Requirement Specification

Search and Rescue - Underwater

Version 1.2

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Contents

1 Introduction

This document is the requirement specification for the project Search and Rescue Underwater in the course TSRT10, Reglerteknisk projektkurs, CDIO, at Linköping University. The purpose of this document is to give the definitions and the goals for this project and list the corresponding requirements that are needed to be fulfilled. The requirements will be presented in the document as seen in Table 1.

Table 1: Requirements priority

Requirement	Version	Description	Priority
x	Original	Basic requirement	1
xx	Original	Advanced requirement	2
xxx	Original	Extra requirement	3

There will be several requirements, therefore a priority system is used and the definition of the priorities are:

- Priority 1 – Must be fulfilled until BP4. These requirements are focused on simulation.
- Priority 2 – Must be fulfilled until BP5. These requirements concern both simulation and real use.
- Priority 3 – Not necessary, but if there are any time or resources left, these requirements would increase the functionality of the final system.

All the priority 1 and 2 requirements need to be fulfilled before the delivery of the product to the customer. Should implementation of these requirements prove to be too difficult due to time constraints or resource constraints, they have to be renegotiated with the customer.

1.1 Definitions

- UAS - Unmanned aircraft system, i.e., drone.
- GUI - Graphical user interface.
- ROS2 - Robot operating system.
- Session - The time span from which the UAS is turned on until the UAS is turned off.
- Mission - Contains all tasks produced by the task planner. Multiple missions can be executed in one session.
- UUV - Unmanned underwater vehicle.
- Emergency pinger - Transmitter of the emergency signal relayed by the UUV.
- Semi-autonomous mode - A mode where the user is coordinating where the UAS should go.

1.2 Parties

In this project there are three parties involved. The customers, Andreas Gällström and Jonatan Olofsson at Saab Dynamics, the client Gustav Zetterqvist at Linköping University, three advisors, Daniel Bossér at Linköping University together with Philip Andersson and Erik Söderberg at Saab Dynamics and a project group working on the project. The members of the project group, their roles, and contact information can be found at the beginning of the document.

1.3 Purpose and goal

The goal of this project is to locate an UUV transmitting a distress signal with a UAS equipped with a hydrophone. The UAS will need to fly out the hydrophone to well-chosen positions within a given area and submerge the hydrophone and listen for the distress signal and locate the UUV. Part of the project is to process the signal chain of hydrophone data and filter out the emergency pinger's signal and choose some coordinates that streamline localization. The second part of the project is the control of the UAS with the weight and imbalance that comes with mounting the hydrophone. The UAS should be able to autonomously fly in a controlled manner to coordinates, descend the hydrophone into the water, process the data and raise the hydrophone again before flying on. To some extent this can be done in simulation, but a UAS must also be built to demonstrate a real operation.

1.4 Application

The different parts of this project aim to both get the hydrophone to communicate with the rest of the programs and find the UUV. But also to get the drone to fly with a cable hanging from it. Therefore, the task must be able to be carried out both with the physical platforms and in virtual simulation environment.

1.5 Background information

One of Saab Dynamics' largest departments designs underwater crafts of various types. These are used for various tasks underwater, for example, inspecting infrastructure. When an underwater craft somehow gets stuck during a mission, an emergency pinger is activated to be able to find the underwater craft and retrieve it. You often then have to go out by boat and lowering hydrophones to find out where the emergency ping sound is coming from. In special environments, it can take a very long time to search an area. Therefore, instead of searching an area manually, an autonomous drone can complete the task.

This project is part of a larger Search and Rescue project at Saab dynamics which also include Search and Rescue Land. Saab has already developed a suitable simulation environment which runs ROS2 and can run in a 3d-environment using Gazebo. As part of this project, the simulation environment should also be extended with specific support for this project. This involves being able to mock/simulate hydrophone data, as well as supporting the pendulum physics between the hydrophone and drone.

2 System requirements

This section will declare all the requirements of the system. The requirements are given a number to determines its priority, with one being the most important.

2.1 General requirements

The general requirements of the simulated system are declared in Table 2 while the general requirements of the physical system are listed in 3.

