A success story of

Indian National Student Autonomous underwater Vehicle Competition

(2011-2017)

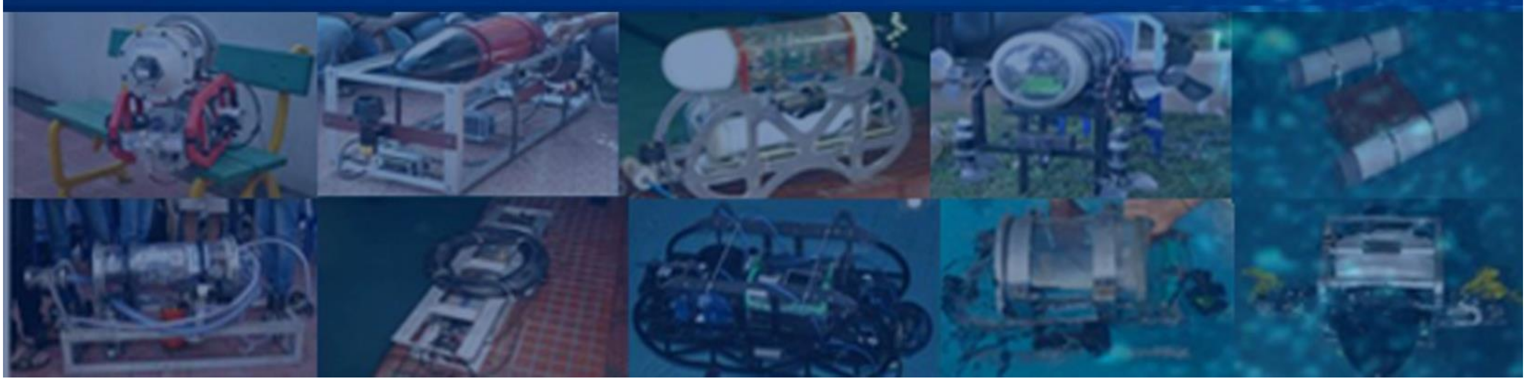
Prepared by

R Venkatesan, R Sundar, Jagadeesh Kadiyam, M A Atmanand

31st August 2018

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY, Chennai

Ministry of Earth Sciences



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Our sincere thanks to

National Committee

- **Dr.M.R.Nayak, NAL, Bangalore, (Retd.)**
- **Dr.ManuKorulla, NSTL, Vizag**
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- **Prof. Krishnankutty IIT Madras**
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- **Mr.David Murphy, Sea-Bird Electronics,USA**
- **Mr.Sean Kery, Woods Hole Oceanographic Institution, USA**
- **Mr.Hunter Brown, University of Michigan, USA**
- **Mr.Justin Manley, Liquid Robotics, USA**
- **Mr.Rafael Mandujano, Vehicle Control Technologies Inc., USA**

INDEX

1. Introduction

National Institute of Ocean Technology (NIOT), under the Ministry of Earth Sciences, along with IEEE OES and OSI conducts a national level competition for students pursuing engineering degree to visualize and design an autonomous underwater vehicle. The conceptual basis for Student Autonomous underwater Vehicle (SAVe) is a highly mobile autonomous underwater vehicle (AUV) to be built based on engineering principles. This innovative initiative was launched in 2011 and so far, NIOT received 17473 website hits. 257 registrations were made and 127 teams had submitted their Preliminary Design Reports (PDR) and 83 teams made oral presentation of Conceptual Design Reports (CDR) to improve their presentation and handle question and answers skills; 28 teams participated in final competition and demonstrated their working and engineered AUVs at swimming pool. Most of the teams used 4-5 thrusters configurations to have 6 DOF controlled by mostly Inertial Measurement Unit (IMU) interfaced with control unit (CPU) and powered by commercial LiPo battery packs. Till now, 4 teams have participated in International competition held at AUVSI foundation San Diego, USA and totally 15 prototypes of AUVs were developed by engineering students in India the since the year 2011. The objective of this competition is to involve young engineering students on the new frontiers of ocean technology and kindle their innovative thinking in this unexplored area of ocean environment and observation.

The most common configuration of the student AUVs is that the linear dimensions of the AUVs were less than 1.5 m in length and weight is less than 35 kgs. The AUV design is a modular hydrodynamic hull structure and made up of acrylic material; mounted on Aluminium metallic frames. Many teams came up with modular thruster mounting frames which could help position the thrusters for good attitude control and this proved good stability of the vehicle against unwanted roll and pitch. All the teams were suggested to use maximum of 4 numbers of thrusters (for 6 degrees of freedom) to optimize the AUVs operation for considerable maneuverability with good energy efficiency and high endurance. Almost all the student AUVs get power supply from Lithium-Polymer (Li-Po) batteries with either 18.5 V or 11.1 V DC input to provide supply for the 19.1 V DC Thrusters and 12 V Mother Board. One of the most common features of the teams is Arduino Microcontroller for controlling the thrusters interfaced with CPU. CPU configurations and capabilities of the teams processor speed varied from 1.6GHz to 2.1 GHz supported by 1GB or 2GB RAM. In fact, almost all the teams learnt to use good quality web cameras for the underwater vision and image processing by placing them in sealed chambers. All the AUVs used face O-rings for the hulls for good sealing effect as well as for faster assembly and disassembly. Water resistant connectors were used to connect the AUV to supportive systems.

The competition received overwhelming response from different institutions in which IEEE came forward to extend financial support. The Office of Naval Research (ONR) also showed interest to provide support for the competition to improve the awareness as well as encourage Students in the field of underwater technologies.

AUVs are self-propelled unmanned submersible vehicles with their own onboard intelligence system to make decisions and are dependent on stored energy of the battery to execute their mission. They generally execute their motion by drift, cruise, or glide through the ocean. The history of AUVs research can be dated back to early 1960's where the first successful development could be attributed to Dimitri Rebikoff's SEA SPOOK. Later, Stan Murphy, Bob Francois and then Terry Ewart of the Applied Physics Laboratory of the University of Washington began development of what may have been first "true" AUV in the late 1950's. Their work led to the development and operation of "The Self-Propelled Underwater Research Vehicle(s)" (SPURV). They were soon followed by others such as SKAT at the Shirshov Institute of Oceanology (Russia); OSR-V (Japan); EAVE West, RUMIC, UFSS (U.S. Navy); EAVE EAST (University of New Hampshire, U.S.); and EPAULARD (France). During the 1990s, AUVs test beds turned into operational systems. In Indian scenario, a significant step in developing a prototype small AUV called Maya was achieved at the National Institute of Oceanography, Goa, India in May 2006. Another AUV named AUV-150 was developed by Central Mechanical Research Institute (CMERI), Durgapur, India and sponsored by Ministry of Earth Sciences, was tested for sea trials in 2011. Today, hundreds of AUVs have been developed worldwide by many countries to accomplish a set of tasks according to defined goals and user emerged different types of mission tasks. An AUV's endurance depends upon speed, mission requirements, payload, and battery type and is quantified in both time and distance.

As most of the AUVs have propellers, more than half of the battery power is consumed by propellers, as a result, reducing the endurance of operation. Of the surveyed AUVs, 46% operate less than 12 hours, 19% between 12-24 hours, and 17% greater than 24 hours. Hence, in order to enhance the range capabilities of an AUV in terms of endurance, powerful and complex systems which are capable of performing underwater (shallow and deep sea) tasks are required to be developed. In this context, The National Institute of Ocean Technology (NIOT), under the Ministry of Earth Sciences, joined with IEEE-Oceanic Engineering Society - India Chapter and Ocean Society of India to provide an opportunity for students pursuing engineering degree to visualize and design an autonomous underwater vehicle. The conceptual basis for Student Autonomous underwater Vehicle (SAVe) is to build a highly mobile autonomous underwater vehicle (AUV) based on engineering principles. The aim of this competition is to attract young talented students to work on under water technology and new frontiers of ocean technology and kindle their innovative thinking in the unexplored area of ocean environment and observation. NIOT has been continuing this capacity building exercise in the field of Underwater Technology by giving technical support to the selected student teams for developing their AUVs and is sponsoring the winning team of SAVe to participate in the Robosub competition organized at San Diego USA.

2. Background of SAVe

National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, announces a competition for students pursuing engineering degree to visualize and design a Student Autonomous underwater Vehicle (SAVe). The focus is on developing innovative underwater technologies needed for ocean observation. Overwhelming response was shown by the students on this maiden initiative to attract young talented Engineers to Ocean Technological developments in India. As it was envisaged earlier, the role of NIOT is to sponsor the selected student team to participate in the International AUV competition in USA.

Fig. 1. NIOT Students Autonomous underwater Vehicle (SAVe)

The main objective of this project is to develop AUVs for specified mission scenarios underwater which can judge the physical aspects of the AUV such as the kinematics, dynamics, physical limitations, and environmental effects. Compared to autonomous aerial or ground vehicle projects, underwater domain imposes the most restriction on sensory devices and its hardware.

3. Competition model

The main focus of this competition is to involve students on the new frontier areas of ocean technology and kindle their innovative thinking in this unexplored area of ocean environment and observation. NIOT will support the winning team with their technical expertise and also sponsor for the International competition being held annually in AUVSI foundation San Diego, USA. The competition is open to all Indian national students. The competition held in three levels viz. Preliminary Design Review (PDR), Critical Design Review (CDR) and Functionality Review (FR).

The Preliminary Design Review (PDR) should consist of , a report comprising of the concept, literature review, design methodology, 3D simulation depicting the concept, brief theoretical substantiation of the design proposed, block diagram of the concept, Project document with methodology of operation, design, 3D model and Video simulation.

In continuation to the PDR, a second level design review to evaluate the detailed description of the concept including detailed specification, circuit level design, detailed mathematical modeling, Commercial Off-The-Shelf equipment required etc.

After completion of the CDR, the developed engineered prototype will be reviewed in the final competition where the students should demonstrate the capabilities of the AUV.

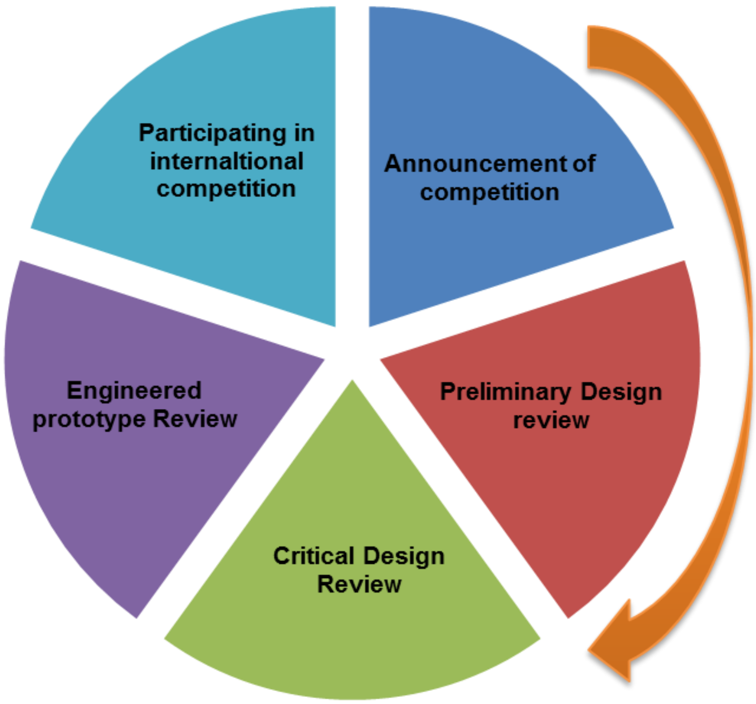


Fig. 2. Competition model

4. Time Management

The competition will start every year in the month of August and the entire stretch of competition spans to duration of 6 to 8 months. The initial period of 2 months is for the registration and PDR document preparation, where the students have to form a team, understand the definition of the problem statement, decide the approach to the problem and finally prepare Preliminary Design Report. After the PDR, the teams have to focus on the financial aspects like funding for the project, costing considerations for different components in the project etc. Sponsorships and fund raising are necessary for teams to kick start the project. Students have to plan well ahead in the initial stages on the time bound deadlines for ordering the components from both National and International market, build, integrate, and test their vehicles. The major factor to be taken into account in the procurement of underwater products is that availability of off the shelf products which might take months' time to receive and could be the cause for missing deadlines. Apart from these, the students have to concentrate on their curricular activities, which is a very important factor to be dealt with win-win attitude in both studies and competition.

Fig. 3. Student teams working during the competition at the swimming pool

This competition model requires a time management strategy to be adhered strictly by the organizers also, where the regular research activities of the Institute shall not be affected, but shall provide required support to the teams in terms of providing facilities for testing the vehicle, mentorship, components procurement etc.

