SURABAYA - INDONESIA

SUROVOTIC

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Mentors:

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I. Abstract

SURO is the latest ROV (Remotely Operated Vehicle) from the SUROVOTIC Team, and it is desaign specialized to do several tasks similar to those in the Pacific Northwest area of Washington State. Our team, SUROVOTIC, is from Sekolah Robot Indonesia. This Year is fiveth time from Sekolah Robot Indonesia in the MATE ROV Competition. however half of our members in SUROVOTIC company are new to this competition. Nevertheless, our company has done countless research about ROV. The design of our ROV is influenced by the missions and tasks given. We believe that maneuver capability in a small design and stability is the key to success in the missions. We named our ROV SURO like in our country SURO is shark.

SURO is able to solve task by task use gripper manipulator. With depth sensor and camera guidance. Our 4 cameras can help to guidance maneuver robot to completed task. We also designed a Graphical User Interface (GUI) to help visualization of Inertial Measurement Unit (IMU) sensor and also displaying other data from the other sensors.

We are optimistic in the performance of our ROV, since SUROVOTIC company is a new but devoted participant in marine exploration.

II. Table Of Content

III. Company Information

Figure 1: Indonesia's very vast water

(Credit: Wikipedia.org)

Organization in our company is mainly based off the necessary sectors when one is trying to develop ROVs. We are divided into the software, hardware, general sciences and economics division ,with intensive cooperation in between each section. The software section manages the programming of the ROVs, and also responsible for configuring the GUI for the control application which is displayed in a computer.

The hardware section conducts a lot of research and work in the hardware of the ROV, obviously, and as such, responsible for the circuitry and type of material suitable for the ROV. Both of this are crucial to the ROV, to give it an interior body and an existing "nervous system." On the other hand, the general sciences department manages the design of the ROV and measures the overall performance of the ROV. The difference between hardware, is that while the hardware pays attention at the circuit and PCB configuration of the ROV, the general sciences pays attention to the performance and exterior design that results from the hardware section's works. As stated before, our focus is maneuverability, portability and speed. Therefore, this section is very crucial. Meanwhile, the economics section is unique. It is involved in not only promoting our company, but also providing general information to the public, especially Indonesian citizens, about ROVs. Indonesia is the base of our company, a maritime nation located in Southeast Asia. Many Indonesian oceans is yet to be explored thoroughly, especially by Indonesian people. We strive to benefit our nation, Indonesia.

Indonesia's waters covers more than 75% of Indonesia. ROVs would be very useful to more easily observe wildlife, including some dangerous ones such as poisonous stingrays and sharks. Moreover, ROVs assist in deeper dives to plant corals, which are currently dying in Indonesia. Not only that, ROVs help archaeologists to explore sunken ships. Currently, they would dive directly to retrieve sunken treasures. Besides all these uniqueness of the economic section, they would of course manage basic economic mechanism of the company such as budget, sponsoring, etc.

Finally, our purpose of this young company is to pioneer a new age of scientific researches in the maritime nation of Indonesia, from Indonesian water to Indonesian citizens, improve knowledge so that we can understand and respect nature more than before. Through cooperation, we will achieve this.

IV. Design Rationale

A. Design Evolution

SURO design process began with considering the thruster configurations. Start with only two thruster for manouver, and upgrade four thruster for manouver. So can increase movement our ROV

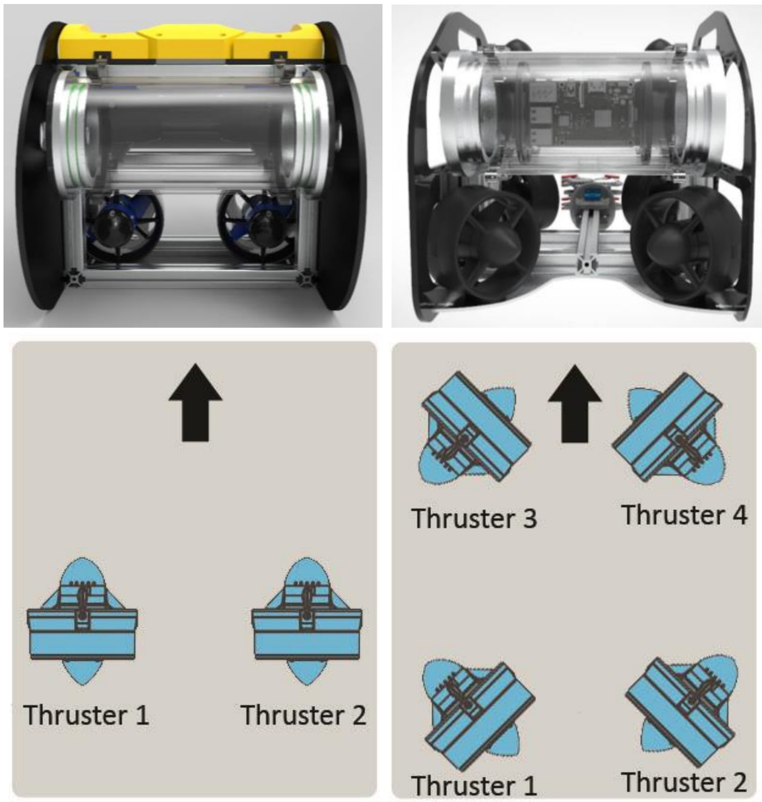


Figure 2: **Design Evolution**
(Credit : Firman)

B. Vehicle Core System

1. Mechanical

Frame and Structure

SURO frame is mainly built using aluminum extrusion 20x20 for the purpose of compact design, lightweight, and high durability. The use of aluminum extrusion also enables us to easily attach, detach, and adjust the position of manipulators, cameras, thrusters, and lights.

