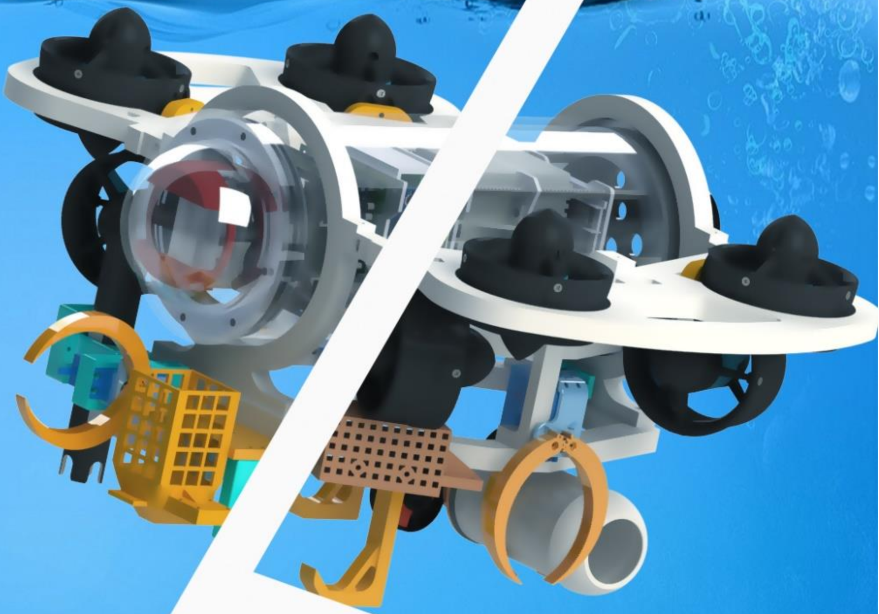
CAS MARINE



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2019 TECHNICAL REPORT

1. INTRODUCTION

1.1. ABSTRACT

The technical report of **CASMarine** remotely operated vehicle (ROV) expresses the company organization of IEEE Yildiz Technical University Circuits and Systems Society, mission and the technical data of the project. The project **CASMarine** is designed to be a ready-to-use ROV for Marine Advanced Technology Education Center's ROV competition that will be held in June 2019. In the process of construction, meanwhile attaching importance to electrical, mechanical and software design, we also paid regard to project management and safety.

The chassis of CASMarine is manufactured from High Density Polyethylene (HDPE). The ROV has eight thrusters controlled from a Main Controller Board (MCB) via peripherals board. Four of these thrusters are in charge of vertical movement while the others are for two-dimensional horizontal movement. The ROV is controlled via a control station on the ground. The Ground Control Station processes the images received from ROV's camera.

The electrical system of ROV has a modular structure. This system consists of a motherboard and 4 sub-module boards, each board has functions including but not limited to power regulation and communication. Also, we designed a custom module board template that may help design a unique module to implement an additional desired function if needed.

The software of the Main Controller System of the ROV is written with SW4STM32 and Keil MDK ARM 5 using C and C++ programming languages. MCB and subsystem boards are also responsible for all the underwater duties and the communication with Ground Control Station.

The company have been very decisive on the sub-task of the project. The development periods of the project were planned before our technical team started to design and manufacturing process. The lessons learnt throughout the design, manufacturing and the test period are also expressed in the report.

1.2. COMPANY ORGANIZATION

The Circuits and Systems Society of IEEE Yildiz Technical University, with its 10+ years of technical experience on unmanned vehicles, will participate in the Marine Advanced Technology Education Remotely Operated Vehicle (MATE-ROV) Competition for the second time this year. Our team attended the MATE-ROV Turkey Competition for the first time on April 2017 and secured 3rd place in the Explorer Category in the MATE-ROV Turkey 2018 competition.

CASMarine Team

2. DESIGN PROCESS

In the first phase of the project, the team observed other teams in the competition area, started to prepare trade-offs on which components would be used. Almost every technical report and specification sheet of previous years were read. Afterwards both the electrical and mechanical designs for the ROV were set in motion.

In that period, CASMarine's software engineers started to find the best platforms for coding, so that the ROV can provide the maximum performance.

Many design drafts in both electrical and mechanical aspects were discarded. The last design that is offered to the customers is the final work of the whole company. Cutting edge technology was used to manufacture the final design.

The material chosen for the chassis of the ROV was HDPE which was then milled on a CNC machine. Lead-free PCBs were used for the Main Controller Board. The ROV CASMarine was tested in all possible conditions it may face and proved successful.

3. MECHANICAL DESIGN

The main frame is designed as an octagonal shape. This structure allows the motors to be placed at the required angles. The enclosure is connected to the outer frame by two clamps, one at the front and one at the rear. The clamp system allows for easier access to the enclosure and easy operation.

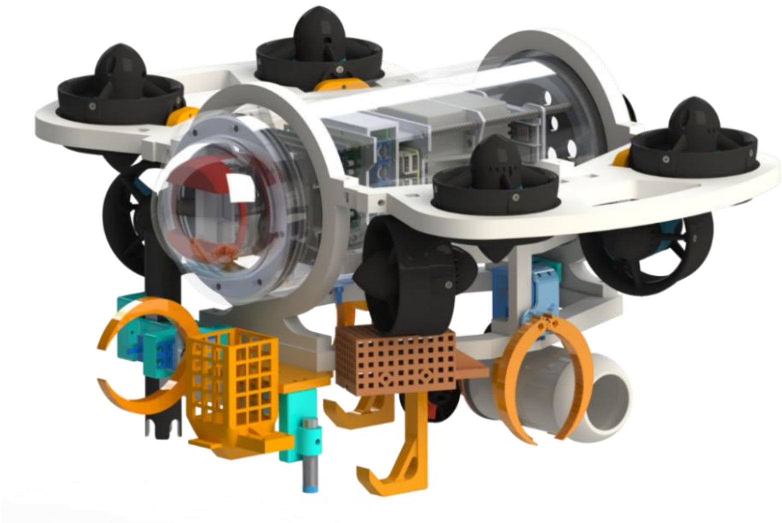


Fig 1: CASMarine V

3.1. CHASSIS

CASMarine is expediently designed by focusing on power and stability according to Marine Advanced Technology's ROV Competition 2019 restrictions. The earlier draft on the frame design was contemplated from high-density polyethylene. This design provides robustness to ROV because its material is solid and lightweight. In this way the vehicle is lighter and faster.

Whole chassis has a modular structure. In this way, the parts causing the disadvantage during the tests can be redesigned without changing the other parts and ROV can work more efficiently.

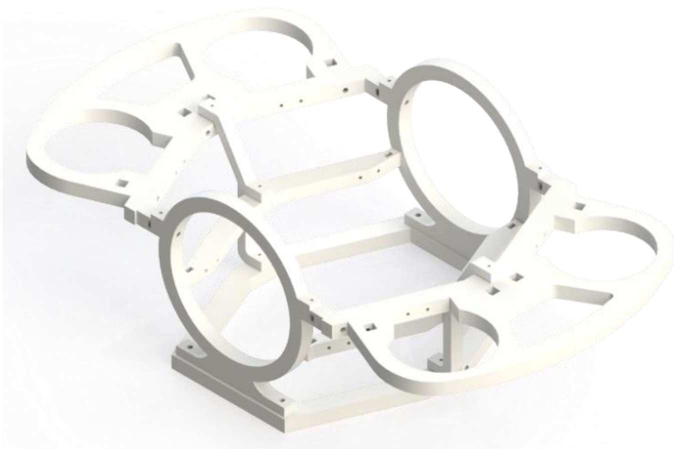


Fig 2: CASMarine V HDPE Chassis

3.2. ENCLUSURE AND FLANGES

The enclosure system is designed as a plexiglass tube that one side of the tube is as dome (for camera view) and the other side of the tube is plain with waterproof cable connectors. The reason that we have chosen a tube for the enclosure is the convenience in the production process and its high manoeuvre potential in fluids.

