Final Report

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Florida State University, Panama City

EML 4551C – Senior Design 1

Dr. Damion Dunlap

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Disclaimer

Some sections of this report were accurate at the time of their creation, however some may not be accurate now due to unforeseen changes after their creation.

Work Breakdown Structure

SENIOR DESIGN: ROBOBOAT

LEVEL	TASK	PERCENTAGE	STATUS	PERSON(S)
1.0	**ROBOBOAT PROJECT**	100%	Complete	Team
1.1	**Milestone 1: WBS**	100%	Complete	Team
1.1.1	*-Break down the project milestones into the work that must be done to complete these items.*	100%	Complete	Bryson Potts
1.2	**Milestone 2: PROJECT CHARTER**	100%	Complete	
1.2.1	*-Create a Mission Statement*	100%	Complete	Bryson Potts
1.2.2	*-Create a Project Description*	100%	Complete	Joseph Earnest
1.2.3	*-Identify market*	100%	Complete	Manning Owens
1.2.4	*-Identify Stakeholders*	100%	Complete	Steven Harrington
1.2.5	*-Develop Assumptions*	100%	Complete	Tamara Mccaskill
1.2.6	*-Define Key Goals*	100%	Complete	Bryson Potts
1.2.7	*-Assign Team Roles and Responsibilities*	100%	Complete	Joseph Earnest
1.2.8	*-Create a Communication Policy*	100%	Complete	Manning Owens
1.2.9	*-Develop a Dress Code Policy*	100%	Complete	Steven Harrington
1.2.10	*-Develop an Attendance Policy*	100%	Complete	Tamara Mccaskill

	1.2.11	*-Create Statement of Understanding*	100%	Complete	Bryson Potts
	1.2.12	*-Develop Code of Conduct Policy*	100%	Complete	Joseph Earnest
	1.2.13	*-Submit a hard copy on canvas*	100%	Complete	Manning Owens
1.3		**Milestone 3: CUSTOMER NEEDS**	100%	Complete	
	1.3.1	*-Develop a Customer Needs Statement*	100%	Complete	Steven Harrington
	1.3.2	*-Create questions to ask customer*	100%	Complete	Tamara Mccaskill
	1.3.3	-Create customer responses	100%	Complete	Bryson Potts
	1.3.4	*-Describe how customer needs are being turned into a specification*	100%	Complete	Joseph Earnest
1.4		**Milestone 4: FUNCTIONAL DECOMPOSITION**	100%	Complete	
	1.4.1	*-Create a functional decomposition chart for boat (using software)*	100%	Complete	Manning Owens
	1.4.2	*-Identify major functions*	100%	Complete	Steven Harrington
	1.4.3	*-Identify sub-functions*	100%	Complete	Tamara Mccaskill
	1.4.4	*-Explain how sublevels correlate to the high level function of each column*	100%	Complete	Bryson Potts
	1.4.5	*-Identify physical action and expected outcome*	100%	Complete	Joseph Earnest
1.5		**Milestone 5: PHASE 1 DESIGN REVIEW**	100%	Complete	
	1.5.1	*- Develop and submit presentation*	100%	Complete	Manning Owens
	1.5.2	*- Introduction*	100%	Complete	Steven Harrington
	1.5.3	*- Project Brief Summary*	100%	Complete	Tamara Mccaskill

1.5.4	*- Background*	100%	Complete	Bryson Potts
1.5.5	*- Design Status*	100%	Complete	Joseph Earnest
1.5.6	*- Project Plan (schedule and budget)*	100%	Complete	Manning Owens
1.5.7	*- Score team being observed*	100%	Complete	Steven Harrington
1.6	**Milestone 6 : TARGETS**	100%	Complete	
1.6.1	*- Generate and log the targets*	100%	Complete	Tamara Mccaskill
1.6.2	*- Write summary of the targets*	100%	Complete	Bryson Potts
1.6.3	*- Write summary of how targets were established*	100%	Complete	Joseph Earnest
1.6.4	*- Write about the targets that interest the customer (customer needs)*	100%	Complete	Manning Owens
1.7	**Milestone 7: CONCEPT GENERATION**	100%	Complete	
1.7.1	*- Generate and submit concepts*	100%	Complete	Steven Harrington
1.7.2	*- 5 Medium Fidelity Concepts*	100%	Complete	Tamara Mccaskill
1.7.3	*- 3 High Fidelity Concepts*	100%	Complete	Bryson Potts
1.7.4	*- 100+ Concepts made*	100%	Complete	Joseph Earnest
1.8	**Milestone 8 : CONCEPT SELECTION**	100%	Complete	
1.8.1	*- Using an engineering decision making document, designate a winning concept*	100%	Complete	Manning Owens
1.8.2	*- House of Quality*	100%	Complete	Steven Harrington
1.8.3	*- Pugh Charts*	100%	Complete	Tamara Mccaskill

1.8.4	*- AHP*	100%	Complete	Bryson Potts
1.8.5	*- Final Selection*	100%	Complete	Joseph Earnest
1.9	**Milestone 9: PHASE 2 DESIGN REVIEW**	100%	Complete	
1.9.1	*- Develop and submit presentation*	100%	Complete	Manning Owens
1.9.2	*- Targets*	100%	Complete	Steven Harrington
1.9.3	*- Concept Generation*	100%	Complete	Tamara Mccaskill
1.9.4	*- Concept Selection*	100%	Complete	Bryson Potts
1.9.5	*- Design Status*	100%	Complete	Joseph Earnest
1.9.6	*- Future Plans*	100%	Complete	Manning Owens
1.9.7	*- Score team being observed*	100%	Complete	Steven Harrington
1.10	**Milestone 10: BILL OF MATERIALS**	100%	Complete	
1.10.1	*- Develop and submit the Bill of Materials*	100%	Complete	Tamara Mccaskill
1.10.2	*- Bill of Materials*	100%	Complete	Bryson Potts
1.11	**Milestone 11: PROTOTYPE PLAN**	100%	Complete	
1.11.1	**- No current information available**	100%	Complete	Joseph Earnest
1.12	**Milestone 12: RISK ASSESSMENT**	100%	Complete	
1.12.1	*- Complete and submit the safety forms*	100%	Complete	Joseph Earnest
1.12.2	*- Safety Expectations*	100%	Complete	Manning Owens
1.12.3	*- Worksheet 1 (project hazard assessment)*	100%	Complete	Steven Harrington
1.12.4	*- Worksheet 2 (project control)*	100%	Complete	Tamara Mccaskill

1.13	**Milestone 13: SUMMER PROJECT PLAN (WBS UPDATE)**	100%	Complete	
1.13.1	*- Develop and submit plan for summer*	100%	Complete	Bryson Potts
1.13.2	*- Document timeline, milestones, and deliverables*	100%	Complete	Joseph Earnest
1.14	**Milestone 14 : PHASE 3 DESIGN REVIEW (POSTER)**	100%	Complete	
1.14.1	*- PDF of poster (24x36 in) summary of all work to this point and future work*	100%	Complete	Manning Owens
1.15	**Milestone 15 : FINAL REPORT (SPRING)**	100%	Complete	

Table 1

Mission Statement

Our mission is to demonstrate skills acquired through FSU-PC's mechanical engineering program by constructing a boat that is capable of meeting the RoboBoat competition standards.

Team Roles

Team Lead - Bryson Potts

The team lead focuses on the overall production of the project and is knowledgeable in all areas of the project's requirements.

- Main point of contact with advisor/sponsors
- Oversees the entire project to make sure that all areas are covered
- Ensures that everyone understands what they are doing

Secretary - Tamara McCaskill

The secretary maintains group organization.

- Records meeting minutes
- Reorganizes throughout the project as necessary

Builders - Manning Owens, LJ Earnest, and Tamara McCaskill

The builders focus on the physical design, fabrication and assembly of the project. These components include:

- Material Selection
- Hull Design
- Construction and Fabrication

- Propulsion Design
- Weight Distribution

Programmers - Bryson Potts, Steven Harrington

Programmers select electronic components and implement code for the project. They must discuss their strategies with the rest of the team before programming the function. Their primary duties are as follows:

- Write and test code for use.
- Ensure actuation of electronic parts.
- Design and maintain a project focused website.

Additional project related tasks will be assigned based on team member availability.

Communication Policy

University emails, official communications, and outside resources, including but not limited to: Google Documents, Zoom, WhatsApp and Basecamp, will be used as methods of communication. Scheduling meetings and assigning work will occur through WhatsApp, any conflicts to completing assignments or attending meetings should be stated at least 24 hours in advance via WhatsApp. File sharing will occur through either Basecamp, Google Documents, or via preferred email address. It is the sole responsibility of each member to receive such communications and to respond as needed within 24 hours.

Dress Code Policy

Policy Statement:

All Clothing must be in good taste and conducive to the function. Roboboat members will wear business attire for presentations/sponsor interactions and casual attire for team meetings.

Business/Professional Attire:

Members should choose business attire such as dresses, pants, shirts, blouses, dress shirts, ties, suits, and skirts. Open toe shoes and sandals are not allowed

Casual Attire:

Members should choose casual attires such as jeans, shorts and any other relaxed clothing for everyday wear. Open toe shoes and sandals are allowed.

Attendance Policy

Attendance policy overview.

Participants in the RoboBoat group are expected to be present and on time for all scheduled project meetings and work. Being tardy or absent should be minimized as it causes disruptions and burdens colleagues.

Code of Conduct

The RoboBoat team will

1. Carry out their responsibilities in a timely manner, with notice of delays.
2. Practice honesty and integrity to the trust placed in completing work.
3. Be respectful to other members.
4. Openly share information and cooperate with peers in discussions and meetings
5. Be present for all meetings with prior notice of delays or absences.
6. Abide by the principles established in this code

Project Description

The goal of this project is to design and build a boat with autonomous function that is capable of completing the course objectives for the 2021 RoboBoat Competition.

Key Goals

The key goals of this design project are:

- Construct an easily maneuverable, stable boat
- Fully autonomous navigation of surroundings with a remote-controllable mode
- Be able to determine surrounding obstacles/environment
- Implement a visual feedback system capable of relaying the POV of the boat.

Market

The market for this project includes the companies that attend the competition scouting for potential employees based on the technical skills demonstrated, and companies that focus on autonomous maritime development. Some of these companies include:

- Office of Naval Research
- SolidWorks
- NVIDIA
- Velodyne Lidar
- Siemens
- Mathworks

Stakeholders

Stakeholders are the Individuals and Organizations who want the project to be successful. Some of these include:

- Project Advisor
- Dr. Damion Dunlap
- Florida State University Administration
- Florida State STEM Department
- SPEAR club
- Independent RoboBoat Club Donors
- RoboBoat Senior Design Team

Assumptions

- Any monetary need is funded
- Any need for tools and manufacturing is available
- Covid-19 will not hinder the ability to work on the RoboBoat
- Competition will be held despite Covid-19
- Weather will not cause the competition to be cancelled
- Weather will not conflict with the ability to test the RoboBoat
- Will be competing in freshwater
- No big waves or wildlife disturbance
- Corrosion of the boat is negligible
- Able to perform testing and maintenance on the boat as often as desired
- Meets criteria to qualify for competition
- Input and help from the Electrical Engineering team
- Purchasing and manufacturing components are made/delivered on time

Statement of Understanding

(i) I am aware that RoboBoat group's policies are available to me in the POLICY folder on Basecamp. It is my responsibility to familiarize myself with these policies.

(ii) In addition, I confirm that I have received, read and understood the following policies:

- Mission Statement
- Team Roles
- Communication
- Dress Code
- Attendance Policy

(iii) I agree to conduct my activities in accordance with RoboBoat group's policies and understand that breaching these standards may result in disciplinary action up to and including termination/removal from the group.

Signed: ________________________________ Date: ______________________

Signed: ________________________________ Date: ______________________

Signed: ________________________________ Date: ______________________

Signed: ________________________________ Date: ______________________

Signed: ________________________________ Date: ______________________

Customer Needs

Customer needs enable design teams to be more informed on the decisions and goals of the product/service in development. The customers for the RoboBoat senior design team are the sponsors/advisors that are providing the means for the team to compete. The customer needs were formulated using the 2020 RoboBoat competition guidelines and from additional expectations given by the team’s advisor, Dr. Damion Dunlap.

The customer needs consist of the following:

1. It cannot exceed 140 pounds, and would ideally be less than 70 pounds.
2. The vehicle cannot exceed six feet, by three feet, by three feet "box".
3. The competition takes place at a freshwater pond, but you will most likely be testing in saltwater conditions.
4. It is recommended the electrical components are covered.
5. Final demos are within the last two weeks of the summer semester, or if going to a competition plan to finish ideally a week before the competition.
6. It will be transported in a pickup truck with a covered cab.
7. Focus on the areas of the competition that will net the most points with the least amount of complexity.
8. The vehicle needs to be battery powered.
9. The vehicle must be fully autonomous, and all decisions can be made onboard the ASV.
10. Any propulsion system is fine (thruster, paddle, etc.), but moving parts must have a shroud.
11. All sharp, pointy, moving, or sensitive parts must be covered and marked.

Interpreted Needs

The interpreted need is the engineering interpretation of the customer need statements.

The interpreted needs consist of the following:

1. The overall weight of the ASV and UAV will be less than 140 pounds.
2. The boat will fit into a six feet, by three feet, by three feet "box".
3. The boat will function as intended in both freshwater and saltwater.
4. Electrical components will be covered in case of inopportune weather conditions.
5. The team will decide whether the boat is planned to go to the competition or not.
6. The boat will be able to fit and be secured in the bed of the truck.
7. Focus on the categories of the competition that accumulates the most points.
8. The watercraft will be provided power by a cordless energy source.
9. The boat will be capable of making decisions and functioning independently.
10. The propulsion system will be determined by team preference, with a covering in case of moving parts.
11. The boat will have appropriate safety measures befitting of the RoboBoat standards.

Explanation of Results

1. The data found in the RoboBoat competition guidelines contains the ideal total weight and maximum total weight for the ASV and UAV.
2. The data found in the RoboBoat competition guidelines contains the UAV size constraint.
3. The buoyancy of the boat may be different in freshwater vs saltwater. The competition will be conducted in freshwater (lower buoyancy), therefore we need to make the boat with fresh water as the primary water.
4. While it is not required that the electrical components be covered, it is highly recommended so that electrical components will not have water damage from rain.
5. If the team competes in the Roboboat competition, then the project has to be completed significantly sooner.
6. The boat can be damaged if it falls out of the truck while driving down the highway. To avoid this we will strap down the boat using ratchet straps.
7. Directing all focus to one aspect of the project can cause problems in other areas and ultimately compromise the design.
8. The best solution for a cordless energy source is a battery.
9. The boat will be controlled by a wireless controller.
10. The propulsion system that will be used needs to contain some drag to allow the boat to decelerate.
11. All necessary precautions will be taken, to assure that no problems will arise during the competition/showcase.

Raw Customer Feedback

Question: Would weight be an issue for this project?

Answer: It cannot exceed 140 pounds, and would ideally be less than 70 pounds.

Interpreted Need: The overall weight of the ASV and UAV will be less than 140 pounds.

Explanation of Result: The data found in the RoboBoat competition guidelines contains the ideal total weight and maximum total weight for the ASV and UAV.

Question: Would size be an issue for this project?

Answer: The vehicle cannot exceed six feet, by three feet, by three feet "box".

Interpreted Need: The boat will be smaller than the size constraint given.

Explanation of Results: The data found in the RoboBoat competition guidelines contains the UAV size constraint.

Question: What type of water will the boat be operating in?

Answer: The competition takes place at a freshwater pond, but you will most likely be testing in saltwater conditions.

Interpreted Need: The boat will need to function similarly in both freshwater and saltwater.

Explanation of Results: The buoyancy of the boat may be different in freshwater vs saltwater.

Question: Do the electrical components of the boat have to be enclosed?

Answer: It is recommended to have electrical components enclosed.

Interpreted Need: Electrical components will be covered in case of inopportune weather conditions.

Explanation of Result: While it is not required that the electrical components be covered, it is highly recommended so that electrical components will not have water damage from rain.

Question: When should the final product be completed?

Answer: Final demos are within the last two weeks of the summer semester, or if going to a competition plan to finish ideally a week before the competition.

Interpreted Need: The team needs to decide whether the boat is planned to go to the competition.

Explanation of Result: If the team competes, then the project has to be completed significantly sooner.

Question: What will be the planned transportation for the boat to the competition?

Answer: It will be transported in a pickup truck with a covered cab.

Interpreted Need: The boat needs to be able to fit and be secured in the bed of the truck.

Explanation of Result: The boat can be damaged if it somehow fell out of the truck while driving down the highway.

Question: What aspect of the competition should we prioritize?

Answer: Focus on the areas of the competition that will net the most points with the least amount of complexity.

Interpreted Need: Focus on the categories of the competition that accumulates the most points.

Explanation of Result: Directing all focus to one aspect of the project can cause problems in other areas and ultimately compromise the design.

Question: Can the boat utilize any type of energy source?

Answer: The vehicle needs to be battery powered.

Interpreted Need: The watercraft will have power supplied by a cordless energy source.

Explanation of Result: The best solution for a cordless energy source is a battery.

Question: How much autonomy should our boat have?

Answer: The vehicle must be fully autonomous, and all decisions must be taken onboard the ASV.

Interpreted Need: The boat will be capable of making decisions and functioning independently.

Explanation of Result: The boat will be controlled by a wireless controller.

Question: What propulsion systems are available for use?

Answer: Any propulsion system is fine (thruster, paddle, etc.), but moving parts must have a shroud.

Interpreted Need: The propulsion system will be determined by team preference, with a covering in case of moving parts.

Explanation of Result: The propulsion system that will be used needs to contain some drag to allow the boat to stop quicker.

Question: What safety precautions should be taken?

Answer: All sharp, pointy, moving, or sensitive parts must be covered and marked.

Interpreted Need: Boat will have appropriate safety measures befitting of the RoboBoat standards.

Explanation of Result: All necessary precautions will be taken to assure that no problems will arise during the competition/showcase.

Question	Answer	Interpreted Need	Explanation of Results
Would weight be an issue for this project?	It cannot exceed 140 pounds, and would ideally be less than 70 pounds.	The overall weight of the ASV and UAV will be less than 140 pounds.	The data found in the RoboBoat competition guidelines contains the ideal total weight and maximum total weight for the ASV and UAV.
Would size be an issue for this project?	The vehicle cannot exceed six feet, by three feet, by three feet "box".	The boat will be smaller than the size constraint given	The data found in the RoboBoat competition guidelines contains the UAV size constraint.
What type of water will the boat be operating in?	The competition takes place at a freshwater pond, but you will most likely be testing in saltwater conditions.	The boat will be smaller than the size constraint given.	The buoyancy of the boat may be different in freshwater vs saltwater.
Do the electrical components of the boat have to be enclosed?	It is recommended the electrical components are covered.	Electrical components will be covered in case of inopportune weather conditions.	While it is not required that the electrical components be covered, it is highly recommended so that electrical components will not have water damage from rain.
When should the final product be completed?	Final demos are within the last two weeks of the summer semester, or if going to a competition plan to finish ideally a week before the competition.	The team needs to decide whether the boat is planned to go to the competition.	If the team competes, then the project has to be completed significantly sooner.
What will be the planned transportation for the boat to the competition?	It will be transported in a pickup truck with a covered cab.	The boat needs to be able to fit and be secured in the bed of the truck.	The boat can be damaged if it somehow fell out of the truck while driving down the highway.
What aspect of the competition should we prioritize?	Focus on the areas of the competition that will net the most points with the least amount of complexity	Try not to perfect one specific characteristic of the project.	Directing all focus to one aspect of the project can cause problems in other areas and ultimately compromise the design.

Can the boat utilize any type of energy source?	The vehicle needs to be battery powered.	The watercraft will have power supplied by a cordless energy source.	The best solution for a cordless energy source is a battery.
How much autonomy should our boat have?	The vehicle must be fully autonomous, and all decisions can be made onboard the ASV.	The boat will be capable of making decisions and functioning independently.	The boat will be controlled by a wireless controller.
What propulsion systems are available for use?	Any propulsion system is fine (thruster, paddle, etc.), but moving parts must have a shroud.	The propulsion system will be determined by team preference, with a covering in case of moving parts.	The propulsion system that will be used needs to contain some drag to allow the boat to stop quicker.
What safety precautions should be taken?	All sharp, pointy, moving, or sensitive parts must be covered and marked.	The boat will have appropriate safety measures befitting of the RoboBoat standards.	All necessary precautions will be taken to assure that no problems will arise during the competition/showcase.

