Test Protocol

Search and Rescue - Underwater

Version 1.0

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Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2022-12-03	First draft.	DA, AR, HF, IL, KD, OH, OP	AR
1.0	2022-12-12	First version.	DA, AR, HF, IL, KD, OH, OP	AR

Contents

1 Introduction

This document is a test protocol which contains information about the tests that have been executed during the project. The purpose of the tests is to verify that the requirements from the requirement specification [1] are fulfilled.

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 Test structure

The order of the tests corresponded to the priority order in the requirement specification [1]. Each test has a short description of how it was executed and under which circumstances it was performed.

1.3 Pass or Fail

After each test, it was determined whether the specific requirements were fulfilled or not. If the requirements were fulfilled, the test was marked with "Pass". If not, it was marked with "Fail".

1.4 Test Protocol

After each test, a test protocol, of which a template can be seen in Table 1, was filled in which included:

- **Test No.:** States the associated number of the test.
- **Test dependencies:** States which other tests must be passed in order to execute the test.
- **Resources:** States the resources needed to be able to execute the test.
- **Req. No.:** States which requirement/requirements the test is testing.
- **Req. description:** States a description of the tested requirements.

- **Test description:** States the description of the test and how it should be executed, and under which circumstances it should be performed.
- **Expected results:** States what is expected beforehand of the test.
- **Reality/Simulation:** States if the test will be executed with real hardware or in simulation.
- **Executed by:** States which person/persons that the test was executed by (with initials).
- **Participants:** States which person/persons that participated in the test (with initials).
- **Test week:** States the week when the test was executed.
- **Test date:** States the date when the test was executed.
- **Test result:** States how the test went.
- **Test comment:** Comments to the test result, for example which of the requirements that were fulfilled and which that were not.
- **Test approved by:** States which person/persons that has approved the test protocol (with initials).

Table 1: Template of the test protocol

<table>
<tr><td colspan="2">Test No.:</td><td colspan="2">Test dependencies:</td></tr>
<tr><td colspan="4">Resources:</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">Reality/Simulation:</td></tr>
<tr><td>Executed by:</td><td>Participants:</td><td>Test week:</td><td>Test date:</td></tr>
<tr><td>Test result:</td><td colspan="2">Comments:</td><td>Pass/Fail:</td></tr>
<tr><td colspan="4">Test approved by:</td></tr>
</table>

2 General simulation

The following tests are meant for testing some general requirements for the simulation.

Table 2: General requirements for simulation.

<table>
<tr><td colspan="2">Test No.: 1</td><td colspan="2">Test dependencies: -</td></tr>
<tr><td colspan="4">Resources: Simulation environment</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>3</td><td colspan="2">The UAS should be able to know its location in simulation.</td><td>1</td></tr>
<tr><td>13</td><td colspan="2">The UAS should be able to measure its remaining battery charge in the simulation.</td><td>1</td></tr>
<tr><td>17</td><td colspan="2">The UAS should be able to communicate in real time with a ground station laptop via Wi-Fi in the simulation.</td><td>1</td></tr>
<tr><td>31</td><td colspan="2">The simulated environment should allow for positioning with GPS.</td><td>1</td></tr>
<tr><td>67</td><td colspan="2">The simulation should take place in a 3d world with land and water.</td><td>1</td></tr>
<tr><td>69</td><td colspan="2">The battery level of the UAS should be simulable.</td><td>1</td></tr>
<tr><td>86</td><td colspan="2">The UAS should at all times be able to be driven manually</td><td>1</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">Open up the simulation environment. Tell the UAS to fly to a specific position.</td><td colspan="2">The world should be 3d and have land and water. The UAS should move to the specified position and report its GPS position to the base station. The base station should continuously receive the UAS's simulated battery level.</td></tr>
<tr><td colspan="4">Reality/Simulation: Simulation</td></tr>
<tr><td>Executed by: OP</td><td>Participants: OP</td><td>Test week: 48</td><td>Test date: 22-11-28</td></tr>
<tr><td>Test result: The test went according to the expected result</td><td colspan="2">Comments:</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: HF</td></tr>
</table>

Table 3: Hydrophone simulation requirements.