5. Motivation to students

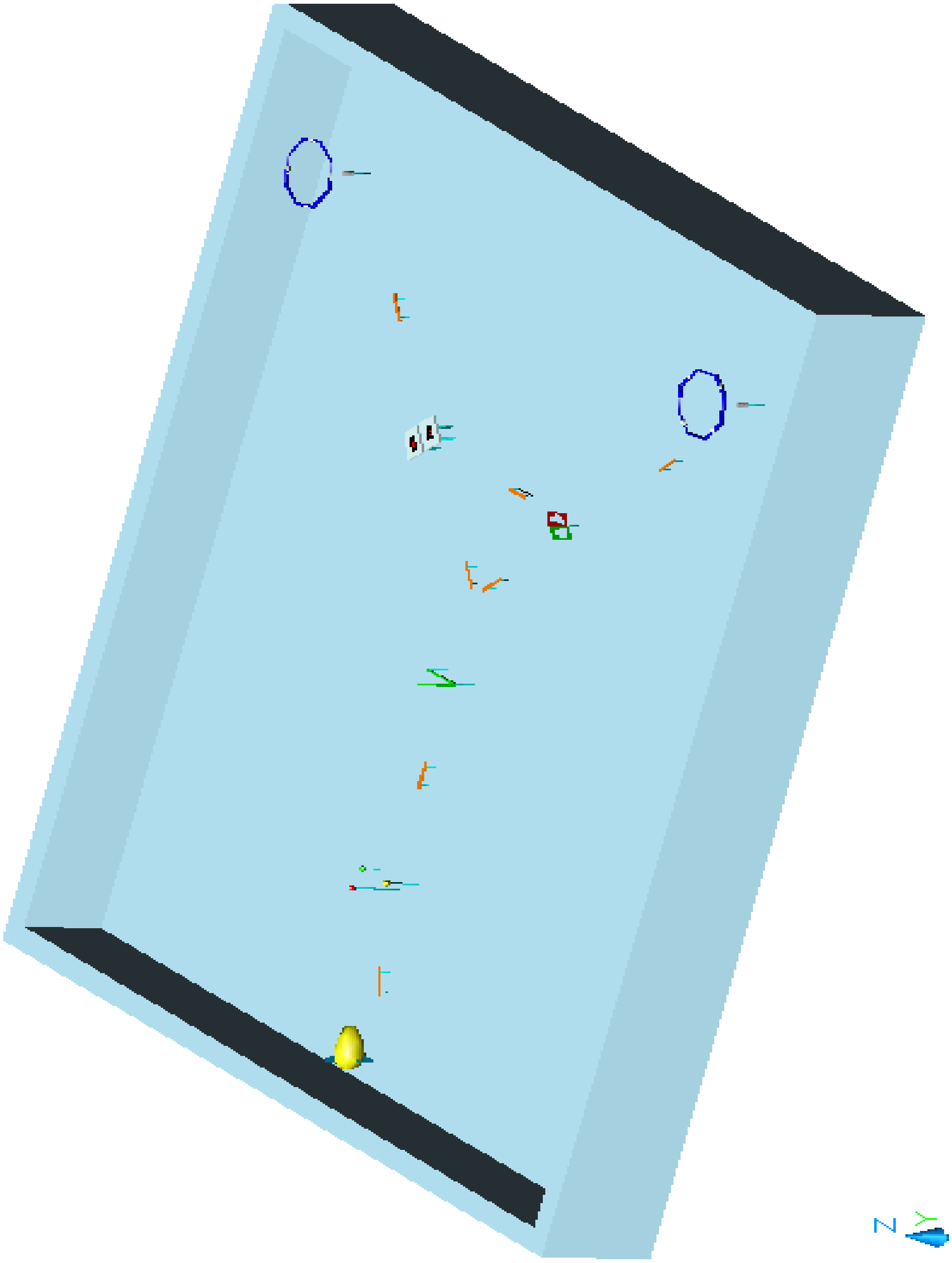
To motivate the engineering or technology students in the field of underwater technology often requires a very practical approach far from the classroom. Educational workshops on marine robotics fulfill this requirement considerably, as the operating medium is the water, it would provide a playful environment. Either in a pool or at sea these educational activities provide students with an exciting environment where they can learn the design, integration and operation of robots. The field of robotics needs basic background of physics and other STEM (Science, Technology, Engineering and Mathematics) disciplines and these sorts of competitions provide a framework that encourages innovation against tough but credible targets and respected benchmarks, through friendly rivalry. The challenge to solve complex tasks in realistic situations forces participants to tackle the issues, often huge, of designing robots capable of working robustly in a realistic environment. Furthermore, the competition against other teams encourages young engineers to study innovative approaches to the problems that often perform better than existing solutions. There is no better way to encourage the development of young and talented people than proposing that they solve challenging tasks at sea in efficient and original ways. To achieve success, they must nurture their technical skills and use notions learned academically in real physical situations. This organized session focuses on both educational and competition efforts in marine robotics. In particular, we are interested in contributions describing the competition/workshop activity history, the number of participating teams/students, the breakthrough results achieved etc. The NIOT competition is an opportunity for motivated students to work together and face challenges themselves to accomplish a unique and rewarding goal. The rewards announced and providing the lab facility to test their vehicles in underwater shall be one of the motivational factors for the team to work against the odds to accomplish their mission.

Fig. 4. Indian students interacting with Mr. Daryl Davidson, Executive Director, AUVSI Foundation, USA at NIOT

Apart from these, success stories of students who later continued their career in ocean-related industries, research institutions, or other robotics fields are valuable examples of the success of the organized competition/workshop to assess its impact from the educational and economic points of view.

6. Mission & Operational criteria

The mission arena and operational design requirements are discussed below



Available Tank Specifications:

Length: 25 Meter

Breath: 20 Meter

Water height: 2 to 2.5 Meter

a. Route

NIOT specifies launching point. Starting from that, AUV has to dive down and follow an “orange path”. AUV has to touch a buoy (meant for imitating “collect flowers”). Then, AUV has to follow the orange path and pass through a “L” shaped PVC bar (AUV has to pass over this) and have a choice of two direction.

In the left side route, AUV has to drop markers in bins (Markers may be plastic /metal sheet boards).

In the right side route, AUV has to fire an arrow through a heart shaped cut out (fire a “torpedo” through a heart cut out).

There exists a connecting path which joins these two routes. Depends on the time left, AUV can complete both routes using the same time.

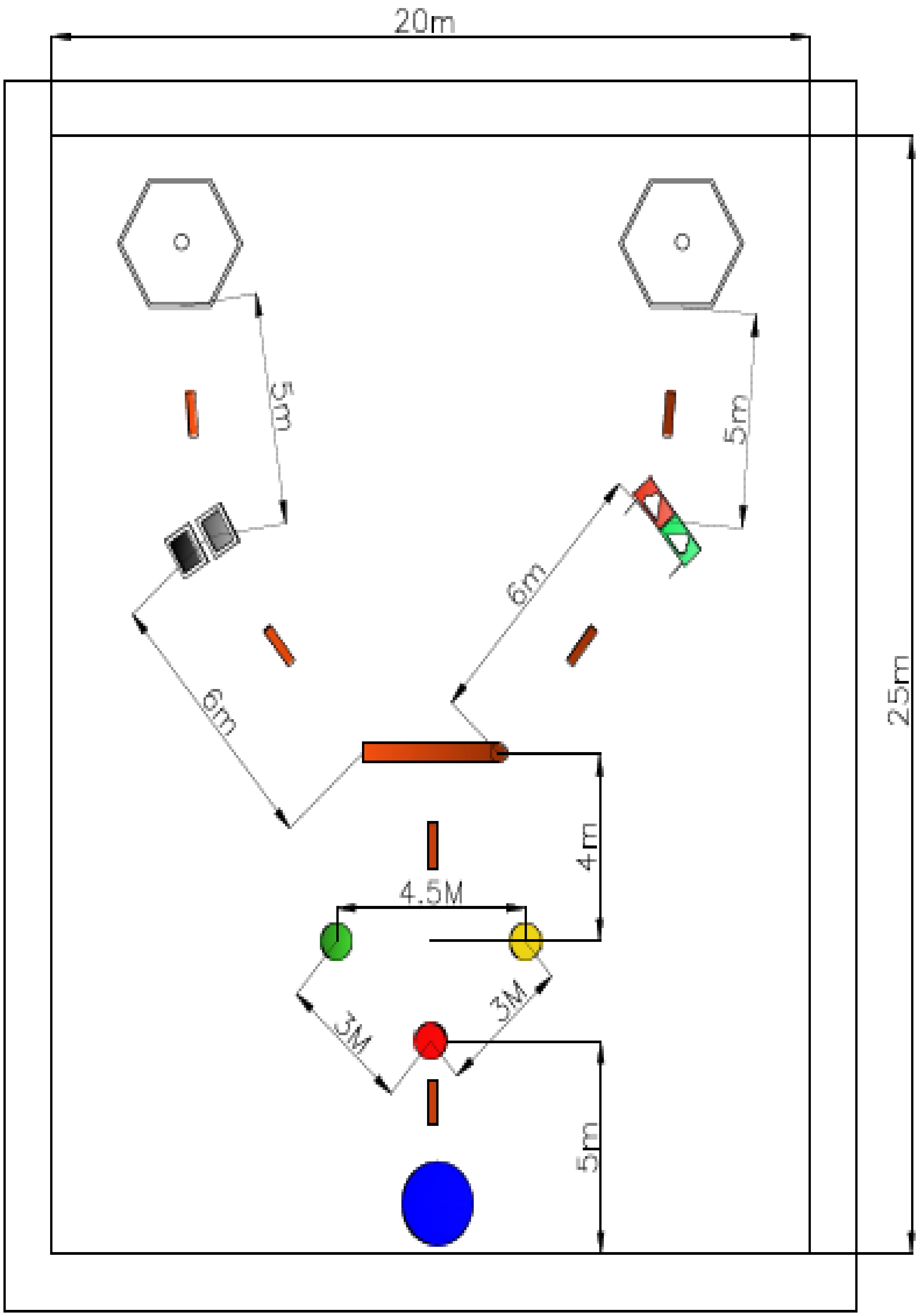
Finally, by following available path, they can surface with in the octagon.

AUV that touches at least one buoy, places at least one marker in the bin and fires at least one torpedo through the heart cutout and surfaces fully within the octagons (no part outside the structure) completes the mission 100%.

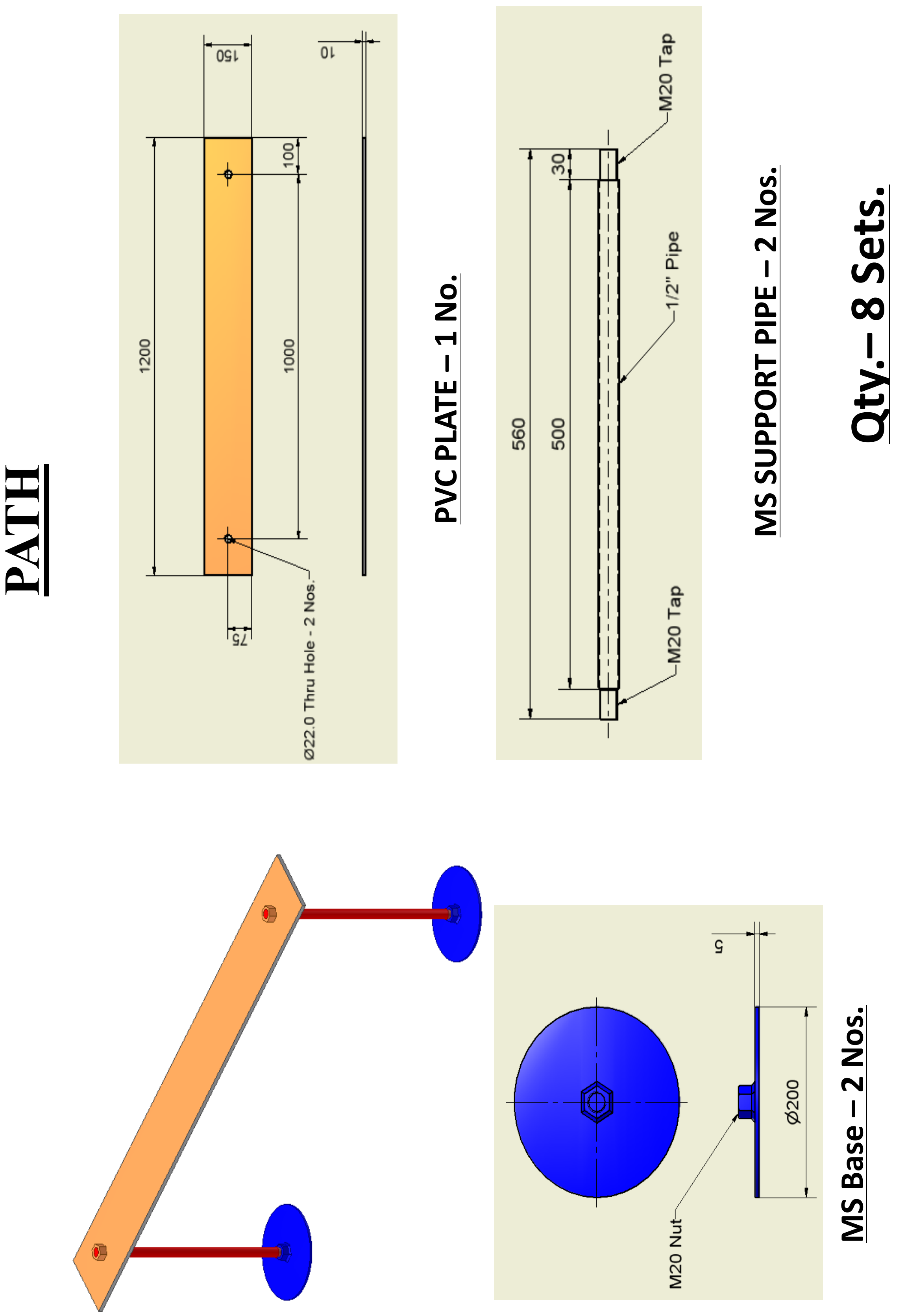
Note:

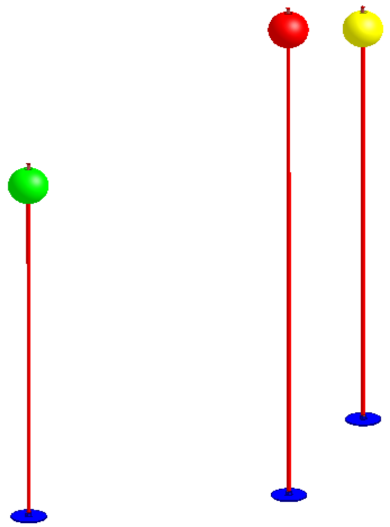
- We may reduce the final Octagon to one depending on the pool size
- In some situations, we may place the targets, markers in bin and fire arrow in heart cutout may be series (one after other).
- With the flexibility we can check their AUV’s adaptation capability

b. Targets Distance:

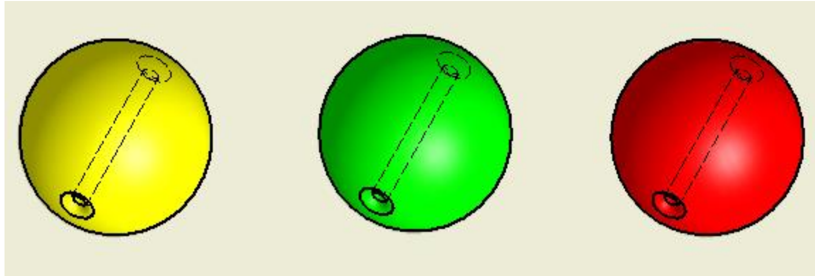


c. **Targets used in tank:**



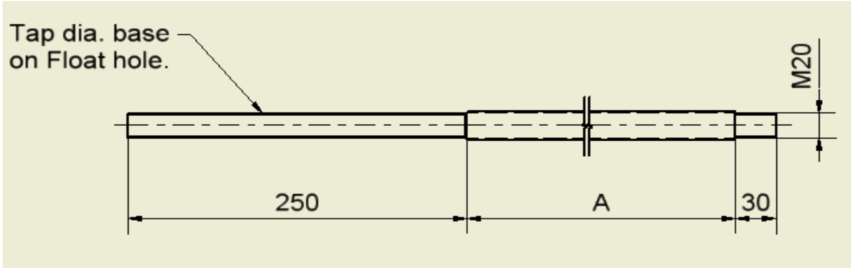


Flowers

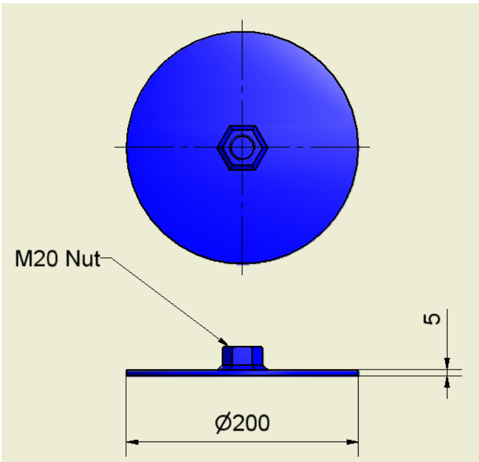


Yellow Float | Green Float | Red Float

Dia. 9" Float – Each 1 No.