Table 2

Functional Decomposition

Functional decomposition is a process that involves breaking down a system's overall functions into smaller subparts. This is best achieved through team brainstorming sessions and the result is to make a diagram that illustrates how a design's general tasks and subtasks fit together. The following functional decomposition breaks down the major and minor functions of an autonomous boat.

Data Acquisition

The data used to generate our functional decomposition came from the RoboBoat competition requirements and the customer needs. We prioritized the system's functions around maneuverability, since a majority of the competition tasks utilize it. The interpreted needs were then simplified, so that the range of solutions were still broad. This technique prevented us from boxing ourselves into a single solution. Finally, we cross referenced the common simplified needs and turned them into our functions.

Functional Decomposition Explanation

As seen in Figure 1, the RoboBoat consists of 8 main functions; Support, Sense, Communicate, Process, Safeguard, Propulsion, Power, and Signal. The support function is for the stability and load carrying capabilities. The sense function is for the detection of surroundings and positions. The communicate function is for receiving and sending relevant information to the correct components. The process function is for interpreting the data received from the controller and data gathered by sensors. The safeguard function refers to the kill switch requirements (remote and manual) to be able to compete. The propulsion system is for the components used to move the boat, with turning and adjusting the speed of the boat. The power system refers to supplying energy to the boat components. The signal function is for the status of the operation of the boat (remote, autonomous, and if the emergency stop is active).

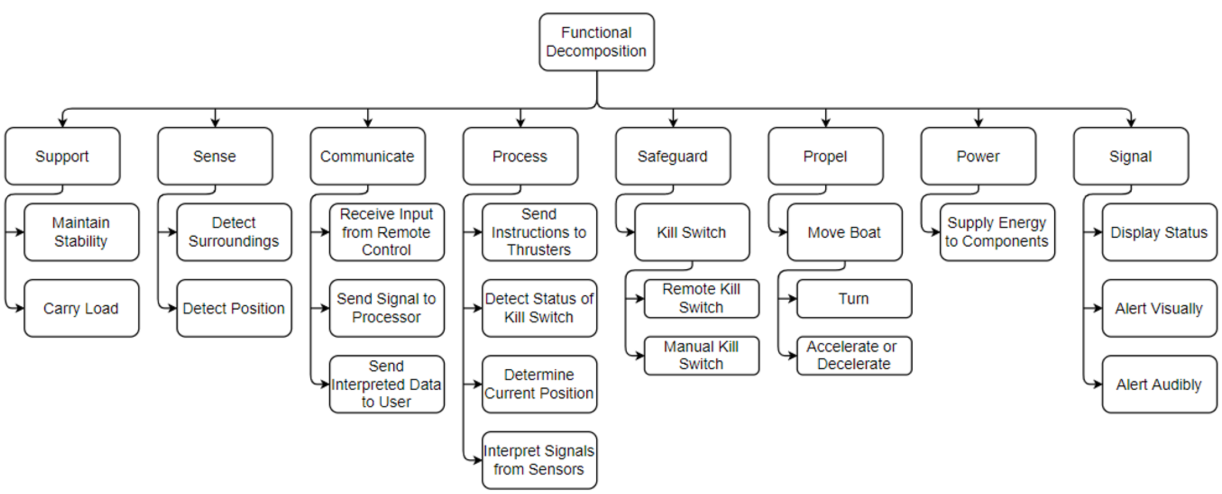


Figure 1: Functional Decomposition

Function Relationships

Support, Power and Propulsion are the main functions that will make the boat function, as without support there is no boat, without propulsion the boat is incapable of movement, and without power the propulsion/communication/process/signals can not function. Sense, Communicate and Process all directly relate as the sense function gives relevant environmental information to the processor, the communication function transfers remote and sensory data received from the sense function to the process function. The processor interprets the data received from the prior functions and determines the next action. The processor then tells the safeguard if it should activate, as well as how the propulsion system should activate, orient, or specify speed of the thrusters. It also updates the status of the signal function

Actions and Outcomes

The RoboBoat competition is a popular and growing autonomous boat competition. This boat will be able to propel and navigate a series of obstacles autonomously along with remote controller capabilities. The weight of the boat will allow for proper floatation, while the propulsion system provides stable directional motion. With the challenge of maneuvering and navigating, rotational motion and water friction will not cause the boat to capsize. The boat will also have to be able to store any electrical components and accessories that are required by the RoboBoat competition rules. The RoboBoat should be capable of completing the given tasks in an efficient and timely manner in order to compete for the best time.

Function Resolution

The purpose of this project is to construct and engineer an autonomous boat with the capabilities of remote control use. The autonomous boat will handle high-speed, stable maneuverability through a timed obstacle course, complete a speed run, handle obstacle delivery, and be capable of docking itself.

Targets and Metrics - Introduction

Targets and metrics are vital in determining the end goal that a design needs to accomplish. The targets and metrics are mainly derived by the functions found in the functional decomposition. The mechanical engineering RoboBoat team is merging with the electrical engineering RoboBoat team, and they will have the final say on the power requirements.

A target is a specific value to design a product to meet. The metric is what method will be used to validate the function from the functional decomposition. There are a couple different types of measures; Performance, Physiological, Subjective, and Objective.

Performance measures are directly quantifiable and reproducible; such as a length, temperature, or pressure. This is easy to confirm, and some performance methods of the RoboBoat would include the weight, size.

Physiological measures are more difficult to measure, they include things that deal with the end user such as comfort, ease of use and mental workload. For the RoboBoat the physiological measures consisted of style.

Subjective measures are performance measurements measured by an end user (preferably a professional). The RoboBoat is not in the stage where subjective measurements can be determined.

Objective measurements are similar to performance but are typically measured with instrumentation. The RoboBoat objective measurements could include motor speed (rpm), thrust and GPS positional accuracy.

Derivation of Targets and Metrics

The functional decomposition was made by taking customer needs and forming them into distinct functions and subfunctions. The functional decomposition is then used to derive the targets and metrics for each function. The values for the targets and metrics were found via component specification sheets, goals based on previous competition performances, the electrical engineering senior design team, and advisor recommendations. The critical were determined as what was needed to have the bare minimum for a boat to compete.

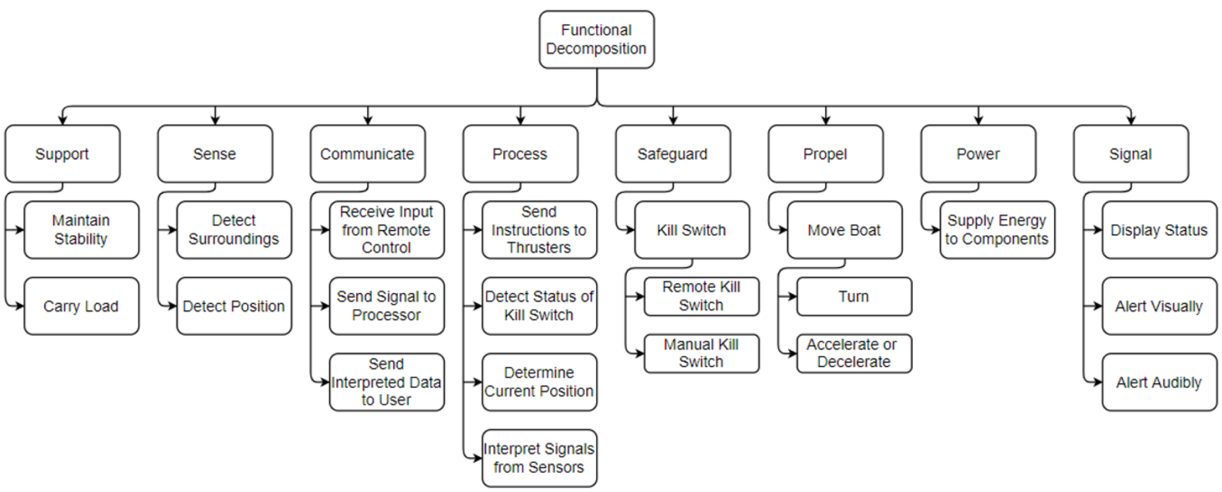


Figure 1: Functional Decomposition

Explanation of Targets and Metrics

The list below explains the functions and their relation to the targets and metrics

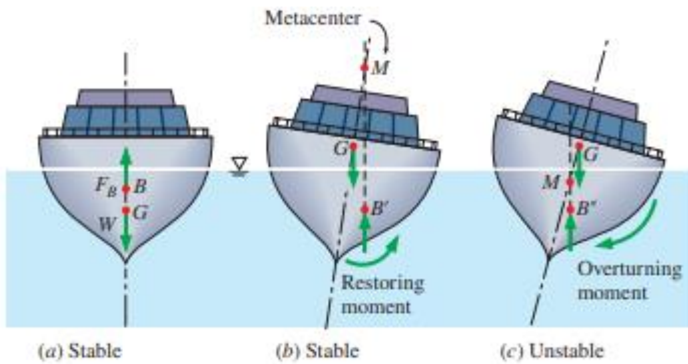


Figure 2: Stability of Boats in regards to Center of Gravity vs Center of Buoyancy

- **Maintain Stability:** A seen in Figure 2, to properly maintain stability the RoboBoat should have a center of gravity below the center of buoyancy, and as the boat rocks the metacentric height GM, which is the distance between the center of gravity G and the metacenter M, will self correct the boats stability. If the center of gravity is above the center of buoyancy then the boat's metacentric height will cause an overturning moment, capsizing the boat. Thus the team aims to have a boat that is bottom-heavy.
- **Carry Load:** The boat hull will contain/support the electrical workings, battery, sensors, processing unit, status indicators, and objects for delivery. The weight distribution and total weight will affect the center of gravity, and therefore directly affects maintaining stability. The target is to be under the weight limit (less than 140 lbs), with stable object placement.
- **Detect Surroundings:** The boat will be equipped with sensors capable of detecting the surroundings of the RoboBoat. Our goal is to detect objects up to 20 feet away.

- **Detect Position:** The boat will be equipped with some sort of GPS system capable of detecting the position of the RoboBoat. The position of the boat will be measured in GPS coordinates. The target is to have a GPS system that provides location within ____ range.
- **Communication:** The three sub functions under communication are “Receive Input from Remote Control”, “Send Signal to Processor”, and “Send Interpreted Data to User”. All of these will be measured in hertz, however each has a different target for the speed at which it needs to be communicated. “Receive Input from Remote Control” and “Send Signal to Processor” should both be at a high hertz rate because it is important that messages are sent to components of the RoboBoat fairly quickly. It is less important that the user see the interpreted data as quickly.
- **Process:** The targets and metrics for Process are similar to Communication. “Send Instructions to Thrusters” and “Interpret Signals from Sensors” should both be receiving information faster than the other sub functions. “Determine Current Position” should be the next fastest, with “Detect Status of Kill Switch” being the slowest. All of these will be measured in hertz.
- **Safeguard:** The safeguard function's target is to cut off the power to the boat, the metric would see if the boat loses power when the kill switches are activated.
- **Move Boat:** The RoboBoat needs to move by generating thrust, the thrust needs to be powerful enough to overcome the weight of the boat and frictional forces between the boat and water. Desired thrust was found by giving a tolerance to the average thrust from the 2019 competition. This will be measured using the same strain-gauge method that the official RoboBoat competition uses.

- **Power:** The RoboBoat will be equipped with a cordless energy source and the energy supplied will be measured in volts.
- **Signal:** The RoboBoat will be capable of both an audible alarm as well as a visual signal to display whether or not the boat is in autonomous or remote-controlled mode. The visual signal will most likely be a set of different color LED lights, with the different colors signifying specific control modes.
- **Other Targets and Metrics:**
    1) Low drag in water, with a metric of testing hull designs in software or an air tunnel and seeing how the flow acts on the design.
    2) Low amount of time needed to reach ideal velocity from rest. This can be tested by using a stopwatch in tandem with on-board programming controlling thrusters.
    3) Low amount of time to have the RoboBoat powered and ready to run the course. Tested by using a stopwatch to check how long the startup time takes.

Critical Targets and Metrics

Function	Metric	Target
Maintain Stability	Buoyancy	Positive buoyancy for >= 30 minutes
	Weight Distribution	Center of Gravity below Center of Buoyancy
Detect Surroundings	Sensor Range	6 meters
	Sensing Speed	Value from spec sheet
Process	Object Detection	Same as Sensing Speed
Move Boat	Thrust	13-18 lbs

Table 3. Critical Targets and Metrics

Our critical targets and metrics are determined by examining our customer needs and our functional decomposition. The critical functions are Stability, Detection, Process, and Propulsion, since without these key functions we are unable to meet the requirements set by the RoboBoat standards. The boat will need stability to maintain buoyancy and to keep from capsizing. The boat will also need to move itself by generating thrust, and to detect its surroundings and determine how to maneuver around any detected obstacles. While all of the listed functions in the Functional Decomposition are needed to make a functional final design, these are the most critical to the project.

Methods of Validation

Stability test

A floating object is considered stable when it has the ability to return to its initial upright position after being disturbed by an outside force. The stability of the boat will be tested by placing it in a lake during various environmental states (rain,wind, waves ect) and observing to see if it will remain or return upright.

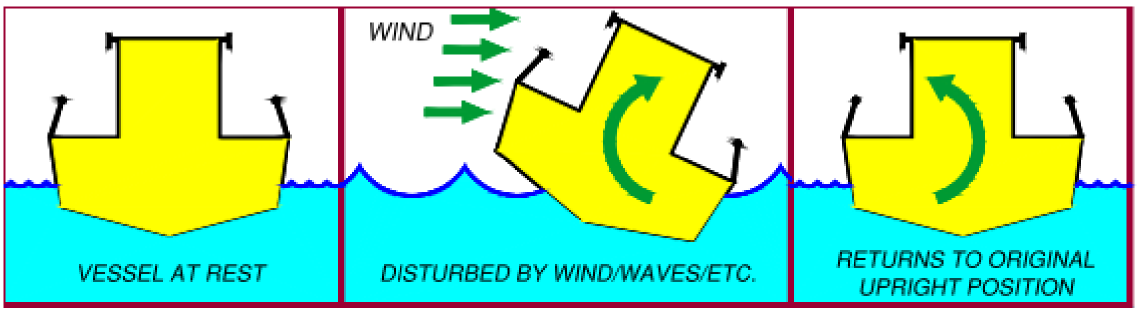


Figure 3a. Stable

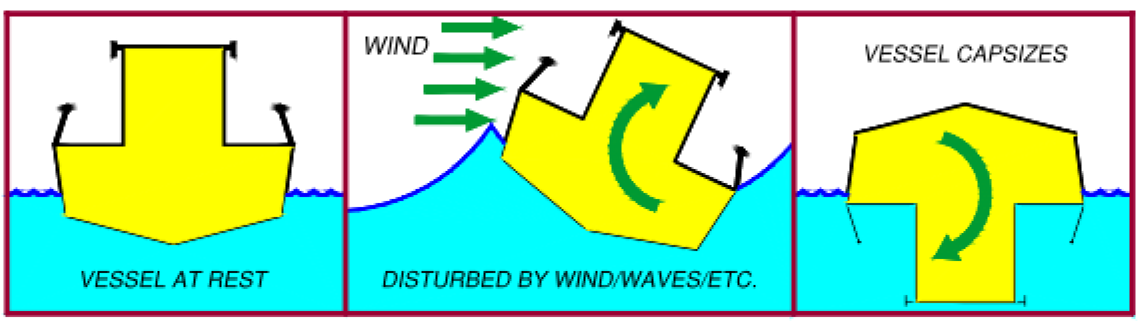


FIgure 3b. Unstable

Detection Test

A majority of the competition tasks will require the boat to navigate through and around various obstacles. In order to accomplish this, the boat must be able to detect its surroundings as well as the positions of targets. Detection tests will be conducted by placing several buoys in a water setup similar to Figure 4. The boat's lidar and gps system will be used to locate specific buoys so that it may travel through or around them. Each trial run will be timed.

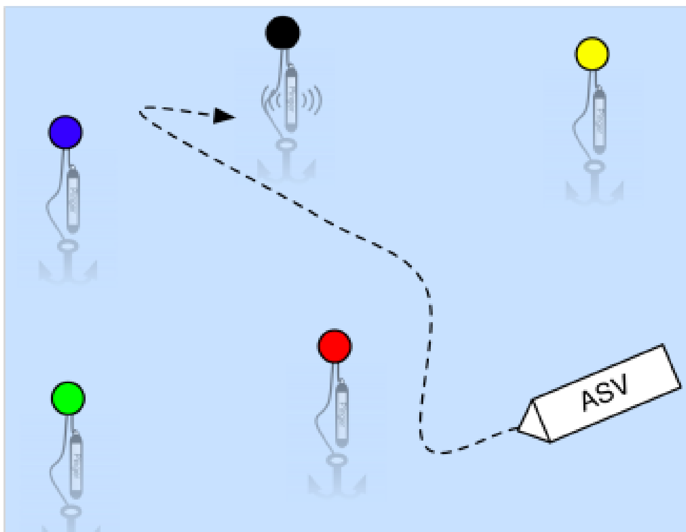


Figure 4. Buoy Set-Up

Thrust Test

Thrust is a static measurement that determines how powerful a motor is. At the beginning of the competition, the boat will have both weight and thrust measurements taken. The thrust of the boat will be measured by attaching it to a thrust measurement system that is similar to the one shown in Figure 5. The boat will then generate as much thrust as possible for 10 seconds. This task can be accomplished in a manned manner (i.e remote, laptop or buttons on the boat to start/stop this task). A similar strain gauge system will be replicated by our team for the practice trials.

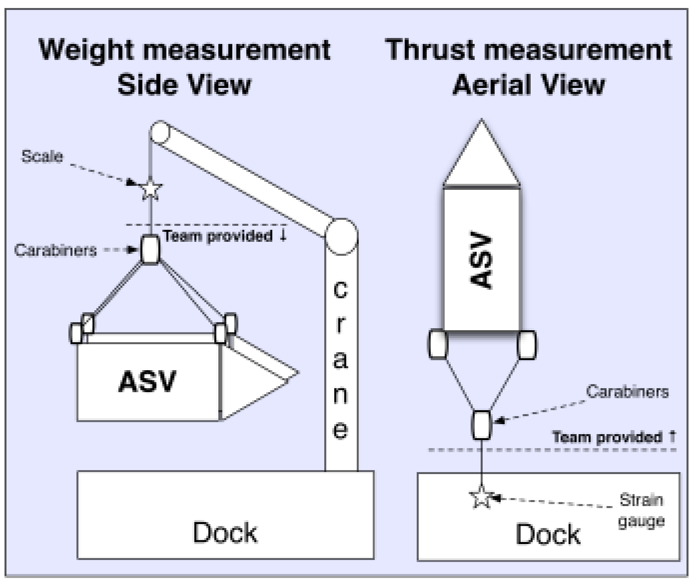


Figure 5. Weight and Thrust measurement Systems

Discussion of Measurements

The tools that we will need to utilize in order to validate our design are water, lidar/GPS, propellers, a stopwatch, strain-gauge system, weight measurement system (like a scale), and tools for measurements (measuring tape, yard stick, meter stick, etc.). We will need to use a body of water in order to conduct a stability test during the following weather conditions: rain, wind, waves. Conducting this test will allow us to observe what the best boat design is going to be in unknown weather. The next tool we will need to test is a lidar and GPS system. This will help us be able to navigate through and around various buoys. We will execute a detection test in order to implement what lidar and GPS system performs the best. We will also use a GPS verification system so that we can make sure our GPS reads right. The next tool we will need to validate our design is a propulsion system (thruster/propeller). Using a thrust test will tell us how powerful the motor is. The next tool that will help us with the design process is a strain gauge. This will be used to measure the deformation of where the propellers are connected to the boat. With the deformation recorded the thrust will be calculated from this device. Next we will use a weight measurement system. This will help us ensure that our boat will stay under 140 pounds once all the parts are placed into order. Lastly, we will use a measurement tool (such as a tape measure, ruler, yardstick, meter stick, etc.) to make sure our boat will fit within the prescribed dimensions. We will conduct tests prior to competition in order to find and implement the best equipment relative to our needs and competition.

