MILESTONE 7: Concept Generation

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EML 4551C – Senior Design 1

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Table of Contents

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.

Hull Shape	Hull Material	Propulsion	Propulsion Amount	Object Detection Sensor	Localization	Electronics Enclosure	Cooling System
Displacement Hulls	Carbon-Fiber	Inboard Propeller	1 Propulsor	Ultrasonic	GPS	Yeti Enclosure	Fans (active intake) + Fan (active outtake)
Planing Hulls	Fiber-Glass	Outboard Propeller	2 Propulsors	InfraRed	Odometer & Gyroscope	Wooden Acrylic	Vents (passive intake) + Fan (active outtake)
Flat Bottom	Aluminum	Fan	3 Propulsors	LiDAR	Triangulation	Carboard Box	Fans (active intake) + Vent (passive outtake)
V-Bottom	Stainless Steel	Sailboat	4 Propulsors	Time of Flight		Carbon-Fiber Box	Liquid Cooling
Tri-Hull (Tunnel Hull)	Rubber	Rowing	Differential Propulsor	Camera/Image Processing		Plastic Box (PLA)	Mineral Water
Pontoon	Plastic (PLA)		2 Differential Propulsors			Plastic box (ABS)	
Semi-Displacement Hulls	Plastic (ABS)		2 Differential Propulsors + 1 Propulsor				
Multi-Hulls	Wood		2 Differential Propulsors + 2 Propulsors				
Catamarans	Titanium		4 Differential Propulsors				
Trimarans	PVC Pipe						
	Ferro-Cement						
	Polyethylene Foam						
	Flex-Tape						
	Flex-Seal						
	Aero-Gel						

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 1, 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.

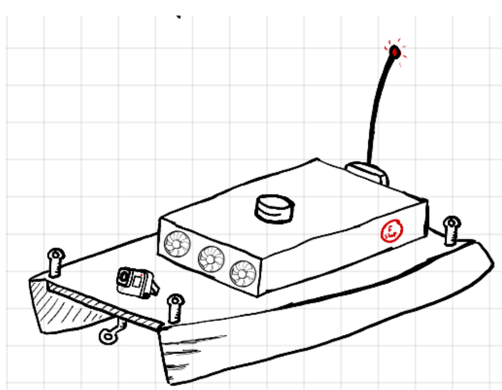


Figure 1: Concept 1 Perspective View

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.