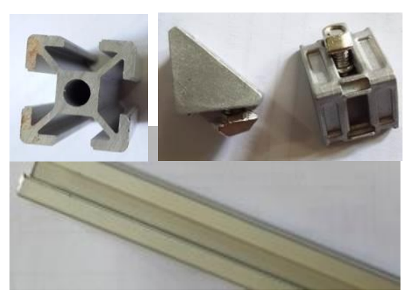


Figure 2: Aluminium Profile type, Angle Bracket,T-nut
(Credit: Daffa)

We do notice that unlike HDPE, aluminium sinks in the water, but with the placement of two acrylic tubes as bouyancy (also use for the waterproof electronics container) it increases SURO stability. SURO aluminum frame use aluminum profile, only one Store available this aluminum in our city, and we must buy one package with 3 meters long.

In designing SURO we also use SolidWorks, so that we can configure the Center Of Gravity (COG), Center Of Balance (COB), and hydrodynamics using software simulations. For the left and right sides of SURO we use 5mm thick acrylic sheet that functions to protect the weak spots of SURO. The acrylic sheets also effectively works as fins to increase SURO stability and also makes SURO looks aesthetically pleasing.

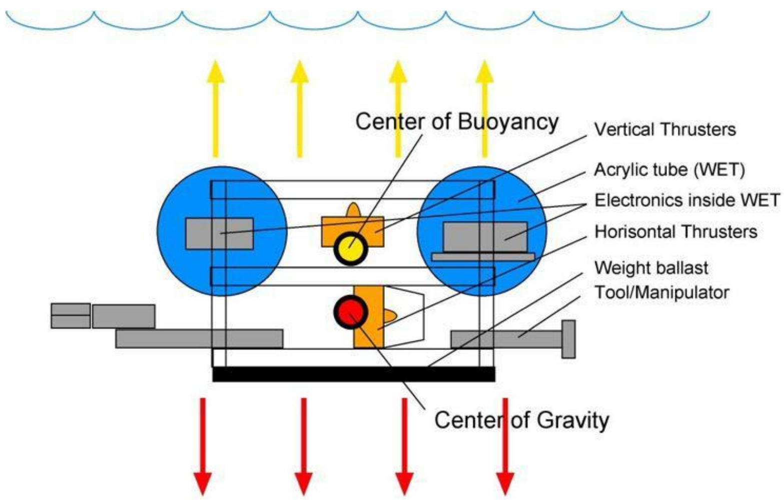


Figure 3: SURO' COG and COB
(Credit: Samuel A.)

Bouyancy

In order to conquer all the missions, SURO needs extreme precision and stability. High precision and stability can be achieved by having a good floatation, this is why we really pay attention to SURO floatation. Configuring the COG and also COB is our first step of designing SURO. The use of two waterproof acrylics tube are also for buoyancy, which we put on top of the ROV as the floatation element. While for the manipulators, frame, and thrusters are located below to provide the best buoyancy and gravity distribution.

Figure 4: Acrylic tube
(Credit: Daffa)

The position of manipulators, thrusters, waterproof electronics tube, and frame design follows the COG and COB principle, any objects with the tendency to float should be put on the upper-side while objects that have the tendency to sink should be located on the bottom side. We also put buoyancy foams on top of SURO to provide small trims and stability.

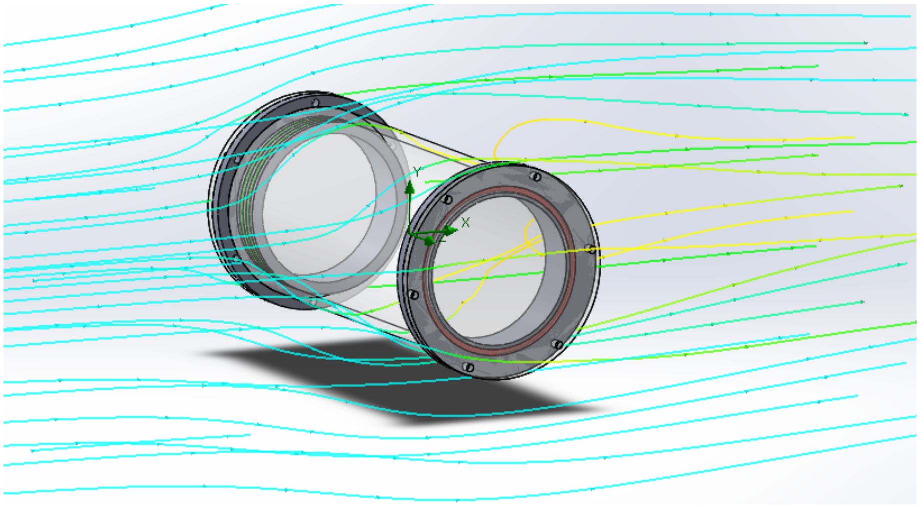


Figure 5: Flow Simulation of SURO Bouyancy
(Credit: Firman)

Waterproof Electronics Tube (WET)

All the electronic components of SURO is located inside our custom built Waterproof Electronics Tube (WET) to prevent it from water and also protection against impact. The other main function SURO' 2 WETs has been explained previously which is as the floatation (because of air spaces inside it). Acrylic tube of 10cm ø with 5mm thickness because it is resistant to high water pressure. We placed our custom built acrylic lids on both side of the acrylic tube. On each lid we use double O-rings so that water is less likely to enter the WET even in higher pressure. We learn this waterproofing technique from OpenROV,BLUEROBOTIC and also from other MATE. ROV contestants from the previous years.