Targets and Metrics Summary

The targets and metrics were derived using a number of resources including component specification sheets, goals based on previous competition performances, the electrical engineering senior design team, and advisor recommendations. Metrics were created as something to measure a specific function by, and then targets were created based on these metrics. This was done using each function of the functional decomposition to be sure that all targets and metrics were covered. It was decided that the critical targets were Maintain Stability, Detect Surroundings, Process, and Move Boat. Table 4 describes all of the targets and metrics with their corresponding functions.

Function	Metric	Target
Maintain Stability	Buoyancy	Positive buoyancy for >= 30 minutes
	Weight Distribution	Center of Gravity below Center of Buoyancy
Detect Surroundings	Sensor Range	6 meters
	Sensor Speed	Value from spec sheet
Detect Position	Sensor Accuracy	Within 14 cm
	Sensor Speed	Value from spec sheet
Communicate	Receive Input from Remote Control	Same as Sensor Speed
	Send Signal to Processor	Same as Sensor Speed

	Send Interpreted Data to User	Same as Sensor Speed
Process	Object Detection	Same as Sensor Speed
	Send Instructions to Thrusters	Same as Sensor Speed
	Interpret Signals from Sensors	Same as Sensor Speed
	Determine Current Position	Same as Sensor Speed
	Detect Status of Kill Switch	Same as Sensor Speed
Safeguard	Kill Switch	If the kill switch is activated, then the boat loses power.
Move Boat	Thrust	13-18 lbs.
Power	Energy Supplied	Up to 60 Volts (decided by the electrical group)
Visual Signal	Colored LED Lights	One color signifies autonomous mode, one color signifies remote-controlled mode.
N/A	Test hull designs in software or air tunnel and see how the flow acts on the design.	Low Drag in Water
N/A	Use a stopwatch in tandem with on-board programming controlling thrusters.	Low amount of time to reach operating velocity from rest.

N/A	Use a stopwatch to check how long the startup time takes.	Low start-up time.

Table 4. Summary of Targets and Metrics

Concept Generation Introduction

The task of a designer is to find the best possible solution to a particular task. The goal for the RoboBoat design team is to find the best solutions to the challenges of the 2021 RoboBoat competition. The RoboBoat team, using concept generation methods, quickly generated concepts and evaluated the viability of RoboBoat concepts. 100 concepts were generated and evaluated, then narrowed down to 5 medium-fidelity concepts.

Concept Generation Tools

The morphological chart was made by examining the functional decomposition and finding means of accomplishing each function. The morphological chart allows us to see many design combinations quickly, by showing a range of components and possible combinations of said components. We found components through evaluation of previous RoboBoats and research of systems that already accomplish some of our sub-function goals.

Navigation	Propulsion	Boat Material	Control Panel Location	Hull	Battery Location	Vision System	Hardware	Receiver Location
ROS	Jet Turbine	Carbon Fiber	Inside	Cathedral	Inside	Go-Pro	Arduino	Top
Lidar	Propellor	PVC	Front	Catamaran	Top	Sony RX0 II		Front
Sonar	Fan	Wood	Back	Trimaran	Back	SeaLife DC 2000		
	Thruster	Fiberglass		Pontoon		DJI Osmo Action		
		Alumunium		V-bottom				
				Flat-Bottom				

Table 5: Morphological Chart

Medium Fidelity Concepts

Concept 1

From Appendix B-Concept 1, we can see the configuration of Concept 1. Concept 1's use of a Catamaran hull allows for more stability and thus more options on component placement. The hull material is strong but light-weight, being made of carbon-fiber, and is reinforced to prevent leaks from manufacturing errors using flex-seal. The 3 Out-Board differential propellers allow for increased mobility and more overall control. The LiDAR is placed on the top of the RoboBoat to allow for increased visibility, with the GPS being located within the acrylic electronics enclosure. The boat is battery-powered and placed low in the hull to ensure a lower center of gravity. The electronics enclosure is cooled by using an intake to outtake fan setup, to ensure fresh cool air is being cycled throughout the enclosure. The perspective view of the boat is seen in Figure 6, but the other sketches of Concept 1 can be found in Appendix A. One con of this design is the cost, being made of carbon-fiber and coated with flex seal can get quite expensive. Another con is that in inclimate weather (rain, snow, fog, etc.) can disturb the LiDar readings. Another con is that the boat uses active vents, which will use more power from the source that could be better utilized.

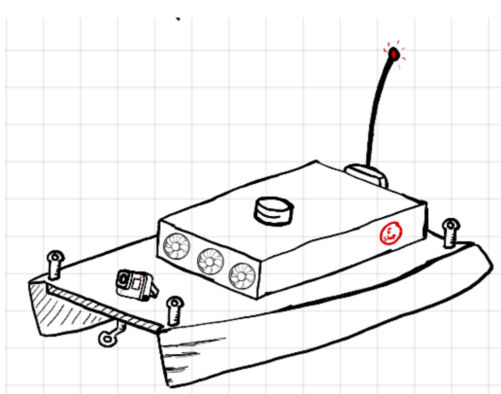


Figure 6: Concept 1 Perspective View

Concept 2

From Appendix B-Concept 2, we can see the configuration of Concept 2. Concept 2's use of a Tri-Hull results in added stability. This also means that we have more freedom for placing components on the boat. The hull is made of Fiber-Glass, which is heavier than some other materials used for boat hulls. This means that the boat will not be easily pushed around by waves and wind. The boat will be coated with paint, however over time the paint could begin to chip, crack, or fade. The boat would most likely have to be repainted eventually. The boat will have 3 outboard motors, two differential propulsors in the rear and one stationary propulsor close to the front. This results in better control and maneuverability. The boat will use an ultrasonic device placed at the highest point for object detection to help with navigation. There will also be a GPS device used for localization. The boat will use a bluetooth signal to communicate with the remote control, with the receiver also being placed at the highest point on the boat. The boat will also be battery powered with the battery being placed close to the rear of the boat with most of the other components. There will also be a visual feedback camera located near the front of the boat so that we can get an idea of what the boat sees when it's on the water. Most of the electronic components will be held within an enclosure made of plastic (PLA). This is good because the plastic material is waterproof and we do not have to worry about harming the components if it gets wet. The cooling system will consist of a vent in the front of the box and a fan in the back of the box to pull cold air over the electronic components. There will be a tow harness located in the front of the boat since this will make it easier if it is being towed in the same direction it is designed to move in. There will also be a point for the deployment harness at each corner of the boat to ensure proper balance during deployment. The perspective view of the boat can be seen in Figure 6, while the other views of the boat can be found in Appendix A.

One of the cons of this concept is the price. Some of the components and materials could become expensive. Also, LiDAR signals can be interrupted by rain, snow, smoke, or anything else in the air that could get in the way of the laser beam coming from the LiDAR sensor. Another con is the fact that the cooling system has a passive intake, meaning that it is not pulling air into the electronics compartment but pushing air out. However, this could help avoid sucking water into the electronics compartment. Also, if the visual camera is not waterproof it could become damaged if the front of the boat tips into the water.

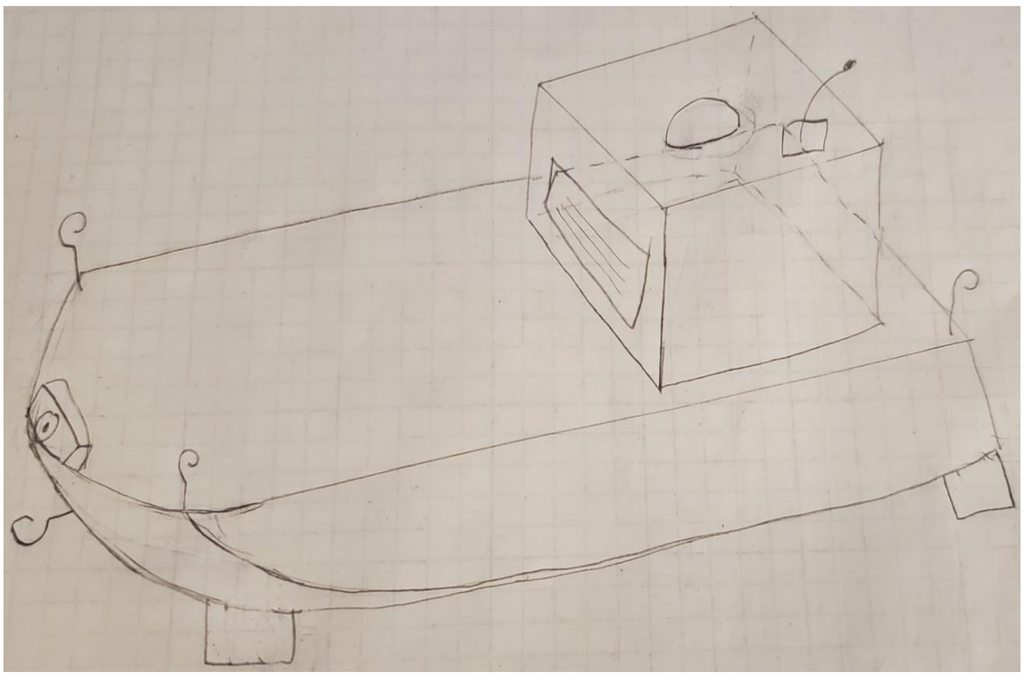


Figure 7: Concept 2 Perspective View

Concept 3

Referring to Appendix A-Concept 3 the perspective, front, back, top, bottom, and cross sectional views are available. Shown in this section is the perspective view for Concept 3. This concept utilizes an aluminum, flat bottom boat sealed with flex seal. This boat uses two pivoting inboard propellers that allows for maximum maneuverability. Mounted to the front of the boat is a lidar sensor used to detect objects. We will use a GPS system for our localization system. We will also use radio for our remote control signal with our antenna receiver located on the back of the boat. This boat will use a battery to power it located in the interior hull. The camera will be mounted on top of the wooden electronic enclosure. The wood electronic enclosure will use an intake and outtake vent to passively cool the electronics. The tow hook is located on the belly of the boat. Lastly the boat will have 4 deployment harness hooks located at each corner of the boat. The features mentioned above will be listed below in appendix B. One of the pro's to this design is the aluminum hull. Aluminum is a lightweight, durable metal that will be able to tackle any obstacle thrown at our way (for our RoboBoat needs). Another pro is that with the swiveling propellers, the boat will be able to have maximum maneuverability. Lastly with the LIDAR sensor in the front, it will position the sensor to detect objects the best. However, one con of this design is the hull shape (flat bottom boat). This particular design can be hard to maneuver because of the lack of drag. The next con is the hull material, aluminum. Aluminum can be very expensive, resulting in us possibly going over budget. Lastly, the wooden electronic enclosure box could allow the electronics to get wet if not sealed properly. If the electronics get wet, our electronics on board would be fried.

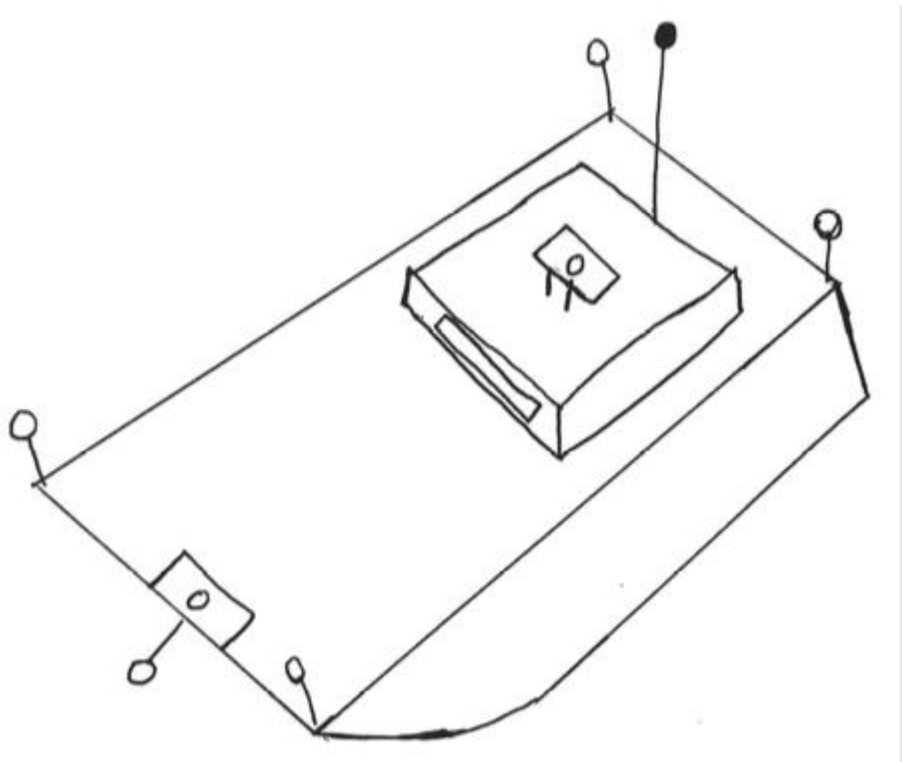


Figure 8: Concept 3 Perspective View

<u>Concept 4</u>

From Appendix B-Concept 4, the use of a pontoon shaped hull provides boat stability and spacious storage area for the required payloads and electrical components. The hull will be made out of wood and coated with epoxy resin. Epoxy resin will provide moisture resistance and increase the fatigue strength of the boat. A disadvantage of the hull shape would be that it requires a large turning radius therefore, it will struggle to make tight turns. The propulsion system will have 3 outboard motors, two differential propulsors in the rear and one stationary propulsor in the front so that it is maneuverable in the water. The boat will utilize a LiDAR for object detection and a GPS device for navigation.Although LiDARs are inexpensive, low hanging clouds and heavy rain can cause them to be inaccurate. A Bluetooth will be used to communicate with the remote control, and a receiver will be placed in the front of the boat. The boat's battery and electrical components will be enclosed in a plastic box. These components will be housed in the lower compartment found in the center of the boat. Also, a GoPro camera will be placed in the front of the boat to provide visual data. The cooling system will consist of a vent on the boat's wall and a fan will be mounted above the electrical components so that they can continuously be blown with cool air. A tow harness will be mounted in the rear of the boat and a hook will be mounted in each corner for the deployment harness. A four point deployment harness will keep the boat balanced any time it is deployed. The perspective view of the boat can be seen in Figure 19, while the other views of the boat can be found in Appendix A.

Figure 9: Concept 4 Perspective View

<u>Concept 5</u>

From Appendix B-Concept 5, we can see the configuration of Concept 5. The V-bottom hull shape allows for the boat to cut through the water with a lower contact surface between the hull and the surrounding water. The fiberglass composition of the boat hull will limit the amount of distance that the boat could be unintentionally moved by water currents, while the hull design allows for a wide weight distribution which will help the boat maintain buoyancy. The boat will be coated with a hydrophobic spray to reduce the friction caused when the boat is moving through the water. It will also help ensure that the insides of the hull are dry, and the electrical components housed within the hull will not suffer water damage. The boat will have 2 differentially steered motors found on the rear side of the boat. This will allow for precise turning and maneuverability. The LiDAR will be placed near the front of the boat to allow for accurate distance measurements. It will be accompanied by a camera used for data collection and to give us a way to ensure accuracy from the perspective of the boat itself. Localization will be managed by a GPS located within the boat. Most of the electrical components will be housed in a plastic (PLA) box found within the hull, this will ensure that the components are safe from water exposure in the event of water breaching the hull while being lightweight and accessible. There will be 2 vents found on the front of the boat to allow for airflow through the hull to keep the electrical components from overheating. They will be accompanied by 2 fans blowing outward on the back side of the boat to ensure the air doesn't become stagnant inside the hull. A perspective view can be seen in Figure 10 while other views can be found in Appendix A . The V-bottom hull allows for a higher speed, but suffers from a lower stability for tight turns. The sensors are sensitive to disturbances and may be inaccurate if used in suboptimal weather conditions. The vents being used as a passive intake may not give enough airflow over the electronic components to sufficiently cool them down while in use.

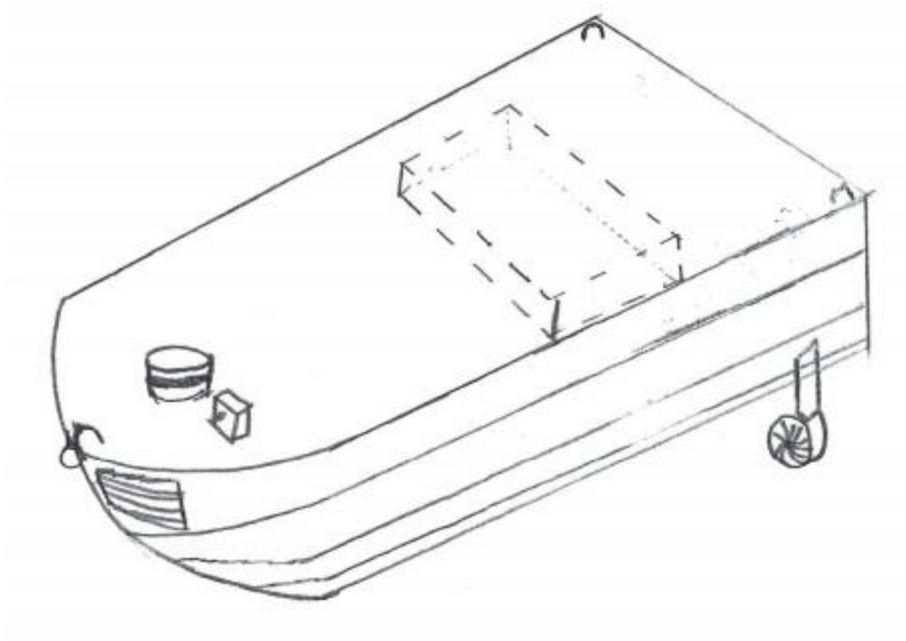


Figure 10: Concept 5 Perspective View

100 Concepts

Hull Shape

1. Displacement Hulls
2. Cathedral
3. Planing Hulls
4. Flat Bottom
5. V-Bottom
6. Tri-Hull (Tunnel Hull)
7. Pontoon
8. Semi-Displacement Hulls
9. Multi-Hulls
10. Catamarans
11. Trimarans

Hull Material

12. Carbon-Fiber
13. Fiber-Glass
14. Aluminum
15. Stainless Steel
16. Rubber
17. Plastic (PLA)
18. Plastic (ABS)
19. Wood
20. Titanium
21. PVC (Polyvinyl chloride) Pipe
22. Ferro-Cement
23. Polyethylene foam
24. Flex-tape
25. Flex-Seal
26. Aero-Gel

Hull Coating

27. Gel
28. Hydrophobic Spray
29. Seamless Polyurea

30. Ceramic Coating
31. Paint
32. Epoxy resin
33. Flex-Seal
34. Flex-Tape
35. Polyurethane
36. Varnish
37. Lacquer
38. Galvanize
39. Powder Coating
40. Penetrol

Propulsion

41. Inboard Propeller
42. Outboard Propellor
43. Fan
44. Sailboat
45. Rowing

Propulsion Amount

46. 1 propulsor
47. 2 propulsor
48. 3 propulsors
49. 4 propulsors
50. Differential propulsor
51. 2 Differential propulsors
52. 3 Differential propulsors
53. 2 Differential propulsors + 1 propulsors
54. 2 Differential propulsors + 2 propulsors
55. 4 Differential propulsors

Object Detection Sensor

56. Ultrasonic
57. InfraRed
58. LiDAR
59. Time of Flight
60. Camera/Image processing

Object Detection Sensor Position

61. Front
62. Top
63. Rear

Localization

64. GPS
65. Odometer & Gyroscope
66. Triangulation

Remote Control Signal

67. BlueTooth
68. Radio
69. Ethernet cable
70. IR signal

Receiver Location

71. Front
72. Top
73. Rear

Power Source

74. Steam Power
75. Gas Power
76. Solar Power
77. Wind Power
78. Battery Power source

Power Source Location

79. Front
80. Top
81. Rear
82. Interior Hull

Visual Feedback Camera Location

83. Front
84. Top
85. Rear

Electronics Enclosure

86. Yeti enclosure
87. Wooden
88. Acrylic
89. Cardboard Box
90. Carbon-Fiber Box
91. Plastic Box (PLA)
92. Plastic Box (ABS)

Cooling System

93. Fans (active intake) + Fan (active outtake)
94. Vents (passive intake) + Fan (active outtake)
95. Fans (active intake) + vent (passive outtake)
96. Vents (passive intake) + vents (passive outtake)
97. Liquid cooling
98. Mineral Water

Tow Harness Locations

99. Front
100. Rear
101. Side
102. Corner
103. Belly of the boat

Deployment Harness Locations

104. 3 point harness: 2 hooks in the front, 1 in the rear
105. 3 point harness: 2 hooks in the rear, 1 in the front
106. 4 point harness: 1 hook in each corner

Concept Generation Conclusion

Fidelity refers to the amount of detail a prototype contains. After brainstorming, the RoboBoat team was able to generate 5 medium fidelity concepts using a morphological chart. Although each concept has its disadvantages, the selected 5 were still the best options for a final prototype.

