordination service. The role of the IoT platform is to keep track of robots and drones' status. Using FIWARE Generic Enablers (GE), status history can be also recorded for later reference. FIWARE implements Next Generation Service Interface (NGSI) protocol that is ETSI standard for context information model. Using FIWARE enables the interoperability of different applications and devices using the NGSI standard. Orion Context Broker, which is the core of FIWARE implement publish-subscribe interface for Entities, enabling reactive application to be built on top of it. Communication with robots and drones with FIWARE platform happens using either MQTT protocol or REST interfaces of FIWARE IoT Agent or Orion directly.

Table 83. FlexiGroBots platform services used in Pilot 2

5.5.2 ISOBUS mission planning

ISOBUS task files contain all information needed for precision farming operation: what to do, where to do it, how to do it, when to do and who does. Most of the information can be planned in FMIS already. However, exact driving lines or routes and exact timing is missing in current commercial systems. FMIS capabilities are explained in more detail in chapter 5.5.3.

ISOBUS mission planning system receives planned ISOBUS TASK file from FMIS system using EFDI communication protocol. The Agricultural Industry Electronics Foundation has defined guidelines for Extended Farm Management Information Systems Data Interface (EFDI), and it will be published later as an ISO standard. The received TASK file defines the agricultural operation, the target parcel (part field) and the machinery used. The user uses this information and plans the target driving routes based on previous driving lines. For example, in silage harvesting, the driving lines of the mower defines the position of the swaths. User selects which swaths are merged and in which order. After that, the planning system calculates driving routes for the windrower also including headland turnings. The driving routes are included in the ISOBUS TASK and the TASK is forwarded to the Robot tractor via the EFDI communication protocol.

5.5.3 MyFarm farm management system

Generally, farmers manage their fields, planning farm production and storing production-related information in applications called farm management systems (FMS) or farm management information systems (FMIS). The project partner MTE is owner of MyFarm platform that includes FMS application Wisu [4] which is currently used by Finnish farmers. Wisu offers farmers and advisors access to modern farm management tools for crop production as an online service. For task file creation and yield map visualization, there is an extension called the Smart Farming module available that increments Wisu with all necessary tools for taking the farm management practices to the precision farming level. This extension respects standards with existing compatibility with ISO-XML in the task files for variable rate applications. With existing capabilities, the task file can be created using e.g., satellite data, and current cultivation plan can be considered when the task file is created almost automatically.

In this project, FMS is closely related to several activities in scenario 2 that all are connected to information exchange at some level. Therefore, information exchange according to the IDSA concept is one of the key targets concerning the visualization of external information sources. Adopting information from external sources to content is another main topic in terms of collected geospatial information enriched with AI treatment. In addition to the IDSA concept, EFDI as a future addition to the ISO11783 standard is explored.

5.5.4 Farm data storage system

For handling and processing data from sensors and drones, VTT has also a setup virtual cloud server for Pilot 2, where partners can share data. The server is acting as testing platform for IDS data sharing as well. Images and data can be shared using IDS dataspace connector.

Image data is stored in the cloud server file system. Server has a service that makes image data automatically available via IDS Dataspace Connector. Server also hosts FIWARE IoT Platform that includes dedicated MQTT Broker. This enables robots and other devices to also store their data in IoT platform and that data can be made available to other organizations via the same IDS Dataspace Connector.

