Report on the functional tests at sea of the first generation

Activity 3.3 - Piloting of the UUV
WP3 - Implementation of the Drone-enabled Monitoring System

SUSHI DROP project (ID 10046731)

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Abstract

WP3 is focused on the definition of requirements, procurement, and validation at sea of a drone, i.e. an Unmanned Underwater Vehicle (UUV) for acoustic and optical characterization of the marine ecosystem at different degrees od resolution. This WP comprehends the functional tests at sea of the first generation of UUV performed in the controlled environment of the Genova harbour. These tests involve the calibration of the navigation guidance and control subsystems and the verification of the navigation performances. These tests are carried out in collaboration with the CNR-ISSIA through the subcontract with LP.

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Overview

This deliverable describes all the functional tests carried out to calibrate and validate the vehicle performance. These tests are fundamental to have a first idea of the vehicle capabilities in the various operational mission scenarios and allow to improve the navigation characteristics by being able to set the different parameters.

This report is organized as follow:

1. Calibration and Equipment Tests: report on the sea tests carried out for all the subsystems on board, aimed at the calibration of the drone.
2. Performances Tests: Validation of vehicle navigation requirements with sea trials.

Calibration and Equipment Tests

In this test stage, both the science data acquisition subsystems (e.g. Pilot Cam, Bottom Cam, Mini CT and Mini SVS) and the Navigation Guidance and Control (NGC) subsystems were calibrated.

These tests have allowed us to validate the characteristics of the drone and to improve its performance by tuning the parameters of the NGC module.

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Buoyancy Calibration

The weight to be added to achieve positive vehicle buoyancy was determined.

The following steps were performed for calibration:

- Starting from the CAD (Computer aided Design) model of the vehicle, a first estimate of the weight in air and of the relative weight in water was made, estimating the buoyancy of the drone; (Performed during the design phase)

FIGURE 1: DRONE WEIGHT CALCULATION

- Once the drone was assembled, it proceeded with the calculation of the weight in water and in air of the components by going to measure the weight and buoyancy of each component in the laboratory. This phase allowed to correct the data estimated in the design phase and to be able

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to calculate a priori the number of weights to be added to the vehicle; (performed in the assembly phase)

- During the sea test phase, the calculated weights were added, and the correct buoyancy of the drone was verified; (Performed in Genova harbor)

FIGURE 2: HARBOR BUOYANCY TESTS

- A table has been generated in which the weight to be added or removed can be calculated according to the components on board. It is important to underline that this table indicates the maximum weights in a standard mission, i.e. considering the average parameters of temperature and salinity of the Adriatic sea; (Executed in Genova harbor)
- Small calibration corrections, which are on the order of grams, must be made whenever the drone is immersed in water, as they are affected by local salinity conditions that vary by mission location and weather. This operation has been integrated into the drone mission checklist. (Performed in Genoa harbor)

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FIGURE 3: HARBOR BUOYANCY TESTS

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	H20SEA	H20	Delta		
Dry Weight	216,4	216,4		[kg]	
Thrust	217	212	5,1	[kg]	
Wet Weight	0,2	-4,9	5,1	[kg]	
Vehicle weight	158			[kg]	ok
Thrust of vehicle	183	179	4,3	[kg]	

YES/NO	SushiDrop	Dry weight [Kg]	Thrust [kg]	Actual weight	Actual thrust	Wet weight [Kg]
1	Blucy Vehicle	158,4	182,9	158,41	182,90	24,49
YES/NO	**Payload**	**Dry weight [Kg]**	**Thrust [kg]**	**Actual weight**	**Actual thrust**	**Wet weight [Kg]**
1	Pilot Cam	1,7	2,1	1,69	2,13	0,45
1	mini-CT	0,6	0,29	0,60	0,29	-0,31
1	mini-SVS+Pressure	1	0,29	1,00	0,29	-0,71
1	Multibeam Canister	9,53	5,90	9,53	5,90	-3,63
1	Multibeam	4,4	3,07	4,40	3,07	-1,33
1	FOG	12,6	6,4	12,63	6,44	-6,19
1	DVL: Nortek DVL500	3,5	3	3,50	3,00	-0,50
1	Transponder USBL Canister	2,6	0,7	2,60	0,73	-1,87
1	Transponder USBL	0,3	0,10	0,30	0,10	-0,20
1	Altimeter	1,15	0,35	1,15	0,35	-0,80
1	Wifi	1,25	1,34	1,25	1,34	0,09
1	Radiomodem	1,33	1,61	1,33	1,61	0,28
1	Bottom Cam	12,20	7,09	12,20	7,09	-5,11
1	AHRS	0,86	0,93	0,86	0,93	0,06
1	Additional weight	5,00	0,45	5,00	0,45	-4,55

TABLE 1: BUOYANCY TABLE

As you can see from the table, when BLUCY is in full equipment, to have a positive buoyancy of 0.2Kg you need to add 5 kg of additional weight.

