CASMARINE

Yıldız Technical University, Turkey

HYDRUS-X

2022 MATE-ROV Technical Documentation

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INTRODUCTION

Abstract

Since its establishment in 1945, the United Nations has addressed many issues regarding the world's citizens. Remotely operated underwater vehicles or "Underwater ROVs" are devices that have been designed to take on some of these issues. The underwater ROVs are developed in a way to help clear the world's water resources and also assist any and all needs of marine-related tasks. As a distinguished member of ROV-AUV manufacturing companies, CASMarine, aims to play its part in helping both the sector and the environment in these trying times.

Competitions like Mate-ROV are an astonishing place for companies like CASMarine to find themselves surrounded by similar companies in a competitive environment. Said competitive environment can help such companies excel in their own area of expertise. As a well known fact, competition most often breeds innovation and development. Competitions like Mate-ROV helps CASMarine develop more intelligently designed systems with the goal of playing our part in the United Nations Sustainable Development goals.

CASMarine was founded in 2016 by a group of inspired engineering students from Yıldız Technical University. The first ever competition CASMarine ever competed in is Mate-ROV 2017, since then the company has been evolving, developing and becoming even hungrier to designing better engineering systems.

The company CASMarine has the fortunate advantage of its history, meaning that being one of the first ever university-based companies to work in the underwater ROV sector, there is a cultivated knowledge towards building a functioning ROV. CASMarine is fairly confident that it is highly possible to ensure an accomplishment worthy of our efforts. With a team of 18 engineering students, the time and effort that went into manufacturing the 10th generation underwater ROV allowed the company to create a very capable design.

For the 2022 Mate-ROV, CASMarine has manufactured Hydrus-X. The 10th generation of CASMarine underwater ROVs, Hydrus-X, is a ROV the company has high hopes for.

Fig 1: Company Photo

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DESIGN RATIONALE

Design Phases

It is essential that an engineering system is designed in a way that it is adaptable to any and all obstacles it may face. CASMarine has always worked towards developing easily-alterable systems as it is most significant that a system is as versatile as it can be. The most recent product of CASMarine, Hydrus-X, is a ROV that can adapt to many different situations.

The design era of Hydrus-X is defined by the previous generations' experiences. It is crucial to CASMarine that every underwater ROV produced is superior to that of the last year's. Having cultivated more knowledge than most other underwater ROV companies in the sector, CASMarine has learned from previous years' successes and failures. One of these advancements has been the inner casing design. Since all of CASMarine's products are produced with the vision of modularity and easy-access, the isolated-volume inside the ROV is one that can be removed easily. With the experiments done on the previous years' underwater ROVs, the chassis has been changed radically. The chassis has been altered to offer maximum protection to the isolated-volume and the electrical components, as well as the thruster cables and sensors located in the end cap.

Hydrus-X's hardware system has been evolving since the foundation of CASMarine. Since most of the founding members of CASMarine were Electronics Engineers, the hardware system of Hydrus-X has evolved further than most other marine companies' systems. The studies done in packaging, PCB designs, peripherals and efficiency methods has led to the 10th generation ROV's hardware system to be the most advanced hardware system in the company's history. The main focus of the company's hardware division has been on modularity and safety since CASMarine wishes the entire ROV as a system to be as modular as it can possibly be. Rather than buying the PCBs from the private sector, the CASMarine Hardware Division chose to design the PCBs in house since it allows the team to be more versatile and faster when a change is needed. Custom made PCBs also offer the company infinite freedom in deciding between different connectors. Not being limited to only a handful of connectors not only reduces the costs but also allows the company to experiment further.

The company's software units are there to provide the soul of the electronic and mechanical systems. The software structure aims to add more versatility and capability to the vehicle.

Since the ROV's capabilities may vary from task to task, the high level and embedded software structures are built in a way that the customer's needs are always satisfied. The design evolution of the software system usually includes the software unit determining the task at hand, starting the algorithm design process and then beginning the test phase to detect any and all possible improvements. The data gained by the tests are then transferred to the most recent software structure

Mechanical Design

The mechanical structure can only be done after a delicate phase of planning. All units within the company work together to develop a general plan and packaging so that the mechanics division may design and manufacture the most efficient and versatile system possible.

The know-how gathered from previous years' underwater vehicles are a tremendous help in creating the overall structure. While designing Hydrus-X, the structure designs are first drawn and displayed on the units board and assessed by the unit members. When a concept is passed the initial inspection it is then modeled in a CAD program so that the hard points can be modeled and tested. After the inspection of the hard points of design, the general model is extruded and the first assembly is made. With the assembly completed, the simulation phase begin for each and every prototype. Although simulations in CAD programs are very effective, the use of actual physical prototypes is also in order. This way the company units have a better time understanding and visualising the general structure since some points may be left unseen in the CAD programs. The prototypes are usually manufactured in the most affordable methods available, when a prototype is successful the main manufacturing process begins.

Fig 1 : General Structure

Manufacturing Phase

Regardless of how great a design is, if the manufacturing process isn't successful the overall design will never reach its full potential. The parts of Hydrus-X have been designed so that the manufacturing process is as simple as it can possibly be. The materials used on Hydrus-X are chosen from affordable yet durable materials thus bringing the overall cost down. The materials are also fairly easy to process via methods such as CNC router. In the case of any damage done on the vehicle, the parts are easily replaceable.

Fig 2 : CNC Router Manufacturing

The main materials used on Hydrus-X are Aluminium 6000 series, high density polyethylene, PLA and thermoplastic homopolymer. The aluminium parts are the frontcap, endcap and flange parts which are processed by turning. The parts that are made on the CNC router are the chassis parts. The material chosen for the chassis, due to its density properties, is high density polyethylene. HDPE has a very close density rating to that of the water. CASMarine mechanics division has also used 3D printing for some complicated compact parts, as it is a quick and relatively affordable way of manufacturing.

Chassis

The chassis design of Hydrus-X is one the company is much proud of. In the previous generation's chassis designs, the general structure was made possible by a skeleton-like design which allowed for much versatility and a high structural rigidity. In this generation the CASMarine Mechanics Unit wanted to keep the versatility and rigidity provided by the skeleton-like design and combine them with the practicality and affordability of the panel-based design philosophy. The panel-based design is a fairly common design method for underwater ROVs. It allows for a affordable manufacturing process and good protection for the thrusters and inner casing. Another big advantage of this generation's design is the fact that the replacement of the panels used in Hydrus-X's structure is very easy.

Fig 3 : Chassis Build

Hydrus-X only has 3 different panels; side panels, front/back panels and inner panels. Main dimensions of Hydrus-X's chassis consist of 380mm in length, 530mm in width and 380mm in height. These panels made from high density polyethylene are quick and easy to manufacture and undemanding to replace thus making Hydrus-X a great product for general use. After connecting/ equipping all the components on Hydrus-X, it had a total mass of 12 kg. The hydrodynamics are also considered in order to have a fairly efficient vehicle.

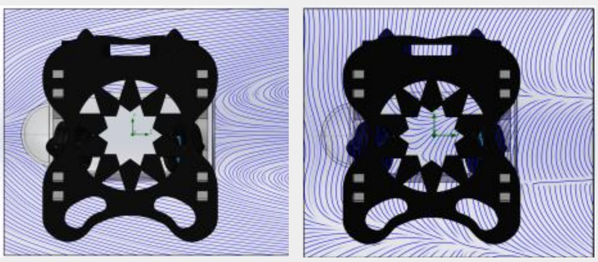

Fig 4 : Hydrodynamics Simulations

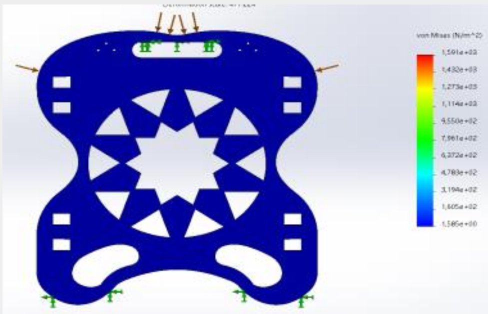

Fig 5 : Stress Simulation

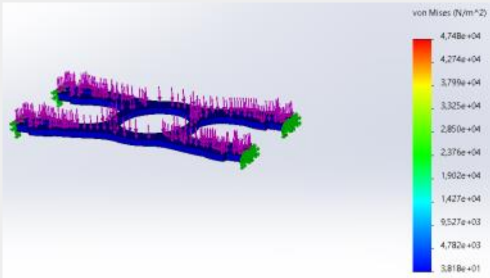

Fig 6 : Stress Simulation

Isolated Volume

Main importance of the isolated volume is to avoid any possible water contact on electronics. After this is satisfied, it has better be transparent in order to have vision on electronics without disassembling the inner case and getting images under water. Also it has to be easy to disassemble-reassemble. The inner case consists of five structural parts, isolation elements and jointing elements.

Fig 7 : Isolated Volume

Acrylic Dome

As the camera has to get clear visuals, first of all the dome should've been made from some transparent material. At that point the most affordable and the most applicable material choice was acrylic. The second problem to solve was determining a geometry for the dome.

First issue was to grant an acceptable strength in order to avoid any water leakage due to some cracking, impact and making sure the dome keeps it's shape under pressure so the image recorded wouldn't be affected.

Therefore the wall thickness for the dome has been selected as 5mm, which was a safe value for Hydrus-X's working depth.

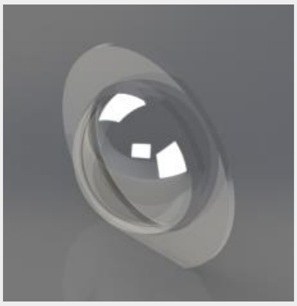

Fig 8 : Acrylic Dome

Thermoplastic Homopolymer Tube

Since CASMarine aimed Hydrus-X's electronics to be visible from outside of the tube, again some transparent material selection was required. At that poing using acrylic for the tube was the most applicable option. Again a strength well enough to avoid water leakage and elastic/ plastic shape deformations was needed. 10 milimeter shas been calculated to be sufficient for the wall thickness. As for the tube length, 300mm has been decided to be sufficient for fitting all the electronics inside.

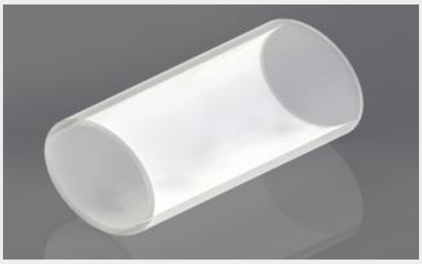

Fig 9 : Homopolymer Tube

Front Cap

Since there were two places to seal in the front cap, this part was the most critical part for the water isolation of the inner casing. The first place to isolate was the dome's connection with the front cap. This part of the front cap was a static and rarely disassembled connection so; if the groove dimensions for the o-ring had been determined well enough, no backup o-rings would've been needed. Thus there's only one o-ring groove on the dome side. At the tube side; this place was to be inserted in the tube. So in the arrangements, tests and any work on the Hydrus-X, this part had to be able to be removed with hand force yet do the isolation. Since this part constituted relatively high risk in terms of isolation, designing extra two grooves for the backup o-rings has been decided to be necessary. All these o-ring groove sizes has been decided following o-ring manufacturers' manuals. Material for this part has been selected as Aluminum 6000 Series. The main reason for selecting Aluminum was the high strength/mass ratio of Aluminum. Aluminum's easy processability was also an advantage. After the design was completed, the front cap had been manufactured on lathe then the jointing holes got opened on milling. Then the front cap has been anodized and finished in order to obtain oxidation.

