Test Plan

Remotely Operated Underwater Vehicle

Version 1.2

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Document History

Version	Date	Changes made	Sign	Reviewer(s)
0.1	2017-09-27	First draft.	MH	MH
0.2	2017-09-29	First revision.	MH	MH
0.3	2017-10-06	Second revision.	MH, AS	MH, AS
0.4	2017-10-10	Third revision.	MH, AS	MH, AS
0.5	2017-10-12	Fourth revision.	MH, AS	MH, AS
1.0	2017-10-16	First version	AS	AS
1.1	2017-11-30	Moved test 29 from Simulation to GUI test and changed some test numbers.	AA	AA
1.2	2017-12-08	Changed some sensor fusion tests that shall now be performed in simulation instead of in a pool.	FN	MH

Contents

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LCS Local Coordinate System

PCS Pool Coordinate System

ROS Robot Operating System

ROV Remotely Operated Underwater Vehicle

SIL Software In the Loop

1 Introduction

In this document, all tests that will be performed during the project will be described. The tests shall be designed in such a way that it is easy to see if a requirement has been fulfilled. All non-trivial requirements in the requirement specification [1] shall be covered in the tests. Table 1 shows the format that the tests will be presented in. The first column is the number of the test. The second column described what requirements that are being tested. Then there is a detailed description of the test in the third column. The fourth column specifies how long time the test requires in hours. The fifth column contains the resources that are needed to perform the test. The sixth column states who is responsible for the test. In the last column, the week that the test will be performed is specified.

Table 1: An example of a test table.

Test nr.	**Req. nr.**	**Test description**	**Time**	**Resources**	**Respons.**	**Week**

2 General System and Interface Tests

Table 2 contains tests that shall verify the requirements on the general system and the interface between the different modules.

Table 2: Tests on the general system and the interface between modules.

Test nr.	**Req. nr.**	**Test description**	**Time**	**Resources**	**Respons.**	**Week**
1	1	Verify that ROS is used as the main framework for software and communication with the ROV by inspecting the code.	0.25	Up-to-date source code.	FN	47
2	7, 8	Log ROS messages during a run. Inspect those messages to verify that the GUI exchanges data with other modules by subscribing and publishing to ROS topics.	0.25	ROV, workstation.	FN	47
3	21, 22, 23	Log ROS messages during a run. Inspect those messages to verify that the control module exchanges data with other modules by subscribing and publishing to ROS topics.	0.25	ROV, workstation.	FN	47
4	49, 50	Log ROS messages during a run. Inspect those messages to verify that the sensor fusion module exchanges data with other modules by subscribing and publishing to ROS topics.	0.25	ROV, workstation.	FN	47

5	97, 99	Log ROS messages during a run. Inspect those messages to verify that the I/O-module exchanges data with other modules by subscribing and publishing to ROS topics.	0.25	ROV, workstation.	FN	47
6	104, 105, 106, 107	Log ROS messages during a run. Inspect those messages to verify that the pathfinder module exchanges data with other modules by subscribing and publishing to ROS topics.	0.25	ROV, workstation.	FN	47
7	2	The output logs shall be inspected after a run to verify that there exists functionality to log raw sensor data, reference signals, control signals and state estimates.	0.5	ROV, workstation.	MM	44
8	3, 4	Use the XBOX-controller and test if the correct thruster is responding to the used button by plotting reference and control signals from the logged data.	0.5	ROV, XBOX-controller, workstation.	AS	44
9	92, 93, 94, 95, 96, 98	Log ROS messages from the I/O-module during a run. Inspect those messages to verify that the sensors can communicate with the I/O module.	0.5	ROV, workstation.	MH	44

3 Design Tests

Table 3 lists the tests that shall verify all the design requirements on the different modules.

Table 3: Tests on the design requirements.

