Requirement Specification
Search and Rescue - Land

Version 1.0

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Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2022-09-15	First draft.	DS	Jakob Åslund
0.2	2022-09-19	First revision	DS, SF	Jakob Åslund
0.3	2022-09-19	Second revision	DS, ES, DG	Jakob Åslund
0.4	2022-09-27	Third revision	RW	Jakob Åslund
1.0	2022-09-27	First version	DG	Jakob Åslund
1.1	2022-11-28	Revision of requirements	DG	Jakob Åslund

CONTENTS

1 INTRODUCTION

This document will list all the requirements needed to fulfill the goals of the project. The requirement will be written in the format below.

Requirement	Version	Description	Priority
1	Original	Description	1
2	Revised	Description	2

There are three different priority levels for all requirements in this document. These are explained below.

1. Level 1 - The requirements on level 1 have the highest priority and must be fulfilled in order to pass the project.
2. Level 2 - The requirements on level 2 are expected to be fulfilled when the project is delivered, but are not essential for basic functionality.
3. Level 3 - The requirements on level 3 are only to be considered if there are time/resources.

The requirements should be fulfilled in priority order. This means that level 2 requirements are only to be worked on after all level 1 requirements are fulfilled etc. Lower level priorities shall therefore not be dependent on higher level priorities. If some level 1 requirements cannot be met, they must either be renegotiated to another level or removed to make sure that all level 1 requirements are fulfilled upon delivery.

1.1 Parties

There are principally two different parties involved in this project: Linköping University and SAAB Dynamics. In the context of the course, the SAAB Dynamics party acts as customers interested in a Search and Rescue-platform, and the University party acts as a company tasked with delivering the product.

The party from Linköping university consists of: Anja Hellander acting as advisor, Jakob Åslund acting as orderer, and the project group which consists of seven master students. Furthermore, the party from SAAB Dynamics consists of: Torbjörn Crona fulfilling the role of customer, and Linus Wiik, Joel Wikner and Åke Johansson acting as additional advisors.

1.2 Purpose and goal

The main purpose of this project is to develop a Search and Rescue-system consisting of an unmanned ground vehicle, called the Rover, and an Unmanned Aerial Vehicle (UAV) collaborating to identify, track and deliver supplies to people in distress. To accomplish this, the system should be able to map and navigate an area with people in distress. Specifically, the Rover should use a LIDAR-sensor to map the environment, whilst, using cameras, collaboratively searching with the UAV for distressed people.

Thus, the goal is to deliver a system according to the aforementioned specifications. The system should also follow design guidelines such as adhering to Google's code standard, developing the system in ROS2 and extending the docker integration of the current project.

1.3 Usage

As mentioned above, the intended use case of the product is deployment in a complex environment with distressed people to save. However, the finished product will only function in an environment as described by Section 2.5. Furthermore, it will perform at the level described by the requirements in this document.

1.4 Background Information

To search for and rescue distressed people by foot can be dangerous and time-consuming. If autonomous robots such as rovers and UAV:s are used instead, the search will be much faster and the chance of finding and rescuing the distressed person will be much higher.[1]

This project has been developed for many years at Linköping university and has had different development goals through the years. Today the system consists of one UAV and one Rover which are equipped with different sensors, cameras and LIDAR which makes it possible to map the environment and creating motion plans in search and rescue missions.

The project has a sister project called "Search and Rescue - Underwater". The cooperation between the two project is slight, while there are visions to unify the project in the distant future.

1.5 Definitions

Below some definitions and acronyms are explained which are recurring in this document.

- **Rover** - Tracked vehicle driving autonomously that maps the test area and seeks distressed persons.
- **UAV** - A quadcopter flying autonomously and seeks distressed persons.
- **Agent** - participant in a mission, Rover and/or UAV.
- **Base Station** - A computer that handles the information from the Rover and UAV.
- **Distressed person** - In simulation, this is a virtual marker that should be found by the Rover and UAV. When doing real tests, this will be RC-cars colored with bright colors.
- **SLAM** - Simultaneous Localization and Mapping.
- **LIDAR** - Light Detection and Ranging.
- **SIL** - Software In The Loop.
- **Qualisys** - Sensor system in the room Visionen that uses cameras and reflective targets to deliver position data.
- **ROS2** - "Robot Operating System", Framework for robot software development.