End Cap

End cap had the exact same design criteria with the front cap. The only exception for this part was having a closed end unlike the front cap. In the design, in addition to the front cap's designing criteria for cable holes for the thrusters' cables, control unit cables were also considered. End cap's instertible part is exactly the same as the Front cap's insertable part. After the design was completed. This part also got manufactured on lathe and then jointing holes and the cable holes at the end got opened on milling. When the production was over, this part was also anodized.

Fig 10 : Front Cap and End Cap

The Flange

CASMarine Mechanics Unit has determined that a flange part was necessary to hold the acrylic dome and front cap pieces together, not only because such part is necessary to distribute the forces exerted upon the dome but also to regulate the light reflection. This part was also manufactured from aluminium 6000 series and got anodized in case of deformations.

O-Rings

As sealing the components is the main purpose of the isolated volume, o-ring selection has been a crucial task. In order to grant water isolation, 5mm o-rings have been decided to be sufficient for Hydrus-X's working depth/conditions. Following the manufacturers' manuals, o-rings inner diameters have been selected smaller up to %5 than the o-ring grooves' diameters. Since the sealing was for the freshwater, using nitrile o-rings was the best option.

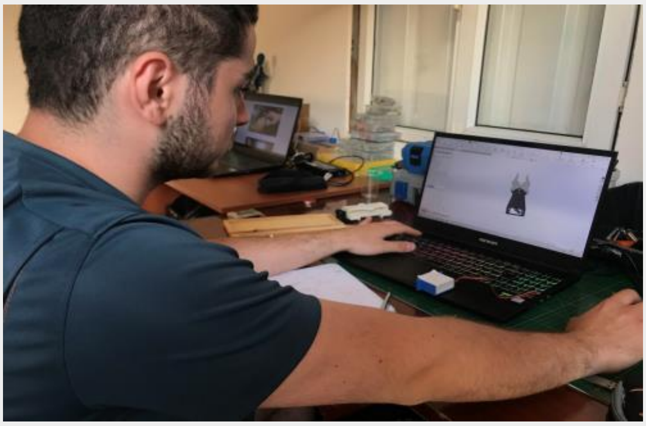

Fig 11: Mechanical Design Process

Propulsion

4 Blue Robotics T100 and 4 Blue Robotics T200 thrusters are located on the chassis With the placement of these 8 thrusters Hydrus-X is able to move in all desired patterns. It can; roll, pitch, yaw, sway and heave. 4 Blue Robotics T200 thrusters located in the upper part have been set perpendicular to the ground.

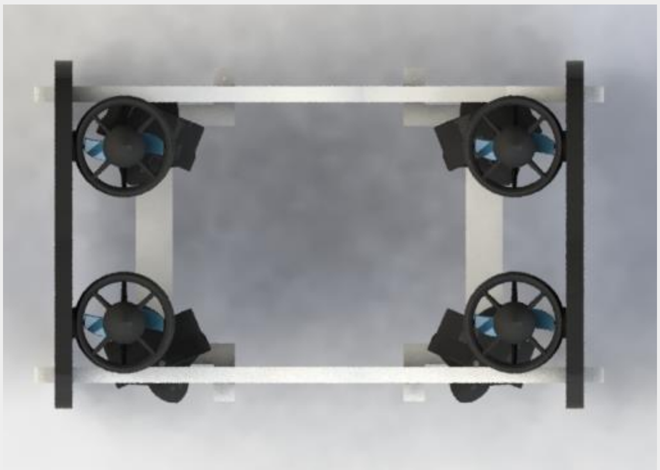

Fig 12 : Thruster Placement

The lower 4 Blue Robotics T100 thrusters . The lower 4 thrusters are set with 22,5 degrees yaw since it is most beneficial to the ROV when 38% of the thrust is in the x axis while the 62% of the thrust is in the y axis. Using 8 thrusters with the current placements allow Hydrus-X to have a very high mobility standart. The lower thrusters are placed close to the centre of mass so that the vehicle is not affected by inertia.

Buoyancy

The density of an underwater ROV is one of its most important physical attributes. Based on CASMarine's know-how gathered from previous generations' underwater vehicles, it has been concluded that the most beneficial density rating for Hydrus-X is a density value that is very close to the density of water at 25° degree Celcius. The mechanics unit of CASMarine has set the value of density a bit higher so that when Hydrus-X is deployed, it is guaranteed that the thrusters responsible for heade are fully sinked. Additional lead has been added to ensure such buoyancy figures.

Fig 13 : Lead

ELECTRICAL SYSTEM RATIONALE

Electrical System

Hydrus-X's electronic hardware system is designed on the principles of low cost, safety, ease of use and stable operation. The vehicle is controlled by a joystick, buttons and sliders from the Surface Control Station. Control data is sent from the Ethernet port of the Surface Control Station to the NVIDIA® Jetson Nano via Fathom ROV Tether cable through the end cap of the enclosure. The ROV supply voltage, 48V DC, is supplied via 16 American Wire Gauge (AWG) with a 30A fuse supplied in series to the enclosure.

The electronic system inside Hydrus-X houses its control and power units, including 3 48V-12V power bricks, CASMarine Power Distribution Board to power the control unit, and CASMarine Smart Power Box module.

The control unit consists of the NVIDIA® Jetson Nano, on which image processing and artificial intelligence algorithms are applied, CASMarine Motherboard, which is responsible for the vehicle's balance control and CASMarine Smart Power Box modules, which provide the connections between CASMarine Motherboard and the peripherals. In addition, CASMarine Smart Power Box modules measure the current consumed by the peripherals. They are housed horizontally in the case to ensure accessibility and modularity.

Fig 14 : Electronic Design Process

48V comes into the enclosure and is converted to 12V by the 48V-12V power bricks. The regulated 12V is transmitted to CASMarine ESCs to control the speed and direction of the motors, the underwater lights, to CASMarine Power Distribution Board to supply power to CASMarine Motherboard and CASMarine Smart Power Box module.

CASMarine Power Distribution Board supplies power to CASMarine Motherboard and CASMarine Smart Power Box. The NVIDIA® Jetson Nano is powered by CASMarine Smart Power Box module. CASMarine Motherboard can control sensors, ESCs (Electric Speed Controller) and servo motors, and also we can send CASMarine Motherboard's signals through CASMarine Smart Power Box to control servos of the grippers which we can do a power conversion and measure the current drawn through it.The custom printed circuit boards were designed with Altium Designer and assembled by CASMarine's Electronics Department.

Power Distribution

On the surface, 220V–48V AC DC Converter is located outside the Surface Control Station. Thus 220V AC is regulated to 48V DC thanks to this AC-DC Converter successfully. Electronic housing contains 3 48V-12V DC-DC Converters which are called Power Bricks are connected parallels by Wago connectors and they provide 1080 Watts power. 12V outputs are multiplied by cable and it is sent to CASMarine Power Distribution Board to power it with the XT60 connector. CASMarine Power Distribution Board that is designed by Electronics engineers of CASMarine Company is a board that supplies CASMarine Electronic Speed Controllers (ESC) of the thrusters.

Fig 15 : 48-12V Converters and Electronics Housing

CASMarine Power Distribution Board supplies power to the underwater lights, CASMarine Motherboard and 3 Smart Power Modules with different header connectors.

12 V is converted to 5 V and 3.3 V with the help of voltage regulators on the CASMarine Power Distribution Board. 5V and 3.3V are sent to the Motherboard through the header connectors. At the same time, a robust and compact board structure is achieved with these header connections. With the ACS714 Hall effect current sensors on the board, the current information drawn by the peripheral units is transmitted to CASMarine Motherboard via these header connections.

Fig 16 : CASMarine Power Distribution Board

Electronics engineers of CASMarine Company have implemented the Power Management in the correct way and developed a safe electronic system in order to prevent overheating and excessive current draw in the system, taking into account the safety precautions.

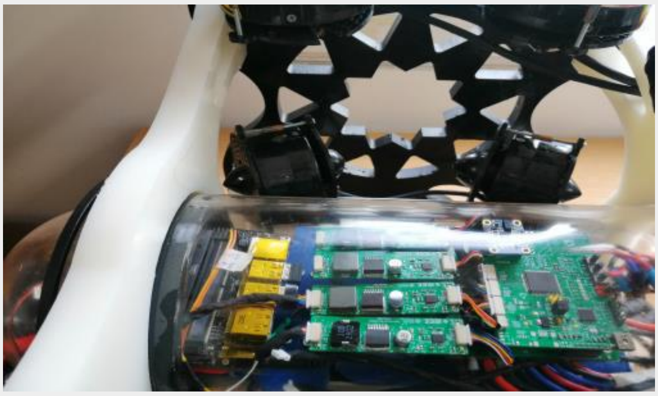

Fig 17 : Electronics Housing in Inner Casing

	Devices	Supply Voltage (V)	Total Power (W)
Hydrus-X	4 x T100 Thrusters	12	414
	4 x T200 Thrusters	12	576
	8 x CASMarine ESC	12	14.4
	NVIDIA Jetson Nano	5	20
	2 x USB Cameras	5	2.2
	2 x Servo Motors	5	30
	2 x Light	12	6
	CASMarine Motherboard	5/3.3	2.5
	CASMarine Leak Sensor	3.3	0.06
	Bar30	5	0.01
	HC-05 Bluetooth Module	5	0.15
	BNO055	5	0.05
	Total Power Consumption	1065.37W	
	ROV Full Load Current	1065.37/48 = 22.2A	
	Fuse Calculation	= (ROV Full Load Current) x (150%) = 22.2 x 1,5 = 33.3A	
	Fuse Value	30A	

Fig 18 : Power Budget Table

CASMarine Motherboard

CASMarine Motherboard is designed to be the main part of Hydrus-X, so all control algorithms work on this board. Arm® Cortex®-M4 STM32F407VGT6[1], which is one of the most suitable microcontrollers to meet all requirements for amateur and professional software development, has been selected as the processor. It is designed to minimize the cable density in the ROV and by considering the signal integrity rules.
CASMarine Power Distribution Board supplies 5V and 3V3 to CASMarine Motherboard via the header connectors. CASMarine Motherboard contains 5V, I²C (Inter-Integrated Circuit) for sensor connections, namely the inertial measurement unit (BNO055) and the pressure sensor (Bar30), ADC for current measurements, digital input for leak sensor, PWM connections for thrusters and servos. In addition to these, there are many digital input and output connections on the board.

Fig 19 : CASMArine Motherboard

CASMarine Motherboard communicates with the NVIDIA® Jetson Nano using the UART peripheral to send data to the control station. Due to the possibility of noise and interference that may occur in the ROV affect the UART [2] communication line, there is an RS-485 [3] module on CASMarine Motherboard and CASMarine Smart Power Box (UART to RS-485).
This board additionally provides balance control of the ROV by using the control algorithms developed by the software department.