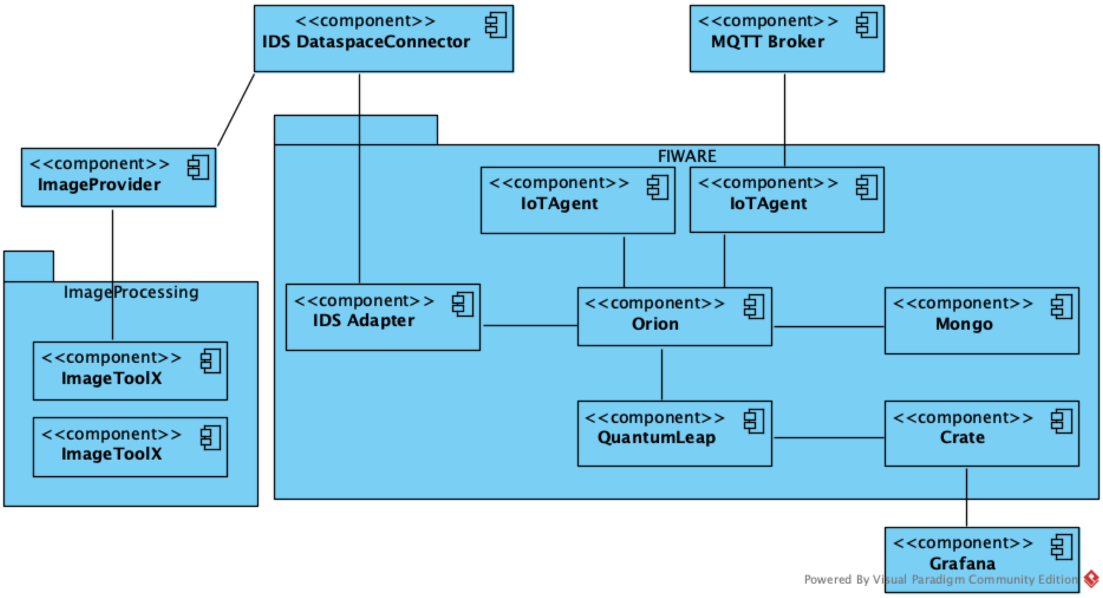


Figure 34. Virtual cloud server connections for data sharing

Server is also used for various data analytics and component testing during the pilot such as multi-robot control and message brokering.

Physically, the data storage system resides on virtualized Ubuntu 20LTS (Long Term Support) server. The host system is a Dell PowerEdge R740 rack server with two Intel Xeon 4208 CPU's (8 cores each). Virtual server has been allocated with 2 CPU cores and 16GB memory and 200GB disk space. The amount of hardware resources can be scaled up if resources become a bottleneck.

5.5.5 Tractor control systems

The tractor control system is distributed system consisting of several components. Most of the components are already commercially available, but they have been modified for robotic use. The master component, robot control, has been specially developed for the robot.

5.5.5.1 Robot control

The Robot control is the master component which implements the communication to external systems and commands all other components of the tractor. The EFDI communication via 4G LTE router is the main communication channel, which is used to deliver the ISOBUS TASK, which defines the autonomous operation, and it is also used to high-level commands, such as start or stop the operation. Robot control software is run on Ubuntu Linux in a dedicated computer, Panasonic Toughbook CF-19.

5.5.5.2 Remote control

Radio Frequency remote control is used to manual control of the tractor in addition to driving inside the cabin. Autec Compact DJC transmitting unit and CRD receiving unit is used. The receiver and transmitter are customised for this usage by the manufacturer. The working distance is about 100 meters.

The RF remote control is also used for safety reasons: if the tractor is too far from remote control or the emergency stop button of the remote control is pushed, the tractor engine is stopped. The driving mode (manual inside the cabin, manual remote, autonomous) is also selected from the RF remote control.

In addition to RF remote control, the tractor has also a remote GUI. From the remote GUI, it is possible to select the ISOBUS TASK file used in the autonomous operation, start or stop the operation and also monitor the operation. The communication between remote GUI and tractor is implemented using EFDI protocol. The remote GUI is run on a Linux operation system in Panasonic ZF-M1 Toughpad.

Figure 35. RF remote controller and remote GUI

5.5.5.3 Valtra Guide

Valtra Guide is a commercial auto-guidance device. It can steer the tractor along predefined driving lines. However, it is not able to command the speed of the tractor or change the driving direction. Those are implemented in the robot control component. The robot control also sends the desired driving lines to the Valtra Guide whenever the driving direction changes, and it also starts the guidance.

Figure 36. Valtra Guide commercial auto steering system. The same terminal is used to control other tractor functionalities and ISOBUS VT/TC. (image source: https://valtrateam.valtra.com/tekniikka/automaattiohjaus-uudistui/)

5.5.5.3.1 Tractor ECU

The Tractor ECU is the main component of the tractor control system. It controls all the functionalities of the tractor (tractor speed and steering angle, engine RPM, external hydraulics, PTO and front and rear hitch). For robotic usage, it is modified such that all the tractor functionalities (ISOBUS Class 3 T-ECU) can be controlled through the ISOBUS CAN-bus.