- **No-fly zone** - A zone which the UAV is restricted from flying into.
- **PDDL** - Planning Domain Definition Language.
- **RPi** - Raspberry Pi.
- **Pixhawk** - The flight controller *Pixhawk 4* that is mounted on the UAV.
- **HW** - Hardware.
- **SW** - Software.
- **Rviz2** - A visualization manager that displays the generated map and agent positions during the mission.
- **Gazebo** - Simulation environment.
- **RC-car** - Small RC-cars controlled by the user, that are used to simulate distressed persons.

2 OVERVIEW OF THE SYSTEM

The system consists of a Rover and a UAV, with an associated simulation environment and a Base Station, which coordinates a Search and Rescue-mission using the vehicles.

2.1 Product Description

The system consists, as stated above, of a UAV and a Rover with associated hardware. In addition to that, a computer is needed to run the Base Station with mission control and visualization software. The Rover and UAV receive tasks to execute from the task planner in the mission control, and report back any findings during the execution of their respective tasks.

2.2 Dependency on Other Systems

The project is independent of systems not mentioned in this document. However, the project utilizes a system called Qualisys in order to generate a ground truth position. This system is installed in the room "Visionen" at Linköping University.

2.3 Design Philosophy

The project should maintain a Software In the Loop (SIL) design. Thus, software applications run by parts of the system should be agnostic to whether it is run on hardware or on software. Furthermore, the system is developed with modularity in mind, given that future work might be done to extend the system.

2.4 Mission

A mission starts in the middle of the test area with the UAV on the Rover. It is required that the number of distressed persons is specified before the mission can start. When the search is initialized, the Rover starts to simultaneously map using a LIDAR and search the area for moving distressed persons using a camera. The UAV lifts from the Rover and starts to search for the moving distressed persons in the mapped area. When a distressed person is identified, the mapping is aborted and moving distressed persons are tracked by the Rover. Meanwhile, the UAV returns to pick up supplies and deliver them to the distressed person. After the supplies are delivered to a distressed person, the rover continues to map and search the unexplored areas. If another distressed person is identified the procedure repeats until the entire area is mapped and all distressed persons are identified which means that the mission is completed. When the mission is completed, both agents return to the start position. The sequence of events for a mission is illustrated in Figure 1.

Requirement	Version	Description	Priority
1	Original	Distressed persons should be able to move up to 5m from their start position	1
2	Original	If a distressed person is identified by the Rover, the UAV should cancel any activity except delivery of supplies and start fetching supplies	1
3	Original	If a moving distressed person is identified by the UAV, the Rover should cancel any activity and intercept the distressed person and then start tracking	1