Test No.: 2		**Test dependencies:** 1	
Resources: Simulation environment			
Req. No.:	**Req. description:**	**Priority:**	
1	The hydrophone and the UAS should be able to communicate with each other in simulation.	1	
14	The UAS should be able to measure its height over the water in the simulation.	1	
16	The UAS should be able to submerge the hydrophone in the water in the simulation.	1	
30	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	
32	The simulated environment should contain a sound source to transmit the emergency pinger underwater.	1	
70	Mocking of hydrophone data should be possible in simulation.	1	
Test description:		**Expected results:**	
Open up the simulation environment. Tell the UAS to position itself at a specific point over the water. Tell the UAS to dip the hydrophone into the water close to a simulated pinger in the water. Start listening with the hydrophone.		The UAS should move to the specified position and report position to the base station and its height over the water. The UAS should dip the hydrophone into the water. The water should be deep enough, so that the hydrophone does not hit the bottom. The base station should receive the mocked audio signal from the hydrophone.	
Reality/Simulation: Simulation			
Executed by: OP	**Participants:** OP	**Test week:** 48	**Test date:** 22-11-28
Test result: The test went according to the expected result	**Comments:**		**Pass/Fail:** Pass
Test approved by: AR			

Table 4: Test protocol for simulatable mission.

Test No.: 3		**Test dependencies:** 1	
Resources: Simulation environment.			
Req. No.:	**Req. description:**		**Priority:**
66	Entire missions should be simulatable.		2
71	Current estimation of the UUV:s position should be shown in simulation.		2
Test description:		**Expected results:**	
Open up the simulation environment and start a mission. Make sure that all the tasks produced by the task planner are executed in the simulation environment.		All the tasks produced by the task planner are executed in the simulation environment. Also, the estimated position if the UUV is continuously updated.	
Reality/Simulation: Simulation			
Executed by: OP	**Participants:** AR, HF, OP	**Test week:** 48	**Test date:** 22-11-30
Test result: The test went according to the expected result.	**Comments:** The current estimated position of the UUV was updated in the terminal during the mission, and a 3D likelihood plot was visible when the mission was completed.		**Pass/Fail:** Pass
Test approved by: AR			

3 Positioning

The following test is meant for testing positioning of the UAS with GPS.

Table 5: Test protocol for position estimation

Test No.: 4		**Test dependencies:** -	
Resources: The UAS, software for positioning with GPS			
Req. No.:	**Req. description:**		**Priority:**
9	The UAS should be able to use GPS to determine its location for the physical implementation.		2
Test description:		**Expected results:**	
Test to see if the UAS is able to position itself with GPS.		The UAS will provide its position using GPS.	
Reality/Simulation: Reality			
Executed by: DA, IL	**Participants:** IL, DA, KD, OH	**Test week:** 48	**Test date:** 22-11-30
Test result: The test went according to the expected result	**Comments:**		**Pass/Fail:** Pass
Test approved by: IL			

4 Real estimation

The following test is meant for testing the requirement for location estimation of the UUV in reality.

Table 6: Test protocol for estimation of the UUV:s location physically.

