TEAM BANGALOREROBOTICS

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Shreyas Atcham Sanath Kumar	Electronics and Control Group
Ashwini Hiremath	Electrical and Programming Group
Manasa Nagaraja	Electrical and Testing Group
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Swaroop Kukke	Design and Electronics Group
Usha Jogappanaik	Software Development and Programming
Shruthi Mohandass	Electrical and Co-ordinating Group
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Team Mentor

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2. ABSTRACT

BangaloreRobotics is a team consisting of multi-disciplinary students participating in MATE ROV competition for the first time.

ROV (underwater robot) is built with engineered designed structure to withstand high pressure at greater depth inside water. ROV as also have good stability and navigational control.

Mechanism of ROV is specially designed to perform the required tasks of the Missions. Mechanisms have very little movable parts and hence produce very little reaction force on the ROV inside the water, which is crucial to maintain the inertia of the ROV intact.

ROV has four major tasks to perform which simulates the oil spill conditions. In the first task ROV concentrates on placing the hook and line to a U-bolt of the riser pipe, the mechanism uses a simple circular hook where a line is attached to it s ring. And the mechanism used for Velcro removal is simple where a hook is placed at the centre of the circular drum which has a circular motion.

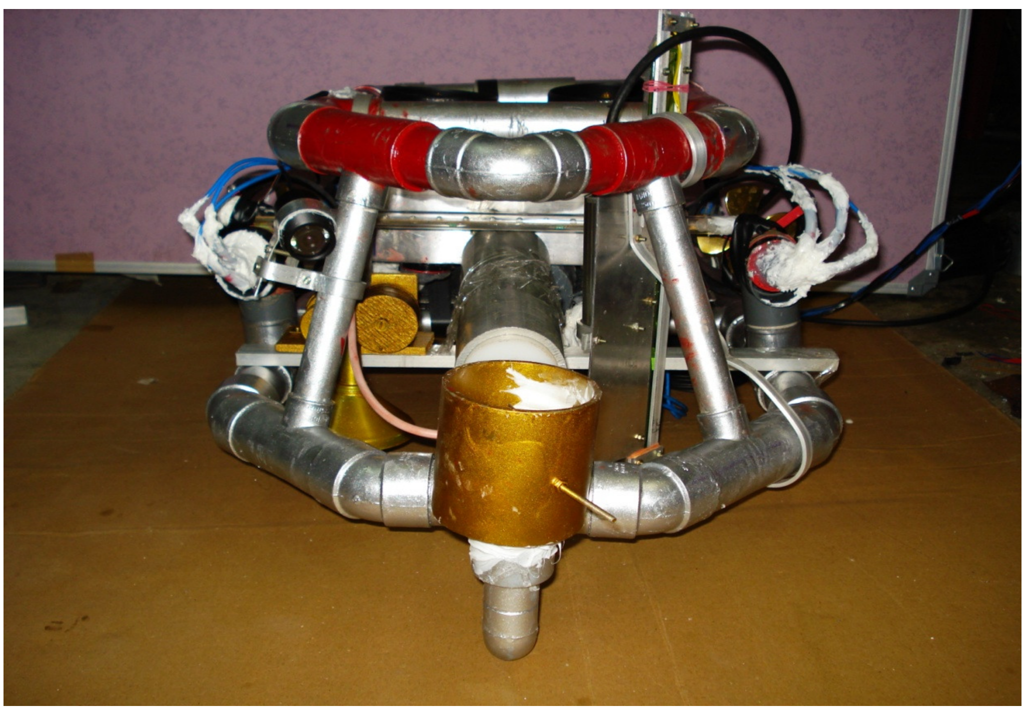
Second task has mechanism to cap the well head which is made up of rubber which fits the inside diameter of the well head pipe and uses a clip to provide better support to cap, hence blocking further oil spill.

In third task, a syringe mechanism is used for collection of the water sample at the specified depth for the given CDOM concentration. A depth sensor is used to determine the depth.

Finally biological samples at the bottom are collected using a smooth scoop mechanism.