Motherboard Board Support Package

IMU&Bar30 Driver

The source codes of IMU and BAR30 Drivers are designed based on a mathematical model of computation method called finite state machines (FSM). The main idea conveyed is that these sensors are in some specified state depending on given inputs. These states are handled by tasks (function groups) based on FSM and should be running periodically.
These sensors employ the I2C protocol and are controlled via interrupt subroutines. These subroutines are used to set the successor sensor values. There are two main states, INIT and READ, in the FSM. Following the INIT state, meaning sensor value is read once correctly, the state changes to READ and values get updated periodically.
Additionally, tasks can also output states as values to be used. This feature allows to monitor sensor connections and ascertain what emergency event to perform.

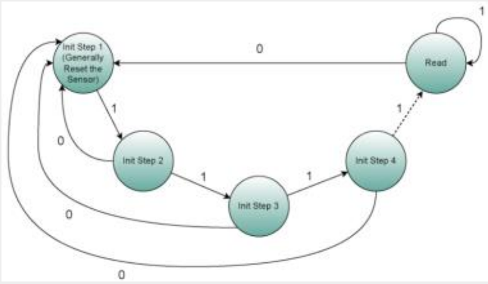

Fig 20 : State machine

UART Driver

In the same sense, an interrupt subroutine is used to get every arrived byte. The subroutine checks for the header, and after finding the header, the successive data is stored. As the last step, CRC32 is checked. This state design shrinks the time required for communication while providing means of monitoring if the communication is OK or NOT.

Motor Control Driver

This is the bridge between control data and the signals going to the motors through the ESC's. It takes six axis speed values such as x, y, z, yaw, roll, pitch and converts these to the acceptable PWM values then outputs.

CASMarine Motherboard Shield

CASMarine Motherboard Shield is designed to speed up the testing process against problems that may occur on the CASMarine Motherboard. This board has the same features as the CASMarine Motherboard. Arm® Cortex®- M4 STM32F407VGT6, the processor we use on the CASMarine Motherboard, is available on the STM32F4DISCOVERY board. The STM32F4DISCOVERY board is designed to sit on this board. It also has more digital I/O connectors than CASMarine Motherboard.

Fig 21: CASMarine Motherboard

CASMarine Smart Power Box

CASMarine Smart Power Box Board basically transmits power to the peripherals such as servo motors and NVIDIA® Jetson Nano. The using current by the peripherals is instantly followed thanks to current sensor. Besides, this board includes signal paths between CASMarine Motherboard and peripherals, via these paths, cable density,complexity and cost are diminished. CASMarine Smart Power Box has one INA250 Current Sensor, one SMPS Buck Voltage Regulator, one Linear Voltage Regulator and signal paths. SMPS Buck Voltage Regulator supplies power to the peripherals by converting 12V from the power distribution to 5V. SMPS Voltage Regulator is preferred because it heats less and it is more efficient than other linear regulators. Also, the 12-3.3V linear voltage regulator on CASMarine Smart Power Box Board reduces the 12V voltage that is received from CASMarine Power Distribution Board to 3.3V and supplies power to the RS485 communication IC and the current sensor IC on the board.

Fig 22 : Smart Power Box

The INA250 continuously measures the value of the current going to the peripherals. If unexpected value is detected, the current is cutt off for the safety of the system. Signal paths on the board carry PWM signals for driving servo motors from CASMarine Motherboard to servo motors. Moreover, CASMarine Motherboard and NVIDIA® Jetson Nano communicate with RS-485 serial communication protocol to be affected less from electronic noise.

CASMarine Leak Sensor

CASMarine leak sensor is designed to quickly and reliably detect a leak inside the ROV before any major damage occurs inside the ROV. Thanks to this sensor, we make sure that our electronic devices inside the ROV are safe. Four re-usable sponge tipped probes with an adhesive backing let you monitor all corners of a Watertight enclosure, from the penetrators to the front and rear flanges. When a leak is detected, the red LED on the board glows, the signal is pulled to 3.3V and this logic information is sent to CASMarine Motherboard. After the logic 1 information is received by CASMarine Motherboard, the algorithm written for this condition starts to work on CASMarine Motherboard and the robot comes to the water surface.

Fig 23 : CASMarine Leak Sensor

CASMarine ESCs

CASMarine ESC is designed to drive Hydrus-X's brushless DC motors. The maximum ratings that the board can withstand are 30V and 30A. Each board is designed to drive a single motor, so 8 CASMarine ESCs are used in the system. ATMEGA328P-AU, one of the most suitable microcontrollers to meet all the requirements of the card, was chosen as the processor. It is designed to minimize the cable density in the ROV and taking into account the signal integrity rules. CASMarine Power Distribution Board supplies 12V to the CASMarine ESCs via the terminal blocks.

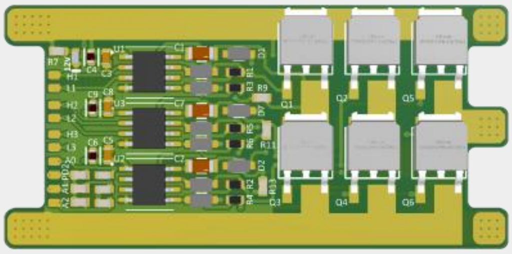

Fig 24 : CASMarine ESC

NVIDIA Jetson Nano

NVIDIA® Jetson Nano™ Developer Kit, is a single board computer that is specially designed for image processing and artificial intelligence. The whole system is capable of performing functions with 5 watts of power. Small size, 4-core ARM -A57 @1.43 GHz processor and 128-core Maxwell graphics high video output thanks to its processor encoding and video decoding performance, Image thanks to CUDA supported architecture in processing applications and artificial neural depends on the speed of parallel processing in their network, it is a mini computer that stands out with its performance. It has been preferred because it is a computer that allows image processing and artificial intelligence.

Fig 25 : NVIDIA Jetson Nano

Cameras

Two HD USB cameras were used in the ROV. The first of these was mounted on the dome in front of the tube to see the front of the ROV. The second is mounted under the ROV to see below.

Chosen for better underwater viewing thanks to feedback from the software department, this camera has low-light performance, good color rendering and built-in video compression. Also, with the Sony IMX322 sensor, this camera has very high light sensitivity, making it the ideal camera.

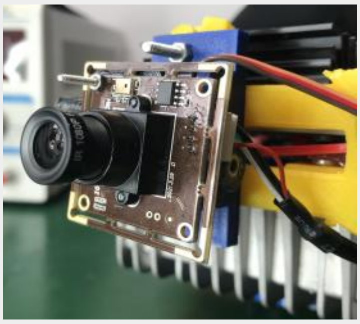

Fig 26 : USB Camera

Underwater Lights

The Hydrus-X is equipped with two 1000 lumens submarine lights. These LED lights have a beam angle of 125 degrees. Equipping the ROV with two lights improves visibility by minimizing shadow effects caused by water.

Fig 27 : Light

SENSORS

9 DOF IMU

The IMU electronic unit has an onboard accelerometer, gyroscope and magnetometer sensors. BNO055 has an ARM Cortex-M0 based main processor that uses fusion algorithms to combine sensor data and send absolute orientation, angular velocity and linear acceleration information to CASMarine Motherboard. Data received from the BNO055 sensor with I²C protocol is used in Hydrus-X's balance and control algorithm. The Motherboard also sends the data to the control station via NVIDIA Jetson Nano to view the 3D model of the vehicle.

Fig 28: 9-DOF IMU

Bar30

Bar30 is a waterproof enclosure with MS5837 high resolution pressure sensor inside which has depth measurement up to 300 meters with a resolution of 0.2 bar. The pressure sensor located on the flange of Hydrus-X, transmits the data obtained with I²C protocol to the Motherboard.

Fig 29: Bar 30

HC-05

Hydrus-x's control algorithm works on the Motherboard which is inside the enclosure. During troubleshooting and debugging processes, recoding does not need a wired connection. Thanks to HC-05 Bluetooth Module, which is connected to the Motherboard, changing the embedded code inside the microcontroller unit can be provided without a cable connection.

Fig 30: HC-05

Cable Management

Thanks to flexible and neutrally buoyant cable management between the ROV and the Surface Control Station, Hydrus-X's small and maneuverable nature is its most important feature underwater. The power transmission is provided by 16 American Wire Gauge (AWG) with a 30A fuse and ethernet communication is provided by a Fathom ROV Tether which is 26 American Wire Gauge (AWG). The Fathom Tether is a high quality tether cable designed specifically for ROVs and other underwater applications. It is neutrally buoyant, has 350 lb breaking strength, and is embedded with water-blocking fibers to seal any leaks. The tether is 7.6 mm in diameter and is slimmer than most comparable ROV tethers. The power cable houses a pair of 14 American Wire Gauge (AWG) DC power lines shielded with XLPE insulation material for both flexibility and durability.The waterproofing is guaranteed by the PVC outer sheath on the outside of the cable. 16 AWG power lines support Hydrus-X's maximum power consumption with an affordable voltage drop at 25 meters.The connectors on both sides are provided with strain relief to reduce potential damage from overcurrent. They are connected to 30 amp fuses on both sides to ensure safety.

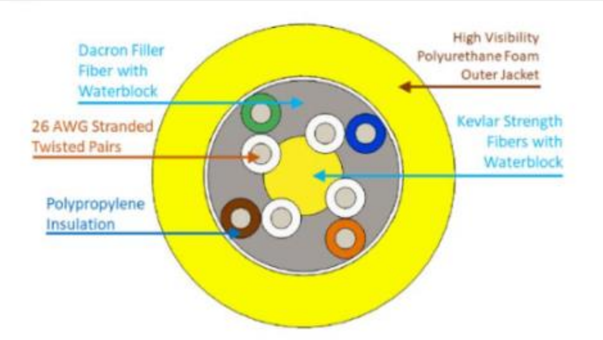

Fig 31 : Inside of Tether Cable

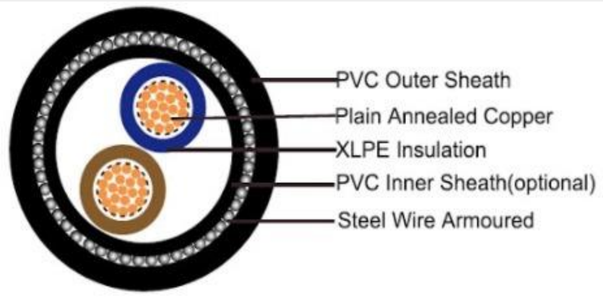

Fig 32 : Inside of Power Cable

Due to the thick tether cable used in the communication between the surface control station and Hydrus-X, it cannot be fitted into the RJ45 connector. Therefore, a keystone jack is used in both the surface control station and Hydrus-X. Keystone jacks are a female connector that connects to a male connector used in LAN cabling.

We are used 14AWG thick, flexible silicone cables to secure the connection between the ESCs (Electric Speed Controller) and the motors. Also MR30 connectors were preferred at ESCs and motor connection points because they take up little space.

