TEAM SCREWDRIVERS

NetraROV

TECHNICAL DOCUMENTATION 2019

Staff Members:

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MATE

MATE ROV COMPETITION

SVKM'S NMIMS Deemed to be UNIVERSITY

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Abstract

NetraROV is the improvised product of Team Screwdrivers, in response to MATE's quest for 'Innovations for Inshore' which signifies the role that ROVs play inshore. The term Netra is derived from indigenous UAV developed by DRDO of India for the purpose of aerial surveillance. Netra is defined as eye in Sanskrit language. An eye helps to convert the light source into electrical nerve impulses, which in end helps humans to see. The same goal is to be followed by NetraROV which would help us to explore and understand the marine-life.

Remote control for NetraROV is carried out by using precise analogue joysticks with trim, which is connected to ROV with a unique tether system that also serves the purpose of providing power and communication to the ROV. The ROV is manoeuvred with the guidance of four cameras on-board the ROV system. This year we have managed to save additional funds by reusing the chassis of last year, thereby giving us an opportunity to improvise the frame and work on different fields of expertise.

Team Screwdrivers, a company of five hard-working people believes that challenging the status quo is the only way to grow. Born from Mumbai, a city which never sleeps, Team Screwdrivers has invested a lot of time to deliver this state-of-the-art product housing the Indian spirit of using advanced technology at an affordable cost.

TEAM SCREWDRIVERS 2019

From Left to Right:

Suryansh Jain, Heetansh Jhaveri, Radhika Heda, Shrineel Nadgauda, Agnel Jenson A.

Safety

Full form of SAFETY is ***Stay Alert for Every Task You do***.

Safety is very important consideration in any organization. The term safety means a state of being protected against physically. Many employees work in industry and each of them needs Safety and that's what the company has appoints safety engineers to provide Safety training to each of the company employees.

Safety Philosophy

With Team Screwdrivers, safety is at our utmost priority and it comes without saying. We never compromise on our safety, be it at the lab, the mechanical workshop or even at the swimming pool. We do not only meet but also try to exceed the given safety guidelines published by MATE. We believe all accidents are preventable and with the proper care and dedication we believe in achieving a safer accident-free environment.

Lab protocols

We at Team Screwdrivers use **Job Safety Analysis (JSA)** forms for our employees to review and ensure safety before pursuing tasks from developing the ROV using machinery or mechanical work to transportation, pre-launch/assembling the ROV, dry run, launch and retrieval. We use machinery under expert supervision and make use of proper protective gear to ensure even our safety. We perform soldering in well ventilated areas and maintain a negative pressure in the room so that the fumes vent via ducts.

Training

We follow a peer-to-peer system where all team members work with utter coordination, help each other with their respective expertise and also make sure that the new member is given proper safety and taught with good care. Veteran employees always supervise and mentor new employees. New employees work in proximity of veteran employees till they demonstrate proper working practices. There is always one veteran employee to supervise the working of the team and ensure safety at all times. We follow a “Buddy System” where no employee works with machinery or soldering work alone. This keeps the environment safe and encourages team bonding.

Operational and safety checklists

Safety protocol and checklists are closely followed before, during and after ROV deployment. Employees also follow operational JSAs for ROV launch, recovery, and waterside safety.

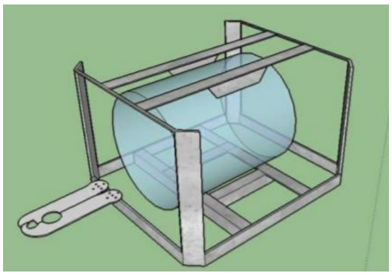
Detailed workshop and operational checklists are provided in the JSA Document.

Mechanical Design Rationale

The components of NetraROV is designed in such a way that the process is streamlined with its mechanical and manufacturing aspects to produce components of desirable quality.
Our aim to create NetraROV was not to make a complex and sophisticated design but to make a more simplistic and realistic design which can be put to real world use and not just the competition aspects. We believe the ROV must perform the given tasks quickly, with minimum maintenance and operational costs.

Structure

While keeping in mind, the ease of availability of raw materials, low-cost requirements and the moisture environment were the factors which were considered. After a quick brainstorm session between the members of our company, we concluded and chose Aluminium as the raw material for the construction of our frame due to its relatively easy availability in India. Aluminium is known for its lightweight, durability nature and resists corrosion. The strength provided by the aluminium joints ensured that thrusters and payload equipment can be easily added to the structure without the need of an intermediate mounting. The chassis is made up with L-Shaped joints to support rods that give additional support to the shrouded thrusters. The bottom of the chassis contains four cuboidal aluminium rods places in a square of 11cm X 11cm so that the Electronic Chamber (EC) can be attached within the hollow space. The sides of the EC compartment include a wedge to mount the main robotic arm of NetraROV, a mount for the secondary arm and tools.



Electronic Chamber (EC)

The Electronic Chamber (EC) is made of a cylindrical mould of acrylic. All wires connecting the electronics within the EC with components outside like the thrusters and cameras are passed through plastic gland connectors and metal penetrators. The sizes of gland connectors used are as follows: Sr No. PG Thread Hole size (approx. diameter) 1 PG 7 13mm 2 PG 9 15.7mm 3 PG 11 19mm 4 PG 19 24mm. The gland connectors were waterproofed with the help of marine epoxy and O-Rings, so that no water passes through the rings. The end cap consists for holes for attaching the gland connector and it is screwed to the hull. The EC closes with an O-ring flange and end cap.