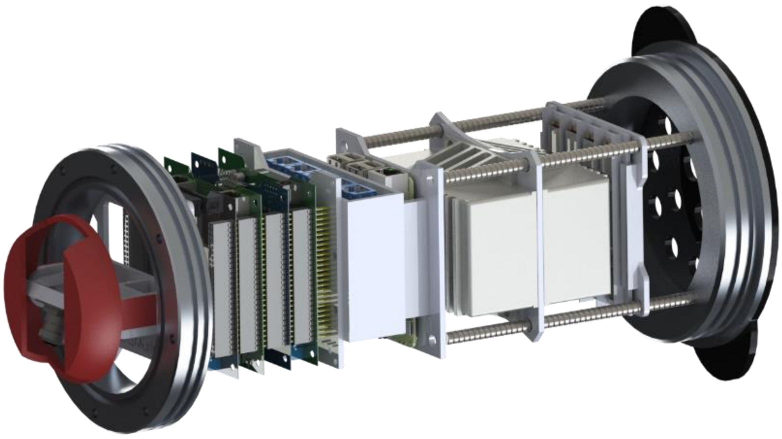


Fig 3: CASMarine V Hardware

The ease of access to electronic circuits makes it possible to quickly fix in system failures during testing and to perform software and hardware changes quickly.

A screwless plug-in mechanism is designed for quick access to the electronic system. The plug mechanism is surrounded by 2 pieces of o-ring for waterproofing. Furthermore, the plug structure is a system that allows the circuits to be easily removed when they are mounted on the circuits and removed.

3.3. WATERPROOF CONNECTORS AND CABLE GLANDS

Flange has 2 waterproof connectors attached to it. One is responsible for data flow while other one is responsible for power. Flange also includes 9 cable glands for motors.

Chosen waterproof connectors for ROV are Weipu WY Series (Bayonet) which has IP67 rating and zinc alloy with chrome plating. The connector has 9 pins and each pin can conduct current up to 13 Amper. Connectors has bayonet docking mechanism.

Fig 4: Waterproof Connectors

3.4. THRUSTERS

The ROV has eight BlueRobotics T100 thrusters controlled from Main Controller Board (MCB) via peripherals board. Four of these thrusters are in the charge of vertical movement while the others are for two-dimensional horizontal movement.

Each thruster can apply 25 Newton of force and each thruster can draw up to 12.5 amper [2].

Fig 5: T100 Thruster

3.5. GRIPPER

The gripper is one of the most important parts for the vehicle to perform its tasks. The robot arm is controlled by commands from the control station. With the movement of the servo motors on it, it performs the object holding process. The robot arm can be produced with 3D printer.

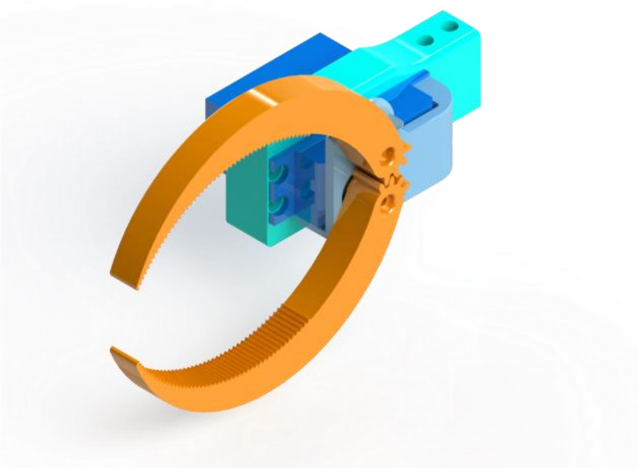


Fig 6: Main Gripper

3.6. PAYLOADS

Stone box has been designed to have minimum volume to satisfy calculated values. To release the stones box includes a solenoid valve that holds 2 hatches. Valve opens when required voltage is applied. Box has been manufactured from PLA using 3D Printer.

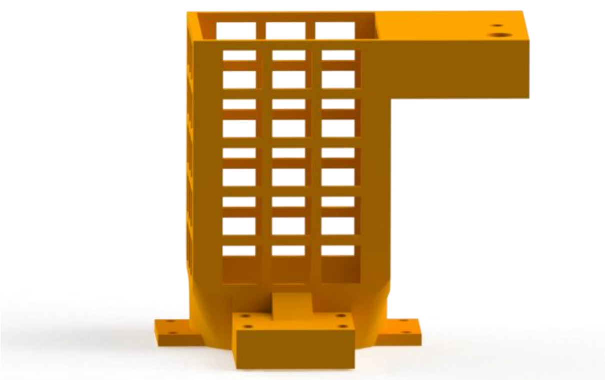


Fig 7: Stone Box

Fish Box includes a solenoid valve that releases hatches when required voltage is applied. With the hatches opened fishes release. Box includes 2 fishes that has been manufactured in given measures.

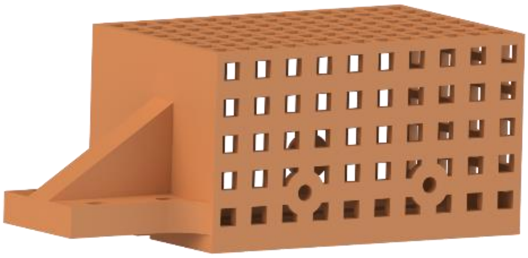


Fig 8: Fish Box

Vertical grippers are designed to grip the parts at the bottom of the vehicle. Two of these grippers are placed at the bottom octagon of the vehicle.

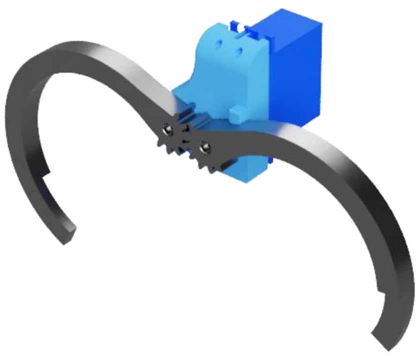


Fig 9: Vertical Gripper

3.7. MECHANICAL SPECIFICATIONS TABLE

Parameter	Value	
Physical		
Length	450 mm	18 in
Width	400 mm	15.7 in
Height	340 mm	13.4 in
Weight in Air	9-10 kg	20-22 lb
Construction	HDPE frame, aluminum flanges/end cap, and plexiglass tubes	
Performance		
Maximum Rated Depth	15 m	50 ft
Thrusters	BlueRobotics T100	
Thruster Configuration	8 thrusters	
Tether		
Length	22 m	70 ft
Working Strength	45 kgf	100 lbf
Buoyancy in Water	Positive	

4. ELECTRONICAL DESIGN

4.1. CONTROL SYSTEMS

In regular, electrical part of the ROV is either the set of many different commercial control boards, sensors, actuators, motors (for example; Arduino Uno, BlueESC etc.) or vehicle-specific electrical systems. However, CASMarine Electronical Control System is extremely flexible for the challenges of the missions.

Fig 10: CASMarine V Electronical Control System

The ROV Main Controller System forms by a Mainboard and many different subsystem boards. All the individual subsystems are designed (or will be designed) to perform a specific mission. Damaged subsystem boards can be changed with a new one and new subsystem boards can be attached for the ROV to achieve a specific work function in the future.

PC-104 Connectors

PC-104 connectors are considered as military grade and since they are DIP connectors, stability of module is significantly increased. PC-104 provides various pin length but in the system 39mm pins are used. Since connectors are gold-plated each pin can conduct current up to 6 Amper and strength of connectors significantly increases durability of system against any possible error.

Fig 11: PC-104 Connectors

4 boards (Motherboard, Communication Board, Regulation Board, Peripherals Board) are connected to each other to become a module via the PC-104 connectors on both sides of the boards. One of the two PC104 connectors provides power flow while the other one provides data flow. Power routes provide 12V, 5V, 3.3V and GND while data routes provide, including but not limited to, Timer, GPIO, I2C, SPI and UART.

Main Controller Board

The Mainboard is the platform that control embedded system in order to form a functional ROV. The Mainboard carries a 100-pin STM32F407VG microcontroller unit, a BNO055 9-degrees of freedom (DOF) absolute orientation inertial measurement unit (IMU) sensor to monitor the position of the ROV, a sixteen channels bidirectional logic level converter circuit (between 3.3V and 5V), 5V and 3.3V power supply headers, one SWD interface for programming, one UART interface for both communication and flash programming, a reset button, power light emitting diodes (LEDs) for 12V, 5V and 3.3V, four user LEDs.

