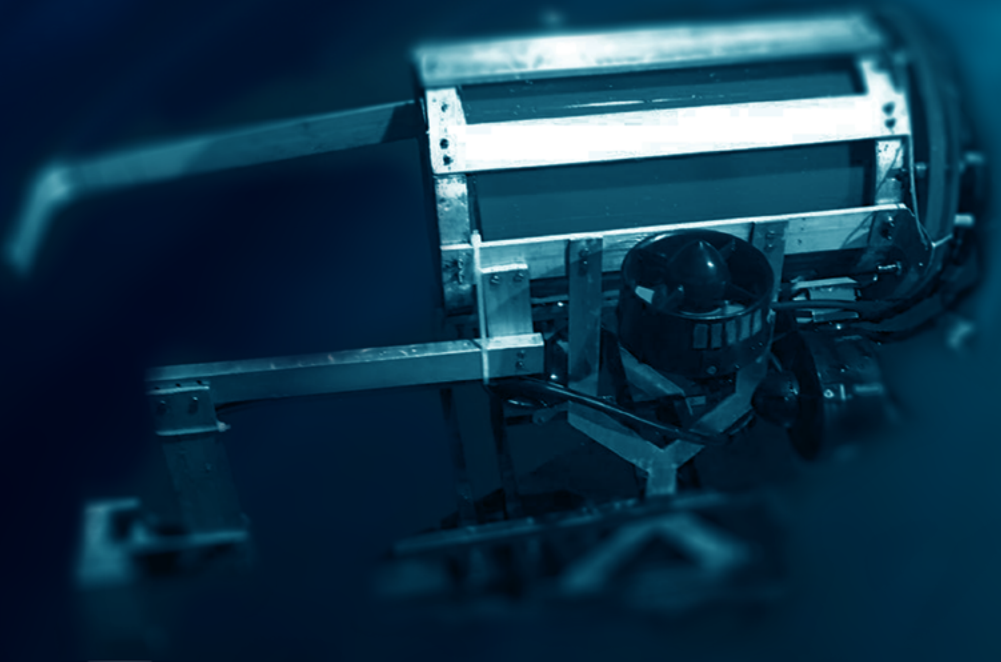
TEAM SCREWDRIVERS

SPYDER



STAFF MEMBERS

(Name-Designation-Graduation)

Rishi Bafna - Chief Executive Officer - 2016
Vijayender Joshi - Chief Technology Officer - 2016
Achal Desai - Design & Fabrication - 2016
Amala Putrevu - Electronics Expert - 2016
Sanjana Gupta - Safety Officer - 2016
Alolika Biswas - Fundraising - 2016
Rajas Jambekar - Software Developer - 2016

Ankit Sharma - Chief Financial Officer - 2017
Shalin Shah - Logistics Manager - 2017
Aditya Mulgundkar - Systems Engineer - 2017

Shambhavi Tripathi - Social Responsibility - 2018
Sarthak Agarwal - Design & Fabrication - 2018
Mridul Sharma - Buoyancy & Waterproofing - 2018

Mentor - Prof. Sawankumar Naik

SVKM's NMIMS MPSTME, Mumbai, India

ABSTRACT

Spyder is the latest creation by Team Screwdrivers in response to the request by NASA and Oceaneering Space Systems (OSS) for a dual purpose vehicle that can travel and be deployed to Europa's deep oceans and can deploy instrumentation, recover critical equipment, collect and analyse oil samples and survey corals as well as carry out wellhead decommission and conversion. These versatile abilities of Spyder are due to its technologically advanced construction that includes six brushless thrusters for propulsion combined with its lightweight aluminium chassis and acrylic electronic chamber which allows easy maneuverability, the thrusters and other electronics on-board Spyder are controlled by a custom designed and manufactured PCB which at its heart is powered by an Arduino Mega. Spyder is equipped with two full HD cameras, which have full pan and tilt capability for pilot comfort and ease of survey. It comes with two custom fabricated mechanical manipulators for ease of carrying out tasks and uses a custom designed tether that provides it power as well as communication lines. Spyder is controlled from topside using a multithreaded JAVA based application that communicates over a single Ethernet cable providing data as well as video feed.

The team of 13 students have worked tirelessly for long hours designing, constructing Spyder and solving the challenges that we faced during its trial runs. We have learned a lot in this journey. Our focus has been to learn and improve upon our past vehicle, Vikrant, while focusing on constructing the most cost effective yet versatile and powerful ROV, and the result is Spyder.

Spyder embodies the Indian spirit of using advanced technology at an affordable cost with the complete construction costing just under 1000 USD!

Team Screwdrivers 2016

Front: Ankit Sharma, Mridul Sharma, Achal Desai, Sarthak Agarwal, Aditya Mulgundkar
Middle: Sanjana Gupta, Shambhavi Tripathi, Alolika Biswas, Amala Putrevu
Back: Shalin Shah, Rishi Bafna, Prof. Sawankumar Naik, Vijayender Joshi, Rajas Jambekar

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1.1. Design evolution

Early stages of design included brainstorming sessions amongst all departments to evaluate factors such as, the cost of elements to be used, ease of manufacturing the design and basic aesthetics as per the size regulations provided by MATE.

The design process started off with a shape resembling that of a submarine, as the centre of gravity (CG) of such a design could be varied without the use of external pneumatics or hydraulics systems. The design was exceeding the size description and hence that design had to be replaced.

Fig. 1.1: CAD Design (Carbon fibre)

The new idea was to build a ROV with a unibody design (fig. 1.1). So the design process started again, but this time around a dual shell design with a fiberglass interior and a carbon fibre exterior. The team soon realised that it did not provide the required design flexibility. It wasn't modular and hence that design was scrapped.

The chassis had to be made completely modular and the electronics chamber easily accessible so as to reduce the effort and time in wiring and rewiring so we chose to construct the chassis out of aluminium, due to its excellent strength to weight ratio.

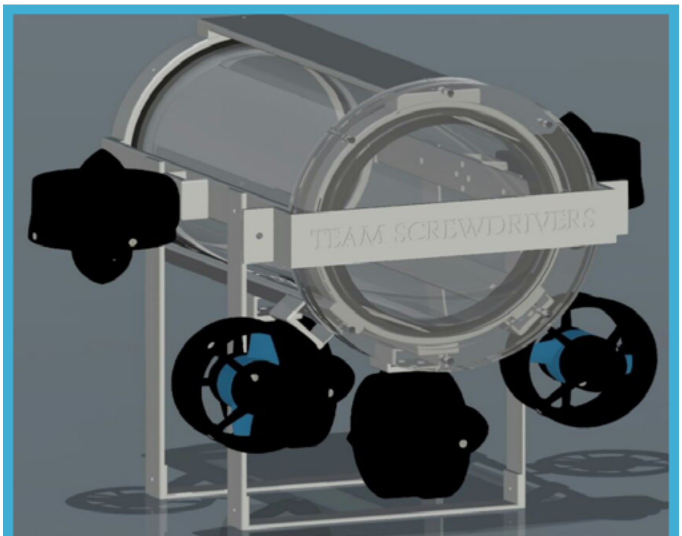

Fig. 1.2 Proposed Design

Aluminium, because of its corrosive resistance, machinability, light weight, and affordability became our final choice. The electronic chamber was made of acrylic as it is affordable, can be easily machined and can be obtained in clear or coloured variety. (fig. 1.2) This design is made keeping in mind the streamline flow.