Rear-View of Electronics Chamber

Buoyancy System

The mechanical design was kept in design such that flexibility in buoyancy system is maintained by keeping in mind the centre of mass (Cm), centre of buoyancy (Cb) and centre of gravity (Cg). Team Screwdrivers originally decided to build NetraROV slightly positively buoyant so as to enable it to flow back to surface in case of disruption in power supply, the electronic chamber was designed in such a way that it makes ROV more positively buoyant. This helps in reducing cost by not having to design a separate ballast weight. The aluminium chassis and thrusters provide negative buoyancy. The placement of components was such that (Cb) was above and greater than Cg so that ROV would not flip in the water and remains balanced.

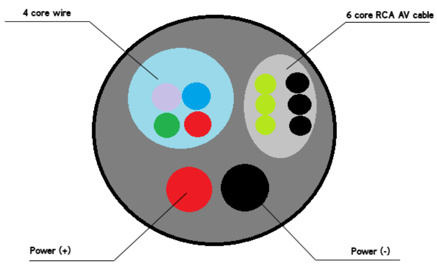
In the later stages of development, we decided to add some additional weights and foam to balance the electronic chamber, because the EC was designed in such a way that it remains positively buoyant throughout, hence a slight shift in Centre of Gravity might cause the ROV to tilt in a particular direction. So, to overcome this factor, we added some additional weights so that the ROV is slightly near to neutral buoyancy.

Waterproofing

Waterproofing an ROV is not a simple task but rather a complicated task. We had to waterproof our Electronic Chamber in a stringent manner such that there is no leakage of water inside the electronic chamber and we had to conduct multiple tests to make sure that our ROV is completely waterproof to function at a depth of 40 ft. We developed an in-house flange with double O-rings Protection using CNC technology. These O-rings are basically a gasket which acts as a mechanical seal between irregular surfaces, and under compression it totally prevents the permeability of water or such fluid. To prevent seepage of water, we had installed penetrator and glands on the end cap of the chamber as many wires to be passed to the electronic chamber. Marine epoxy was used to seal enclosures. While testing ROV many times, we faced the problem of water condensation inside the electronic chamber. So, to overcome this, we used industrial grade silica gel packed in cloth to absorb the moisture. DC motors were first coated with epoxy, and the gearbox was filled with thick grease to prevent seepage of water. The connections were enclosed in a case. It is also one of the difficult task we had faced while waterproofing the pressure sensor chip, as one part of the chip has to be in contact to the fluid whose pressure it has to measure while the remaining parts has to be waterproofed, epoxy was used to waterproof the sensor. The DC motor of robotic arm was also being waterproofed by filling the gearbox with thick grease to prevent seepage of water and then coating it with marine epoxy. All epoxied electrical connections are sealed using liquid electrical tape to avoid any current leaks or a short circuit.

Tether

For faster communication, we had used two RS485 convertors than CAT-6 Ethernet cables which are used for video signals and sensor values. The video had a higher latency making it difficult to control the ROV. We switched to serial-to-serial connection and analogue RCA cables for reducing the latency and improving the reliability of data signal. RS485 adds simplicity to the communication protocol as it is a direct point to point communication by enabling the differential 32 channel communication of 1200 metres from 10Mbps to 100kbps. RS485 is connected to the 4-core cable in the tether which is 20m long. The tether winder also contains 2 10AWG Power lines. The power supply cables which are selected can carry up to 60A of current keeping in mind the durability, minimum resistance and flexibility of cables. The power lines are rated for a resistance of 0.08 Ohms and with estimated peak draw of 30A, we suffer a voltage drop of only 30*0.08 = 2.4V. This provides us a minimum operating voltage of 45.6V, well above the 36V rated cut off voltage of our DC to DC converters on-board ROV. The tether is negatively buoyant, so to make it neutrally buoyant we had attached small pieces of foam to the tether. To reduce the oral communication from the tether operator and the ROV, we attached the rotary encoder to the tether housing to provide better estimation to the tether operator.



Electrical Design Rationale

All the electronics in NetraROV are placed within the acrylic Electronic Chamber (EC). The EC houses the PCB and associated wiring for the thrusters and motors. The size and complexity of the circuit has been reduced significantly due to the use of PCBs and the RC controller. The electric board of NetraROV has been designed for maximum isolation between high power and low power signals, so as to reduce the likelihood of electromagnetic interference between the wires in the EC. It is supplied power through a Delta DC/DC CONVERTER 12V 50A. A 12 to 6V Custom Converter powers the servos present in the ROV. A FRSky 40A Hall Current Sensor Module is used to read the current in the wires real time. It acts as protection to the 30A Littel Fuse housed in a Little Fuse holder.

Cameras

NetraROV uses 3 HD TVL cameras which provide real-time video over just one cable with 3 views at a time. There are 2 waterproof Cameras which are outside the EC. We purchased waterproof cameras as they are already IP67 rated which reduces the need of additional housing and waterproofing. They operate at low voltage which gives out high-resolution output. The camera has low-lux rating which helps to observe marine-life even where the lighting conditions are dimmed.