<table>
<tr><td colspan="2">Test No.: 5</td><td colspan="2">Test dependencies: 11</td></tr>
<tr><td colspan="4">Resources: UUV, UAS, controller</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>76</td><td colspan="2">In the physical implementation, the system should be able to estimate the UUV:s location within 100 meters of real position.</td><td>2</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">Place the emergency pinger at a well known position under the water. Enter the semi-autonomous mode and tell the drone to go to different locations and measure the signal from the emergency pinger. From these measurements, estimate the position of the UUV.</td><td colspan="2">The estimated location of the UUV is within a radius of 100 meters with respect to the emergency pinger.</td></tr>
<tr><td colspan="4">Reality/Simulation: Reality</td></tr>
<tr><td>Executed by: AR, HF</td><td>Participants: AR, HF</td><td>Test week: 46</td><td>Test date: 22-11-14</td></tr>
<tr><td>Test result: The test went according to the expected result</td><td colspan="2">Comments: Instead of using the drone, the test was made by manually placing the hydrophone at different locations in a lake. Therefore, it was not dependent of test 11. The estimated location was within a radius of six meters with respect to the emergency pinger, when using the minimization of the loss function with the Gauss-Newton approach.</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: AR</td></tr>
</table>

5 Real Sensor test

This test is for testing all requirements regarding physical sensors

Table 7: Test protocol for real sensor test.

<table>
<tr><td colspan="2">Test No.: 6</td><td colspan="2">Test dependencies: 20, 21</td></tr>
<tr><td colspan="4">Resources: Hardware</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>22</td><td colspan="2">The UAS should be able to measure its height over the water for the physical implementation.</td><td>2</td></tr>
<tr><td>25</td><td colspan="2">The UAS should be able to communicate in real time with a ground station laptop via Wi-Fi for the physical implementation.</td><td>2</td></tr>
<tr><td>36</td><td colspan="2">The physical environment should allow for positioning with GPS.</td><td>2</td></tr>
<tr><td>37</td><td colspan="2">The physical environment should contain a sound source to transmit the emergency pinger underwater.</td><td>2</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">Setup the UAS outside. Manuelly fly the drone to a specific point over a bucket of water. Have an active pinger in the bucket. Make the UAS dip the hydrophone into the bucket. Start listening with the hydrophone. Land the UAS</td><td colspan="2">The UAS should report its GPS position to the base station and its height over the water. The base station should receive the recorded audio signal from the hydrophone. The base station should continuously receive the UAS's battery level</td></tr>
<tr><td colspan="4">Reality/Simulation: Reality</td></tr>
<tr><td>Executed by: DA, IL</td><td>Participants: DA, IL, KD, OH</td><td>Test week: 48</td><td>Test date: 22-11-30</td></tr>
<tr><td>Test result: The test went according to the expected result.</td><td colspan="2">Comments: The test was made in a lake.</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: IL</td></tr>
</table>

6 Simulation estimation

The following test is meant for testing the requirement for location estimation of the UUV in simulation.

Table 8: Test protocol for estimation of the UUV:s location in simulation.

<table>
<tr><td colspan="2">Test No.: 7</td><td colspan="2">Test dependencies: 2</td></tr>
<tr><td colspan="4">Resources: Simulation environment, operational algorithms for positioning.</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>6</td><td colspan="2">A semi-autonomous mode for detecting the UUV should be implemented in simulation, where the user will be able to suggest a search area.</td><td>1</td></tr>
<tr><td>75</td><td colspan="2">In the simulation environment, the system should be able to estimate the UUV:s location within 30 meters of real position.</td><td>1</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">Place the UUV at a well known position under the water in the simulation environment. Enter the semi-autonomous mode and tell the drone to go to different locations and measure the signal from the UUV in simulation. From these measurements, estimate the position of the UUV.</td><td colspan="2">The estimated location of the UUV is within a radius of 30 meters with respect to the real location of the UUV.</td></tr>
<tr><td colspan="4">Reality/Simulation: Simulation</td></tr>
<tr><td>Executed by: OP</td><td>Participants: OP, AR</td><td>Test week: 48</td><td>Test date: 22-11-30</td></tr>
<tr><td>Test result: The test went according to the expected result</td><td colspan="2">Comments: The estimated position of the UUV was within a radius of 1 meter in the simulation without noise.</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: HF</td></tr>
</table>

7 Task planner

The tests have been separated to two groups; one for simulation and one for reality.

7.1 Simulation

The following tests are to be conducted in the simulation environment.