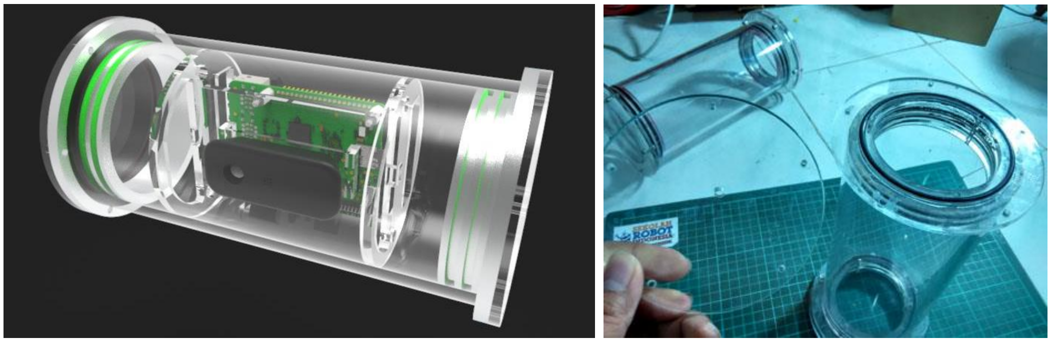


Figure 6: WET new design
(Credit: Abyan)

During our mission testing and practice there has never been water leakage and this technique has been proven to work effectively and is reliable for the missions to be faced by SURO. For the cable penetrators we insert our cables to aluminum tube with hex nut to lock aluminum tube, then we use 5 minutes epoxy glue to secure the cables and seal it to the lid preventing water leak.

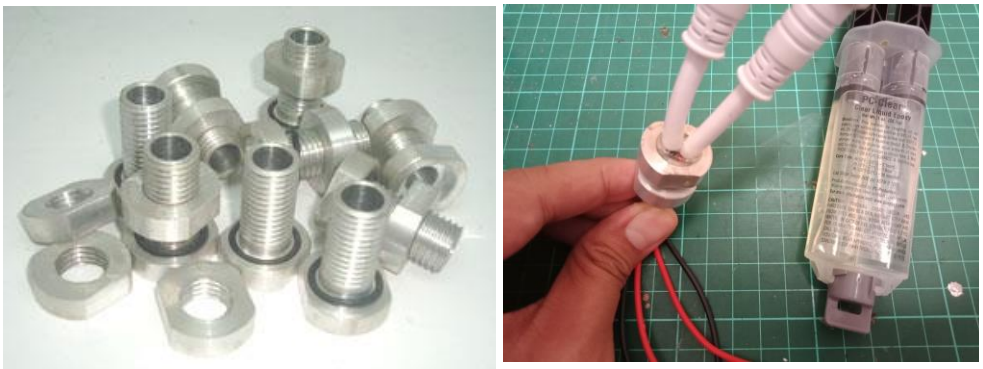


Figure 7: Cable penetrator tube and Epoxy glue
(Credit: Abyan)

Propulsion

SURO is powered by two T200 for up/down and four T100 brushless thrusters for manouver from Blue Robotics. Four horizontal motors are positioned at an angle of 30 degrees relative to the longitudinal axis. The resulting vector thrust not only allows for greater speeds, but allows SURO to strafe in any direction. Two thrusters fixed in the vertical axis allow for up and down movements.

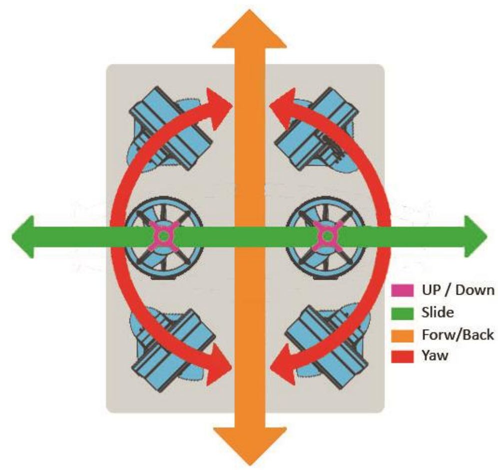


Figure 8: SURO Degrees of freedom
(Credit: Abyan)

2. Electronic

Camera

We were using a total of 4 cameras for SURO. The main camera was a CCTV camera; it is placed inside our electronics tube. The function of our main camera is to wide view. These three cameras were placed to to focus on the ROV's gripper for task and to provide better view for the pilot.

Figure 9: Car Camera
(Credit: Abyan)

Tether

In the world of ROV, the role of tether is essential. The tether is what connects power, data signals, and video signals from the ground control to the ROV and vice versa. The length of our tether is 12 meters and consists of 4 main cables. For the main power of SURO we use 4mm^2 (11 AWG) red and black stranded cables with PVC coating. For the power cables we need to do a couple of research for choosing the suitable cable thickness. When the cable is too thick, it will be heavy and stiff, on the other hand if the cable is too thin there will be a drop in voltage because the current reaches 22 Amperes and the resistance is too high because we use 20 meters cable length.

Figure 10: Tether management
(Credit: Abyan)

According to the maximum standard of 25 Amps we use 4mm^2 and after we tested there is no drop voltage problem and the cable is also not too stiff, so we decided to use this cable. For serial communication we use telephone cable with 4 wire. And for video cable use a video cable to transmit data video

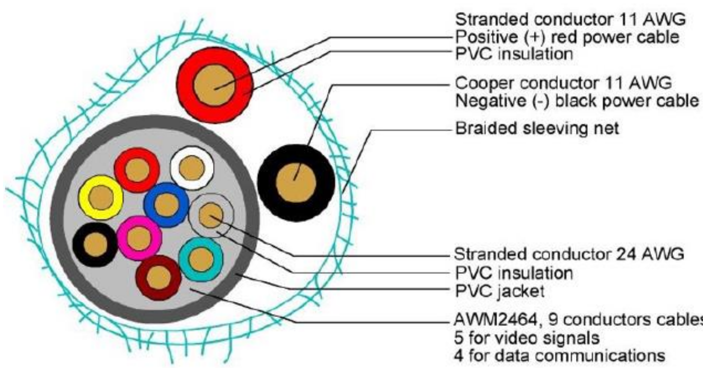


Figure 11: Tether cross section diagram
(Credit : Abyan)

Ground Control System

SURO is controlled from the ground control using a joystick game controller. This remote control communicates via USB to laptop/PC in the ground control box as input variables in our Graphical User Interface (GUI) using Visual Basic software then relays the controller information through RS232 serial communication to our Arduino Nano microcontroller on SURO. The microcontroller is programmed using C language with various Arduino libraries. The onboard Arduino Nano then uses 4 Electronic Speed Controllers

Figure 12: Ground station
(Credit: Abyan)

(ESC), which drives our 4 brushless motor thrusters. Other input and output on board are 2 servo motors for gripper, 4 cameras, Inertial Measurement Unit (IMU) sensor, temperature sensor, and depth sensor. For the IMU and depth sensor we utilize I2C communication. All these inputs and outputs are mounted to our custom made Printed Circuit Board (PCB) to connect it to our micro-controller.