The gaps between the plates of the chassis would allow the fluid to pass easily.

If any thrusters or attachments such as the robotic arm have to be changed or repaired, the independent plates can be dismounted and the required work done, thus the whole chassis does not need to be disassembled.

1.2. Buoyancy

Team Screwdrivers decided to build Spyder slightly positively buoyant so as to enable it to float back to the surface in case of any disruption in power supply. This was achieved by using the electronic chamber as the main source of positive buoyancy on the ROV. This saved us the effort of designing ballast tanks and dealing with pneumatics and air compressors, this also saved a considerable amount of money. The aluminum chassis and thrusters provide negative buoyancy. The placement was decided and altered to make a well-balanced ROV after taking in note the center of gravity (CG) and the center of buoyancy (CB). The important task was to ensure that the CB was above the CG otherwise the ROV would be imbalanced and would flip over in the water. This was ensured by position two thrusters on the underside of the ROV along with the ROV stand which shifted the CG downwards, thus providing good stability to the ROV.

1.3. Waterproofing

Electronic chamber is the home of all the equipment that enables the ROV to function. Team Screwdrivers had to ensure that it is completely waterproof to function at a depth of 40ft. This was a complicated task as waterproofing an object that is to be permanently sealed is comparatively easier than waterproofing a re-openable container. After doing some research on the design of such containers, we found one successful method - using O - rings (fig 1.3).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. Lot of wires had to be passed through the electronic chamber, to prevent seepage of water, we installed glands on the end-cap of the chamber. Silicone-based epoxy was used to seal test enclosures. Cameras were enclosed in a watertight enclosure made of acrylic with a gland at back for the wire. To prevent condensation from adversely affecting the electronics inside the chamber and the camera lens inside the external casing, we used industrial grade silica gel packed in cloth to absorb the moisture.

Fig. 1.3 Cable Gland waterproofing

LEDs were enclosed in another acrylic casing and also treated with epoxy to prevent any access of water to it. 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. Servos that move the camera were filled with grease from inside to prevent water from entering, and with wires enclosed in a case. Waterproofing the tiny pressure sensor chip was another one of the waterproofing tasks; the pressure sensor requires a tiny portion of it to be exposed to the fluid whose pressure it needs to measure, but the remainder of the sensor needs to be waterproofed. To accomplish this we use epoxy. Temperature sensor was enclosed in a stick-like case keeping in mind the task.

1.4. Programming

Spyder is controlled from a laptop using two joysticks. The controller program is based on Java platform and has been written in Eclipse IDE. Java programs cannot directly interface with external devices. Thus, we make use of JInput library for reading the joystick inputs. The controller program implements a graphical user interface which is designed in JavaFx platform. We have used the scenebuilder software from Gluon. All user interactions with the controller are via the joystick and the Graphical User Interface.

The first joystick is used mainly for manoeuvring purposes. The x, y and z axes on the joystick provide left-right, forward-backward, up-down as well as rotation movements for Spyder. Along with that, some misc. functions such as camera servo position and LED on/off are also controlled with the use of buttons on the joystick. The second joystick is used for controlling the robotic arm functions. The combination of axes and buttons on the joystick are used for controlling the forward and reverse motion of motors used in the robotic arm.

The main feature of the java controller system is the ability to configure the axes and buttons of any number of joysticks, to control any component of Spyder. E.g. The controlling of the motors can be easily switched from axis x to axis y on the joystick or from axis x to buttons 2 and 3 on the other joystick.

In case a controller is disconnected and reconnected, the GUI (fig. 1.5) allows re-discovery of controllers connected to system. Each controller is identified by its name, type and a special identifier assigned by the controller system which distinguishes it from other controllers of the same or different make.
A special configuration window can be accessed on the GUI which allows the user to select the controls.

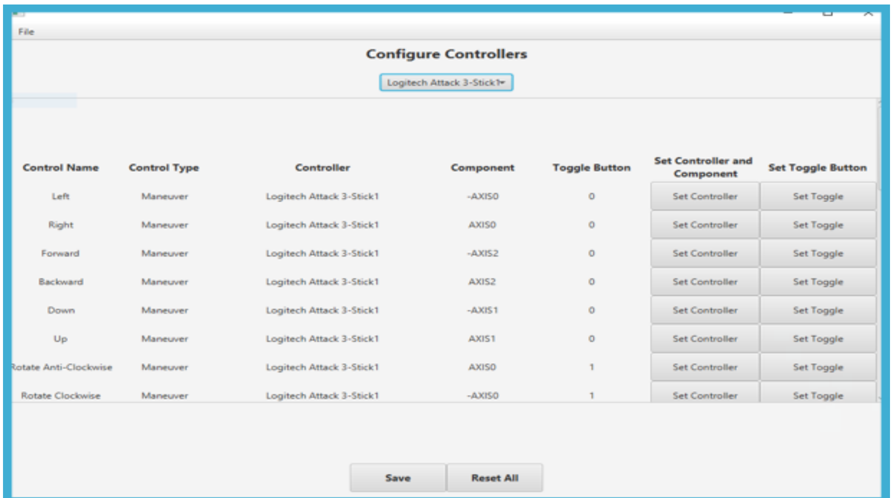

Fig. 1.4 Configuration Panel

The main GUI of the controller has been custom designed to show the status of each component of the ROV for precision control.

The controller system communicates with Arduino mega 2560 by sending commands over the Ethernet. The communication is done over TCP protocol. A connection is required to be established between the controller system and the Arduino for communication.