Table 2: General requirements for simulation

Requirement	Version	Description	Priority
1	Original	~~The hydrophone and the UAS should be able to communicate with each other in simulation.~~	1
1	Revised	The hydrophone and the UAS should be able to communicate with each other in simulation.	2
2	Original	The user should always be able to interrupt the autonomous mode and control the UAS manually in simulation.	1
3	Original	The UAS should be able to know its location in simulation.	1
4	Original	A backup plan to reach land if the battery gets low or an accident occurs above water should be implemented in simulation.	1
5	Original	~~A fully autonomous mode for detecting the UUV should be implemented in simulation.~~	1
5	Revised	A fully autonomous mode for detecting the UUV should be implemented in simulation.	3
6	Original	A semi-autonomous mode for detecting the UUV should be implemented in simulation, where the user will be able to suggest a search area.	1

Table 3: General requirements for physical implementation

Requirement	Version	Description	Priority
7	Original	~~The hydrophone and the UAS should be able to communicate with each other for the physical implementation.~~	2
7	Revised	The hydrophone and the UAS should be able to communicate with each other for the physical implementation.	3
8	Original	The user should always be able to interrupt the autonomous mode and control the UAS manually for the physical implementation.	2
9	Original	~~The UAS should be able to use GPS and the positioning system in *Visionen* to determine its location for the physical implementation.~~	2
9	Revised	The UAS should be able to use GPS to determine its location for the physical implementation.	2
9	Revised	The UAS should be able to use the positioning system in *Visionen* to determine its location for the physical implementation.	3
10	Original	A backup plan to reach land if the battery gets low or an accident occurs above water should be implemented for the physical implementation.	2
11	Original	A fully autonomous mode for detecting the UUV for reality should be implemented.	3
12	Original	A semi-autonomous mode for detecting the UUV should be implemented for the physical implementation. The user will be able to suggest a search area.	2

2.2 UAS

The requirements for the UAS are described in Tables 4 and 5.

Table 4: UAS requirements in simulation

Requirement	Version	Description	Priority
13	Original	~~The UAS should be able to measure its remaining battery charge in the simulation.~~	1
13	Revised	It should be possible to measure the UAS:s remaining battery charge in the simulation.	1
14	Original	The UAS should be able to measure its height over the water in the simulation.	1
15	Original	The UAS should be able to land and take off with the hydrophone in the simulation.	1
16	Original	The UAS should be able to submerge the hydrophone in the water in the simulation.	1
17	Original	~~The UAS should be able to communicate in real time with a ground station laptop via Wi-Fi in the simulation.~~	1
17	Revised	The UAS should be able to communicate in real time with a ground station laptop via Wi-Fi in the simulation.	3
18	Original	The UAS should be able to fly with the hydrophone in the simulation.	1
19	Original	~~The UAS should estimate how long it can travel on the remaining battery charge and use this to determine when to emergency land in the simulation.~~	1
19	Revised	It should be possible to estimate how long the UAS can travel on the remaining battery charge and use this to determine when to emergency land in the simulation.	1
20	Original	The UAS should be able to fly with the hydrophone in the water in the simulation.	3

Table 5: UAS requirements for physical implementation

Requirement	Version	Description	Priority
21	Original	The UAS should be able to measure its remaining battery charge for the physical implementation.	2
22	Original	The UAS should be able to measure its height over the water for the physical implementation.	2
23	Original	The UAS should be able to land and take off with the hydrophone for the physical implementation.	2
24	Original	The UAS should be able to submerge the hydrophone in the water for the physical implementation.	2
25	Original	~~The UAS should be able to communicate in real time with a ground station laptop via Wi-Fi for the physical implementation.~~	2
25	Revised	The UAS should be able to communicate in real time with a ground station laptop via telemetry for the physical implementation.	2
26	Original	The UAS should be able to fly with the hydrophone for the physical implementation.	2
27	Original	~~The UAS should estimate how long it can travel on the remaining battery charge and use this to determine when to emergency land for the physical implementation.~~	2
27	Revised	The UAS should estimate how long it can travel on the remaining battery charge and use this to determine when to emergency land for the physical implementation.	3
28	Original	The UAS should be able to fly with the hydrophone in the water for the physical implementation.	3

2.3 Environment

The requirements of the simulation environment in which the mission should take place in are listed in Table 6 while the requirements of the physical environment are listed in Table 7.

Table 6: Environment requirements for simulation

Requirement	Version	Description	Priority
29	Original	The simulated environment should have a safe spot where the UAS can land.	1
30	Original	The simulated environment should contain a water area deep enough for the UAS to dip the hydrophone in the water without hitting the bottom.	1
31	Original	~~The simulated environment should allow for positioning with GPS.~~	1
31	Revised	The simulated environment should allow for positioning with GPS.	3
32	Original	The simulated environment should contain a sound source to transmit the emergency pinger underwater.	1
33	Original	The simulated environment should contain obstacles where the UAS cannot pass.	3

Table 7: Physical environment requirements

Requirement	Version	Description	Priority
34	Original	The environment should have a physical safe spot where the UAS can land.	2
35	Original	The environment should contain a physical water area deep enough for the UAS to dip the hydrophone in the water without hitting the bottom.	2
36	Original	The physical environment should allow for positioning with GPS.	2
37	Original	The physical environment should contain a sound source to transmit the emergency pinger underwater.	2
38	Original	The physical environment should contain obstacles where the UAS cannot pass.	3

2.4 Task planner

The primary goal for the task planner is to set up a plan for where the UAS should submerge the hydrophone in order to locate the UUV. An extended version of the task planner would be to set up this plan dynamically, based on collected data from the hydrophone. The requirements for the task planner are given in Table 8.

