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UNEXMIN DELIVERABLE D1.2

ROBOTIC PLATFORM PROTOTYPE TECHNICAL AND MISSION SPECIFICATION

Summary:

This document outlines final technical and mission specifications of the first prototype (UX-1) robotic platform developed in UNEXMIN project. Technical specifications include general layout of the platform and platform subsystems. Mission specification outlines the mission structure and procedures included in a mission.

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1 UX-1 General Specifications

General specifications of UX-1 are listed below:

Size:	Sphere ø 600 mm
Weight:	106 Kg
Control:	5 Degrees of freedom
Maximum speed:	0.5 m/s
Operating depth:	500 m

Figure 1-1 shows the general layout design of UX-1. Main components visible are:

1. Multibeam sonar
2. Camera
3. Laser scanner
4. Thruster
5. Doppler velocity log (DVL)

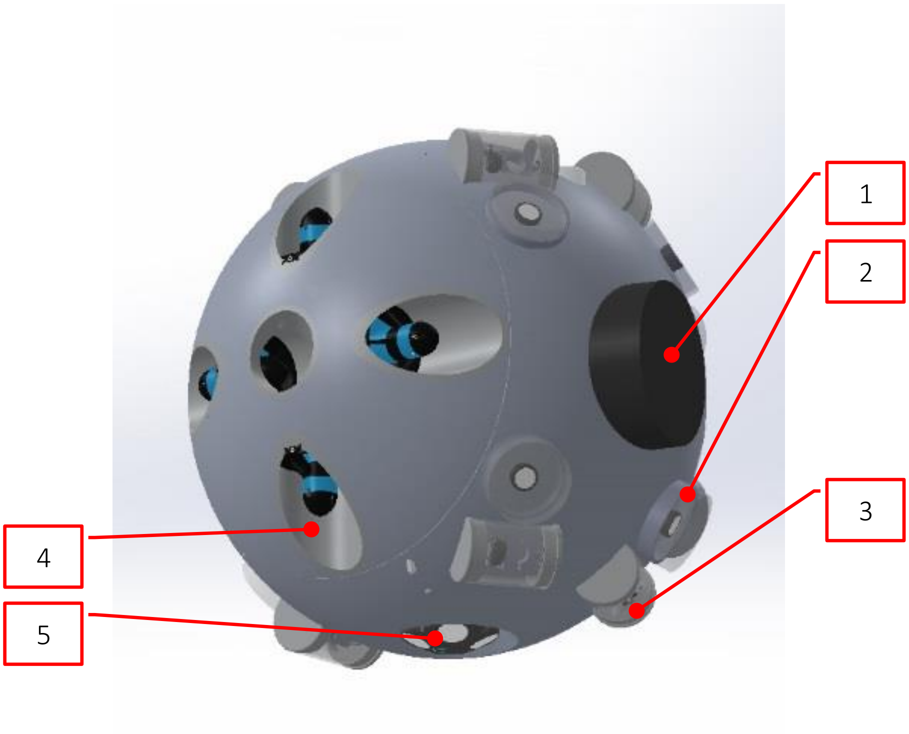

Figure 1-1 3D CAD model of UX-1

Other main components not visible in the figure are:

1. Digital CHIRP sonar
2. Inertial navigation system
3. Ph sensor
4. Electrical conductivity sensor
5. Magnetic field sensor
6. Hyperspectral camera

2 Subsystem Specifications

2.1 Subsystem Main Component Dimensions and Weights

Table 2-1 main components of systems and their individual dry weights and dimensions.

Table 2-1 Main component and their dimensions and weights

Component	Weight [kg]	Dimensions
Thruster	0.34 kg	113(L)x110(D) mm
Ballast system	14.00 kg	
Pendulum mechanism	To be determined	200(H)x300(D) mm
Inertia sensor	0.65 kg	90(H)x90(D) mm
DVL	2.80 kg	122 (H)x 114(D) mm
Multibeam Sonar	3.70 kg	114 (H)x 80(D) mm
Inertial navigation system	0.860 kg	90 x 90 x 96 mm
Laser scanner	0.21 kg	90(H)x90(D) mm
Camera & case	0.45 kg	125(H)x100(D) mm
Computer	6.00 kg	277(L) x 169(W) x76(H) mm
Instrumentations package	0.50 kg	155(H)x100(D) mm
Pressure hull	16 kg	

2.2 Perception System

These subsystems are used to measure the environmental conditions for survey purposes and to obtain the information needed for navigation and guidance.