Contents

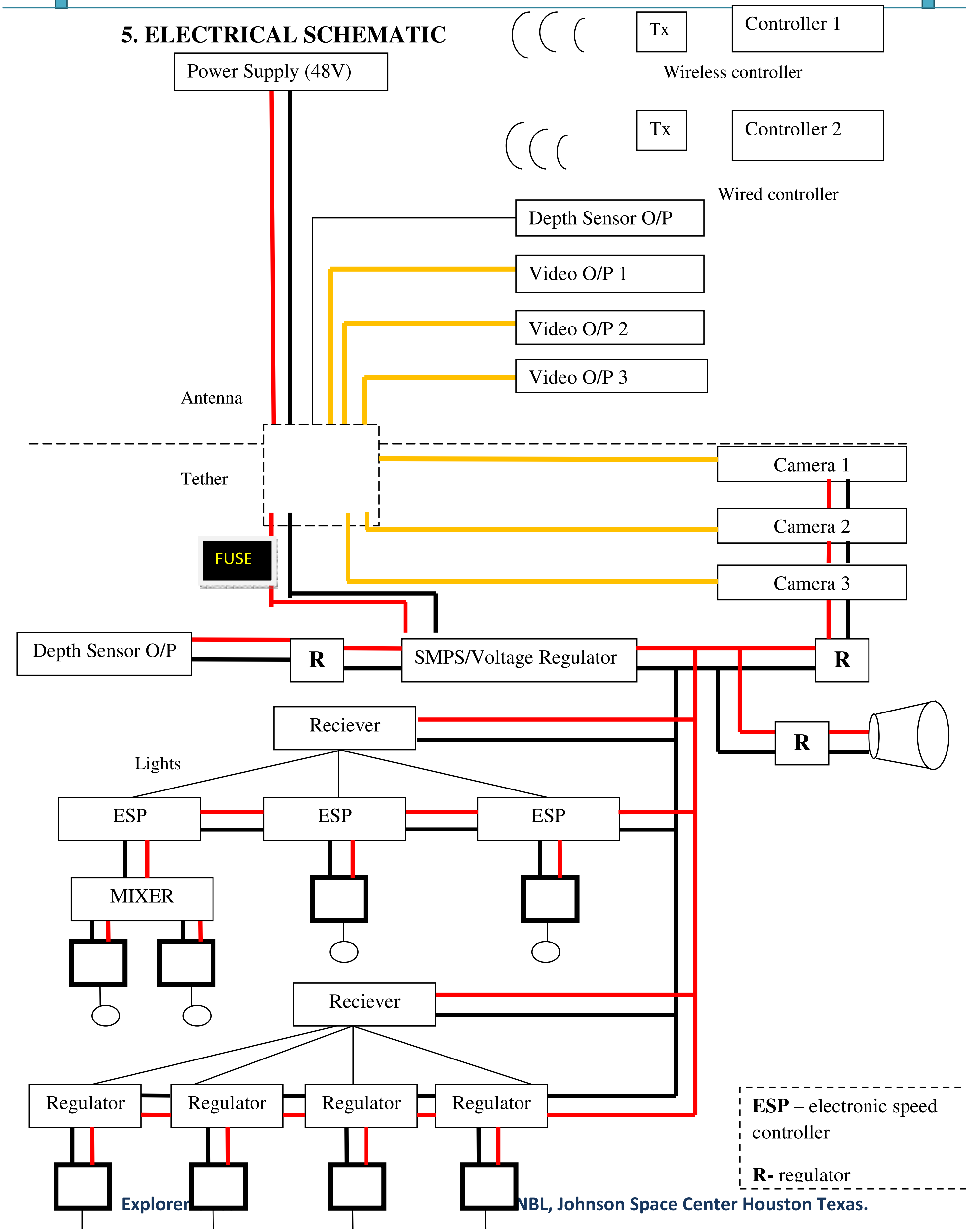
3. PHOTOGRAPHS



BUDGET SHEET

SL N0	COMPONENTS	Qty	PURCHASED	BORROWED
1	STRUCTURAL MATERIALS		$600	
2	SEALANTS AND WATER PROOFING AGENTS		$250	
3	STATIONARY			donated
4	CAMERAS Lights Camera Action + Shipping	3	$577.22	
5	400HS CRUSTCRAWLER THRUSTERS	6	$2860	
6	Dc Geared MOTORS	8	$120	donated
7	HYDRA SPEED CONTROLLERS Crustcrawler USA	6	$1883	
8	0v-5v 19mH2O DEPTH Transducer, HK	1	$600	Bangalorerobotics
9	FABRICATION, Machining		$1200	
10	VIDEO MONITORS Haier 7” USA	1	$83	
11	WIFLY MODULE RN-134 Mouser	2	$198	
12	SIX AXES GYROSCOPE , Sparkfun USA	1	$54	
13	FT06 TX AND RX	2	$120	Bangalorerobotics
14	MICRO CONTROLLERS Atmega8	6	$18	
15	OSD232- VIDEO OVERLAY, USA	1	$203	
16	RESISTORS, WIRES AND OTHER COMPONENTS			Bangalore
18	BATTERIES –VISION 12v18A	6	$280	
19	TETHER and other CABLE s		$100	
20	BALLAST TANKS Acrylic	2	$60	
21	SMPS	1	$600	
22	SYRINGEs	10	$4	
23	CATIA V5R19 STUDENT EDITION (1yr)	1	$100	
24	LAPTOP VAIO	1	$1000	
25	VMLAB AND WINAVR			Open Source
26	Airfares India –US-India	14	$23,000	
27	ACCOMODATION		$3,700	
30	CMos Camera	2	$60	
32	8 servo Controller	2	$53.98	
33	Invertable steering mixer –Robot Market place		$239.	
34	Seabotix BTD150	4	$1800	Bangalorerobotics
35	40A Blade fuses,	20	$39.80	
36	40A manual Resettable fuses - Cabelas	2	$16	
37	Import Duties & Taxes		$4550	
	Total spent (till 20th May)		$44,016=00	

5. ELECTRICAL SCHEMATIC



Circuit breaker is very important and is a very essential element in a rov if not used the elements of the rov could be permanently damaged. In our rov we are using 40 A resettable fuse ie if the current level increases more than 40 A and voltage more than 32 volts then it disconnects the power supply to the rov and we can reset it manually.

6. DESIGN RATIONALE

6.1 STRUCTURE AND FRAME

Materials used:

- 1½ inch PVC pipe
- 1 ½ inch coupling
- 1 ½ inch T
- 1 ½ inch elbow
- 1 ½ 45 elbow
- PVC Glue

The ROV frame is designed in the form of a pentagon in the top view. The shape was chosen keeping in mind the stability, water resistance and ease of handling. The ROV has a dimension to fit into a box of 50x30x20 and is constructed using materials stated above.

The frame provides essential strength to the vehicle without compromising on the stability. The centre of gravity is perfectly at the motor line of the frame and hence eases the steps to stabilize it.

The top frame of the ROV is made smaller than the bottom frame to help mount the camera for perfect viewing of the mechanisms.

Extensions are provided in the structure for mounting of the propulsion systems and camera and the shape is suitable for fitting of the mechanisms.

We have used a motion sensor (LPR530), MEMS Gyroscope (LY530ALH) and a MEMS accelerometer (ADXL335) for stabilizing the ROV. Using the above sensors we will have complete control of the rov as we can read its position speed and inclination thus providing us with 6 axis of control.

