Remotely Operated Underwater Vehicle

Project Documentation

REVISION HISTORY AND APPROVAL RECORD

Revision	**Date**	**Purpose**
First	14/11/23	Creation of the document and establish the objectives of the project and define the dateline.
Last check	19/11/23	Revision of the entire document.

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Position	Communication Responsible	Position	Project leader

Preliminary notes

This document is an example of a Project Documentation for didactic purposes. It is a simplified version of the *PMBOK standard project* documentation that has been adapted for a basic level and is intended to be part of the project documentation for the ENTIC subject.

1. Executive Summary

The overall goal of the “ENTIC-ROUV” project is to design and build a product and a business idea based on the use of a Remotely Operated Underwater Vehicle. The project has been divided in two parts A & B.

PART A:

In the first part, the engineering team builds, in the shortest possible time, a standardized ROUV platform following already stated guidelines.

The platform chosen to implement the electromechanical part is a customized version of the *MIT SeaPerch ROUV* www.seaperch.org, Telecom-BCN signed an agreement with *MIT Sea Grant* in order to use the original design of the basic vehicle (electromechanical part). This platform is improved by adding an electronic system able to acquire the vehicle depth through pressure measurement and display it in a remote computer through a communications link.

PART B:

In the part B of our project we will add some upgrades to our initial ROUV. The functions of our submarine will be: water quality control and to follow a previously planned route. Although, we’ll still have the manual control of the ROUV. To achieve our objectives we will use three different sensors such as water temperature sensor, water conductivity sensor and turbidity sensor.

Apart from just adding these three sensors, we will use Matlab to plot the data collected with Arduino – like we did in Part A with the pressure sensor. With all the data collected by the four sensors – including the pressure one – we’ll be able to assess the water’s quality. For the autopilot, we’ll use some drivers for the engines. We will be able to switch between manual and auto mode with a basic on/off switch. The ROUV in the auto-mode option will be controlled through a series of delays, previously programmed, after the engine activation. Finally, all the new affixes will be located in the ROUV’s payload adding more weight to the total mass of the submarine.

2. Product purpose and justification

2.1. *Product Need*

Our product, a prototype of a remote-operated underwater vehicle (ROUV) designed to collect data from the water, addresses a critical need in the field of underwater infrastructure development. The necessity for such a tool arises from the challenges faced by companies involved in laying underwater wires, particularly in assessing the suitability of specific submarine grounds for wire installation. Here are key reasons why your product is needed:

Efficient Data Collection: Traditional methods of collecting data in underwater environments can be time-consuming and costly. Our ROUV offers a more efficient and cost-effective solution, allowing companies to gather necessary information without the need for extensive resources.

Remote Operation: The remote-operated nature of our vehicle eliminates the need for human divers to manually collect data. This enhances safety by reducing the risks associated with human divers working in challenging underwater conditions.

Precise Decision-Making: Companies that build underwater wires require accurate and comprehensive data to make informed decisions about the feasibility of laying wires in specific locations. Our ROUV's data collection capabilities contribute to more precise decision-making in choosing suitable routes for underwater cables.

Risk Mitigation: Assessing the underwater terrain before installing cables helps in identifying potential risks and challenges, such as rocky or uneven seabeds. By providing detailed data, our product aids in mitigating risks and avoiding potential damage to cables during and after installation.

Environmental Impact Assessment: Our ROUV can also be instrumental in collecting environmental data, allowing companies to assess the impact of laying cables on the underwater ecosystem. This information is crucial for ensuring compliance with environmental regulations and minimizing ecological disturbances.

<u>Time and Cost Savings:</u> The efficiency of our ROUV in data collection translates to significant time and cost savings for companies involved in underwater wire installation projects. Quick and accurate assessments can streamline the planning and execution phases of such projects.

<u>Data-driven Decision Support:</u> Our product empowers companies with data-driven decision support. By analyzing the collected data, companies can make informed choices about the most suitable routes for underwater wires, optimizing the overall effectiveness of their infrastructure projects.

In summary, our prototype of a remote-operated underwater vehicle addresses the critical need for efficient, safe, and accurate data collection in underwater environments. By providing valuable insights, it plays a pivotal role in supporting companies that build underwater wires in making well-informed decisions and enhancing the overall success of their projects.