Components included in perception sensors are listed in Table 2-2.

Table 2-2 Perception sensors

Component	Number	Model
Multibeam sonar	1	
Doppler velocity log	1	
Digital CHIRP sonar	1	Micron DST Sonar
Camera	6	
Laser scanner	6	
Inertial navigation system	1	Spatial FOG
Ph sensor	1	
Electrical conductivity sensor	1	
Magnetic field sensor	6	
Hyperspectral camera	1	

2.3 Propulsion system

Propulsion system consists of eight individual BlueRobotics T200 thrusters (Table 2-1). Thrusters are placed in a cross manifold, where two thrusters are located in the x-axis and other two in the z-axis. In each axis, thrusters are placed in the opposite direction. There are two manifolds in each side of the sphere (Figure 1-1). Thrusters offer possibility for translation along all three main axis (x – longitudinal /surge, y- vertical /heave, z- lateral/sway) and roll and yaw (rotation around vertical and longitudinal axis).

Thrusters are independently controlled by an Electronic Speed Controller (ESC). The ESC used in this subsystem is Vedder Electronic Speed Controller (VESC) (Table 2-4), which is an open source project. This controller can be communicated by PPM signal (RC servo type), analog, UART, I2C, USB or CAN-bus interfaces. Moreover, this ESC controller can provide rotational speed feedback from the thrusters.

Table 2-3 BlueRobotics T200 thruster technical specifications

Max Thrust – Forward [12V]	34.83 N
Max Thrust – Reverse [12V]	29.43 N
Rotational speed	300-3800 1/min
Operating Voltage	6-20 V
Max Current	25 A
Max Power	350 W
Length	113 mm
Diameter	100 mm
Propeller Diameter	76 mm
Weight (with 1m cable)	0.34 kg

Table 2-4 VESC electronic speed controller specifications

Operating voltage	8-52 V
Operating current	50 A
Max Current	240 A
PCB size	40(W) x 60(L) mm
Weight	< 0.10 kg
Control Interfaces	PPM, Analog, UART, I2C, USB, CAN-Bus

2.4 Ballast System

The Ballast system provides long distance vertical motion (heave) along the shafts. It consists of ballast tank, reservoir and pump. Pump is driven by a small brushless electric motor controlled by a VESC (Chapter 2.3) and reduction gear to match the rotational speed of the motor and pump. Initial design will use transformer fluid and a bladder to control the volume of the submarine. Specifications of the ballast system are given in Table 2-5.

A secondary option being studied, but applicability of which is not yet confirmed, is to use the water to control the weight of the submarine. This would be the preferable solution because of the weight and space issues, but it contains numerous technical issues to be solved.

The System must be placed on the horizontal axis of UX-1 to avoid changing center of gravity (CG) and center of volume (CV) when the ballast is altered. Shape of ballast to be defined after instrumentation sizes and locations are confirmed.

Table 2-5 Ballast system specifications

Total fluid volume	4 l
Specified buoyancy altering capability	±1 l in any conditions
Max Power	700 W
Total weight estimated	14.00 kg

2.5 Pendulum

The Pendulum subsystem is responsible for changing the pitch angle (around vertical/y-axis). The Pendulum consists of a cylinder in which are placed three batteries eccentrically. Planetary gear and stepper motor are used to rotate the pendulum in relation to UX-1. As rotated pendulum creates a torque which gives UX-1 a pitch desired pitch angle. Specifications of the pendulum system are given in Table 2-1.