DESIGN RATIONALE

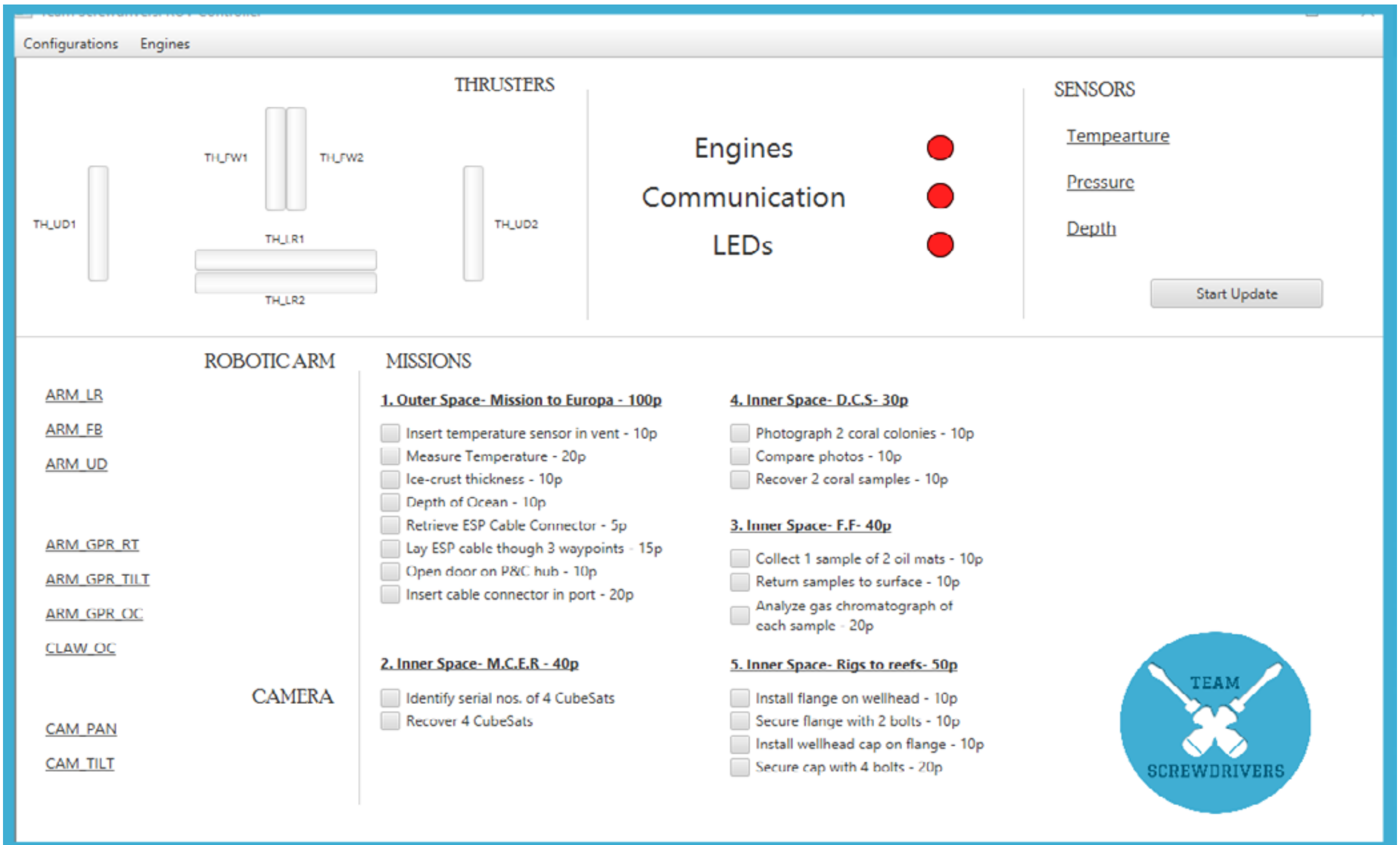

Fig. 1.5 Graphical User Interface

The tasks have been separated using their basic functions, like manoeuvring, robotic arm control, camera servo, LED control, GUI updation, receiving sensor data from Arduino, etc. All these tasks are designed to run in parallel. This increases the throughput of the system and makes the system extremely coherent.

The Arduino accepts commands from the controller in a specific format. When a command is received, it first validates the command by its format. Commands sent to the ROV are used to directly run the ROV components. No processing is done on the arduino which reduces its workload thus keeping the microcontroller ready for the next command.

The Arduino is responsible for fetching the temperature sensor readings and the pressure sensor readings. It processes the input from the sensors, calculates the temperature and pressure value and sends it to the java controller system via the Ethernet.