Concept Selection Introduction

The FSU-PC design team was tasked with constructing an autonomous boat for the 2021 RoboBoat Competition. Thus far, we have generated a function decomposition diagram from the interpreted customer needs and competition requirements, devised important targets and metrics, and produced a morphological chart that led to the generation of 5 medium fidelity sketches for a possible boat design. The final concept selection was achieved through the following processes: Binary Comparison Chart, House of Quality (HoQ), Analytical Hierarchy,Pugh Chart, and a final Decision Matrix.

Binary Comparison Chart

A binary comparison chart is used to compare customer requirements one by one to decide how important they are with respect to other customer requirements. However, when comparing requirements, they are not given weighted values at first. It is simply determined whether one requirement is more important than the other. After all requirements have been compared, the totals are taken to find the appropriate weighting for the requirements. These weightings are then used in the house of quality chart for the importance factor.

	1	2	3	4	5	6	7	Total
1. Weight	-	1	0	0	0	1	0	2
2. Size	0	-	0	0	0	1	1	2
3. Buoyancy	1	1	-	1	1	1	1	6
4. Stability	1	1	0	-	0	0	1	3
5. Sensing	1	1	0	1	-	1	1	5
6. Maneuvering	0	0	0	1	0	-	1	2
7. Safety	1	0	0	0	0	0	-	1
Total	4	4	0	3	1	4	5	n-1=6

Figure 10: Binary Comparison Chart

House of Quality (HoQ)

The House of Quality is used to relate our customer needs to engineering characteristics to determine priority. Using the importance factors found by the binary comparison chart, we can directly compare how our engineering requirements will relate to our customer needs. This allows us to focus our attention on characteristics that will more heavily impact the ability of our final design to meet our found customer requirements.

		Engineering Characteristics								
Improvement Direction		↑	↑	↑	↓	↓	↓	↑		↓
Units		N	M	MHz	cm	cm	kg/m3		N/A	N
Customer Requirements	Importance Factor	Thrust	Sensing Distance	Processing Speed	Center of Gravity	Localization Accuracy	Material Density	Strength/Density	Coating/Seal	Drag Force
Weight	2	3			9		9	9	1	3
Size	2	1	1		3	3	3			9
Buoyancy	6				9		9	1	3	1
Stability	3	3			9		3	3		1
Sensing	5		9	9		9				
Maneuverability	2	9	3	3	3	3	1			9
Safety	1	1	1	1		1	1	9	3	
Raw Score (517)		36	54	52	111	58	90	23	51	42
Relative Weight %		7	10.44	10.06	21.47	11.22	17.6	4.5	9.86	8.1
Rank Order		8	4	5	1	3	2	9	6	7

Figure 11: House of Quality

Each engineering characteristic is compared to the given customer requirements and rated based on a scale of 0,1,3,9 for how related they are, with a 0 having no correlation and a 9 having a high correlation. By doing this comparison we were able to determine that our most influential characteristic is the center of gravity, which will heavily impact the stability and buoyancy of our final design. This also finds that the least impactful characteristic is the coating, which will directly affect how the boat will interact with the water but is not as influential to the success of the final design as the other listed characteristics.

AHP

The AHP chart is used to compare how much more important the row is versus the column, or vice versa. To do this, we assign either a 1, 3, 5, 7, or 9 to whatever is more important, depending on level of importance. 3 low on importance and 9 being a higher importance. This is read as "row compared to column".The only time a 1 is used is when the same two categories are compared to each other, or two categories are very similar. Once we declare the importance level between two categories with either a 3, 5, 7, or 9. We write the inverse of the whole number when they are compared again (every category will be compared twice in different orders). Once the chart is filled out, all the scores are added up and recorded on the SUM row at the bottom. Using the categories in the respective column, the column with the lowest sum results in being the most important while the column with the highest sum results in being the least important. The order from most to least important characteristics are: Maneuverability, Reliability, Reparability, Hull Design, Cost, Hull Material, and Speed.

	Hull Design	Hull Material	Reliability	Reparability	Speed	Maneuverability	Cost
Hull Design	1	3	0.3	0.3	7	1	3
Hull Material	0.3	1	0.2	0.3	5	0.2	1
Reliability	3	5	1	3	3	0.2	3
Reparability	3	3	0.3	1	3	0.3	3
Speed	0.14	0.2	0.3	0.3	1	0.14	0.2
Maneuverability	1	5	5	3	7	1	5
Cost	0.3	1	0.3	0.3	5	0.2	1
Sum	8.74	18.2	7.4	8.2	31	3.04	16.2

Figure 12: AHP

Normalization and Criteria Weight

Figure 13 shows the Normalization and the Criteria Weight. The normalization is found dividing each cell by the sum of the column it is in. Once each cell is calculated, all the cells should add up to be 1. Also the Criteria Weight column is all the values of each row averaged out. The sum of these should also come out to equal 1.

	Hull Design	Hull Material	Reliability	Reparability	Speed	Maneuverability	Cost	Criteria Weight
Hull Design	0.114	0.165	0.041	0.037	0.226	0.329	0.18	0.157
Hull Material	0.034	0.055	0.027	0.037	0.161	0.066	0.062	0.063
Reliability	0.343	0.275	0.135	0.366	0.097	0.066	0.18	0.21
Reparability	0.343	0.165	0.041	0.122	0.097	0.099	0.185	0.15
Speed	0.016	0.011	0.041	0.037	0.032	0.046	0.012	0.03
Maneuverability	0.114	0.275	0.676	0.366	0.226	0.329	0.309	0.328
Cost	0.034	0.055	0.041	0.037	0.161	0.066	0.062	0.065
Sum	1	1	1	1	1	1	1	1

Figure 13: Normalized AHP

Pugh Chart

A Pugh Chart is a tool used to evaluate multiple options of a design against each other. A baseline is used to compare to an existing or proven concept. Values found using the House of Quality and AFP were used to find how we would determine which concept was best based on the Pugh Chart.

Selection Criteria	Baseline		Concepts				
			1	2	3	4	5
Material	RoboBoat 2020 DATUM		+	S	-	-	S
Center of Gravity			-	S	-	S	+
Thrust			+	+	S	+	S
Drag Force			+	-	-	S	S
Cost			-	S	-	-	S
	Total	# of plus	3	1	0	1	1
		# of minus	2	1	4	2	0
		# of same	0	3	1	2	4

Figure 14: Pugh Chart

The datum used for the Pugh Chart is the 2020 FSU PC senior design teams concept, we compared it to their design to see if our new concepts would be better or improve their design. The material selection criteria was to determine which material had the best strength ratio (Figure 15), which was measured by taking the tensile strength and dividing it by the density. The center of gravity (CG) was analyzed by observing the component placement on each type of hull and estimating the CG location. The thrust force is related to the weight, drag, size, and amount of power we have supplied to the thrusters, to measure this we made assumptions to simplify the problem. The assumptions suggest that thrust is greater with lighter boats, and more thrusters distributes power evenly (making the total amount of thrusters generate the same thrust but can maneuver the boat more easily). The drag force of the boat was evaluated based on the hull shape and size of each concept, we considered that we would be moving more slowly through the water so boat hulls like the flat bottom and v-hull would not benefit from high speed planing effects. The cost of the boat was mainly evaluated based on the assumption that the GPS system is the system used from the RoboBoat club (same for each design), the LiDAR system is the same for each design, and that the electrical engineering side would be handling the battery. This left the material as the main cost consideration, therefore it was evaluated based on the cost to strength ratio of each material (Figure 15).

	Density (g/cm^3)	Cost ($/Kg)	Tensile Strength (Gpa)	Strength Ratio (GPa/(g/cm^3))	Cost/ Strength Ratio
Carbon Fiber	0.9721	21.5	3.8	3.91	5.66
Fiber Glass	0.7869	5.51	1.02	1.298	5.402
Aluminum Alloy	2.7	15.98	0.339	0.1256	47.14
Wood	0.75	4.5	0.047	0.0627	95.74

Figure 15: Material Characteristic Comparison

Based on the Pugh Chart we found that the first concept was the best choice, with 3 of the selection criteria being better than the datum and 1 being worse than the datum.

Decision Matrix

The Decision Matrix was used to determine if our concepts are feasible based on data found in the Pugh Chart.

	Importance Weight Factor	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Aesthetics	1	3	3	3	3	3
Component Space	3	3	1	9	3	3
Stability	9	9	3	3	9	3
Manufacturability	9	3	1	9	3	3
Total	198	120	42	138	120	66

Figure 16: Decision Matrix

The decision matrix found that Concept 3 was the easiest to manufacture and would have the most space for our components. Although considering the benefits found from the pugh chart, AHP and HoQ, it is determined that it would be worth the more difficult manufacturing to have the catamaran design. Therefore we acknowledge that it will be more difficult to manufacture, but will be pursuing the catamaran.

Final Decision

Therefore based off of the concept selection tools it is deemed that concept 1 would be the best design to pursue. There should be some modifications that will occur during the future design phase of the project, as one issue found with this concept is that the CG may need to be corrected based on component placement. It was also found that it would be worth it to use fiberglass for this design over carbon fiber as it is more cost effective for its strength and weight. It will use 3-4 differential thrusters to ensure good maneuverability in combination with high thrust.

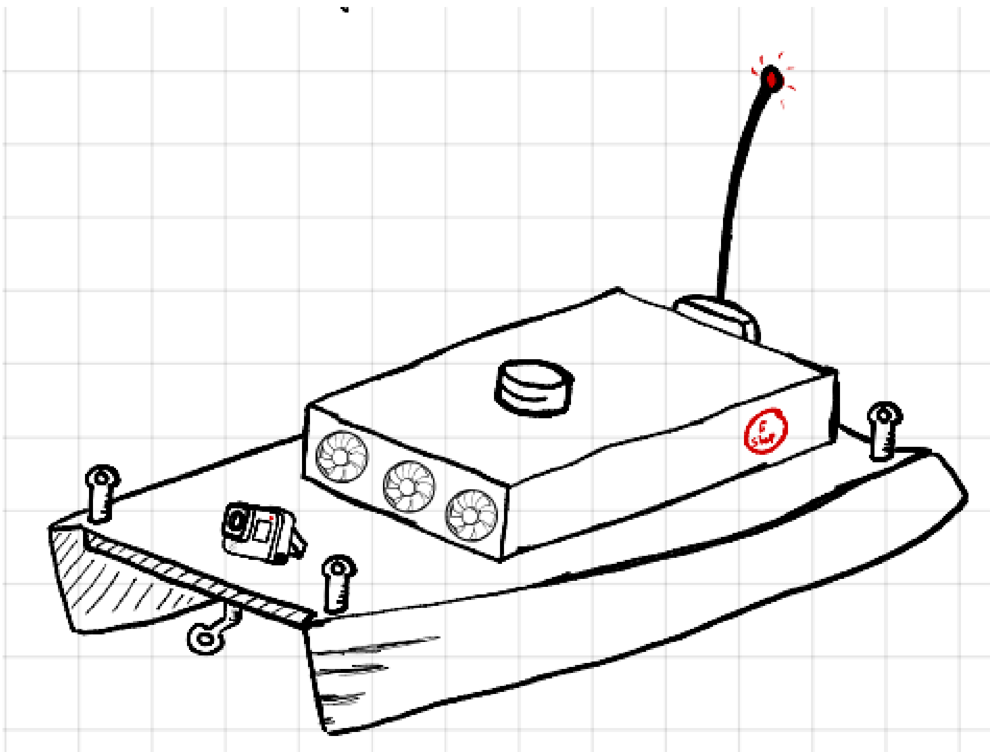


Figure 6: Perspective View

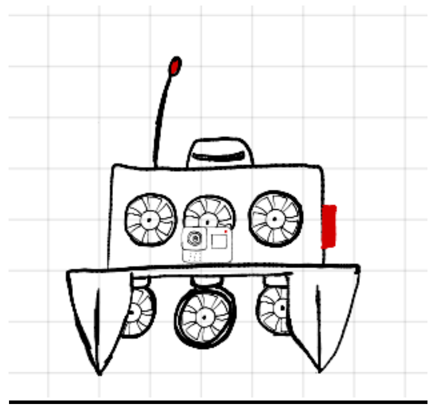
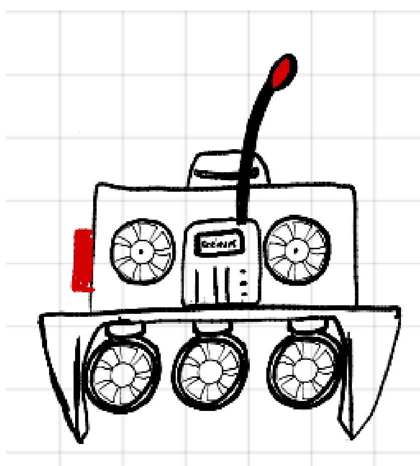


Figure 6 Additional View: Front View



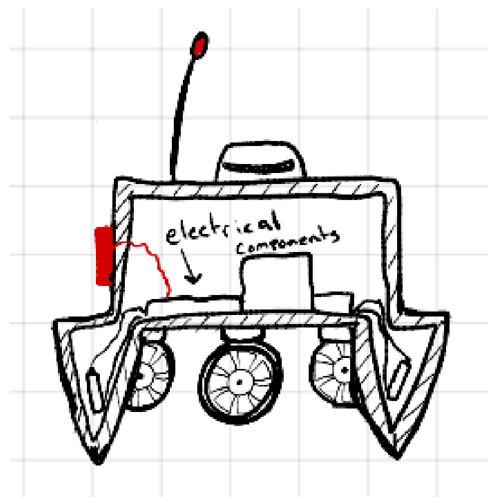
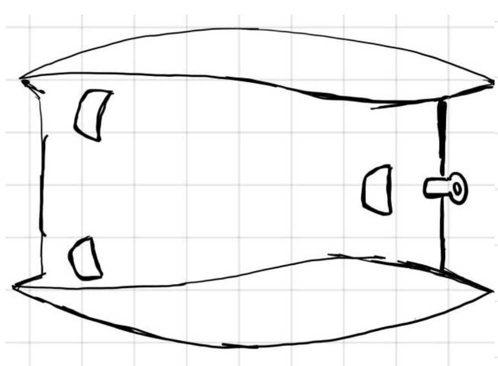


Figure 6 Additional View: Rear View **Figure 6 Additional View: Cross-Section View**



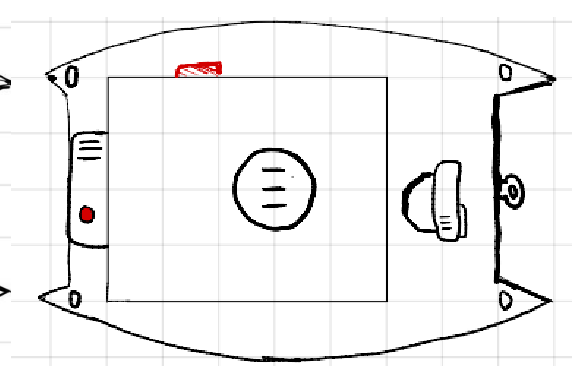


Figure 6 Additional View: Bottom View **Figure 6 Additional View: Top View**

Bill of Materials

Line Items	Vendor	Quantity	Cost/Unit	Order Time	Order Cost	Contingency	Total Cost	In Stock	Notes
Ouster OS1-16 Lidar	RoboBoat	1	$0.00	N/A	$0.00	0	0	☑	Lidar Provided by RoboBoat
VectorNav VN-300	VectorNav	1	$5,000.00	Unknown	$5,000.00	0	$5,000.00	☐	Preacquired GPS system will be made available once RoboBoat club is formed
GoPro Hero 7	Walmart	1	$170.00	2 days	$170.00	0	$170.00	☑	
DotStar Matrix 8x32 - 256 RGB LED Pixels	Adafruit	1	$100	1-2 Weeks	$100	1	$200	☐	Orders placed at Adafruit at $200+ recieve free shipping, with the contingency we reach this price and therefore shipping was not included.
BlueRobotics T200 Thrusters	BlueRobotics	4	$206.00	1-2 Weeks	$898.76	1	$1,121.10	☑	
Fiberglass	Greenlight Surf Co.	900 sq ft	$7.68 / yd^2	4-8 days	$673.18	10 yd^2	$738.72	☑	
PLA	Amazon	2	$23.31	2 days	$46.62	1	$69.93	☐	
Nvidia GEFORCE RTX 3060 TI	Best Buy	1	$399.99	7 days	$399.99	0	$399.99	☐	
Intel CPU	Amazon	1	$164.99	2 days	$164.99	0	$164.99	☑	
Tow Hooks	Home Depot	5	$1.61	5 days	$16.02	0	$16.02	☐	
Carrying Device (Radio Flyer Wagon)	Amazon	1	$89.99	6 days	$89.99	0	$89.99	☐	
Resin kit	The Epoxy Experts	1	$75.97/gallon	1-5 days	$111.72	0	$151.93	☐	
Mixing kit	The Epoxy Experts	1	16.84/pack	1-5 days	$16.84	0	$40.41	☐	
Gel Coat	Bottom Paint Store	1	$38.88/qt	3 days	$38.88	0	$38.88	☐	
LL120 RGB 120mm Fan (3-Pack)	Corsair	2	$129.99/Pack	2-5 days	$259.98	1	$389.97	☐	
Rocket M5 Wifi Access Point	Ubiquiti	1	$89.00	2 days	$101.86	0	$101.86	☑	Orders placed at Ubiquiti over $100 recieve free 2-day shipping
AirMax AMO-5G10 Antenna	Ubiquiti	1	$125.00	2 days	$125.00	0	$125.00	☑	
FrSky Taranis X9 Lite Remote Control	Aloft Hobbies	1	$102.00	Unknown	$102.00	0	$102.00	☐	
DAP Alex Plus 10.1 oz. White Acrylic Latex Caulk	Home Depot	1	$2.58	Store Pickup	$2.58	1	$5.16	☐	
RealSense D435i Depth Camera	Intel	1	$199.00	3 days	$208.02	0	$208.02	☑	
						Overall Cost			
				(assume business days)					

Figure 17: Bill of Materials

Prototype Plan

The RoboBoat team will be making multiple prototypes that will help to finalize the final design of our boat.

Hull Prototypes

The hull prototypes will consist of making CAD models of the hull with slight variations in the design (flat front versus a pointed front, wide pontoons versus thin pontoons, etc.). We will then run the models through flow software to find which designs are best. After narrowing down the designs to a couple of models, we will make small-scale hull models to see how it would sit in the water and use weight (that is the scaled-down equivalent of our components) to see how the boat sits in the water with different component placements. These models would be constructed by 3D printing the CAD models we narrowed down and using them as a mold for a hand layup of fiber-glass. The cost of the prototypes would be around $20-$60 in PLA Filament (depending on the infill and support requirements), and the fiberglass cost would be around $24 at $8 per 30" x yard. By teaming up with the Digital Design Studio (DDS) at FSU PC we can bring the PLA cost to $0. The 3D printing process and fiber-glass layup will take the most amount of time for this prototype, although with the amount of 3D printers the DDS has we are able to cut that time dramatically down. Total max cost ($84), Total min cost ($24).

Software Prototype

The software prototyping will be handled by the Electrical Engineering Senior Design team.