Fig 12: Mainboard

- STM32F407VGT6 microprocessor, 32-bit ARM Cortex® -M4 core, 1-Mbyte Flash Memory, 192- Kbyte RAM, LQFP100 package
- SWD Programming Port
- Power Port (12V-5V-3.3V-GND)
- 2 x9-DOF Adafruit compatible IMU Port
- 2 x 8-bit Bi-directional Logic Level Converter
- 3 x I2C Buffer
- PC104 (Military/Aerospace Type Connector)

Communication Subsystem Board

The Communication Subsystem Board builds all the communication between the ROV and the outer world. All the control signals, sensor measurements are transmitted and received on via this board. The ethernet controller on this board may be reached by a RJ45 connector from outside.

Fig 13: Communication Board

- STM32F107RCT6 microprocessor: ARM® 32-bit Cortex®-M3 CPU with 64/256 KB Flash, USB OTG, Ethernet, 10 timers, 2 CANs, 2 ADCs, 14 communication interfaces, LQFP64 package
- 1 x SWD Programming port
- 1 x UART Serial communication port
- 1 x embedded Lan8720A Ethernet module
- 1 x CH340 TX-RX debug interface
- 7 x Timer output

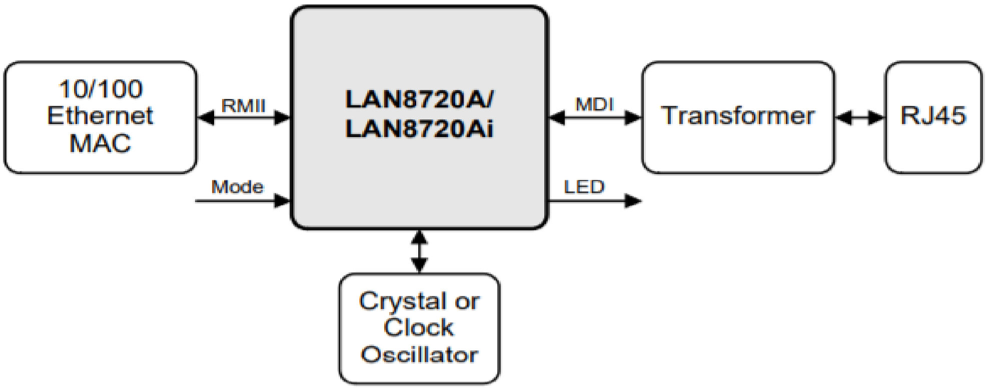


Fig 14: LAN8720 Connection Diagram

Board includes LAN8720A ethernet module to communicate with ground control station. Design provides both embedded and external shield attachment.

- Data Rate: 10/100 Mbps
- Supply Voltage: 1.6V to 3.6V
- Supply Current (Max): 49mA

Electrical Power Subsystem Board

Electrical Power Subsystem Board can regulate 12V to 3.3V 5V 9V and adjustable voltage. 3.3V regulation unit has TPS54231 Switching Mode Power Supply which regulates 12V supply voltage to 5V and directs it to AMS1117 Linear Drop-Out Regulator which regulates 5V to 3.3V [3]. The reason LDO is being used is to get low ripple voltage at output and increase efficiency. In 5V regulation unit LM2678 SMPS which can supply current up to 5 Amper is being used. In 9V regulation unit LM7809 LDO is being used. Board also include an adjustable regulation unit which includes TPS54231 SMPS. To adjust the output voltage board includes a potentiometer.

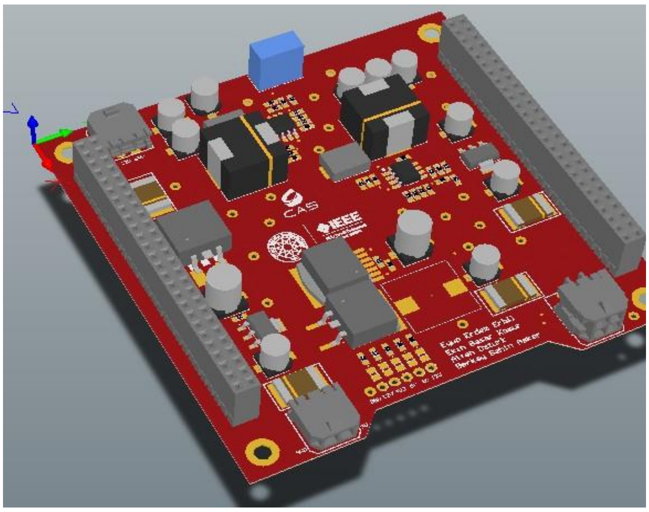


Fig 15: Power Subsystem Board

- High current protection on both input and outputs.
- Regulates 12V input voltage to 3.3V and can provide up to 800mA.
- Regulates 12V input voltage to 5V and can provide up to 5A.
- Regulates 12V input voltage to 9V and can provide up to 800mA.
- Regulates 12V input voltage to adjustable voltage and can provide up to 2A
- PC104 (Military/Aerospace Type Connector)

Our Electrical Power Subsystem Board has over voltage protection which cut offs just that power line's voltage. By default, our boards have 3.3V, 5V and 9V voltages. Over voltage protection is made to cut off the voltage if it has 3.5V, 5.6V, 9.8V and above values. Board also has 3A resettable fuse at both in input and outputs. When 3A threshold is reached power cuts off just on that power line. Also, board has reverse voltage protection on input.

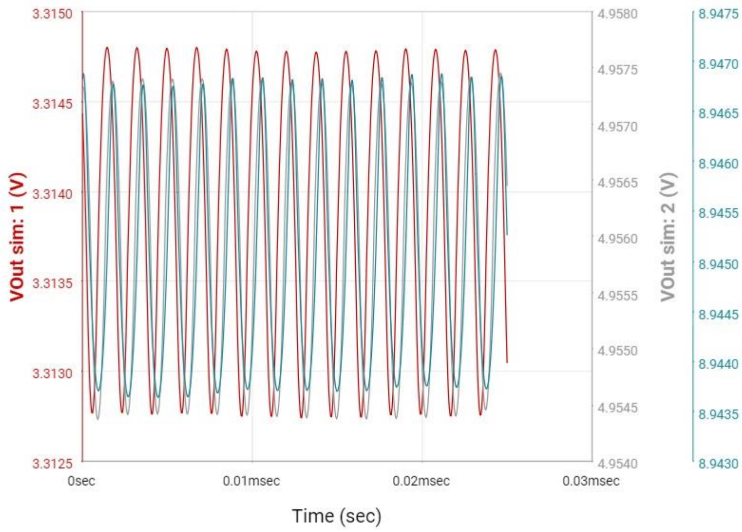


Fig 16: EPS Board Output Voltage Test Result

Peripherals Board

Peripherals Board is connected to other boards at the module via PC-104 connector. Board includes every pinouts of motherboard's processor STM32F407VGT6 and acts as an interface to other boards at the module. UART, SPI, I2C and SWD pins are accessible through on-board headers as well as regulated 3.3V, 5V, 12V. In order to use various sensor board includes PWM, GPIO, ADC pinouts. Also, board has a 20x2 IDC connector to transmit every pinout to Sub-Peripherals Board.

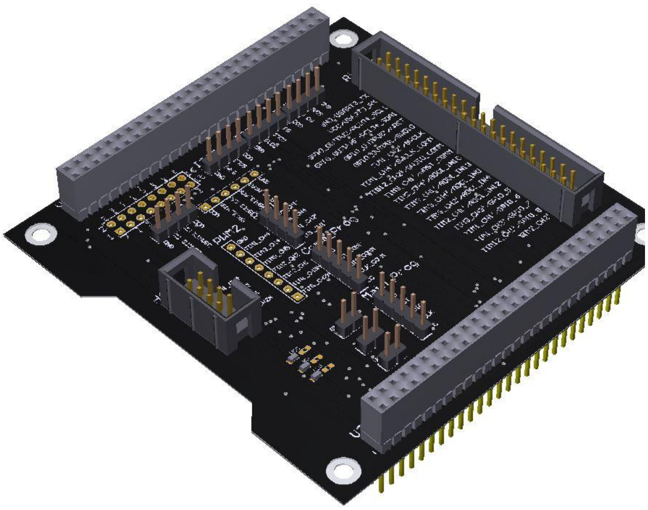


Fig 17: Peripherals Board Connections

- Compatibility with other boards via PC-104 connector
- 1 x UART Serial communication port
- 3 x I2C port
- 1 x SPI port
- 2 x SWD Programming port
- 3V3,5V,12V Outputs
- Connection with communication board via 4X2 IDC connector
- with Sun-Peripherals board via 20x2 IDC connector
- 7 x PWM output
- 5 x ADC, 5 x GPIO, 2 x PWM, 3 x GND output.