Table 2-6 Pendulum system specifications

Central hollow cylinder	
Inner diameter	296 mm
Outer diameter	300 mm
Length	200 mm
Weight	1.40 kg
Batteries	
Length	173 mm
Height	74 mm
Width	68 mm
Weight	1.92 kg
Stepper motor	
Basic step Angle	1.8 degrees
Holding torque	1.75 Nm
Current per Phase	1.4 A
Voltage	6.3 V
Rotor Inertia	$480x10^{-7}$ kgm^2
Frame size	56.40 mm
Mass	1.00 kg

2.6 Power Supply System

The power supply system consists of five batteries. Three of the batteries are located in the pendulum and two elsewhere in the robot. Batteries provide five hours continuous operation of the robot. Power supply system includes battery management system which includes necessary safety and condition monitoring features, balancing features for discharging and charging etc.

Each 16 Ah 22.2 V battery pack may be split into two 32 Ah 11.1 V batteries in order to not use voltage regulator.

Table 2-7 Battery technical specifications

Multistar High Capacity 6S 16000mAh Multi-Rotor LiPo Pack	
Capacity	16 Ah
Configuration	6S2P / 22.2V/ 6 Cell
Constant Discharge Coefficient	10 C (= 160 A)
Peak Discharge Coefficient (10sec)	20 C (= 320 A)
Weight	1.92 kg
Length	173 mm
Height	74 mm
Width	68 mm
Charge Plug	JST-XH
Discharge Plug	XT90

2.7 Computer

The initial version of the computer is Speedgoat computer (Table 2-1), which is an open frame real-time target machine. This computer version will be used in the real-time experiments as a target machine between the simulations in Matlab and actual subsystems (thrusters, pendulum, ballast). The computer is equipped with ADC and it includes also RS232, UPD real-time ethernet, USB 2 and 3. During later stages of development a smaller and dedicated embedded computer will be employed to free space and weight to other subsystems and data storage.

Microcontrollers will be used to connect the main CPU with the independent subsystems. Using this configuration, it is possible to reduce operations in the main CPU. It also improves system reliability and survivability by enabling keeping safe and known operation point in case of CPU failures.

Table 2-8 Speedgoat computer technical specifications

Mainboard	
Processor	Intel i7-3555LU
Number of cores	Dual-core
Clock speed	2.5 GHz
Storage	
Hard drive	256GB
Main Interfaces	
Ethernet	4 x Intel 82574IT PCI
USB	4 x USB 3.0/2.0/1.1
Serial ports	4 x RS232
Power supply	
Input voltage	9.36 - 36 VDC input range, ESD and EMC protected
Mechanical specifications	
Width	277 mm
Depth	169 mm
Height	076 mm
Weight	approximately 6.24 kg

3 Pressure Hull

The outer structure of the robot is a spherical integrated pressure hull. All subsystems are contained in it. Using an integrated pressure hull instead of an open frame layout, which is used in conventional Remote Operated underwater Vehicles (ROV) gives definite advantages in weight and space management.

The pressure hull is divided in two individual pieces with thickness of 7 mm made of aluminium. There is six circular port holes with glass windows cameras. DVL, multibeam sonar and laser scanners are placed outside of the pressure hull in pockets. Service hatch is designed around the manifold in order to provide accessibility to components inside the hull

4 Mission Specifications

Each mission consists of four phases which each include several steps.

1. Pre-mission procedures
    - Mission planning
    - Mission data upload
    - Pre-dive checks according to checklist
        - Built-in-tests (BIT)
        - Visual inspection
        - Pressure hull nitrogen charge (abs. 1.5 bar)
    - Test dive to 1 m depth with WIFI-link
        - Test dive BIT
        - Leakage check (visual and leakage sensor data)
2. Launch
3. Survey mission
    - Travel through previously mapped area using pre-planned path
        - Minimum sensor usage, no data collection, highest efficiency speed
    - Mapping an unmapped area
        - All sensors active, sampling frequency according to mission plan, speed according to sampling frequency
    - Travel back
        - Turning point is determined on the basis of actual power usage
        - Automatic path pre-planning based on collected data
        - Minimum sensor usage, data collection in points very data is inconsistent or missing, highest efficiency speed
4. Post-mission procedures
    - Data download
    - Post-dive checks according to checklists
        - Visual inspections
        - Condition monitoring data analysis
    - Repair and maintenance actions