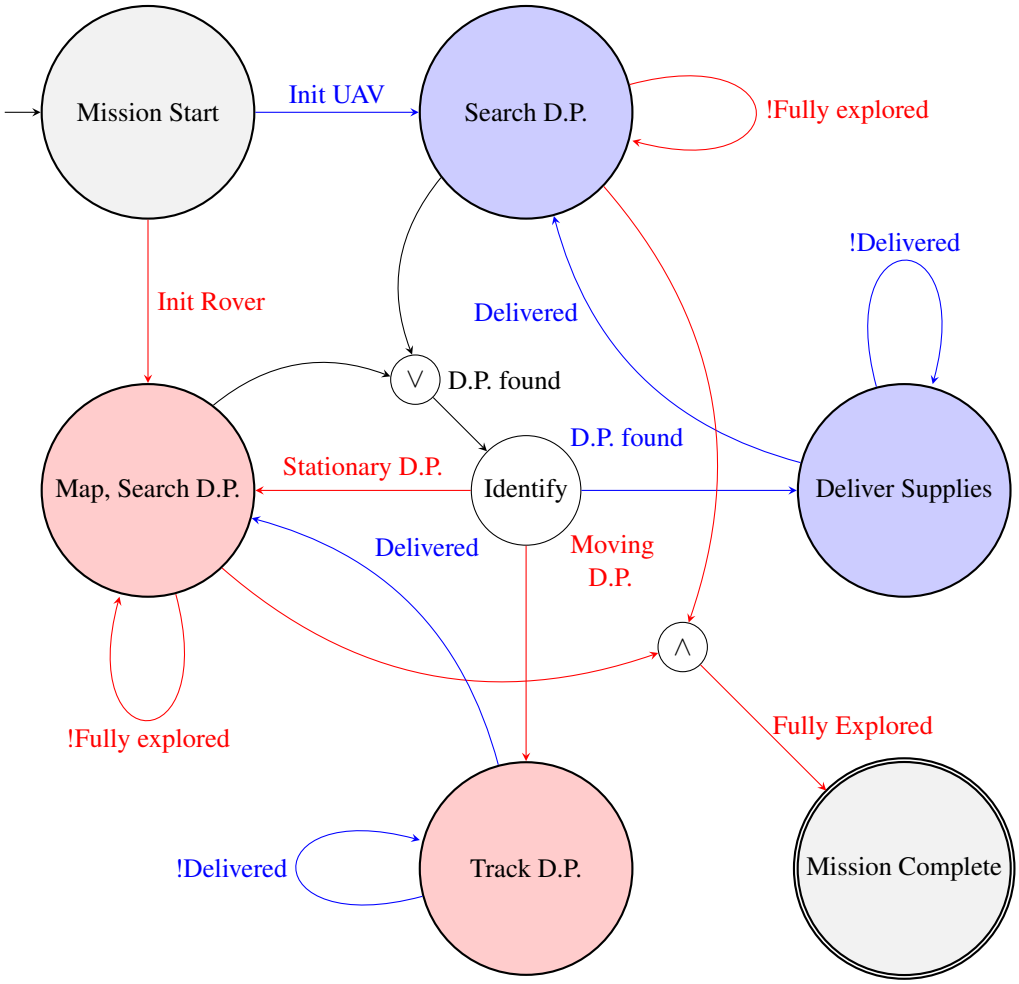

Figure 1: Illustration of the sequence of events for a mission. Red arrows indicate actions dependent on the Rover and blue arrows indicate actions dependent on the UAV, red states are only visited by the rover and blue states by the UAV. D.P. = Distressed person, ! = FALSE, ∨ = OR, ∧ = AND

2.5 Environment

The environment is arena "Visionen" at Linköping University, which limits the possible search area. The possibility of placing obstacles in the arena exists to mimic real world environment. The environment will include no-fly zones where the UAV is restricted from flying, obstacles which the rover should not collide with, as well as distressed persons. The distressed persons will be simulated by small RC-cars. The arena also includes the Qualisys system.

Requirement	Version	Description	Priority
4	Original	The system should be able to handle up to 2 distressed persons	1
5	Original	The system should be able to handle an environment with maximum 8 obstacles	1
6	Original	An obstacle should be 1-9 m wide and have a rectangular shape	1
7	Original	The system should be able to handle an environment with 1 no-fly zone	1
8	Original	The system should be able to handle an environment with 4 no-fly zones	2
9	Original	A no-fly zone should be 1-4 m^2, have a rectangular shape and stretch from the floor to the ceiling	1

2.6 General Requirements

Listed below are the general requirements for the system.

Requirement	Version	Description	Priority
10	Original	It shall be possible to specify a no-fly zone as a mission parameter, as specified in Section 2.4	1
11	Original	The system should be able to complete a mission, as specified in Section 2.4, and in an environment, as specified in Section 2.5, in simulation	1
12	Revised	The system should be able to complete a mission, as specified in Section 2.4, and in an environment, as specified in Section 2.5, while running on HW	2

3 ROVER

This section aims to give a general description of the Rover while also specifying the requirements set on the Rover.

3.1 General Description of the Rover

The Rover is a repurposed minesweeper machine that has two tracks. There is a surface on top of the Rover that is used as a landing pad for the UAV.