Table 9: Test protocol for manual override.

Test No.: 8		**Test dependencies:** 1, 7	
Resources: Simulation model and the GUI			
Req. No.:	**Req. description:**		**Priority:**
2	The user should always be able to interrupt the autonomous mode and control the UAS manually in simulation.		1
29	The simulated environment should have a safe spot where the UAS can land.		1
68	Emergency landings should be simulable.		1
Test description:		**Expected results:**	
The test is initialized by starting a mission. Then, the user presses the button that tells the UAS to fly to the safe-spot and abort the mission. When the UAS is about to land at the safe-spot, the user takes control over UAS by manually steer it.		The UAS should abort the mission when the emergency landing is called upon, and it should fly to the predefined spot. When it is supposed to land and the user drives the UAS manually, it should abort the landing attempt and fly according to the manual control.	
Reality/Simulation: Simulation			
Executed by: IL	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** The UAS works as intended in the simulation, the manual control comes from by sending positions to the UAS in terminal.		**Pass/Fail:** Pass
Test approved by: DA			

Table 10: Test protocol for the battery performance in simulation.

Test No.: 9		**Test dependencies:** 1, 7	
Resources: The simulation environment and the GUI			
Req. No.:	**Req. description:**		**Priority:**
4	A backup plan to reach land if the battery gets low or an accident occurs above water should be implemented in simulation.		1
19	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
Test description:		**Expected results:**	
The test is started by letting the UAS hover on a fixed location, around 50 meters away from the safety-spot. There it will hover until the battery gets too low.		When the battery level gets too low, in relation to distance from the safety spot, the UAS should perform an emergency landing.	
Reality/Simulation: Simulation			
Executed by: IL	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** The UAS have a simple linear battery implantation and the estimation of how long it can travel is implemented with a constant speed to make it simple.		**Pass/Fail:** Pass
Test approved by: DA			

7.2 Reality

The following tests are to be conducted physically.

Table 11: Test protocol for communications for the task planner

Test No.: 10		**Test dependencies:** 7	
Resources: The UAS, the controller and the Base station			
Req. No.:	**Req. description:**		**Priority:**
39	The task planner should coordinate the UAS.		2
42	The task planner should be able to communicate with the UAS		2
Test description:		**Expected results:**	
A mission is started, where the task planner, on the base station, sends instructions to the UAS. The tasks that will be sent are pre-defined locations where the UAS is supposed to submerge the hydrophone.		The UAS should follow the instructions of the task planner.	
Reality/Simulation: Reality			
Executed by: IL	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** The task planner can coordinate the UAS with help of the telemetry.		**Pass/Fail:** Pass
Test approved by: KD			

Table 12: Test protocol for simple task.

Test No.: 11		**Test dependencies:** 6, 7, 10	
Resources: The UAS, the controller and the GUI			
Req. No.:	**Req. description:**		**Priority:**
12	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
Test description:		**Expected results:**	
Create a mission in the GUI and choose a location for the UAS to submerge the hydrophone and fly to a new defined location.		The UAS should estimate a location given the submerge-points from the user.	
Reality/Simulation: Reality			
Executed by: IL	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** The user can define points on a map where the UAS will fly to and make a dipping motion and then fly back to the start postion.		**Pass/Fail:** Pass
Test approved by: KD			

Table 13: Test protocol for manual override in reality.

Test No.: 12		**Test dependencies:** 6, 8, 11	
Resources: The UAS, the controller and the GUI			
Req. No.:	**Req. description:**		**Priority:**
8	The user should always be able to interrupt the autonomous mode and control the UAS manually for the physical implementation.		2
Test description:		**Expected results:**	
The test is initialized by starting a mission. Then the test is aborted by manually steering the UAS.		The UAS should abort the mission and fly according to the manual control.	
Reality/Simulation: Reality			
Executed by: IL and DA	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** The UAS pilot can do an arbitrary input on the controller of the UAS will abort the autonomous flying and listen to the pilot.		**Pass/Fail:** Pass
Test approved by: KD			

Table 14: Test protocol for emergency actions.