2.2. *Product Objectives*

PART A:

The developed ROUV platform must be a basic system that allows underwater vehicle movement and its depth tracking. The design has to include enough electrical power supply and space to install useful payloads to develop different specific applications. It must also include a communication system to send depth data (or any other type of information) to a computer and the software that processes and plots this information. The whole system must be built with the tools available in the lab.

PART B:

In this second part we're aiming to design and implement a system that will be able to collect data from the different sensors that are added to the basic version of the ROUV (Part A). We will use all the data collected to plot 4 real time graphs with a Matlab script (we'll still use the pressure sensor used in the initial version of the ROUV).

The information will be processed with the Arduino One microprocessor like we did in the first part of the project. To send the information to the computer we will use the same cable using the serial port. The transmission won't be wireless because using electromagnetic waves through water brings lots of drawbacks due to transmission losses. The problem in water (in sea water it's even worse) is that the conductivity is not zero (Sea water: $\sigma \sim 2 - 5\frac{1}{\Omega m}$, Distilled water: $\sigma \sim 10^{-2} - 10^{-4}\frac{1}{\Omega m}$) thus causing Power losses. This can be reduced by transmitting at a very low frequency but this still not being a factible option.

Finally to reduce the human error in piloting the submarine and make it more autonomous, we will use drivers to control the ROUV without using the switches and following a pre-established route.

3. Project Description

3.1. *Requirements*

PART A:

In order to fulfill the generic requirement of constituting a ROUV platform to host or support additional functionalities, the system requirements for part A would be:

- The ROUV should be able to explore a water reservoir and report its depth along navigation to an external computer
- The ROUV should be able to move forward and backward, upward and downward and to turn to both sides in an active way.
- In case of motor or power supply failure, the ROUV should float and provide means to be easily recovered
- The ROUV should allow allocating a payload container that could host the control circuits and the possible subsystems developed in part B.
- The ROUV should be able to send data to a computer.
- The system should include software to process and plot the data sent by the ROUV.
- The cost should be low enough to allow building a device for every team, and should allow re-using as much parts as possible at the end of the project and recycling the remaining parts

PART B:

- The ROUV must be able to transmit data and be controlled by switches out of the water or switch to autopilot from the mobile phone using Bluetooth technology.

- The structural integrity of the body must be robust enough to endure potential risks, ensuring the continued functionality of the ROUV.
- ROUV must be able to receive data from all sensors (turbidity, TDS, temperature, depth)
- Develop a Matlab script with the ability to receive, process, and display data transmitted by the ROUV.
- Project costs must be as low as possible.

3.2. *Specifications*

PART A:

According to the previously listed requirements, constraints and assumptions, the following specifications can be stated:

- In order to fit in the test vessel and in the lab workbench, the overall ROUV size will be smaller than 40 cm (length) x 25 cm (width) x 25 cm (height).
- It will have three electrical motors, one for the upward and downward movement, and the other two to move forward, backward and turn left and right.
- It will be able to carry a payload with a minimum size of 12x6x6 cm^3 and 150 g of weight.
- It will have positive buoyancy but will be able of sinking and rising with the only aid of an electrical motor (no gas-reservoir actuators).
- It will be connected to an external 12V battery through a 10 m tether. The battery will be protected against overload by a fuse.
- At least a manual control of the electrical motors through switches will be implemented. The switches will be placed in an external box at the proximal end of the tether.
- The tether will contain the wires to implement a bi-directional communication link, power supply and the control of the electrical motors.
- The communications will be serial using the RS-232 standard
- The ROUV depth, expressed in meters, should be displayed in an external computer, connected to the proximal end of the tether. The data will be processed and plotted using the MATLAB® programming platform. The measurement full-scale should be 3 m.

PART B:

According to the previously listed requirements, constraints and assumptions, the following specifications can be stated:

- The sensor data needs to be processed by Arduino and the data needs to be transmitted to the external computer via RS-232 serial communication link.
- The collected data will go through a computational process, and the results will be visually presented through graphs using the MATLAB programming platform. This involves employing MATLAB's computational and graphical capabilities to analyze and represent the ROUV's sensor information, ensuring a comprehensive and user-friendly display of the data on an external computer connected to the tether.
- It will have the capability to switch between manual and autopilot modes through a mobile device.