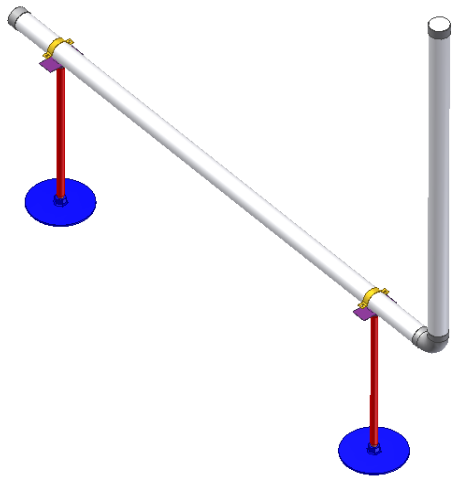
MS Support Pipe		
Sl.No.	A	Qty.
1	2100	1
2	2500	1
3	3000	1

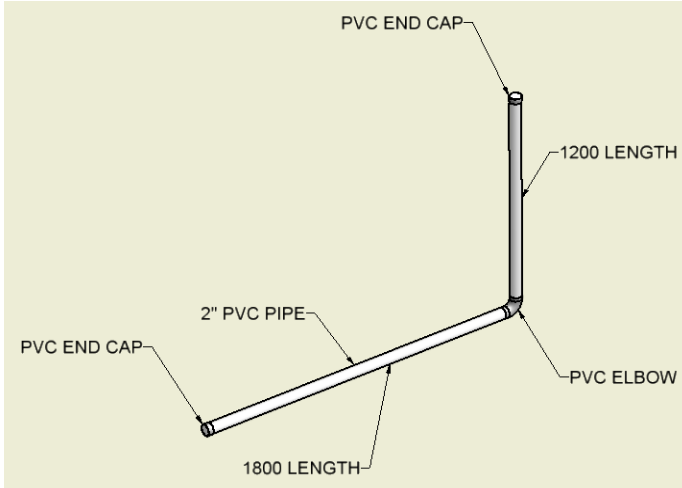


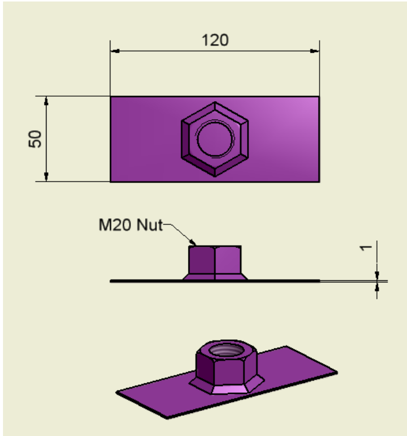
MS Base – 3 Nos.

Qty.– 1 Set.

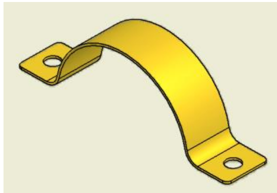
“L”ove Lane



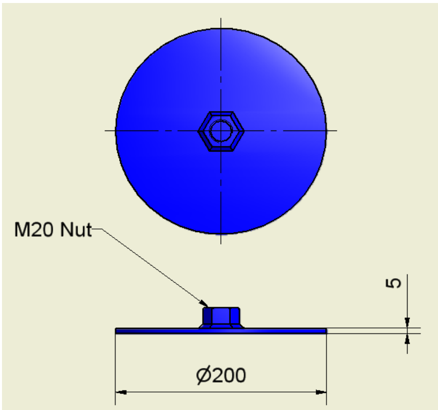




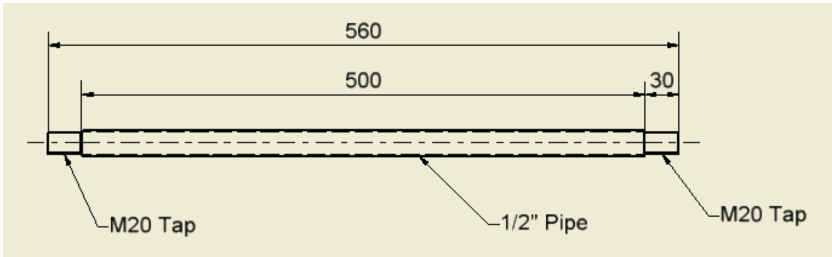
PIPE LOCK (MS) – 2



2” Clamp – 2



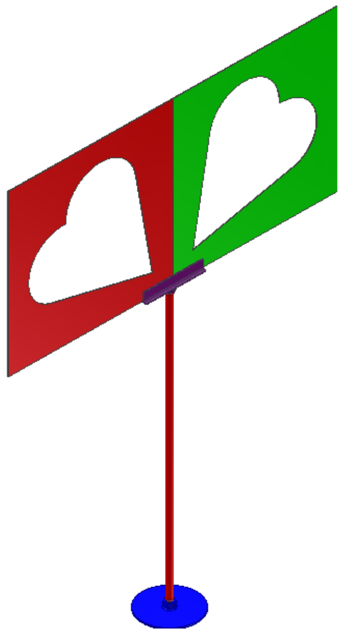
MS Base – 2

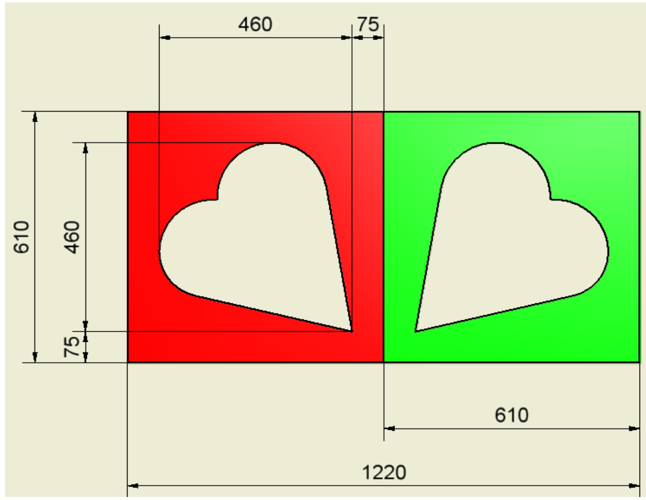


MS SUPPORT PIPE –

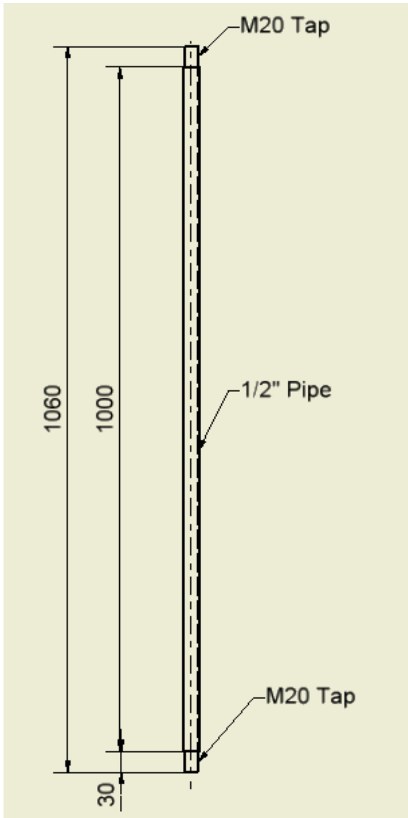
Qty.– 1

Cupid

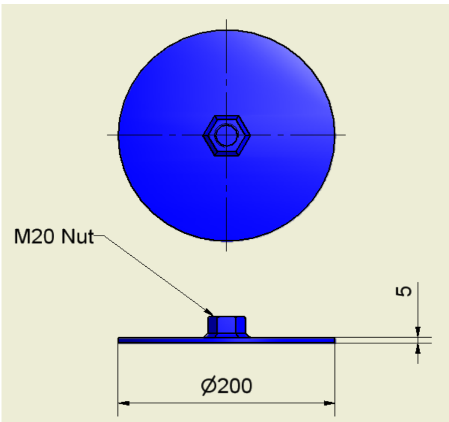




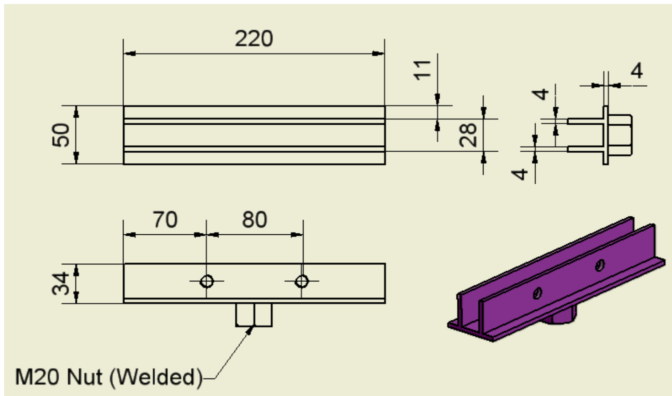
PVC PLATE (10



MS support pipe – 1



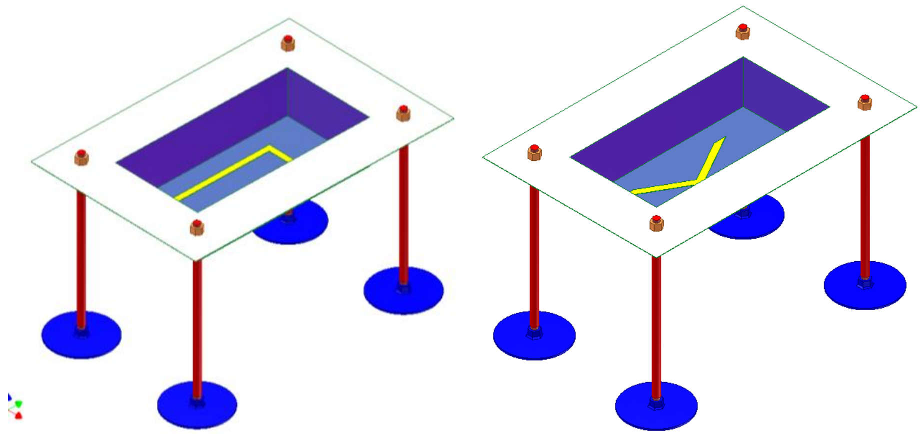
MS Base – 1

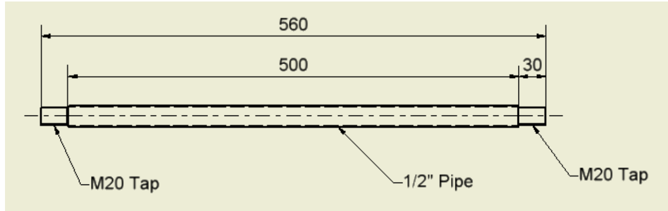


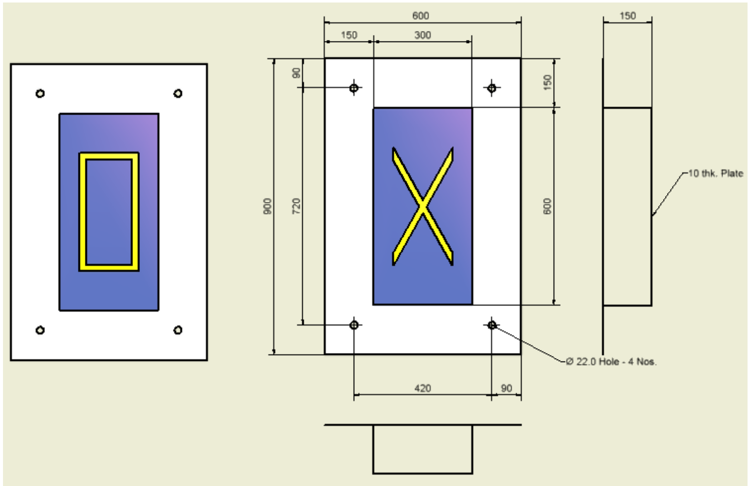
MS CLAMP – 1

Qty.– 1

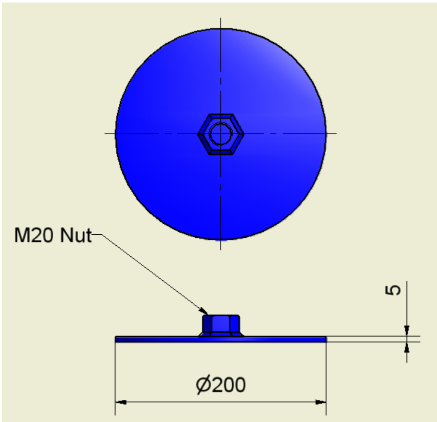
Path and bins





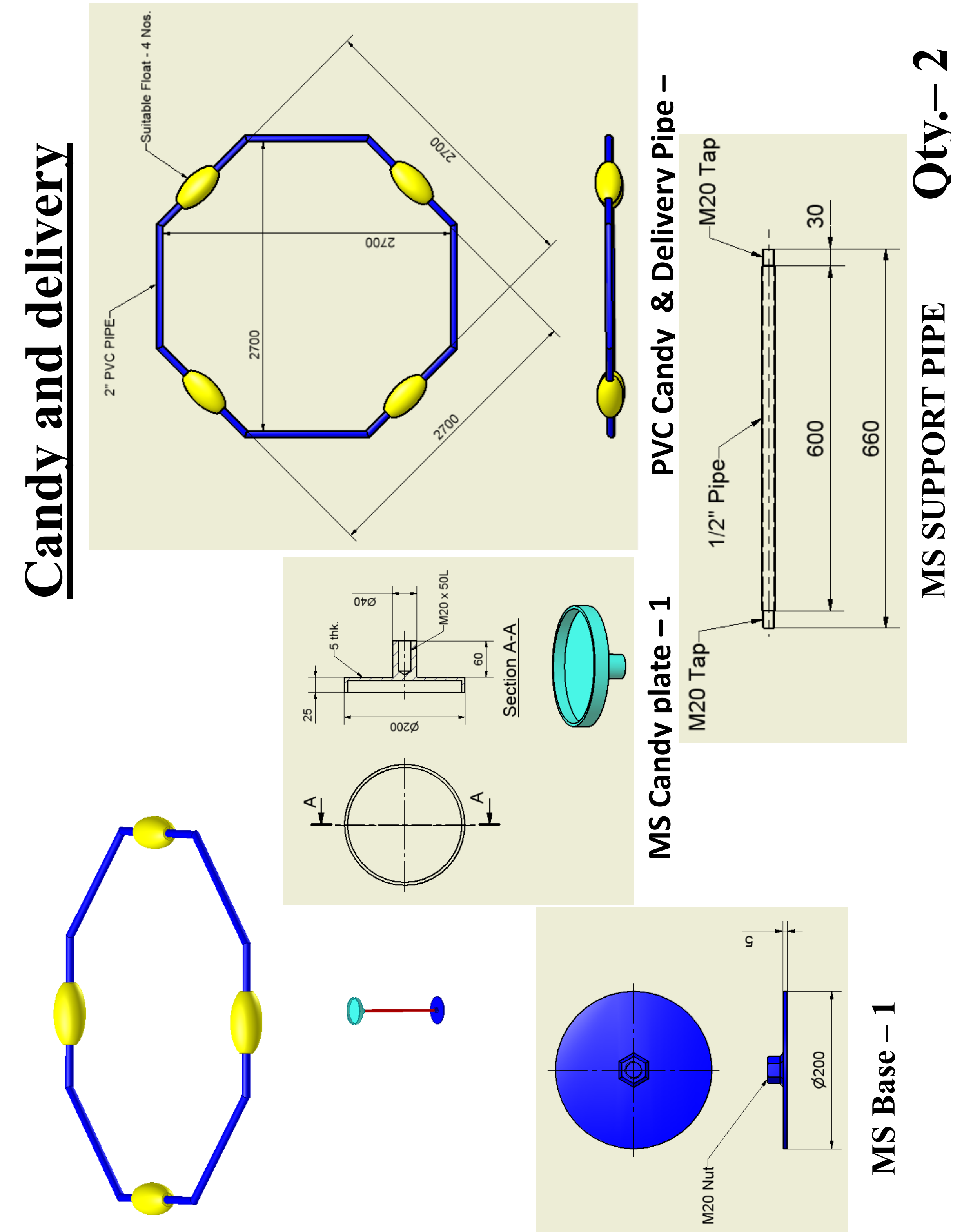


<u>Bin– 2 Nos. (one mark with Letter “O” & another mark with Letter “X”)</u>



<u>MS Base – 8</u>

<u>Qty.– Each 1</u>



courtesy : AUVSI Foundation

d. List of Components

Sl. No.	Description	Material	Qty.
1	Path Plate	PVC / MS	8 Nos.
2	9” Spherical Float - Red	Float	1 No.
3	9” Spherical Float - Yellow	Float	1 No.
4	9” Spherical Float - Green	Float	1 No.
5	2” Pipe	PVC	25 mts.
6	Pipe Lock (“L”ove Lane)	MS	2 Nos.
7	2” Pipe Clamp	Ready made	2 Nos.
8	600 x 600 x 10 mm Plate (Cupid)	PVC / MS	2 Nos.
9	Clamp (Cupid)	MS	1 No.
10	Bin (Path & Bins)	PVC / MS	2 Nos.
11	Ell. Float (Candy & Delivery)	Float	8 Nos.
12	M20 Nuts	SS	13 Nos.
13	M10 x 30L Bolt	SS	2 Nos.
14	Candy Plate (Candy & Delivery)	MS	2
15	Base	MS	32
16	Support Pipe - 500 L (Path,”L”ove Lane, Path& Bins)	MS	26
17	Support Pipe - 600 L (Candy & Delivery)	MS	2
18	Support Pipe - 2100 L (Flowers)	MS	1
19	Support Pipe - 2500 L (Flowers)	MS	1
20	Support Pipe - 3500 L (Flowers)	MS	1
21	Support Pipe - 1000 L (Cupid)	MS	1