The Rover is equipped with a Raspberry Pi 4b as its main computer, powered by a USB type C cable. Connected to it is an Arduino that sends signals to the motors, gets odometry data from the wheel sensors, and gets signals from the RC remote controller that it passes to the RPi. The Rover is also equipped with a Raspberry Pi camera, that will be used to identify persons in distress. The Remote Controller (Futaba 4PLS) is used to manually drive the Rover. There is also an IMU that can be connected to the RPi. An overview of the system can be seen in Figure 2.

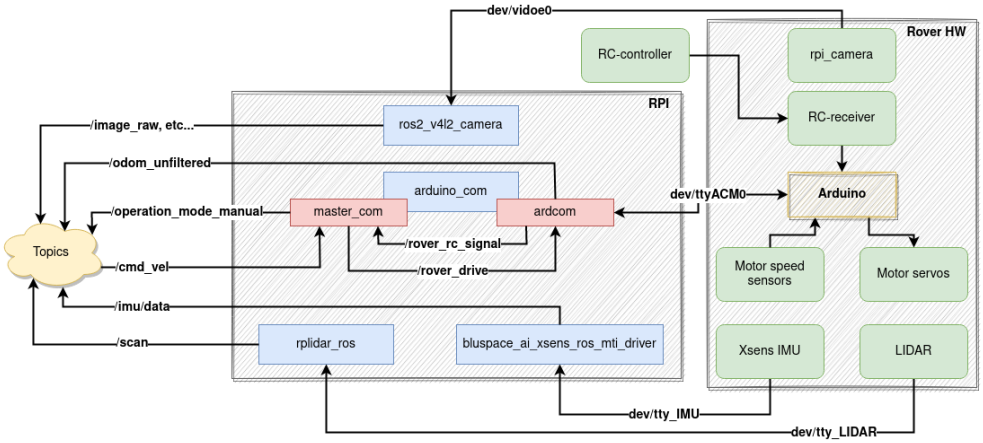

Figure 2: System overview of the Rover

3.2 Interface

Listed below are the interface requirements on the Rover.

Requirement	Version	Description	Priority
13	Original	The motion planner, controller and SLAM-module should work the same way on HW and in simulation	1

3.3 Design Requirements

Listed below are the design requirements on the Rover.

Requirement	Version	Description	Priority
14	Original	All software run by the RPI should be packaged as ROS2-packages	1

3.4 Functional Requirements on the Rover

This section describes the functional requirements on the Rover.

3.4.1 *Hardware*

Listed below are the functional requirements on the Rover, that should work both in simulation and on hardware.

Requirement	Version	Description	Priority
15	Original	The Rover must be able to navigate using a motion plan that avoids collisions	1
16	Original	The Rover must not deviate more than 15 cm from the motion plan at any specific sample	1
17	Original	The Rover shall receive its position from Qualisys positioning system while running HW	1
18	Original	The Rover must identify static distressed persons with the camera	1
19	Original	The Rover must identify moving distressed persons with the camera	1
20	Original	The Rover shall be able to differentiate between different types of distressed persons	1
21	Original	The area shall be mapped with SLAM using a LIDAR on the Rover	1
22	Original	An IMU shall be mounted and implemented to increase the positioning accuracy of the Rover	3
23	Original	It shall be possible to take control of the rover manually	1

3.4.2 *Simulation*

Listed below are the functional requirements on the Rover, that should work only in simulation.

Requirement	Version	Description	Priority
24	Original	The Rover shall receive its ground truth position in simulation to emulate the Qualisys system	1
25	Original	The Rover shall be able to track and follow an identified distressed person	1
26	Original	The Rover must not collide with distressed persons	1
27	Original	The Rover must keep a safety distance of 0.25 meters to distressed persons	2

4 UAV

This section aims to give a general description of the UAV while also specifying the requirements set on the UAV.

4.1 General Description of the UAV

The UAV is a quadcopter based on the **Lumenier QAV-R 2** frame that consists of a Pixhawk 4 flight controller and a Raspberry Pi 4b connected with UART. These are mounted on the UAV frame with actuators, a battery, a camera and an RC-receiver. An overview of the system can be seen in Figure 3.