On deck ground control includes Ammeter and Volt meter to easily check power load and voltage input that is supplied to SURO. GUI will display the datas from the sensors on SURO and help the pilot to control SURO movements and its manipulators.

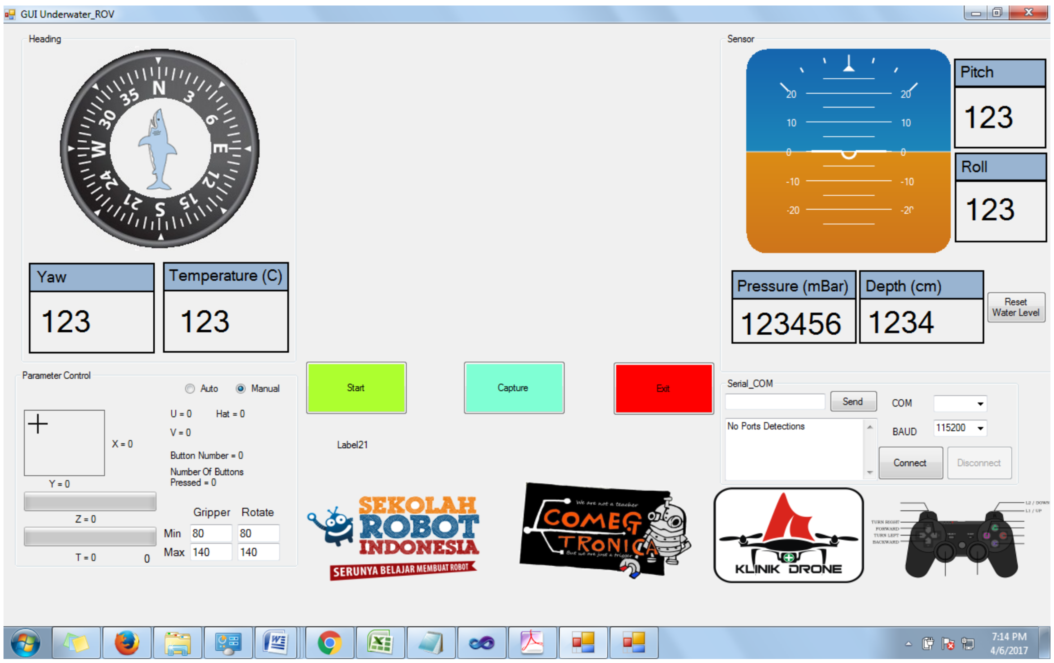


Figure 13: GUI made using Visual Basic
(Credit: Abyan)

3. Mission Specific Tool

Main Gripper

Our company decided to design and make a gripper with 1 Degrees of Freedom (DOF) with high voltage and high torque analog waterproof servos that can grip up to 180º. Using collinear gripper grabbing objects with various sizes are much easier especially in task #1 (Aircraft) for remove debris, returning engine, and returning all liftbag to the surface, task #2 (Earthquake) for build OBS, disconect cable connector, closing the door, releasing OBS, and Returning OBS to the surface. task #3 (Energy) for installing array tidal turbine, installing i-AMP, placing mooring and elgrass

Figure 14: SURO Gripper
(Credit: Abyan)

habitat monitoring and restoration. The gripper is made using laser cut 3mm,5mm acrylic sheets for precision and aluminum cnc and use 1 waterproof motor servo.

Inertial Measurement Unit (IMU) Sensor

To help visualization of position and direction of SURO we added GY85 IMU sensor. Gyro, acceleration, and compass data is translated into our GUI software in the laptop display. This helps pilot to control SURO precisely and feel confident to tackle all of the missions.

Figure 15: IMU
(Credit: Abyan)

Water Depth Sensor

For task #3 (Energy) - given height on the mooringi use equipped with a water depth sensor (MS5803-14BA). The data of the sensor will be output to the Graphical User Interface to allow the Depth.

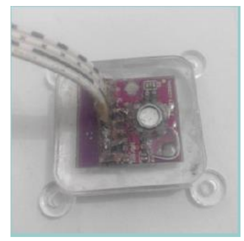


Figure 16: Depth Sensor
(Credit: Abyan)

Lighting

For help guidance if area is not capable light. For holder led our team make from 3D print laser.

Figure 17: Make holder from 3D print, and place to side robot
(Credit: abyan)