7. Evaluation criteria

The competition consists of three levels viz. Preliminary design review (PDR), critical design review (CDR) and functionality review (FR).

a. Preliminary Design Report (PDR)

Upon announcement of this student AUV competition on NIOT web site and communication to Academic Institutions, entries are expected to be submitted to NIOT through educational institutions in the form of a Preliminary Design Report (PDR) which contains the concept, literature review, design methodology, 3D simulation depicting the concept, brief theoretical substantiation of the design proposed, block diagram of the concept, Project document with theoretical modeling, methodology of operation, design, 3D model, Video simulation etc. After the selection of the successful entries qualifying for Phase I the group would involve in developing the concept.

b. Conceptual Design Report (CDR)

NIOT will request the selected team to submit Conceptual Design Report CDR with detailed description of the concept including detailed specification, circuit level design, detailed mathematical modeling, Commercial Off-The-Shelf equipment (COTS) required etc. NIOT shall also extend its expert guidance to the selected teams and they would be asked to make a presentation at NIOT (Phase II).

The following points should be dealt in detail in the Conceptual Design Report and the PowerPoint presentation:-

- Objective
- Literature survey
- Mechanical Design
- Electronics and Control system design
- Software design
- Control features and maneuverability
- Energy/power budget
- Team Strength

c. Functionality review (FR)

Then successful teams would be requested to demonstrate the working prototype vehicle in a swimming pool. The teams would be evaluated based on the mission requirements and performance of the vehicle. The winning team would participate in the International AUV competition in USA.

ESSO - National Institute Of Ocean Technology, Chennai
Ministry of Earth Sciences
Email: auv@niot.res.in, niotauv@gmail.com

National Student Competition on Student Autonomous underwater Vehicle (SAVe)

CDR Evaluation sheet

Sl. No.	Registration Id	University / College	Objective (10 marks)	Mechanical design (20 marks)	Electronics &Control system design (20 marks)	Software design (10 marks)	Control features and maneuverability (20 marks)	Energy/power budget (10 marks)	Team Strength (10 marks)	Total mark obtained
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

National Students Autonomous underwater Vehicle Competition(SAVe)

National Institute of Ocean Technology, Chennai

Final Evaluation Sheet

S.No	**Description**	**Max Points**	**Scores obtained**					
			Team 1	**Team 2**	**Team 3**	**Team 4**	**Team 5**	**Team 6**
1	Technical document & Uniform	10						
2	System realization based on review	10						
3	System weight in air (< 38 kg), Length (≤ 1.83 m), Width (≤ 0.91 m),Height (≤ 0.91 m)	10						
4	System autonomy in water	10						
5	System following the designated path	10						
6	System Passing gate & identifying balls	10						
7	System avoiding the obstacles in the path	10						
8	Dropping the designated object at assigned place	10						
9	System surfacing at designated place after completion of assigned job	5						
10	Time duration to complete the assigned job (<30 minutes)	5						
11	Failure contingency plan	5						
12	Team involvement	5						
	Total points	100						
	Rank							

Examiner Signature & Name with Date

8. Design approach for AUV

Following steps can help in developing the design of an AUV that is capable of competing in the Competition.

a. **Problem statement**: Every year, the problem is uploaded on the NIOT web site. The teams willing to participate should be clear about the requirement to design the vehicles as per the target provided.

b. **Determining the requirements**: Requirements can be categorized into two primary categories: *Primary Requirements* and *Secondary Requirements*.

i. Primary Requirements: The primary requirements include the system's desired ability to utilize a general purpose CPU and motherboard for high-level software, cameras for object recognition, motors and propellers for propulsion and power budget for function of AUV. An inertial measurement unit should be used for navigational purposes to help in guiding the system through the course. The degree of difficulty associated with the AUV system is partly responsible for many of its technical design attributes and the complexity of autonomy.

ii. Secondary Requirements: After taking into account what the system is capable of doing in its functional requirements, it's important to lay down prime rules on how well it must perform these desired functions. These performance requirements will measure the system's ability to perform various functions such as the system should be submersible, withstand a depth up to 25m without leakage and the minimum runtime (one hour) of the system in order to satisfy the requirements of the competition. While performing tasks, it is expected that the system behaves accurately so as to guarantee consistent mission success throughout the course.

The teams can reconsider the requirements investigated by them during the entire course of the project. However, it should be noted that changing individual parameters often has ripple effects on other aspects of the design. Therefore, before altering the design plan these effects should be considered.

iii. Checking feasibility & developing conceptual design(s): Feasibility should be assessed to determine the probability of success for a given design. Once the best design is decided, a study of the major components within the design to determine basic functionality should be started. Components of the design like power components, navigational hardware, propulsion, basic hydrostatics and dynamics, major structural components etc. should be considered. Component specification like required propulsion power, battery container size, high-level hydro requirements should be investigated. Specifications are further developed throughout the development process.

iv. Budget requirement: The cost analysis for the major components should be done to get an idea of budget requirements. Along with the cost analysis, the project plan and timeline should be assessed.

v. Designing the AUV: After the selection of concept option, it needs to be matured through a final fabrication design. The design process is an iterative one, which requires trade-off between the various disciplines.

9. Testing

Testing of the individual components, sub-systems and the entire system is a vital step towards the successful design and fabrication of the AUV. Real time testing of the AUV in-water not only provides practice in competition-like environment but also exposes potential design improvements. In-water testing helps greatly in the identification of problems and thus design improvements can be implemented before the competition. The following tests can be conducted to ensure successful operations:

- Hull integrity
- Structural tests
- assembly
- Endurance
- Thrusters
- Electronics
- Software
- Fail-safe checks
- Control
- Vibration response
- Component & Vehicle assembly
- Ballasting & trimming
- Functionality test in both air and water
- Mission simulation

Before testing, it is very important to check whether the system is ready for test or not. A checklist of procedures, that need to be completed before the actual test, should be prepared. This will help in avoiding potential problems due to an unimplemented installation or procedure and thus in-turn will reduce the chance of equipment damage or safety issues. Once, all the items in the checklist are ticked, the system is considered to be ready for testing.

10. Theoretical Background

10.1 Mechanical System

The mechanical subsystem begins with designing several factors that are needed to be taken into serious consideration for the design process. These include buoyancy, hydrodynamic damping, Coriolis & added mass. Stability of the vehicle is dependent upon external forces especially Pressure.

i. Buoyancy

Buoyancy is one of the most significant factors that affects the stability of the vehicle as well as its ability to submerge under water. As per the Archimedes principle, a solid body submerged in a fluid will have upward buoyant force acting on it which is equivalent to the weight of displaced fluid, enabling it to float or at least to appear to become lighter. So if the buoyancy exceeds the weight of the object then it floats else if the weight exceeds the buoyancy, the object sinks & if the buoyancy equals the weight, the body has neutral buoyancy and will remain at its level.

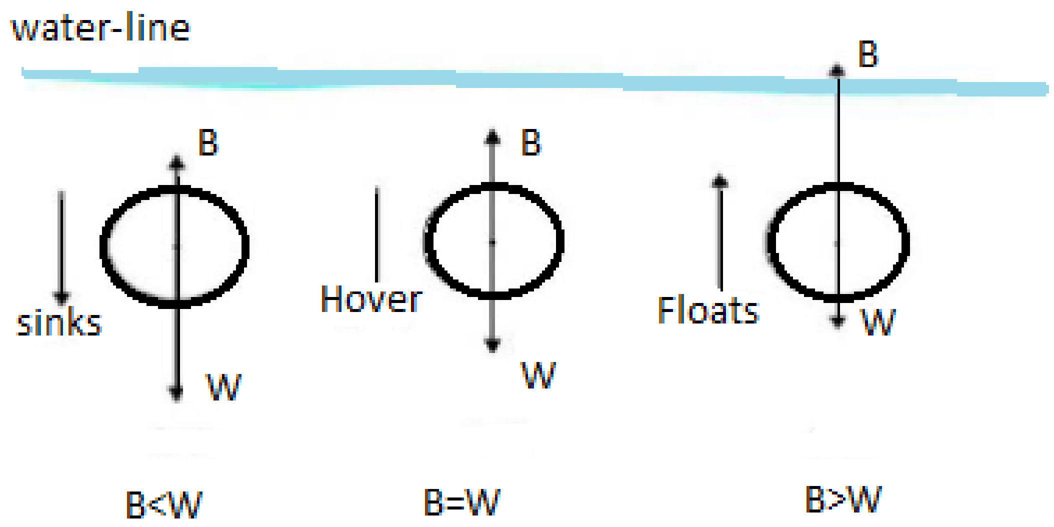


Fig. 5. Effect of Buoyancy

ii. Hydrodynamic Damping

When a body is moving through the water, the main forces acting in the opposite direction to the motion of the body are hydrodynamic damping forces. These damping forces are mainly due to drag and lifting forces, as well as skin friction. Skin friction can be considered negligible when compared to form drag forces, and so, it is usually sufficient to only take into account the latter when calculating damping forces. Damping forces form a significant part of the forces experienced by an underwater vehicle while performing motion.

Drag is a force, generated by the interaction and contact of a solid body with a fluid (liquid or gas). The drag equation gives the drag experienced by an object moving through a fluid:

$$\textbf{Thrust} = \textbf{Drag} = \mathbf{D} = \mathbf{1/2\rho A s^2 Cd}$$

Where

D is the force of drag,

ρ is the density of the fluid,

s is the velocity of the object relative to the fluid,

A is the reference area, and

Cd is the drag coefficient

iii. Stability

Assuming static conditions the stability of a static body underwater is predominantly affected by the positions of the center of gravity, CG, and center buoyancy, CB.

The center of buoyancy (CB) is the centroid of the volumetric displacement of the body.

Ideally, the two center of mass & buoyancy should be aligned vertically some distance apart from each other with CG below CB. This configuration produces a righting moment, RM, when the vehicle rolls or pitches that is directly proportional to the perpendicular distance between CG and CB, as well as to both B and W. This moment is conducive to the vehicle's stability, acting as a passive roll and pitch control system. The moment is given by,

$$\mathbf{R_M = ½ * d * (B + W)}$$

Where d is the perpendicular distance between the acting forces B and W.

If CG and CB coincide in the same position in space, the vehicle will be very susceptible to perturbations. That means it won’t be able to rectify the error produced in the vehicle during the motion. If CG and CB are not aligned vertically with each other in either longitudinal or lateral directions, then instability will exist due to nonzero moment.

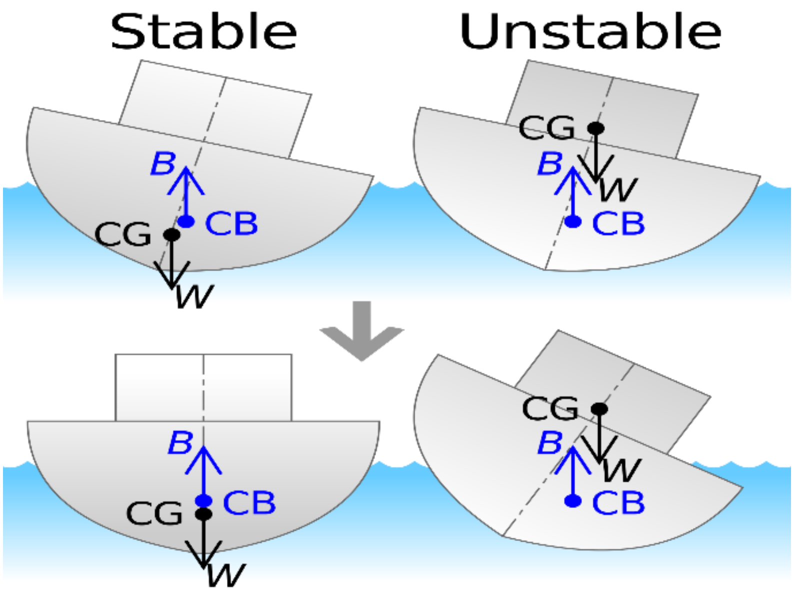


Fig. 6. a) Stable configuration of underwater body b) Instability of an underwater body through misalignment of center of mass & buoyancy

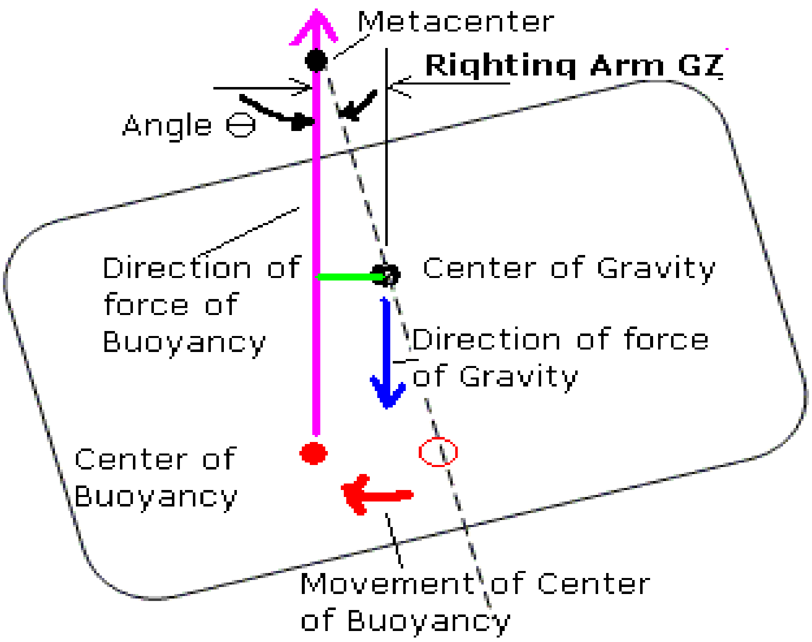


Fig. 7. Righting Moment caused by roll or pitch of the vehicle

iv. Added Mass

When a body moves underwater, the immediate surrounding fluid is accelerated along with the body. This affects the dynamics of the vehicle in such a way that the force required to accelerate the water can be modeled as an added mass. Added mass is a fairly significant effect and is related to the mass and inertial values of the vehicle.

v. Environmental Forces

Environmental disturbances affect the motion and stability of a vehicle. For an underwater vehicle waves, currents & winds affect the motion of the body. When the vehicle is operating underwater, the effect of wind and waves can be largely ignored. So the most prominent disturbances are caused by currents. In a controlled environment such as a pool, the effect of all of these forces is minimal. Other factors, such as extreme high or low temperature or extreme sunshine can interfere with sensor recognition.

vi. Hydrostatic Pressure

Underwater pressure is caused by the weight of the medium, in this case water, acting upon a surface. Pressure is usually measured as an absolute or ambient pressure; absolute denoting the total pressure and ambient being of a relativistic nature.