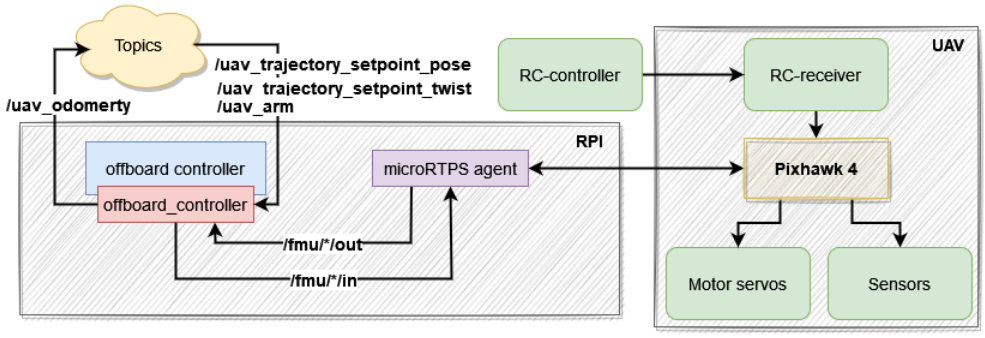

Figure 3: System overview of the UAV

4.2 Interface

Listed below are the requirements for the interface between the UAV and the rest of the system.

Requirement	Version	Description	Priority
28	Original	The UAV shall communicate with the Base Station using ROS2	1
29	Original	The offboard controller and motion planner should work the same way on HW and in simulation	1

4.3 Design Requirements

Listed below are the requirements set for the overall design of the UAV and its software.

Requirement	Version	Description	Priority
30	Original	The Pixhawk and Raspberry Pi shall be able to communicate with each other	1
31	Original	The UAV shall be able to receive and utilize position and orientation data from its sensors and the Qualisys system when running on HW	1
32	Original	All software run by the RPi should be packaged as ROS2-packages	1

4.4 Functional Requirements on the UAV

This section describes the functional requirements on the UAV

4.4.1 *Hardware*

Listed below are the functional requirements on the UAV, that should work both in simulation and on hardware.

Requirement	Version	Description	Priority
33	Original	A motion planner must be implemented for the UAV	1
34	Original	"No-fly zones" shall be avoided by the UAV motion planner with a distance of at least 20 cm	1
35	Original	The UAV shall be able to take off autonomously and rise to an altitude between 2 and 4 meters where it holds its position	1
36	Original	The UAV shall be able to land and shut down the propellers autonomously	1
37	Original	The UAV must follow the trajectory set by the motion planner and not deviate from the path more than 20 cm at any specific sample	1
38	Original	The UAV must identify static distressed persons with the camera	1
39	Original	The UAV must identify moving distressed persons with the camera	1
40	Original	The UAV shall be able to drop off real supplies with the HW	3
41	Original	The UAV must be able to differentiate between different types of distressed persons	1
42	Revised	The UAV must be able to start autonomously from the Rover while the Rover is stationary	2
43	Revised	The UAV must be able to land autonomously on the Rover while the Rover is stationary	2
44	Original	The UAV must be able to land autonomously on the Rover while the Rover is moving	3
45	Original	It shall be possible to manually take control of the UAV	1

4.4.2 *Simulation*

Listed below are the functional requirements on the UAV, that should work both on software and on hardware.

Requirement	Version	Description	Priority
46	Revised	The UAV shall be able to deliver supplies to distressed persons by hovering over them and signaling a supply drop by lowering its altitude.	1
47	Original	The UAV shall be able to follow distressed persons by tracking them using the camera	1
48	Original	A minimum safety distance of 50 cm shall always be held to distressed persons	1

5 BASE STATION

This section aims to give a general description of the Base Station while also specifying the requirements set on the Base Station.

5.1 General Description of the Base Station

The Base Station represents the generalization of the concept of an operator in a complex mission. It handles task planning and delegation of the tasks to the agents participating in the mission. Furthermore, it should act as the interface for the user of the system to visualize and interact with the mission.