Table 8: Task planner requirements

Requirement	Version	Description	Priority
39	Original	The task planner should coordinate the UAS.	2
40	Original	The task planner should choose the next submerge-point for the UAS based on collected data from the hydrophone.	3
41	Original	The task planner should process the collected data from the hydrophone in real time	3
42	Original	The task planner should be able to communicate with the UAS.	2

2.5 Motion planner

The motion planner is responsible for planning the routes between locations determined by the task planner. Its requirements for the simulation environment are listed in Table 9 and for the physical implementation in Table 10.

Table 9: Motion planner simulation requirements

Requirement	Version	Description	Priority
43	Original	~~The motion planner should make sure the hydrophone does not oscillate more than one meter horizontally in the simulation.~~	1
43	Revised	The motion planner should make sure the hydrophone does not oscillate more than four meters horizontally in the simulation.	1
44	Original	The motion planner should make sure the hydrophone does not touch the ground when flying in simulation.	1
45	Original	The motion planner should make sure the hydrophone touches the water only when supposed to, in the simulation	1
46	Original	The motion planner should make sure the UAS does not touch the water in the simulation environment.	1
47	Original	The motion planner should use a motion planning algorithm in the simulation environment.	1
48	Original	Different motion planning algorithms should be implemented in the simulation environment.	3

Table 10: Motion planner requirements for physical implementation

Requirement	Version	Description	Priority
49	Original	~~The motion planner should make sure the hydrophone does not physically oscillate more than one meter horizontally.~~	2
49	Revised	The motion planner should make sure the hydrophone does not physically oscillate more than 45^o horizontally.	2
50	Original	The motion planner should make sure the hydrophone does not physically touch the ground when flying.	2
51	Original	The motion planner should make sure the hydrophone physically touches the water only when supposed to.	2
52	Original	The motion planner should make sure the UAS does not physically touch the water.	2
53	Original	The motion planner should use a motion planning algorithm for the physical implementation.	1
54	Original	Different motion planning algorithms should be implemented.	3

2.6 Limitations

This section states the limitations of the project. The limitations can be seen in Table 11.

Table 11: Limitations

Requirement	Version	Description	Priority
55	Original	The UAS is limited to fly in an area of in line of sight.	2
56	Original	~~The UAS is limited to fly within the reach of the controller and the Wi-Fi connection of the control station.~~	2
56	Revised	The UAS is limited to fly within the reach of the controller and the telemetry connection of the base station.	2
57	Original	The UAS is limited to performing the mission in an environment restricted to the environmental requirements listed in Table 7.	2

2.7 GUI

The GUI will only be for physical use and will be used to control the UAS manually, as well as give missions for the UAS to complete autonomously. It will also show information during flights. The requirements for the GUI are shown in Table 12.

Table 12: GUI requirements

Requirement	Version	Description	Priority
58	Original	The GUI should display elapsed time for the current session and mission.	2
59	Original	~~The GUI should display an estimate of flown distance for the current session and mission for performance comparison.~~	2
59	Revised	The GUI should display an estimate of flown distance for the current mission.	2
60	Original	~~The GUI should enable the user to choose between manual, semi-autonomous and autonomous flying.~~	2
60	Revised	The GUI should enable the user to choose between manual and semi-autonomous flying.	2
61	Original	The GUI should enable the user to choose between different motion planning algorithms.	3
62	Original	The GUI should display the battery level of the UAS.	2
63	Original	~~The GUI should display an estimate of the remaining time the UAS can fly with the current battery level.~~	2
63	Revised	Requirement removed.	-
64	Original	The GUI should enable the user to cancel a mission, commanding it to fly back to the starting position.	2
65	Original	~~The GUI should show a visualization of the explored area. This includes estimated position of UUV, position of the UAS and planned route.~~	2
65	Revised	The GUI should show a visualization of the explored area. This includes the position of the UAS and the planned route.	2

2.8 Simulation

The system should use a simulation environment to test against before running on the real UAS. Table 13 describes the requirements for the simulation environment. It also has requirements for what things should be simulated and how the simulation environment should be further developed as part of the project.