3.3. *Work Breakdown Structure*

PART A:

The Work Packages and the corresponding tasks are:

WP1: Mechanical

Short description: The goal of this WP is to build the PVC structure of the remote operated underwater vehicle (ROUV), according to the directions stated in “ENTIC-lab, WP1 – MECHANICAL” document. The vehicle structure is formed by PVC pipes that must be cut to size and assembled. After that three motors must be attached to the structure. Finally, a tray must be placed at the bottom of the structure to carry the payload box.

Planned: start date: week 1, end date: week 3

Task 1.1 Cut PVC pipes

Task 1.2 Make pipes holes for motors

Task 1.3 …

Task ….

WP2 …

PART B:

WP6: Final assembly and water tests

Short description: The goal of this WP is to implement and test the LM35 temperature sensor with the Arduino API.

Planned: start date: week 11, end date: week 12

Task 6.1 Mount the Command Box

Task 6.2 Mount the Payload Box

Task 6.3 Final verifications and troubleshooting

WP7: Temperature Sensor

Short description: The goal of this WP is to implement and test the LM35 temperature sensor with the Arduino API.

Planned: start date: week 8, end date: week 8

Task 7.1 Implement the logic to interpret the data serialized by the LM35

Task 7.2 Draw a schematic of how to wire the Arduino to the LM35 sensor

Task 7.3 Wire the sensor according to the schematic

Task 7.4 Test the values displayed by the code interpreting LM35 sensor data

WP8: Drivers

Short description: The goal of this WP is to integrate the H-bridge circuit encapsulated by the 2-channel DC Motor Driver L298 module to drive the Johnson Pumps installed in the ROUV.

Planned: start date: week 9, end date: week 10

Task 8.1 Implement the logic to drive the DC motors in C++ (Arduino API)

Task 8.2 Draw a schematic of how to wire the motors to the L298 drivers

Task 8.3 Wire 2 L298 drivers to the 3 motors

Task 8.4 Write a Unit Test checking all motor control combinations

Task 8.5 Realize an Integration Test of the three motors working in unison

WP9: Turbidity & TDS Sensor

Short description: The goal of this WP is to implement and test the TSW-20M and CQRSENTDS01-TDS sensor

Planned: start date: week 9, end date: week 10

Task 9.1 Implement the logic to interpret the data serialized by the sensors

Task 9.2 Draw a schematic of how to wire the Arduino to both sensors

Task 9.3 Wire the sensors according to the schematic

Task 9.4 Display the values interpreted by the code

Task 9.5 Calibrate both sensors according to the data collected

WP10: Graphical User Interface

Short description: The goal of this WP is to build an interface to display the data gathered by the different sensors and the velocity achieved by the motors controlled by the L298

Planned: start date: week 11, end date: week 12

Task 10.1 Write MATLAB (or python.matplotlib) code to interpret individual RS-232 data

Task 10.2 Implement each individual graph into a subplot (the GUI)

Task 10.3 Test the transmission and connection between all modules and laptop

WP11: Hardware integration

Short description: The goal of this WP is to integrate every module inside the physical structure of the ROUV

Planned: start date: week 11, end date: week 12

Task 10.1 Draw schematic of the wiring of every module

Task 10.2 Check wiring of every module

Task 10.3 Insulate the circuit from the outside so that ROUV can be submerged

4. Project Deliverables

PART A:

The project deliverables are:

- Weekly updated Gantt Diagram
- Results of every WP (questions)
- Demonstration of the ROUV performance at the end of WP 6

PART B:

The project deliverables are:

- Weekly updated Gantt Diagram.
- Demonstration of the efficiency of all sensors in various water positions.
- Demonstration of correct data processing.
- Demonstration of the final product. Guarantee of correct operation of the autopilot.

5. Specifications Evaluation

PART A:

Make a spiral immersion with the 3 motors in the water tank recording the depth with the computer. Check the plot with the tank height.

PART B:

For the drivers part we will write a Unit Test checking all the combinations of the engine and after that we will perform an Integration Test of the three engines working together simultaneously.

To check the correct performance of the sensors, we will calibrate each sensor before we integrate these to the ROUV and we will make sure that every sensor works perfectly. In case one sensor does not work correctly, we will have to fix it by comparing the sensor reading to the real measure (E.g. the temperature sensor or the pressure one).