Depending on the depth the force acting on the vehicle operating under water is the sheer weight of the fluid above the vehicle, up to the water's surface. The resulting hydrostatic pressure is isotropic that means the pressure acts in all directions equally, the pressure increases linearly with the water depth as according to Pascal's law:

$$\mathbf{p = \rho g h}$$

Where, p is the Pressure due to water on the vehicle;

ρ is the density of water

g is the force of gravity;

h is the depth of the vehicle

We must consider that at sea level, pressure due to air is 14.7psi or 1atm. & for every 10m of depth, pressure increases by about 1atm, hence, the absolute pressure at 10m underwater is 2atm. Although this increment is linear in nature, the increase in pressure as depth increases is fairly large and underwater vehicles must be structurally capable of withstanding this pressure to survive.

vii. Thruster configurations

The thruster configurations that can be considered are as follows:

- **One Hull, five thrusters**

The one-hull solution may consist of a cylindrical hull with five thrusters attached to a skeletal frame. Two thrusters would be used for horizontal motion and the other two for depth control while the remaining one would control the rotation along the horizontal axis.

Advantages-

1) It uses 5 thrusters and deriving 4 DOF from them namely surge, heave, roll and yaw. This configuration is easy to control.

2) Due to components being housed in just one hull, the need for through-hull connections would be minimal.

3) The five-thruster configuration would allow for easier modeling and control of the vehicle in software.

4) The frame, supporting the hull and thrusters, would also allow for modularity and relative ease in attaching external devices.

Disadvantages-

1) The amount of available space would be restrictive. So maintenance, inspection and addition of components would be inhibited.

2) It leaves 2 motions uncontrolled.

3) Due to the use of five thrusters power consumption would be far greater than that with the torpedo design

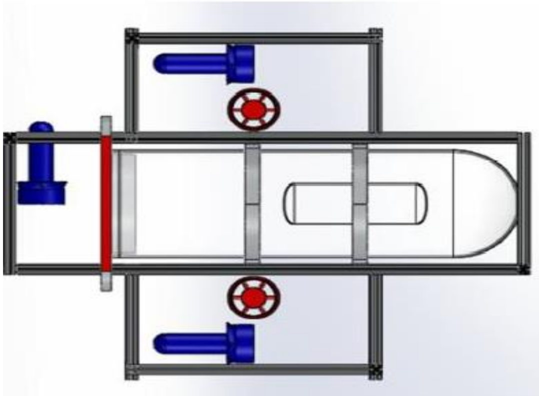


Fig. 8. One hull-five thrusters

- **One Hull, six thrusters**

The one-hull solution may consist of a hull with six thrusters attached to a skeletal frame. Here two thrusters would be employed for horizontal motion, two for depth control while the remaining couple would control the rotation along the horizontal axis.

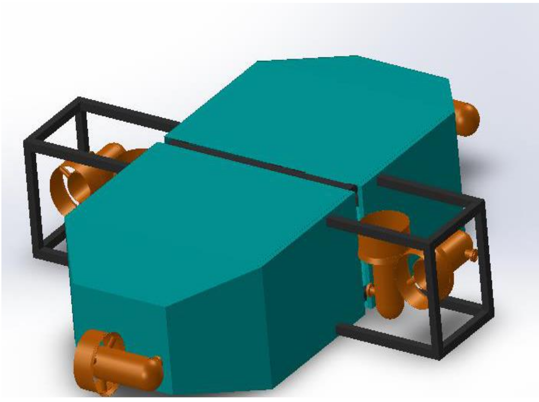


Fig. 9. One hull - six thrusters

Advantages-

1) It uses 6 thrusters and derives 5 DOF from them. This configuration is even easier to control.
2) As the components are housed in just one hull, the need for through-hull connections would be minimal.
3) Ease in machining and construction because of its simple structure.
4) The six-thruster configuration would allow for easier modeling and control of the vehicle in software.
5) The frame, supporting the hull and thrusters, would also allow for modularity and relative ease in attaching external devices.

Disadvantages-

1) Due to the use of six thrusters power consumption would be far greater than that with the torpedo design & the five thruster configuration.
2) The cost rises substantially due to the use of six thrusters.

- **Two Hulls, Four Thrusters**

This is similar in structure to the one-hull solution, but consists of two hulls; an upper and lower one & finally for the right & left.

Advantages-

1) Increased space for components
2) An innate metacentric righting moment produced from a dense lower hull and a highly buoyant upper hull. Batteries would be housed in the lower hull to lower the center of mass while the remaining components would be situated in the upper hull.

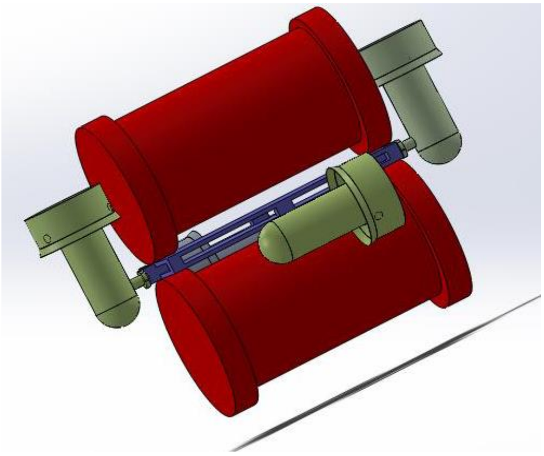


Fig. 10. Two hulls - four thrusters

Disadvantages-

1) The need for more through-hull connections to link components in both hulls.

Other advantages and disadvantages of this design are akin to those of the one-hull solution.

- **Two Hulls, Two Rotating Thrusters**

Comparing the footsteps of the two hull design above, this design is unique as it has rotational thrusters which allow both horizontal and vertical motion simultaneously.

Advantages-

1) Utilizing two thrusters, this design would require much less power

2) Reduced construction complexity both mechanically and electronically.

Disadvantages-

1) Need for powerful servos to be able to effectively rotate the thrusters.

2) Difficulty in guaranteeing watertight seals around these rotating mechanisms.

3) Software modeling would generate some difficulty, mostly attributable to the rotational nature and dynamics of the thrusters.

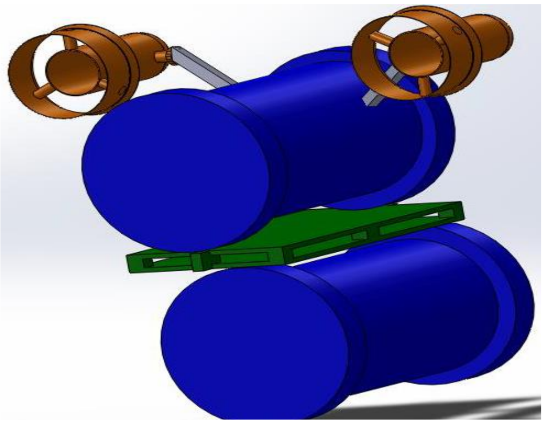


Fig. 11. Two hulls - two rotating thrusters

viii. Choosing the Final Design

The qualities sought in an ideal design would be-

- As low center of mass as possible.
- As high center of buoyancy as possible.
- Centers of drag aligned with centers of thrust.
- Shrouds for propellers, not only to protect users, but also to avoid possible damages.
- Symmetry for ease of design and construction, as well as easy modeling.
- Adequate internal hull space for electronic components
- Sufficient space to accommodate external devices on the frame
- A longitudinally adjustable center of mass to assist in static stability

The following points should be considered while selecting the design-

- Easy to machine and simple structure so easy to construct

- Use readily available materials, and uncomplicated design, to expedite construction.
- Relative ease in ensuring watertight integrity because of the lack of rotating mechanical devices such as bow planes and rudders
- High modularity & high adaptability. The frame must accept various parts in various configurations as competition requirements change.
- Relative ease foreseen in software control implementation in using a six thruster configuration when compared to using a ballast tank and one thruster system
- High range of motion provided by the six thruster configuration
- Ease in submerging with two vertical thrusters
- Static stability due to the separation of the centers of mass and buoyancy, and dynamic stability due to the simple alignment of thrusters with easily identifiable centers of drag.
- Design a carry handle for safe, easy transportation and hoisting.
- Maintain a minimum distance of 18” between the inertial measurement unit (IMU) housing and any source of magnetic interference.
- Minimize weight while retaining sufficient rigidity to withstand thrust forces.

Precisions in controlling the vehicle and overall simplicity need to be pursued in the mechanical design over speed and sleekness. Although speed and sleekness are generally desirable qualities in AUVs, there is no real need for these as per the tasks required for the underwater competition.

ix. Hull, its material and shape

It is desired to implement a reliable, repeatable, and quickly deployable system. The hull housing payload has the responsibility of protecting the electrical system from contact with water and thus has to have a sealing mechanism. To accomplish this objective, the design of the hull has to be provided with an O-ring. When load is applied due to the latches, the O-ring deforms and blocks the passage between end cap and hull and thus prevents water passage into system.

O-rings should be added to join the two molds that would prevent from water leakage. Both caps implement a double O-ring sealing system that is fault tolerant to the repeated opening and closing of the vehicle during development. The caps are locked to the submarine using guide holes that align with complementary holes on the hull. Threaded stainless steel rods could be used in guide holes and wing nuts are used to complete the seal of the system.

The hull should be light and strong, i.e., it should have a high strength to weight ratio. For this purpose, Fiber Reinforced Plastics (FRP), Aluminium alloy and Acrylic should be used as the hull material.

The shape of the hull decides its ability to withstand hydrostatic pressure and the amount of drag experienced by it, which decides the thruster power required. Ideally, a spherical shape is desirable but it offers serious issues of poor packaging and tedious stability control. Thus, it is suggested to use more hydro dynamically evolved shape which overcomes these issues and provide more streamlined characteristics.

10.2 Electronics, Navigation & Control

The electrical subsystem payload will consist of the cameras, temperature sensor, depth sensor, communication module etc. The single on board computer should support multiple applications such as image processing, PWM generation, multithreading etc. The power supply management unit will be designed so as to provide effective power to the entire payload as well as the thrusters, which are used for the propulsion of the AUV.

The thrusters used for propulsion and navigation require a controlled input so that they can respond in the desired manner quickly and with least possible error. For this purpose, a closed loop PID control will be implemented over the thruster driving signal to enable self-adjustment of thrusters' output based on sensor readings. This PID controller will be tested and tuned using SIMULINK in MATLAB.

The AUV would navigate on the basis of readings from the pressure sensor (depth), IMU (Inertial Measurement Unit) and cameras (through image processing).

The pressure sensor would be used to maintain the depth of the AUV. The thrusters controlling the heave and roll motion will be controlled by the pressure sensor reading through an independent PID controller and will bring the AUV to the desired height of operation. An IMU would be used in combination with the pressure sensor, which would also help in self-adjustment of the AUV orientation.

The thrusters providing the surge and yaw motion will be controlled by the image processing data, through an independent PID controller, to perform the various tasks. Cameras would obtain a continuous feed of images, on which image processing algorithms would be applied, to navigate the entire course correctly. For the entire course, the AUV would travel along the directions given by the orange line. Each oncoming of task during the traversal of AUV would be immediately recognized by the AUV and it would prepare itself accordingly for performing the task. After completing the task, the AUV would adjust its height again (with the help of the pressure sensor) and get the new direction from the orange path till the image processing stops when it encounters the colored octagon region and the AUV surfaces henceforth.

i. Speed control of thrusters

When it comes to thrusters, we have a lot of options. What we need is thrusters, which could account for the necessary and required propulsion in water, counter-act all the drag forces that would be there and provides sufficient speed without taking too much load on themselves. Commercially available thrusters provide the necessary thrust, and thereby the force required, and has a very high reliability and control features.

The thrust required to drive an AUV is given by the relation:

$$Thrust=12*\rho*v_2*C_D$$

Where, $\rho=densityofwaterv=velocityoftravelC_D=dragcoefficient$

These thrusters require a controlled input so that they can respond in the desired manner quickly and with least possible error. These thrusters have an inbuilt microcontroller which gives the feedback of the rpm and torque. The circuitry required for speed control of each thruster is given as:

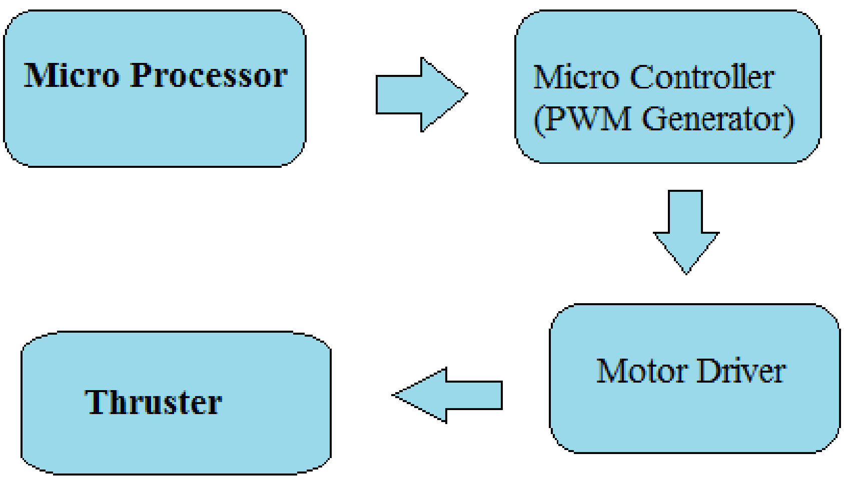


Fig. 12. Motor Control Block Diagram

The role of various components can be described as:

Microprocessor: Our Intel Atom microprocessor will take input from the cameras and perform the decision taking part with respect to the change in position and orientation of the AUV in order to accomplish the specific task at hand. This information will be communicated to the Motor Controller.