Table 13: Simulation requirements

Requirement	Version	Description	Priority
66	Original	~~Entire missions should be simulable.~~	1
66	Revised	Entire missions should be simulable.	2
67	Original	The simulation should take place in a 3d world with land and water.	1
68	Original	Emergency landings should be simulable.	1
69	Original	The battery level of the UAS should be simulable.	1
70	Original	Mocking of hydrophone data should be possible in simulation.	1
71	Original	~~Current estimation of the UUV:s position should be shown in simulation.~~	1
71	Revised	Current estimation of the UUV:s position should be shown in simulation.	2
72	Original	~~The next dipping position should be shown in the simulation.~~	2
72	Revised	The next dipping position should be shown in the simulation.	3
73	Original	Probability ellipsoids should be visualized in the simulation.	3
74	Original	The dynamics of the UAS + hydrophone system should be simulated.	1

2.9 Reliability

The reliability of the system is listed in Table 14. However, considering the uncertainty of the challenges in this project, it is difficult to determine the possible achievements. Therefore, no requirements are set to indicate how accurate the result may be.

Table 14: Reliability requirements

Requirement	Version	Description	Priority
75	Original	In the simulation environment, the system should be able to estimate the UUV:s location within 30 meters of real position.	1
76	Original	In the physical implementation, the system should be able to estimate the UUV:s location within 100 meters of real position.	2

3 Economy

The parties involved each have different responsibilities. To clarify what economical expectations each party has, some requirements are presented in Table 15.

Table 15: Economy

Requirement	Version	Description	Priority
77	Original	Each member in the project group should spend 240 hours on the project.	2
78	Original	Saab Dynamics should provide 40 hours of counseling throughout the project.	2
79	Original	ISY should provide 40 hours of counseling throughout the project.	2
80	Original	ISY should provide a room throughout the project.	1
81	Original	Equipment will be funded by ISY or Saab Dynamics, given their approval.	1
82	Original	Each project member should document the time spent on the project.	2

4 Safety requirements

It is important to ensure everyone's safety at all times and to follow laws regarding UAS:s. The requirements in Table 16 are made to ensure this.

Table 16: Safety requirements

Requirement	Version	Description	Priority
83	Original	The UAS must have an emergency-stop where the UAS aborts the mission and lands at a predefined safety spot.	2
84	Original	The UAS must have an emergency-stop where the UAS turn off all its systems.	2
85	Original	All individuals in the testing area should be informed when an "in air"-test will happen.	1
86	Original	The UAS should at all times be able to be driven manually.	1
87	Original	If the UAS looses connection, it should return to a predefined safety-point and land.	2
88	Original	If a flight is to be performed outside, laws and regulations, with respect to control zones, must be followed.	1
89	Original	If a flight is to be performed inside *Visionen*, no person should be inside the designated flight area.	1
90	Original	Safety goggles should be used by all involved during testing	1
91	Original	Batteries should be charged under supervision or in the designated charging station in *Visionen*	1

5 Deliveries

The deliveries of the project will occur during *Beslutspunkter/Decision points* denoted BP2, BP3, etc. These are all listed in Table 17.

Table 17: Delivery Requirements

Requirement	Version	Description	Priority
92	Original	BP2. Delivery of *Requirement Specification*, *Project plan*, *Timetable* and a draft of the *Design Specification*.	1
93	Original	BP3. Delivery of *Design Specification* and *Test plan*.	1
94	Original	BP4. Delivery of a draft based on the simulation environment and a *Test protocol* of the environment's functionality. A decision also needs to be made to determine if the project only will exist in a simulation environment or being further developed with the given hardware.	1
95	Original	BP5. Delivery of the user manual, *Test protocol* and the entire functionality of the system. A presentation will be held to show that the requirements in the *Requirement Specification* are met.	2
96	Original	BP6. Delivery of *After study* with a follow-up of the results and used time, *Technical Report*, poster, webpage, movie for publication and *Installation guide*.	-

6 Documentation

This section describes all the documents that are to be produced throughout the project, see Table 18. Since the documents are to be read by all parties of the project, the requirements of the documents are stated in Table 19.

Table 18: List of documents to be produced

Document	Language	Reason	Format
Requirement specification	Eng	State the goals and requirements for the project.	PDF
Project plan	Eng	Describe how the project is to be executed.	PDF
Time plan	Eng	Show how much time each sub-task is estimated to take, and to be updated each week with the used time for each person in the group.	Spreadsheet
Design specification	Eng	A description of the system and its subsystems in detail.	PDF
Test plan	Eng	Describe how the tests of the system will be performed.	PDF
Test protocol	Eng	To summarize the testing results.	PDF
User manual	Eng	A guide for how to use the system.	PDF
Technical report	Eng	A technical report of the system.	PDF
After study	Eng	Evaluation of the project and project continuation.	PDF

Table 19: Document requirements

Requirement	Version	Description	Priority
97	Original	All documentation should follow the LIPS-standard.	1
98	Original	When software is updated, version management should be used.	1
99	Original	All code should follow the Google coding standard.	1