6.2 PROPULSION

Smooth propulsion is one of the most important requirements for a ROV. The comparative weightlessness, three axis movement and low friction inside water make the navigation of ROV critical. Four 400HFS Crust-Crawler Thrusters are used for propulsion- two Thrusters for vertical navigation and the other two for horizontal navigation. The placements of the thrusters are as shown in the picture below.

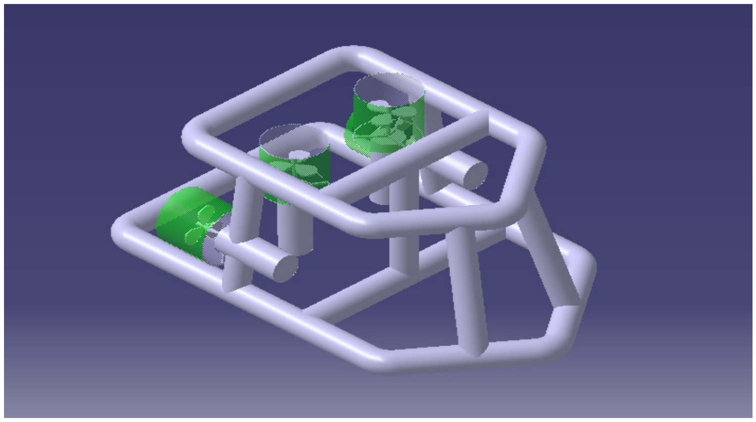


FIGURE 6.2 POSITION OF THRUSTER

Vertical thrusters are used for up/down movement, there is no need to control these thrusters individually both the vertical thrusters must work identically hence vertical thrusters are connected to a mixer, the mixer overlays the control of both the thrusters onto a single channel of a transmitter.

Horizontal thrusters are used for forward/reverse movement and turning (left, right). Both the thrusters are used at the same speed for forward movement one of the thrusters are turned off (long turn) or reversed (spin) for turning.

Specifications of the 400HFS Thrusters:

Motor thrust	15 lbs Max , 50vDC	8 lbs @ 12- 24vDC optimum
Voltage	12- Max 50 V)	12 – 24V optimum *
Current	11.48 A max	5A max
Power consumption	400W Max	100 – 150W

*We used 12V18AH Vision valve regulated rechargeable Battery for testing the ROV.

6.3 WATER PROOFING

Water is the biggest problem for any electrical or electronic circuits. So it is the at most priority to prevent water invading an electronic circuits in an underwater robot (ROV) for proper functionality. In order to provide water proofing we came up with several materials and methods to do it.

We used four materials to water proof different component. Each material was used for specific purpose.

- **Silicone GE 2000 and Silicone GP Wacker series**

  GE 2000 and GP wacker silicone has the following characteristic :

  1.It is used for sealing, bonding, repairing and mending.

  2.Long life.

  3.Good weatherability.

Silicone was used to water proof electrical connections of wires, motor connectors, sealing and bonding the end caps of the electronic circuit containers from outer side.
Proofing of wires and connector was done by placing a transparent and flexible level tube over the wires or connectors, the silicone was injected using a syringe into the tube where the electrical solder points and connectors (bullet) are present.
The drawback of this process was the material to be proofed should be clean, free from dust and oil and should be non-porous. Apart from that any uneven surface while proofing makes the surface porous and vulnerable to water leakage.

- **Gel wax and Araldite**

Gel wax is transparent, water resistant, light and buoyant. At normal temperature the wax is semi hard and flexible. But it is fragile and can be made into bits of pieces.
When heated it melts into a liquid form. The liquid wax can be poured into any container to get the particular shape. It cools down and get its original property and becomes hard.

Araldite is adhesive resign which are used to bond glass. wires. Pipes etc. It has a varied application. It is water resistant, highly durable, quick setting time and highly tensile.

Proofing of normal camera was done by using all water proofing material. And the procedure will be explained in the appendix

6.4 MECHANISMS:

6.4.1 VELCRO REMOVER

This mechanism was designed primarily to minimize the force required to pull the strip.
The mechanism was chosen from 3 alternatives

1. Gripper mechanism: A robotic arm gripper
2. Hook : A hook mounted on to the vehicle
3. A Rotating Cylinder

Though the gripper and hook mechanism proved worthy in the ease of removal they had a disadvantage of

- Aiming the mechanism was difficult.
- Mechanism was complicated

So the Rotating cylinder mechanism was chosen

Structure:

It consists of a hook fixed on a cylinder. The cylinder is fixed to the motor shaft and care was taken to see that's the cylinder centre coincides with the motor shaft. The cylinder-Motor assembly is fitted to the ROV frame with the help 1 ½ PCV pipe and was placed in the front of the ROV. The cylinder diameter was fixed keeping in mind the angle of rotation required to remove the Velcro strip.

Working:

The ROV is maneuvered to fix the hook on to the ring. When the hook is in place, the drum is rotated by the motor so that the hook pulls the Velcro and wind the Velcro on to the drum thus removing the Velcro strip effectively with the use of less force.

SPECIFICATION

Drum diameter	80mm
Drum height	10mm
Motor speed	30 RPM, High Torque geared DC motor
Angle of rotation to remove the strip	190 degrees
Length of hook	50mm

After successive trails it was found that the mechanism is fast and easy to operate and requires less force to remove the strip. It is reliable as the slipping of the strip is minimum.