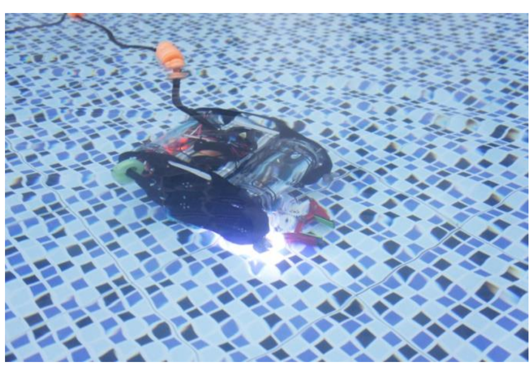
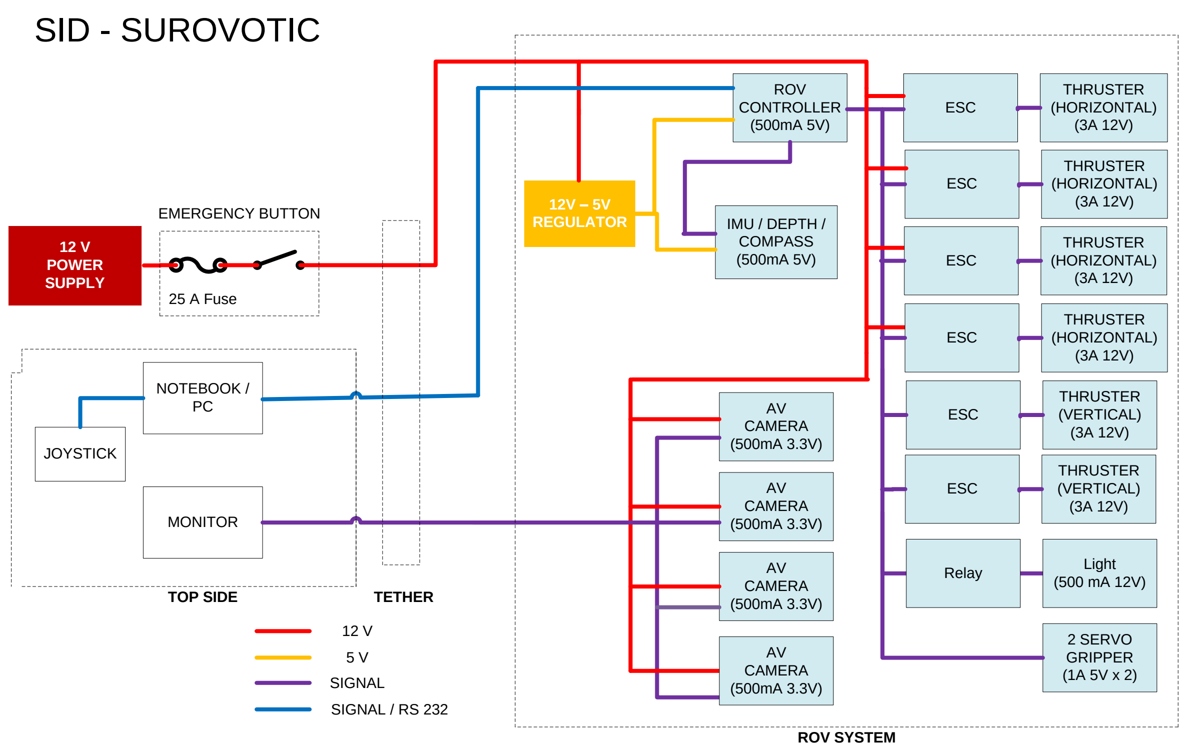


Figure 18: Test Lighting SURO task #3

(Credit: Tri Susanto.)

C. System Integration Diagram (SID)



TOTAL CURRENT

6 X Thruster (3A 12V)	= 18A	12V
2 X Servo (1A 5V)	= 0.8A	12V
1 X Rov controler (100mA 5V)	= 0.04A	12V
1 X IMU (100mA 5V)	= 0.04A	12V
1 X Light (500mA 12 V)	= 0.5A	12V
4 X AV Camera (500mA 3.3V)	= 0.55A	12V
TOTAL	**= 19.93A**	**12V**

MAXIMAL CURRENT	**= 25A**	**12V**
TOTAL CURRENT USE	**= 19.93A**	**12 V**
Safety Current	**= 5.07 A**	**12V**

Our ROV have Safety current 20%

Figure 19: SID SURO 2018
(Credit: Firman)

V. Safety

A. Philosophy

Safety is our company's highest priority. All of our members build the ROV in our workshop which is fully equipped with safety equipment's and provides a safe environment for working. Our company also provide an ROV with complete safety features to prevent users from unwanted accidents. Our training, safety procedures, and Personal Protective Equipment (PPE) allow us to prevent unwanted accidents.

B. Required Personal Protective Equipment (PPE)

- Safety glasses, masks, an hearing protection when using power tools
- Masks when soldering PCB parts and other electronic components
- Working gloves when doing mechanical work
- Silicone gloves and masks when applying Epoxy glue

Figure 20: goggle and face mask

(Credit: Abyan)

C. Working Environment Safety

- Solder fume extractor when soldering cables and electronic components
- Open space/outdoor when applying and drying epoxy glue or casting resin

D. ROV Mechanical

- No sharp edges
- Strain relief for tether
- Double O-ring for waterproof electronics tube lid (tested in 20 meters depth)
- Implement danger labels for moving parts

E. ROV Electronics

- 25 Amp fuse on the positive side of the main power source
- All electronics parts are placed inside the electronics tube
- All wiring and electrical parts are properly waterproofed
- Emergency Cut Off Switch (panic button)
- Ampere and volt meter display

F. Safety Protocol Chceklist

Before testing SURO underwater, members must perform a systematic dry run as unforeseen problems are easier to resolve in air than underwater. The company has established safety checklist.

	Pre-mission Safety Checklist
	All items attached to ROV are secure
	All cables are securely fastened
	Single inline 25 Amp fuse is in place
	Sharp edges have been smoothed
	No exposed propellers
	Tether is not tangled and fully secured
	All wiring and components for ground control is properly connected
	All ground control elements are secured inside an enclosure
	Check electrical power connections
	Make sure waterproof electronics tubes (WET) are tightly sealed
	Dry test to check manipulators, thrusters, cameras, and sensors are functioning properly
	On-deck team is wearing safety glasses and closed toed shoes

Table 1: Safety checklist

(Credit: Firman)

VI. Project Management

A. Organization Structure, Planning and Procedures

Company

SUROVOTIC promotes about new team member and open recruitment. After get new team member, Senior members guide all about job desc plan and review mission. Work together to build schedulle.