5.5.5.3.2 ISOBUS Task Controller

ISOBUS Task Controller is a commercial device, which was developed for precision farming purposes. It uses a prescription map of the ISOBUS TASK file, and RTK-GPS to calculate the desired setpoint commands to the implements. Commands are sent to ISOBUS Implement ECU via ISOBUS CAN-bus.

5.5.5.4 Implement

Different commercial agricultural implements are used in this project. The Hardi Mega 1500l 21m VPZ sprayer is ISOBUS compliant, hence, an ISOBUS controller can be used. However, in the silage harvesting, the implements used for Claas Liner 370 rake and ELHO V-Twin 750 swather are not ISOBUS implements. For these tools, the implement control must be developed in the project using previous experience [5].

5.5.5.5 Machine vision system

For safety reasons, the machine vision system is implemented in the robot tractor. The machine vision system is based on a Zed2 stereo camera made by StereoLabs. The machine vision system monitors the foreground of the tractor, and if it detects obstacles, it first decreases the speed and eventually stops the tractor. The object detection is based on Zed SDK and it is run on NVIDIA Jetson Xavier AGX AI computer. The machine vision system could also be used to improve the positioning accuracy of RTK-GPS where positioning otherwise works poorly, such as near buildings.

Figure 37. Zed2 stereo camera is used to detect the obstacles in front of the tractor (image source: https://www.stereolabs.com/zed-2/)

Figure 38. The machine vision software is run on NVIDIA Jetson AGX Xavier (image source: https://developer.nvidia.com/embedded/jetson-agx-xavier-developer-kit)

5.5.6 UGV control system

The control system of the robot is based on the following three main communication and control channels on-board: WLAN, CAN and 4g/5g. The WLAN is intended for enabling the toolpoint to move as freely as possible along the linear truss between the rovers. The CAN is used for any wired connection between the rover wheels as well as the toolpoint and the robot arm used in the Rumex-weeding demonstration. The robot itself uses a 4g/5g network for any external communication with the user.

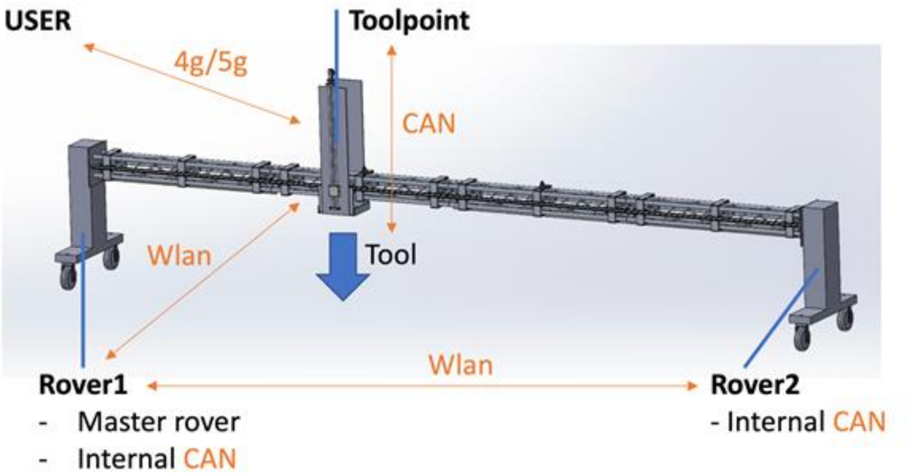


Figure 39. The general architecture of the UGV by Probot

VTT's UGV:

- Intel NUC controller, implementing mission, task, action and trajectory control layers (C++ .exe modules, with CAN-interfaces) as well as 3D Rumex detector (C++ .exe module, running as a ROS node),
- CAN-bus controller for platform wheel control, and robot arm joint control.

5.5.6.1 ROS

The Robot Operating System (ROS) is an open-source, meta-operating system for robots. It provides the services expected from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management [6]. It also provides tools and libraries for obtaining, building, writing, and running code across multiple computers. The ROS runtime is a peer-to-peer network of processes (potentially distributed across machines) that are loosely coupled using the ROS communication infrastructure [6].