Test No.: 13		**Test dependencies:**6, 8, 11	
Resources: The UAS, the controller and the GUI			
Req. No.:	**Req. description:**		**Priority:**
34	The environment should have a physical safe spot where the UAS can land.		2
83	The UAS must have an emergency-stop where the UAS aborts the mission and lands at a predefined safety spot.		2
84	The UAS must have an emergency-stop where the UAS turn off all its systems.		2
Test description:		**Expected results:**	
The test is initialized by starting a mission. Then, the user presses the button that tells the UAS to fly to the safe-spot. When the UAS has landed, the stop-button is pressed.		The UAS should abort the mission and fly according to the manual control. When the emergency landing is called upon, the UAS should fly to the predefined spot. When the stop button is pressed, all motors should turn off.	
Reality/Simulation: Reality			
Executed by: IL	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** The controller have a button that makes the UAS fly back to the launch point and lands. The controller also have a button for killing all the systems of the UAS.		**Pass/Fail:** Pass
Test approved by: DA			

Table 15: Test protocol for telemetry safety-implementation

<table>
<tr><td colspan="2">Test No.: 14</td><td colspan="2">Test dependencies: 6, 11, 13</td></tr>
<tr><td colspan="4">Resources: The UAS, the controller and the GUI</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>56</td><td colspan="2">The UAS is limited to fly within the reach of the controller and the telemetry connection of the base station.</td><td>2</td></tr>
<tr><td>87</td><td colspan="2">If the UAS looses connection, it should return to a predefined safety-point and land.</td><td>2</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">The test is initialized by starting a mission. Then the telemetry is turned off.</td><td colspan="2">The UAS should abort the mission and fly to the predefined emergency-spot.</td></tr>
<tr><td colspan="4">Reality/Simulation: Reality</td></tr>
<tr><td>Executed by: IL</td><td>Participants: OH</td><td>Test week: 48</td><td>Test date: 22-12-01</td></tr>
<tr><td>Test result: The UAS meets the expected results of the test.</td><td colspan="2">Comments: When the connection is lost, the UAS flies back to the launch point and lands.</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: KD</td></tr>
</table>

Table 16: Test protocol for the battery performance in reality

Test No.: 15		**Test dependencies:** 9, 11, 13	
Resources: The UAS, the controller and the GUI			
Req. No.:	**Req. description:**		**Priority:**
10	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
21	The UAS should be able to measure its remaining battery charge for the physical implementation.		2
Test description:		**Expected results:**	
The test is started by letting the UAS hover on a fixed location, around 50 meters away from the safety-spot. There it will hover until the battery gets too low.		When the battery level gets too low, in relation to distance from the safety spot, the UAS should perform an emergency landing. The area must be free of obstacles.	
Reality/Simulation: Reality			
Executed by: IL	**Participants:** OH	**Test week:** 48	**Test date:** 22-12-01
Test result: The UAS meets the expected results of the test.	**Comments:** When the battery reaches 30 % the UAS files back to the launch point and lands.		**Pass/Fail:** Pass
Test approved by: DA			

8 Motion Planner and Control System

This section describes the tests relevant to the motion planner and the control system.

8.1 Simulation

The following tests are to be conducted in the simulation environment.

Table 17: Test protocol for UAS takeoff, flying and landing with the hydrophone in simulation.