Fig 33: Keystone Jack

Fig 34 : MR30 Connector

Surface Control Station (SCS)

The Surface Control Station is a product of CASMarine company which is designed and manufactured according to the necessities. It is responsible for displaying camera images and sensor datas on the LCD display, supplying 48VDC to power the ROV and managing controlling inputs such as joystick, button-switches and sliders.

Fig 35: Surface Control Station

Surface control station consists of several main parts such as main computer, LCD display and CASMarine Control Station Board. Apart from these parts, there are emergency button, power switch of ROV, signal switches, sliders, RGB leds and USB ports on the plate of the SCS. The wiring inside the control station is made to meet the safety criteria. Cables are identified with colored labels according to other functions. Inside of the SCS, there is a single board ASUS Mini-PC that processes camera images and sensor data sent from ROV via ethernet communication, and a 20 inch screen that displays these datas to the user together with our own designed interface.

Control Station Board

Custom-made Control Station Board ,which is another product of the research and development of CASMarine team members on printed circuit boards, converts the information from analog input elements such as the button and slider used in the control of the ROV to digital data. It transmits the obtained data to the main computer. At the same time, it is the unit responsible for driving RGB LEDs that visually transmit the necessary information about the robot's operation with hardware elements to the user and communication of these elements with the main computer. There is a STM32F107RCT6 processor on CASMarine Control Station Board. The most important feature of the card is that it has the ability to control too many units with very few pins by using different methods. One of these methods is the Charlieplexing button matrix method.

Fig 36: CASMarine Control Station Board

There is also a SD Card holder on the board that can be used to store data. SD Card communication is provided by SPI Protocol. As with other peripheral elements, our own prepared Board Support Packages and Drivers are used in CASMarine Control Station Board.

Control Station Board Board Support Package

Demux Driver

A Demux integrated circuit is used to control 16 LEDs with 16 buttons at the control station. In this way, 16 LEDs can be controlled with 4 pins coming out of the microcontroller(The 4 pins in the demux are S0,S1,S2,S3). Demux is responsible for connecting any of the 16 pins to the Common Input pin and Turn On or Off the LEDs.

The algorithm turns on or off the LEDs in a very serial manner, respectively, after checking whether the LEDs should light up according to the signals from the buttons. In this way, although no LEDs are lit at the same time, because each LED flashes at a frequency of more than 50 Hz, the LEDs appear to be lit at the same time, providing accurate information to the user.

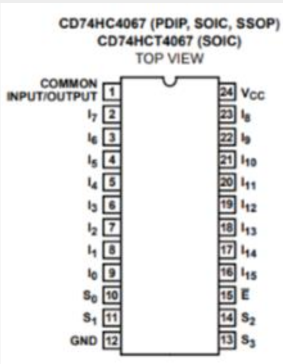

Fig 37: Demux Integrated Circuit Pinout

Button Matrix Driver

The Button Matrix, which used 4 input and 4 Output pins to read 16 buttons, was placed on the hardware. The algorithm outputs columns one by one. At this time, the microcontroller performs signal control from 4 rows for each column. A total of 16 buttons periodically read the digital signal.

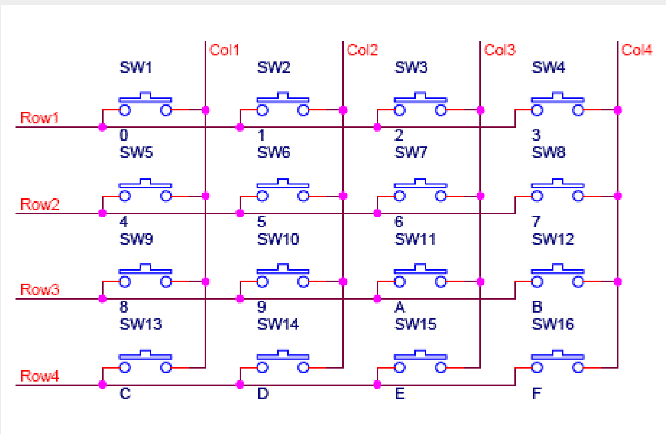

Figure 38 : Button Matrix Method

SOFTWARE

The software system of the ROV consists of four different computing devices: Surface control station computer, NVIDIA Jetson Nano, CASMarine Motherboard and CASMarine Surface Control Station Board. Manual control of the ROV is implemented by calculating the required speed values according to joystick data and sending PWM signals to thrusters. The data coming from the buttons and sliders on the surface control station are read by the Control Station Board and transferred to the Motherboard to execute the task these peripherals assigned for. All of the embedded and high level softwares are developed by CASMarine Software Department using C/C++ and Python programming languages.

Custom Operating System

In the custom hardware, we are using the Custom Operating System that is designed by the embedded software department members. It is built on a technique called the Non-Preemptive Periodic Scheduler and utilises the SysTick Interrupt subroutine on ARM Cortex-M microprocessors. In the SysTick Interrupt, all counters, which are special for their respective tasks, are scheduled to be incremented periodically. These counters are evaluated for their tasks to be running or waiting. Our drivers are optimised for this Custom Operating System.

Control Software

The software system of the ROV consists of four different computing devices: Surface control station computer, NVIDIA Jetson Nano, CASMarine Motherboard, and CASMarine Surface Control Station Board. Manual control of the ROV is implemented by calculating the required speed values according to joystick data and sending PWM signals to thrusters. The data coming from the buttons and sliders on the surface control station are read by the Control Station Board and transferred to the Motherboard to execute the task these peripherals are assigned for.

All of the embedded and high-level software are developed by the CASMarine Software Department using C/C++ and Python programming languages.

Balance Algorithm

There are an unlimited number of factors that affect the movement of the ROV. Due to reasons such as a misaligned centre of weight or strong water currents, it is hard to bring about the intended movement. To address this issue, a balancing algorithm based on PID (Proportional-Integral-Derivative) three-term controller is used. Simple in structure, reliable in operation, and robust in performance, PID controllers are one of the most popular controllers in industries.

The controller calculates an error value for a setpoint. In the PID function, the error value is used to execute the proportional term, the integral term for the reduction of steady-state errors, and the derivative term to handle overshoots. Error-values of roll, pitch, and yaw axes are calculated with absolute orientation data from the BNO055 9-DOF IMU sensor while destabilisation error in the z-axis is calculated with the MS5837 pressure sensor.

Thrusters on top move the roll and pitch axes to maintain the upright position of the ROV. Consequently, if there is no change to the z-axis input, the vehicle will stay at a fixed depth. Thrusters on the bottom are responsible for the movement in the x and y axes. To reach a certain setpoint, the balance algorithm will rotate the ROV about the yaw axis, thus, producing the intended movement.

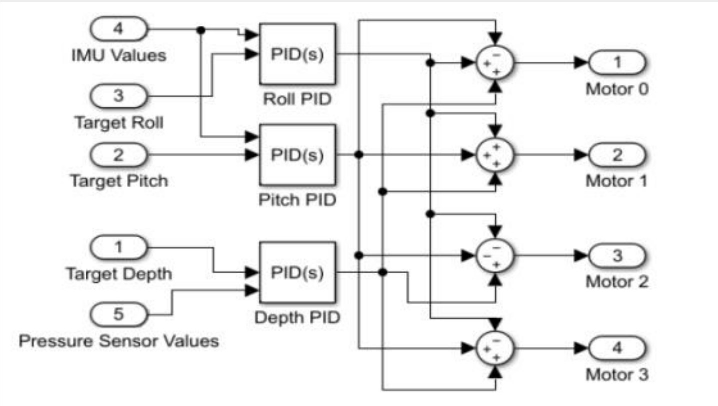

Fig 39 : PID Algorithm Scheme

Surface Control Station Software

The ground control station consists of a graphical user interface for co-pilot and pilot, buttons, switches, and sliders, and a computer. The graphical user interface contains sub-windows for assigning tasks to buttons, switches, sliders, and the PID menu. It also displays important ROV information, including sensor data and ROV status. There are also two parts that display images from the robot's cameras in the interface that help us perform important tasks. The entire interface and its components were programmed using Python and the PyQT5 and OpenCV libraries. These interfaces communicate with the Control Station Board and the NVIDIA Jetson Nano to read sensor data and send command data.

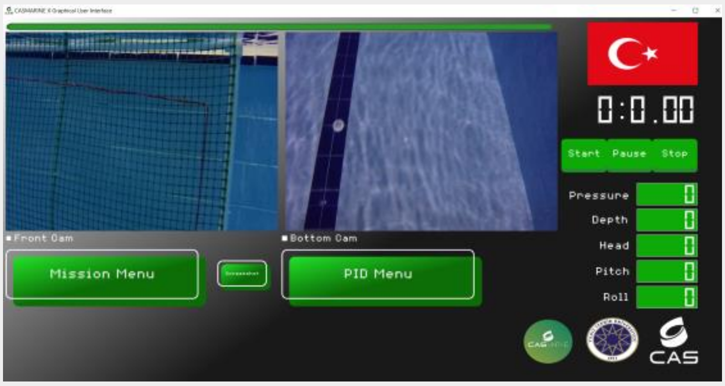

Fig 40 : CASMarine GUI

Communication Software

Communication, in its broadest sense, can be described as the exchange of information between things. Things, in the context of robotics, may refer to the data transfer between different functions, cards and computers. However, the medium of communication changes with the type of devices and connection between them.

Hence, the software team implemented different algorithms for differing occasions. They can be summed up as follows:

- The User Datagram Protocol (UDP) is employed between the Control Station PC which is stationed on the land and the NVIDIA Jetson Nano which resides in the Hydrus-X. UDP is a networking protocol and offers high speed communication. It is employed in Hydrus-X as a means to transfer joystick control axes, provide underwater camera stream and send other
- The UART serial communication is used
  1. to exchange sensor data, ROV state data and joystick input between the NVIDIA Jetson Nano and the Motherboard.
  2. for the ROV state data and other inputs which are taken from the GUI.

The NVIDIA Jetson Nano and the Control Station PC are powerful machines. Normally the program resources are limited to the sub-particles of the machine's CPU called process and its sub-particles threads. However, there are several softwares, including communication that needs to run simultaneously on these machines. To achieve this, parallelization and concurrency theories are realized using multiprocessing and threading methods. To solve the synchronization problem with the variables of different programs, instead of lock primitives, data structures such as queues and stacks are incorporated into the design of algorithms of all tasks.

Version Control

Trying to fit in a new age that is guided by the pandemic and as an endeavour to maintain professionalism, CASMarine took advantage of several applications and online services. To keep the code files safe while collaborating with their colleagues, the software team utilized Git and its cloud hosting site Github as its version control system. Github's main functionality of update, revert, and distribution of repositories made online development and safe progression possible. Also, its branching and merging mechanisms provided the development process with means of trying different ideas quickly without discarding the original code, building new software demos for simultaneous test&debugging and bringing projects together with so little effort. Consequently, this online collaboration has greatly reduced the contagiousness of Covid-19 within the company by reducing the active number of people using the company facilities.