TVL700

MPU 6050

MPU 6050 is a three-axis Gyroscope Accelerometer Sensor Module compatible with Arduino Mega. It provides real-time values of thruster acceleration and orientation of the ROV. The BME280 is an integrated environmental sensor specifically designed for placement in low size and power conditions. It tracks temperature, pressure and humidity of the EC and alerts pilots of any waterproofing failure or damage. The thrusters are controlled by electronic speed controllers, which are mounted on the board itself and segregated in a stack structure.

GP-87

This is a new smart sensor incorporating 3 sensors i.e MPU6050, BMP180 & HMC5883L. This reduces IO Complexity and provides the values of all three sensors real-time through Arduino.

Arduino MEGA

An Arduino Mega 2560 module acts as the heart of the electronics present in the EC of NetraROV which coordinates all activities of the ROV. The control box also features an Arduino for the Joysticks and point to point Serial Communication using RS485 Converter.

Power and Propulsion System

To provide propulsion, we had used six 80W DC motor. It draws a current of 3 amperes, maximum current in full load with maximum rotation speed of 400 Rpm on the propeller. The three DC motors which double drives are used to drive the motor. For the improvement during the runtime, the driver decelerates or send the motor reversal command it returns the power to batteries. To provide regulated power for video and other electronics, we had used a highly efficient DC-DC convertor which provides 12V for camera and feeds the other electronics by 5V and 3.3V.

Navigation and Control System

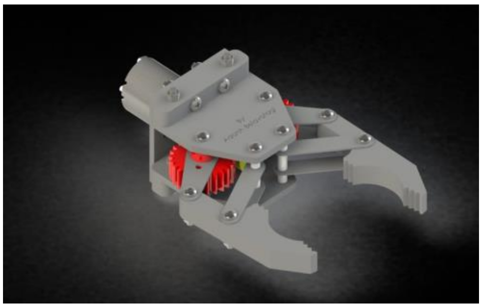
Smart electronic board case made of ABS material is used in which all the control system is placed. By sending the high-level commands, an on-board pilot operate autonomously with the given set of on-board sensors. All the electronic modules and sensors are interfaced with mainly one autopilot which is ATMega Arduino microcontroller. The sensors include a pressure sensor for sensing depth, temperature sensor for monitoring the temperature of water, PH sensor which detects the PH of water. These sensors are interfaced with microcontroller using analogue devices. The processed data is transferred through RS232 link to the main microcontroller i.e. autopilot microcontroller. The microcontroller is responsible for gathering data from sensing modules and generating commands to actuators i.e. closing the loop to operate ROV autonomously. For different axis, closed feedback control loops are implemented in the on board microcontroller. There is also possibility of commanding the actuators manually. The operator is able to take control of the ROV and overrides the AVR auto commands. The microcontroller sends the sensors data over a RS485 bus to the surface control console (SCC) in fixed intervals of time which is helpful in prototyping and testing different control schemes on SCC. Sensors are operating are based on water conductivity. In case of water leakage, the conductivity of water drives a buzzer in surface control station and ROV will stop work immediately so that operator can shut down the sensitive electronics and command the ROV upward quickly. A video camera is mounted in front of ROV inside the electronic chamber. Video signal is converted to Ethernet and transferred by a single cable between the TOV and control console.

Surface Control Console (SCC)

The operator can interact with the ROV using a surface control console (SCC) composed by a graphical user interface and an RS485 link for communication. This allows to monitor the state of ROV during operation and gives visual feedback to the operator and also feeds the information such as heading, roll and pitch, depth is also displayed on adjustable time. By editing the parameter of controller, it can activate or deactivate onboard controller to tune them directly during the operation. It can also give trajectory commands.

Robotic Gripper

We had designed robotic gripper in such a way that it would complete the tasks given by the MATE competition. In order to complete all the tasks, the ROV needed to pick up and lift the different objects and place them as given in



competition specs, we have used one robotic arm which has two DoF motion by using dc motor which is being waterproofed. The arm can complete the tasks with precise specification and is controlled by dual axis joystick.