After all the tests, we will be able to check the correct working of the Matlab scripts with the sensor’s own readings.

6. Project Management and Team Description

To design this ROUV you need a team of five persons. Each person will have a different role with different tasks:

MANAGER: Schedule the meetings and assign the tasks to the members of the team. Take the necessary decisions in order to solve any disagreement.
MATERIALS: Take the responsibility of the supplied material. Manage the components required in each project phase.
TOOLS: Take the responsibility of the team toolbox. Distribute the tools among the team members.
GANTT: Take the responsability of the daily project planning. Upload GANTT diagrams in Tom's Planner.
DOCUMENTS: Take the responsability of the daily project documentation. Update questions & other deliverables in Atenea.

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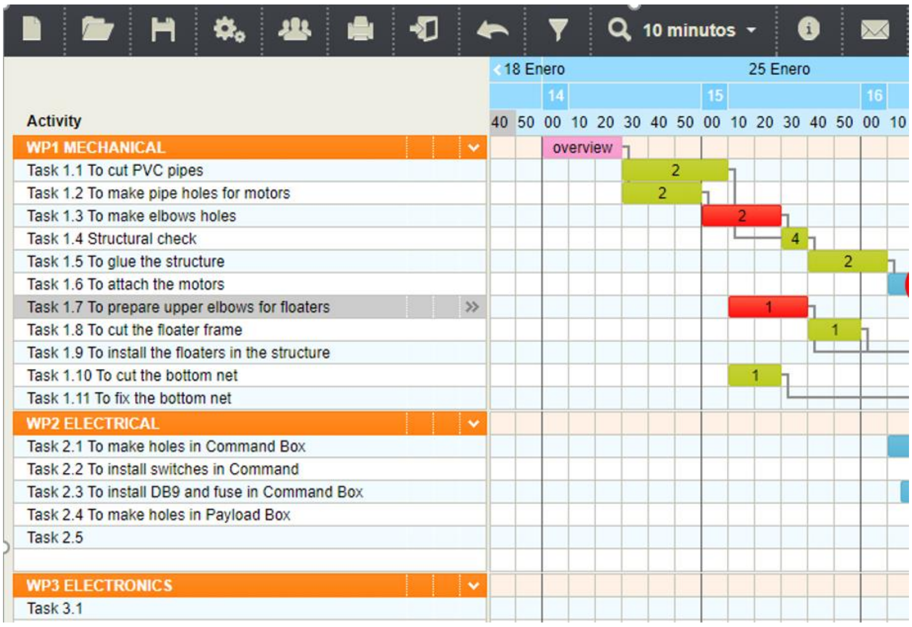
Aitor Pitarch	aitor.pitarch@estudiantat.upc.edu	MATERIALS
Ignasi Fernández	ignasi.fernandezbilbeny@gmail.com	PROJECT MANAGER

A project leader coordinates tasks, allocates resources, and ensures team efficiency to achieve project goals. Effective planning, organization, and regular communication, such as weekly Google Meet sessions, are crucial for tracking progress and maintaining a collaborative and streamlined workflow. Assumes a pivotal role in task coordination and resource allocation for project success. Consistent communication, exemplified through weekly Google Meet sessions, is imperative for progress tracking. Profound comprehension of individual team members facilitates adept navigation of diverse situations. Guided by core leadership values, including empathy, effective communication, and adaptability, the project leader exemplifies a strategic approach to project management.

7. Time Plan and Milestone List

PART A:

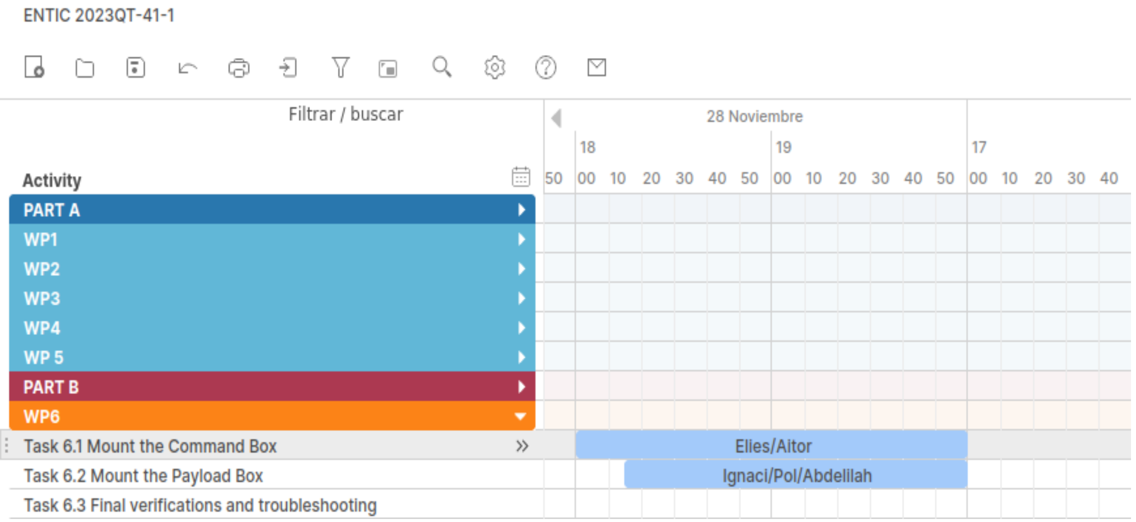


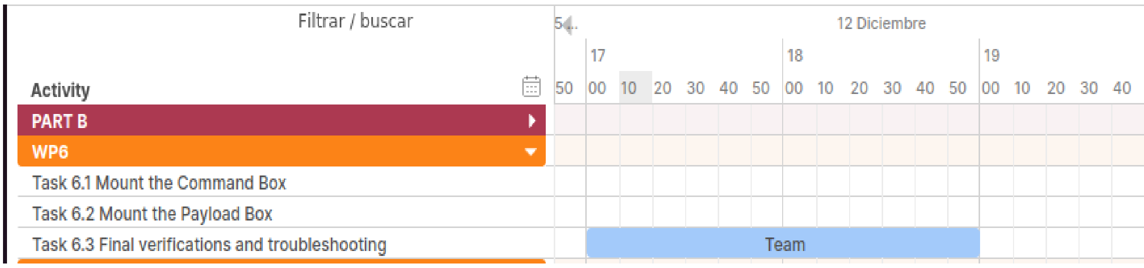
Milestone list:

1. ROUV structure completed
2. Electrical motors control finished
3. Depth measurement system specifications checked
4. Final electronics assembling in the payload box, functional check
5. Payload sealing verification fulfilled
6. Reliable communications with laptop completed and verified
7. Depth graphical presentation completed
8. Successful water test

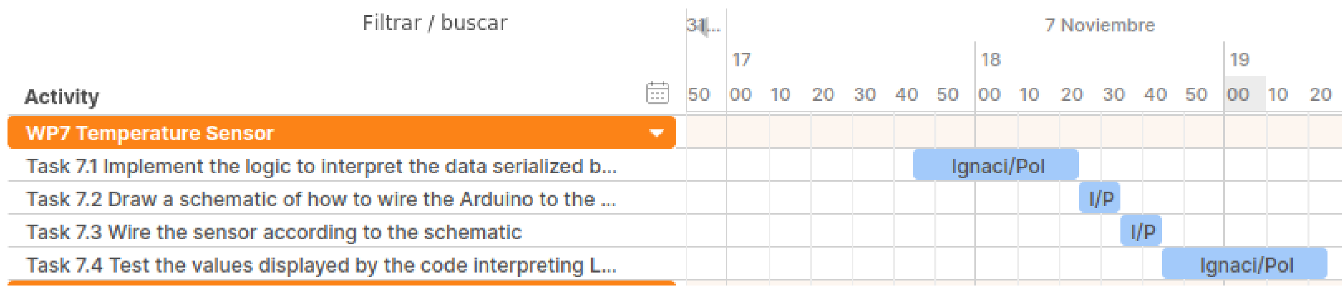
PART B:

WP6 Final assembly

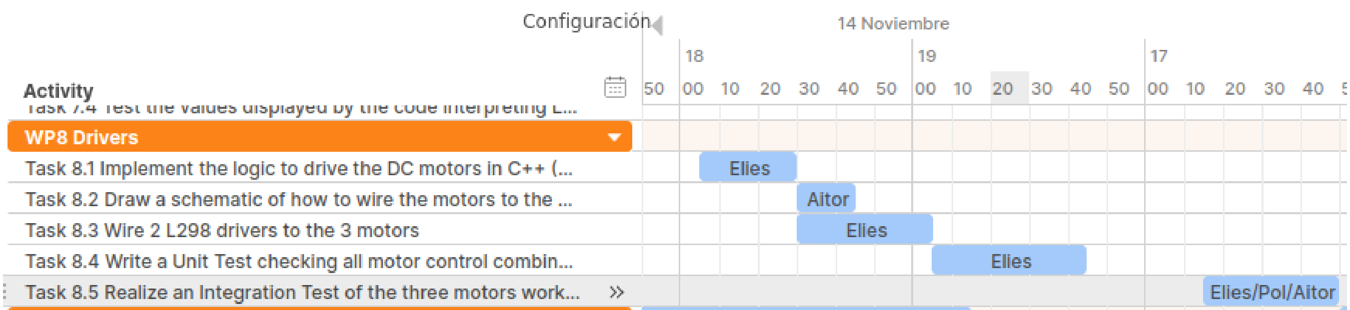




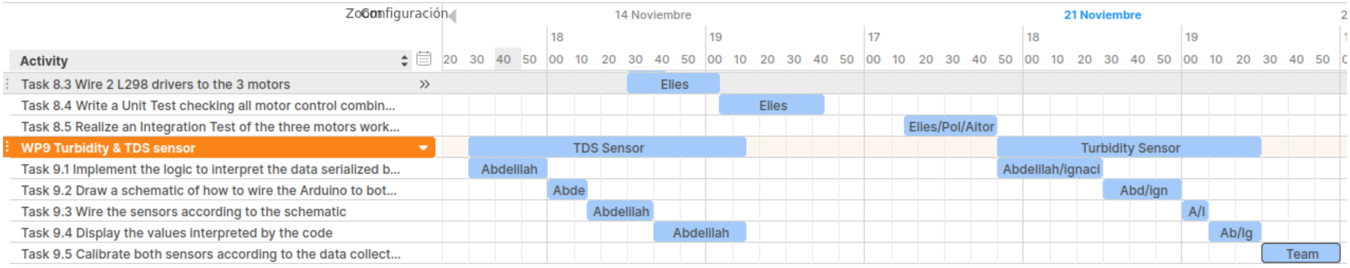
WP7 Temperature Sensor



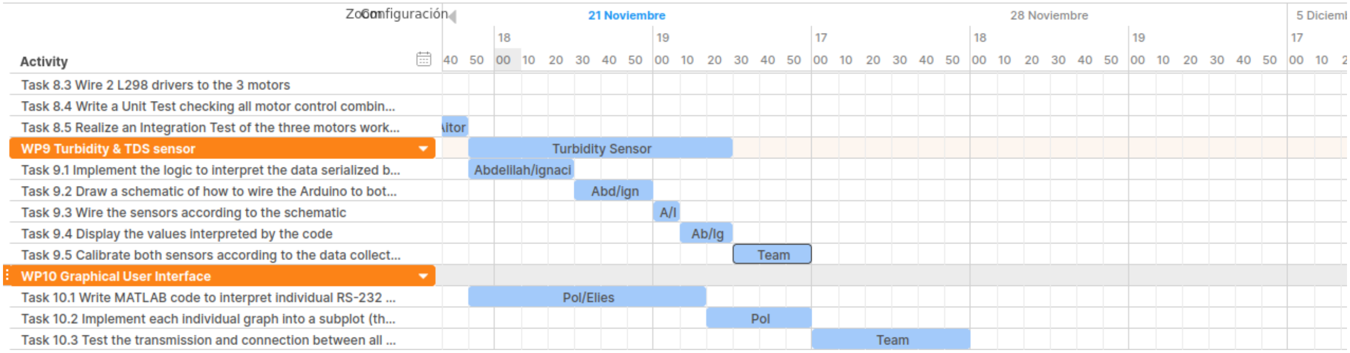
WP8 Drivers



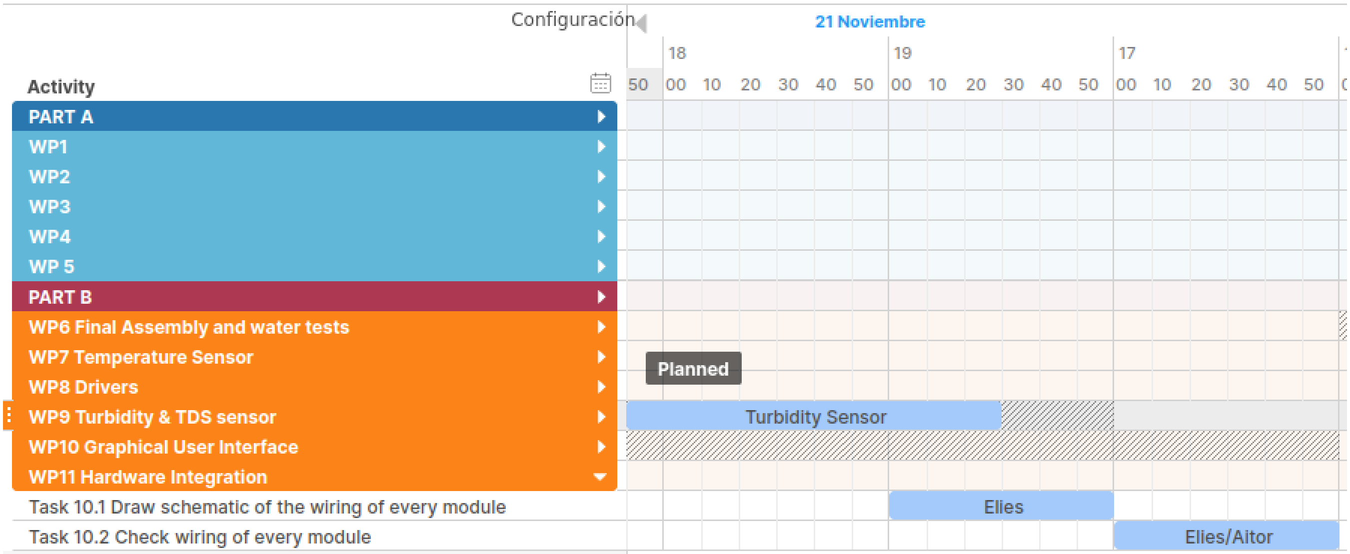
WP9 Turbidity and TDS sensor



WP10 Graphical User Interface



WP11 Hardware Integration



<u>Milestone list:</u>

1. Receive data from all sensor
2. Test digital motor control (Arduino with drivers)
3. Build and test the MATLAB GUI
4. Unassembled ROUV working (sensors, drivers, application)
5. Assemble and test ROUV

8. BoM

PART A:

The components that have been used in part A and their cost are listed below:

Materials List (REUSABLE ITEMS):	€/unit	#	€	Materials List (RECYCLABLE ITEMS):	€/unit	#	€
3 motors set	69	1	69	PVC pipe (1 m)	1,65	2	3,3
Clamps	0,8	3	2,4	PVC elbow	0,4	10	4
Screws	0,2	3	0,6	PVC tee	0,6	4	2,4
Washers	0,1	6	0,6	Floater support (50 cm)	0,1	1	0,1
Power Supply wires	0,5	1	0,5	Plastic net (40x30 cm)	0,3	1	0,3