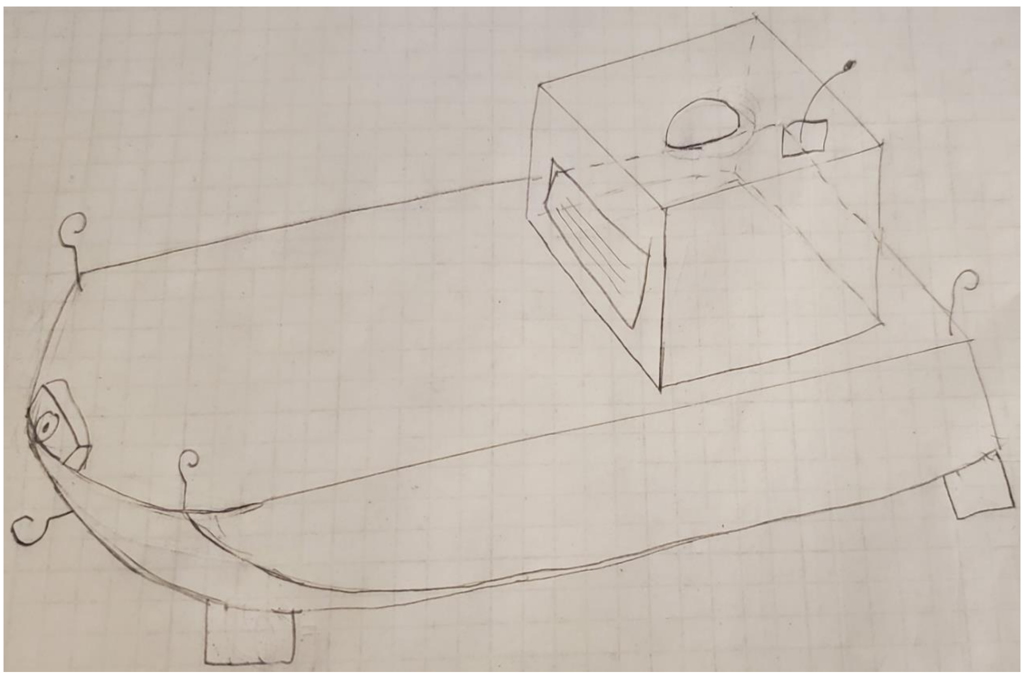


Figure 1: Concept 2 Perspective View

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.

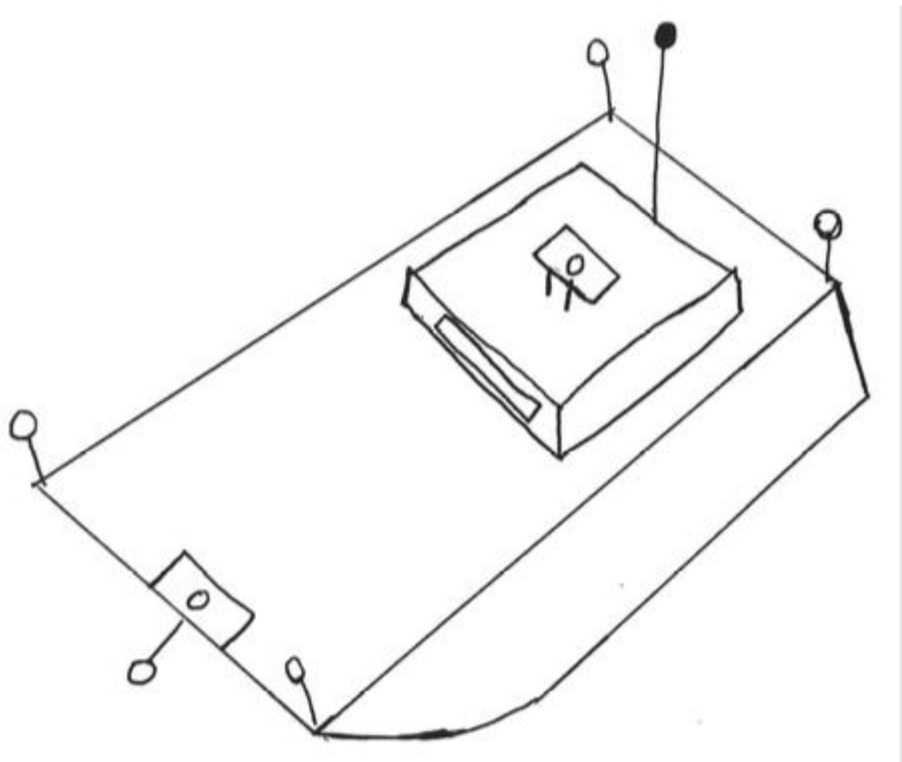


Figure 3: Concept 3 Perspective View

Concept 4

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 4: Concept 4 Perspective View

Concept 5

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 5 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.