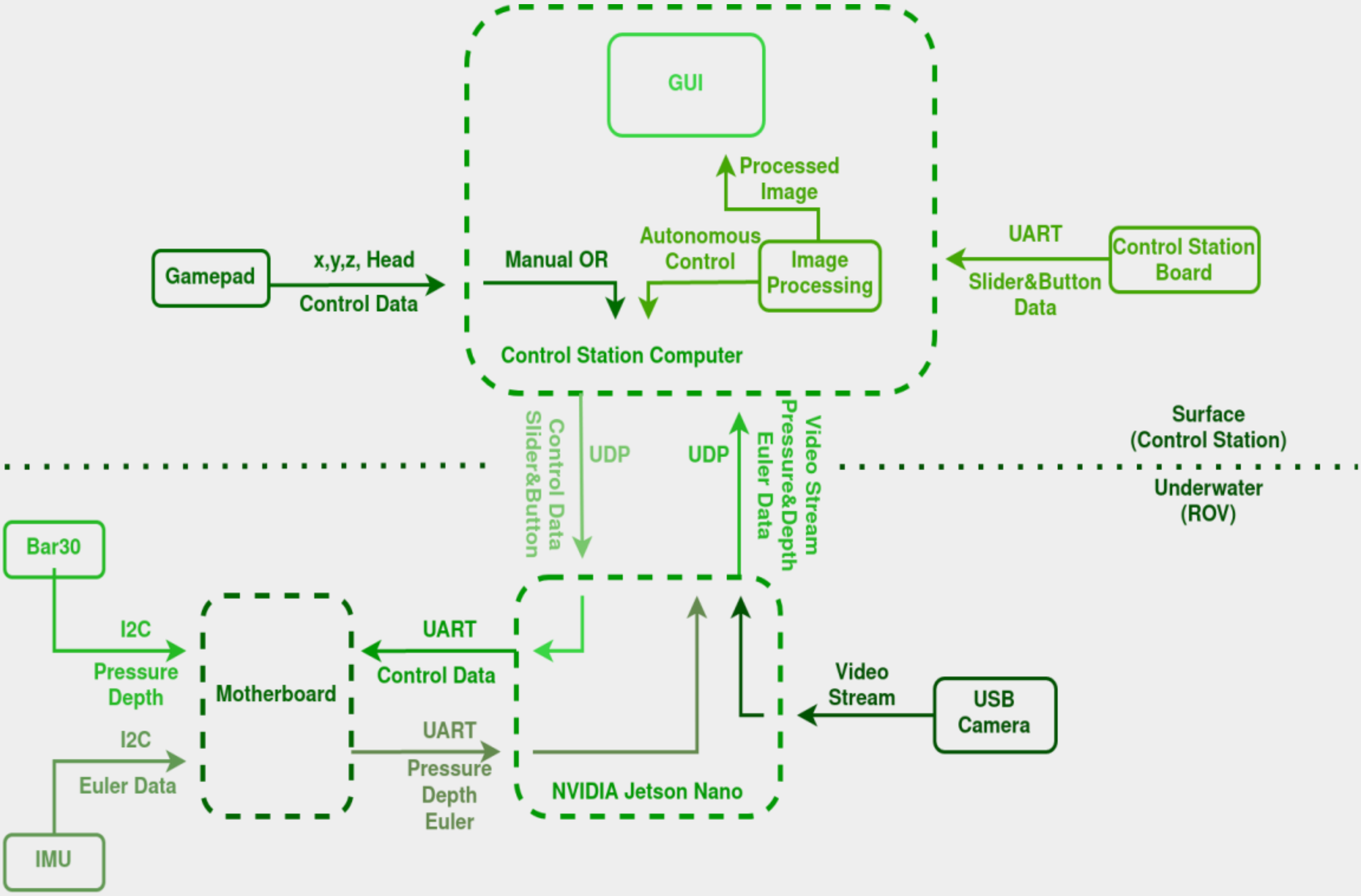

Fig 41 : Data Flow

TOOLS

Multi-Purpose Gripper

In order to accomplish a number of specific tasks, many distinct tools are required. One of those distinct tools is the gripper. Marine rovs are often expected to pick up and carry objects during their missions. CASMarine have designed a gripper that not only grips one type of object but can also grip other objects which have different dimensions to one another. In order to accomplish the tasks, Hydrus-X's gripper has been designed with two main working axis. The gripper closing-opening axis and the rotation axis. The rotation axis helps to carry objects in a form which they don't directly apply too much force on the servos. As the main deal was to work properly under water, lubrication was a big problem. Therefore a gripper design with a gearset has been avoided in spite of it's reliable applications with servos under proper lubrication. Working with servos, the main movement generated was rotation. For a proper working design it was a must to transfer rotation into a linear form in order to have a coordinated movement in each gripper jaw. Therefore a small slide on the gripper body and a rod to move linearly through the slide has been designed. Connecting the jaws on the linear rod via beams, a coordinated movement has been obtained with the gripper jaws. Using the described mechanism, in order to accomplish all the tasks, maximum grip width of the gripper has been set as 44mm. The gripper has a total length of 280mm.

Fig 42 : Multi-Purpose Gripper

Servo Casings

Since the servo motors are a crucial part of the ROV, it is very important to distribute the forces present on them. Because the gripper will have the duty of holding and carrying a number of objects with different sizes and masses, the servo motors which are responsible for the gripper will be under the influence of different forces. The servo casings which are made of PLA filament are present in the system to make sure the forces are not detrimental to the motors. The design process of the servo casings aimed to transfer and resist the forces that the servo gears are being affected by, thus reducing the amount of stress in the system.

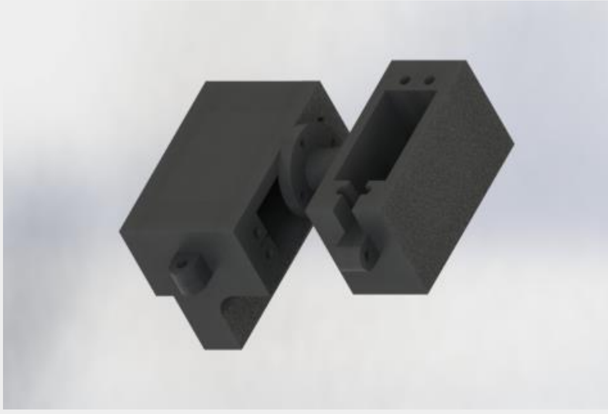

Fig 43 : Servo Casings

Vertical Float

The float designed by the CASMarine team, changes its density by giving and receiving water to the syringes inside, and thus it moves in vertical directions in the water. The center of gravity of the float is adjusted to keep the float upright in the water.

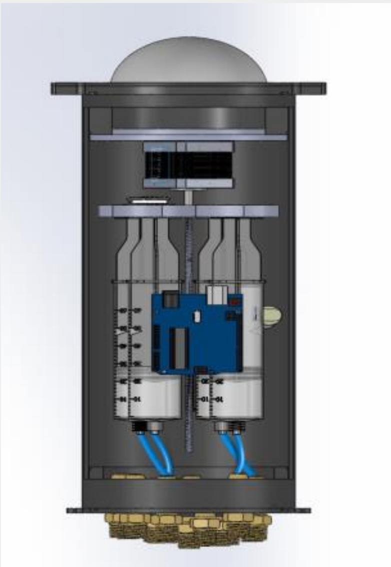

Fig 44 : Vertical Float

The system has a Bar30 sensor in order to determine how deep the float is located in the water. There is an Arduino board inside which the algorithm runs. The float also has a bluetooth module that interacts with surface. The arduino fills the syringe with water or empties it by sending signals to the stepper motor driver according to the signals from the Bar30 sensor and the bluetooth module. The electronic system in the device is powered by a 9V alkaline battery.

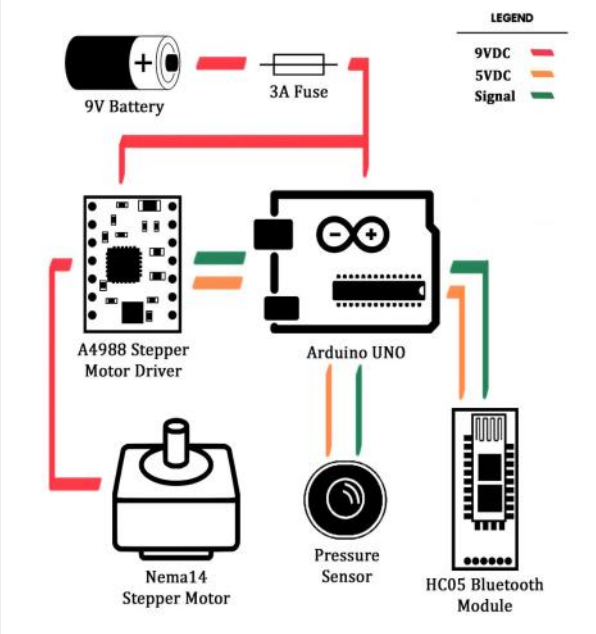

Fig 45 : Vertical Float SID

Autonomous Line Tracking

To inspect the damaged areas of the fishing net, the images taken by the ROV are divided into 9 equal parts in a 3x3 grid format. The red line to be tracked is determined by the HSV color filtering method. The algorithm calculates the pixel density within each grid cell of the images captured by the camera. The pixel threshold value suitable for the following distance is compared with the pixel value of the line detected in the cells.

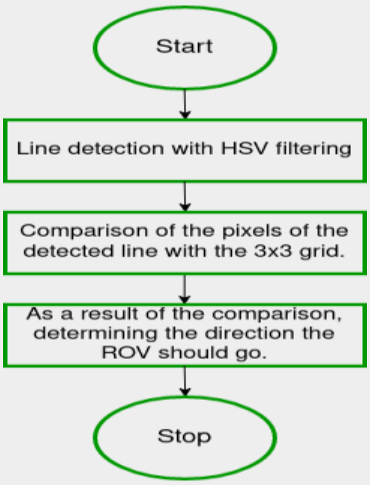

Fig 46 : Line Tracking Flowchart

As a result of the comparison, whether or not a line is detected in the cells is stored in a 3x3 matrix variable throughout the runtime. The algorithm uses this stored cell data to guide the vehicle. The algorithm calibrates the ROV's following distance and height throughout the runtime using the cell data from the images.

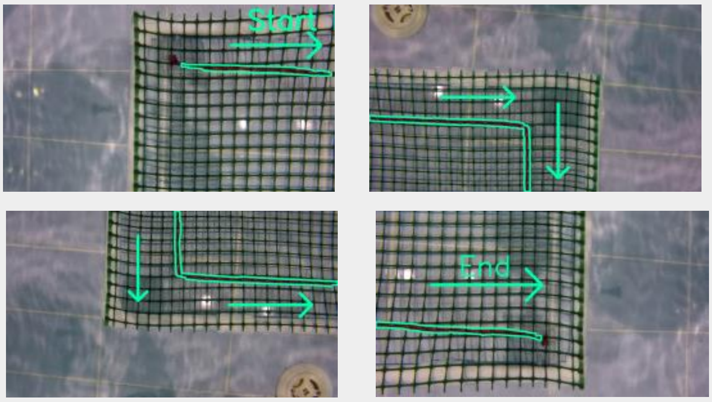

Fig 47 : Deciding which direction to go

Detecting Morts

Detector, which is developed with deep learning methods for detecting morts and fish, can detect the object by using AI. The dataset created by the team has +2000 images which are generated from practice videos given by the MATE and labelled as morts and fish. The dataset was trained with the YOLO V4 model. Google Colaboratory Cloud System is used for training environment in order to a faster and more efficient training process. After approximately 28 hours of training, the trained model has average 96% accuracy and and it is able to highlight the morts with a red box and display them on the video screen.