Assessment Plan

Testing on the prototype will be carried out in various forms. One form of testing will be completed using a flow simulator to compare the aerodynamic characteristics of each of our models. We will also be putting the models in water to test their buoyancy and how they sit in the water, as well as how component placement affects the prototypes. This will then be used to determine how to place components on the final product.

Our critical targets include maintaining stability, detecting surroundings, processing, and moving the boat. Our metrics for maintaining stability are buoyancy and weight distribution. We aim to have a positive buoyancy for at least 30 minutes, and we want to make sure the center of gravity is below the center of buoyancy. Our metrics for detecting surroundings are sensor range and sensing speed. This will be tested using Solidworks software. We want the sensor range to be 6 meters, and the sensing speed will be 20 Hz. The metric for processing is object detection and will have a target of 327,680 points per second. The metric for moving the boat is thrust, and we aim to have between 13 and 18 lbs of thrust.

The results gathered from the assessment tests will be used to update our design and ensure that our critical targets will be met. These results will be used to make changes to our hull design and increase the functionality of our written code. Changes to the hull design include reshaping of the hull, updating the weight distribution of internal components, as well as changing the thruster orientation and positioning. The code will be rewritten as needed to quicken the processing speed and remove any unnecessary code.

Risk Assessment

The RoboBoat team evaluated the risks involved with future work to be done on the project. We evaluated manufacturing, wiring, testing and transportation.

Manufacturing

The boat will be manufactured at the High Performance Materials Institute, (HPMI) at the FSU Tallahassee campus. The process will consist of 6 steps; the mold, fiber-glass layup, vacuum sealing, curing, sanding and coating the boat hull. The main risks are lacerations, breathing hazards, skin irritation/inflammation, and eye irritation/inflammation. The risk will be minimized as the HPMI professionals will be able to help with the process.

Wiring

The wiring consists of 3 parts, connecting components (motherboard, cpu, gpu, LiDar, etc.), connecting the batteries to the system, and any soldering that is needed. The main risks are burns, fumes, dropping components on feet or other limbs, and electrocution.

Testing and Transportation

Final product testing will consist of having an autonomous boat, that will have to make its own decisions and if all goes wrong and the remote-control feature fails then possible harm to the testing team may occur. The risks may include lacerations, colliding with the boat, and getting dragged by the boat. The risks with transporting the boat may include dropping the boat on feet/limbs, slipping, injury by lifting, lacerations, entanglement. The driver of the vehicle for transport also assumes the risks that come with operating a vehicle.

Risk Mitigation

The risks will be mitigated by wearing proper personal protective equipment (PPE), such as closed toe shoes, masks, goggles, gloves, long sleeve shirts and pants as well as using ventilation for the fumes. We also will have fire extinguishers and have first aid kits on hand, and if the situation becomes drastically worse, emergency services will be contacted.

All documents relating to risk management can be found in figures 18 through 23.

Project Hazard Assessment Worksheet

PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engineering	Start Date: 3/31/2021	Revision Number: 1
Project:Manufacturing			Location(s): HPMI (High Performance Materials Institute)	
Team member(s): Bryson Potts, LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Mold	HPMI	LJ Earnest	Lacerations Breathing Fumes Burns	Gloves Ventilation Mask	Mask Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Layup	HPMI	Manning Owens	Lacerations Breathing Fumes Breathing Fibers Skin Inflammation Skin Irritation	Gloves Ventilation Mask	Mask Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Vacuum Seal	HPMI	Tamara McCaskill	Equipment Failure	Equipment used by profesional	Gloves Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low	Plan Safety Controls Supervisor Authorization
Curing	HPMI	Steven Harrington	N/A	Temperature	Gloves Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Sanding	HPMI	Bryson Potts	Frictions Burns Lacerations Breathing Particles Particles in Eyes	Gloves Ventilation Mask Goggles	Mask Gloves Goggles Long Sleeves Pants	Put Scraps in Trash Bag Take Directly to Dump Site	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Coating	HPMI	LJ Earnest	Breathing Fumes Eye Irritation Skin Irritation	Gloves Ventilation Mask Goggles Long Sleeves	Mask Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low	Plan Safety Controls Supervisor Authorization

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts		3/31/2021	Steven Harrington		3/31/2021
LJ Earnest		3/31/2021	Tamara McCaskill		3/31/2021
Manning Owens		3/31/2021			

Figure 18

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engineering	Start Date: 3/31/2021	Revision Number: 1
Project: Wiring			Location(s): Room B309	
Team member(s): Bryson Potts,LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Connect Components	B309	Manning Owens	Lacerations Dropping Components	Gloves Grounding Steel Toe Shoes	Gloves Steel Toe Shoes Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Connect Battery	B309	Tamara McCaskill	Electrocution Fire Acid Burns Breathing Fumes Dropping Battery	Gloves Grounding Steel Toe Shoes Ventilation Temp Control	Gloves Goggles Steel Toe Shoes Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low-Med	Plan Safety Controls Supervisor Authorization
Soldering	B309	Steven Harrington	Burns Fumes Electrocution	Gloves Goggles Ventilation	Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts	[signature]	3/31/2021	Steven Harrington	Steven Harrington	3/31/2021
LJ Earnest	[signature]	3/31/2021	Tamara McCaskill	[signature]	3/31/2021
Manning Owens	Manning Owens	3/31/2021			

Figure 19

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engine	Start Date: 3/31/2021	Revision Number: 1
Project: Testing			Location(s): In-Water	
Team member(s): Bryson Potts,LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	**Location**	**Person Assigned**	**Identify hazards or potential failure points**	**Control method**	**PPE**	**List proper method of hazardous waste disposal, if any.**	**Residual Risk**	**Specific rules based on the residual risk**
Final Product Testing	In-Water	Group Effort	Lacerations Collisions Getting Dragged	Approach Carefully Mark Sharp Areas	Close-Fitting Clothes Gloves	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	**Signature**	**Date**	**Name**	**Signature**	**Date**

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	**Signature**	**Date**	**Name**	**Signature**	**Date**
Bryson Potts	[illegible]	3/31/2021	Steven Harrington	Steve Harrington	3/31/2021
LJ Earnest	[illegible]	3/31/2021	Tamara McCaskill	[illegible]	3/31/2021
Manning Owens	[illegible]	3/31/2021			

Figure 20

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engineering	Start Date: 3/31/2021	Revision Number: 1
Project: Transportation			Location(s): N/A	
Team member(s): Bryson Potts,LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Lifting	N/A	Group Effort	Wet Floors Loose Eletrical Cables Heaby Objects Dropping Entanglement Lacerations Falling Bruising Boken Bones Back Pain Death	Proper Technique Steel Toe Shoes Slip-Resistant Shoes	Close-Fitting Clothes Steel Toe Shoes	N/A	HAZARD: CONSEQ: Moderate Residual: Med	Limit Number of Workers Buddy System PI Approved Project Hazard Control Copy Sent to Safety Committee
Carrying	N/A	Group Effort		Proper Technique Steel Toe Shoes Slip-Resistant Shoes	Close-Fitting Clothes Steel Toe Shoes	N/A	HAZARD: CONSEQ: Moderate Residual: Med	Limit Number of Workers Buddy System PI Approved Project Hazard Control Copy Sent to Safety Committee
Securing	N/A	Group Effort	Crushing Lacerations Entanglement	Steel Toe/Slip Resistant Shoes	Close-Fitting Clothes Steel Toe Shoes	N/A	HAZARD: CONSEQ: Moderate Residual: Med	Limit Number of Workers Buddy System PI Approved Project Hazard Control Copy Sent to Safety Committee
Vehicle Operation	N/A	Manning	Crushing Lacerations Fire Death	Licensed Observant	Seatbelt	N/A	HAZARD: CONSEQ: Moderate Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts		3/31/2021	Steven Harrington		3/31/2021
LJ Earnest		3/31/2021	Tamara McCaskill		3/31/2021
Manning Owens		3/31/2021			

Figure 21

Project Hazard Control- For Projects with Medium and Higher Risks

Name of Project:		**Date of submission:**
Team member	**Phone number**	**e-mail**
Bryson Potts	*850-326-2043*	abp19e@my.fsu.edu
LJ Earnest	*850-703-2455*	jde19@my.fsu.edu
Steven Harrington	*850-598-7820*	smh19n@my.fsu.edu
Tamara McCaskill	*850-815-8192*	tkm19@my.fsu.edu
Manning Owens	*334-596-6937*	mwo19@my.fsu.edu
Faculty mentor	**Phone number**	**e-mail**
Damion Dunlap	*850-770-2204*	ddunlap@fsu.edu
Patrick Walters	*NA*	walters.patrick.s@gmail.com

Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

Wiring: ensure that no one electrocuted by being cautious of live and dead wires
Manufacturing: ensure that no one breathes in or touches chemical that could compromise one's health status
Testing: ensure that no one is in the way of the boat during its propulsion
Transportation: ensure that everyone is wearing protective shoes so that in the scenario of the boat dropping on ones' foot, there would be some coverage. Also make sure that everyone lifts with proper form

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

If an accident were to occur, our first step would be to identify if the accident was critical (to the student) or not. If not critical, we will evaluate if anything is messed up and go from there. If a team member is in critical condition we will contact 911 first, then contact Dr. Dunlap and catch him up to speed with what happened.

List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone number	Faculty or other COE emergency contact	Phone number
Bryson Potts	*850-326-2043*	*Damion Dunlap*	*850-770-2204*
LJ Earnest	*850-703-2455*	*Damion Dunlap*	*850-770-2204*
Steven Harrington	*850-598-7820*	*Damion Dunlap*	*850-770-2204*
Tamara McCaskill	*850-815-8192*	*Damion Dunlap*	*850-770-2204*

Figure 22

Manning Owens	*334-596-6937*	*Damion Dunlap*	*850-770-2204*
Safety review signatures			
Team member	Date	Faculty mentor	Date

Report all accidents and near misses to the faculty mentor.

Figure 23

Senior Design: RoboBoat

Level	Task	Dates	Status
1.0	RoboBoat Project	5/10/2021 - 7/30/2021	In Progress
1.1	Engineering Design Day	4/8/2021	Not Started
1.2	Finals	4/19-23/2021	Not Started
1.3	Graduation	4/24/2021	Not Started
1.4	RoboBoat Submission Deadline (Competition)	5/24/2021	Not Started
1.5	Critical Design Review Presentation	5/31/2021	Not Started
1.6	Critical Design Review Report	6/4/2021	Not Started
1.7	Test Readiness Review Presentation	6/28/2021	Not Started
1.8	Test Readiness Review Report	7/9/2021	Not Started
1.9	Final Demonstration Video	7/23/2021	Not Started
1.10	Final Presentation	7/26/2021	Not Started
1.11	High Resolution Graphic	7/26/2021	Not Started
1.12	Final Poster	7/26/2021	Not Started
1.13	Operation Manual	7/30/2021	Not Started
1.14	Team Photo	7/30/2021	Not Started
1.15	Final Report	7/30/2021	Not Started

*All tasks will be completed together as a team rather than assigning a specific person to a task

Appendix

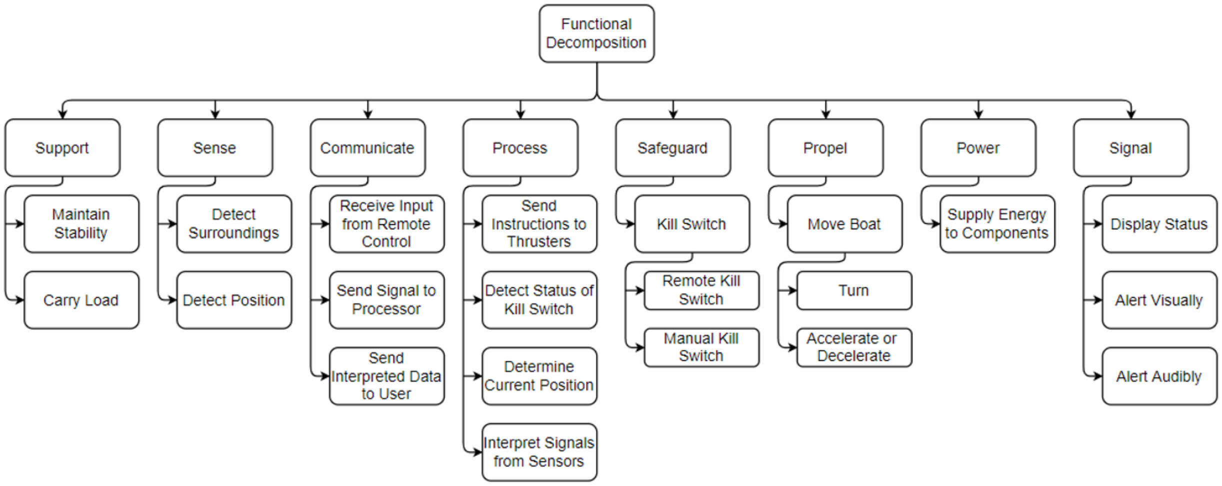


Figure 1: Functional Decomposition

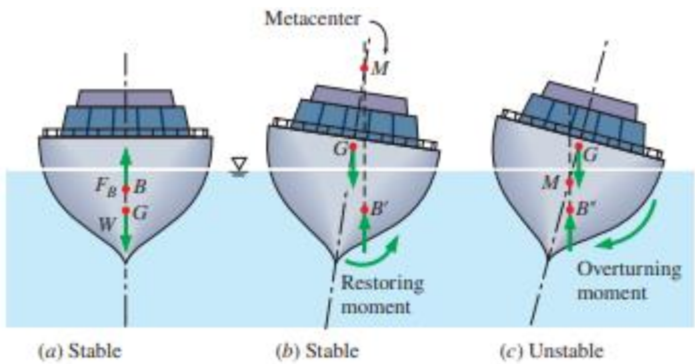


Figure 2: Stability of Boats in regards to Center of Gravity vs Center of Buoyancy