Subperipherals Board

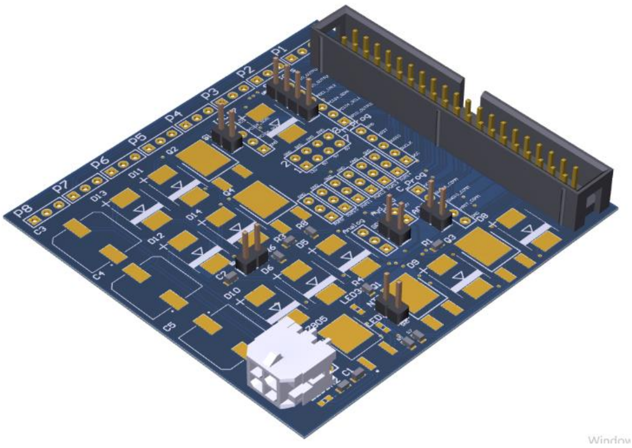


Fig 18: Subperipherals Board

- 6 PWM outputs that are used for drive 6 servo motors.
- 8 PWM outputs that are used for driving the 8 thrusters.
- 20 x 2 IDC connector that is used for establishing connection with the peripherals board.
- SWD port that is used for programming communications board and motherboard.
- 1 x UART port.
- 1 x I2C port.
- 1 x ADC.
- 12V and 5V power output

4.2. SENSORS

BNO055 IMU

The IMU includes a processor that was built on ARM architecture. This processor draws data from the internal gyroscope, accelerometer and magnetometer sensors which then it applies various filters to. The processor on the IMU communicates with the motherboard's processor (STM32F407) via I2C protocol.

Inclination data drawn from the sensor is then fed through the balance algorithm to be utilized as margin of error for the PID algorithm.

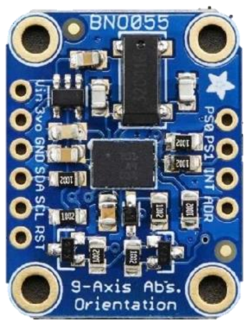


Fig 19: Bosch BNO055 9-DOF IMU

Pressure Sensor

Chosen sensor for underwater pressure calculation is BlueRobotics' Bar30 which includes MS5837 pressure sensor. The sensor communicates with the motherboard's processor (STM32F407) via I2C protocol.

Fig 20: Pressure Sensor

The pressure data drawn from the pressure sensor is then used to calculate concurrent depth with 2mm of accuracy [4]. Depth data drawn from the sensor is then fed through the balance algorithm to be utilized as margin of error for the PID algorithm.

pH Meter

This industrial pH electrode is made of sensitive glass membrane with low impedance. It can be used in a variety of PH measurements with fast response and excellent thermal stability. It has good reproducibility, is difficult to hydrolysis, and can eliminate basic alkali error.

In 0pH to 14pH range, the output voltage is linear. The reference system which consist of the Ag/AgCl gel electrolyte salt bridge has a stable half-cell potential and excellent anti-pollution performance [5].

Fig 21: Hioshi phMeter Sensor

4.1. MONITORING SYSTEMS

The ROV has 2 IP cameras which are placed in front and bottom of it. These are in charge of monitoring underwater footage to pilot. IP cameras stream its live view over HTTP MJPEG Streaming to Ground Control Station through ethernet cable. Model of IP Cameras is Dahua IPC-HDW1230s. It can stream at 30fps@1080p. It has angle of view of 104°/92° for horizontal and 55°/50° for vertical. Due to its large angle of view and our Pan&Tilt System, the pilot can observe underwater easily and control the ROV more accurately.

Fig 22: IP Camera Board

5. SOFTWARE

5.1. EMBEDDED SOFTWARE

MCB software of CASMarine is written to operate on the CASMarine Main Controller System carries an ARM based STM32F407VG microcontroller. The embedded code is written using the C and C++ programming language on SW4STM32 IDE by IEEE YTU CAS Company's engineers.

Balance Algorithm

Stabilization is an important matter of unmanned vehicle industry. With environmental disturbances (waves and currents) and unexpected environmental disturbances such as strong waves, the ROV could lose its stability. A balance algorithm was used to achieve stabilization.

The balance algorithm is based on PID (Proportional-Integral-Derivative) controller. PID controller is one of the most popular controllers applied in industries. Simple in structure, reliable in operation and robust in performance, therefore it has popularity among control engineers.

The proportional, integral, and derivative (PID) controller is well known as three term controllers. The input of the controller is the error from the system. The Kp, Ki, and Kd are referred as the proportional, integral, and derivative constants (the three terms get multiplied by these constants) respectively. In the PID controller, the error gets managed in three ways. In the PID function, the error will be used on the PID controller to execute the proportional term, the integral term for reduction of steady-state errors and the derivative term to handle overshoots.

Four motors can move the robot in roll, pitch axes and stabilize depth of ROV. The speed of the motors depends on three variables. These variables are pitch PID, roll PID, depth PID. The pitch PID and roll PID value is the speed vector required for the targeted angle on the pitch and roll axis, depth PID value is the speed vector required for the targeted depth [7].

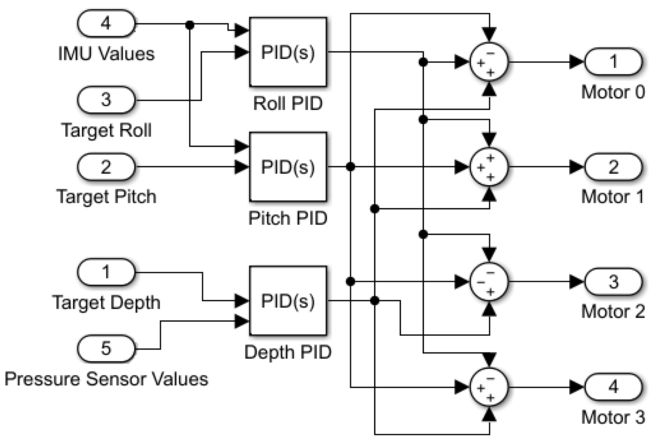


Fig 23: PID Values Calculation Diagram

To calculate the error values of destabilization, BNO055 9-DOF IMU and BlueRobotics high resolution pressure sensor was used. I2C protocol is used to read data from BNO055 and pressure sensors.

Horizontal Thrusters Force Calculation

The movement in the x and y axes is one of the essential requirements for ROV. The ROV has four motors to perform horizontal movements. These motors are placed at a specific angle to generate a force vector in any horizontal direction.

$$F_{HM1} = — F_{HM2} \; (1)$$

$$F_{HM2} = — F_{HM4} \; (2)$$

The required motor speeds are calculated based on the HM1 and HM4 motors. Then, the HM2 and HM3 motors are run opposite to the HM1 and HM4 motors as mathematically shown in (1) and (2).

$$F_y = F_{HM1} \oplus \cos(\pi/8) + F_{HM4} \oplus \cos(\pi/8) \; (3)$$

$$F_x = F_{HM1} \oplus \cos(3\pi/8) + F_{HM4} \oplus \cos(5\pi/8) \; (4)$$

Corresponding axis forces can be calculated using (3) and (4).

In numerical linear algebra, the Gaussian elimination method [4], also known as the Liebmann method or the method of successive displacement, is an iterative method used to solve a linear system of equations. The motor speeds are adjusted to generate the required motor forces calculated using the Gauss elimination method.