Test nr.	Req. nr.	Test description	Time	Resources	Respons.	Week
10	17, 18, 19, 20	Verify that all code is version controlled and that all code is written and commented in English by inspecting the code. Also verify that all C++ source code written for ROS fulfills the ROS coding standard and that all other C++ code fulfills Google's coding standard by inspecting the code.	2	Up-to-date source code.	FN	47
11	24	Verify that it exists a controller for control of the linear and angular velocity by inspecting the code.	0.5	Up-to-date source code.	GJ	46
12	25	Verify that it exists a controller for control of the attitude and position by inspecting the code.	0.5	Up-to-date source code.	GJ	46
13	26	Verify that it exists a controller for following a reference trajectory by inspecting the code.	0.5	Up-to-date source code.	GJ	46
14	51	Log ROS messages from the sensor fusion module, the pathfinder module and the control module during a run. Inspect those messages to verify that the sensor fusion module runs on the Raspberry Pi.	0.5	ROV, workstation.	MH	47
15	64	Verify that a mathematical model exists that describes the dynamic of the ROV by inspecting the model.	0.5	Up-to-date model.	MJ	44
16	71	Verify that there exists a GUI for the simulator by inspecting the code.	0.5	Up-to-date source code.	AN	46
17	78	Verify that the simulator has been built in Matlab/Simulink by inspecting the simulator environment.	0.25	Up-to-date source code.	AN	46

18	81	Run a simulation and tilt the ROV close to -90° and 90°. Inspect the position estimation to verify that the known environment has been modelled in the simulator with non visible bottom and surface.	0.5	Up-to-date source code.	AN	46
19	82	Verify that the the sensors on the ROV have been implemented in the simulator by running a simulation and inspecting the output from the sensor module.	0.5	Up-to-date source code.	AN	46
20	79	Start a simulation and then change some parameters in the model while still using the same control signals and verify that the simulator produces different state estimates by inspecting the logged data.	0.5	Up-to-date source code.	AN	46
21	80	Run a simulation while using the mathematical model and check that the simulator is running without any error messages.	0.5	Up-to-date source code.	AN	46

4 Graphical User Interface Tests

Table 4 lists the tests on the functionality requirements regarding the GUI.

Table 4: Tests on the functionality requirements regarding the GUI.

Test nr.	Req. nr.	Test description	Time	Resources	Respons.	Week
22	9	Use a script to input references in angles, angular velocities, position and linear velocity and verify that the same references are shown in the GUI by inspecting the GUI.	0.5	Workstation.	AA	44
23	10	Verify that it exists functionality in the GUI to present state estimates, references, control signals and active operating mode by inspecting the GUI. Document by taking screen-shots of the GUI.	0.5	ROV, workstation.	AA	44
24	11	Verify that the functionality in the GUI to present a graphical representation of the reference trajectory exists by inspecting the GUI. Document by taking screen-shots of the GUI.	0.5	Workstation.	MM	46
25	12, 106	Specify the start and end points for the pathfinder module in the GUI. Log ROS messages from the pathfinder module and inspect those messages to verify that the path that is returned from the pathfinder module has the same coordinates for start and end points.	0.5	ROV, workstation.	AA	44
26	13, 14	Verify that it exists functionality in the GUI to present a graphical representation of the map, the ROV's position estimate and the ROV's attitude estimate by inspecting the GUI and comparing it to the estimates from the sensor fusion module.	0.5	ROV, workstation.	MM	46

27	15	Switch mode and make the control module send a message containing its current mode. Verify that it's the same that is shown in the GUI. Document by inspecting the logged data and by taking screen-shots of the GUI.	0.5	ROV, workstation.	MM	45
28	16	Run a simulation and send new parameters from the GUI to the control module and the sensor fusion module while still using the same control signals. Verify that different state estimates are produced by inspecting the logged data.	0.5	ROV, workstation.	AA	45
29	72	Log the times that states are estimated from the sensor fusion module and the times that the position and attitude are updated in the GUI and compare them to verify that the delay is no greater than 100 ms.	0.5	Up-to-date source code.	MM	47

5 Control System Tests

Table 5 lists the tests on the functionality and performance requirements regarding the control system.

Table 5: Tests on the functionality and performance requirements regarding the control system.

Test nr.	**Req. nr.**	**Test description**	**Time**	**Resources**	**Respons.**	**Week**
30	5	The ROV will be given a reference trajectory and it shall be able to follow this trajectory. References and estimated states will be logged and compared to verify that the maximum deviation is no greater than 0.1 meters in position, 1 degree in attitude and 0.05 m/s in linear velocity.	0.5	Up-to-date source code.	GJ, AS	46