Fig 48 : Model Training on Google Colab

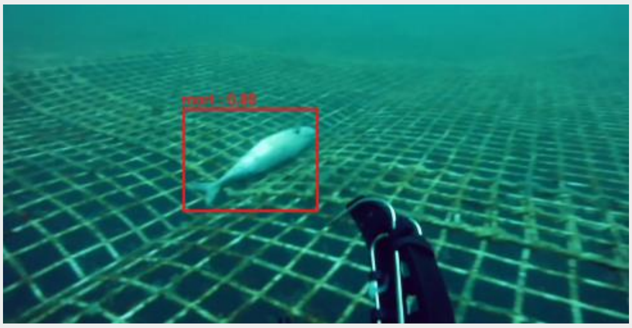

Fig 49: Detecting a mort on the practice video

Fish Size Measurement

The edge detection algorithm was used to measure fish length. To cancel the image's noise coming from the camera, blur operations were first performed.

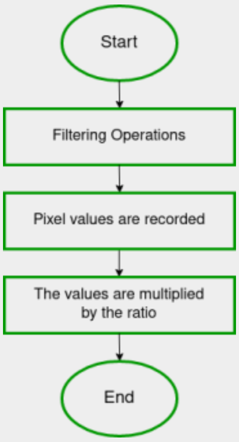

Fig 50 : Measurement Flowchart

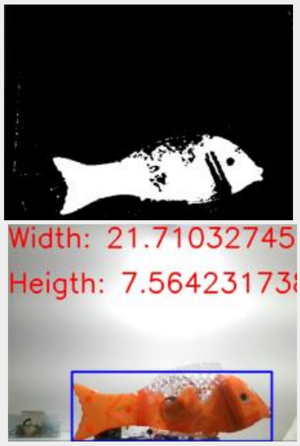

Fig 51 : Result

Then morphological operations are applied with respect to the unity and integrity of the image. The edge detection algorithm is then used to detect the edges of the objects in the image. The contours of the output whose edges are detected are found, their coordinates are recorded, and the edge of the contour with the largest area is drawn with a rectangle. Finally, the coordinates of the contour with the largest area are multiplied by the proportionality constant obtained from the previous calculations, and the estimated size of the object in proportional form is recorded. The proportionality constant is; obtained by proportioning the pixel values obtained by image processing methods by placing an object with known dimensions at a certain distance from the camera to the actual length of the object.

Autonomous Mapping

The algorithm that flies over the search area and maps it autonomously is developed using the OpenCV library. First, the ROV is brought to the start line of the search area and positions. Before the start to fly over the area, ROV fixes itself to this depth for flying all the search area with the same height by using control algorithms.

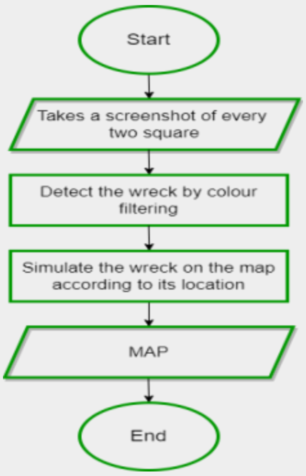

Fig 52 : Mapping Flowchart

While the ROV is flying over the search area, the mapping algorithm starts for autonomous mapping of the field. ROV takes a screenshot of every two squares and to accurately identify different points of interest, ROV finds the brownest HSV values from the search area image for detecting the wreck.

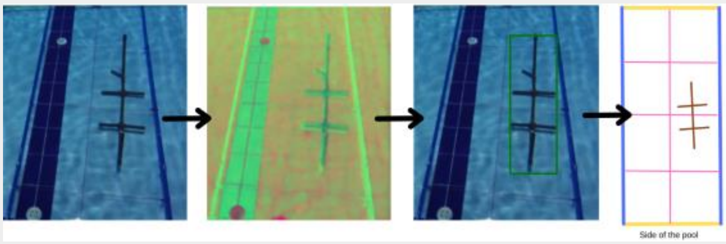

Figure 53 : Simulating the wreck on the map

If the wreck is detected on the image, it is determined in which location it is and the algorithm simulates the wreck on the 2x4 grid map. If an object other than the wreck is detected, the algorithm does not simulate these objects on the grid map. When the ROV has reached the end of the search area, the mapping algorithm displays the created map on the GUI screen.

Photomosaic of the Wreck

To create a photomosaic of the wreck site, 8 different images of 8 different rectangles are taken by the pilot. After the images are taken, all steps are performed autonomously. The algorithm uses a 2 verified structure to make the images as understandable as possible. The first verification is achieved by a combination of HSV color filtering and line detection. The algorithm detects lines on the masked image. The intersection points of the detected lines are found. The intersection points represent the corners of each rectangle of the wreck site. Up to this point, the first verification algorithm has worked. If not enough corners are detected, the 2nd verification algorithm is run.

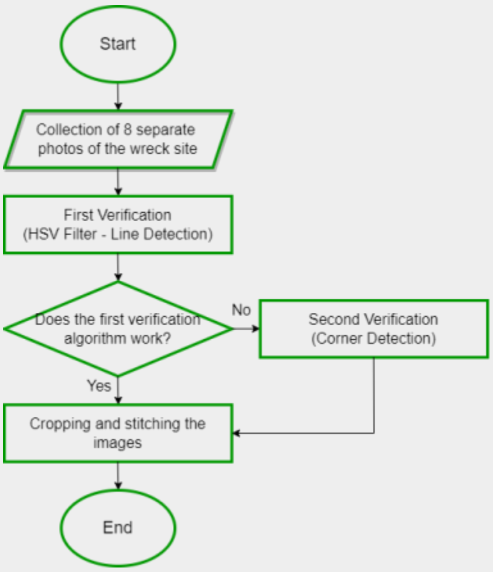

Fig 54 : Autonomous Photomosaic Flowchart

The second verification is a customized version of the Shi-Tomasi Corner Detector. The algorithm determines the probable ROI (Region of Interest) of the wreck site rectangles that can be detected. The corner search is performed with the Shi-Tomasi Corner Detector in these determined ROI. In this way, the most suitable corners are determined. Rectangles with fixed corners are clipped. The algorithm combines the cropped images to create a photomosaic. By using the 2-verified structure minimizes the negative effects of the environmental conditions.

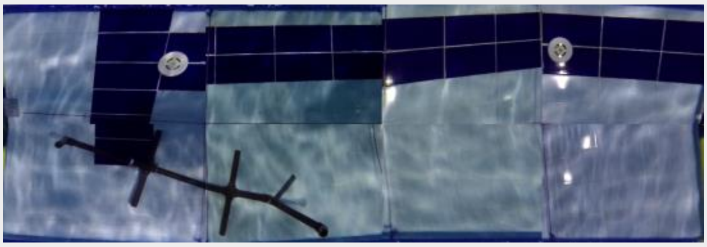

Figure 55 : Stitched images

Measuring the Length of the Wreck

To measure the length of the wreck, the HSV color filter method, which detects the base color of the wreck, and the fish size measurement method in Fish Size Measurement Tool were used. The coordinates of the wreck are obtained using the edge detection algorithm in Fish Size Measurement Tool Using these coordinates, the top left point (stern) and top right point (bow) of the wreck are determined. The pixel value between these detected points and the proportionality constant used in Fish Size Measurement Tool are multiplied. The estimated length of the wreck is determined.

Innovations

As mentioned, the purpose of our company will be to develop underwater systems and take part in the development of these technologies. One of the innovations for this purpose is our project " Real-Time Image Enhancement and Restoration in Underwater Vehicles and Application to Hardware", which helps to one of the major problems caused by low light and less quality in the underwater images. The image restoration and enhancement algorithms increase and fix the low light and colour problems in the images. Because of that these algorithms require high processing power in real-time systems, we run these underwater image enhancement and restoration methods with the help of the CUDA technology.

Our other project named “Configurable Electronic System Design for Unmanned Underwater Vehicle” mainly aims to provide flexibility to research and development studies by providing a modular structure and to reduce the costs in the production processes.

Lastly, Instead of using a driving control system and development kit that is produced by another company, we design a system whose driving control board, control algorithms and user interface are designed by our company members.The development named “ Interface Assisted

Driving Control System and Development Kit for Unmanned Systems" is now used at HYDRUS-X and Ground Control Station. These three projects were entitled to be supported within the scope of The Scientific and Technological Research Council of Turkey 2209-B Industry Oriented Undergraduate Research Projects in this year.

SAFETY

Safety Philosophy

CASMarine company acts with the awareness that safety is the most important and first principle in all of its works. Accordingly, the team has set some safety standards that all the current and new members of the team must comply with. While determining these standards, all safety rules published by MATE (Oceaneering Americas Region HSE Employee Handbook) are taken into account. Those safety standards are considered from the beginning of the planning and design process, applied in the testing and assembly process and becomes the most important factor in the operation of the ROV.

Training

CASMarine has adopted training as one of the most important principles ever since it was founded. New members are subjected to safety training not only in their own field but also in all areas that the team has been working on. continuously.

Fig 56 : Training with New Employee

Veteran employees closely supervise and mentor new employees as they begin to use the equipment.This ensures that all employees have the essential skills to minimize risks of accident and deal with emergency situations New members are subjected to certain evaluations after these training sessions and receive feedback

Safety Standards

Laboratory Standards

A multitude of different devices and methods are used by the company for the ROV's manufacturing and assembly process. To ensure a safe working environment, several special procedures are put in order.

Such rules must be strictly fallowed and obeyed by all unit members so that the process may continue without errors. It is obligatory to be accompanied by a person working at the points where these signs are located. Masks and gloves should be used in electronic work. Repairmen should wear apron, safety glasses, fireproof gloves and hard hat while working. When working with chemical products (epoxy, cleaning alcohol, etc.), a gas mask, fireproof gloves and stainless container should be used. With the introduction of COVID-19 into our lives this year, we have brought a new rule to our laboratory. The number of people entering the laboratory was limited, there was a safe distance and mask requirement.

Fig 57: Safety Precautions

Such rules must be strictly fallowed and obeyed by all unit members so that the process may continue without errors. It is obligatory to be accompanied by a person working at the points where these signs are located. Masks and gloves should be used in electronic work. Repairmen should wear apron, safety glasses, fireproof gloves and hard hat while working. When working with chemical products (epoxy, cleaning alcohol, etc.), a gas mask, fireproof gloves and stainless container should be used. With the introduction of COVID-19 into our lives this year, we have brought a new rule to our laboratory. The number of people entering the laboratory was limited, there was a safe distance and mask requirement.

Vehicle Standards

As early as the research & development stage, CASMarine examined the MATE safety requirements for the vehicle, attributed each of them to the suitable department, and ensured that safety lies intrinsically in HYDRUS-X's construction. Electronics engineers have a 30A fuse set by MATE and an emergency stop button to shut down the entire system in case of emergency.