Motor Controller: The controller's task is to actually realize the orientation and position determined by the microprocessor. Also, the desired levels should be achieved as soon as possible and with least error.

Generally Digital Signal Processors (DSPs) are used for motor control applications because they are specialized processors that cater to fast digital signal processing and can perform arithmetic operations faster than normal microprocessors. But, they have no flash memory and require a more robust and well-designed board for working. Microcontrollers, on the other hand, are multifunctional and possess a power-off non-erasable memory but are relatively slower.

The class of low-end DSPs, called the 'control oriented DSPs', integrate many DSP processing capabilities with a microcontroller style instruction set and on-chip peripherals. They act as successful compromise between the DSP and microcontroller and will be apt for motor control purpose of our AUV.

Pulse Width Modulation: The various techniques that are applicable for speed control of DC motor include:

- Using potentiometers
- Pulse Width Modulation (PWM)

Among the various techniques available for speed control of DC motor (inside thrusters) using voltage regulation, Pulse Width Modulation (PWM) is most convenient for autonomous control and can be easily implemented using counter/timer circuits. It has almost 90% efficiency and runs cooler than normal power amps and therefore apt for our functional requirements.

Pulse-width modulation (PWM) of a signal or power source involves the modulation of its duty cycle, to control the amount of power sent to a load. The duty cycle of a signal is the fraction of time for which the signal is high in one time period.

ii. IMU (Inertial Measurement Unit)

An IMU is a device that is used to measure the velocity and orientation using a combination of gyroscopes, accelerometers and magnetometers. An IMU works by detecting the current rate of acceleration using one or more accelerometers, and detects changes in rotational attributes like pitch, roll and yaw using one or more gyroscopes. Many options like VN-100 by VectorNav and Xsens by MTI and RAZOR IMU by SPARKFUN ELECTRONICS are commercially available.

The three sensors in the IMU perform the following functions:

- Accelerometer measures the linear acceleration along the 3 axes. Both static as well as dynamic accelerations are taken care of by this device. Static measurements are generally with respect to gravity and the dynamic refers to sudden shocks. It is affected by gravity and can determine orientation with respect to earth's surface.
- Gyro meter measures angular acceleration about the 3 axis. Accelerometer alone can measure orientation with respect to earth's surface, if the gravity is the only force acting. Since, this is not the case, a gyroscope is used for correction of orientation values and a gyro-accelerometer combo will give more accurate orientation values.
- Magnetometer is an instrument used for measuring the strength and direction of a magnetic field. An important use of magnetometers is in measuring the earth's magnetic field. This can be used to find the heading of an AUV and also provides a yaw reference for the Z-axis drift compensation.

The Arduino code can also be modified to give directly the YPR (Yaw, Pitch and Roll) values which are computed from the 9 readings using different algorithm. These readings can be directly read from the IMU by slight modifications in code.

iii. Depth Sensor

The depth sensor would be used to determine the depth of the AUV continuously so that an appropriate distance could be maintained from the bottom of the pool.

This could also be used as a parameter for effective estimation of the "orange path" at the bottom of the pool, by adjusting the height of the AUV (along with the IMU inputs).

Pressure transducer (or depth sensor) and its interfacing is important as well because it would help us in navigating the AUV at an appropriate depth, a level at which is neither too deep (too close to the base of the seabed (or pool) might result in collision) nor too shallow (the tracks at the bottom of the pool and the events to be performed might not be present in the camera range (for the bottom camera) and camera field of view (for the front camera)).

The depth sensor would give us output based on the pressure in the outside environment. The output would be analog voltage or current.

The most common type of depth sensors are based on strain-gauge based transducer. That current would be used to decode the pressure at any particular depth.

iv. Power Management

The power management unit, containing multiple batteries, would not only supply power to the onboard processor, sensors, thruster motors and other ICs but also to the drop and throw mechanisms and kill switch, when required.

The thruster motors and their driver ICs could be powered from a separate battery combination and the processor and sensors would be powered from a different battery. This is necessary since thrusters require a lot of power and current and it is not desirable to draw a lot of current from a single battery. The different power requirements of the entire system would be met by taking batteries of different voltage and power ratings.

Li-ion/Li-Po batteries would be used because they are much lighter than other batteries of the same ratings from different categories and they are rechargeable too. Moreover, unlike other batteries, Li batteries can handle hundreds of charge/discharge cycles.

Since batteries of exact ratings are not available in the market for all of the components, custom circuitry would be required to be built for power distribution to all the components. Also, current monitoring would be required since each component has its own specific current, voltage and power ratings. Therefore, current sensors would be used for the same purpose. Switching regulators ensure regulated power supply to different electronic boards (circuits) mounted in the hull.

v. Onboard Computer

The main board should have the following functionality:

- High computation capacity
- Processing the sensor inputs
- Interfacing with the SD card or some other storage device (like Hard-Disk/Solid State
- Drive) for storing content larger than the memory size of the processor
- Supporting protocols like serial communication, com-port communication etc.
- Multithreading, so that multiple tasks can be carried out at the same time
- Providing a high clock speed (high processing rate) so that it can suffice the high requirement of image processing.

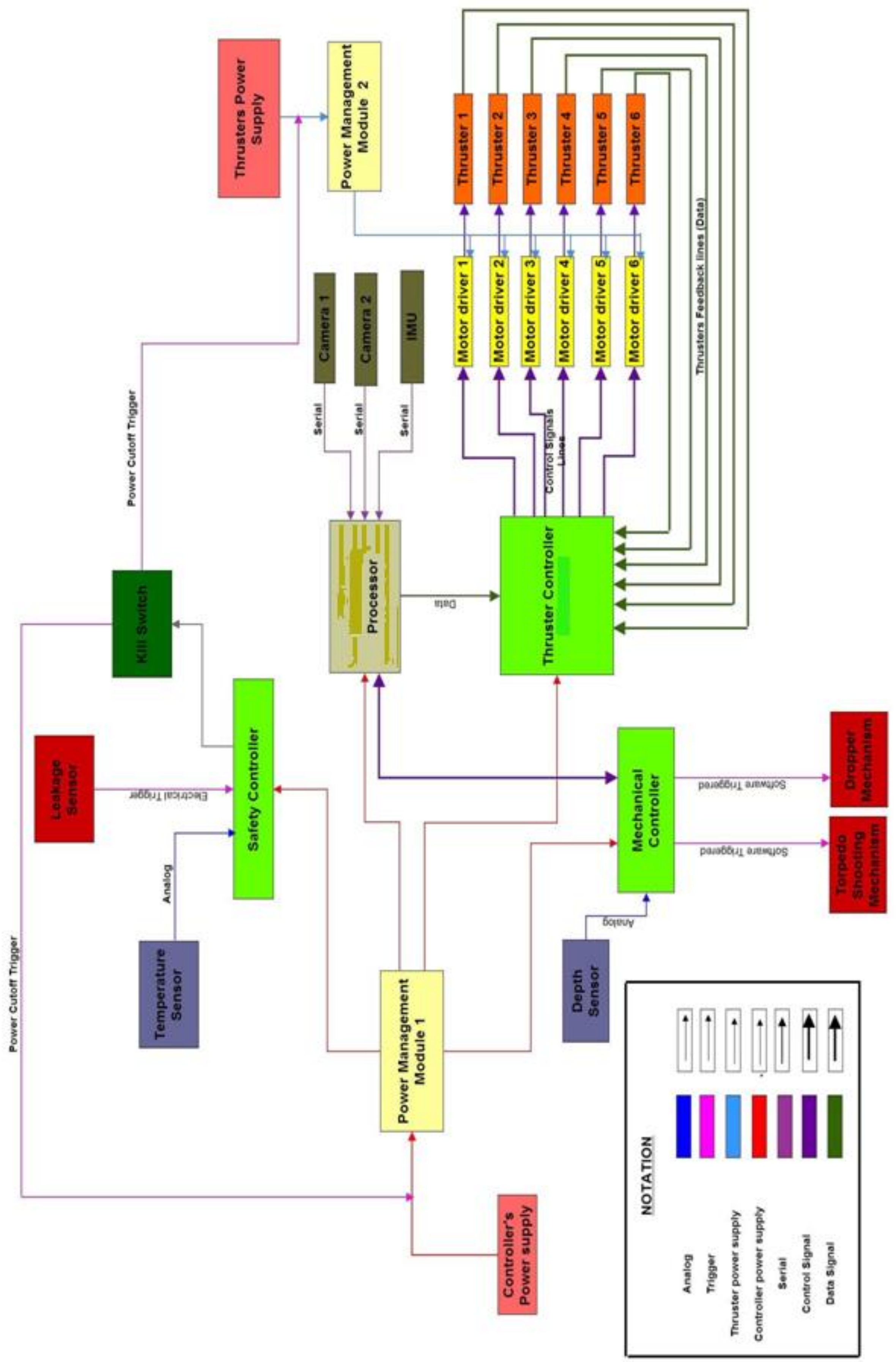
vi. Kill switches:

The kill switches would be used in the following conditions in the AUV:

1) In case too much internal heating occurs in which case supply to the main computer would be cut, if the heat level crosses some predefined threshold.

2) In case of water seepage inside the AUV in which case the current supply to the AUV would be cut to avoid any serious damage to the components.

In the first case, the kill switch would be implemented by interfacing the temperature sensor with the main board. The integrated circuit temperature transducer produces an output current proportional to absolute temperature.


Thrusters Power Supply
Power Management Module 2
Power Cutoff Trigger
Thruster 1
Thruster 2
Thruster 3
Thruster 4
Thruster 5
Thruster 6
Motor driver 1
Motor driver 2
Motor driver 3
Motor driver 4
Motor driver 5
Motor driver 6
Thrusters Feedback lines (Data)
Camera 1
Camera 2
IMU
Serial
Serial
Serial
Control Signals Lines
Kill Switch
Processor
Data
Thruster Controller
Leakage Sensor
Electrical Trigger
Safety Controller
Analog
Temperature Sensor
Mechanical Controller
Software Triggered
Software Triggered
Dropper Mechanism
Torpedo Shooting Mechanism
Analog
Depth Sensor
Power Management Module 1
Power Cutoff Trigger
Controller's Power supply
NOTATION
Analog
Trigger
Thruster power supply
Controller power supply
Serial
Control Signal
Data Signal

10.3 Software Analysis

The software system of the AUV comprises of several modules. The software can be broken into mainly two modules i.e. Middleware System and the AUV Mission Planner. The Middleware system bridges the gap between hardware and the AUV Mission Planner. The system will collect different sensor data, convert it to a digital signal, and filter its output. The system will also respond to digital inputs, which take analog signals and converts them to digital signals to be used by the AUV Mission Planner.

The main software module in the entire software hierarchy is the AUV Mission Planner. The Mission Planner will be created using an open-source Linux stack. The software framework consists of several important components installed on top of the Linux system along with the AUV Mission Planner. The AUV Mission Planner's architecture is based on a Model-View-Controller, or MVC pattern.

This model summarizes working of all the sensors, actuators, and data from the dashboard and control system. The system uses a technique in artificial intelligence known as an intelligent agent, which is the controller in the MVC pattern.

The Intelligent agent can be broken into several key components. A kernel interconnects and communicates between all the other key sections. Additionally, the kernel sends and receives the state information from the AUV Bridge. The kernel responsibility is to connect all the software modules and synchronize their function. The kernel will also be able to connect with and relay information to the External GUI. The kernel is responsible for hooking key features such as the Mission task, AUV EYE, Logging and state to interfaces with the External GUI. Finally, the kernel is responsible for keeping the system in a stable state. It must be able to protect against malfunctioning of any subsystems.

The AUV EYE runs captured camera feed data through encapsulated OpenCV filter algorithms, which will allow the AUV to detect objects via properties such as color and shape as mentioned in the Mission Task. The Logging system takes all commands, status, or state information and creates a log for that data. This can then be reviewed through the External GUI to rerun a mission.

The last main component is the AUV Mission Task. The Mission Task is used to read in mission files and generate a plan of how to execute that mission. The commands and tasks to be performed are then passed back to the kernel, which relays the information to the bridge.

The AUV Bridge is composed of two key components: the model and a simulator. The model connects to hardware or a simulator. Commands sent to the model are then transferred to physical elements in the AUV hull. If the AUV Bridge is connected to the simulator, the simulator will then emulate the intended commands within a graphical computer environment.

i. Software Frameworks

Several well tested frameworks for fast production time and increased reliability were looked at and the following is a selection of frameworks have been used by different AUV teams in competitors for years:

QT - Developed by Nokia and recently acquired by Digia, is a platform-independent, open-source framework complete with a GUI creator and various libraries ranging from networking to XML file parsing. QT has a large online community support base and has been used successfully by several collegiate competitors. QT will be used for the External GUI

OpenCV - Is an open-source computer vision library written in C and C++. There is an OpenCV binding for C++, which will greatly reduce the amount of time required for members to familiarize with the library. OpenCV is also compiled for easy integration into IDEs such as Qt Creator and any of the Visual Studio languages. The abundance of high level pre-made filters such as Canny edge detectors, Hough transforms for line and circle detection, in conjunction with lower level image manipulation (at the pixel level) makes for a very powerful library.

ZeroMQ - The AUV model and AUV kernel are separate processes, which complicates communication between the two modules. To mitigate this complexity, we intend to use ZeroMQ, an abstracted messaging library that handles many of the complications of socket level communication behind the curtains.

LabView – This software is ideal for any measurement or control system. The LabViewVISA(Virtual Instrument Software Architecture) is a standard for configuring, programming, and troubleshooting instrumentation systems comprising GPIB, VXI, PXI, Serial, Ethernet, and/or USB interfaces. VISA provides the programming interface between the hardware and development environments such as LabVIEW, LabWindows/CVI, and Measurement Studio for Microsoft Visual Studio. NI-VISA includes software libraries, interactive utilities such as NI I/O Trace and the VISA Interactive Control, and configuration programs through Measurement & Automation Explorer for all your development needs.

E. GAZEBO – This is a multi-robot simulator for outdoor and indoor environments. Gazebo is capable of simulating a population of robots, sensors and objects, but does so in a three-dimensional world. It generates both realistic sensor feedback and physically-plausible interactions between objects (it includes an accurate simulation of rigid-body physics).