31	6	To verify that the hover mode works as expected a test shall be performed where the ROV is moved from its position and rotated by hand when hover mode is activated. The ROV should then return to the same position and attitude as before. Reference signals, estimated states and control signals will be plotted.	0.5	Up-to-date source code.	GJ	45
32	27, 31, 32, 33, 34, 35	Perform a step in roll from 0° to 30° and inspect the plots with respect to stationary error, rise time, overshoot, settling time and disturbance in the other two rotational degrees of freedom to verify the performance.	1	Up-to-date source code.	GJ, AS	45
33	27, 31, 32, 33, 34, 35	Perform a step in pitch from 0° to 30° and inspect the plots with respect to stationary error, rise time, overshoot, settling time and disturbance in the other two rotational degrees of freedom to verify the performance.	1	Up-to-date source code.	GJ, AS	45
34	27, 31, 32, 33, 34, 35	Perform a step in yaw from 0° to 30° and inspect the plots with respect to stationary error, rise time, overshoot, settling time and disturbance in the other two rotational degrees of freedom to verify the performance.	1	Up-to-date source code.	GJ, AS	45
35	28, 36, 37, 38, 39	Perform a step in roll angular velocity from 0 rad/s to 0.5 rad/s and inspect the plots with respect to stationary error, rise time, overshoot and settling time to verify the angular velocity performance about the roll axis.	1	Up-to-date source code.	GJ, AS	45
36	28, 36, 37, 38, 39	Perform a step in pitch angular velocity from 0 rad/s to 0.5 rad/s and inspect the plots with respect to stationary error, rise time, overshoot and settling time to verify the angular velocity performance about the pitch axis.	1	Up-to-date source code.	GJ, AS	45

37	28, 36, 37, 38, 39	Perform a step in yaw angular velocity from 0 rad/s to 0.5 rad/s and inspect the plots with respect to stationary error, rise time, overshoot and settling time to verify the angular velocity performance about the yaw axis.	1	Up-to-date source code.	GJ, AS	45
38	30, 40, 41, 42, 43	Perform a step in the ROV's position in the PCS x-axis by 1 m and inspect the plots with respect to stationary error, rise time, overshoot and settling time to verify the performance.	1	Up-to-date source code.	GJ, AS	45
39	30, 40, 41, 42, 43	Perform a step in the ROV's position in the PCS y-axis by 1 m and inspect the plots with respect to stationary error, rise time, overshoot and settling time to verify the performance.	1	Up-to-date source code.	GJ, AS	45
40	30, 40, 41, 42, 43	Perform a step in the ROV's position in the PCS z-axis by 1 m and inspect the plots with respect to stationary error, rise time, overshoot and settling time to verify the performance.	1	Up-to-date source code.	GJ, AS	45
41	29, 44, 45, 46, 47, 48	Perform a step in the LCS x-axis velocity from 0 m/s to 0.2 m/s and inspect the plots with respect to stationary error, rise time, overshoot, settling time, disturbance in pitch and roll angle and disturbance in rotational (degrees of freedom) velocities to verify the performance.	1	Up-to-date source code.	GJ, AS	45
42	29, 44, 45, 46, 47, 48	Perform a step in the LCS y-axis velocity from 0 m/s to 0.2 m/s and inspect the plots with respect to stationary error, rise time, overshoot, settling time, disturbance in pitch and roll angle and disturbance in rotational (degrees of freedom) velocities to verify the performance.	1	Up-to-date source code.	GJ, AS	45

43	29, 44, 45, 46, 47, 48	Perform a step in the LCS z-axis velocity from 0 m/s to 0.2 m/s and inspect the plots with respect to stationary error, rise time, overshoot, settling time, disturbance in pitch and roll angle and disturbance in rotational (degrees of freedom) velocities to verify the performance.	1	Up-to-date source code.	GJ, AS	45

6 Sensor Fusion Tests

Table 6 lists the tests on the functionality and performance requirements regarding the sensor fusion.

Table 6: Tests on the functionality and performance requirements regarding the sensor fusion.