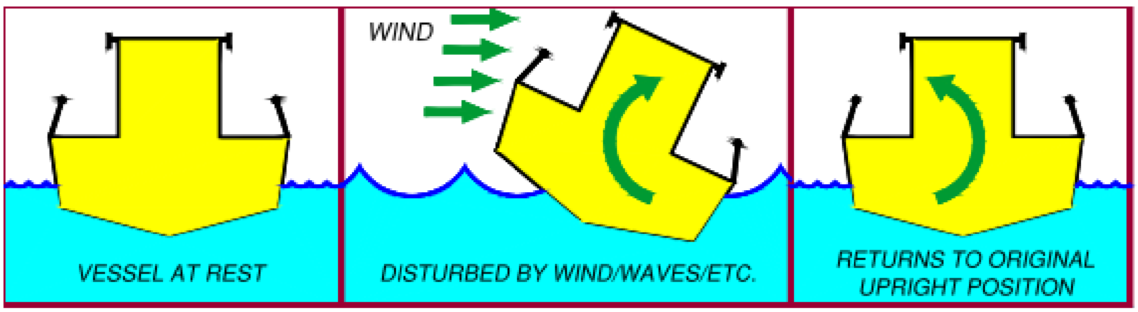


Figure 3a. Stable

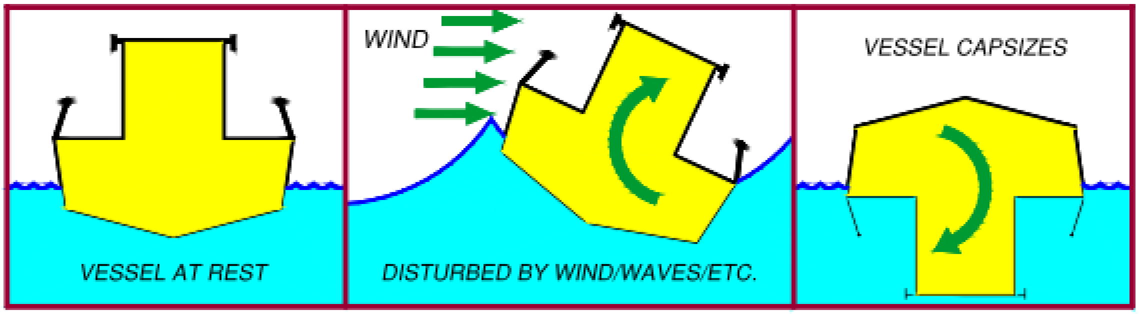


FIgure 3b. Unstable

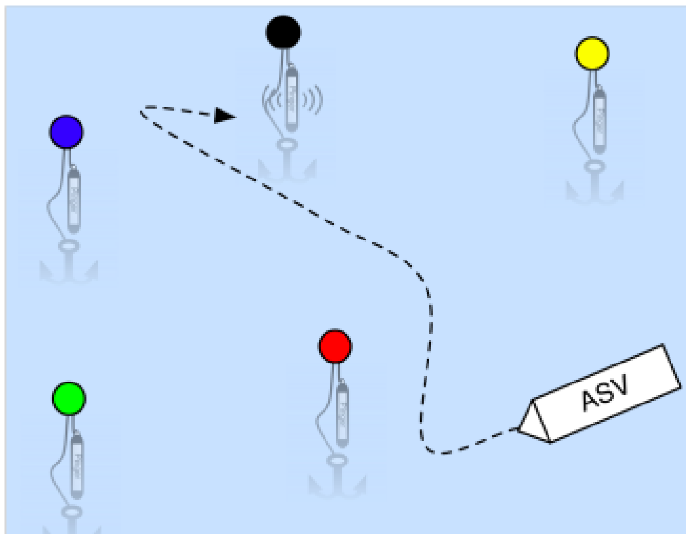


Figure 4. Buoy Set-Up

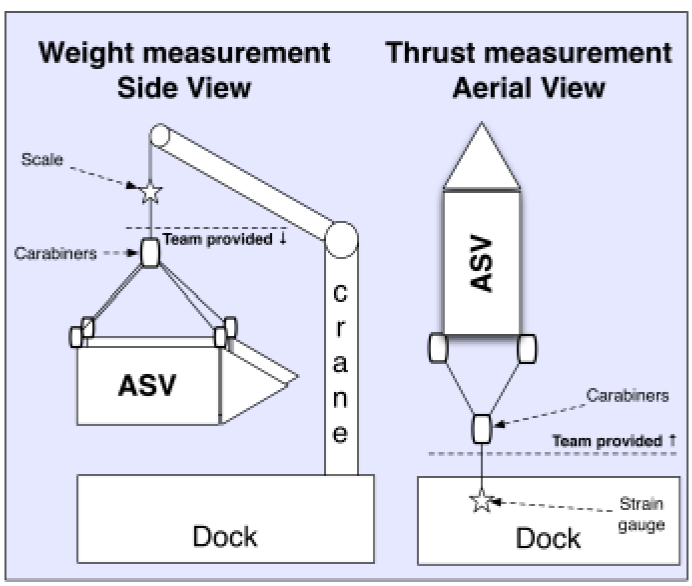


Figure 5. Weight and Thrust measurement Systems

Appendix A - Concept Figures

Concept 1

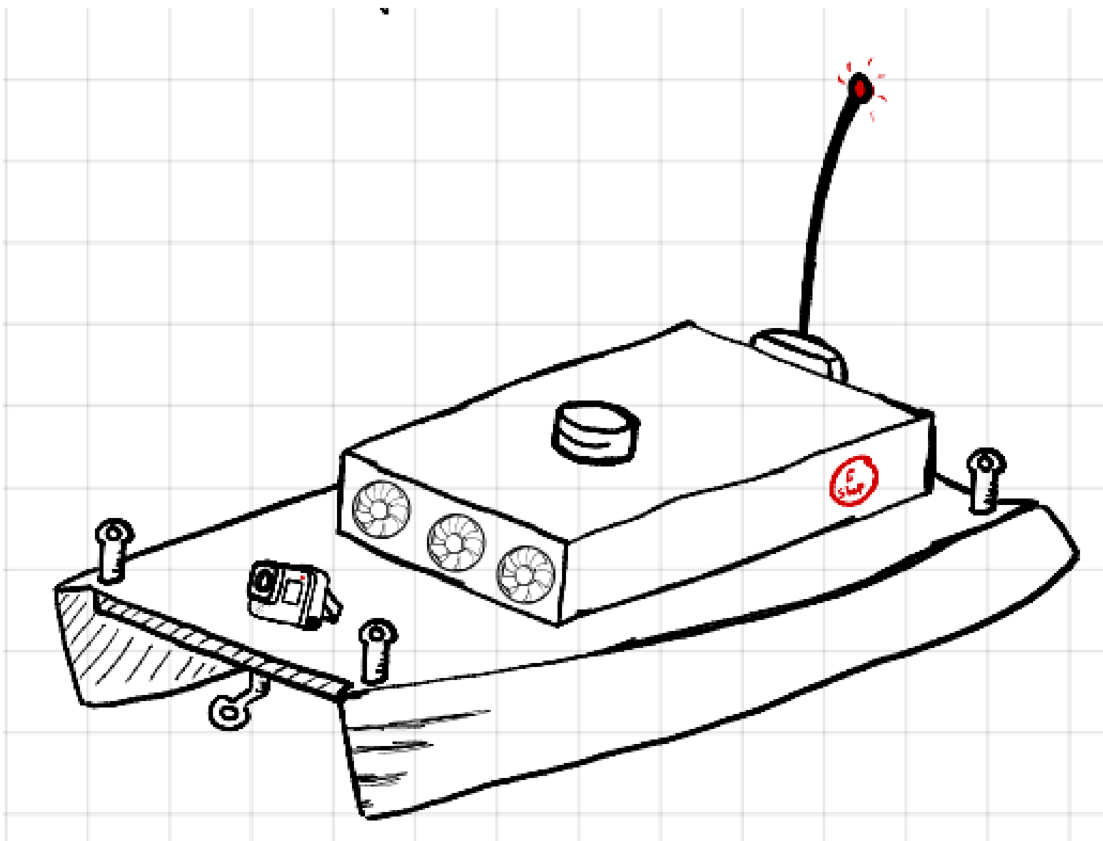


Figure 6: Concept 1 Perspective View

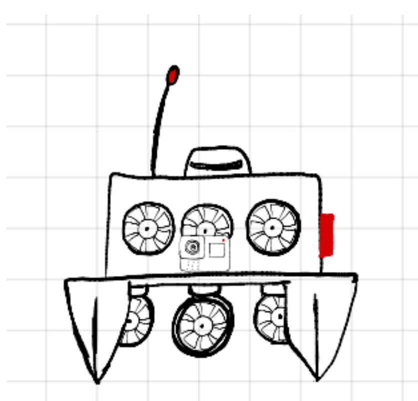
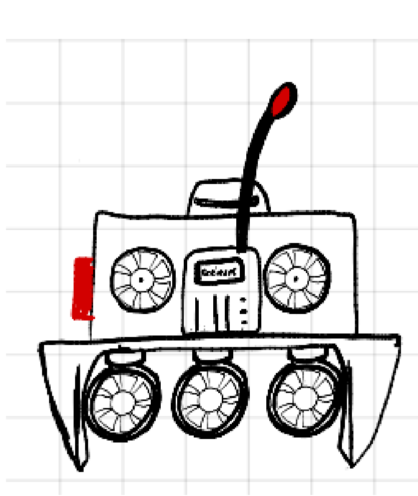
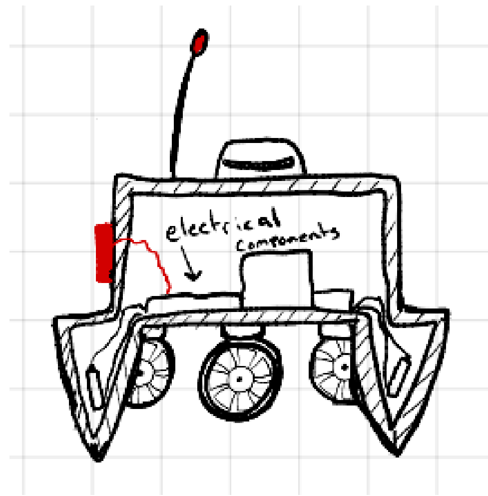


Figure 6: Concept 1 Front View

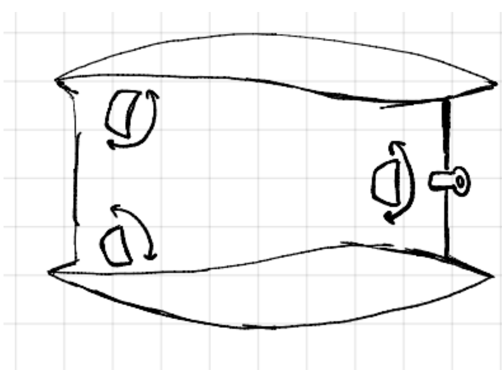
Figure 6: Concept 1 Additional Views



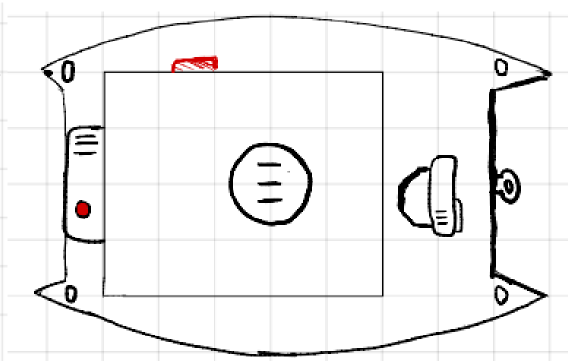
Rear View



Cross-Section View



Bottom View



Top View

<u>Concept 2</u>

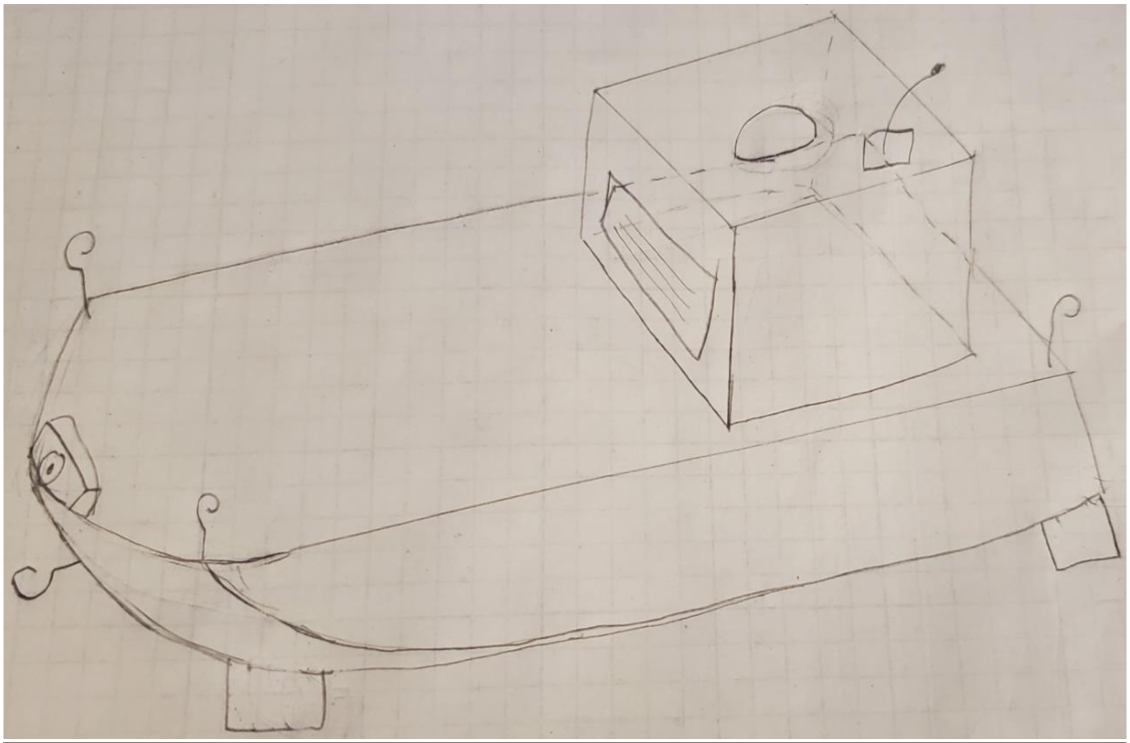


Figure 7: Concept 2 Perspective View

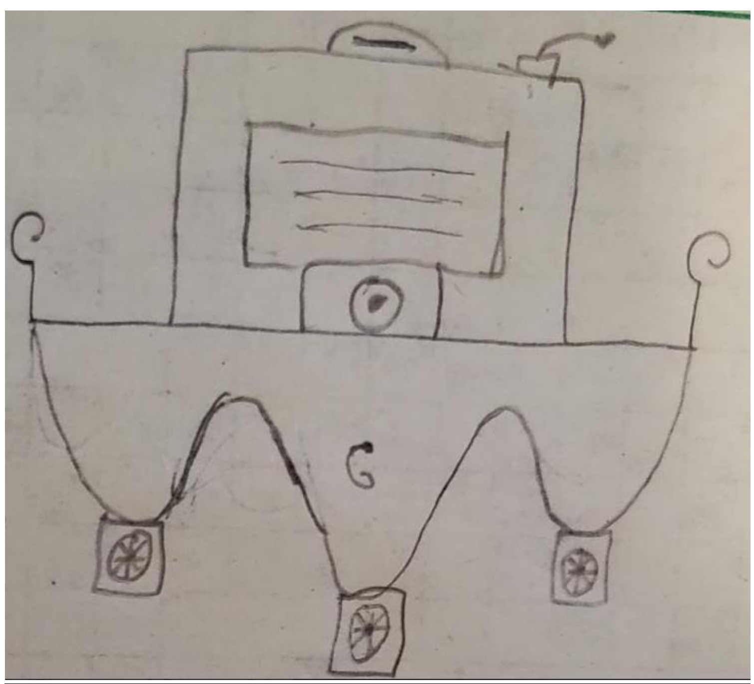
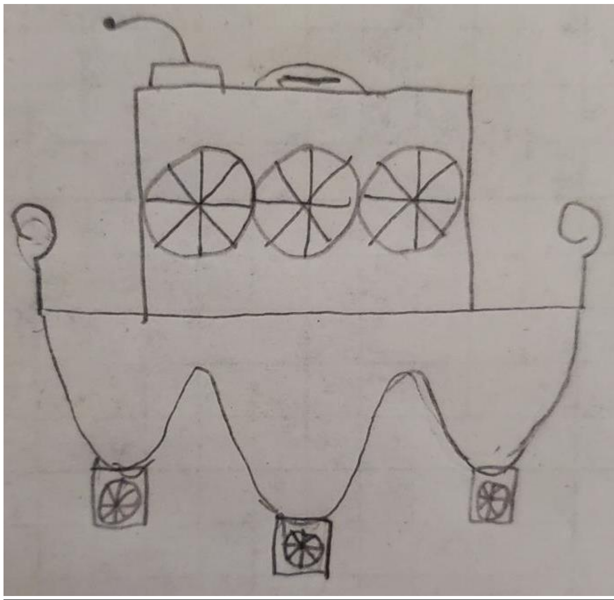
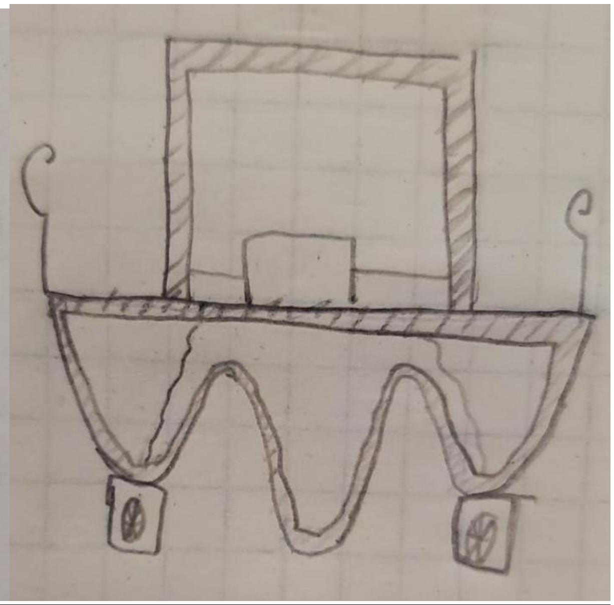
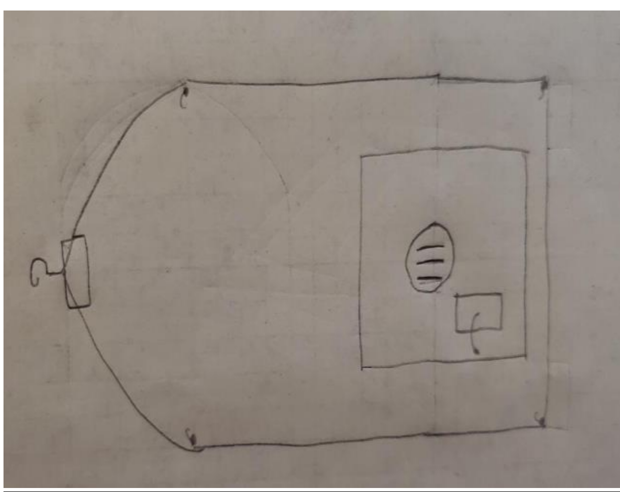
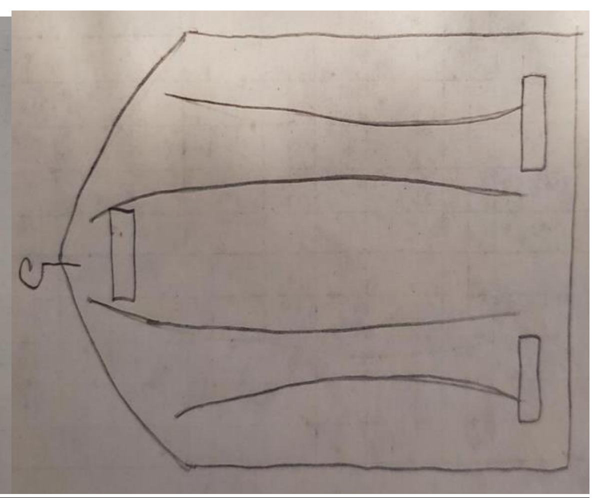


Figure 7: Concept 2 Front View

Figure 7: Concept 2 Additional Views

Rear View **Cross-Section View**

Top View **Bottom View**

Concept 3

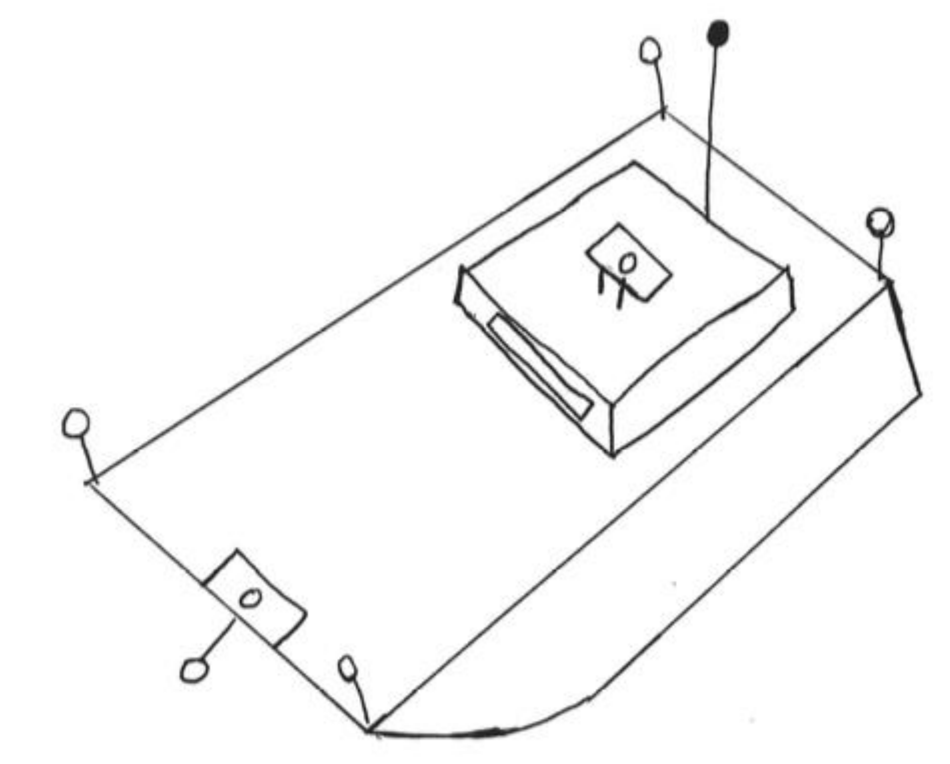


Figure 8: Concept 3 Perspective View

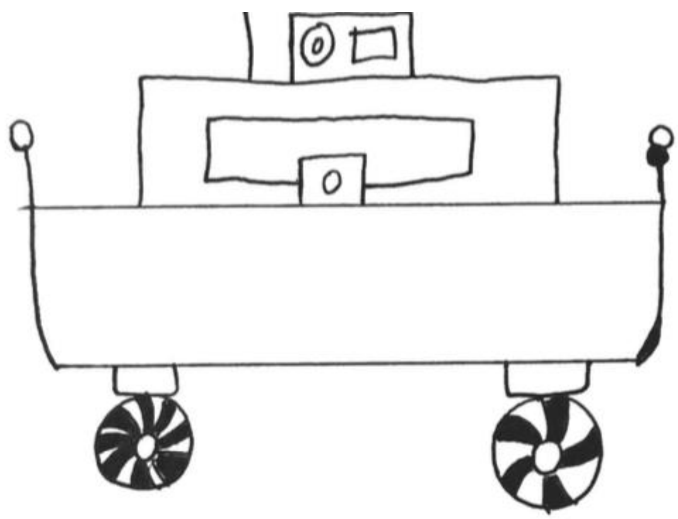
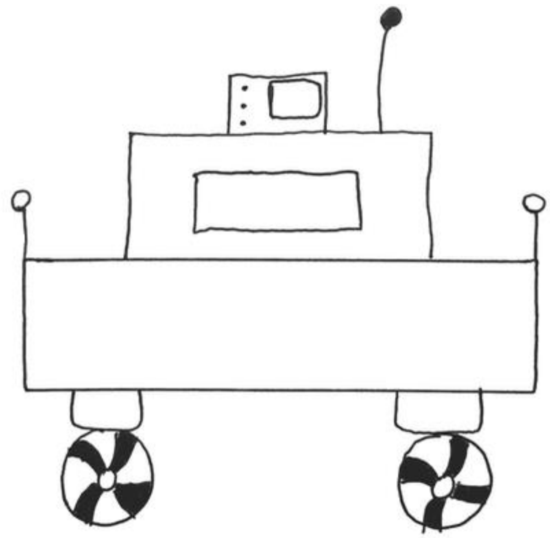
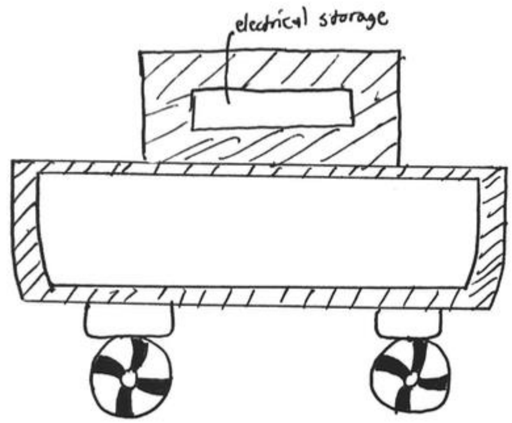