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Thruster Control Matrix Estimation

This at-sea calibration phase allowed refinement of the parameters constituting the vehicle's Thruster control matrix (TCM). The steps followed for calibration and parameter estimation are reported below:

- The first TCM estimation was performed during the design phase by calculating the several parameters from the drone CAD; (performed during the design phase)
- The characterization of the thrust of each motor has been performed, i.e. the motors have been tested in the tank present in the laboratory of CNR-ISSIA calculating for each range of rotation the effective thrust of the motor; (performed during assembly)
- The TCM is calculated considering the previous two steps and has been implemented within the NGC software.
- During sea trials, the refinement of TCM parameters was carried out:
    - The navigation data of the drone has been collected during specific maneuver, e.g. forward navigation, lateral navigation, vertical navigation, cross input navigation.
    - These data have been analyzed in real time by CNR-ISSIA using the least squares method with the decoupled dynamic model of the drone.
    - The new parameters have been implemented into the NGC software.

Yaw Autopilot and Depth Autopilot Estimation and Calibration

During this test phase the autopilot parameters were estimated and updated within the navigation software. The steps followed for these tests follow the sequence shown below:

- Acquisition of vehicle’s navigation data during specific maneuver.
- The first estimation of Yaw Autopilot and Depth Autopilot parameters has been carried out by CNR-ISSIA engineers using least squares method of the decoupled dynamic model of Blucy.
- The estimated parameters are implemented into the NGC software.
- The parameters were tuned during sea trials in the port of Genoa, to improve the performance of the autopilots in terms of accuracy, response speed, and steady state error in the presence of external disturbances such as sea current.

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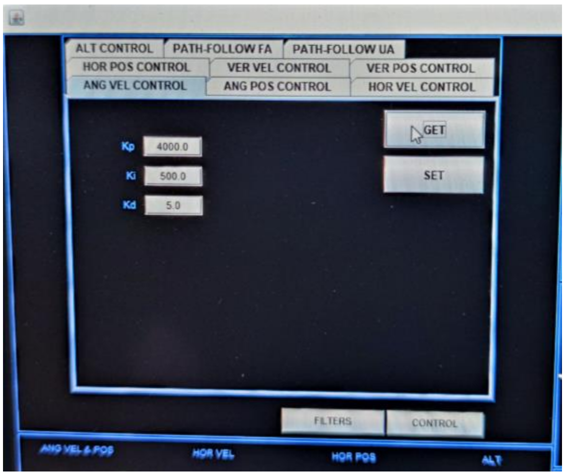

FIGURE 4: IMPLEMENTATION OF AUTOPILOT PARAMETERS IN NGC SOFTWARE

Bottom Camera Assembly and Test

In this test phase the remote control of the bottom camera subsystem has been implemented, by installing an ethernet router inside the canister, to allow the control of the camera during sea missions.

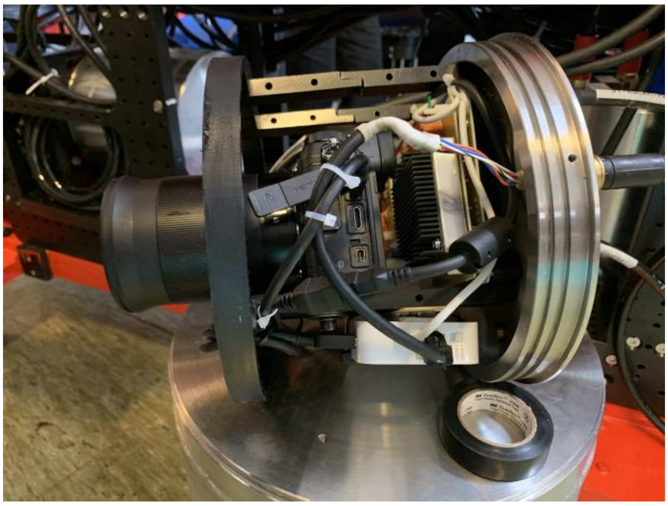

FIGURE 5: BOTTOM CAMERA ASSEMBLY

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During the sea trials of this subsystem, optimal shooting settings were identified, verifying the proper functioning of all constituent parts of the subsystem, and validating photo quality and data transfer rates.