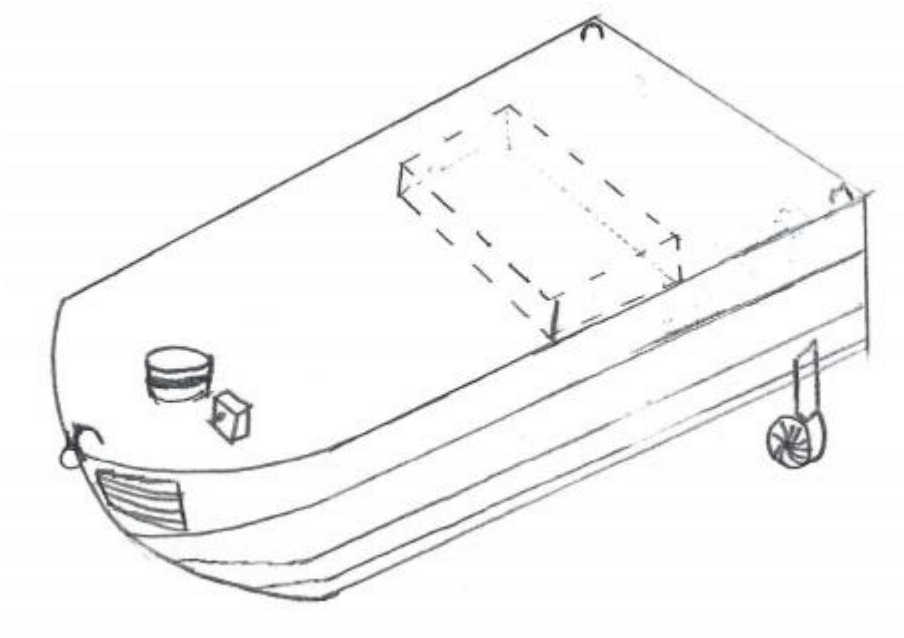


Figure 5: Concept 5 Perspective View

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

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.