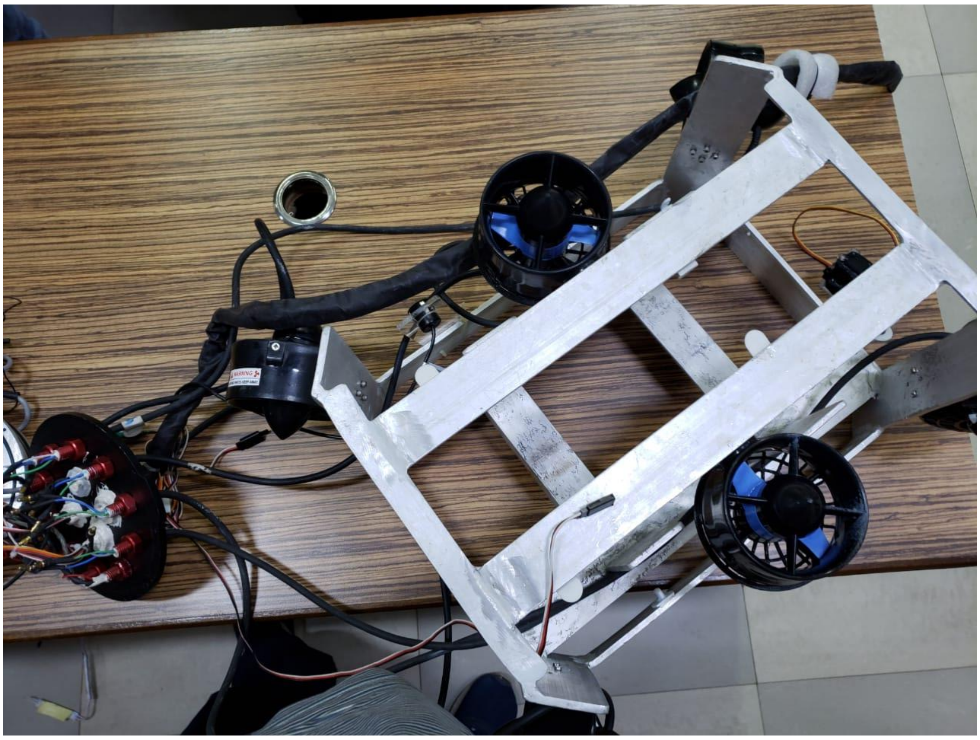
Power Budget

Unit	Current (A)	Voltage (V)	Power (W)	Quantity	Total
Arduino Mega	0.75	12	9	1	9
Blue Robotics T100	11.25	12	105	6	810
Gripper DC Motor	2	7	14	1	14
Cameras	0.4	12	4.8	3	14.4
Servos	1.0	6	6	1	6
Lights	0.5	12	6	4	24
Sensors	0.3	5	1.5	3	4.5
Total		**12**			**882**

Peak Power Available at Top of Tether W (30A*48V)	1440
Power Loss Due to Tether Resistance (30A^2*0.08Ohm)	72
Peak Power Available to ROV end of Tether	1368
Regulator Efficiency, % (estimated)	85
Power Loss, W (Peak Power/Efficiency)	205.62
Power After Conversion at ROV	**1162.8**

Payload Rationale

The ROV has 3 payloads to perform various tasks. By reducing the system complexity, all payloads in the ROV are electrically connected which increases redundancy. The mechanical manipulator arm is its main payload system which consists of DC motor being waterproofed. The arm has fibre ripper which when closes is length 8 inches and breadth 4.5 inches. The primary concern of choosing the gripper by keeping in mind its importance the design and selection of material of manipulator arm took a several tests for different materials to be used which can perform different tasks given MATE competition specs. This saves time and ensures that the ROV does not need to return to the base station for replacement of any payload system tool.