Test No.: 16		**Test dependencies:** 1	
Resources: A computer with simulation environment installed			
Req. No.:	**Req. description:**		**Priority:**
15	The UAS should be able to land and take off with the hydrophone in the simulation.		1
18	The UAS should be able to fly with the hydrophone in the simulation.		1
44	The motion planner should make sure the hydrophone does not touch the ground when flying in simulation.		1
74	The dynamics of the UAS + hydrophone system should be simulated.		1
Test description: Start the simulation environment. Tell the UAS to lift off. Tell the UAS to fly to another location and then land.		**Expected results:** The UAS should be able to take off, fly a route and land without any instabilities or crashes. When flying, the hydrophone should not touch the ground.	
Reality/Simulation: Simulation			
Executed by: DA	**Participants:** KD	**Test week:** 48	**Test date:** 2022-11-28
Test result: Requirements were fulfilled.	**Comments:** The UAS can fly with the hydrophone in the simulation and it does not touch the ground when flying. Thus the dynamics of the UAS with the hydrophone can be simulated. Landing and take off can be a bit strange at times in simulations due to restrictions of the physics in Gazebo.		**Pass/Fail:** Pass
Test approved by: IL			

Table 18: Test protocol for submerging the hydrophone in water in simulation.

Test No.: 17		**Test dependencies:** 1, 16	
Resources: A computer with simulation environment installed			
Req. No.:	**Req. description:**		**Priority:**
45	The motion planner should make sure the hydrophone touches the water only when supposed to, in the simulation		1
46	The motion planner should make sure the UAS does not touch the water in the simulation environment.		1
Test description: Start the simulation environment. Tell the UAS to fly over a water mass and submerge the hydrophone in the water. Then tell the UAS to ascend.		**Expected results:** The UAS should submerge the hydrophone in the water without touching the water itself and then ascend without crashing.	
Reality/Simulation: Simulation			
Executed by: DA	**Participants:** KD	**Test week:** 48	**Test date:** 2022-11-28
Test result: The requirements were fulfilled.	**Comments:** The UAS does not touch the water at all, and the hydrophone only touched the water when supposed to.		**Pass/Fail:** Pass
Test approved by: IL			

Table 19: Test protocol for oscillation of cable in simulation.

Test No.: 18		**Test dependencies:** 16	
Resources: A simulation environment with the cable dynamics implemented.			
Req. No.:	**Req. description:**		**Priority:**
43	The motion planner should make sure the hydrophone does not oscillate more than four meter horizontally in the simulation.		1
Test description:		**Expected results:**	
Fly the UAS manually in simulation and measure the oscillations of the cable. The route should include acceleration, retardation, a take-off and a landing.		The oscillations are less than 1 m in horizontal orientation.	
Reality/Simulation: Simulation			
Executed by:	**Participants:**	**Test week:** 48	**Test date:** 2022-11-28
Test result: The motion planner fulfills the criteria.	**Comments:** When setting the maximum horizontal speed to 2 m/s the oscillations in the hydrophone are 2 m or less.		**Pass/Fail:** Pass
Test approved by: IL			

Table 20: Test protocol for motion planning algorithm in simulation.

Test No.: 19		**Test dependencies: -**	
Resources:A computer with simulation environment installed			
Req. No.:	**Req. description:**		**Priority:**
47	The motion planner should use a motion planning algorithm in the simulation environment.		1
Test description:		**Expected results:**	
Check in the simulation environment if a motion planning algorithm is implemented.		A motion planning algorithm is implemented in the simulation environment.	
Reality/Simulation: Simulation			
Executed by: DA	**Participants:** KD	**Test week:** 48	**Test date:** 2022-11-28
Test result: It uses a motion planning algorithm.	**Comments:** The UAS uses the pre-existing motion planning algorithm implemented by PX4.		**Pass/Fail:** Pass
Test approved by: IL			

8.2 Reality

The following tests are to be conducted physically.

Table 21: Test protocol for landing, flying and take-off with the hydrophone.