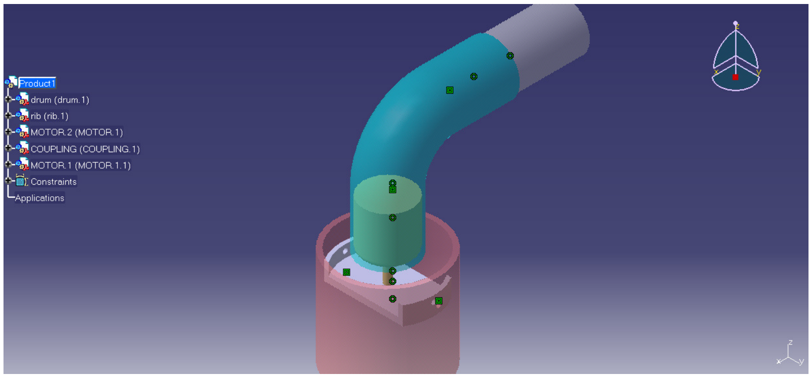


Fig 6.4.1 VELCRO REMOVER

6.4.2 WATER SAMPLER

A syringe mechanism is designed and is used for collection of the WATER sample at the specified depth for the given CDOM concentration. We aim to collect upto 150cc of water sample. The syringe body was fabricated using an Aluminum tube.

Specifications:

- Density of aluminium 2700 **kg/m3**.
- Inner diameter 64mm
- Length of cylinder 80mm
- Weight of the tube **1.3 kg.**
- The Piston thickness 12mm.

Thus the travel length of the piston for collecting water sample is 8cm-3cm = 5cm. Now, according to our calculations the volume comes up to:

Volume= pi*r*r*h

= pi*32*32*50 cubicmillimeter

= 160 cubic centimetre approx.

One end is closed and water proofed by tight fitting (no tolerances) of an aluminium cap. A nozzle on the cap helps in water suction. The piston is fabricated using Delrin and O-Rings are used for pressure sealing (**2 rings**). The O-RING dimensions are calculated keeping in view, the possibility of water leaking from the other side which may dilute the sample. The piston is coupled to the motor using a screw rod.

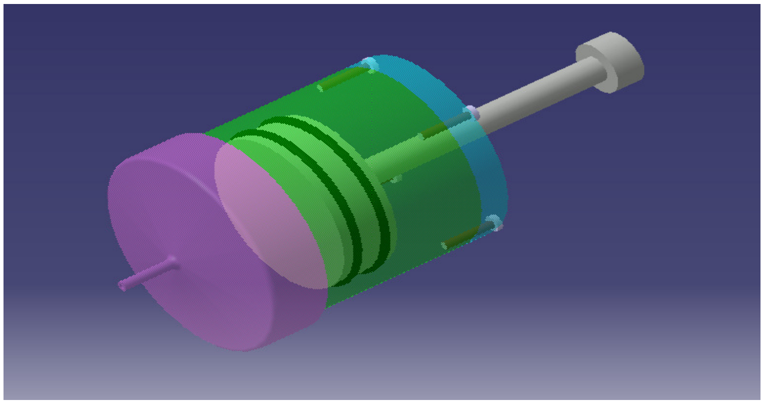


FIGURE 6.4.2 SYRINGE DESIGN OF WATER SAMPLER

Initially we had thought of Spring-loading for the syringe. Spring was attached to the piston rod and retracted to the length required and hooked. A release switch was used. When the switch is operated the tensioned spring contracts and pulls the piston thus sucking in water.

Possible failures:

- The hooked spring may give up due to forces on the ROV underwater.
- If the hook fails, it cannot be used any more for sampling water as it is not reversible.

Overcoming it:

We chose to use a motor and a screw rod instead. The motor can be reversed and there is minimal possibility of failures. It can also withstand forces without failure.

6.4.3 CAPPING MECHANISM

The CAP is made of rubber and is tapered .

The cap covers the wellhead opening thus stopping the flow of oil.

The cap head is 1.5 inch in diameter and sits on the top of well head when capped.

We need to ensure that the cap stays in place and won't come out once it is released. For this purpose an M-shaped clip is attached to the cap head.

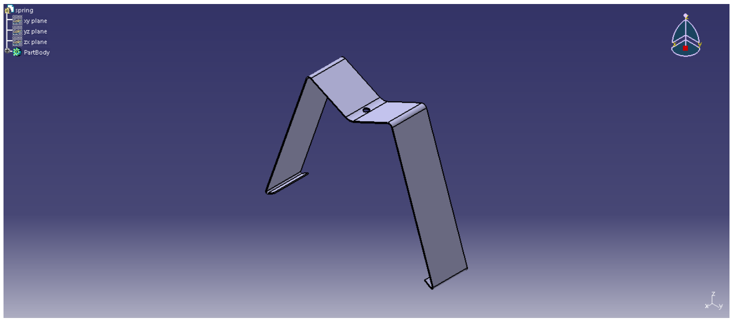


FIGURE 6.4.3.1 CATIA DESIGN OF THE M CLIP

The clip will be wide apart, but on loading from the top will compress inwards and clings to the groove at the bottom of the 1.5 inch PVC wellhead coupling. The compressing force is provided by the settling weight of the ROV.

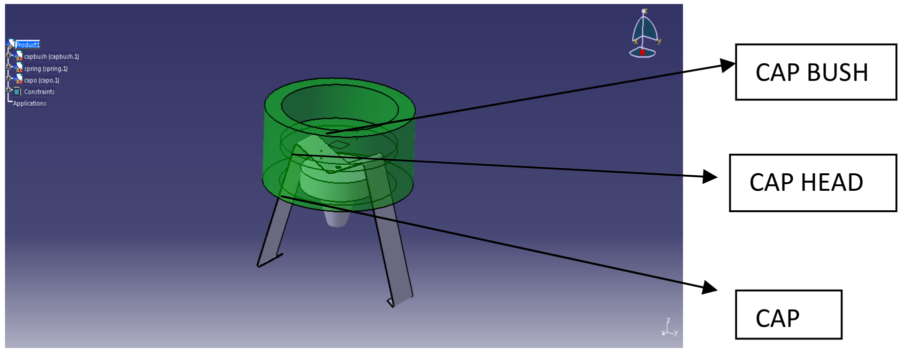


FIGURE 6.4.3.2 FINAL CAP ASSEMBLY

6.4.4 BIO-SAMPLER

The bio sample collection mechanism was chosen between 2 options.