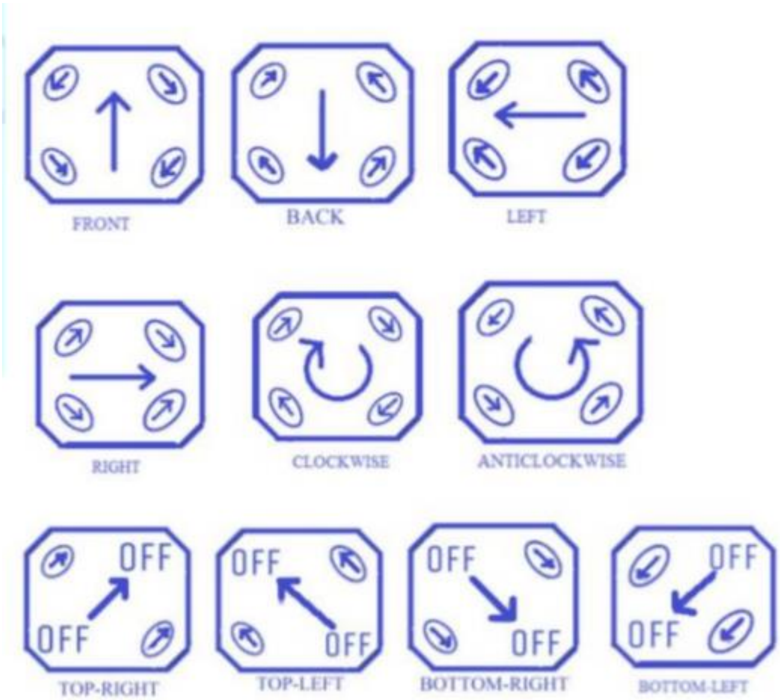


ROV at initial stages of development

Software Design Rationale

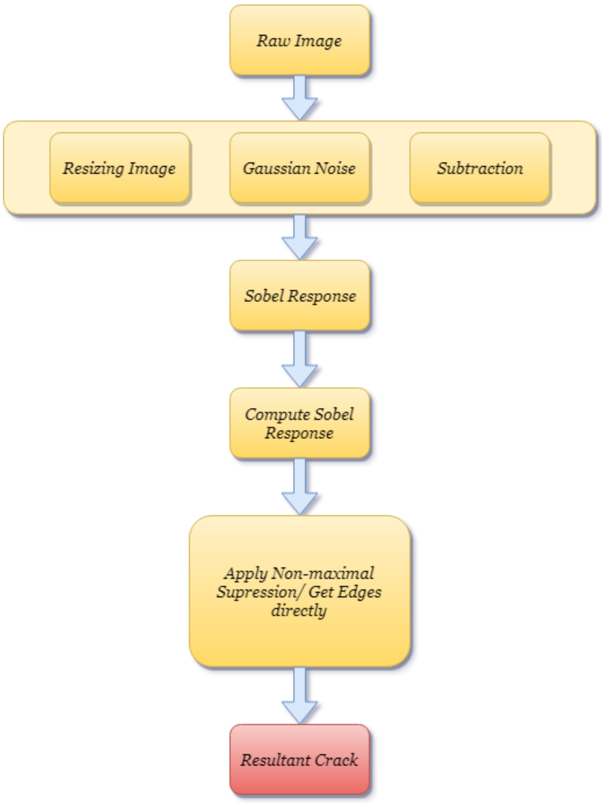
Programming

To ensure safety and overrides our mistake, we came up with two modes of control i.e. primary and backup. To control thrusters, we have used 2-2 axis joystick which has one of its kind trimming features. This allows extremely precise motion control which cannot be achieved by any other controllers (PS3/XBOX). This helps in maintaining level altitude. Apart from this feature, the ROV has altitude holding PID which uses the pressure/depth sensor to determine depth which is used as the reference as well as error for the PID. To provide a controlled and precise motion, the robotic arm is is controlled using a potentiometer connecter to Arduino microcontroller. The servo controlling the angle of the measuring tape has 2 positions for each of the orientations for measuring the distances. The servo controlling the angle of the measuring tape has 2 positions for each of the orientations for measuring the distances.



With the help of programming we managed to achieve 5 DoF Motions with our thrusters.

Image Detection Algorithm



Algorithm Description:

Step 1: Image Acquisition

With the help of standard OpenCV method, VideoCapture, a stream of image frames is captured from the analog camera mounted on the ROV.

Step 2: Pre-Process

Pre-Process involves the following stages:

– **Resizing the image**: This is done so that we can reduce the workload of the algorithm. This also helps with increasing accuracy for detection of contours.
– **Gaussian Noise:** Decreases noise and improves the contour approximation for shape recognition.
– **Subtraction:** Subtracting the smooth image from the image acquired via the ROV camera, thus resulting in removal of small noises present in the image

Step 3: Calculate Sobel Response: Calculates the mixed image derivatives which is further used to calculate the magnitude and angle of the crack

Step 4: Post processing:

The image in this stage is sent for filtering. Any edges found in the cracks are smoothed either by using non maximal suppression, or we can smooth the cracks using the normalize method.

Build vs Buy

There were multiple instances where the employees had to take build vs buy decisions. This is very crucial as our prime motive was to develop a powerful and innovative ROV but on a tight budget. We choose to build most of the ROV components such as the Electronics Chamber and its end cap/flange in a price which was almost 7 times cheaper than a similar option for purchase at Blue Robotics. Also, we contrasted our own tether rather going for ready Fathom which saved us a lot of money. We also waterproofed the Robotic Arm DC motor rather than buying expensive waterproof motors. The team also found a cheaper alternative for cameras. Usually cameras cost a major factor in ROVs however we purchased cheaper FPV Cameras which are used in Drones. There multiple advantages of this. They have very low latency due to its application use and they are small in size with a wide view (120 degrees). We found a very reliable way of using them with AV Cables. We choose to 3D print thruster shrouds then buying them. This saved us a lot of money while building the components, rather than just buying it.

New vs Used

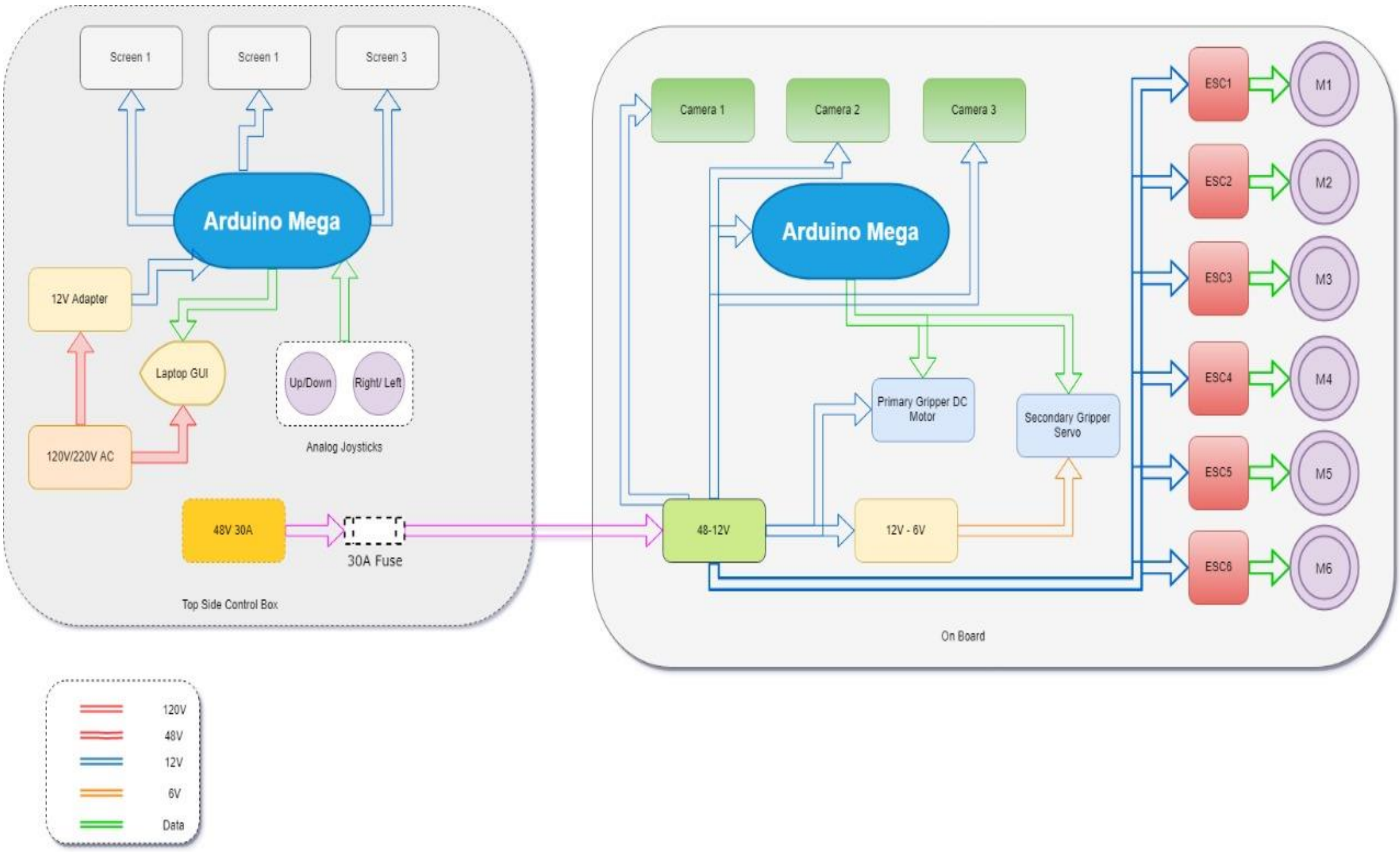
The team was able to save a lot of money ($1200) by reusing the frame of our previous year and also decided to reuse T100 and T200 Thrusters from our previous ROV. We didn't want to compromise waterproofing and safety of our ROV and hence we strictly purchased new components used in waterproofing, penetrators, cables. Fuse, etc. We choose to reuse the thrusters as they performed well in multiple tests.