<table>
<tr><td colspan="2">Test No.: 20</td><td colspan="2">Test dependencies: -</td></tr>
<tr><td colspan="4">Resources: UAS, hydrophone and manual controller.</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>23</td><td colspan="2">The UAS should be able to land and take off with the hydrophone for the physical implementation.</td><td>2</td></tr>
<tr><td>26</td><td colspan="2">The UAS should be able to fly with the hydrophone for the physical implementation.</td><td>2</td></tr>
<tr><td>50</td><td colspan="2">The motion planner should make sure the hydrophone does not physically touch the ground when flying.</td><td>2</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">Start the UAS and try to take off. If the take-off is successful, hover and fly around. If this is successful, try to land.</td><td colspan="2">The UAS should be able to take off, fly a route and land without any instabilities or crashes. When flying, the hydrophone should not touch the ground.</td></tr>
<tr><td colspan="4">Reality/Simulation: Reality</td></tr>
<tr><td>Executed by: IL, DA</td><td>Participants: KD, OH</td><td>Test week: 47</td><td>Test date: 2022-11-25</td></tr>
<tr><td>Test result: The results were as expected</td><td colspan="2">Comments: The drone started without any problems. It flew very stable with the hydrophone and landed without any problem.</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: KD</td></tr>
</table>

Table 22: Test protocol for submerging the hydrophone in water.

Test No.: 21		**Test dependencies:** 20	
Resources: UAS, hydrophone and an area with water			
Req. No.:	**Req. description:**		**Priority:**
24	The UAS should be able to submerge the hydrophone in the water.		1
51	The motion planner should make sure the hydrophone physically touches the water only when supposed to.		1
52	The motion planner should make sure the UAS does not physically touch the water.		1
Test description: Fly the UAS in semi-autonomous over a water mass and submerge the hydrophone in the water. Ascend the UAS.		**Expected results:** The UAS should submerge the hydrophone in the water without touching the water itself and then ascend without crashing.	
Reality/Simulation: Reality			
Executed by: IL, OH	**Participants:** DA, KD	**Test week:** 48	**Test date:** 2022-11-30
Test result: The results were as expected.	**Comments:** The UAS descended and submerged the hydrophone in a controlled fashion. The hydrophone only touched the water when desired and the UAS did not touch the water at all.		**Pass/Fail:** Pass
Test approved by: DA			

Table 23: Test protocol for depth of water area in physical implementation.

Test No.: 22		**Test dependencies:** -	
Resources: A water area, measuring device.			
Req. No.:	**Req. description:**		**Priority:**
35	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
Test description:		**Expected results:**	
Measure the depth.		The water is deep enough.	
Reality/Simulation: Reality			
Executed by: DA, KD	**Participants:** OH, IL	**Test week:** 48	**Test date:** 2022-11-30
Test result: The results were as expected.	**Comments:** The water was deep enough.		**Pass/Fail:** Pass
Test approved by: IL			

Table 24: Test protocol for oscillation of cable in physical implementation.

Test No.: 23		**Test dependencies:** 20	
Resources: UAS with the cable and hydrophone.			
Req. No.:	**Req. description:**		**Priority:**
49	The motion planner should make sure the hydrophone does not physically oscillate more than 45^o horizontally.		2
Test description:		**Expected results:**	
Fly the UAS manually and measure the oscillations of the cable when the UAS hovers. The route should include; acceleration, retardation, a take-off and a landing.		The cable should not oscillate more than 45^o in the horizontal orientation.	
Reality/Simulation: Reality			
Executed by: DA, IL	**Participants:** OH, KD	**Test week:** 47	**Test date:** 2022-11-25
Test result: The hydrophone did not oscillate more than 45^o.	**Comments:** When starting and stopping at short intervals the oscillations peak, but with a maximum horizontal speed of about 3 m/s the oscillations were kept to a minimum. Even when the oscillations were at the largest, the impact on the UAS was were small to non.		**Pass/Fail:** Pass
Test approved by: OH			

Table 25: Test protocol for motion planning algorithm in the physical implementation.