Appendix A - Concept Figures

Concept 1

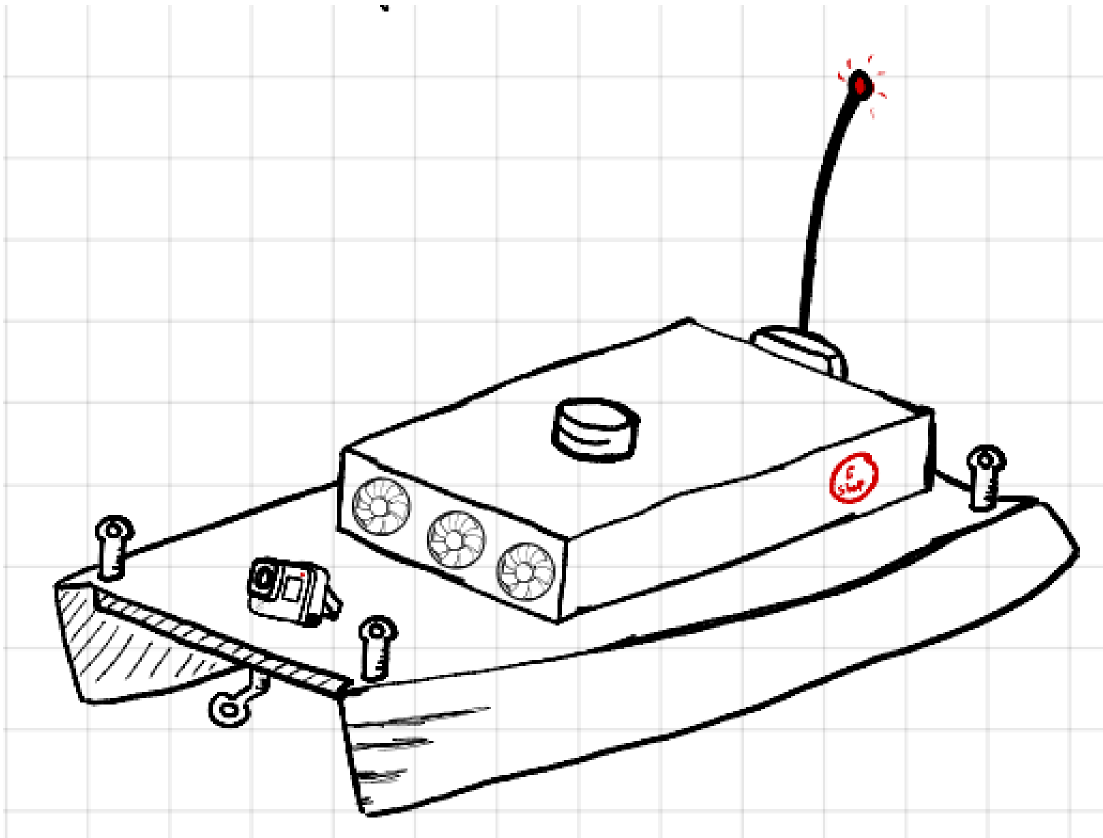


Figure 1: Concept 1 Perspective View

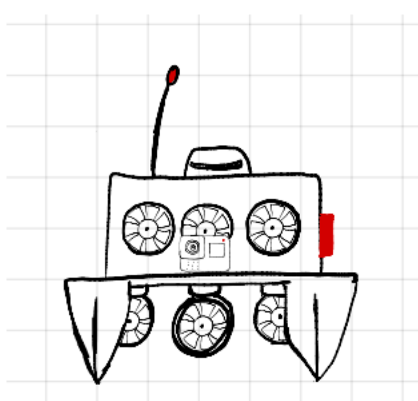
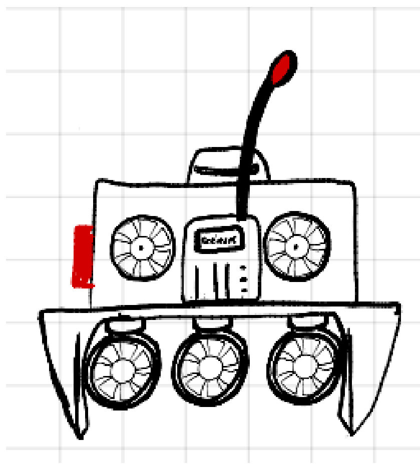
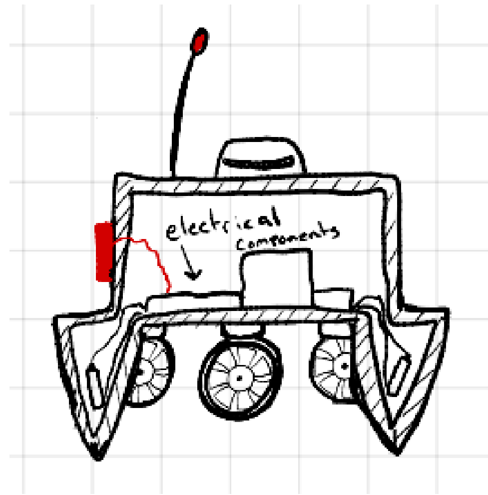