DESIGN RATIONALE

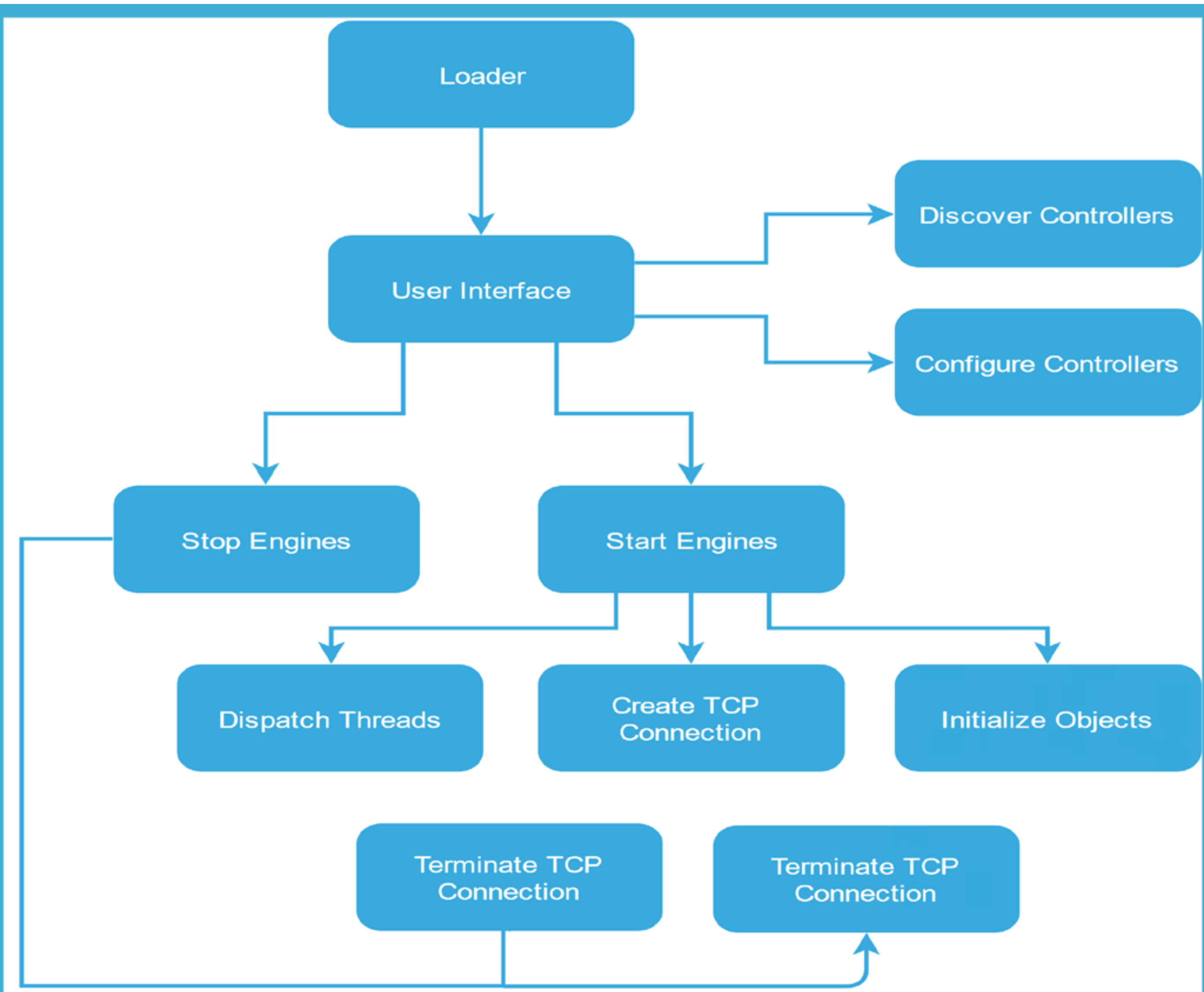

Fig. 1.6 Data Flow Operation

A 5 second security system is in place on the arduino to protect Spyder in case the communication between the ROV and the controller is broken. The Arduino is constantly waiting for command from the controller and keeps a track of time since last command. In case the time exceeds 5 seconds, Spyder shuts off all systems and waits for the communication to resume.

DESIGN RATIONALE

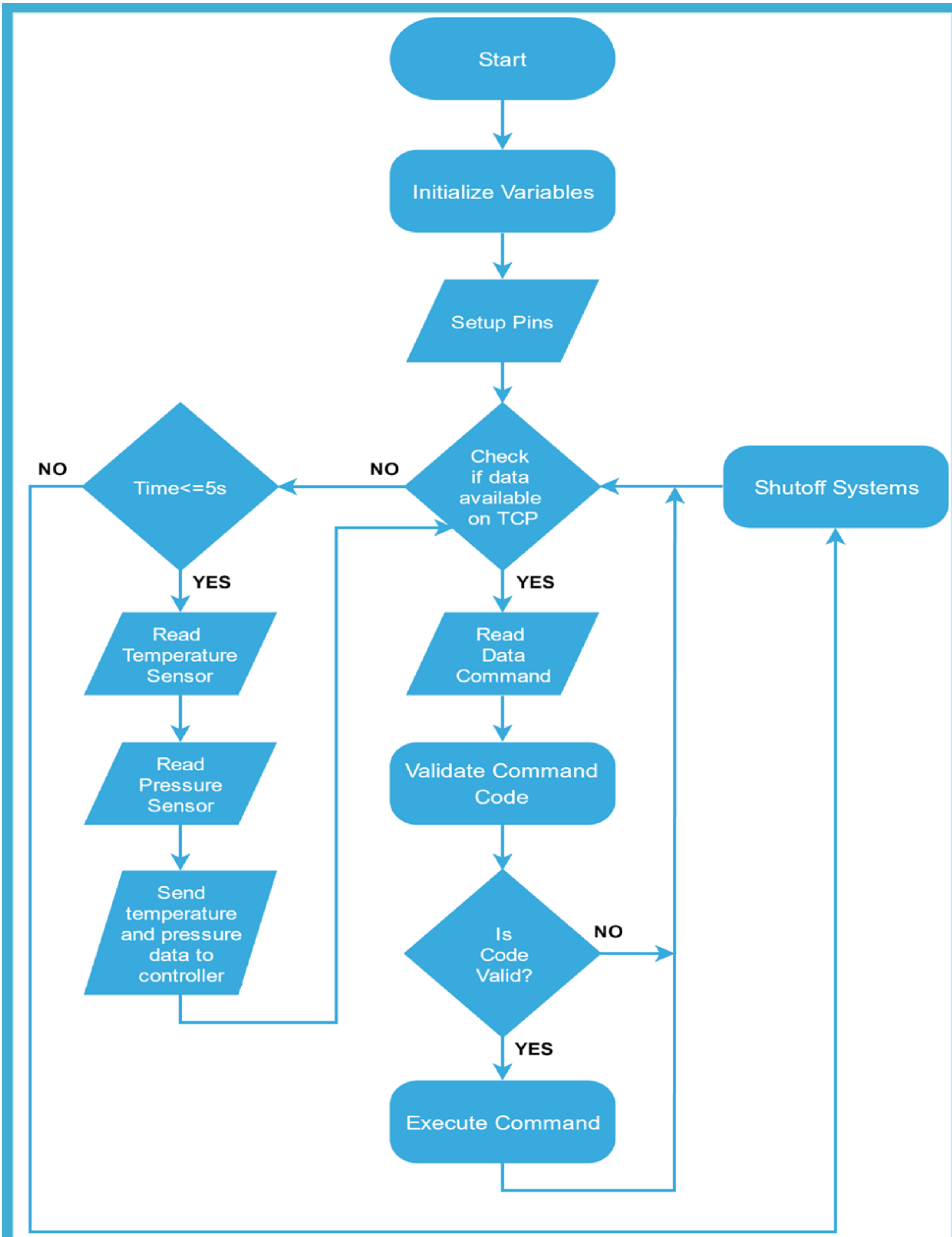

Fig. 1.7 Software Flowchart

The Arduino program accepts the command sent by the Java controller, validates it and executes the command affecting the ROV components. Along with this, the Arduino system also sends the temperature and pressure sensor data to the Java controller intermittently. If the ROV does not receive any communication from the controller for more than 5secs, it shuts off all systems and waits for communication to resume.

1.5 Tether

Tether is based on a very simple design. Tether contains one Cat6e Ethernet cable for communications between Arduino and Cameras on the ROV and Topside Computer. Tether also contains 2 DC Power lines with a conductor cross-section area of 6mm square, which is equivalent to 9-10AWG wire. The DC power lines were selected such that they provided minimum resistance while providing enough flexibility. 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 onboard Spyder.

1.6. Thrusters.

Fig. 1.8 Thrusters on SPYDER

Six thrusters were attached to Spyder for primary propulsion. Team Screwdrivers had an advantage to use our past year's team thrusters as they were in good shape and performed well under testing. This saved us a considerable amount of money, in logistics.

Team Screwdrivers is using BlueRobotics' T100 thrusters. These are brushless electric motor based thrusters. The thrusters' housing is made of high-strength, UV resistant polycarbonate injection moulded plastic. These thrusters are operated using Afro Electronic Speed Controllers (ESCs) which are operated on 12V DC. The thrusters are rated for a maximum forward thrust of 2.36 kgf and a maximum reverse thrust of 1.82 kgf.

The six thrusters on-board Spyder are divided into three groups. The vertical group of thrusters are responsible for the diving and rising of the ROV, these thrusters are placed symmetrical on two side plates. These thrusters are numbered 1 and 6 in the figure below.

DESIGN RATIONALE

Then we have the forward group of thrusters, these thrusters are mounted on the 45 degree inclined plates of the ROV, the thrusters are placed slightly towards the rear of the ROV, just as a propeller is placed on a ship or boat, these are identified as 2 and 4 in the figure.