Test No.: 24		**Test dependencies: -**	
Resources:UAS with Raspberry Pi.			
Req. No.:	**Req. description:**		**Priority:**
53	The motion planner should use a motion planning algorithm for the physical implementation.		1
Test description:		**Expected results:**	
Check if the UAS in the physical implementation has a motion planing algorithm implemented.		The UAS has a motion planing algorithm implemented.	
Reality/Simulation: Reality			
Executed by: IL, DA	**Participants:** KD, OH	**Test week:** 47	**Test date:** 2022-11-25
Test result: The UAS has a motion planning algorithm	**Comments:** The UAS uses PX4 implemented motion planning algorithm.		**Pass/Fail:** Pass
Test approved by: IL			

9 GUI

This section describes the tests relevant to the GUI.

Table 26: Test protocol for user input via the buttons on the GUI.

<table>
<tr><td colspan="2">Test No.: 25</td><td colspan="2">Test dependencies: -</td></tr>
<tr><td colspan="4">Resources: A base station with the GUI.</td></tr>
<tr><td>Req. No.:</td><td colspan="2">Req. description:</td><td>Priority:</td></tr>
<tr><td>60</td><td colspan="2">The GUI should enable the user to choose between manual and semi-autonomous flying.</td><td>2</td></tr>
<tr><td>64</td><td colspan="2">The GUI should enable the user to cancel a mission, commanding it to fly back to the starting position.</td><td>2</td></tr>
<tr><td colspan="2">Test description:</td><td colspan="2">Expected results:</td></tr>
<tr><td colspan="2">Start the GUI and click on the buttons for toggling flying mode. Click on the button for starting a semi-autonomous mission. Let the UAS fly away and then click on the button for canceling a mission.</td><td colspan="2">The UAS should toggle between modes. It should also cancel a running mission.</td></tr>
<tr><td colspan="2"></td><td colspan="2">Reality/Simulation: Reality</td></tr>
<tr><td>Executed by: KD, IL</td><td>Participants: OH, DA</td><td>Test week: 48</td><td>Test date: 2022-12-01</td></tr>
<tr><td>Test result: The results were as expected.</td><td colspan="2">Comments: The mode was switched between manual and semi-autonomous mode back and forth through the GUI. The UAS was then commanded to fly away, which it did. Later, the mission was cancelled manually through the GUI.</td><td>Pass/Fail: Pass</td></tr>
<tr><td colspan="4">Test approved by: OH</td></tr>
</table>

Table 27: Test protocol for information displayed on the GUI.

Test No.: 26		**Test dependencies:** 15	
Resources: A base station with the GUI.			
Req. No.:	**Req. description:**	**Priority:**	
58	The GUI should display elapsed time for the current session and mission.	2	
59	The GUI should display an estimate of flown distance for the current mission.	2	
62	The GUI should display the battery level of the UAS.	2	
Test description:		**Expected results:**	
Start the GUI and start a mission.		The GUI should display all the information listed.	
Reality/Simulation: Reality			
Executed by: KD, IL	**Participants:** OH, DA	**Test week:** 48	**Test date:** 2022-12-01
Test result: The results were as expected.	**Comments:** A mission was started and the UAS flew away. The GUI displayed the elapsed time and flown distance for the mission at all times, as well as the battery level of the UAS.	**Pass/Fail:** Pass	
Test approved by: DA			

Table 28: Test protocol for the map visualization displayed on the GUI.

Test No.: 27		**Test dependencies: -**	
Resources: A base station with the GUI.			
Req. No.:	**Req. description:**	**Priority:**	
65	The GUI should show a visualization of the explored area. This includes the position of the UAS and the planned route.	2	
Test description:		**Expected results:**	
Start the GUI and start a mission.		The GUI displays a map with an estimated position of the UUV, position of the UAS and the planned route.	
Reality/Simulation: Reality			
Executed by: KD, IL	**Participants:** OH, DA	**Test week:** 48	**Test date:** 2022-12-01
Test result: The results were as expected.	**Comments:** A mission was started and the UAS flew away. The GUI displayed the position of the UAS and the planned route at all times.	**Pass/Fail:** Pass	
Test approved by: DA			

References

[1] Requirement specification. 2022-09-15.