1) The conventional gripper mechanism.
2) The scooping mechanism

The conventional gripper had several disadvantages:

- Aiming is difficult
- Cannot be used on delicate Sea creatures as the closing force could be large

To overcome the above disadvantages, the SCOOP mechanism is used.

Mechanism:

It consists of semi-circular scoop actuated by 2 electric motors. It is fitted in the bottom of the ROV.

The scoop is made up of a soft mesh material to minimize the damage to the sample.

SPECIFICATIONS:

Motor speed	10 RPM

WORKING:

Initially the scoop is open. When the ROV is positioned above the sample to be collected, the motors are actuated to close the scoop. Thus the sample is picked up.

On successive trials it was found that the mechanism is very easy to use and can collect large no of samples at a given time. As it is made of soft material it is very advantageous to collect delicate samples

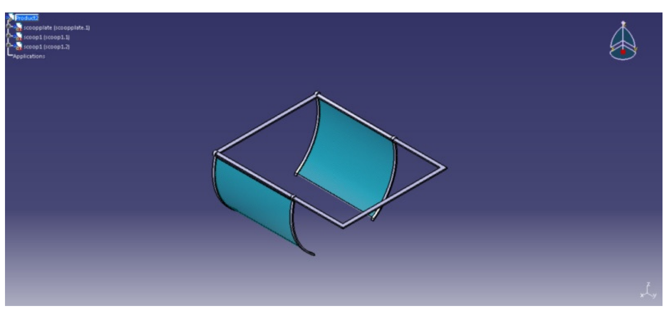


FIGURE 6.4.4 SCOOPING MECHANISM

6.4.5 Homebrewed DEPTH SENSOR

Handmade Depth sensor

We are using a handmade depth sensor for our rov and to check its reliability we have also incorporated a COTS depth sensor. The picture of our dept sensor is as shown below.

It consists of a tube which has a scale on it. One end (bottom) is open for water to enter and the other end is sealed to capture air and make sure that it doesn't escape. This tube is fitted to the ROV vertically with the open end at the bottom causing the air to be trapped inside it

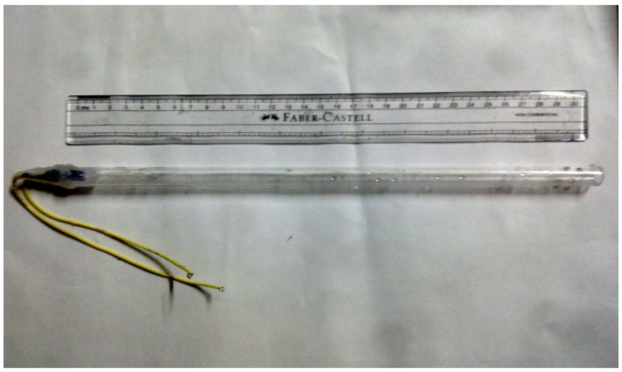


FIGURE 6.4.5 HOMEBREWED DEPTH SENSOR

when the ROV moves into water. The air gap inside the tube is directly proportional to the depth as we travel deeper into the water the air gap will reduce because of the increasing water pressure. Hence by finding the volume of water that has entered the tube we can measure the depth. The working of this depth sensor can be understood better with this example:

Length of the tube: 30 cm

Min detectable increase of water: 1mm

We can calculate the level of water inside the tube say at 20 feet as follows

Water will get compressed by half for every increase in 1 Bar. At 33 feet the pressure of water is 2 Bar. Hence the air gap at 33 feet will be 30/2=15cm

Depth of water at 33 feet=15cm

Depth of water at 20 feet=X

X=15*20/33=9.09cm

<u>Risk management</u>:

We use a commercial Pressure Transducer to measure depth.

We are thankful to Bangalore Robotics Pvt. Ltd for lending us a COTS depth transducer.

The Transducer has an output range of 0-5 volts corresponding to 0-19 m of water. This output is given to an ADC channel of microcontroller (Atmega8) and since voltage to depth variation of the sensor is linear the digital output of the ADC is multiplied by a constant to obtain the depth. This depth information is transmitted to PC – GUI through UART. The depth sensor is suitably mounted onto the ROV so as to correspond to the depth measuring mark on the water sample container, when the ROV collects water samples. The following flow chart describes the working of depth sensor in brief.

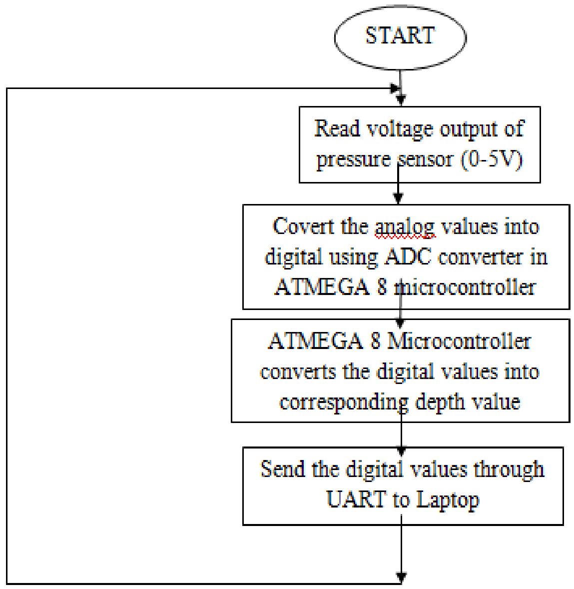


FIGURE 6.4.5 DEPTH SENSOR

6.4.6 HOOK

The hook designed to attach the line onto the u-bolt of the raiser pipe is shown below. The blue part of the hook is solid whereas the grey part is flexible through which the u bolt is forced in.