Mechanical engineers make sure all sharp edges are eliminated through filling and deburring. Thrusters are shrouded with guards to prevent potential safety hazards such as thruster interference from loose components and peripherals. Visible warning stickers such as “sharp edges” and “electrical hazard” are placed on the components as well. Tether strain relief has been made to prevent the tension from getting on the cable while wiring the vehicle. Thus, in emergency situations, it can be pulled by the vehicle cable. All connections on the vehicle are fixed with a water resistant nutlock and there is no loose screw connection. All cable connection operations of the vehicle were carried out based on the insulation factor. In this context, our vehicle successfully passed the short circuit tests applied after the cable connection processes. As a precaution against possible malfunctions that may occur in any of the cable connections in the vehicle, the conductive parts that are not included in the vehicle's cable connection system are subjected to hard anodizing.

Figure 58 : Thruster guards and warning stickers

Fig 59: Emergency Button

LOGISTICS

Company Organization

CASMarine has not made any changes in the organizational structure it has used since its establishment in 2016. The company has four technical departments in its structure that focus on the relevant technical areas of the vehicle. These are Mechanical, Electronic, Embedded Software and High Level Software departments. All departments are led by a single technical leader and these leaders are directly accountable to the CEO and CTO.

Technical department leaders plan the progress of their departments and carry out the progress of the processes together with the employees in their departments. The branches of duty within the departments are as follows:

- **Mechanics:** Enclosure, Chassis, Flange, Electronic Housing, Mission-Specified Units
- **Electronics:** Power Electronics, Analog Circuit Design, Digital Circuit Design, Cabling
- **Embedded Software:** Control Algorithm Software, Communication Algorithm Software, Sensor Software, Ground Control Station Software
- **High Level Software:** Image Processing & Autonomous Driving, Communication, User Interface
- **Organization :** Marketing, Sponsorhip, Finance

This distribution of tasks allows employees to be equally distributed over all required tasks to ensure that each person has a suitable role to work on.

Project Management

Since its establishment, CASMarine has not made any major changes in the process cycle, except for minor needs-oriented adjustments. This process cycle consists of 4 phases: Training, Design, Production and Test Phase.

During the training phase, our team organizes basic technical trainings that are open to everyone at the beginning of each new school term. There are almost 500 students who attended our basical technical trainings fromour university. By bringing together and grouping people who want to do projects after these trainings, it enables these people to create a small project together. Then, those who want to work with us enter our interviews, and those who pass our interviews enter our candidate staff, called the Core Staff, and are subjected to an intensive training and assignment period of 3 months. During this 3-month period, Core Staff members receive Altium Designer, SOLIDWORKS, C and Python trainings according to the departments they choose.

Throughout this process, elimination continues, studies are carried out for our vehicle with the people remaining after the training process, and new members of our our company are gradually given responsibilities. Before the design phase, a Gantt Chart is prepared by the CEO, CTO and department heads, including the time schedule and deadlines of the process. Our company starts the design phase before the mission specification is published, until the mission specification is published, departments only start the design of structures that are independent of the tasks. Everything done after the publication of the mission specification is updated to be suitable for the competition and the stage continues. During this period, a meeting is held regularly within each department once a week, and a general meeting is held with the participation of the whole team. In these meetings, the process is evaluated in departmental and general dimensions and ideas are exchanged. In this way, the opinions of all team members are evaluated and the solution is reached in a shorter and easier way. When the designs of the mechanical and electronic products are finished, reviews are made on the designs and improvements are made where necessary. After the reviews, the production phase starts.

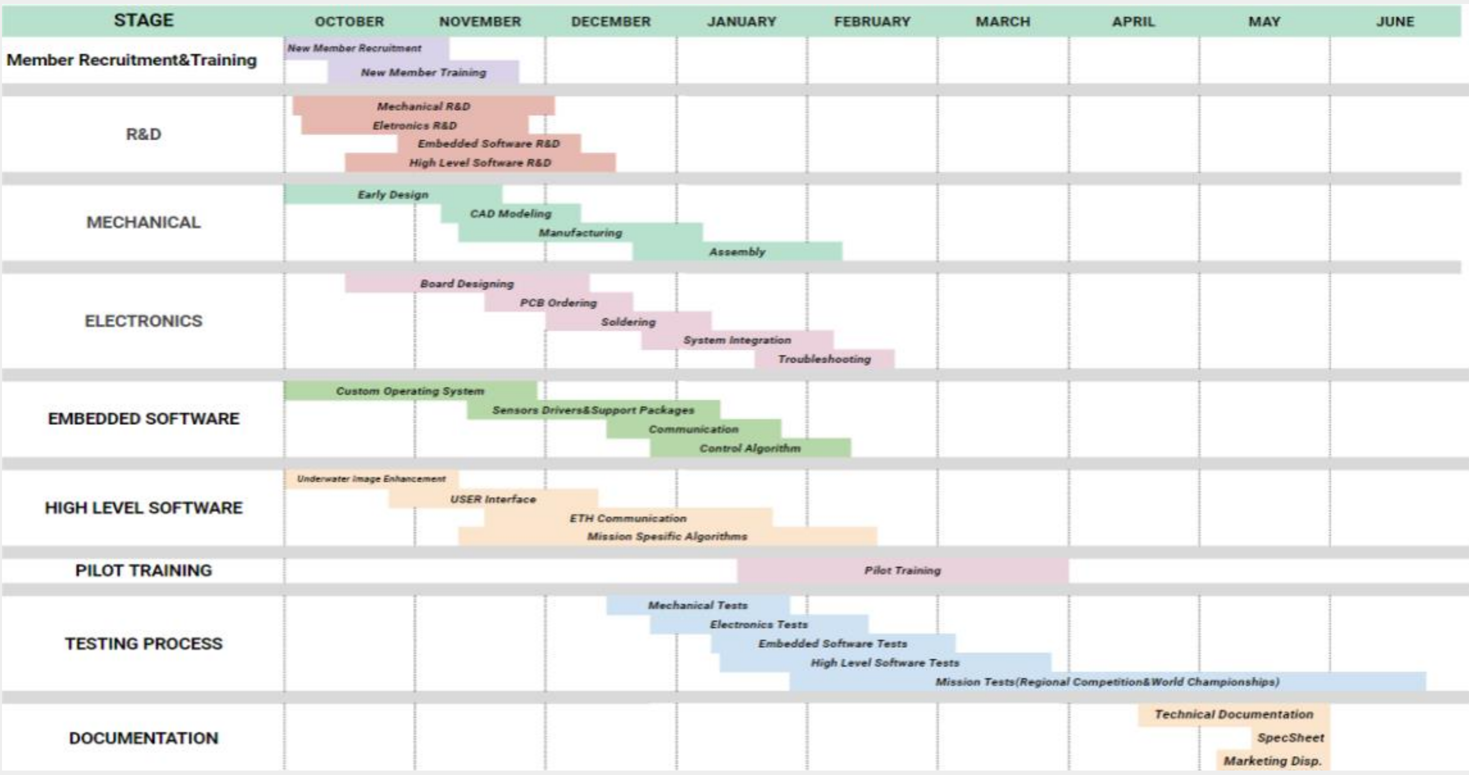

Fig 60 : Project Management Gantt Chart

Project Budget and Costs

At the beginning of each competition period, an estimated expenditure plan and budget are prepared with the net expenses of the previous period, improvements to be made and add-ons to be added. This spending plan and budget is updated after the mission spec is released. Revenues are obtained from sponsors, donors and, where necessary, team members. The CFO is responsible for generating revenues, sponsorship relationships and controlling expenditure items and is in constant communication with the CEO on this issue. Figure 61 displays the budget list.

CONCLUSION

Challenges

Throughout the development process for the ROV, the company has faced various convolutions. These convolutions can be categorized under two different titles in accordance with their nature being whether technical or nontechnical.

Non-Technical

The prolonged spread of the Covid-19 virus in the world has created many difficulties for the CASMarine company as well as the rest of the world. The ambiguity and the lack of consistency about the regulations concerning the higher level education institutions made it hard for the company to plan its actions and agendas beforehand. As the company facilities are located in the university campus and a vast number of members are accommodated in dormitories, it proved impossible to escape from the results of the said circumstances.

Also, since the school pool is accessible by the whole student body, the company faced difficulties in the arrangement of pool sessions for performing necessary underwater tests.

Technical

The company has faced problems with delayed product delivery and erroneously produced parts regarding the mechanical design of the ROV and had to reschedule their agenda carefully so as not to disrupt the whole process. The company has also faced misfortunes about the wrong cable delivery and the faulty voltage regulator delivery by the senders. During the underwater tests, a leakage occurred from the connection where the ethernet cable goes into the ROV. While testing the PCBs before using them in the ROV, some production defects are detected and taken care of swiftly by the electronics team.

Testing and Troubleshooting

No system or product is born free of errors and defects. As such, some methodological problem solving techniques should be developed to foresee the occurrence of these errors and to come up with solutions to address them. Concerning the design and the characteristics of the mechanical body of the ROV, a wide range of digital simulations, such as stress and flow analysis, are performed. Only after perfecting these simulations, pressure and leak testings are done.

The CASMarine company produces its own development cards which are used on the ROV. The design schematics of these cards are in accordance with the needs of aspects of the ROV and all related teams. After the

Income	Budget	Type
Budget from Last Year	$466,5	Income
Yıldız Technical Univestiy Funding	$320	Income
R&D Support Fund	$860	Income
Total Cash Income	**$1646,5**	
Sponsorships		
Mechanical Sponsorship	**Budget**	**Type**
Material Sponsorship	$83	Sponsorship
Manufacturing Sponsorship	$49	Sponsorship
Electronical Sponsorship	**Budget**	**Type**
Material Sponsorship	$1664,5	Sponsorship
Manufacturing Sponsorship	$50	Sponsorship
Total Sponsorship Income	**$1846,5**	
Entry Expenses	**Cost**	**Type**
MATE Entry Fee	$320	Funding
Test Models Manufacturing	$82	Purchased
Total Entry Expenses	**$402**	
Surface Control Station Expenses		
Mechanical Expenses		
Manufacturing Expenses	**Cost**	**Type**
Control Station's Grid	$20	Re-used
Material Expenses	**Cost**	**Type**
Control Station's Tough Case	$50	Re-used
Electronical Expenses		
Manufacturing Expenses	**Cost**	**Type**
PCB Manufacturing	$15	Re-used
Material Expenses	**Cost**	**Type**
Electronical Components of PCB	$30	Re-used
Electronical Components of SCS	$13	Re-used
Buttons-Switchs-Sliders	$20	Purchased
Main Computer	$907	Purchased
Gamepad	$45	Re-used
Monitor	$55	Re-used
Keyboard&Mouse	$20	Re-used
USB Multipiler	$3	Re-used
USB Cable	$4	Re-used
Total SCS Expenses	**$1182**	
NON-ROV (Vertical Float)Expenses		
Mechanical Expenses		
Manufacturing Expenses	**Cost**	**Type**
3D Printing	$10	Sponsorred
Material Expenses	**Cost**	**Type**
Bipolar Stepper Motor	$9	Purchased
Aluminum Tube	$212,5	Sponsorred
Electronical Expenses		
Material Expenses	**Cost**	**Type**
9V Battery	$8	Purchased
Stepper Motor Driver	$1,2	Purchased
Arduino UNO	$13	Re-used
Bar30 Pressure Sensors	$97	Purchased
Bluetooth Sensor	$5	Sponsorred
Total NON-ROV Expenses	**$355,7**	