No	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	MATE Mission Review																
2	Budgeting																
3	Initiate Design Concept & Research																
4	Frame , Control R & D																
5	Electronic R & D																
6	Build ROV																
7	Finalize ROV																
8	ROV Testing																
9	Regional Competitions																
10	Review																
11	Rov Testing for International																
12	International Competition																

Table 2: Table management

(Credit: Firman)

B. Budget and Cost Production

A large part of the budget for developing SURO was allocated to buy thruster, because is very important to ROV Movement, beside that buy electronic component and sensor. On the other hand, the budget for mechanical components was more conservative, reducing overall costs of developing SURO. The budget and cost projection of SURO are attached in Appendix D and E, respectively.

VII. Lesson Learned

A. Technical

Mastering the programming language for Arduino was possibly the most helpful and useful skill learned by our programmers this year. Even during the development phaase, we already know that we want to use Arduino on SURO.This meant that the software developers and electrical engineers had to get started right away on

Figure 21: Lesson Learn
(Credit: Abyan)

learning the new language and understanding the new microcontrollers.

We have learned many skills, including how to use basic if statements, arrays, serial commands, and the most important skill of all, knowing how to troubleshoot. The many important lessons learned during that process are what allow the SURO to dive today.

Our company also learn about waterproofing techniques such as using waterproof electronics tube (WET), casting resin, and also applying epoxy glue.

B. Interpersonal

Our team members learned to work efficiently. This happens because of our member's school activities making them spend their nights on working the ROV and reducing their sleeping time. On example was working on the ROV mechanics. Due to the limited amount of time our member had so we have to work on it on holidays, or even stay up late at night building the acrylic tube and building the frame. Through this opportunity to work, we all learned to appreciate our time, and our fellow member's time because we want to finish this ROV as expected and efficiently.

Figure 22: Firman build hardware module
(Credit: Tri Susanto.)

Figure 23: Firman design new SURO
(Credit: Tri Susanto.)

Figure 24: Pilot and copilot
(Credit: Tri Susanto.)

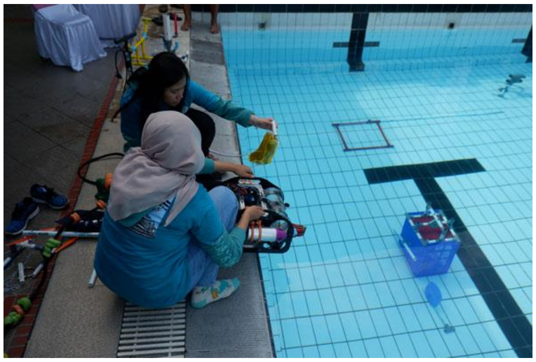


Figure 25: Zita and Brena dry test
(Credit: Tri Susanto.)

VIII. Troubleshooting

When SURO failed to work properly, we need to identify and analyze the problem causing the failure and also how to isolate it to solve the problem. We initially dry test our ROV, if there is no problem we move to the bathtub and if everything works fine then we test it in a pool for real test. During this procedure we have tested using 1 Waterproof Electronics Tube (WET) and there is stability issues, so we made another design using 2 WETs. Another troubleshoot that we face is because the use of 2.5 mm^2 (14 AWG) for power line causes voltage drop and unable to turn on our ESCs. We tried cutting the wire to reduce cable resistance, it works. So we changed our thin cable into a thicker 4 mm^2 (11 AWG) and the voltage drop problem is no longer an issue. Those are some examples of specific problems that we can troubleshoot. All of our members are required to get involved when troubleshooting, so that every member have the troubleshooting experience.

IX. Future Improvement

we always looking for new technologies to implement in our products. Even if we thought that SURO is great enough, there will always be rooms for revision and improvements. For future we want our ROV can stabilizing in pool like a holding depth and holding position, so ROV get stable to completed mission. We are also in progress of learning the Raspberry Pi and Beaglebone so we can install it to our ROV and make it a better ROV. For tethering we want to change cable with neutrally buoyant tether combines rugged strength and durability with high-performance electrical.

X. Reflection

After done making SURO, we found out that our team makes great improvements from last year. Not only for the ROV, but also our for members' ability and teamwork when making a ROV. As a team, we spent our nights together making SURO. Through this competition our team personnel gain more confidence and experience in themselves and as a whole team. We also know each other better. Although we have new personnel, they are quick-learner. They also learned a lot of things this year. After so many errors in making SURO, we know how to face some challenge and finishing it well.

XI. Reference

1. MATE ROV website for scoring and task information http://www.marinetech.org/
2. The Arduino Reference Library, which provided software-programming details http://arduino.cc/en/Reference/Libraries
3. Bluerobotics website www.bluerobotics.org
4. Indonesia Arduino Site www.arduino.web.id

XII. Acknowledgements

SUROVOTIC would like to extend their most sincere gratitude to the following benefactors for their support in the development of SURO:

Our Parents - for full supporting SUROVOTIC
Sekolah Robot Indonesia – for providing labs for to use.
Warung Joglo Sate Ayam Ponorogo – for allowing us to use the swimming pool for testing
Dhadhang SBW and Tri Susanto – our mentors, whose guidance and advice helped us improve both our technical and non-technical skills.
MATE Center – for organizing the international competition.
ASEAN MATE Regional – for organizing the ASEAN Competition
REAA (Ali, Sobrun, Mamat, Erik) – for supporting SUROVOTIC