Gazebo was originally designed to aid in the development process of algorithms for robotic platforms. Because Gazebo realistically simulates robots and environments, code designed to operate a physical robot can be executed on an artificial version. This helps to avoid common problems associated with hardware such as short battery life, hardware failures, and unexpected and dangerous behaviors. It is also faster to spin up a simulation engine than continually run code on a robot, especially when the simulation engine can run faster than real-time.

ii. Mission Planner

The majority of the artificial intelligence takes the form of the mission planner. This planner is responsible for loading and parsing Mission Task, generating a directed graph of tasks, and developing a plan to maximize mission points in the least amount of time. A new plan is generated after the completion (or failure) of every task. An abstract class will be used to allow the development of several planning algorithms. The current plan is to implement an algorithm based on uniform weightage search or Dijkstra's algorithm, but focusing instead on the path with maximum point value. A pseudo-code variation of Dijkstra's algorithm exploring the largest point-value and taking time-cost into account is shown in Algorithm below. This modified version uses heuristics, including task point-value and a scaled time-cost in points, to determine the highest-valued path to take. Distances in this modified version are assumed to be scaled to point-values – if a task worth few points is placed far from the current task, the agent may pass it up to increase the mission end time bonus.

iii. External GUI

The External GUI will be a graphical user interface which displays the state of the AUV. This will be the most critical component in testing the AUV. The main window will display the entire state of system. A mock design was created which shows the main window. The main window is comprised of multiple layers. Telemetry information will be displayed and updated if the robot is currently running play-back information. The latest image data will display the robot's current location and may contain additional information within the image that is produced by the filter chain. Finally, additional subsystems, such torpedoes, will be presented to the viewer. Additional features that are being considered include an AUV EYE and a Mission

Task. These additional features are optional requirements and may not be implemented. The AUV EYE editor will take a collection of encapsulated OpenCV filters to be chained together and make a custom pipeline for filtering of image data. The mission planner will have a graphical interface where tasks could be placed upon a map. These positions would allow the robot to approximate its location when it goes to perform its tasks.

iv. Image Processing

The need for image processing is essential for every important tasks in the competition. One major requirement for image processing is being able to align with a marker. To perform this task, the robot needs to be able to recognize both the shape and color. The main tasks these algorithms need to perform is object detection. This allows the planner to recognize objects and determine its next action to be performed. Image processing will be done using the OpenCV Library. Images will be filtered using the AUV EYE module. The module will contain filters which bind the OpenCV algorithms and filters to the AUV Operating System. This gives consistency in the desired input and output formats. The benefit of doing this is that we can construct a chain or pipeline of filters to perform operations in a dynamic manner. Also, the filter chain will be used to change the image within the AUV dashboard through a graphical interface. The updated chain can then be dynamically loaded while running a mission.

11. Contribution to underwater technology

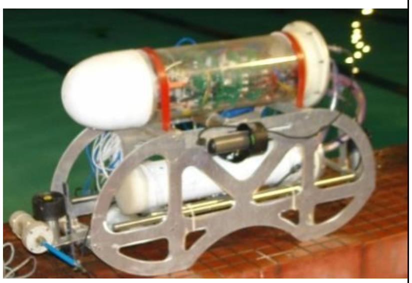
This entire process proved well and helped in the development of 10 underwater vehicle prototypes in India. Students have come up with brilliant ideas of naming their vehicles for the competition such as Amogh, Sedna, Poseidon, Tiburon, Jal Netra, Varun, Samudra, Zyra, Leviathan, Delfino, Hydra. The success of this competition is based, in part, on the fact that India has ten AUVs having different configurations from the following institutions:

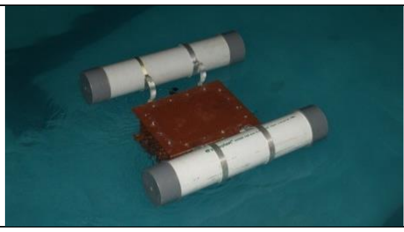
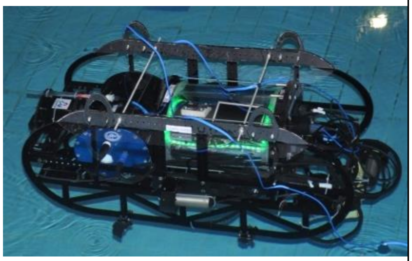
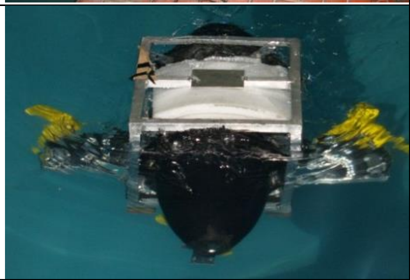
1. Indian Institute of Technology, Kharagpur
2. Indian Institute of Technology, Madras
3. Saveetha Engineering college, Chennai
4. SRM university, Chennai
5. Panimalar Institute of Technology, Chennai
6. Indian Maritime University, Vishakhapatnam
7. Delhi Technological University, New Delhi
8. Ambedkar Institute of Advanced Communication Technologies and Research, New Delhi

9. National Institute of Technology, Rourkela
10. Hindustan University, Chennai

Fig. 13. Winning teams of National AUV competition in the year 2014 and 2015

This is a major contribution by students in the field of Underwater Technology. The competition received overwhelming response from different institutions in which IEEE- OES has come forward to extend financial support. The Office of Naval Research (ONR) also has shown interest to provide support for the competition to improve the awareness as well as encourage Students in the field of underwater technologies.

Sl.No	AUV Name	College Name	AUV Photo	Salient features
1	iKAT	IIT Kharagpur		• Positive buoyancy • 2 Cameras, DVL, 6 Thrusters • Dimensions of the vehicle are 130cm x 45cm x 55cm • Rated depth 25m • Weight 30kg • Endurance 3 hrs
2	AUV AMOGH	IIT Madras		• Modular, hydrodynamic, dual hull, heavy bottom design • 6 thrusters that provide 4 degrees of freedom • Maximum surge speed of 1m/s • Maximum operable depth of 20m • Weighs 36.5kg with a net positive buoyancy of 0.2% • In-water endurance time of 2 hours • Underwater subconn connectors for inter hull connections • Custom designed motor controllers and compact PCB's

Sl.No	AUV Name	College Name	AUV Photo	Salient features
3	DNA	Saveetha Engineering college		• hull is cylindrical with semi-hemispheres • two thrusters • Weighs 20 kg • AUV has two pumps to maintain buoyancy • 2 cameras
4	SEDNA	SRM University		• 8-Thruster configuration provide 6-dof control –(added roll control) • Run time - 1hr 30 mins Dimensions – 1000 x 500 x 400mm • Battery pods for hot-swappable power • Custom plug & play PCB's • 6-piece modular frame with two thruster configurations • Custom enclosures with CNC machining & anodizing • Software ported to ROS framework with support for active localization using Doppler Velocity log.
5	VYUHA	Panimalar Institute of Technology		• 4- Thruster • Positive Buoyancy • 2 cameras • Weighs 24 kg • In-water endurance time of 1hr 30 mins
6	JALNETRA 3.0	Indian Maritime university		• Cost effective/cheap and light weight • Robust programming with soft coding • Equipped with advanced array of sensor. e.g.- DVL, CTD, etc., • Hydro dynamically and hydrostatically stable • Easy launch and retrieval
7	SEDNA	Delhi Technological University		• Modular, hydrodynamic • 4 thrusters that provide 4 degrees of freedom • Positive Buoyancy • 2 cameras • Weighs 23 kg • In-water endurance time of 1hr 30 mins
8	SAMUDRA	Ambedhkar university, Delhi		• Transparent body: Polycarbonate i.e. Poly methyl methacrylate. Positive buoyancy • Fault checking: Implemented algorithms in such a manner that there is regular checking of communication between our processing board, microcontroller board and other peripherals. If there is any loss of communication the system stops working and due to

Sl.No	AUV Name	College Name	AUV Photo	Salient features
				positive buoyancy the system comes to surface automatically • Very compact vehicle
9	TIBURON	NIT Rourkela		• Use of servo motors for effective 3D placing of AUV • Computer vision and windows platform • Creating our own debugging platform with open framework libraries and windows form application. • Graphic LCD for showing the data from on-board computer. • Rubber damping for controlling vibrations and crush copper rings for water proofing.
10	POSEIDON	Hindustan university		• Light weight, compact in shape • High performance & low power consumed electronics is used • AUV is designed to be slightly positive buoyant such that when there is any electrical failure it will be automatically surfaces to the water level • Grabber system is employed to drop marker in the bin. • High end camera is used for higher resolution and increased input FPS.

12.Global scenario

Globally, many countries such as USA, Europe, Singapore and Hong Kong are conducting the underwater AUV competitions. Though the competition model varies country to country, the basic concept remains the same where the rules and procedures for the competition are set initially and registrations are opened for participants throughout the World. In India, the competition model differs in a way that NIOT associates with students from the initial stages of development. The procedure starts from Preliminary Design Review to the Engineered Prototype Review, where the students are made familiar in the Underwater Technology.

13. Capacity building

Organizing workshops and training programs provide student with an exposure to the International arena on the beforehand. Three workshops have been conducted till now and these attempts create a platform to provide students in establishing newer contacts in the underwater Industry. During these events, people across the world with similar motives join together and this helps the students to improve domain knowledge. NIOT succeeded in guiding the most useful sponsorships and encouraging the industry to donate hard-to-find or expensive components. Few sponsors from Industry/component manufacturers agreed to provide students, the components at a discounted price or agreed to give components on loan at free of cost. Furthermore, one of the other motivating factors is mentorship throughout the competition. This model is one of its kinds, where the mentors from NIOT and other National Institutes guide the teams to develop problem solving capabilities and get expertise in design and development.

Furthermore, the students develop problem solving capabilities in their respective fields together with managerial skills to establish the team, handle time bound situations and control the stress caused by issues that occur during the competition.

14. Summary and Conclusions

The initial impetus for this competition has come from the fact that India's quest towards the unexplored areas of underwater technology. As for the world scenario, all the countries are looking at oceans as an opportunity to exploit and extract the resources. This could be possible by the continuous thriving for technological innovations and students are the best possible wealth that any country can have. Thus, today at the helm of growing needs for energy and resources, NIOT's vision to provide students an opportunity to make innovations in building AUVs has succeeded in part, on the fact that India has 10 AUVs having different configurations where approximately 3 - 4 prototypes are developed in a span of 6-8 months every year. This capacity building exercise would be continued which would help keep India in the league of developed Nations in the field of Underwater Technology.

15. Acknowledgement

We thank the Ministry of Earth Sciences (MoES), Govt. of India, for funding the National Institute of Ocean Technology SAVe competition programme and NIOT staff, HRD, NIOT and experts from different Institutions like NIO, Goa, NSTL, Visakhapatnam, DRDO, IIT Madras, committee members and Indian students. Thanks are due to the Aquatic Complex, Chennai and IIT Madras for providing the swimming pool for the competition. We also thank the IEEE –OES madras chapter for the sponsorship for this SAVe competition.

16.References

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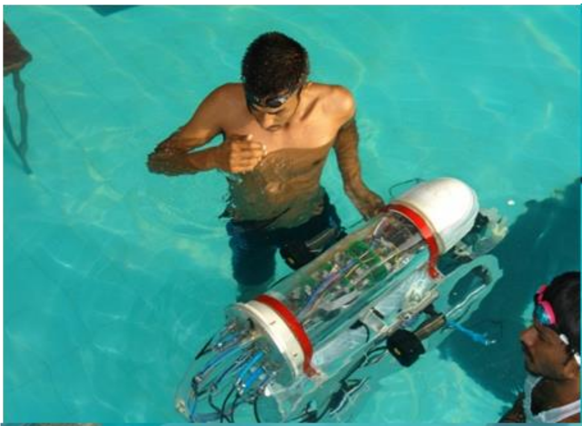
12. http://www.sauc-europe.org/

17.Student AUVs demonstrated by teams at National level competition








18.International competition at San Diego USA

Four teams have successfully participated in the Robosub, an International competition held at AUVSI foundation San Diego, USA

1. Indian Institute of Technology Kharagpur-2011
2. Panimalar Institute of Technology Chennai -2012
3. Indian Institute of Technology Madras-2014
4. SRM university Chennai -2015
5. Indian Institute of Technology Bombay - 2017

19.Student Photos

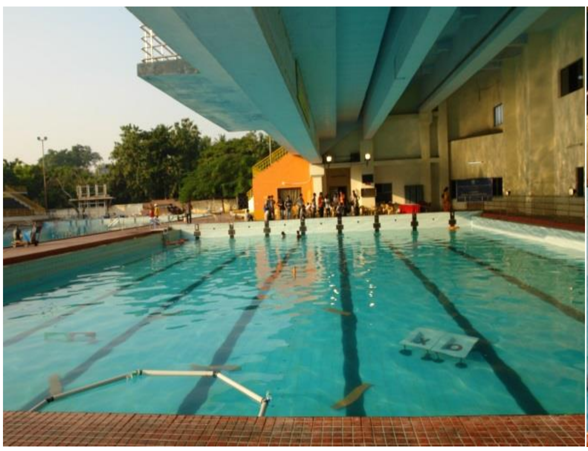
SAVe 2011 Photos

SAVe 2012 Photos



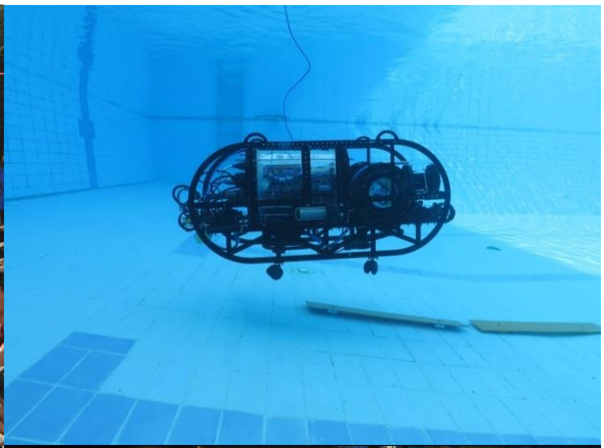



SAVe 2014 Photos




SAVe 2015 Photos


NATIONAL STUDENT AUTONOMOUS
UNDERWATER VEHICLE (SAVE) COMPETITION
IIT MADRAS




2 mts DEEP


NATIONAL INSTITUTE OF OCEAN TECHNOLOGY

20. ANNEXURE

List of Participants (SAVe 2011)

Sl No.	Reg No	Name	Name of the College	Selected for
1	SRN00071	Ashish Kumar Jha, Amit Kumar, Kamlesh Kumar, Rituraj Mishra, Ashish Sharma	Ambedkar institute of Technology, Delhi.	PDR, CDR & FINAL
2	SRN00102	Sachin Sharma, Irshad Ahmad Ansari, Varun Katha, Prince Khurana, RaghavNagpal	Dr. B R Ambedkar National Institute of Technology, Jalandhar.	PDR & CDR
3	SRN00092	Sandeep kumarDinodiya, Sachin Kumar, HarshitTripathi,Kshitiz Srivastava, Yudhveer Singh Sheoran	Department Of ship Technology /Cochin University of Science and Technology,Kochi-682 022, kerala, Tel:2575714	PDR
4	SRN00086	Ashish Kumar Kashyap, Dhirendra Singh Jaysariya, Harsh Bhardwaj, Vikas Pandey, VivekUpadhayay	BabuBanarsi Das Institute of Technology, Ghaziabad.	PDR & CDR
5	SRN00143	Inesh Singh, Daman makhija, Akshaymediratta, Gaurav kumarsingh, JayanthikrishnaMangaraju	Symbiosis Institute of Technology, Symbiosis International University, Gram :Lavale, Tal : Mulshi, Dist : Pune - 411 042. Phone : 020-39116250	PDR
6	SRN00083	Kaushik Acharya, AtinAngrish, Sayed Aweze, Ankit Kulshrestha, Sarvesh	Birla Institute of Technology &Science , Rajasthan.	PDR & CDR
7	SRN00037	Chitta Naga KashyapaRavikiran, Ashwin A Gadgil, Ankush Kumar, SoumyaRanjanSubudhi, Chari PrathameshSakharam	Indian Maritime University, Visakhapatnam.	PDR, CDR & FINAL
8	SRN00088	Rajeev.M, VinothKumar . C, Sidharth. K, Siva Shanmugam, Dinesh Rajan R	AmetUniversity,Chennai,	PDR & CDR
9	SRN00154	Amal.B, Anshul Sharma, MiteshKarwa, Manish Anand, Abhilash Mishra	Motilal Nehru National Institute of Technology, Allahabad.	PDR, CDR & FINAL
10	SRN00056	K.Mari Kumar, L.HariPrasanth, V.Sathish Kumar, T.DevaArjuun, B Gnanasekaranthan,	KalaignarKarunanidhi Institute of Technology, Coimbatore.	PDR, CDR & FINAL
11	SRN00106	K.G.Ramsundar, S.Jagan,S.T.Pradeep,K.K.Premnath,K.Adarsh	Kumaraguru college of Technolgoy, Coimbatore.	PDR, CDR & FINAL