Test nr.	**Req. nr.**	**Test description**	**Time**	**Resources**	**Respons.**	**Week**
44	52, 56	Initialize the ROV with a deviation of 0.6 meters from its simulated position and verify that the ROV is able to estimate its position, after it has been moved around for 30 seconds during a simulation, by inspecting the logged data and comparing to the simulated position.	1	Up-to-date source code.	MH, FN	45
45	53, 57	Initialize the ROV with a deviation of 15° in each of the three angles and verify that the ROV is able to estimate its attitude, after it has been moved around for 30 seconds during a simulation, by inspecting the logged data and comparing to the simulated attitude.	1	Up-to-date source code.	MH, FN	45
46	52, 58	Verify that the estimation of the ROV's position is maintained within 0.3 meters of the true position when this limit has been reached by moving the ROV around during a simulation and comparing the estimated position with the simulated position.	1	Up-to-date source code.	MH, FN	45

47	52, 59	Let the position and attitude initially be unknown in the sensor fusion module and move the ROV around in the pool with an XBOX-controller. Then stop the ROV after 1 minute and compare the estimated states to the true position and attitude. By filming with a camera, marking the pool with tape into a grid and using the fact that the size of the ROV is known, the ROV's true position and attitude can be measured afterwards.	1	ROV, workstation, pool, camera, tape, XBOX-controller.	MH, FN	45
48	54, 60	Validation of the estimates of linear velocities shall be performed by running the ROV in 0.15-0.40 m/s over 2-3 meters with an XBOX-controller. By filming with a camera and measuring the size of the tiles in the pool, the elapsed time and the distance can be measured. Then the measured mean velocity will be calculated and compared to the estimated velocity from the sensor fusion module to verify that the error is no greater than 0.1 m/s.	1	ROV, workstation, pool, camera, XBOX-controller.	MH, FN	45
49	55, 61	Validation of the estimate of angular velocity in yaw angle shall be performed by letting the ROV complete 1 turn about the z-axis with an average speed between $35°/s$ and $45°/s$ during a simulation. Then the simulated angular velocity will be compared to the estimated angular velocity from the sensor fusion module to verify that the error is no greater than $5°/s$.	1	Up-to-date source code.	MH, FN	45

50	55, 61	Validation of the estimate of angular velocity in roll and pitch angle shall be performed by letting the ROV rotate from -30° to 30° with an average speed between 60°/s and 80°/s during a simulation. Then the simulated angular velocity will be compared to the estimated angular velocity from the sensor fusion module to verify that the error is no greater than 8°/s.	1	Up-to-date source code.	MH, FN	45
51	53, 62	Validation of the estimates of the attitude shall be performed by rotating the ROV to around 50° about each axis during a simulation. The estimates from the sensor fusion model will be compared to the simulated attitude to verify that the error is no greater than 1° in each angle.	1	Up-to-date source code	MH, FN	44
52	63	To verify that the sensor fusion module is able to produce state estimates with a maximum delay of 4 ms, the times that the ROV produces state estimates will be logged and inspected.	0.5	ROV, workstation.	MH, FN	44

7 Modelling Tests

Table 7 lists the tests on the functionality and performance requirements regarding modelling.

Table 7: Tests on the functionality and performance requirements regarding modelling.

Test nr.	**Req. nr.**	**Test description**	**Time**	**Resources**	**Respons.**	**Week**
53	66, 68, 69	Validate the model in each of the angular DOF's by collecting validation data when the ROV is excited one DOF at a time. Then verify that the validation data fits the data from relevant sensors to at least 85 %.	1	ROV, workstation, pool.	AS	46

54	65, 67, 70	Validate the model in each of the linear DOF's by collecting validation data when the ROV is excited one DOF at a time. Then verify that the validation data fits the data from relevant sensors to at least 85 %.	1	ROV, workstation, pool.	AS	46

8 Simulation Tests

Table 8 lists the tests on the functionality and performance requirements regarding simulation.

Table 8: Tests on the functionality and performance requirements regarding simulation.

Test nr.	Req. nr.	Test description	Time	Resources	Respons.	Week
55	73	Specify the initial state of the ROV. Then start a simulation and inspect the simulator to verify that the initial state is the same that was specified.	0.5	Up-to-date source code.	AN	46
56	74, 75, 76, 77	Verify that the GUI for the simulator shows angular velocities, linear velocities, attitude and a 3D visualization of the ROV by inspecting the GUI.	0.5	Up-to-date source code.	AN	46
57	83, 91	Use an XBOX-controller to control the ROV in a pool for one minute and log the reference signals. Validate the SIL simulator by sending those reference signals to the simulator and comparing the output from the simulator to the estimated states from the sensor fusion module to verify that it fits to at least 85 %.	0.5	ROV, XBOX-controller, workstation, pool.	MJ	46
58	84, 91	Use an XBOX-controller to control the ROV in a pool for one minute and log the reference signals. Validate the HIL simulator by sending those reference signals to the simulator and comparing the output from the simulator to the estimated states from the sensor fusion module to verify that it fits to at least 85 %.	0.5	ROV, XBOX-controller, workstation, pool.	MJ	46