The Acrylic Tube which would serve as our Electronic Chamber.

Reinforced ABS material is used to build IP-20 standard shrouds.

System Integration Diagrams (SIDs)

Detailed Interface Block Diagram of our Systems Onboard NetraROV



Accounting

The budget had been discussed in the start of the process to ensure as this is one of the most important aspects. Team members made sure that the components in good shape are reused instead of purchasing. However, components which are crucial for safety such as fuse, etc. are brand new. We were able to achieve our target of making robust and innovative ROV despite keeping a lower budget. We kept a buffer at all places to ensure cost overheads were taken care of urgently if required. Since we were running on schedule at most of the times, we were able to save cost overheads.

	Type	Category	Expenses	Description	Notes	Amount	Remaining Amount
1	Purchased	Electronics	Thrusters	BlueRobotics T100	Used for vehicle propulsion	39,883.07	46,283.07
2	Reused	Electronics	Thrusters	BlueRobotics T200	Used for vehicle propulsion	22,000	68,283.07
3	Reused	Hardware	Aluminium	Aluminiuim Bars, L-Bracket	Construction of ROV Frame	700	68,983.07
4	Purchased	Hardware	Nuts and Bolts	Stainless steel nuts and bolts	Used for securing different parts of the frame	400	69,383.07
5	Reused	Hardware	Washers	Stainless steel washers	Used along nuts and bolts	200	69,583.07
6	Purchased	Electronics	Arduino	Arduino Mega 2560 R3, Uno & Nano	Used for Onboard vehicle control	4,000	73,583.07
7	Purchased	Electronics	USB Shield	Arduino Shield	Joystick for Arduino	350	73,933.07
8	Purchased	Hardware	Acrylic	Electronic Chamber	Used as waterproof chamber housing electronic components	1,600	75,533.07
9	Purchased	Electronics	Camera	TVL Cameras	Used for providing video feed from ROV	3,200	78,733.07
10	Purchased	Electronics	Motor	Servo Motor	Used in Manipulators	4,000	82,733.07
11	Reused	Electronics	3-Way Splitter	3 to 1 splitter	Splitting and isolating AV Signals	400	83,133.07
12	Purchased	Electronics	DC Converters	DC to DC converter	Used for converting 48V to 12V	7,202.61	90,335.68
13	Purchased	Electronics	Sensor	Pressure Sensor	Used for measuring Pressure	500	90,835.68
14	Purchased	Electronics	Sensor	Temperature Sensor	Used for measuring temperature	400	91,235.68
15	Purchased	Electronics	Fuses	LittelFUse and Holder	Used for Overcurrent protection	3,000	94,235.68
16	Purchased	Electronics	Precise Joysticks	Controller with trimming feature	Used as a controller	500	94,735.68
17	Purchased	Electronics	ESC	Electronic Speed Controller	Used for speed control in thrusters	12,000	106,735.7
18	Reused	Electronics	Tether	AV Wire (20m)	Used for providing power to ROV from land surface.	120	106,855.7
19	Purchased	Electronics	Tether	4 core wire	Used for communication between ROV and the command centre.	150	107,005.7
20	Reused	Hardware	Connector	Anderson Connector	Used for Connection	190	107,195.7
21	Purchased	Waterproofing	Cable Glands	PG Cable Glands	Used for Waterproofing	130	107,325.7
22	Purchased	Waterproofing	Marine Epoxy	Water repellent fluid	Used for Waterproofing	2,391.02	109,716.7
23	Purchased	Waterproofing	Silicone	Silica Gel	Used for Waterproofing	200	109,916.7
24	Purchased	Electronics	Wires	Different assortment of wires.	Used for connection of different components	420	110,336.7
25	Purchased	Electronics	PCB	Copper board and misc components for PCB	Used in fabrication of PCB	200	110,536.7
26	Purchased	Electronics	Servo	Servo Motor	Used to perform different tasks	944	111,480.7
27	Cash Donated	General		University Aid		200,000	