In Pilot 2, ROS is used to interface 3D cameras with a ROS driver to the Rumex detector software, which is implemented as a ROS node. This ROS node is further interfaced to VTT's Rumex weeding mobile robot platform controller, with a proprietary TCP/IP interface. All this software runs in an embedded Intel NUC controller, running Linux (Ubuntu 18.04).

5.5.7 Drone control system

Drone control system consists of drones, ground control system and cloud service. Drones are equipped with a flight controller and a payload controller for a camera or other devices related to drone tasks.

5.5.7.1 Flight controller

Drone flight controller is the component responsible for controlling the flight of the drone. Depending on the actual model of the drone, the drone flight controller can communicate with the ground control system using MAVLink protocol or DJI proprietary protocol.

Figure 40. Pixhawk 4 flight controller

Flight controller is an independent system that interprets autonomous flight plans and computes individual steps from the plan. Flight controller can also give commands or signals to other components such as cameras to trigger action. For example, in a survey mission flight controller sends trigger signal to the camera based on defined mission parameters to achieve desired image overlap and coverage.

In addition, flight controller has several analog or discrete 5V signal output which can use for predefined tasks. Flight controller has also several serial communication interface to other robot components such as GPS, and other computing devices.

5.5.7.2 Drone payload controller

Payload controller is an onboard computer that can communicate with flight controller, ground station and payload devices. In the previous project, VTT has implemented Raspberry Pi based onboard controller that can proxy messages between the ground control station and Pixhawk flight controller. Payload in the VTT case is an experimental multispectral camera that is controlled by Raspberry pi. Pi and Pixhawk are connected two ways, serial bus communication for MAVLink communication and GPIO communication for enabling flight controllers to control the camera.

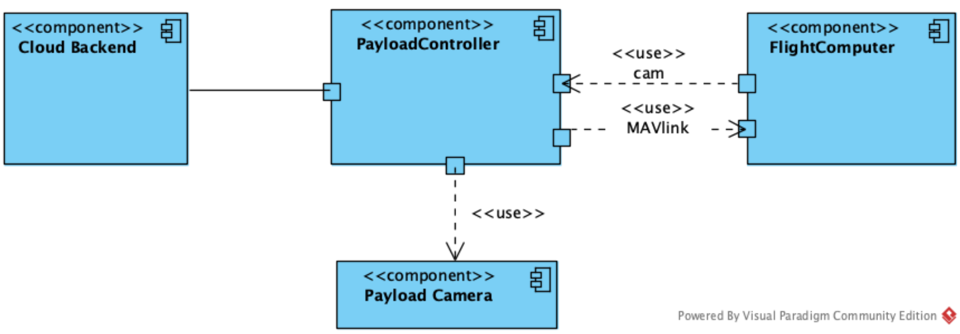


Figure 41. Communication with drone payload controller

Payload controller software is implemented to send interrupts to Raspberry Pi GPIO where the flight controller sends trigger signals and initiates image taking sequence on each trigger signal.

The payload controller can also directly access the internet via WLAN (or LTE if legally possible) and forward data to the cloud backend for processing. Via payload internet connection, drone is also capable to receive commands from the cloud backend.

5.5.7.3 Spraying application planning

The software dedicated to the DJI Agras-T16 spraying drone will be used for task planning and execution. Those are DJI Terra, and DJI Assistant 2 for MG. The applications support KML-format.

5.5.7.4 Orthophotos and classification

A DroneDeploy cloud service is applied to provide fluent orthophotos and 3d-maps automatically. In addition, Agisoft Metashape and ENVI software is used for manual processing. Orthophotos are further processed in both Microimages TNT GIS and QGIS software. To automate processing, TNT scripts enable the running of geospatial scripts via various types of control scripts such as shell, batch, bash, PHP, JavaScript, Python, etc.

5.5.8 Test fields

The pilot 2 implementations in the agricultural context consist of data collection and actual pilot demonstration. The main data will be collected in three different locations in Finland, while the actual Pilot demonstration will happen in two locations: Ruukki and Jokioinen. A third location (Mikkeli) will be used for prototype development. A dedicated silage field in Ruukki (Figure 39) will be used for the robotized tractor testing and piloting.