The multifunctional group of thrusters are the horizontal thrusters, these are numbered 3 and 5 in the figure below, and these are placed on the bottom plate of the ROV. This pair of thrusters not only provides Spyder with the ability to move left and right, but also the ability to rotate clockwise and anti-clockwise on its own axis.

This pair of thrusters is the only pair of thrusters that can be operated asymmetrically, i.e. one thruster in forward operation and other in backward operation, all other thrusters always operate in the same direction.

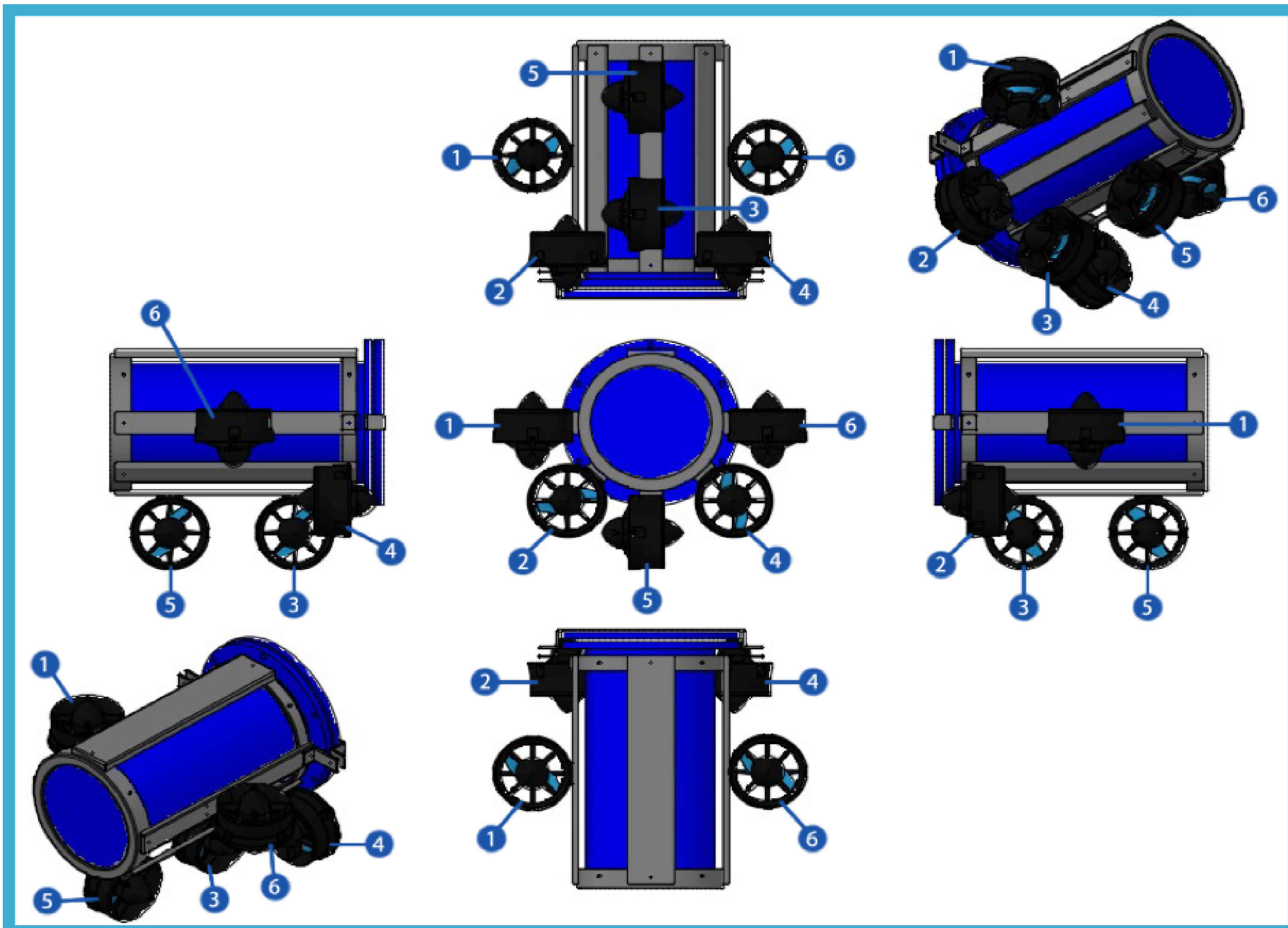

Fig. 1.9 Thruster Placement Diagram

In upward/downward motion of Spyder, if the Centre of Gravity is shifted slightly from the exact centre of the ROV, the thruster of that side is provided with more power than the other to manage the motion. Clockwise/Anti-clockwise motion is maintained by the rotational thrusters (refer thruster placement diagram and name the thruster).

All the 6 thrusters were managed in a way so as no thruster interferes with the thrust of any other thruster during operation and do not create any drag.

1.7. Electronics.

All the electronics are housed in an acrylic 'electronics chamber' (EC) which has an end cap with an O ring that can be opened when needed, but is waterproof. The tether carrying the high power cables and LAN cables are fed to the EC by means of glands on the end cap. The EC houses the PCB and associated wiring for the thrusters and motors.

The aim of miniaturization of the circuit has been achieved by means of a printed circuit board, which has been designed in-house. The electric board of Spyder has been designed to have maximum isolation between high power and low power signals, so as to reduce the likelihood of electromagnetic interference. The design has been made with the goal of efficient conversion, high signal integrity and reusability in mind.

Unit	Current (in A)	Voltage (in V)	Power, W	Quantity	Total
Arduino	0.5	12	6	1	6
BlueRobotics T100	8	12	96	6	576
Ethernet Hub	1	12	12	1	12
Cameras	1	12	12	2	24
Servos	0.5	7	3.5	2	7
Lights	4	12	48	2	96
DC Motor	2	12	24	8	192
Total		**12**			**913**

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 Efficieny, % (Estimated)	85
Power Loss, W (Peak Power/Efficiency)	205.2
Power After Conversion at ROV	**1162.8**

Fig. 1.10 Power Budget

The high voltage conversion is done on-board using two DC-DC converters in parallel, i.e. the Delta Electronics DSQ48SC12 modules. These are high efficiency modules with 95% efficiency rated at 48 V/42 A. The thrusters are controlled by electronic speed controllers which are mounted on the board itself as socketable components. The DC motors, which are used in the custom fabricated mechanical manipulators, are driven by L298N motor drivers.

There are two IP-enabled cameras: one is mounted on the chassis in its own housing, and one within the EC. They are powered by the 12 V rail and communicate over Ethernet. The cameras

DESIGN RATIONALE

along with Arduino are plugged into an Ethernet switch on-board the Spyder. This allows us to use a single Ethernet cable for all our communications needs. The high voltage rail powers the electronic speed controllers of the thrusters, Ethernet switch, IP cameras, LEDs through relays, and the motor drivers. The low voltage conversion from 12 V to 5 V is done on board using a standard linear regulator with heat sink. The low voltage rail powers the camera servo motors, and the gyroscope.