Figure 1: Concept 1 Front View

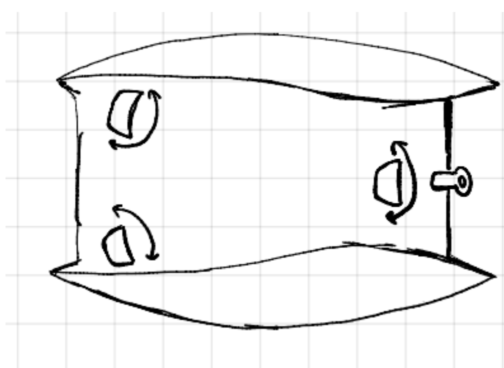
Figure 1: Concept 1 Additional Views



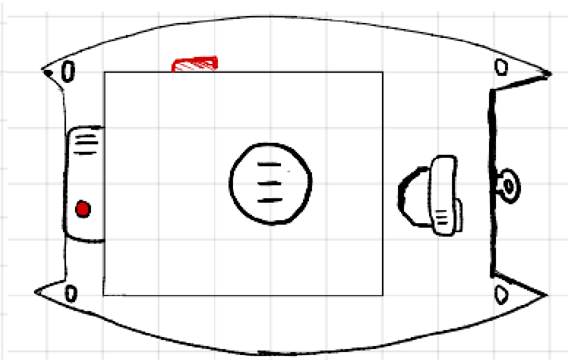
Rear View



Cross-Section View



Bottom View



Top View