Ethernet Communication

ROV, utilizes a communications board to establish its communications with the control station. This communication method employs 2 types of protocols; SPI, which handles the exchange between motherboard and the communications board, and Ethernet, which handles the exchange between the control station and the communications board. The communications board takes advantage of DMA to perform the conversion between SPI and Ethernet protocols.

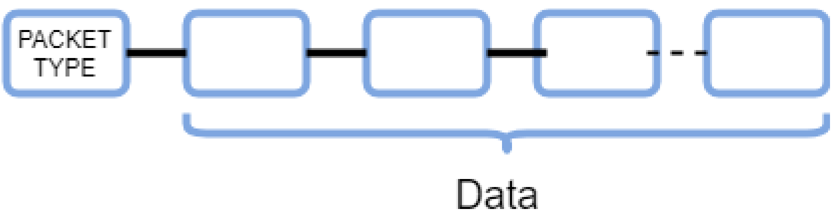


Fig 24: Communication Packet Diagram

Lower, hardware layers of the Ethernet communication are processed internally by an integrated circuit called LAN8270 Ethernet PHY. The remainder of the layers are developed at a software level. Communication between the processor and the Ethernet PHY integrated circuit is handled with a protocol called RMII (Reduced Media Independent Interface). Compared to its predecessor MII

(Media Independent Interface), RMII requires double the clock frequency(50MHz) but it uses half the pin connections. Even though the higher clock frequency proved difficult to work with, the flexibility decreased number of pin connections provides, more than made up for it.

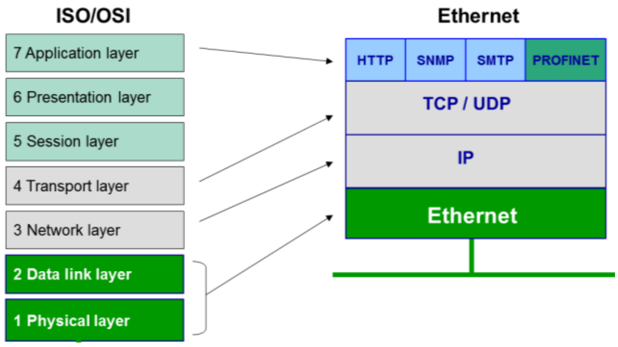


Fig 25: OSI Layers

The preferred method of communication on the transport layer is handled by an Ethernet protocol called UDP instead of its alternative TCP. The reason being; although TCP protocol operates more reliably by checking whether the packages arrived their destination, which makes TCP substantially slower. This handicap hinders the ground control stations ability to perform manoeuvres requiring immediate response.

To prevent synchronization problems between Ethernet and SPI, DMA is used. DMA acts as a second master to the core of the processor by handling the SPI communication as to prevent overloading the processor by taking some of the processing load off of it.

To circumvent possible synchronization issues, the processor stores the last data received over the Ethernet until the motherboard requests said data. SPI protocol allows the data to flow both ways since it has the ability to gather and to send data simultaneously. This allows communications to have considerable decrease in delays.

Benthic Detection Software

Using the feature of OpenCV and Java, it detects color and shape of objects. Image processing can be easily turned on/off by clicking to a button. For the future developments on camera number, ROV's image processing program supports two image process at the same time.

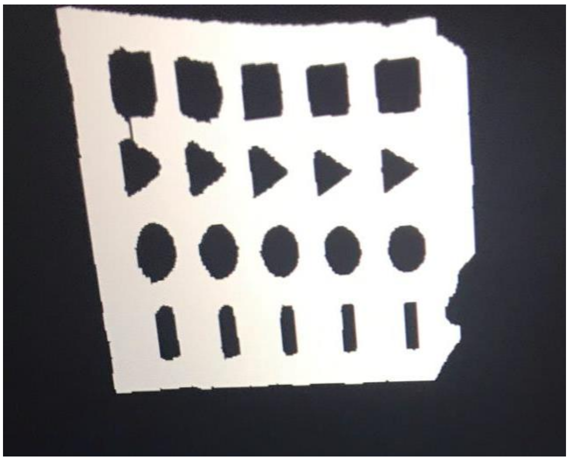


Fig 26: Benthic Detection

Firstly, the frame is converted from bgr format to hsv format and determines white lower and white upper values. Since the background of the paper that contains the shapes is white, we apply a white filter. And then we apply erode and dilate operation to remove the noises. Later then, contours are found and have the largest area is determined. The largest area is cut slightly from the edges of the contour and applied bitwise not operation to the frame because of the shapes colour is black. And again, contours are found and determine the approximate edges. If contour have 3 edges, this contour is triangle and if it has 4 edges and these edges equals each other, this is square else this is rectangle. Finally, if has more than 10 edges, this is a circle.

Autonomous Driving Software

Image Processing Software allows autonomously driving the ROV. As a matter of payload, the ROV must follow the red line on the wall. The red line which is representing the route the ROV should follow is placed on black coloured grids. The ROV starts following the line by detecting red rectangle. Image Processing Software using some filters to the frame that taken by the ROV's camera.

Filtering process starts with colour filter. Colour filter filters red colour with inRange function from OpenCV library. It blurs the frame for smoothness with medianBlur function. Then it applies erosion two times on frame to clear noise with erode function. When the noise is cleared, it dilates the frame two times to get more evident contour.

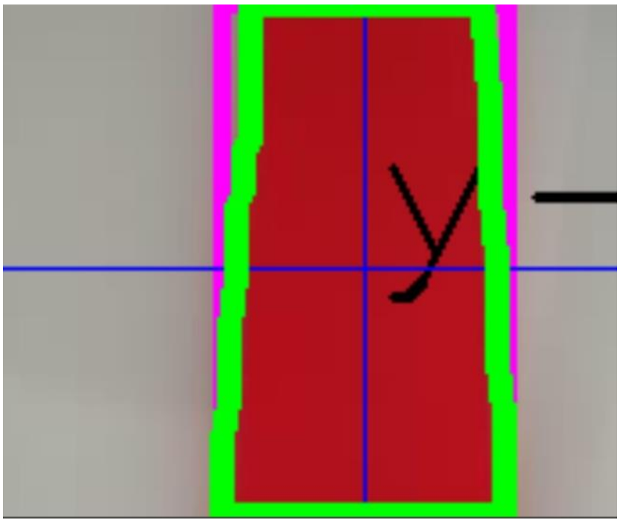


Fig 27: Autonomous Driving Footage

Then it finds contours and detects rectangle. It finds center of the rectangle and compare with center of the bounding rectangle of largest contours. If these two centers are not equal, it calculates direction of rotation and sends it to the ROV then gest next frame. Else, it passes the frame and gets next frame.

6. GROUND CONTROL STATION

The Ground Control station is tasked to manage the controller inputs (such as the buttons, sliders, joystick etc.), monitoring the ROV (displaying the camera data and gyro data fetched from the ROV), process the images received from ROV and to establish the main communication bus in the system (UDP) on the Ethernet interface.

Fig 28: Ground Control Station

6.1. GCS HARDWARE

On the front panel of Control Station, there are 4 buttons, 4 switches, 3 sliders for controlling ROV and 1 emergency button and 1 switch for controlling power.

Inside the Ground Control Station, Arduino Mega is assigned to collect the data from the buttons and sliders on the box and send them to the main computer via UART interface.

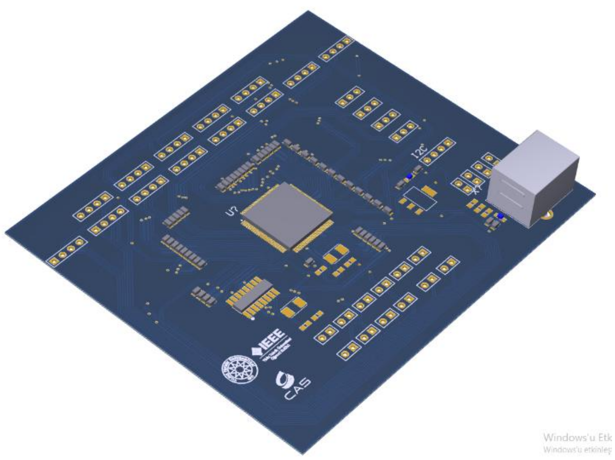


Fig 29: GCS I/O Board

Main computer of the CASMarine Ground Control Station is a computer formed by a motherboard, SSD hard disk, RAM, power source and a monitor. It is not an ordinary personal computer (PC) but a computer assembled with only the necessary and sufficient components by the well qualified engineers of CASMarine company. This solution is chosen so that the CASMarine can provide more savings on power consumption but less complexity in the design.