Fig. 1.11 DC-DC Converter

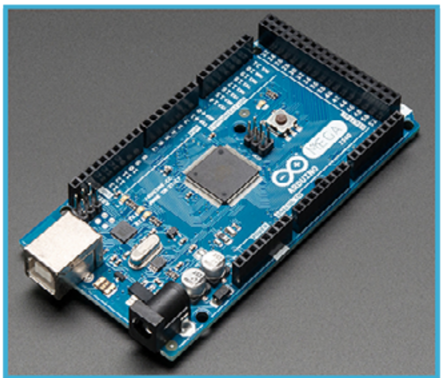

Fig. 1.12 Arduino Mega 2560

Fig. 1.12(c) Temperature sensor

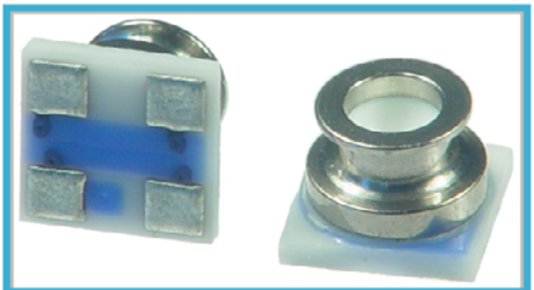

Fig. 1.12(a) Pressure Sensor

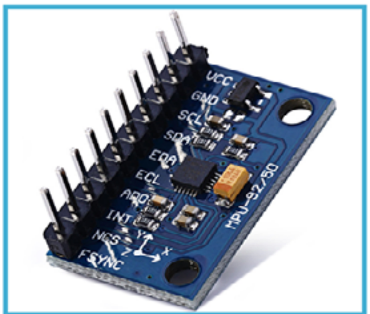

Fig. 1.12(b) MPU-9250

Fig. 1.16 Soldering Process

SAFETY

Team Screwdrivers has always made safety of the team and its products its first priority. Team members are given a complete safety brief for the working and handling of the product.

Vehicle safety

Designing of Spyder was done keeping in mind the safety hazards and tackling them at an early stage of the process.

Spyder was built with the aim of being user-friendly as well as performing well in difficult environments. This requires the ROV to have a rugged design. To improve safety while being handled by human, all edges were filleted and made smooth. All sharp edges were avoided in the chassis as well as the EC. Visible warning labels were affixed on the moving components such as thrusters, claw, gripper, rack and pinion.

Workshop safety

Team Screwdrivers believes in maintaining a safe work environment for all its members and minimising hazardous factors, by taking well instructed precautionary measures. Factors taken into account were:

- The members were instructed to be fully clothed and covered.
- Wearing safety shoes.
- Wearing gloves while handling the product.
- Wearing safety goggles while working.
- Wearing masks to avoid inhalation of harmful chemicals.
- Maintaining a well ventilated work station.
- Avoiding flammable materials at work station.
- The tools to work with were marked properly with warning labels.
- No loose ornaments were left unhandled.

Operational safety

- All team members were taught swimming.
- Ensured there was always more than 1 member to pick up heavy objects.
- The team members were given basic safety lessons, such as back safety, electrical safety, hazardous materials' handling, housekeeping, and tool safety.
- New team members were guided by the experienced members on various operations to be carried out.
- Various stages of waterproofing were tested to keep the electronics dry and prevent a short circuit.
- A prepared full safety checklist is to be used before immersing Spyder in water.
- Wires were properly insulated with no copper strands left loose so as to prevent short circuit.

SAFETY

Fig. 2.1

Equipment worn for personal safety - Helmet, safety Goggles, Industrial ear-muffs, mask, gloves, float jacket, full sleeves, close toed shoes

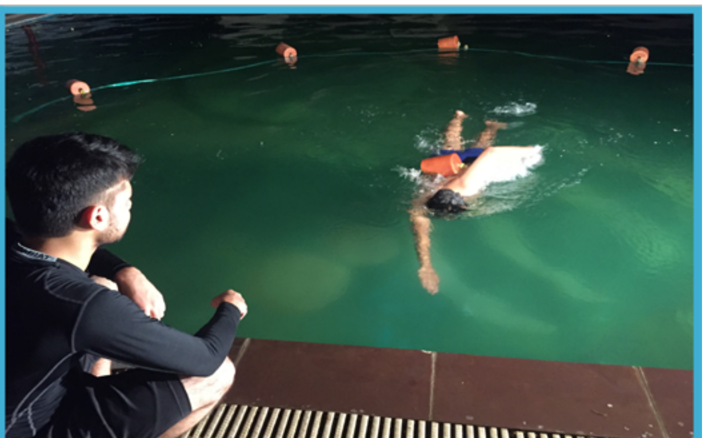

Fig. 2.2 Pool Safety Lessons for team members

CONCLUSION

Lessons learned (Technical)

Team Screwdrivers while working on Spyder faced a myriad of technical challenges mainly due to new members in the team, but these challenges were successfully tackled by the team. The first major challenge was vehicle design, especially with additional points for weight and size. We focused on constructing the most multifunctional yet small sized ROV while being lightweight at the same time. A lot of research was done on unique materials like carbon and glass fibre but eventually settled on aluminium due to ease of work and affordability, an important lesson from this was that a simple design is often the solution to any task. Thus we decided to keep the ROV design minimalistic and elegant.

The second major challenge the team dealt with was waterproofing, making the acrylic chamber perfectly watertight with multiple holes for Tether and wiring made this already difficult task even more challenging. The team went through multiple solutions for waterproofing from cable glands to waterproofing agents like epoxy. We eventually overcame this problem by using a combination of square cut silicon O-rings along with waterproofing agents for holes in the end-cap of the electronics chamber.

Another challenge the team faced, mainly during trials, was achieving the required buoyancy. The team followed a trial and error method for this and it took quite a while to achieve the perfect balance that was desired. This included couple of redesigns and adjustments and using the proper tether and attachments.

One recurrent problem throughout was the difference between practical knowledge and theoretical knowledge. Team Screwdrivers is blessed with talented members with great knowledge. This was very beneficial during the design stage, but the team faced some challenges during the construction phase as many of those designs were not implementable due to non-technical constraints..

Lessons learned (Motivational)

Team Screwdrivers consists of very versatile members and one important lesson that we 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.

At the same time, all team members came together irrespective of departments, and joined forces when times got tough and the deadlines were nearing.

Improvements

While this year's focus has been on size and weight, more can be achieved with further refinement. By reducing the size of the electronics boards, the required size of the electronic chamber gets reduced, which would make it possible to design an even smaller ROV which is more nimble and easily manuverable. Also working with durable hard plastic as the primary construction material as compared to metals such as aluminium in the future would allow a further weight reduction and easier, faster prototyping and construction.