<u>Concept 2</u>

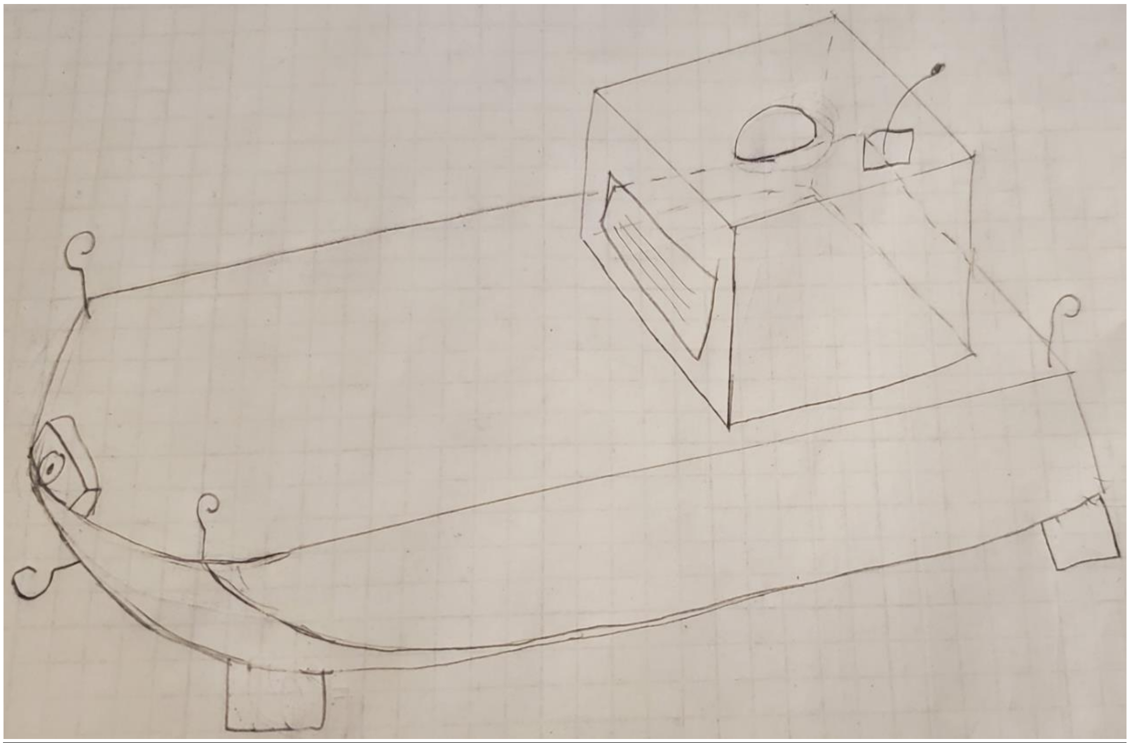


Figure 2: Concept 2 Perspective View

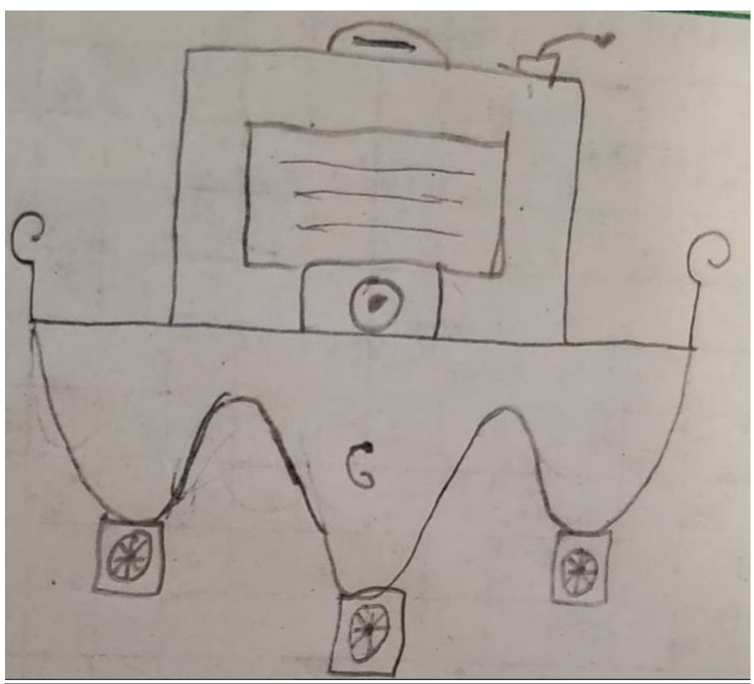
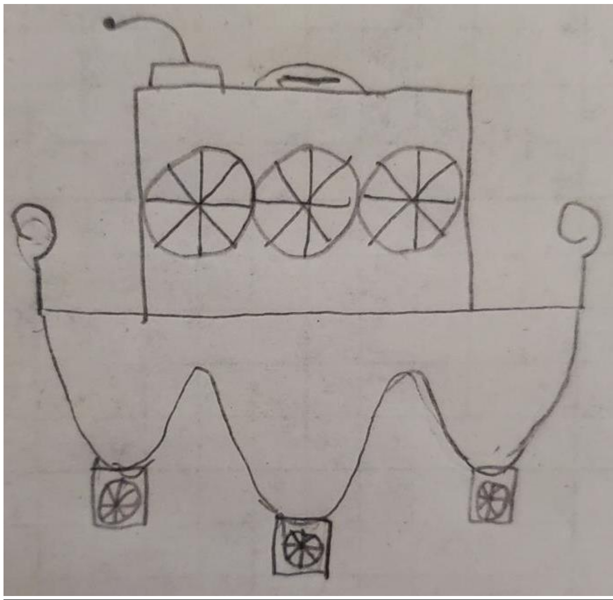
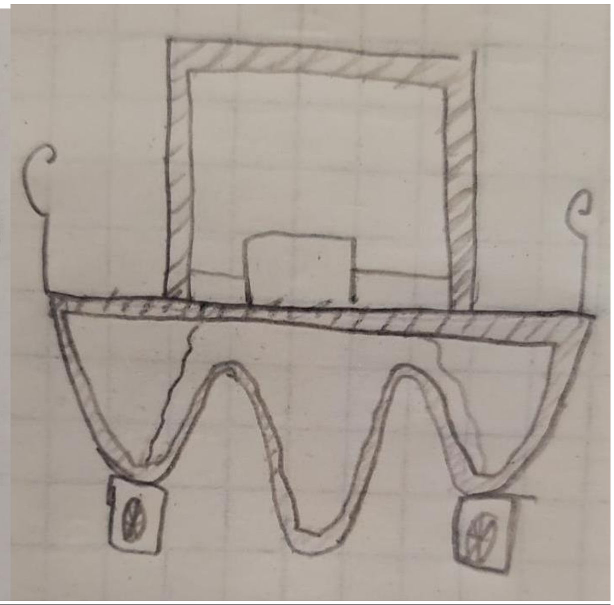