ROV Expenses		
Mechanical Expenses		
Manufacturing Expenses	**Cost**	**Type**
Turning	$14	Sponsorred
CNC Router	$20	Sponsorred
3D Printing	$15	Sponsorred
Material Expenses	**Cost**	**Type**
Aliminium 6000	$35	Purchased
Thermoplastic Homopolymer	$25	Purchased
Raise 3D Premium PLA Filament	$30	Sponsorred
High Density Polyethylene	$20	Purchased
Savöx Servo	$109,125	Re-used
Penetrator	$53	Sponsorred
Tower Pro Sg90 Servo Motor	$2,73	Re-used
Enclosure Vent and Plug	$17,5	Re-used
Electronical Expenses		
Manufacturing Expenses	**Cost**	**Type**
PCB Manufacturing	$50	Sponsorred
PCB Shipping	$40	Sponsorred
Material Expenses	**Cost**	**Type**
Electronical Components	$187,5	Sponsorred
Soldering Materials	$50	Purchased
Electronical Connectors	$120	Purchased+Sponsorred
Power Cable	$87,5	Re-used
Data Cable	$600	Sponsorred
IMU Sensor	$66,25	Re-used
Bar30 Pressure Sensors	$97	Purchased
220V-48V Power Converter Care	$57	Purchased
48V-12V Power Regulators x3	$84	Re-used
Blue Robotics T200 Thrusters x4	$680	Sponsorred
Blue Robotics T100 Thrusters x4	$480	Re-used
NVDIA Jetson Nano	$145	Re-used
USB CAM x2	$164	Purchased
Total ROV Expenses	**$2909,6**	
Total Expenses	**$4849,3**	
Total Re-used and Sponsorred Items	**$3297,23**	
Total Cash Income	**$1646,5**	
Net Balance	**$94,43**	
Next Year Investment	**$94,43**	

Fig 61 : Project Budget Table

designing process, the cards are cross-validated between the electronics team members in order to come to a consensus about going to production. The produced cards, then, are tested periodically until the deployment of the ROV.

The CASMarine company software team separates into two branches: the high level software team and the embedded software team. Hence, the testing phase for these teams follows different patterns. The embedded software team built their algorithms as logic functions and truth tables. Thus, they predicted and controlled every possible result that an algorithm could produce by discretizing the related input and output variables. Then, these variables are tested using the debug properties of the used IDE. They also employed the use of oscilloscopes to ascertain the runtime of their algorithms and debug LEDs to monitor the behavior of the ROV with no need for any software. The high level software team utilized the standard output screen for basic debugging. They also employed the use of oscilloscopes to ascertain the runtime of their algorithms and debug LEDs to monitor the behavior of the ROV with no need for any software. The high level software team utilized the standard output screen for basic debugging. They also implemented a graphical user interface to see the result of their algorithms and use it as a feedback mechanism.

Lessons Learned

In the light of our previous experiences, our technical and institutional perspectives have evolved in a highly constructive trajectory. Regarding technical aspects, experiences have guided us to develop fast and reliable methods of design principles, and fast emergency manoeuvres. Examples such as cable-less coding with bluetooth and SSH protocols, or custom made boards to suit our specific needs are just a few noteworthy aspects. On the corporate side of things, we have adapted the hybrid working style as a by-product of the pandemic. To this end, collaboration platforms, namely Google Workspace and Github, are used for scheduling and sharing codes & files. This put away the oral working tradition and established a professional work approach.

Future Improvements

CASMarine has always used the knowledge cultivated from past years' projects to come up with a better improved, more sophisticated system every year. With this vision, it is fairly clear to CASMarine that the next years' remotely operated vehicle will indeed be superior to its predecessor.

The CASMarine company is fairly enthusiastic about future improvements. After the innovations that had been done this year, one of the future improvements we want to add to our vehicle is to make ROV's architecture based on the Robot Operating System(ROS). We aim to use ROS in our vehicle in the future because of the advantages it offers such as having a modular system organized around maintained nodes, better control features and being a standard operating system used in robotics studies.

In addition, autonomous navigation studies will be carried out in order for our vehicle to be more successful in autonomous tasks and to drive without pilot intervention in the pool.

Also, we aim to use some acoustic sensors such as sonar and hydrophone on our ROV for a deep exploration at underwater. Thanks to it, our ROV will be able to underwater mapping and detecting acoustic waves.

Corporate Responsibility

Every year, the CASMarine Company volunteers to deliver several free robotics trainings to our university's students. More than 1000 students from various departments at our institution apply to these trainings, which we conduct to instill a passion of robotics and create awareness in the field of underwater exploration, and each training has roughly 250 students. We even support students with such little knowledge of robotics, encouraging and integrating them into our community.

We give Arduino, Robotics, and underwater robotics instruction to high school kids as part of the STAR Project, in collaboration with the IEEE Wie (Women in Engineering) Committee, one of the other committees of IEEE YTU, the student organization with which we are connected. Our team conducts similar trainings at the high school they attend for a day, raising awareness about topics such as underwater vehicles for future engineers and women in engineering. In addition, following the course, we coach these students and help to their growth.

Figure 62 : Robotics Training for Besiktas Anatolian High School Students

APPENDIX

Safety Checklist

Pre-Start Checks

- All team member are wearing their masks/safety gear.
- Disconnecting power before checking the following steps.
- All parts are fastened and fixed in place.
- Fuse is functional.
- Cables are all connected and are tied down.
- Propellers are safe to function with no obstacles
- All seals are correctly installed
- Power switches are functional
- Endcaps are connected correctly
- Connect the vacuum and pump the volume to –30kPa
- Plug the vent and call "Watertighness safe!"

Pre-water Checks

- Connect tether to control station and power the system.
- Check the camera system.
- Check the joystick and thrusters are working.

In-Water and Retrieval Checks

- When first launched, check for unusually big bubbles.
- Call for retrieval.
- Check if thrusters are stopped and power is off.
- If safe to retrieve the ROV, secure it with the necessary equipment.

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Prof. Dr. Ozan Erdinc – His time, experience, and management for the team

Assoc. Prof. Revna Acar Vural - Her time, experience, and management for the team

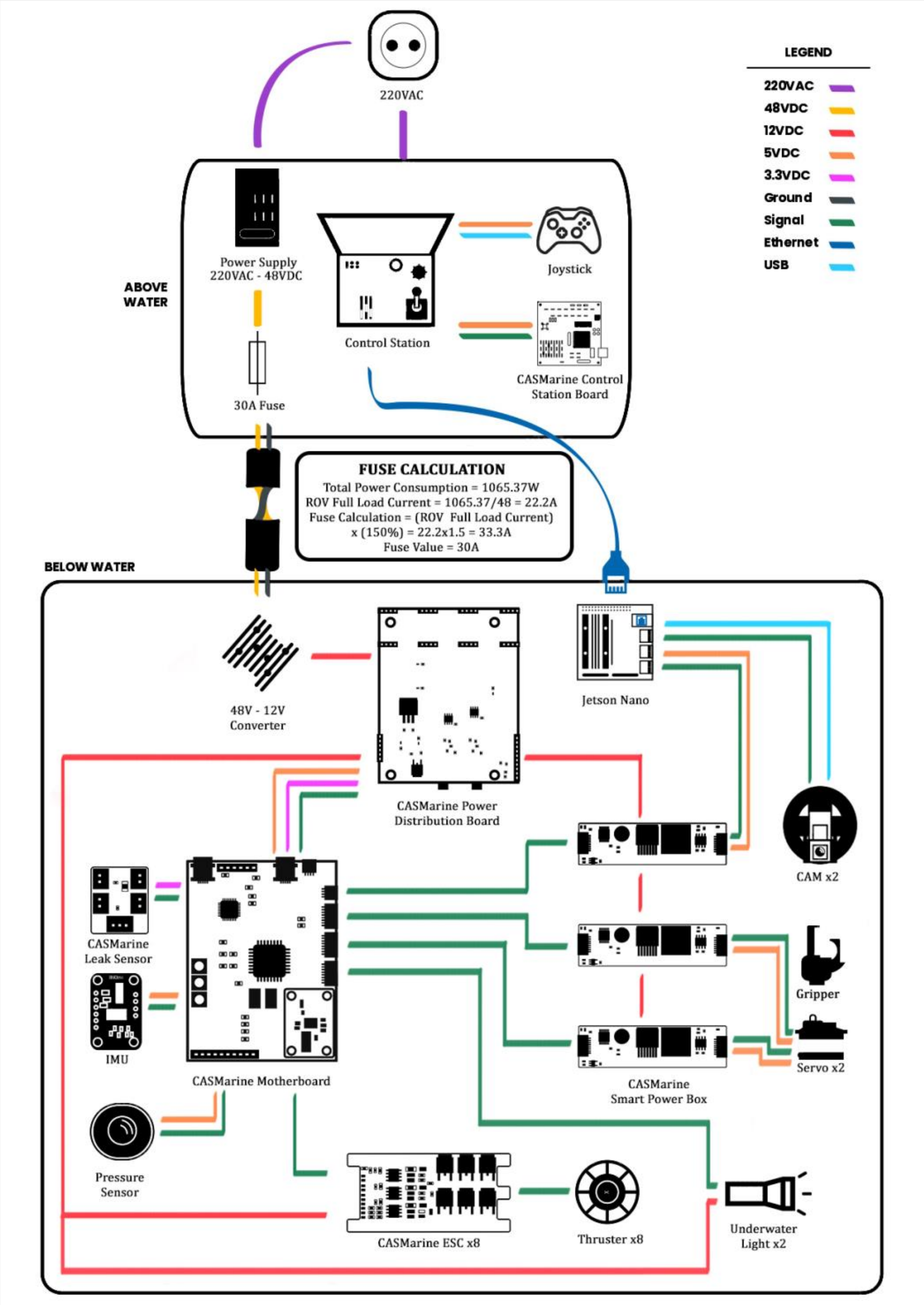
220VAC
LEGEND
220VAC
48VDC
12VDC
5VDC
3.3VDC
Ground
Signal
Ethernet
USB
ABOVE WATER
Power Supply
220VAC - 48VDC
Control Station
Joystick
30A Fuse
CASMarine Control
Station Board
FUSE CALCULATION
Total Power Consumption = 1065.37W
ROV Full Load Current = 1065.37/48 = 22.2A
Fuse Calculation = (ROV Full Load Current)
x (150%) = 22.2x1.5 = 33.3A
Fuse Value = 30A
BELOW WATER
48V - 12V
Converter
Jetson Nano
CASMarine Power
Distribution Board
CAM x2
CASMarine
Leak Sensor
IMU
CASMarine Motherboard
Gripper
Servo x2
CASMarine
Smart Power Box
Pressure
Sensor
CASMarine ESC x8
Thruster x8
Underwater
Light x2

Fig 63 : SID