CONCLUSION

Senior Reflections - Rishi Bafna, CEO

I have been a part of Team Screwdrivers for last 4 years, since its inception. This year I am participating at the MATE ROV Competition for the 3rd time. I started as an executive from the fundraising team and this year I am proud to represent the team and the country as the CEO of Team Screwdrivers. Being a part of this organization has helped me gain experience and knowledge beyond my field of education and curriculum. A cocktail of ideas, discussions, debates, brainstorming sessions, fights, achievements and fun times is what makes the entire process engaging and this is why I cherish being here. Additionally, the competition has provided a global platform where one can share their talent and learn from others. The enthusiasm, the passion, the mixing of various cultures, the vision of different teams and the entire environment at the event makes the entire competition, nothing less than an international summit. This variety of technology, interaction and the learning experience is what makes this competition unique and this is what has made me realize my actual potential and interests.

Senior Reflections - Vijayender Joshi, CTO

My journey started with Team Screwdrivers in 2014 for MATE 2015 competition, from my initial role in the team as a junior programmer to Chief Technical Officer for the team in 2015 has been a tremendous experience. For the MATE 2015 competition I got a chance to hone my programming skills and experiment with embedded programming, starting from there I got involved into more inter departmental things such as electronics where I learned much more about Integrated Circuits and Printed Circuit Boards and this year has been even more of a learning experience as I got introduced to AutoCAD Inventor, Solidworks 3D and EaglePCB. As a member of Team Screwdrivers I have not only gained technical knowledge but also invaluable interpersonal skills and gained a deep interest in the field of marine engineering. Due to graduate in summer 2016, this marks my last year as the member of Team Screwdrivers but I have made great friends during this journey and have gained unparalleled experience which will definitely be useful lifelong.

Junior Reflections - Mridul Sharma

Being one of the most junior members of the team that has had an intriguing past, I wanted to put all the effort possible from my end. I have learnt a lot in these past few months – from designing components to troubleshooting problems. Being in charge of the waterproofing involved with the product, I researched a great deal and tested new ways to achieve it. To sum it up, I would like to improve on the problems faced this year to help the team reach new heights in the future.

CONCLUSION

Acknowledgement

First and foremost, we would like to thank Mr. Sawankumar Naik, our faculty mentor, for introducing us to this competition and encouraging us to push our limits and aim for the sky.

Also, a special thanks to –

- MATE Centre and Marine Technology Society's (MTS) ROV Committee for organising this event and providing us with the opportunity to compete
- NASA for hosting the competition in Neutral Buoyancy Labs, Houston, Texas
- Forge, Mumbai for providing access to their makerspace and access to tools and machinery
- SolidWorks for providing Solidworks CAD software
- SVKM's CNM School for providing access to the swimming pool for testing of ROV
- Joyo Plastics and Joyous World for donating plastic household articles and corporate gifts for outreach programs.
- Fugro Survey (India) Pvt. Ltd. for providing financial assistance
- Decent Engineers for providing financial assistance
- Krishna Enterprises for providing financial assistance
- Kotak Mahindra Bank for providing financial assistance
- SKIL Infrastructure Pvt. Ltd. for providing financial assistance
- Meritt Transmissions Pvt. Ltd. for providing financial assistance
- Midtown Holding, Leasing & Properties Pvt. Ltd. for providing financial assistance
- Advanced Music Labs for providing guidance and assistance in fabrication of printed circuit board
- Nehru Science Centre (NSC) Mumbai, for letting Team Screwdrivers conduct outreach activities.

Last but not the least; we would like to thank our family members, friends and junior volunteers of the team, for giving us their support and good wishes.

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- Arduino.cc – Arduino 2560 Mega documentation
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APPENDIX A: SAFETY CHECKLIST

- Pre-Launch

- ☑ Power Supply is switched off
- ☑ Electronics Chamber is sealed with O-rings present where needed
- ☑ Tether is untangled and uncoiled on the deck
- ☑ Tether is securely connected to Power Supply and ROV
- ☑ All local connections on ROV are secure and watertight
- ☑ All nuts are tightened and secure
- ☑ All components mounted on ROV are secure and tight

- Launch

- ☑ Deck crew wearing gloves, closed shoes and glasses
- ☑ Power Supply switched ON, 48V supply verification
- ☑ Test camera feed
- ☑ ROV launch only by designated call-out “Launch now”
- ☑ Check for air bubbles on ROV deployment, cancel deployment in case of many big air bubbles
- ☑ Thruster test
- ☑ Deck crew to withdraw post deployment

- Recovery

- ☑ Deck crew to recover ROV only after call-out from Pilot
- ☑ Deck crew to call-out after recovery
- ☑ Immediate Power Supply cut off post recovery
- ☑ ROV to be secured on deck
- ☑ Tether and power systems disconnected

APPENDIX B: BUDGET

Date	Type	Category	Expense	Description	Sources/Notes	Amount (INR)	Running Balance (INR)
05-10-2014	Re-used	Electronics	Thrusters	BlueRobotics T100	Used for vehicle propulsion	INR 45,000.00	INR 45,000.00
17-12-2015	Purchased	Hardware	Aluminium	Aluminium Bars, L Bracket	Used for vehicle frame	INR 1,400.00	INR 46,400.00
17-12-2015	Purchased	Hardware	Nuts & Bolts	Stainless Steel Nuts and Bolts	Used for securing different parts of the frame	INR 800.00	INR 47,200.00
17-12-2015	Purchased	Hardware	Washers	Stainless Steel Washers	Used along with Nuts & Bolts	INR 200.00	INR 47,400.00
10-01-2015	Re-used	Electronics	Arduino	Arduino Mega 2560 R3	Used for onboard vehicle control	INR 600.00	INR 48,000.00
10-01-2015	Re-used	Electronics	Ethernet Shield	ENC28J60 Module	Used for Ethernet to Arduino communication	INR 200.00	INR 48,200.00
05-01-2016	Purchased	Hardware	Acrylic	Electronic Chamber	Used as warterproof chamber for electronic housing	INR 2,250.00	INR 50,450.00
07-01-2016	Purchased	Electronics	Camera	IP Board Camera Module	Used for providing video feed from ROV	INR 870.00	INR 51,320.00
11-01-2016	Purchased	Electronics	Motors	DC Motors	Used in manipulators	INR 1,800.00	INR 53,120.00
10-01-2015	Re-used	Electronics	Ethernet Switch	D Link 10/100 Network Switch	Used for Networking Arduino, Camera and Tether	INR 400.00	INR 53,520.00
16-01-2016	Purchased	Electronics	DC Converters	DC to DC Converter	Used for converting 48V to 12V	INR 7,500.00	INR 61,020.00
16-01-2016	Purchased	Electronics	Sensor	Pressure Sensor	Used for measuring Pressure	INR 350.00	INR 61,370.00
16-01-2016	Purchased	Electronics	Sensor	Temperature Sensor	Used for measuring Temperature	INR 300.00	INR 61,670.00
20-01-2016	Purchased	Electronics	Fuses	Polyswitch fuses	Used for overcurrent protection	INR 320.00	INR 61,990.00
01-12-2014	Re-used	Electronics	Joystick	Generic Joystick	Used as controllers	INR 670.00	INR 62,660.00
12-01-2016	Purchased	Electronics	Motor Drivers	L298N Module	Used for controlling DC Motors	INR 800.00	INR 63,460.00
05-03-2016	Purchased	Electronics	Tether	6mm sq wire 22 metre	Used for carrying power to the ROV from topside	INR 1,200.00	INR 64,660.00
05-03-2016	Purchased	Electronics	Tether	Cat6 wire 25 metre	Used for communication between ROV and topside	INR 300.00	INR 64,960.00
07-01-2016	Purchased	Hardware	Connector	Anderson Connector	Used for Connection	INR 190.00	INR 65,150.00
04-02-2016	Purchased	Waterproofing	Cable Glands	PG Cable Glands	Used for Waterproofing	INR 130.00	INR 65,280.00
07-02-2016	Purchased	Waterproofing	Marine Grease	Marine Grease	Used for Waterproofing	INR 220.00	INR 65,500.00
07-02-2016	Purchased	Waterproofing	Silicone	Silicone	Used for Waterproofing	INR 200.00	INR 65,700.00
15-01-2016	Purchased	Electronics	Wires	Different assortment of wires	Used for connection of different components	INR 150.00	INR 65,850.00
15-02-2016	Purchased	Electronics	PCB	Copper Board & miscellaneous components for PCB	Used in fabrication of PCB	INR 600.00	INR 66,450.00
10-02-2016	Purchased	Electronics	Servo	Servo Motor	Used for camera pan and tilt	INR 450.00	INR 66,900.00
01-05-2016	Cash donated	General	-	University Aid	-	INR 2,00,000.00	INR 1,33,100.00