XIII. APPENDICES

A. Appendix A : Arduino Microcontrollr Flowchart

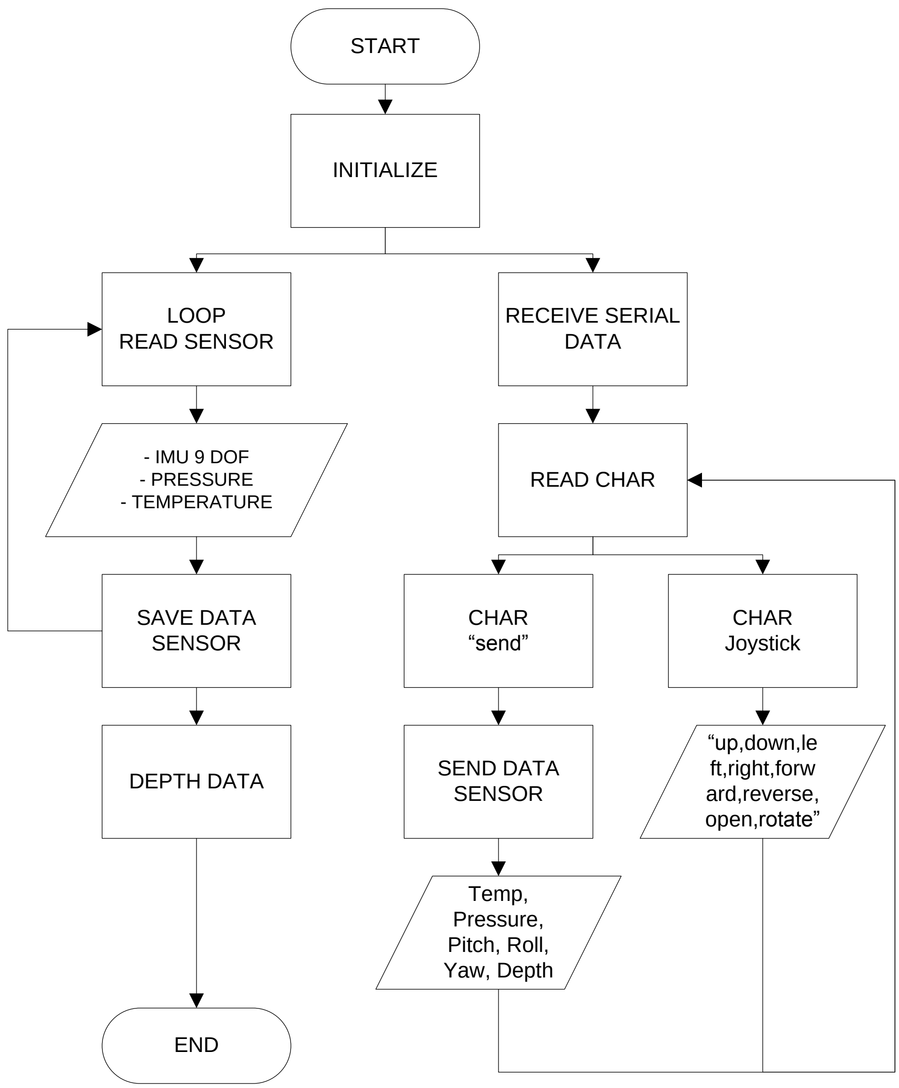


Figure 26: Microcontroller Flow Cart
(Credit: Firman)