Figure 8: Concept 3 Front View

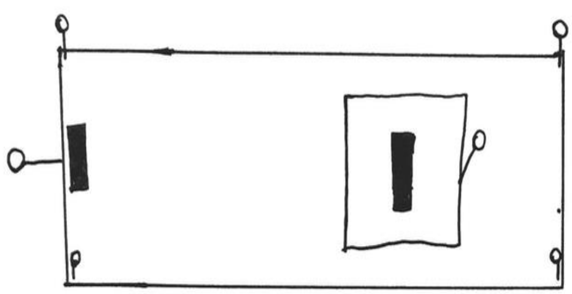
Figure 8: Concept 3 Additional Views



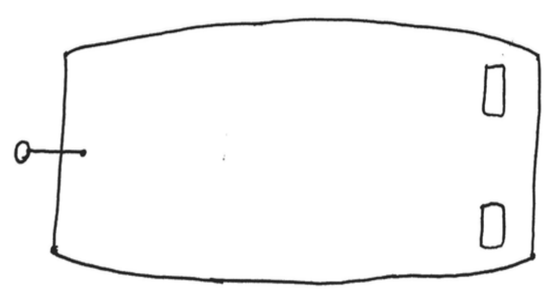
Rear View



Cross-Section View



Top View

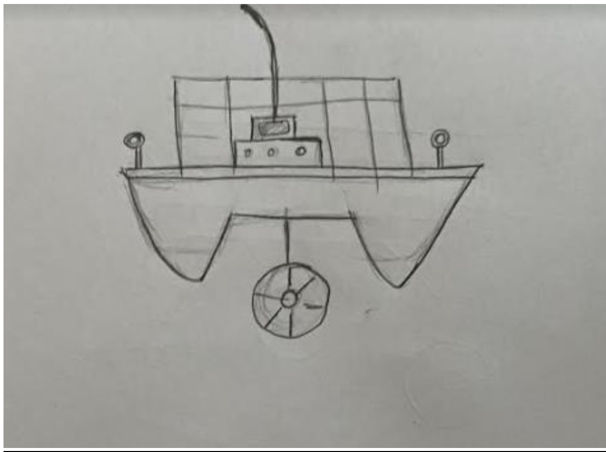


Bottom View

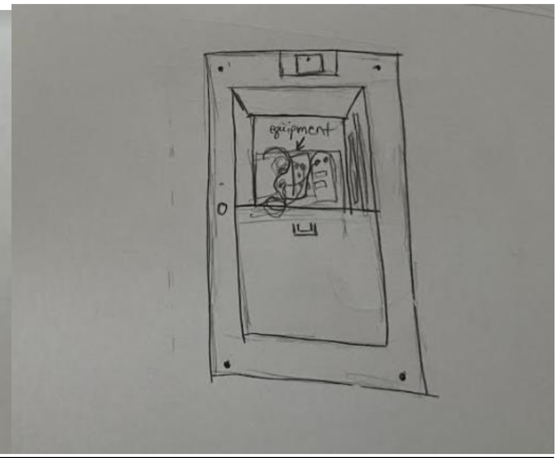
Concept 4

Figure 9: Concept 4 Perspective

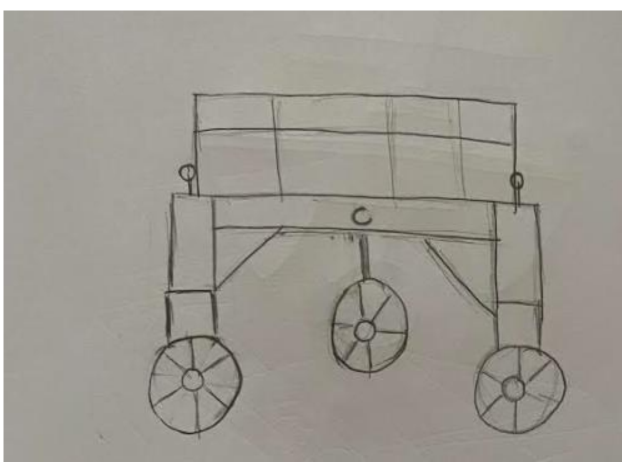
Figure 9: Concept 4 Additional Views



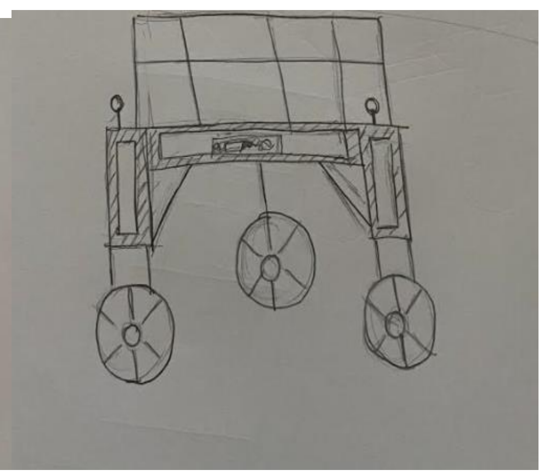
Front View



Top View



Rear View



Cross-section View

Concept 5

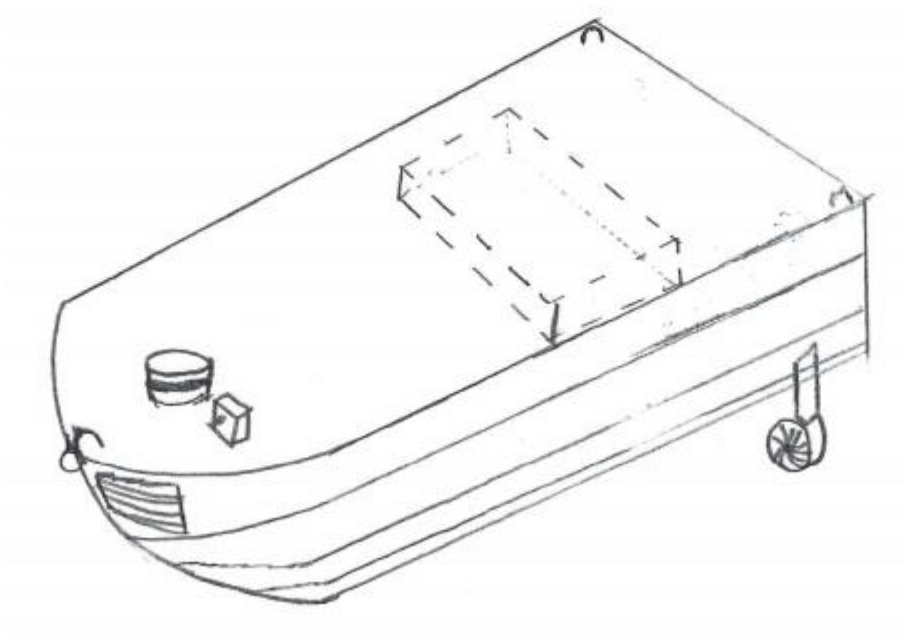


Figure 10: Concept 5 Perspective VIew

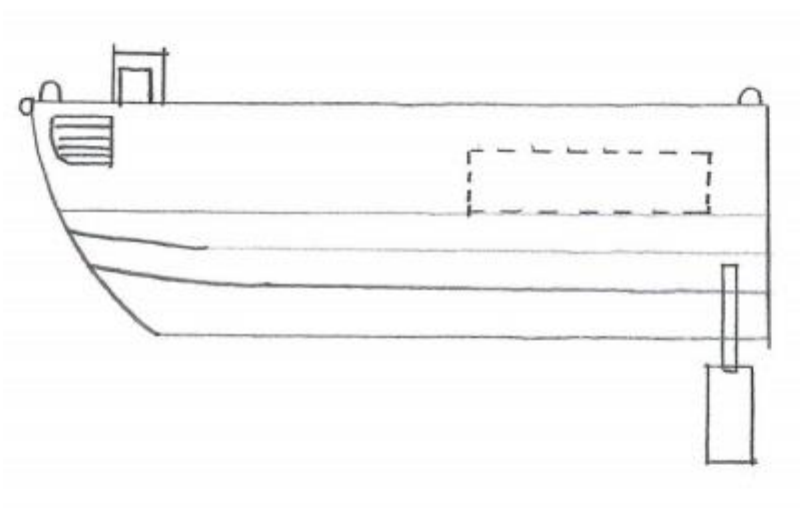
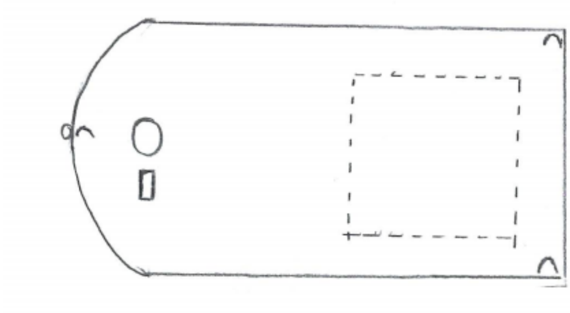
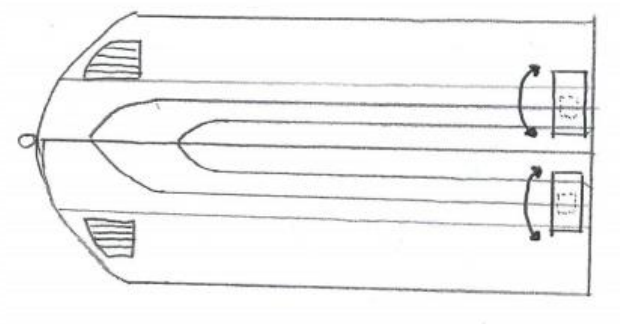


Figure 10: Concept 5 Side View

Figure 10 : Concept 5 Additional VIews



Top View



Bottom View

Front View

Back View

SENIOR DESIGN: ROBOBOAT

LEVEL	TASK	PERCENTAGE	STATUS	PERSON(S)
1.0	**ROBOBOAT PROJECT**	100%	Complete	Team
1.1	**Milestone 1: WBS**	100%	Complete	Team
1.1.1	*-Break down the project milestones into the work that must be done to complete these items.*	100%	Complete	Bryson Potts
1.2	**Milestone 2: PROJECT CHARTER**	100%	Complete	
1.2.1	*-Create a Mission Statement*	100%	Complete	Bryson Potts
1.2.2	*-Create a Project Description*	100%	Complete	Joseph Earnest
1.2.3	*-Identify market*	100%	Complete	Manning Owens
1.2.4	*-Identify Stakeholders*	100%	Complete	Steven Harrington
1.2.5	*-Develop Assumptions*	100%	Complete	Tamara Mccaskill
1.2.6	*-Define Key Goals*	100%	Complete	Bryson Potts
1.2.7	*-Assign Team Roles and Responsibilities*	100%	Complete	Joseph Earnest
1.2.8	*-Create a Communication Policy*	100%	Complete	Manning Owens
1.2.9	*-Develop a Dress Code Policy*	100%	Complete	Steven Harrington
1.2.10	*-Develop an Attendance Policy*	100%	Complete	Tamara Mccaskill
1.2.11	*-Create Statement of Understanding*	100%	Complete	Bryson Potts

1.2.12	*-Develop Code of Conduct Policy*	100%	Complete	Joseph Earnest
1.2.13	*-Submit a hard copy on canvas*	100%	Complete	Manning Owens
1.3	**Milestone 3: CUSTOMER NEEDS**	100%	Complete	
1.3.1	*-Develop a Customer Needs Statement*	100%	Complete	Steven Harrington
1.3.2	*-Create questions to ask customer*	100%	Complete	Tamara Mccaskill
1.3.3	-Create customer responses	100%	Complete	Bryson Potts
1.3.4	*-Describe how customer needs are being turned into a specification*	100%	Complete	Joseph Earnest
1.4	**Milestone 4: FUNCTIONAL DECOMPOSITION**	100%	Complete	
1.4.1	*-Create a functional decomposition chart for boat (using software)*	100%	Complete	Manning Owens
1.4.2	*-Identify major functions*	100%	Complete	Steven Harrington
1.4.3	*-Identify sub-functions*	100%	Complete	Tamara Mccaskill
1.4.4	*-Explain how sublevels correlate to the high level function of each column*	100%	Complete	Bryson Potts
1.4.5	*-Identify physical action and expected outcome*	100%	Complete	Joseph Earnest
1.5	**Milestone 5: PHASE 1 DESIGN REVIEW**	100%	Complete	
1.5.1	*- Develop and submit presentation*	100%	Complete	Manning Owens
1.5.2	*- Introduction*	100%	Complete	Steven Harrington
1.5.3	*- Project Brief Summary*	100%	Complete	Tamara Mccaskill
1.5.4	*- Background*	100%	Complete	Bryson Potts

1.5.5	*- Design Status*	100%	Complete	Joseph Earnest
1.5.6	*- Project Plan (schedule and budget)*	100%	Complete	Manning Owens
1.5.7	*- Score team being observed*	100%	Complete	Steven Harrington
1.6	**Milestone 6 : TARGETS**	100%	Complete	
1.6.1	*- Generate and log the targets*	100%	Complete	Tamara Mccaskill
1.6.2	*- Write summary of the targets*	100%	Complete	Bryson Potts
1.6.3	*- Write summary of how targets were established*	100%	Complete	Joseph Earnest
1.6.4	*- Write about the targets that interest the customer (customer needs)*	100%	Complete	Manning Owens
1.7	**Milestone 7: CONCEPT GENERATION**	100%	Complete	
1.7.1	*- Generate and submit concepts*	100%	Complete	Steven Harrington
1.7.2	*- 5 Medium Fidelity Concepts*	100%	Complete	Tamara Mccaskill
1.7.3	*- 3 High Fidelity Concepts*	100%	Complete	Bryson Potts
1.7.4	*- 100+ Concepts made*	100%	Complete	Joseph Earnest
1.8	**Milestone 8 : CONCEPT SELECTION**	100%	Complete	
1.8.1	*- Using an engineering decision making document, designate a winning concept*	100%	Complete	Manning Owens
1.8.2	*- House of Quality*	100%	Complete	Steven Harrington
1.8.3	*- Pugh Charts*	100%	Complete	Tamara Mccaskill
1.8.4	*- AHP*	100%	Complete	Bryson Potts

1.8.5	*- Final Selection*	100%	Complete	Joseph Earnest
1.9	**Milestone 9: PHASE 2 DESIGN REVIEW**	100%	Complete	
1.9.1	*- Develop and submit presentation*	100%	Complete	Manning Owens
1.9.2	*- Targets*	100%	Complete	Steven Harrington
1.9.3	*- Concept Generation*	100%	Complete	Tamara Mccaskill
1.9.4	*- Concept Selection*	100%	Complete	Bryson Potts
1.9.5	*- Design Status*	100%	Complete	Joseph Earnest
1.9.6	*- Future Plans*	100%	Complete	Manning Owens
1.9.7	*- Score team being observed*	100%	Complete	Steven Harrington
1.10	**Milestone 10: BILL OF MATERIALS**	100%	Complete	
1.10.1	*- Develop and submit the Bill of Materials*	100%	Complete	Tamara Mccaskill
1.10.2	*- Bill of Materials*	100%	Complete	Bryson Potts
1.11	**Milestone 11: PROTOTYPE PLAN**	100%	Complete	
1.11.1	**- No current information available**	100%	Complete	Joseph Earnest
1.12	**Milestone 12: RISK ASSESSMENT**	100%	Complete	
1.12.1	*- Complete and submit the safety forms*	100%	Complete	Joseph Earnest
1.12.2	*- Safety Expectations*	100%	Complete	Manning Owens
1.12.3	*- Worksheet 1 (project hazard assessment)*	100%	Complete	Steven Harrington
1.12.4	*- Worksheet 2 (project control)*	100%	Complete	Tamara Mccaskill
1.13	**Milestone 13: SUMMER PROJECT PLAN (WBS UPDATE)**	100%	Complete	

1.13.1	*- Develop and submit plan for summer*	100%	Complete	Bryson Potts
1.13.2	*- Document timeline, milestones, and deliverables*	100%	Complete	Joseph Earnest
1.14	**Milestone 14 : PHASE 3 DESIGN REVIEW (POSTER)**	100%	Complete	
1.14.1	*- PDF of poster (24x36 in) summary of all work to this point and future work*	100%	Complete	Manning Owens
1.15	**Milestone 15 : FINAL REPORT (SPRING)**	100%	Complete	

Table 1: WBS

Question	Answer	Interpreted Need	Explanation of Results
Would weight be an issue for this project?	It cannot exceed 140 pounds, and would ideally be less than 70 pounds.	The overall weight of the ASV and UAV will be less than 140 pounds.	The data found in the RoboBoat competition guidelines contains the ideal total weight and maximum total weight for the ASV and UAV.
Would size be an issue for this project?	The vehicle cannot exceed six feet, by three feet, by three feet "box".	The boat will be smaller than the size constraint given	The data found in the RoboBoat competition guidelines contains the UAV size constraint.
What type of water will the boat be operating in?	The competition takes place at a freshwater pond, but you will most likely be testing in saltwater conditions.	The boat will be smaller than the size constraint given.	The buoyancy of the boat may be different in freshwater vs saltwater.
Do the electrical components of the boat have to be enclosed?	It is recommended the electrical components are covered.	Electrical components will be covered in case of inopportune weather conditions.	While it is not required that the electrical components be covered, it is highly recommended so that electrical components will not have water damage from rain.

When should the final product be completed?	Final demos are within the last two weeks of the summer semester, or if going to a competition plan to finish ideally a week before the competition.	The team needs to decide whether the boat is planned to go to the competition.	If the team competes, then the project has to be completed significantly sooner.
What will be the planned transportation for the boat to the competition?	It will be transported in a pickup truck with a covered cab.	The boat needs to be able to fit and be secured in the bed of the truck.	The boat can be damaged if it somehow fell out of the truck while driving down the highway.
What aspect of the competition should we prioritize?	Focus on the areas of the competition that will net the most points with the least amount of complexity	Try not to perfect one specific characteristic of the project.	Directing all focus to one aspect of the project can cause problems in other areas and ultimately compromise the design.
Can the boat utilize any type of energy source?	The vehicle needs to be battery powered.	The watercraft will have power supplied by a cordless energy source.	The best solution for a cordless energy source is a battery.
How much autonomy should our boat have?	The vehicle must be fully autonomous, and all decisions can be made onboard the ASV.	The boat will be capable of making decisions and functioning independently.	The boat will be controlled by a wireless controller.
What propulsion systems are available for use?	Any propulsion system is fine (thruster, paddle, etc.), but moving parts must have a shroud.	The propulsion system will be determined by team preference, with a covering in case of moving parts.	The propulsion system that will be used needs to contain some drag to allow the boat to stop quicker.
What safety precautions should be taken?	All sharp, pointy, moving, or sensitive parts must be covered and marked.	The boat will have appropriate safety measures befitting of the RoboBoat standards.	All necessary precautions will be taken to assure that no problems will arise during the competition/showcase.