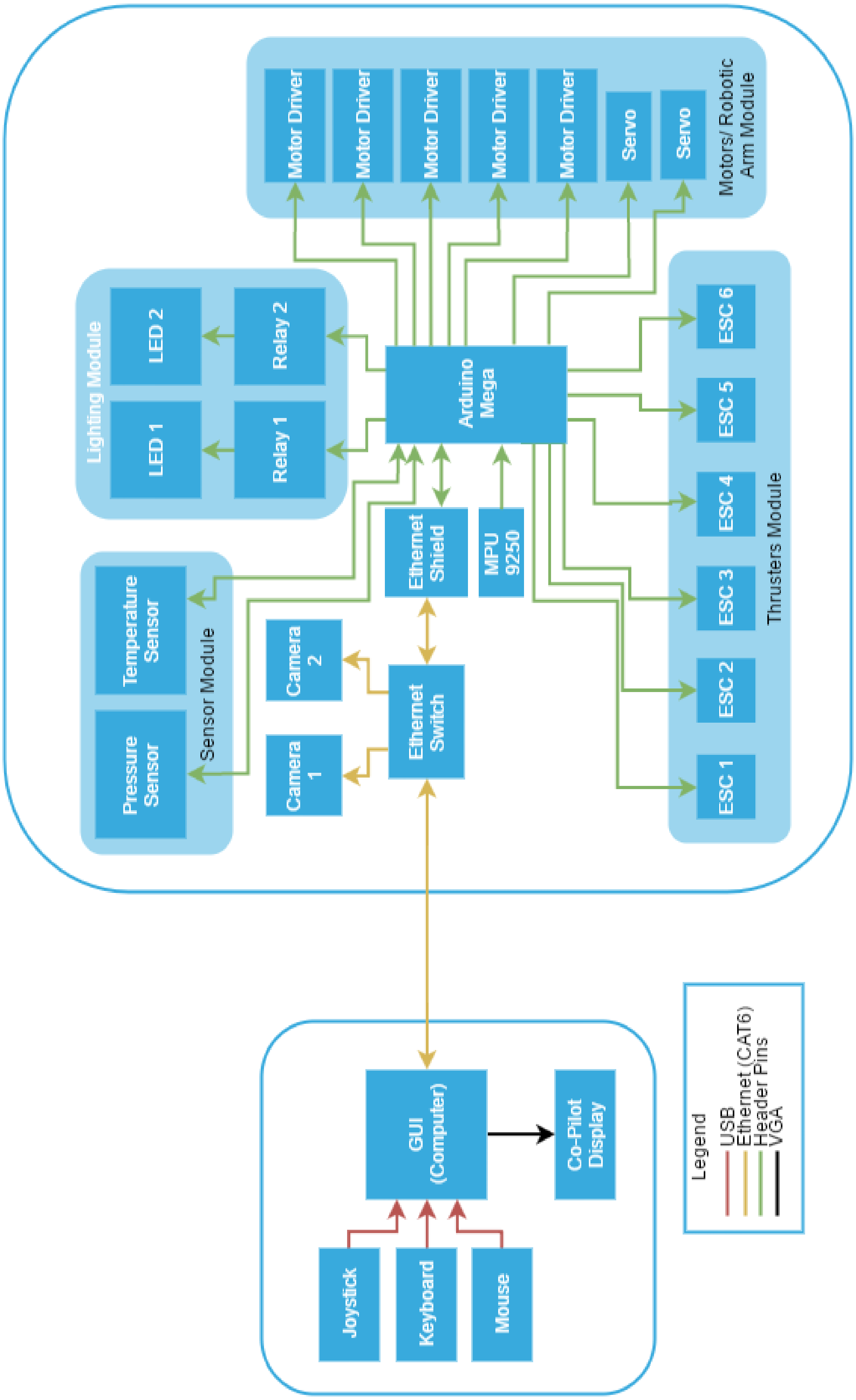
Total Raised (INR)	INR 2,00,000.00
Total Spent (INR)	**INR 66,900.00**
Final Balance (INR)	INR 1,33,100.00
Total Raised ($)	$2,966.26
Total Spent ($)	**$992.22**
Final Balance ($)	$1,974.05

All Amounts mentioned are in INR (Indian Rupees) since majority of the purchases have been in the local currency. The exchange rates as of 20th May 2016, 1600 hrs, UTC is 1 USD=67.4249 INR). The final balance amount was returned to the Universitv. The Travel and transit costs of the Team are not included in the above accounts.

Travel and Accomodation Costs

Date	Type	Category	Expense	Description	Sources/Notes	Amount (INR)	Amount ($)
25-04-2016	Purchased	Logistics	Travel	Flight	Travel Expense for 13 Team Members	INR 8,84,000.00	$13,110.88
10-05-2016	Purchased	Logistics	Accomodation	Stay during Competition	4 Rooms at Holiday Inn Houston Webster	INR 2,58,358.73	$3,831.80

APPENDIX C: SYSTEM INTERCONNECTION DIAGRAM



APPENDIX D: DATA INTERCONNECTION DIAGRAM