6.2. GCS SOFTWARE

Control station user interface allows to control robot. It is written in Java and is designed to support many technologies. Consists of functional buttons, camera frames, 3D modelling, chronometer, check list, pictures, notification screen and finally terminal sections

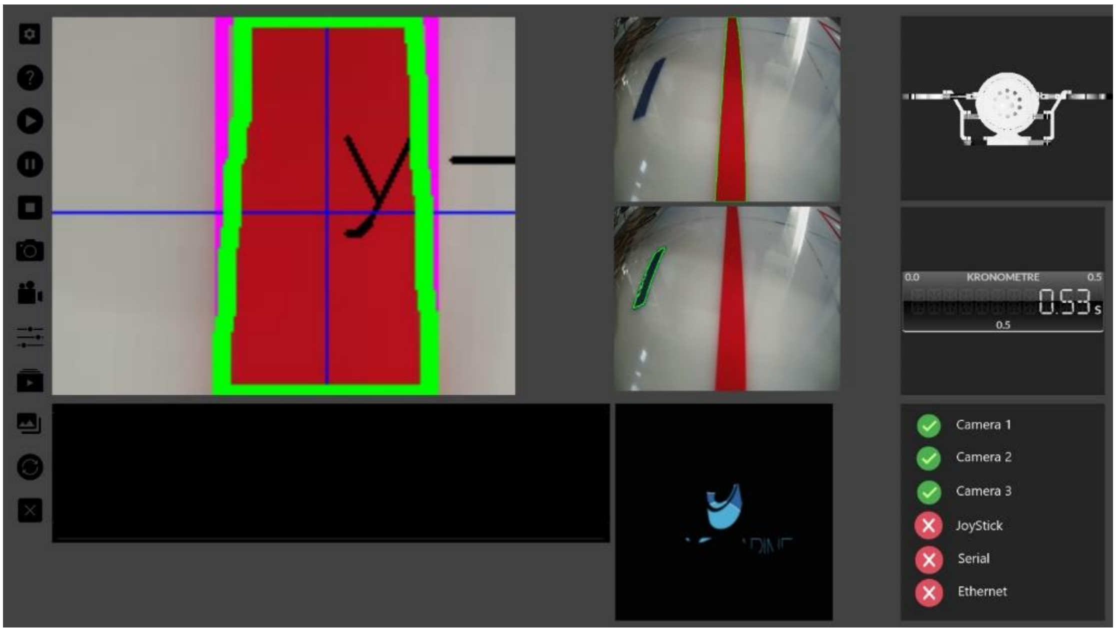


Fig: GCS Graphical User Interface

Functional buttons consist of configuration settings, button assignments, image processing settings, playback, pause, stop, refresh, taking photo, video capture, video playlist, album, help and exit buttons. So, this allows to user to change the pid values without programming into the robot.

Additionally, ground control station software sketches the 3D model of ROV using data received from ROV's sensors. It gets roll, pitch and yaw values from BNO055 then orients the model simultaneously. Furthermore, Checklist checks the operation of camera, Arduino, joystick and ethernet. If there is an error in anywhere, it is reported on the notification screen. Also, the terminal provides some commands to execute the corresponding functions. Pid values can be configured from the command line to the robot, ping can be measured with the ping command, can go to debug mode and can run many more functions.

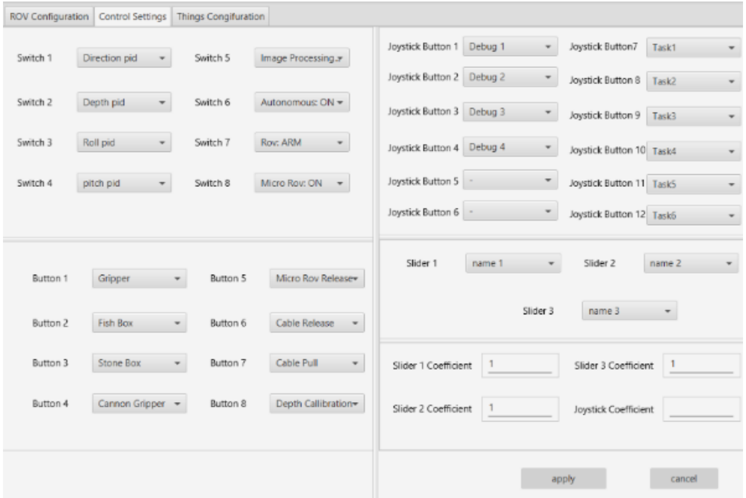


Fig 30: GCS GUI Settings Screen

Config settings section allows to easily change the robot's pid values. In addition, all these values are updated in a file so that the current values are automatically loaded when the robot is turned off and on. The control settings section allows you to assign the desired task to the desired button or switch.

7. MICRO ROV

Our Micro ROV design is based on the shape of a torpedo which achieves its mobility with 2 thrusters placed behind the Micro ROV and 1 servo-driven counterweight in the ROV.

We manufactured this particular design from polyoxymethylene is a thermoplastic which also known as Delrin. This material is characterized by its high strength, hardness and rigidity. Its density is 1.410–1.420 g/cm3. When the inner gap considered, this design's overall density is slightly lower than water's density. This situation helps us to dock Micro ROV to the Main ROV.

Fig 31: Micro ROV Design

Micro ROV is supplied with 12V DC and communicates over UART (Universal Asynchronous Receiver/Transmitter). These lines provided with 4-pin flat phone cable. The circuit includes 2 SMPS (Switch Mode Power Supply), 1 Arduino Pro Mini, 1 Bosch Sensortec BNO055 IMU, 2 Hobbywing xRotor 20A ESCs, 1 MG90S Micro Servo and 1 generic DVR camera. While 1 SMPS circuit isolating the +12V DC line from the whole system to supply clean +12V for the camera, other SMPS regulates the voltage to +5V to supply the servo of counterweight.

Micro ROV controlled via Arduino Pro Mini development board with Bosch BNO055 IMU attached to it. This controller communicates with the Ground Control Station over Splitter Box and Main ROV. We obtain the IMU data and process it in our control algorithm to stabilize the Micro ROV while moves according to commands sent from Ground Control Station. The control algorithm is based on PID which a well-known and proven algorithm in control area is. According to output of the control algorithm, two BLDC-driven thrusters stabilize the Micro ROV in yaw axis while servo-driven counterweight stabilize it in pitch axis with principle of changing the center of mass.

8. SAFETY

8.1. LABOR DISCIPLINES

As IEEE YTU CAS Company, we provided safety in each part of manufacturing. All of the safety instructions were applied properly by every team member while working with dangerous contents such as chemicals, hot glue, and epoxy.

Our electronics sub-team used required equipment such as gloves and extractor. Soldering and programming was made with ESD materials in clean room.

8.2. ROV SAFETY SYSTEMS

Our Electrical Power Sub-system Board has over voltage protection which cut offs just that power line’s voltage. In regular, our boards have 3.3V, 5V and 9V voltages. Over voltage protection is made to cut off the voltage if it has 3.5V, 5.6V, 9.8V and above values. We also have 3A resettable fuse for protection. Also, board has reverse voltage protection on input.

In our Ground Control Station, there is a kill switch which can be used for cutting the power off of ROV by user. There is also an Emergency Stop Button to cut all system’s (ROV and GCS) power.

Warning labels are placed on thrusters and moving parts.