Primarily, the user may interact with the mission visually through Rviz2.

5.2 Design Requirements

Listed below is the design requirement for the Base Station.

Requirement	Version	Description	Priority
49	Original	The Base Station should handle communication between the Rover and UAV using ROS2	1

5.3 Functional Requirements on the Base Station

Listed below are the functional requirements for the Base Station.

Requirement	Version	Description	Priority
50	Original	A mission planner shall be implemented to carry out the mission	1
51	Original	A PDDL task planner shall be implemented to carry out the mission	3
52	Original	The base station shall be able to order the Rover to explore an indicated area autonomously	1
53	Original	The Base Station shall keep track of the map, the Rover, the UAV and distressed persons	1
54	Original	The base station should be able to tell the rover to track a distressed person while the UAV collects supplies	1

6 SIMULATION ENVIRONMENT

The simulation environment is developed for the possibility of running the system without actual hardware. For this project, it means that new functionalities can be simulated and evaluated in a "safe environment" before being tested on actual hardware.

6.1 General Description of the Simulation Environment

The simulation environment is run in the simulation software called Gazebo. The environment can be changed through the native tools in Gazebo and then be saved as different mission scenarios. The simulation environment can simulate both rovers and UAV:s in a SIL-fashion, i.e. running mostly the same software as the real hardware does.

6.2 Design Requirements

Listed below is the design requirement for the simulation environment.

Requirement	Version	Description	Priority
55	Revised	The simulation shall be moved outside the project's Git repository	1

6.3 Functional Requirements on the Simulation Environment

Listed below are the functional requirements on the simulation environment.

Requirement	Version	Description	Priority
56	Original	The simulation environment shall be able to simulate a UAV	1
57	Original	The simulation environment shall be able to simulate a Rover	1
58	Original	Different stationary distressed persons must be simulated in the environment	1
59	Original	The simulated distressed persons must be able to move along a line or a circle	1
60	Original	The simulation must be independent of the rest of the mission system (i.e. should not need to be run when hardware is used)	1
61	Original	The simulation shall have the option to choose between custom maps	2
62	Original	The simulation environment must be able to simulate a no fly zone	1
63	Original	The simulation shall be able to simulate more than one Rover	2
64	Original	The simulation shall be able to simulate more than one UAV	2

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Requirement	Version	Description	Priority
65	Original	The simulated UAV shall be able to simulate picking up supplies and dropping them in Gazebo	3

7 GRAPHICAL USER INTERFACE

This section aims to give a general description of the GUI while also specifying the requirements set on the GUI.

7.1 General Description of the GUI

A GUI on the Base Station will be implemented. The goal is to include the visualization from Rviz2, have a start and stop button and certain control parameters. The GUI should act as an easier way of interacting with the mission control instead of using the terminal when on an active mission. This will enable a more intuitive way of handling start/stop/abort/pause of the mission. This means that when configuring and launching the software the terminal(s) will still have to be used, however the operator will essentially be able to use some basic functionalities of the software using the GUI.

7.2 Functional Requirements on the GUI

Listed below are the functional requirements on the GUI.

Requirement	Version	Description	Priority
66	Original	The GUI should give the user the same visualization of the map as the same one that Rviz2 enables	2
67	Original	The GUI should have a start and stop button for the mission at hand	2
68	Original	A user shall be able to change control parameters for the rover and UAV controller during a mission	2
69	Original	A user shall be able to change between two search strategies prior to a mission	3

8 PERFORMANCE REQUIREMENTS

In this section, the performance requirements are listed for the project. The maximum number of consecutive mission is restricted to 4 because of limited test possibilities.

Requirement	Version	Description	Priority
70	Original	The system must be able to complete 3 out of 4 missions successfully	1
71	Original	The system must be able to complete 4 out of 4 missions successfully	2
72	Original	The Rover should not stop for longer than 5 seconds while exploring during the mission	3

9 ECONOMY

This section specifies the requirements for the economic part of the project.