Performance tests

In order to validate Blucy's performance, navigation tests were performed in ROV mode with manual control and autopilots engaged. The performance tests allowed to improve the navigation capabilities of the vehicle by changing the parameters of the autopilots.

Maneuverability tests

The drone was piloted in Manual ROV mode, without the intervention of autopilots, to evaluate the vehicle maneuverability in different operational scenarios. In particular, the following tests were performed:

- Max Forward speed tests.
- Max lateral speed tests.
- Lateral maneuverability tests.
- Dead reckoning test in manual mode.
- Maneuverability of the vehicle in dive mode.

The tests have allowed to improve the performance of the drone's response to remote controls, by modifying the parameters of the NGC software.

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FIGURE 6: PERFORMANCE TESTS: MANUAL NAVIGATION

Autopilots Maneuvers

In this test phase Blucy was piloted in automatic ROV mode, with the intervention of the Yaw Autopilot and Depth Autopilot, to verify the performance and maneuverability of the vehicle during mission operations.

In particular, the following tests were carried out:

- Yaw Autopilot tracking error test.
- Yaw Autopilot responsiveness.
- Depth Autopilot tracking error test.
- Depth Autopilot responsiveness.
- Simulation of maneuver in typical mission.
- Simulation of data acquisition in typical mission.

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These tests allowed to improve the behavior of the vehicle, by acting on the parameters of the autopilots.

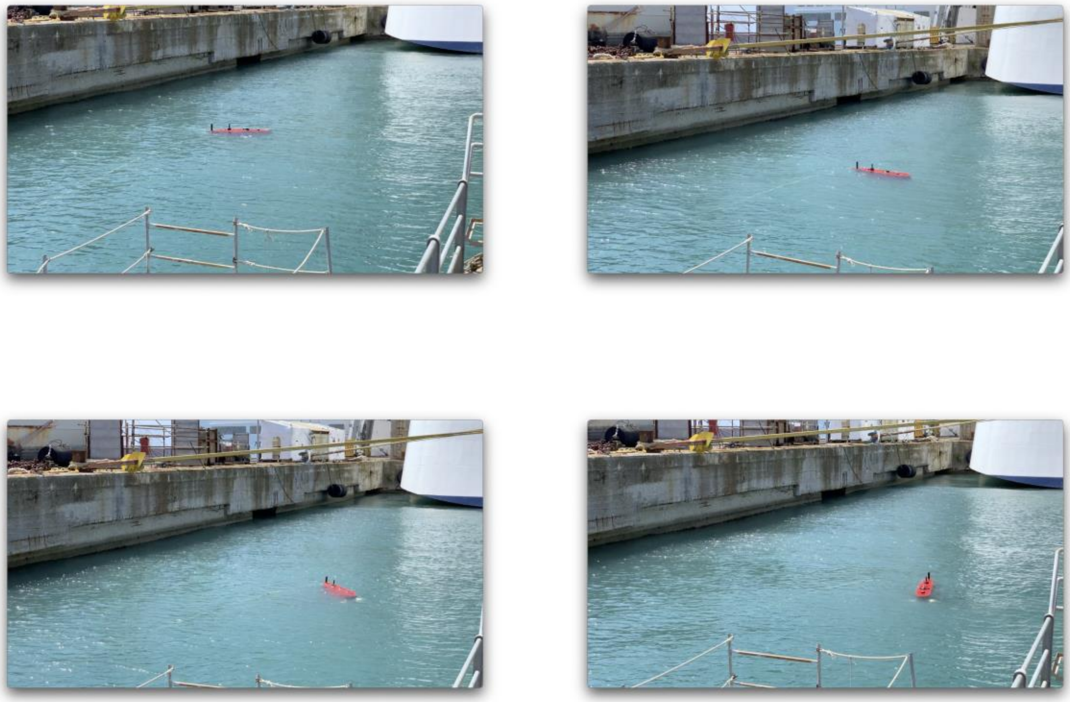

FIGURE 7: IMAGES SEQUENCE OF UUV MANEUVERS

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