12	SRN00118	S.Thileepan, S.Yuva Narayanan, R.AshwinYogesh, P.Dharanitharan, S.SaiBalaji	Saveetha Engineering College, Chennai.	PDR, CDR, FINAL
13	SRN00148	D.MonishaGnanachandra, U.Ramya,T.Shriram, Rachel Priyanka.J, Anand.M	Velammal Engineering College, Chennai.	PDR & CDR
14	SRN00032	Nanda gopal.R.L ,Raja kumaaran .H Gandhi .M,Shivakumaran .E ,Vijayakumar .R	Institute of Road and Transport Techonlogy / Erode 638 316	PDR
15	SRN00145	Ankur Anal, Hemanth A S, R Vimal Kumar, R. Balamurugan, V.Varsha	Indian Maritime University, Visakhapatnam.	PDR & CDR
16	SRN00114	Chahar Ravi Kumar, Rajdeep Ghosh, Varinderdeep Singh, Amanjot Singh, Alakshendra Singh	Padre Conceicao college of Engineering, Goa.	PDR & CDR
17	SRN00060	Chidambararaja.S, M.N.Sarath Kumar, B.Gowthamraj, R.Ramesh Raja, S.Senthil Kumar	PSG College of Technology, Peelamedu,Coimbatore.	PDR & CDR
18	SRN00097	T.ShyamRamanath, A.Sudharsan, R.FelixUdhayaraj	Sri Sairam Engineering College, Chennai.	PDR, CDR & FINAL
19	SRN00151	AnubhavSahoo, Siddhant Agarwal, Nuralivirani,PrajapatiDhavalPratapsiddarthakhastgir	Indian Institute of Technology, Kharagpur.	**PDR, CDR, FINAL & SELECTED IN SAVe 2011 AND PARTICIPATED IN THE INTERNATIONAL COMPETITION AT SAN DIEGO**

List of Participants (SAVe 2012)

Sl. No.	Reg No	Name	Name of the College	Selected for
1	SRN00006	Mr.VenayChawda, Mr. Aby Raj P.M, Mr. Thileepan.S, Mr. Rahul Shah, & Mr. Arshdeep Singh Multani,	Vellore Institute of Technology University, Vellore-632014.	PDR & CDR
2	SRN00007	Mr. Nikhil Sharma, Mr.Chandrashekhar, Mr. Mudit Tiwari, Mr. Akshay Gupta, & Mr. Rohitash Garg,	Chandravati Group of Institute, Facutly of Enginnering, Rajasthan – 321 001.	PDR & CDR
3	SRN00008	Mr. Kamlesh Kumar, Mr. Himanshu Gupta, Mr. AshwinAggarawal, Mr. Himanshu Jain, & Mr. Rahul Chauhan,	Ambedkar Institute of Advanced Communication Technology &Resarch, Delhi-110031.	PDR, CDR & FINAL
4	SRN00010	Mr. ReejuDatta, Mr. BhushanUdayTaskar, Mr. Anurag, Mr. Vinay Yadav, & Mr. Sharat Chandra,	Indian Institute of Technology, Kharagpur – 721 302.	PDR, CDR & FINAL
5	SRN00011	Mr.B.HariPrasadh, Mr. M.Gowtham, Mr. R.R.ManojKumar,Mr. R.Pradeep,& Mr. M.Vinoth,.	Saveetha Engineering College, Chennai - 602105	PDR, CDR & FINAL
6	SRN00013	Mr. AnanthaKrishnan.R, Mr. Ankur Anal, Mr. Balamurugan.R Mr. L.S.Lingesh, & Mr. VimalKumar.R,	Indian Maritime University, Visakhapatnam – 530 005.	PDR & CDR
7	SRN00016	Mr. Allen Antony, Mr. DipinDixit.M, Mr. Akhilesh Kumar Singh, Mr. Abhishek Kumar, Mr. Sachinkumar Singh,	Kalasaligam University, KrishnanKoil - 626126.	PDR, CDR & FINAL
8	SRN00020	Mr. D.Pavansrikar, Mr. Roy Thoms, Mr. S.Vijay Narayanan, Mr. Mukesh.k& Mr. SujotGaonkar,	Indian Maritime University, Visakhapatnam - 530 005.	PDR & CDR
9	SRN00022	Mr. S.Anand,Mr. R.Rajesh, Mr. M.SaroujCharan, Mr. S.V.Kaushik,& Mr. B.Prassanna,	Panimalar Institute of Technology, Poonamallee, Chennai-600123	**PDR, CDR, FINAL & SELECTED IN SAVe 2012 AND PARTICIPATED IN THE INTERNATIONAL COMPETITION AT SAN DIEGO**

10	SRN00030	Ms. R.Revathy,Ms. S.Sujitha, Ms. P.Surekha,Ms. L.Shobana& Ms. S.Vinithra,	Panimalar Institute of Technology, Poonamallee, Chennai-600123	PDR & CDR
11	SRN00031	Mr. G.M Aswin,Mr. Avinash B.P, Mr. MuthiahN.K,Mr. N.S Giridharan,& Mr. AnjanavaMitra,	R.M.D Engineering College, RSM Nagar,Kavaraipettai-601206.	PDR & CDR
12	SAV00032	Mr. C.N.K.Ravikiran, Mr. AshwinA.Gadgil , Mr. SoumayRanjanSubudhi,Mr. Ankush Kumar,& Mr. PrathameshS.Chari,	Indian Maritime University, Visakhapatnam – 530 005.	PDR, CDR & FINAL
13	SRN00033	Mr.DhruvH.Prajapati, Mr. Ankit Ghosh, & Mr. Bikram Senapati,	Indian Maritime University, Visakhapatnam – 530 005.	PDR & CDR
14	SRN00034	Mr. M.Abhishek,Mr. U.NarenChandrasekaran, Mr. G.Ashok Kumar, Mr. R.AravindNarain,& Mr. B.Prabhu,	R.M.D Engineering College, RSM Nagar, Kavaraipettai – 601 206.	PDR & CDR
15	SRN00035	Mr. J.SasiKumar,Mr. S.Satheesh, Mr. S.VijayVignesh, Mr. K.Sankara Narayanan & Mr. I.CastroAmalan,	Panimalar Institute of Technology, Poonamallee, Chennai-600123	PDR & CDR
16	SRN00036	Mr. SaurabhRaj,Mr. RamsinghChaunan, Mr. SauravChandra,Mr. Pratik Naik,& Mr. Arjun Mandrekar,	Indian Maritime University, Visakhapatnam Pin- 530005.	PDR, CDR & FINAL
17	SRN00041	Mr.Md.Tabrez,Mr. FarazAhamad Khan, Mr. MizraShariqBeg,Mr. Md.AbuShahzer, & Mr. FerazFehmi,	Zakir Husain College of Engg& Tech, AMU, Aligrah – 202 002.	PDR, CDR & FINAL

List of Participants (SAVe 2014)

Sl. No.	Reg No	Name	Name of the College	Selected for
1	SRN-0005	1.Akshansh Tiwari 2.Aditya Sharma 3.Rohit Goyal 4.Md Nawaz Alam 5.Bhagwan Singh Chauhan	Government Engineering College Bharatpur, Bharatpur - 321 001.	PDR & CDR
2	SRN-0009	1.Prateek Murgai 2.Prince Kumar 3.Akshay Jain 4.Vatsal Rustagi 5.Raj Kumar Saini	Delhi Technological University, Delhi - 110 042.	PDR, CDR & FINAL
3	SRN-0011	1.Raja .T.E 2.Akshaya Dayal 3.Himal Dwarakanath 4.R.Gowtham 5.M.Siva Subramanian	SRM University, SRM Nagar, Kattankulathur - 603 203	PDR, CDR & FINAL
4	SRN-0012	1.Rishabh Singh Verma 2.Aarshay Jain 3.Mohammad Saad Khan 4.Himanshu Vimal 5.Chittesh Sachdeva	Netaji Subhas Institute of Technology, New Delhi - 110 078.	PDR & CDR
5	SRN-0013	1.Mihir Shah 2.Promit Choudhury 3.Mohammad Arshad Zubair 4.Triyambak Tripathy 5.Cheerudeep Chintha 6.Dinesh Sutar	SRM University, SRM Nagar, Kattankulathur - 603 203	PDR & CDR
6	SRN-0014	1.Rohit Sharma 2.Aditya Naagar 3.Rohit Singh Panwar 4.Vibhanshu Jain 5.Abhishek Arora 6.Manav Kapoor	Ambedkar Institute of Advanced Communication Technologies &Research ,Geeta Colony, New Delhi- 110 031.	PDR, CDR & FINAL
7	SRN-0015	1.M.Vijaya Ganesh 2.V.L.Venkatavaradhan 3.B.Sai Shankar 4.A.Thirumuruga Perumal	Sri Sai Ram EnginneeringCollege,Chennai 600 044.	PDR & CDR
8	SRN-0017	1.Vineet Upadhyay 2.Kishore Natarajan 3.Rakesh Sirikonda 4.Ravikiran Bobba 5.Vignesh Krishnakumar	Indian Institute of Technology Madras Chennai 600 036.	**PDR, CDR, FINAL & SELECTED IN SAVe 2014 AND PARTICIPATED IN THE INTERNATIONAL COMPETITION AT SAN DIEGO**

9	SRN-0019	1.Md.Abu Shahzer 2.Faraz Ahmad Khan 3.Mohd.Haris Siddiqui 4.Ali ShazanGulrez 5.Jatin Varshney	Aligarh Muslim University, Zakir Husain College of Engineering & Technology	PDR & CDR
10	SRN-0021	1.Shantanu 2.Anurag Pandey 3.Aaditya Sharma 4.Niranjan Kumar Singh 5.George J Puthur	Indian Maritime University, Gandhigram, Visakhapatnam - 530 005	PDR & CDR
11	SRN-0022	1.Naveen Kumar Gupta 2.Madhukar 3.Siddhartha Satpathi 4.Ravi Kumar 5.Mohit	Indian Institute of Technology Kharagpur, Kharagpur - 721 302	PDR, CDR & FINAL
12	SRN-0023	1.Akash Verma 2.Ankit Goyel 3.Kush Bhatia 4.Vinayak Agrawal 5.Nikhil Khinchi	Indian Institute of Technology Delhi HauzKhas, New Delhi - 110 016.	PDR & CDR
13	SRN-0024	1.P.Vignesh 2.L.Sneha 3.S.G.Lokesh 4.K.Gopinath 5.R.Vijaya Kumar	Saveetha Engineering College, Chennai 602 105.	PDR & CDR
14	SRN-0028	1.Saurav Chandra 2.Ramsingh Chauhan 3.Pratik Naik 4.Arjun Mandrekar 5.Abhinow Kumar Singh	Indian Maritime University, Gandhigram, Visakhapatnam - 530 005	PDR

List of Participants (SAVe 2015)

Sl. No.	Reg No	Name	Name of the College	Selected for
1.	SRN00001	1. Vishnu Sharma 2. Rajorshi Paul 3. Prabhat Kumar 4. NevinValsaraj 5. PrudhviDharmana	Indian Institute of Technology Kharagpur	PDR, CDR & FINAL
2.	SRN00003	1. HomagniSaha 2. NalanaMithunBabu 3. Debendra Pradhan 4. Rajooru Satish Kumar Reddy 5. Dinesh Kumar Sahoo	National Institute of Technology, Rourkela	PDR, CDR & FINAL
3.	SRN00006	1. Varun Kumar Soni 2. Ashwini Kumar 3. Sukant Kumar 4. Vishal Kumar Jha 5. Abhishek Kumar	Indian Maritime University, Visakhapatnam	PDR, CDR & FINAL
4.	SRN00007	1. Sanchit Gupta 2. K Pavana Siddhartha 3. Varun Gupta 4. Sibi George 5. AayushMaloo	Indian Institute of Technology Madras	PDR, CDR & FINAL
5.	SRN00008	1. Abhishek Attal 2. Abhishek Shastry 3. Arpit Agarwal 4. AkshayMasare 5. Kevin Jose	Indian Institute of Technology Kanpur	PDR, CDR & FINAL
6.	SRN00009	1. Aditya Rastogi 2. Shubham Raina 3. Danendra Singh 4. Madhav Aggarwal 5. Siddhartha Mukherjee	Delhi Technological University, Delhi	PDR, CDR & FINAL
7.	SRN00010	1. S Surya Kumar 2. M Gokulavasan 3. A P R Sakthivel 4. E Dhinagaran 5. S Daniel Gilbert	Hindustan University, Chennai	PDR, CDR & FINAL
8.	SRN00011	1. Akshay Raj Dayal 2. Abhishek Bansal 3. KeerthiSagar 4. Aniket Ray	SRM University, Chennai	**PDR, CDR, FINAL & SELECTED IN SAVe 2015 AND PARTICIPATED IN THE INTER-NATIONAL COMPETITION AT SAN DIEGO**

9.	SRN00012	1. Vyshnavi Lakshmi Burle 2. Rakshitha G 3. Guruprasad S 4. Immadi Mahesh Kumar 5. AniruddhaShandliya K	K.S.School of Engineering and Management, Bangalore	PDR
10.	SRN00013	1. Vibhanshu Jain 2. Abhishek Arora 3. Abhishek Jain 4. ShekharSuman 5. VivekGoel	Ambedkar Institute of Advanced Communication Technologies and Research, Delhi	PDR, CDR & FINAL
11.	SRN00014	1. Jason Abu Mathews 2. Priyadarshan L 3. Himanshu Agrawal 4. Vivek George Koshy 5. Vishnu Shankar	Sathyabama University, Chennai	PDR, CDR & FINAL

List of Participants (SAVe 2017)

Sl.No	Registration Id	College Name	Selected for
1	SRN-00001	National Institute of Technology, Calicut	PDR, CDR
2	SRN-00003	R V College Of Engineering,Chennai	PDR, CDR
3	SRN-00004	SAVEETHA SCHOOL OF ENGINEERING ,Chennai	PDR, CDR & FINAL
4	SRN-00005	SRI SAIRAM COLLEGE OF ENGINEERING, Chennai	PDR, CDR
5	SRN-00006	IIT BHUBANESWAR	PDR, CDR
6	SRN-00007	Indian Institute Of Technology Bombay, Mumbai	PDR, CDR & FINAL
7	SRN-00008	Indian Institute of Technology Kanpur	PDR, CDR & FINAL
8	SRN-00009	SAVEETHA ENGINEERING COLLEGE, Chennai	PDR, CDR & FINAL
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National Institute of Ocean Technology,
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