Requirement	Version	Description	Priority
73	Original	Each member will spend 240 hours on the project	1

Other resources provided to the group:

- ISY will provide 40 hours of guidance on the project
- ISY will provide a project room located in the B-building on Campus Valla
- SAAB Dynamics will provide 40 hours of guidance on the project
- Additional expenses will be provided by SAAB Dynamics
- Limited time in Visionen

10 DELIVERIES

In this section all deliveries are presented and what should be met for each delivery including the deadline for each delivery. In Table 20 the deadlines for each delivery are shown.

Table 20: Deadline for deliveries

Date	Delivery
21/9	BP2
6/10	BP3
25/11	BP4
Half a week before delivery of project	BP5
12/12	Delivery of project
12/12	After study
13/12	Poster presentation
15/12	Web page
19/12	BP6

10.1 BP2

The following requirements must be met for BP2.

Requirement	Version	Description	Priority
74	Original	Requirement specification	1
75	Original	Project plan, including time plan	1
76	Original	First draft of design specification	1
77	Original	Verbal presentation of the system	1

10.2 BP3

The following requirements must be met for BP3.

Requirement	Version	Description	Priority
78	Original	Design specification	1
79	Original	Test plan	1

10.3 BP4

The following requirements must be met for BP4.

Requirement	Version	Description	Priority
80	Original	Milestone no. 1-4 in [2]	1
81	Original	A first draft of a working simulation environment for the system	1

10.4 BP5

The following requirements must be met for BP5.

Requirement	Version	Description	Priority
82	Original	All functionality	1
83	Original	Test protocol	1
84	Original	User manual	1
85	Original	Presentation showing that all requirements have been met	1

10.5 BP6

The following requirements must be met for BP6.

Requirement	Version	Description	Priority
86	Original	Technical report	1
87	Original	After study	1
88	Original	Poster presentation	1
89	Original	Web page	1
90	Original	Product movie	1

11 DOCUMENTATION

This section presents all the produced documents and their purpose, target group and format also some requirements about general documentation is presented.

Requirement	Version	Description	Priority
91	Original	All documents should follow the LIPS-standard	1
92	Original	All documents should be handed in prior to deadline	1

Table 27: All the produced documents in the project.

Document	Language	Purpose	Target group	Format/media
Requirement specification	English	Describes all the requirements that must be fulfilled in the project.	Orderer, Customer	PDF/electronic
Project plan	English	Describes how the project is to be executed and also contains activities and milestones.	Orderer, Customer	PDF/electronic
Time plan	English	Describes how much time each activity is planned to take.	Orderer, Customer	PDF/electronic
Design specification	English	Describes in detail how the different parts of the system are supposed to be constructed and implemented.	Orderer	PDF/electronic
Test plan	English	Describes how the system is supposed to be tested in order to verify functionality.	Orderer	PDF/electronic
Test protocol	English	Describes the results of all the performed tests.	Orderer	PDF/electronic
User manual	English	Describes how the system is correctly used. An installation guide is also included which describes how the system is correctly installed.	User	PDF/electronic
Technical report	English	Describes in detail all the technical aspects of the system.	Orderer, Customer	PDF/electronic
After study	English	Contains a discussion about the work flow, time consumption, experiences and problems encountered during the project.	Orderer, Customer	PDF/electronic

12 SAFETY REQUIREMENTS

The section presents the safety requirements of the product.

Requirement	Version	Description	Priority
93	Original	The UAV must have a kill switch on the RC-controller which cuts the power to all the actuators	1
94	Revised	The UAV shall make an audible signal when the battery level is low	1
95	Original	The UAV shall land if it looses its RC-connection	1
96	Original	The UAV shall land if the Pixhawk loses its connection to the RPi	1
97	Original	The UAV shall land if it loses connection to Qualisys over two seconds	1
98	Original	The Rover shall stop if it loses connection to the Base Station	1

REFERENCES

[1] Jakob Åslund. *Search and Rescue - Land*. Linköping, Sweden, 2022.

[2] Operation Watch Landlubber with editor Rickard Wretlind. *Project Plan Search and Rescue - land*. Linköping, Sweden, 2022.