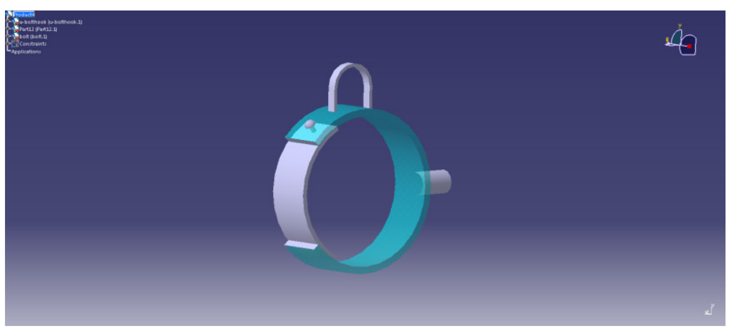


FIGURE 6.4.6 HOOK MECHANISM

6.5 CONTROL AND COMMUNICATION SYSTEM

Eight channels are provided by the system get complete control over the ROV:

- Left horizontal thruster
- Right horizontal thruster
- Two vertical thrusters
- Velcro Removal mechanism
- Capping mechanism
- Two channels for Water sampler Motors

- Bio-sampler Motor

Each channel controls one motor through motor controller using the further described communication techniques

6.5.1 MOTOR CONTROLLER

Accurate Control of the Thruster is very important for effective navigation of the ROV. Hydra 120 is a brushless electronic thruster speed controller. It is connected to one of the channels of the receiver for enabling the transmitter to control the thruster. It can work at a max of 25Volts and draws a max of 120Amps and generates heat hence inbuilt water controlled heat sinks are used. It is a programmable controller having the following features which enable high flexibility

- Reverse Type
- Reverse throttle amount
- Low voltage cut-off
- Timing advance
- Start power

It has 2 wires for power supply three output wires connected to the thrusters and one connector for the receiver. The Picture of Hydra 120 is shown below

6.5.2 FT06-C RADIO CONTROL SYSTEM

The FT06-C radio control system which as a receiver and transmitter working at 40 MHZ is a h control system which has been modified to control the
thrusters of the ROV.

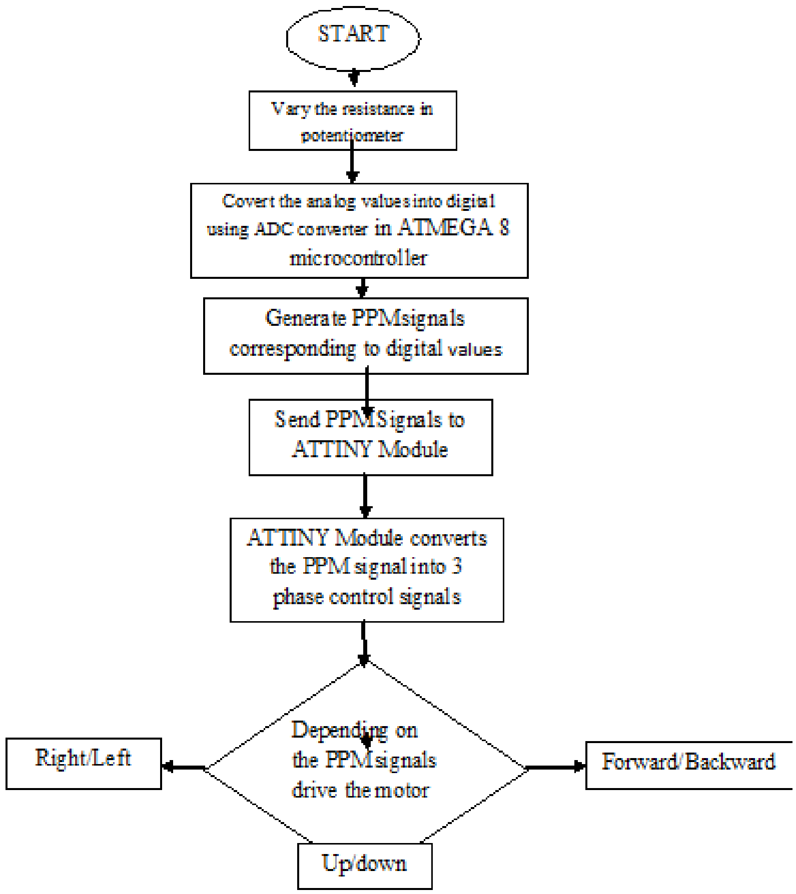
<u>TECHNICAL ASPECTS</u>

- Receiver has 6 standard channel output , hence we have 6 possible controls.
- Channel 1,2,3,4 and 6 also works as reverse switch.
- The receiver gets its BEC (5V, 3A) from the hydra 120 speed controller.
- Ideal up throttle adjust.

The Receiver with its antenna is placed in ROV inside a water proofed container and the channels of the speed controller is connected to the receiver inside the container. Calibration of the transmitter control with respect to hydra speed control can be performed by programming it.

6.5.3 PPM TRANSRECIEVER

The transmitter consists of an ATMEGA8 microcontroller which encodes the output of various potentiometers (joystick) into a PPM signal which is transmitted through a wire and is decoded by ATTINY44 microcontroller at the receiver which controls the thrusters. The steps involved are shown in the following flowchart.