B. **Appendix B:** Graphical User Interface (GUI) Flowchart

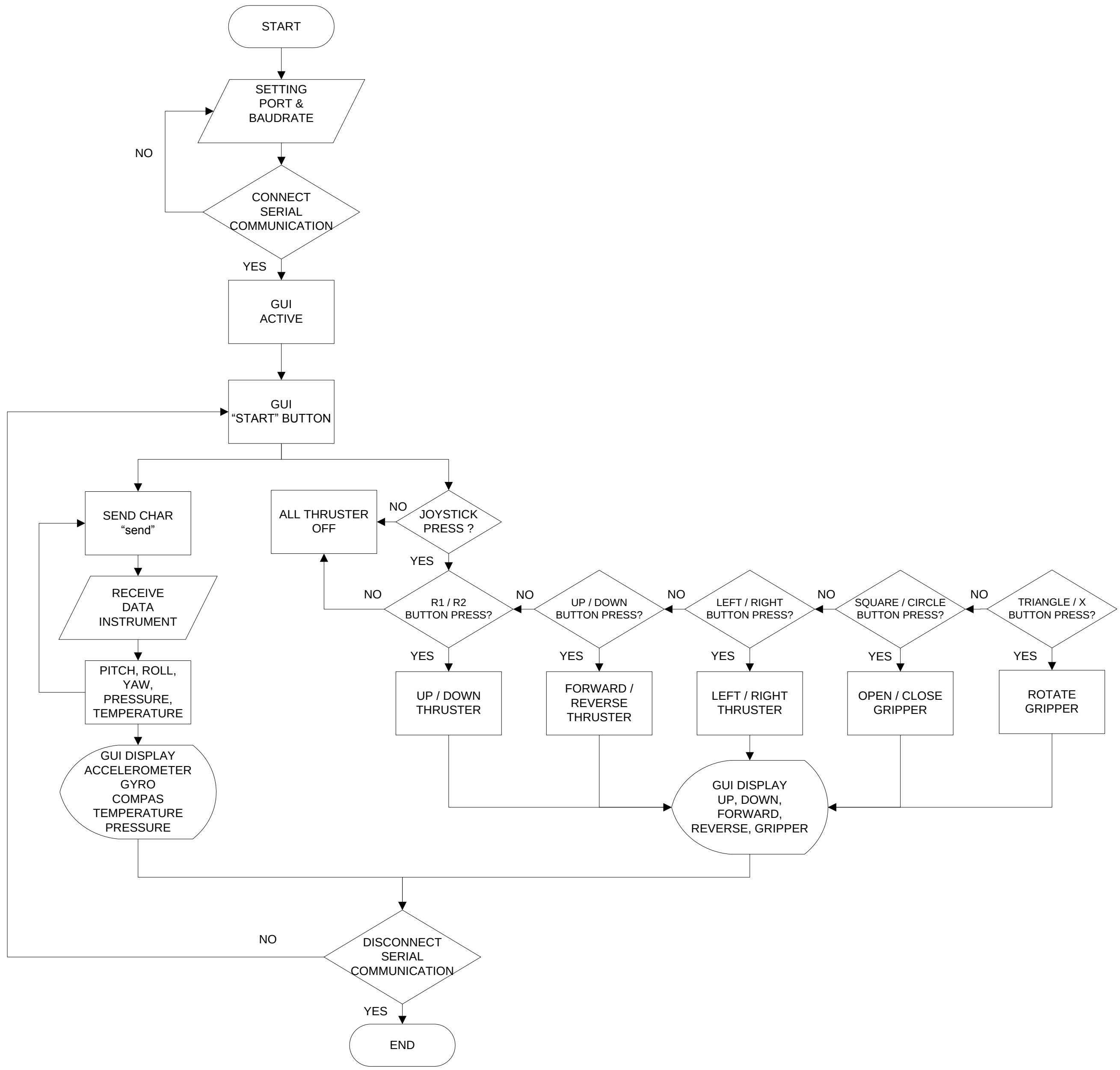


Figure 27: GUI Flow cart

(Credit: Firman)

C. **Appendix C:** Budget

Income				
Source	QTY			**Amount ($)**
SUROVOTIC Member	6	-	5.000,00	30.000,00
Expenses				
Category	**Type***	**Description/Examples**	**Projected Cost ($)**	**Budgeted Value ($)**
Travel	Purchased	Airfare (4 member, 2 mentor) @$2.500	15.000,00	15.000,00
Travel	Purchased	Accomodation,Hotel for 10 days (4 member, 2 mentor) @2.300	14.100,00	14.100,00
ROV Part	Re-used		1.529,60	1.529,60
ROV Part	Purchased		390,00	390,00
Rent Pool	Purchased	rent pool for practice	210,00	210,00
Shuttle	Purchased	competition shuttle	120,00	120,00
registration MATE	Purchased	Registration MATE International	150,00	150,00
		Total Income:		30.000,00
		Total Expenses:		31.499,60
		Total Expenses-Re-use:		29.970,00
		Balance		30,00

Table 3: Budgeting

(Credit: zita)

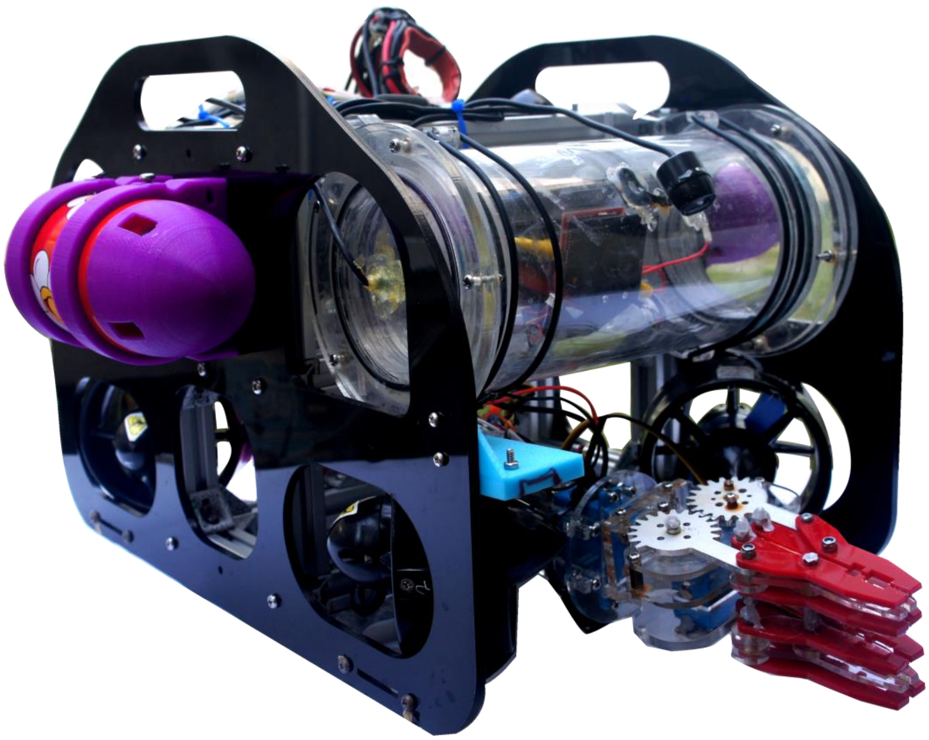
D. **Appendix D:** Cost Projection

SURO ELECTRICAL AND MECHANICAL	TYPE	QTY	UNIT COST ($)	TOTAL ($)
Brushless motor thruster T100 with shipping	re-used	4	165	660
basic ESC for T100	re-used	4	35	140
Cable pentrator T100	re-used	4	5,4	21,6
Brushless motor thruster T200 with shipping	re-used	2	200	400
ESC for T200	re-used	2	25	50
Cable penetrator	re-used	2	4	8
arduino nano	purchase	1	10	10
aluminium profile	purchase	1	10	10
t-nut	purchase	30	1	30
acrylic tube	re-used	2	20	40
WET	purchase	4	20	80
acrylic 5mm and cutting	purchase	2	15	30
Aluminium base	purchase	1	60	60
Servo waterproof	re-used	1	40	40
camera	re-used	4	15	60
cable 11AWG 30mtr	re-used	1	20	20
monitor 7"	re-used	2	40	80
monitor 7"	purchase	2	40	80
IMU Sensor	re-used	1	10	10
Ground control	purchase	1	80	80
Joystick ps	purchase	1	10	10
TOTAL INVESTED (PURCHASED & RE-USED)				**1919,6**
TOTAL ROV RE-USED				**1529,6**
TOTAL ROV PURCHASED				**390**

Table 4: Cost Projection

(Credit: zita)

E. **Appendix D:** Summary Sheet



Dimensions: 38 cm x 26 cm x 28 cm

Dry Weight: 11 kg

Approximate Total Cost: $1919