8.3. ROV SAFETY PROCEDURE CHECKLIST

PRE-LAUNCH CHECK LIST

•KEEP POWER SUPPLY OFF

•CONNECT POWER CABLE TO THE ROV

PRE-DIVE CHECK LİST

• LAUNCH GROUND CONTROL STATION

• POWER THE ROV

• LAUNCH THE ROV

• CHECK ELECTRONIC SYSTEM FROM GROUND STATION

• PUT THE ROV ON THE GROUND AND PROVIDE SAFETY

• PUT THE ROV IN MANUAL MODE

• ARM THE ROV

• PRESS THE FORWARD/REVERSE STICK FORWARD TO CHECK THAT THE VECTORED THRUSTERS ARE SPINNING FREELY AND IN THE CORRECT WAY

• PRESS THE ASCEND/DESCEND STICK FORWARD TO CHECK THAT THE VERTICAL THRUSTERS ARE SPINNING FREELY AND IN THE CORRECT WAY.

• DISARM THE ROV.

• PUT ROV INTO WATER

• ARM THE ROV

• CHECK WHOLE VEHICLE AGAIN FROM GROUND STATION (CAMERA, ELECTRONIC DEVICE…)

• LEAK CHECK

• ROV'S BUOYANCY AND STABILITY CHECK

DIVE CHECK LİST

• START TIMER

• IF MISSION IS COMPLETED, TAKE ROV TO THE GROUND

9. PROJECT MANAGEMENT

The company works in a strict collaboration principle. Whole process of the production including project planning, preliminary design, manufacturing and testing have been supervised by Chief Technical Officers of these sub-teams. This collaboration between teams drives the company to produce the best of their capabilities. Our Chief Executive Officer and Chief Technology Officers made sure that all team members understood the competition rules and requirements.

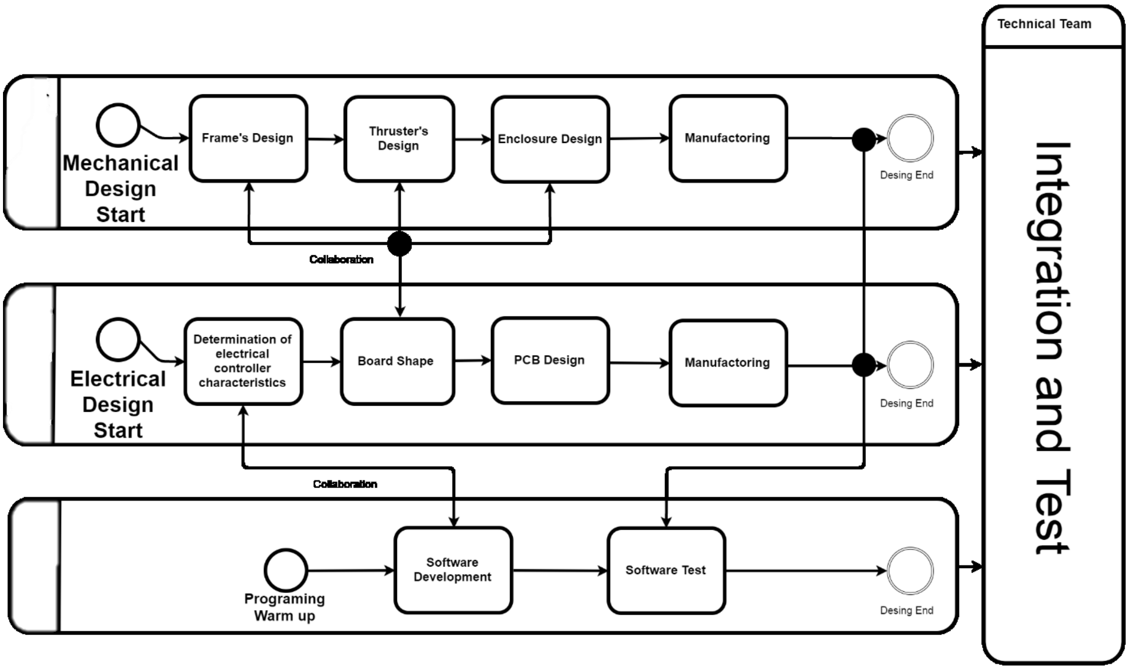


Fig 32: Design and Manufacturing Phases

9.1. TEAM STRUCTURE

The team of CASMarine is formed by ten undergraduate students of Yildiz Technical University. The team works on not only technical issues but also on project management and resource management. Different sub-teams form the whole company. These groups may be referred firstly, the technical team and the project and budget management team. The technical team is also divided into three sub-teams named mechanical, electrical and software teams.

9.2. POTENTIAL CLIENTS

Companies such as DSI, Cengiz Holding, Limak Holding, Ramboll and Audubon are maintaining their activity in the underwater sector. Companies like these may be possible clients in the future.

At the same time Su Altı Araştırma Derneği, Aktif Balık Adamlar Derneği and Sufod are maintaining their activity in the underwater research. Because of that they also can be be possible clients in the future.

9.3. BUDGET MANAGEMENT

CASMarine company’s wish is to offer their customers the best price and the best performance at the same time. In the light of this ideology, we always tried to find the best solution with less cost to the project. Our Company offered us the best purchasing options after hard efforts.

ROV			
Item	**Qty**	**Price**	**Sub-Total**
IP Camera	3	$100,00	$300,00
BlueRobotics T-100 Thruster	8	$120,00	$960,00
Waterproof Servo	5	$30,00	$150,00
PC-104 Connector	8	$5,00	$40,00
Cable Gland	9	$1,00	$9,00
Power Converter	3	$25,00	$75,00
CAT6 Cable	1	$12,00	$12,00
Aluminium and HDPE	1	$80,00	$80,00
TTR Power Cable	1	$22,00	$22,00
Cable Socks	1	$6,00	$6,00
PCB Production	1	$100,00	$100,00
Pressure Sensor	2	$70,00	$140,00
IMU Sensor	2	$35,00	$70,00
Ethernet Switch	1	$20,00	$20,00
ESC	8	$15,00	$120,00
Components	1	$200,00	$200,00
TOTAL			**$2304,00**

Fig 33: ROV's budget table

Ground Control Station			
Item	**Qty**	**Price**	**Sub-Total**
48V Power Supply	1	$120,00	$120,00
Button, Slider, Switch Emergency Button	40	$0,20	$8,00
Motherboard	1	$80,00	$80,00
Processor	1	$150,00	$150,00
PSU	1	$80,00	$80,00
RAM	1	$80,00	$80,00
Mouse-Keyboard	1	$30,00	$30,00
Monitor	1	$80,00	$80,00
TTR Power Cable	1	$90,00	$90,00
Joystick	1	$70,00	$70,00
Mano Box	1	$80,00	$80,00
SSD	1	$30,00	$30,00
Cables	1	$7,00	$7,00
TOTAL			**$905,00**

Fig 34: GCS Budget Table

10. ACKNOWLEDGMENTS

As CASMarine company, we would like to express our gratitude to the following for their support:

Yildiz Technical University - for providing us a useful workspace.

Asst. Prof. Umut Engin AYTEN - for mentoring us.

Yildiz Technical University Social Facilities Office– for providing a pool for testing.

Shell Turkey – for sponsoring.

TeknoPark YTU – for providing manufacturing and workspace.

MATE Center – for organizing competition.

Samtech – for sponsoring.

Molex – for sponsoring.

Yumak Aluminium – for sponsoring aluminium manufacturing.

11. CONCLUSION

11.1. TESTING AND TROUBLESHOOTING

We made market research for the servo motor that we plan to use in our robot arms then we ordered various servo motors that are suitable for our system and tested them underwater. After the test results we choose the most suitable servo motor for our system.

11.2. CHALLENGES

One of the most challenging part of our development stage was autonomous tasks. Autonomous tasks mostly depend on image processing. Due to the hardness of image processing underwater, we researched a lot about filtering and smoothing frames. It took very long time and so much experiments to accomplish image processing successfully.

11.3. LESSON LEARNED

As IEEE YTU CAS we are very satisfied with the final outcome of CASMarine 2019. We were able to find solutions to the problems we faced in last year's competition. Last year, we had connection loss issues because of our motherboard system. We designed new modular system to solve this issue.

11.4. FUTURE IMPROVEMENTS

Our electronics team still works for Electrical Speed Controllers board.

Our mechanical team is working on a new thruster design. We are planning to use these thrusters in our future designs.