PPM TRANSRECEIVER

6.5.4 WIRELESS WIFLY

The WIFLY GSX module is a stand alone, embedded wireless module. Because of its small form factor and extremely low power consumption, the RN-131G is perfect for mobile wireless applications. The WIFLY GSX module incorporates a 2.4GHz radio, processor, TCP/IP stack, real-time clock, crypto accelerator, power management and analog sensor interfaces. In our ROV it is used for wireless communication between PPM transmitter and receiver, thus eliminating the wired link in the above described transreceiver. It is configured to work in standalone ADHOC mode.

6.6 STABILITY AND BUOYANCY

The design of our ROV fuses the stability into the structure by flooding the bottom of the ROV (making it heavier) whereas the ROV's top is filled with air. Hence the ROV is prevented from toppling.

MEMS ACCELEROMETER and GYROSCOPE is incorporated to further enhance the stability which is used to detect fast variations in the ROV's 3-D pose and further programming a microcontroller to neutralize these jerks.The rov is designed to be neutral buoyant.

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6.6 CAMERA

Cameras are the eyes of a ROV; the ease of control depends mostly on its placement. We are using ¼" colour CMOS camera with a 6mm lens. In our ROV we are using three cameras imported at discount from Luisht Camera Action, USA, to enable better monitoring of the on board systems. The placement of the cameras are as shown in the below figure.
The specifications of the camera are as follows

Type	colour
Picture elements	Pal: 512h X 582 ;NTSC : 512h X 582
Horizontal resolution	400 lines
Mini illumination	4 white led's
Lens	6 mm
Video output	1V p-p
Weight	55g
Power supply	12 V

6.7 TETHER AND TETHER MANAGEMENT

Tether is used for communication between the user and ROV and for providing the power supply to rov. It also includes video cables which stream live video from the cameras fitted on the ROV. Tether is 14 m long and is buoyant so we should make sure to have a snag.

7. CHALLENGES AND TROUBLE SHOOTING TECHNIQUES

The company has faced challenges of varied range and has successfully dealt with it, the major challenges faced are

- Water proofing of electronic circuits

The electronics circuits and electrical wires had to be water proofed to prevent the shorting of current and preventing the malfunction and failure of electronic and electrical circuits. Proofing the transparent fibre tube and PVC end cap container at a depth of 40 feet was a difficult task just by using a PVC glue and silicone sealer (GP wacker series, GE 2000).

As the sealant would seal under cleaned oil free surface, removal and fixing of the end cap is time consuming, and the sealant requires proper drying process and pore free surface. Major problem being the water entering under higher pressure.

- Control system

The initial control of the ROV is done by using a radio control system using a FT06-C radio controller. The problem faced by the controller are the receiver antenna should be in detectable range , but due to unavailability and scarcity of a 40 feet depth water pool the performance and working of the controller at that particular depth is uncertain. The controller receiver antenna must either be on the surface of the water, which turns out to be non convincing method.

So to overcome the above problem we have a control system which is wired .we use signals generated from a handmade joy stick using potentiometer which provides a signal to ATMEGA8 control which performs analog to digital conversion. The signal generated will be a PPM (pulse position modulation) and will be provided to ATTINY44 decoder which in turn the decoded signal is given to the speed controller.

- Pressure and depth sensing

The first attempt to detect under water pressure was done by using a HOPER F pressure sensor, but it had a limitation to detect pressure which was corresponding to only 10 ft, which was not sufficient to check depth of 40 feet range.

To overcome this we have designed our own depth sensor and we have used COTS depth sensor as reference and used for comparative study and troubleshooting.

- Cost effectiveness

The company faced problems in securing sponsorship and raising required funds. As the funds required for construction of the ROV was steep and expensive, team decided to use few electronic and electrical instruments and circuit from the older projects done by BANGALOREROBOTICS. Also, students had to bare the travel expenses by themselves and few individuals opted for making a temporary loan.

8. RISK MANAGEMENT AND STANDBY SYSTEMS:

Every system will have certain limitations /thresholds/risks so we should take required measures/steps to ensure that these critical events/conditions does not occur. Let us have a look on the various possible risks and the methodology used to overcome it.

During propagation the ROV’s thrusters may stop working due to various reasons such as colliding with an object, failure of a thruster or over powering. Hence we have used two redundant thrusters in our rov as backup if one of the thrusters fails. The thruster can fail if there is a sudden rise of voltage or current hence we wave incorporated voltage monitors which will monitor the voltage drop across the thrusters and will keep the voltage drawn within the max limit.

We are using wired control for the ROV. It could fail if there are loose contacts and it has a disadvantage of power loss. So we have a wireless control system as backup which works on Adhoc mode.

The first attempt to detect under water pressure was done by using a handmade pressure sensor, but it may fail under unexpected situations hence we used a CTOS depth sensor for the ROV. If there is a cut in the tether it could short circuit the power lines or send unwanted signals to the controller causing to have no control over the rov so he have fixed a kill switch connected to the battery which will disconnect the power supply to the rov when pressed.

9. REFLECTION ON THE EXPERIENCE AND SKILL GAINED

The experiences gained during the preparations for the MATE ROV competition were enormous. The team developed the skills necessary for technical fields, problem solving, critically thinking, analysis, troubleshooting, effective communication, project and funds management.

The skill gained were plenty, out of which the team feels that skill of working as a group is the major gain obtained while working on design and building process of the ROV. The theme of the group was “unity is strength “. When the group members were shortlisted by our team mentor , each individual of the team had few things in common. Excitement, aspiration , loads of ideas and eager to taste success were few.

When the preparations were started our mentor and team advisors poured in there valuable experiences about their success, failures and achievements. Work started with the history of ROV and requirements of ROV. As the time passed by team members where no longer individuals but were more like a swarm of enthusiast.