Link cable	9,4	1	9,4	Command box	5,8	1	5,8
Floaters	0,8	2	1,6	Switches	2,3	3	6,9
Sealing gland	1,5	3	4,5	Payload box	14,78	1	14,78
Rubber O-ring	0,3	3	0,9	Silicon pipe (10 cm)	0,3	1	0,3
DB9 serial	0,94	2	1,88	Pipe terminal	0,02	1	0,02
DB9 screws & nuts	0,2	2	0,4	PCB prototype board	5,78	1	5,78
Fuse clip	1,02	1	1,02	PCB connector	0,5	1	0,5
Fuse	0,3	1	0,3	Arduino prototype PCB	3	1	3
GND terminal	0,01	1	0,01	8 pins IC socket	0,3	1	0,3
Fuse & term. screws	0,15	2	0,3	16 pins IC socket	0,31	1	0,31
Payload box fixing	3,06	4	12,24	Capacitors (4x330 nF 1x45 nF)	0,15	5	0,75
Box fixing screws	0,1	4	0,4	PCB sockets strip	3,14	2	6,28
Electrical connector	0,7	1	0,7	Short PCB pins strip	0,2	1	0,2
PCB jumper	0,97	1	0,97	Long PCB pins strip	0,68	1	0,68
Pressure sensor	10,98	1	10,98	Diode	0,04	1	0,04
Differential amplifier	2,87	1	2,87	Plastic strip	0,02	15	0,3
RS232 transceiver	1,06	1	1,06	Rigid connection wires	0,2	10	2
ARDUINO UNO	17	1	17	Flexible connection wires	0,15	1	0,15
139,63				**58,19**			
197,82							