Total Cost (₹)	111,480.70
Total Cost After Reusing (₹)	22,910
Final Balance (₹)	88570.70
Total Raised (₹)	155315.08
Total Cost ($)	1604.88
Total Amount Spent ($)	958.93
Total Raised ($)	2235.92

Miscellaneous Expenditure

1	Purchased	Logistics	Travel	Flight	Travel Expense for 5 Team members	560,000	USD 8060
2	Purchased	Logistics	Accommodation	Stay during Competition		100,000	USD 1440
3	Purchased	Outreach	Kits for Outreach	Gifts, kits, components for outreach		150,000	USD 2160

All amounts are presented in the document in local currencies (Indian Rupees) and US Dollar, since majority of the components were brought locally.

All conversions were done according to the conversion rate of **1 USD = 69.46 INR** on *24th May 2019* at *1325UTC*. The final balance amount is intended to be security amount, in case if any component requires any upgrade or fails, our company would be requiring these funds to buy newer components. The remaining amount will be returned to the University after the competition.

The travel and accommodation costs have not been included in the above accounts.

Logistics

We received a lot of components from our previous years ROV and upon rigorous testing it was determined that most of the components are in good shape. This helped us in saving a lot of money in logistics and new purchases. However, things which are crucial and can hamper safety are strictly new such as Fuse, etc. Most of the components were available locally. Locally the purchased items were handled by our company employees.

Outreach Activities

CTO explaining the wiring system onboard a Scout-Class ROV at a workshop conducted in Nehru Science Centre.

A quick quiz session with the kids from different schools.

Former CEO/CTO explaining the theoretical aspects of ROV movement in water and the forces acting on it.

Current CEO explaining the kids on how to build a ScoutClass ROV out of PVC Pipes.

Schoolchildren showing off their newly made invention.

For past six years, since the founding of Team Screwdrivers we have always worked our best to educate the younger minds into the world of technology that revolves around machines and electronics. With the number of children going to school increasing every year, it was a necessity for our company to take an initiative and teach them something different out of the Indian Education Curriculum, something they won't have thought of learning it at an early age. We have managed to conduct technical workshops at several different places for all kinds of audiences who were keen to take part in it, starting from primary schools, secondary schools to the esteemed Nehru Science Centre located in the commercial capital of India, "Mumbai".

Our work has always inspired them to do something different in their regular school-life, despite being an optional choice to opt for the workshops, a good number of children were always keen to take part in it. They were dedicated and were simply excited to learn how underwater vehicles manoeuvred in water, which would rather make it seem like a difficult task for the children to take part in. The efforts of our company employees who dedicated their time to teach these children paid off when the children were quickly able to understand the scientific and electronic logic behind how the ROVs worked. They quickly managed to assemble a Scout-Class ROV under the guidance of our employees who took care of the safety procedures.

Watching the kids pilot their own invention made them excited as they managed to invent something different then they would usually think of.

In all these years, we have managed to educate more than 70,000 children (and counting) hereby understanding the importance of social growth with scientific approach.

Our Faculty Mentor was our driving force for our outreach which was well executed by our company members. We have not only conducted workshops related to ROVs, but have also conducted workshops on building of drones, RC Planes, Arduino and sensors, etc. Our outreach also consisted of lectures, seminars on recent advancements in technologies such as Hyperloop, Additive Manufacturing, Artificial Intelligence, Humanoids, etc.

Critical Analysis

Testing and Troubleshooting

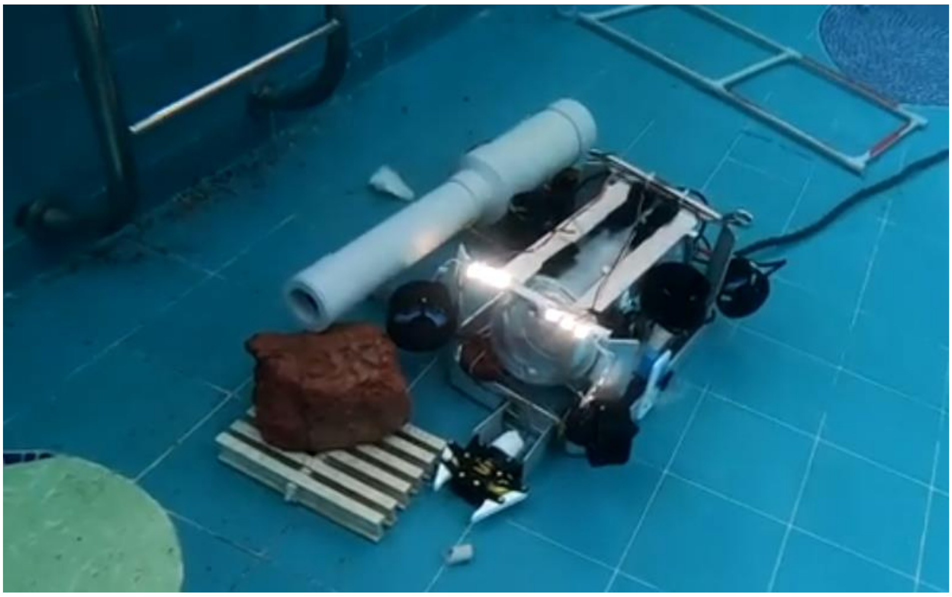
We strictly always believe on the functionality and working of our ROV and hence performing multiple tests on different components would give us a real-time update of what components might require fixes during troubleshooting.