59	85	Validate that it exists functionality to choose whether or not to use the sensor fusion module in HIL mode by running a HIL simulation and inspecting the simulator environment when switching between using the sensor fusion module and not using it.	0.5	Up-to-date source code.	AN	46
60	86	Send a new parameter setting as user input to the simulator while running a simulation and log the time that the parameter is sent and the time that the parameter is changed in the simulator to verify that the delay is no greater than 100 ms.	0.5	Up-to-date source code.	AN	46
61	87	To verify that the simulator environment is able to log data from simulation runs, the simulator shall be run and the output logs shall be inspected and documented.	0.5	Up-to-date source code.	AN	47
62	88	Run the ROV in a pool for 1 minute by using an XBOX-controller and log the data. Then use the same control signals and sensor measurements in the simulator and compare the simulated state estimates to the logged state estimates to verify that the simulator environment is able to import log data from real world measurements.	0.5	ROV, workstation, pool, XBOX-controller.	AN	47
63	89	Run a SIL simulation and inspect the control signals to verify that it is possible to simulate control signals without running the control module on the ROV.	0.5	Up-to-date source code.	AN	46
64	90	Run a SIL simulation and inspect the state estimates to verify that it is possible to simulate state estimates without running the sensor fusion module on the ROV.	0.5	Up-to-date source code.	AN	46

9 Hardware Tests

Table 9 lists the tests on the functionality requirements regarding the hardware.

Table 9: Tests on the functionality requirements regarding the hardware.

Test nr.	Req. nr.	Test description	Time	Resources	Respons.	Week
65	100	To verify that the ROV is waterproof to a depth of 3.8 meters, a test will be performed where the ROV is sent to the bottom of a 4 meters deep pool. The ROV will then be inspected for water leaks. The depth will be plotted from the logged data for documentation.	0.5	ROV, workstation, pool.	MJ	46
66	101	To verify that it is possible to replace the battery of the ROV in less than 30 minutes, a test will be performed where the battery is replaced and the elapsed time is measured.	0.5	ROV, timer.	MJ	46
67	102	Remove the acrylic tube to verify that it is possible to physical access the hardware that contains the control- and I/O-module of the ROV.	0.5	ROV.	MJ	46

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10 Pathfinder Tests

Table 10 lists the tests on the functionality requirements regarding the pathfinder.

Table 10: Tests on the functionality requirements regarding the pathfinder.

Test nr.	Req. nr.	Test description	Time	Resources	Respons.	Week
68	108, 110	Send start and end coordinates from the GUI to the pathfinder module and verify that the ROV moves from the start coordinates to the end coordinates in the pool without colliding with any virtual obstacles or walls by plotting the ROV's path in the pool.	0.5	ROV, workstation, pool.	MM	45
69	109, 110	Send coordinates for 4 locations from the GUI to the pathfinder module and verify that the ROV moves through those 4 locations in the pool without colliding with any virtual obstacles or walls by plotting the ROV's path in the pool.	0.5	ROV, workstation, pool.	MM	45

11 Security Tests

In Table 11, the tests on the security requirements of the system are listed. These tests shall be performed in a small pool before the major part of the testing is performed on the ROV. This is to ensure that the ROV behaves according to the security requirements during development.

Table 11: Tests on the security requirements of the system.

Test nr.	Req. nr.	Test description	Time	Resources	Respons.	Week
70	115	Set the ROV in horizontal motion in a pool and detach the ethernet cable from the workstation. The ROV should then stop its motion when it detects that the connection has been lost. Verify this by inspecting the logged data.	0.5	ROV, workstation, pool, camera.	AA	43

12 Fulfillment of Other Requirements

In the requirement specification [1], the possibilities to upgrade-, economy- and delivery requirements are trivial to verify. Therefore, no tests will be planned for those requirements. Security requirement 116 is also trivial and is already fulfilled so there is no need to plan a test for that requirement either. Another requirement that is trivial is requirement 103 since it can be verified by simply looking at the ROV.

References

[1] Marcus Homelius. *Requirement Specification, Remotely Operated Underwater Vehicle*. 2017.