PART B:

The components that have been used in part B and their cost are listed below:

Materials List (REUSABLE ITEMS):	€/unit	#	€	Materials List (RECYCLABLE ITEMS):	€/unit	#	€
- Turbidity sensor	19,77	1	19,77				
-TDS sensor	16,98	1	16,98				
-Drivers L298N	13,98	1	13,98				
50,73							
50,73							

TURBIDITY SENSOR

Productos comprados: **Precio**

1 de: *Jadeshay Módulo Sensor de Turbidez,Monitorización de la Calidad del Agua Aguas residuales Módulo de detección del Valor de turbidez TSW-20M* €21,49

Vendido por: jadeshay (Perfil del vendedor)

Estado: Nuevo

Subtotal de producto(s): €17,76
Envío: €0,00

Total antes de impuestos: €17,76
Impuestos: €3,73

Total: €21,49
Promoción aplicada: -€1,72

Importe total:€19,77

TDS SENSOR

Productos comprados:	**Precio**
1 de: *CQRobot Ocean: TDS (Total Dissolved Solids) Meter Sensor Compatible with Raspberry Pi/Arduino Board. for Liquid Quality Analysis Teaching, Scientific* Vendido por: CQRobot-ES (Perfil del vendedor) | ¿Tienes dudas sobre el producto? Pregunta al vendedor Estado: Nuevo	€12,99

Subtotal de producto(s): €10,74
Envío: €3,30

Total antes de impuestos: €14,04
Impuestos: €2,94

Total: €16,98

Importe total: €16,98

DRIVERS

Pendiente de envío

Productos comprados:	**Precio**
1 de: *Greluma 4 Piezas L298N módulo de Placa controladora de accionamiento de Motor Puente Doble H DC Paso a Paso para Arduino* Vendido por: Lumatech-EU (Perfil del vendedor) Estado: Nuevo	€13,98

9. Communications management plan

PART A:

To ensure good communication and avoid wasting time on arbitrary and unnecessary things like deciding when and how we gather information, we decide to leave the responsibility to our project leader. His job is not to decide what information can be shared, it is to establish a communication order and to guarantee an organized communication.

We classify the information communicated in two groups; the verbal communication and the documents shared. As verbal communication we refer to the explanation of the state of each task and to assign every group member a task to do as we reach an agreement of when it needs to be finished those assigned tasks. Two weekly google meetings are set to guarantee that everybody is always occupied with a task and to predict possible misunderstandings in terms of who does what. As a supplementary source of communication we use a whatsapp group chat to explain brief concepts and share feedback.

The documents shared are organized on a google drive folder divided by work packages, those documents are: definitive project documents, support information compiled form internet and atenea, video documentation of the project itself and various drafts of multiple terms.

The days we set the meetings are flexible respecting everybody`s availability but attempting to gather at least the day before the lab session. Usually the documents are shared during the lab sessions as we work on our assigned tasks and it’s in the meetings that we organize them and communicate which document we require.

PART B:

As the communication strategy applied in part A was successful, we decided to keep it and to modify as few things as possible. In part B, unlike in part A, we have to purchase the necessary materials to accomplish our project. As soon as we knew exactly what to buy we financed ourselves with *Revolut*. *Revolut* is a fintech firm that provides banking and payment services. The company offers multi-currency cards and mobile app that include currency exchange, peer-peer payment and bank transfer solutions. A promotion which was available let us invite three friends to revolut and receive 50€ for each one that registered and paid with his revolut account a minimum of 10€ each. So we bought three things we needed as an inversion so we could earn 150€. We used that money to pay the initial inversion of 30€ and the rest of the materials needed. That strategy was planned in various meetings and made thanks to our communication.