ROV is safe when it's on land, but that's not what it was designed for, hence we do have to conduct tests underwater to get a brief idea what small-fixes would be required to improvise our ROV in technical, electrical and aesthetical aspects or to eliminate the problem caused during the period of inspection.

As a prerequisite, the employees made sure that they are double checking procedures at every step to eliminate the high possibility of occurrence of an error. This took a little more time than expected, but in the end, it would lead to save a lot of troubleshooting time. The company calls this procedure as elimination at detection.

During programming, even missing out a small bracket or a semi-colon would cause multiple errors in functioning of a component. Since these errors in general seem out small, they are usually missed out by the compiler while compiling the code.

A mini multi-meter was always kept handy with our company's Safety Officer who checked out if there is an issue arising at the time of manoeuvring the ROV, which could be caused by short circuit or if the supply of voltage supply drops below than the optimum voltage supply.



NetraROV in action

Challenges

Technical

The team faced a roadblock of technical challenges mainly due to new members in the team, but these challenges were successfully tackled by the team as time went through. The first main challenge that is notable to mention is the technical logic behind the working of a ROV. Our team was sufficiently qualified and had excelled in different fields of expertise, so that acted as a catalyst in our equation to learn about the working of a ROV. Most notable challenge that would be worth mentioning was related to waterproofing of our Electronic Chamber and other components which would remain exposed underwater. We had to apply marine epoxy and had to grease the mechanism of components so that the moisture wouldn't affect the functioning of that component.

Our aim was not to make a complex and sophisticated design but to make a more simplistic and realistic design which can be put to real world use and not just the competition aspects. We believe the ROV must perform the given tasks quickly, with minimum maintenance and operational costs. Hence to make this low-cost agenda work, we re-used several components from our last year ROV that included thrusters, etc which led us to greatly bring down the cost of production of NetraROV.

Another issue that included with our NetraROV frame was related to the positioning of Centre of Gravity (CoG), since the frame was positively buoyant there was a probability that ROV might flip due to change in the position of Centre of Gravity. After a quick analysis it was found out that the Electronic Chamber was the reason behind it, so we had tightened and secured our Electronic Chamber with the help of EVA foam to avoid the Electronic Chamber from deviating even by a minute distance. A small deviation caused the ROV to tilt, which in end caused disruption in manoeuvring.

Non-Technical Challenges

One important lesson that the employees of Team Screwdrivers learned was the importance of task delegation and separation of duties. This became especially important during the construction phase as concurrent engineering allows us to prototype and test much faster than limited members working on construction. Team Screwdrivers started with 10 members however only 5 choose to continue due to changing academic calendar. It was really challenging for the new members to handle multiple tasks and work under pressure. All team members came together irrespective of departments, and joined forces when times get tough and the deadlines were nearing.

Lessons Learnt

Technical

One major troubleshooting we had done was related to one of the six thrusters powering NetraROV, it was not initializing and/or was abruptly stopping at the time we were providing power to the thrusters. We had to open our T100 thruster casing to find out if there are any external factors affecting the functioning of the thruster. We closed the case and tightened up the screws when there weren't any significant signs of damage to the thruster, so we had to open Arduino IDE in our laptop to look up for any lapses regarding what is causing the thruster to not initialize. After a brief research, we had found out the values for Electronic Speed Controller for particular T100 thruster was not sufficient, so we had to go-ahead with a trial-and-error method of finding out the values which would be sufficient enough to initialize the ESC to power up the thruster. We started by increasing the value by +5 to +15. At one point the thruster managed to initialize by the time we increased the value by 15, hence we were able to make all our six thrusters work independently without any lapses.

Non-Technical

We have learnt that everyone in our team should diligently maintain the scheduled deadline regarding the completion of the task assigned to us. Completion of tasks assigned to us before the specified deadline would give us ample amount of buffer time to improvise and test the working of our product or in worst possible cases, it would give one final chance of troubleshooting the problem caused by malfunctioning of the component.

Building and working on this ROV has helped in bonding of the newly joined team members together who never knew their respective colleagues in past. Working under pressure has always helped us to yield better results and we strive to do our best in what we initially think of by breaking the bubble and by challenging our comfort zones.

> "Teamwork begins by building trust. And the only way to do that is to overcome our need for invulnerability." – Patrick Lencioni

> "It is literally true that you can succeed best and quickest by helping others to succeed."
> – Napolean Hill

> "None of us, including me, ever do great things. But we can all do small things, with great love, and together we can do something wonderful." – Mother Teresa

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