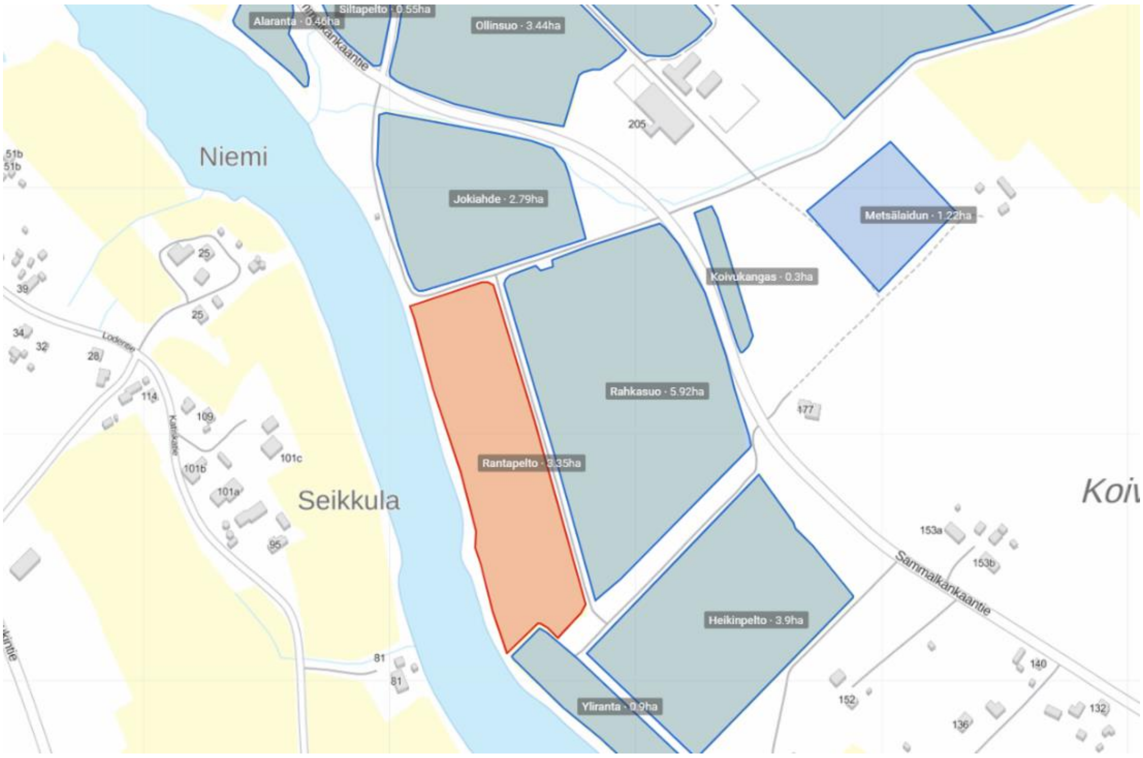


Figure 42. 3.5ha test field (orange) for robotized tractor in Ruukki, Finland.

Rapeseed field tests managed by Luke project JUOTVAI (Alternative management options of couch grass and insect pests of oilseed crops 2021-2024) in Jokioinen will be used as a part of rapeseed pest mapping tests.

6 Conclusions

This document described the detailed planning of Pilot 2. The pilot focuses on three main use cases: robotized tractor in a silage harvesting fleet, pest control of a rapeseed field and a grass field weeding. These main use cases consist of 7 detailed (sub) use cases (A-G). This document describes these use cases in detail including the functional and non-functional requirements and the involved datasets and the description of robotics, devices and the platform. The main outcome of this document is the pilot specific implementation architectures and the detailed definition of the use case plan. This document provided an overview of the systems to be developed within the FlexiGroBots-project. The results of this document will be used as input in the following deliverables: D.5.2, D5.3 and D3.2.

Next, the practical implementation of the presented use cases continues. The steps are presented in D2.7. The technical description of all the pilot-specific components and the information required for their integration and deployment will be determined.

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