11.5. REFLECTIONS

"This is my third year in CASMarine team. I gained experience about underwater robotic technologies. As a team we developed technical skills in various topics such as water tightness, 3D modelling, balance algorithm, and image processing. This way, I also gained experience about project management. I believe that the experience of this team is a great opportunity for all engineer candidates to see and understand what is working in a team and what does people do while creating a complicated product."

-Buğra Tufan

"This is my first year in CASMarine team and I am glad to be a part of this team. I have improved myself in embedded system development and mechanical system design. By working with this team, I think I earned important things for my future life."

-Umut Ediz

12. REFERENCES

[1]OpenROV, 2018, OpenROV Operators Manual. [online] Available at: https://openrov.dozuki.com/Guide/OpenROV+Operators+Manual/80 [Accessed 9 Aug. 2018].

[2] T100 Thruster, Blue Robotics. https://www.bluerobotics.com/store/thrusters/t100-thruster/

[3] M. Madsen, A. Knott, M. A. E. Andersen, Low power High Frequency Switch-Mode Power Supply With 50V Input and 5V Output, IEEE Transactions on Power Electronics, Vol. 29, Issue 12, Dec. 2014Yong-Jie Yang, Xiu-Xiu Chen, Xiao-Mei Zhang, The Development of Concentrations for Production Data Collection System Of Submarine Cable, Wireless Communication and Sensor Network (WCSN) International Conference, Dec. 2014

[4] MS5837-30BA Datasheet, Dec. 2015

[5] Industrial pH Probe, DFRobot. https://www.dfrobot.com/product-1074.html

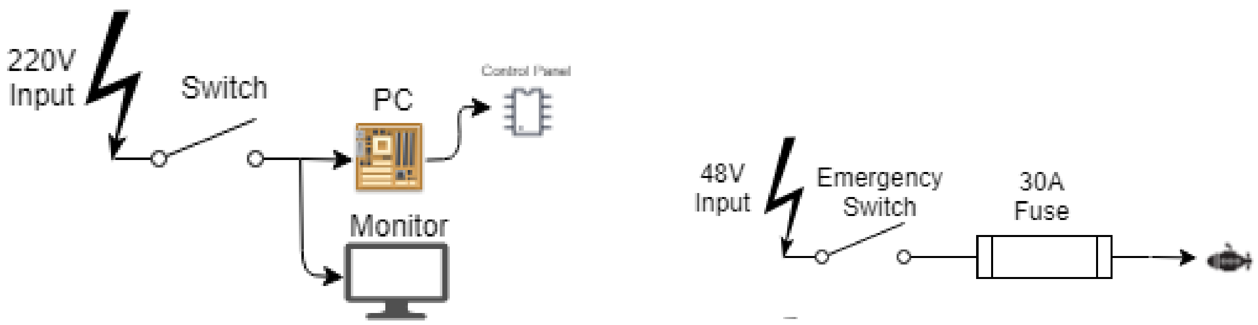
[6] Saeed, M., Nisar, S., Razzaq, S., Masood, R., & Imran, R. Gaussian Elimination Method-A Study of Applications. *Glob. J. Sci. Front. Res*, *15*, 2015

[7] R. Eren, M. Alan, B. Tufan, E. Erbil, U. Ayten, "Modular Electrical Control System for Small Scale Underwater Vehicles", 6th International Conference on Control Engineering & Information Technology, Oct. 2018

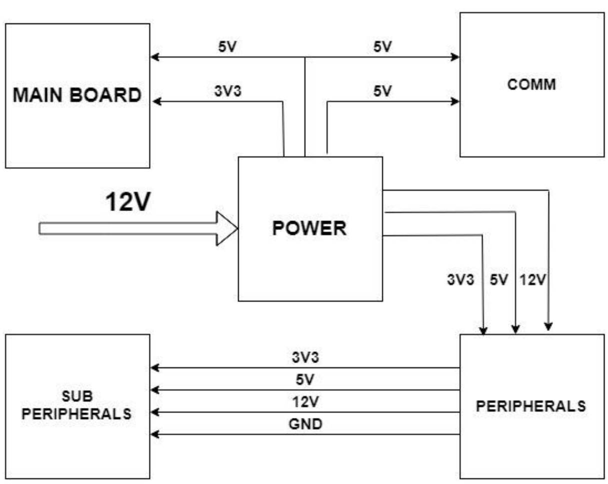
APPENDIX I: GANTT CHART

	November				December				January				February				March				April			
Works / Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Electronical Design and Manufacturing	■	■																						
Control Algorithm Development		■	■																					
Comm. Software Development				■	■																			
Ground Control Station GUI						■	■	■	■															
Material Purchases						■	■	■																
Chassis Manufacturing									■	■														
Mechanical System Assemby											■	■	■											
Software and Electronical System Assembly														■	■									
Tests															■	■	■	■	■	■	■	■	■	
Reporting																					■	■	■	

APPENDIX II: Electrical SID



APPENDIX III: Electrical SID of ROV



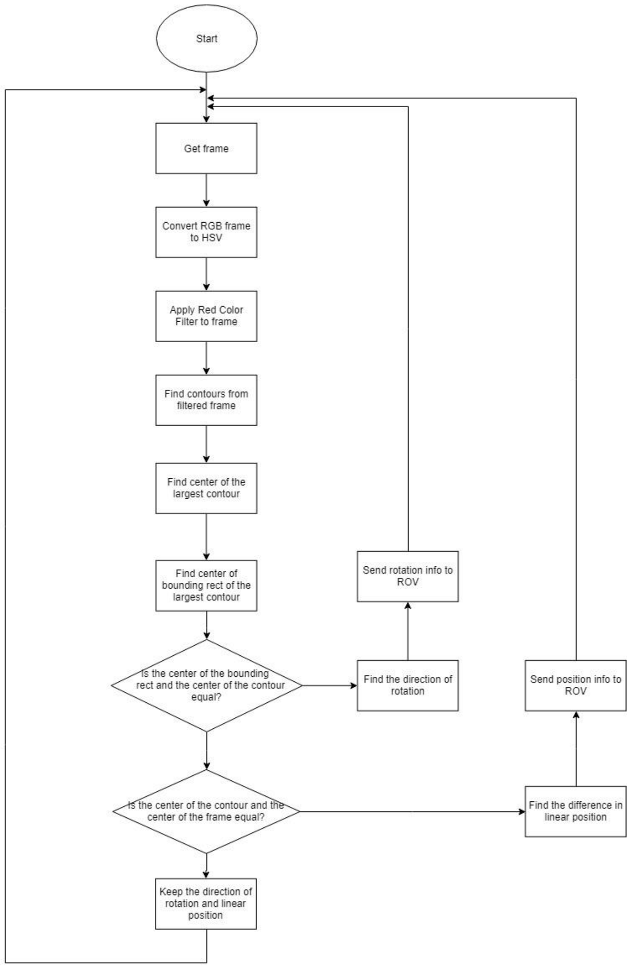
APPENDIX IV: Budget Plan

Budget Plan			
ROV			
Item	**Qty**	**Price**	**Sub-Total**
IP Camera	3	$100,00	$300,00
Thrusters			$1000,00
Waterproof Servo		$30,00	$150,00
Cable Gland	9	$1,00	$9,00
Power Converter	3	$25,00	$75,00
Cables	1	$12,00	$12,00
Aluminium and HDPE	1	$80,00	$80,00
Cable Socks	1	$6,00	$6,00
PCB Production	1	$100,00	$100,00
Sensors		$500,00	$500,00
Ethernet Switch	1	$20,00	$20,00
ESC	8	$15,00	$120,00
PCB Components		$500,00	$500,00
Ground Control Station			
48V Power Source	1	$120,00	$120,00
Control Panel Components		$25,00	$25,00
Custom PC Components		$600,00	$600,00
Cables		$100,00	$100,00
Joystick	1	$70,00	$70,00
Mano Box	1	$80,00	$80,00
Other Expenses			
Transportation		$11000	$11000
Accomodation		$3000,00	$3000,00

Total: 17867 Dolar

APPENDIX V: Software Flow Diagram

Image Recognition Software Flow Diagram



Embedded Software Flow Diagram