Table 2: Customer Needs

Function	Metric	Target
Maintain Stability	Buoyancy	Positive buoyancy for >= 30 minutes
	Weight Distribution	Center of Gravity below Center of Buoyancy

Detect Surroundings	Sensor Range	6 meters
	Sensing Speed	Value from spec sheet
Process	Object Detection	Same as Sensing Speed
Move Boat	Thrust	13-18 lbs

Table 3. Critical Targets and Metrics

Navigation	Propulsion	Boat Material	Control Panel Location	Hull	Battery Location	Vision System	Hardware	Receiver Location
ROS	Jet Turbine	Carbon Fiber	Inside	Cathedral	Inside	Go-Pro	Arduino	Top
Lidar	Propellor	PVC	Front	Catamaran	Top	Sony RX0 II		Front
Sonar	Fan	Wood	Back	Trimaran	Back	SeaLife DC 2000		
	Thruster	Fiberglass		Pontoon		DJI Osmo Action		
		Alumunium		V-bottom				
				Flat-Bottom				

Table 4: Morphological Chart

	1	2	3	4	5	6	7	Total
1. Weight	-	1	0	0	0	1	0	2
2. Size	0	-	0	0	0	1	1	2
3. Buoyancy	1	1	-	1	1	1	1	6
4. Stability	1	1	0	-	0	0	1	3
5. Sensing	1	1	0	1	-	1	1	5
6. Maneuvering	0	0	0	1	0	-	1	2
7. Safety	1	0	0	0	0	0	-	1
Total	4	4	0	3	1	4	5	n-1=6

Table 5: Binary Comparison Chart

		Engineering Characteristics								
Improvement Direction		↑	↑	↑	↓	↓	↓	↑		↓
Units		N	M	MHz	cm	cm	kg/m3		N/A	N
Customer Requirements	Importance Factor	Thrust	Sensing Distance	Processing Speed	Center of Gravity	Localization Accuracy	Material Density	Strength/Density	Coating/Seal	Drag Force
Weight	2	3			9		9	9	1	3
Size	2	1	1		3	3	3			9
Buoyancy	6				9		9	1	3	1
Stability	3	3			9		3	3		1
Sensing	5		9	9		9				
Maneuverability	2	9	3	3	3	3	1			9
Safety	1	1	1	1		1	1	9	3	
Raw Score (517)		36	54	52	111	58	90	23	51	42
Relative Weight %		7	10.44	10.06	21.47	11.22	17.6	4.5	9.86	8.1
Rank Order		8	4	5	1	3	2	9	6	7

Table 6: House of Quality

	Hull Design	Hull Material	Reliability	Reparability	Speed	Maneuverability	Cost
Hull Design	1	3	0.3	0.3	7	1	3
Hull Material	0.3	1	0.2	0.3	5	0.2	1
Reliability	3	5	1	3	3	0.2	3
Reparability	3	3	0.3	1	3	0.3	3
Speed	0.14	0.2	0.3	0.3	1	0.14	0.2
Maneuverability	1	5	5	3	7	1	5
Cost	0.3	1	0.3	0.3	5	0.2	1
Sum	8.74	18.2	7.4	8.2	31	3.04	16.2

Table 7: AHP

	Hull Design	Hull Material	Reliability	Reparability	Speed	Maneuverability	Cost	Criteria Weight
Hull Design	0.114	0.165	0.041	0.037	0.226	0.329	0.18	0.157
Hull Material	0.034	0.055	0.027	0.037	0.161	0.066	0.062	0.063
Reliability	0.343	0.275	0.135	0.366	0.097	0.066	0.18	0.21
Reparability	0.343	0.165	0.041	0.122	0.097	0.099	0.185	0.15
Speed	0.016	0.011	0.041	0.037	0.032	0.046	0.012	0.03
Maneuverability	0.114	0.275	0.676	0.366	0.226	0.329	0.309	0.328
Cost	0.034	0.055	0.041	0.037	0.161	0.066	0.062	0.065
Sum	1	1	1	1	1	1	1	1

Table 8: Normalized AHP

Selection Criteria	Baseline		Concepts				
			1	2	3	4	5
Material	RoboBoat 2020 DATUM		+	S	-	-	S
Center of Gravity			-	S	-	S	+
Thrust			+	+	S	+	S
Drag Force			+	-	-	S	S
Cost			-	S	-	-	S
	Total	# of plus	3	1	0	1	1
		# of minus	2	1	4	2	0
		# of same	0	3	1	2	4

Table 9: Pugh Chart

	Density (g/cm^3)	Cost ($/Kg)	Tensile Strength (Gpa)	Strength Ratio (GPa/(g/cm^3))	Cost/ Strength Ratio
Carbon Fiber	0.9721	21.5	3.8	3.91	5.66
Fiber Glass	0.7869	5.51	1.02	1.298	5.402
Aluminum Alloy	2.7	15.98	0.339	0.1256	47.14
Wood	0.75	4.5	0.047	0.0627	95.74

Table 10: Material Characteristic Comparison

	Importance Weight Factor	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Aesthetics	1	3	3	3	3	3
Component Space	3	3	1	9	3	3
Stability	9	9	3	3	9	3
Manufacturability	9	3	1	9	3	3
Total	198	120	42	138	120	66

Table 11: Decision Matrix

Appendix B - Concept Combinations

Concept 1

Hull Shape - Catamaran

Hull Material - Carbon-Fiber

Hull Coating - Flex-Seal

Propulsion - Out-Board Propellor

Propulsion Amount - 3 Differential Propulsors

Object Detection Sensor - LiDAR

Object Detection Sensor Position - Top

Localization - GPS

Remote Control Signal - Radio

Receiver Location - Rear

Power Source - Battery

Power Source Location - Interior Hull

Visual Feedback Camera Location - Front

Electronics Enclosure - Acrylic

Cooling System - Fan (Active Intake) + Fan (Active Outtake)

Tow Harness Location - Front

Deployment Harness Location - 4 points (1 in each corner)

Concept 2

Hull Shape - Tri-Hull (Tunnel Hull)

Hull Material - Fiber-Glass

Hull Coating - Paint

Propulsion - Outboard Propeller

Propulsion Amount - 2 Differential Propulsors + 1 Propulsor

Object Detection Sensor - Ultrasonic

Object Detection Sensor Position - Top

Localization - GPS

Remote Control Signal - BlueTooth

Receiver Location - Top

Power Source - Battery Powered

Power Source Location - Rear

Visual Feedback Camera Location - Front

Electronics Enclosure - Plastic Box (PLA)

Cooling System - Vents (passive intake) + Fan (active outtake)

Tow Harness Location - Front

Deployment Harness Location - 4 Point Harness (1 in each corner)

Concept 3

Hull Shape - Flat Bottom

Hull Material - Aluminum

Hull Coating - Flex-Seal

Propulsion - Inboard Propellor

Propulsion Amount - 2 Differential Propulsors

Object Detection Sensor - LiDAR

Object Detection Sensor Position - Front

Localization - GPS

Remote Control Signal - Radio

Receiver Location - Rear

Power Source - Battery

Power Source Location - Interior Hull

Visual Feedback Camera Location - Top

Electronics Enclosure - Wooden

Cooling System - Vent (passive intake) + Vent (passive intake)

Tow Harness Location - Belly of Boat

Deployment Harness Location - 4 points (1 in each corner)

Concept 4

Hull Shape - Pontoon

Hull Material - Wood

Hull Coating - Epoxy Resin

Propulsion - Onboard Propellor

Propulsion Amount - 3 Propulsors

Object Detection Sensor - LiDAR

Object Detection Sensor Position - Front

Localization - GPS

Remote Control Signal - Bluetooth

Receiver Location - front

Power Source - Battery

Power Source Location - Interior Hull

Visual Feedback Camera Location - Top

Electronics Enclosure - Plastic

Cooling System - Vent (passive intake) + Vent (passive intake)

Tow Harness Location - Rear

Deployment Harness Location - 4 points (1 in each corner)

Concept 5

Hull Shape: V-Bottom

Hull Material: Fiberglass

Hull Coating: Hydrophobic Spray

Propulsion: Out-Board Propeller

Propulsion Amount: 2 differential propulsors

Object Detection Sensor: LiDAR

Object Detector Location: Front

Localization: GPS

Remote Control Signal: BlueTooth

Receiver Location: Rear

Power Source: Battery Power Source

Power Source Location: Interior Hull

Visual Feedback Camera Location: Front

Electronics Enclosure: Plastic Box (PLA)

Cooling System: Vents (passive intake) + Fan (active outtake)

Tow Harness Location: Front

Deployment Harness Locations: 3-point harness: 2 hooks in the rear, 1 in the front

Appendix C - 100 Possible Concepts

Hull Shape

107. Displacement Hulls
108. Cathedral
109. Planing Hulls
110. Flat Bottom
111. V-Bottom
112. Tri-Hull (Tunnel Hull)
113. Pontoon
114. Semi-Displacement Hulls
115. Multi-Hulls
116. Catamarans
117. Trimarans

Hull Material

118. Carbon-Fiber
119. Fiber-Glass
120. Aluminum
121. Stainless Steel
122. Rubber
123. Plastic (PLA)
124. Plastic (ABS)
125. Wood
126. Titanium
127. PVC (Polyvinyl chloride) Pipe
128. Ferro-Cement
129. Polyethylene foam
130. Flex-tape
131. Flex-Seal
132. Aero-Gel

Hull Coating

133. Gel
134. Hydrophobic Spray
135. Seamless Polyurea

136. Ceramic Coating
137. Paint
138. Epoxy resin
139. Flex-Seal
140. Flex-Tape
141. Polyurethane
142. Varnish
143. Lacquer
144. Galvanize
145. Powder Coating
146. Penetrol

Propulsion

147. Inboard Propeller
148. Outboard Propellor
149. Fan
150. Sailboat
151. Rowing

Propulsion Amount

152. 1 propulsor
153. 2 propulsor
154. 3 propulsors
155. 4 propulsors
156. Differential propulsor
157. 2 Differential propulsors
158. 3 Differential propulsors
159. 2 Differential propulsors + 1 propulsors
160. 2 Differential propulsors + 2 propulsors
161. 4 Differential propulsors

Object Detection Sensor

162. Ultrasonic
163. InfraRed
164. LiDAR
165. Time of Flight
166. Camera/Image processing

Object Detection Sensor Position

167. Front
168. Top
169. Rear

Localization

170. GPS
171. Odometer & Gyroscope
172. Triangulation

Remote Control Signal

173. BlueTooth
174. Radio
175. Ethernet cable
176. IR signal

Receiver Location

177. Front
178. Top
179. Rear

Power Source

180. Steam Power
181. Gas Power
182. Solar Power
183. Wind Power
184. Battery Power source

Power Source Location

185. Front
186. Top
187. Rear
188. Interior Hull

Visual Feedback Camera Location

189. Front
190. Top
191. Rear

Electronics Enclosure

192. Yeti enclosure
193. Wooden
194. Acrylic
195. Cardboard Box
196. Carbon-Fiber Box
197. Plastic Box (PLA)
198. Plastic Box (ABS)

Cooling System

199. Fans (active intake) + Fan (active outtake)
200. Vents (passive intake) + Fan (active outtake)
201. Fans (active intake) + vent (passive outtake)
202. Vents (passive intake) + vents (passive outtake)
203. Liquid cooling
204. Mineral Water

Tow Harness Locations

205. Front
206. Rear
207. Side
208. Corner
209. Belly of the boat

Deployment Harness Locations

210. 3 point harness: 2 hooks in the front, 1 in the rear
211. 3 point harness: 2 hooks in the rear, 1 in the front
212. 4 point harness: 1 hook in each corner

Appendix D - Bill of Materials

Line Items	Vendor	Quantity	Cost/Unit	Order Time	Order Cost	Contingency	Total Cost	In Stock	Notes
Ouster OS1-16 Lidar	RoboBoat	1	$0.00	N/A	$0.00	0	0	☑	Lidar Provided by RoboBoat
VectorNav VN-300	VectorNav	1	$5,000.00	Unknown	$5,000.00	0	$5,000.00	☐	Preacquired GPS system will be made available once RoboBoat club is formed
GoPro Hero 7	Walmart	1	$170.00	2 days	$170.00	0	$170.00	☑	
DotStar Matrix 8x32 - 256 RGB LED Pixels	Adafruit	1	$100	1-2 Weeks	$100	1	$200	☐	Orders placed at Adafruit at $200+ recieve free shipping, with the contingency we reach this price and therefore shipping was not included.
BlueRobotics T200 Thrusters	BlueRobotics	4	$206.00	1-2 Weeks	$898.76	1	$1,121.10	☑	
Fiberglass	Greenlight Surf Co.	900 sq ft	$7.68 / yd^2	4-8 days	$673.18	10 yd^2	$738.72	☑	
PLA	Amazon	2	$23.31	2 days	$46.62	1	$69.93	☐	
Nvidia GEFORCE RTX 3060 TI	Best Buy	1	$399.99	7 days	$399.99	0	$399.99	☐	
Intel CPU	Amazon	1	$164.99	2 days	$164.99	0	$164.99	☑	
Tow Hooks	Home Depot	5	$1.61	5 days	$16.02	0	$16.02	☐	
Carrying Device (Radio Flyer Wagon)	Amazon	1	$89.99	6 days	$89.99	0	$89.99	☐	
Resin kit	The Epoxy Experts	1	$75.97/gallon	1-5 days	$111.72	0	$151.93	☐	
Mixing kit	The Epoxy Experts	1	16.84/pack	1-5 days	$16.84	0	$40.41	☐	
Gel Coat	Bottom Paint Store	1	$38.88/qt	3 days	$38.88	0	$38.88	☐	
LL120 RGB 120mm Fan (3-Pack)	Corsair	2	$129.99/Pack	2-5 days	$259.98	1	$389.97	☐	
Rocket M5 Wifi Access Point	Ubiquiti	1	$89.00	2 days	$101.86	0	$101.86	☑	Orders placed at Ubiquiti over $100 recieve free 2-day shipping
AirMax AMO-5G10 Antenna	Ubiquiti	1	$125.00	2 days	$125.00	0	$125.00	☑	
FrSky Taranis X9 Lite Remote Control	Aloft Hobbies	1	$102.00	Unknown	$102.00	0	$102.00	☐	
DAP Alex Plus 10.1 oz. White Acrylic Latex Caulk	Home Depot	1	$2.58	Store Pickup	$2.58	1	$5.16	☐	
RealSense D435i Depth Camera	Intel	1	$199.00	3 days	$208.02	0	$208.02	☑	
						Overall Cost			
				(assume business days)					

Figure 17: Bill of Materials

Appendix E - Risk Management

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engineering	Start Date: 3/31/2021	Revision Number: 1
Project:Manufacturing			Location(s): HPMI (High Performance Materials Institute)	
Team member(s): Bryson Potts, LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Mold	HPMI	LJ Earnest	Lacerations Breathing Fumes Burns	Gloves Ventilation Mask	Mask Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Layup	HPMI	Manning Owens	Lacerations Breathing Fumes Breathing Fibers Skin Inflammation Skin Irritation	Gloves Ventilation Mask	Mask Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Vacuum Seal	HPMI	Tamara McCaskill	Equipment Failure	Equipment used by profesional	Gloves Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low	Plan Safety Controls Supervisor Authorization
Curing	HPMI	Steven Harrington	N/A	Temperature	Gloves Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Sanding	HPMI	Bryson Potts	Frictions Burns Lacerations Breathing Particles Particles in Eyes	Gloves Ventilation Mask Goggles	Mask Gloves Goggles Long Sleeves Pants	Put Scraps in Trash Bag Take Directly to Dump Site	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Coating	HPMI	LJ Earnest	Breathing Fumes Eye Irritation Skin Irritation	Gloves Ventilation Mask Goggles Long Sleeves	Mask Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low	Plan Safety Controls Supervisor Authorization

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts		3/31/2021	Steven Harrington		3/31/2021
LJ Earnest		3/31/2021	Tamara McCaskill		3/31/2021
Manning Owens		3/31/2021			

Figure 18

Project Hazard Assessment Worksheet

PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engineering	Start Date: 3/31/2021	Revision Number: 1
Project: Wiring			Location(s): Room B309	
Team member(s): Bryson Potts,LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Connect Components	B309	Manning Owens	Lacerations Dropping Components	Gloves Grounding Steel Toe Shoes	Gloves Steel Toe Shoes Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
Connect Battery	B309	Tamara McCaskill	Electrocution Fire Acid Burns Breathing Fumes Dropping Battery	Gloves Grounding Steel Toe Shoes Ventilation Temp Control	Gloves Goggles Steel Toe Shoes Long Sleeves Pants	N/A	HAZARD: CONSEQ: Negligible Residual: Low-Med	Plan Safety Controls Supervisor Authorization
Soldering	B309	Steven Harrington	Burns Fumes Electrocution	Gloves Goggles Ventilation	Gloves Goggles Long Sleeves Pants	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts	[illegible]	3/31/2021	Steven Harrington	[illegible]	3/31/2021
LJ Earnest	[illegible]	3/31/2021	Tamara McCaskill	[illegible]	3/31/2021
Manning Owens	[illegible]	3/31/2021			

Figure 19

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engine	Start Date: 3/31/2021	Revision Number: 1
Project: Testing			Location(s): In-Water	
Team member(s): Bryson Potts,LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Final Product Testing	In-Water	Group Effort	Lacerations Collisions Getting Dragged	Approach Carefully Mark Sharp Areas	Close-Fitting Clothes Gloves	N/A	HAZARD: CONSEQ: Minor Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts	[illegible]	3/31/2021	Steven Harrington	[illegible]	3/31/2021
LJ Earnest	[illegible]	3/31/2021	Tamara McCaskill	[illegible]	3/31/2021
Manning Owens	[illegible]	3/31/2021			

Figure 20

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Dunlap	Phone#: 850-770-2204	Dept.: Mechanical Engineering	Start Date: 3/31/2021	Revision Number: 1
Project: Transportation			Location(s): N/A	
Team member(s): Bryson Potts,LJ Earnest, Manning Owens, Steven Harrington, Tamara McCaskill			Phone#: 850-326-2043	Email: abp19e@my.fsu.edu

Experiment Steps	Location	Person Assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Lifting	N/A	Group Effort	Wet Floors Loose Eletrical Cables Heaby Objects Dropping Entanglement Lacerations Falling Bruising Boken Bones Back Pain Death	Proper Technique Steel Toe Shoes Slip-Resistant Shoes	Close-Fitting Clothes Steel Toe Shoes	N/A	HAZARD: CONSEQ: Moderate Residual: Med	Limit Number of Workers Buddy System PI Approved Project Hazard Control Copy Sent to Safety Committee
Carrying	N/A	Group Effort		Proper Technique Steel Toe Shoes Slip-Resistant Shoes	Close-Fitting Clothes Steel Toe Shoes	N/A	HAZARD: CONSEQ: Moderate Residual: Med	Limit Number of Workers Buddy System PI Approved Project Hazard Control Copy Sent to Safety Committee
Securing	N/A	Group Effort	Crushing Lacerations Entanglement	Steel Toe/Slip Resistant Shoes	Close-Fitting Clothes Steel Toe Shoes	N/A	HAZARD: CONSEQ: Moderate Residual: Med	Limit Number of Workers Buddy System PI Approved Project Hazard Control Copy Sent to Safety Committee
Vehicle Operation	N/A	Manning	Crushing Lacerations Fire Death	Licensed Observant	Seatbelt	N/A	HAZARD: CONSEQ: Moderate Residual: Low-Med	Plan Safety Controls Buddy System Supervisor Authorization
							HAZARD: CONSEQ: Residual:	
							HAZARD: CONSEQ: Residual:	

Principal investigator(s)/ instructor PHA: I have reviewed and approved PHA worksheet.

Name	Signature	Date	Name	Signature	Date

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date	Name	Signature	Date
Bryson Potts	[illegible]	3/31/2021	Steven Harrington	Steve Harrington	3/31/2021
LJ Earnest	[illegible]	3/31/2021	Tamara McCaskill	[illegible]	3/31/2021
Manning Owens	[illegible]	3/31/2021			

Figure 21

Project Hazard Control- For Projects with Medium and Higher Risks

Name of Project:		**Date of submission:**
Team member	**Phone number**	**e-mail**
Bryson Potts	*850-326-2043*	abp19e@my.fsu.edu
LJ Earnest	*850-703-2455*	jde19@my.fsu.edu
Steven Harrington	*850-598-7820*	smh19n@my.fsu.edu
Tamara McCaskill	*850-815-8192*	tkm19@my.fsu.edu
Manning Owens	*334-596-6937*	mwo19@my.fsu.edu
Faculty mentor	**Phone number**	**e-mail**
Damion Dunlap	*850-770-2204*	ddunlap@fsu.edu
Patrick Walters	*NA*	walters.patrick.s@gmail.com

Rewrite the project steps to include all safety measures taken for each step or combination of steps. Be specific (don't just state "be careful").

Wiring: ensure that no one electrocuted by being cautious of live and dead wires
Manufacturing: ensure that no one breathes in or touches chemical that could compromise one's health status
Testing: ensure that no one is in the way of the boat during its propulsion
Transportation: ensure that everyone is wearing protective shoes so that in the scenario of the boat dropping on ones' foot, there would be some coverage. Also make sure that everyone lifts with proper form

Thinking about the accidents that have occurred or that you have identified as a risk, describe emergency response procedures to use.

If an accident were to occur, our first step would be to identify if the accident was critical (to the student) or not. If not critical, we will evaluate if anything is messed up and go from there. If a team member is in critical condition we will contact 911 first, then contact Dr. Dunlap and catch him up to speed with what happened.

List emergency response contact information:

- Call 911 for injuries, fires or other emergency situations
- Call your department representative to report a facility concern

Name	Phone number	Faculty or other COE emergency contact	Phone number
Bryson Potts	*850-326-2043*	*Damion Dunlap*	*850-770-2204*
LJ Earnest	*850-703-2455*	*Damion Dunlap*	*850-770-2204*
Steven Harrington	*850-598-7820*	*Damion Dunlap*	*850-770-2204*
Tamara McCaskill	*850-815-8192*	*Damion Dunlap*	*850-770-2204*

Figure 22

Manning Owens	*334-596-6937*	*Damion Dunlap*	*850-770-2204*
Safety review signatures			
Team member	Date	Faculty mentor	Date

Report all accidents and near misses to the faculty mentor.

Figure 23