As the time progressed experiments, mechanism designs, project abstract and synopsis were successfully completed. We learnt the important aspects such as time management, safety measures, creativity, discipline and responsibility. The work was assigned and time limit was bound for a short time we were able to put in every week in spite of regular college and academic curriculum. Failure and success were met. After every major experiment, there was a mandatory group discussion. Group discussion helped us to arrive at a problem solving faster and every time a different and feasible ideas where evolved.

The group were supportive to each and every individual in times of despair. Funds were managed as temporary loan for individuals who could not afford for their travelling expenses. Team performed few outreach programs to spread the word about technology which was one of the satisfying experiences.

10. FURTHER ENHANCEMENTS

As a part of future ideas, we plan to incorporate the following features.

- Quasi autonomous navigation capabilities i.e, autonomous balancing of the ROV
- DSP filtering of camera signals for better visions.
- Tether management either by using of sensors with anti-tangle auto correction programming.
- Increasing depth capabilities of the vehicle.
- Total autonomy.
- Monitoring the total health of the ROV and its functional parts.

11. REFERENCES

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3. www.wikipedia.org
4. Master slave control of autonomous under water vehicle (2007). Dr Venkatesh, Guide, Vikram Bashyam, Dilip Kumar, C Raghavendra , KSIT , India.
5. David Merrimans RC Submarines; WTC
6. www.**rc-submarines**.com/
7. MATEROVER Website Tutorials about ROV Techniques.

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APPENDIX - A

PVC PIPES-PRESSURE RATING

Maximum operating and required minimum bursting pressures at *73°F (23°C)* for PVC pipe fittings according ASTM D1785 "Standard Specification for Poly Vinyl Chloride (*PVC*) Plastic Pipes Schedules 40 and 80 are indicated in the diagram and table below

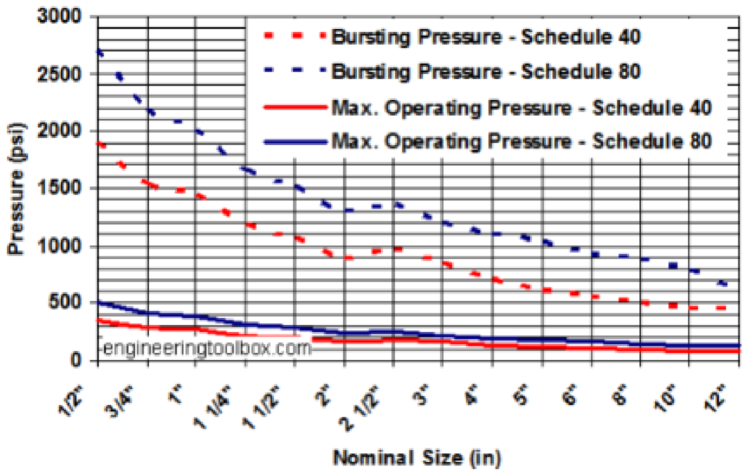

FIGURE APPENDIX A: PVC PIPES PRESSURE RATING

PVC				
Nominal Pipe Size *(inches)*	Required Minimum Burst Pressure *(psi)*		Maximum Operating Pressure *(psi)*	
	Schedule 40[1)]	Schedule 80[2)]	Schedule 40	Schedule 80
1/2	1910	2720	358	509
3/4	1540	2200	289	413
1	1440	2020	270	378
1 1/4	1180	1660	221	312
1 1/2	1060	1510	198	282
2	890	1290	166	243
2 1/2	870	1360	182	255
3	840	1200	158	225
4	710	1110	133	194
5	620	1040	117	173
6	560	930	106	167
8	500	890	93	148
10	450	790	84	140
12	420	600	79	137

1. ASTM D2466 - 06 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
2. ASTM D2467-04e1 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

- *1 psi (lb/in^2) = 6,894.8 Pa (N/m^2)*

Note! The maximum operating pressures derates with temperature. At the maximum operating temperature for PVC - *140°F (60°C)* - the strength is derated to approximately *20%* of the strength at *73°F (23°C)*.

APPENDIX - B

CAMERA WATER PROOFING

A CMOS camera of dimensions less than 2 inches in length and 1 inch in thickness was embedded in a 75 mm pvc end cap. Audio, video and power cables where fixed to the end cap. The wires were water proofed with the silicone (GE 2000) to prevent water entering into the end cap via wires. The camera which is placed inside the cap was made sure it came up to the required height of the open end of the cap. Saw dust & wood was used to make sure so that camera position was fixed firmly to the centre of the end cap for best camera view.

The remaining space and void inside the end cap was filled with heated gel wax. Gel wax was filled to the lens level which is the same level as open end cap. And the liquid wax is allowed to cool.

The top of the end cap is covered with a 3 mm glass covering the circular open end. Araldite is used to fix the glass over it. Araldite being a sealant and adhesive makes sure that transparent glass is fixed tightly and seals water from entering into the end cap.

In case of any leakage from the surface of glass, the wax prevents water from entering the camera which is placed at the centre.

APPENDIX - C

SCHEDULE

MARCH

Start | Initial discussion and planning | Analyzing the structure and stability of ROV | Testing the buoyancy of the structure of ROV | Working on the Semester project

March 10

Semester Internal Exams

March 31

APRIL

Waterproofing the structure | Worked on speed controller and 3 phase motor | Placed an order for the components | Semester Internal Exams

April 1

Testing the ROV in the pool | Pressure Testing | Working on the Semester project and seminar

May

Worked on the individual task mechanism | Testing and discussion | Working on the ROV Technical Report | Working on the Semester project

May 1

Semester End Exams

May 25