Figure 2: Concept 2 Front View

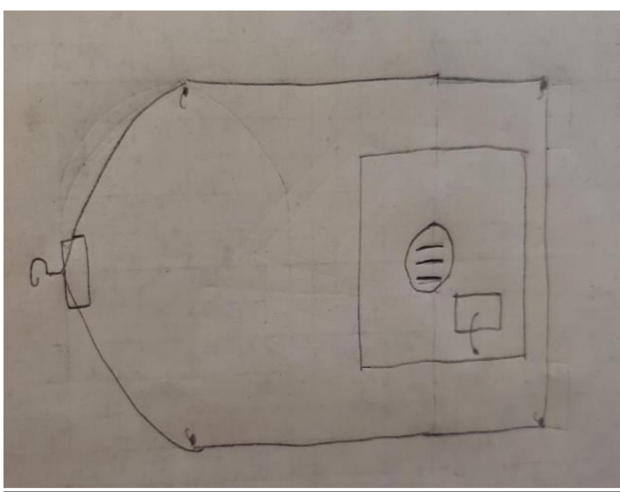
Figure 2: Concept 2 Additional Views



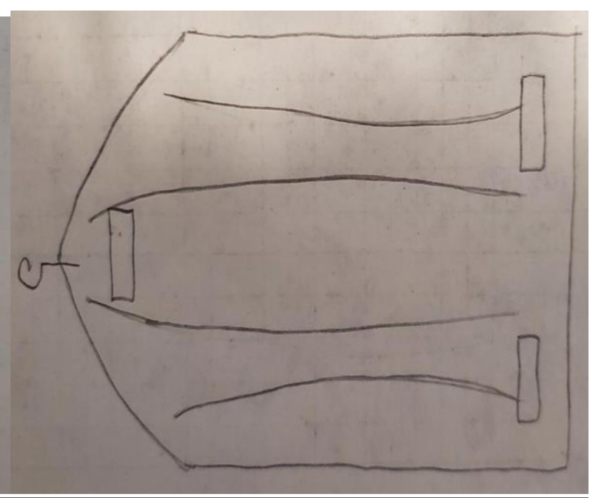
Rear View



Cross-Section View



Top View



Bottom View

Concept 3

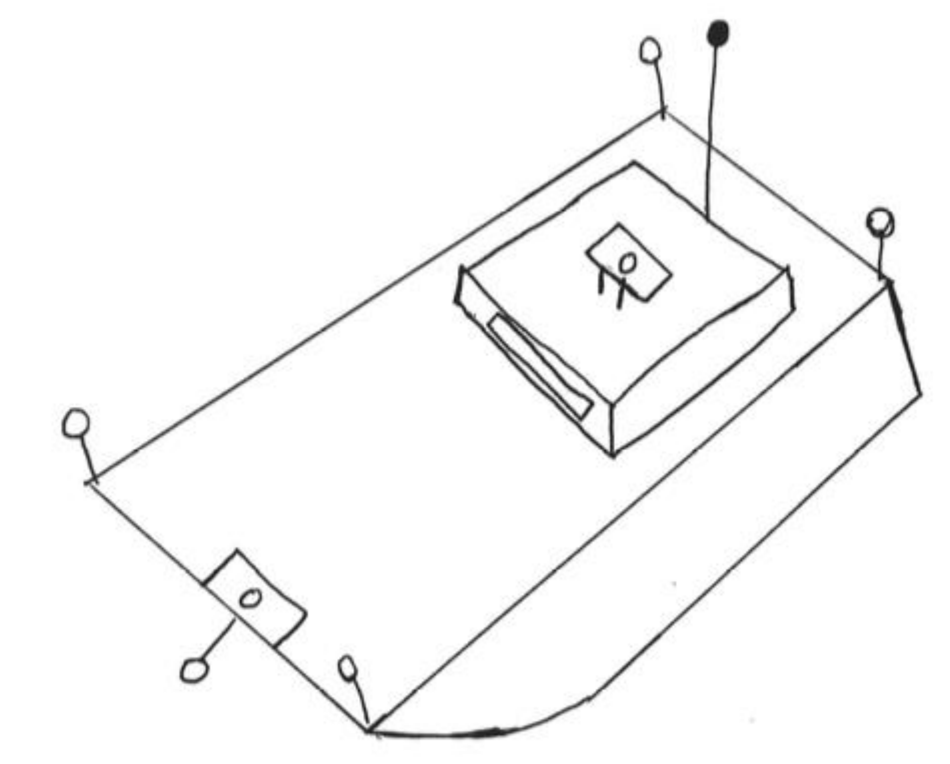


Figure 3: Concept 3 Perspective View

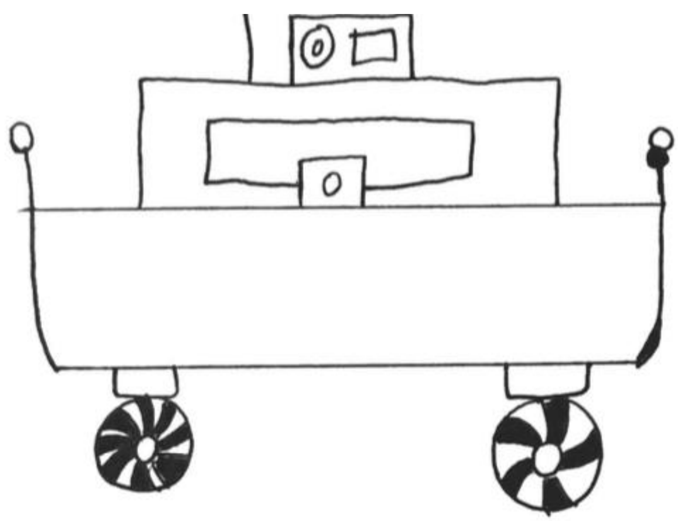
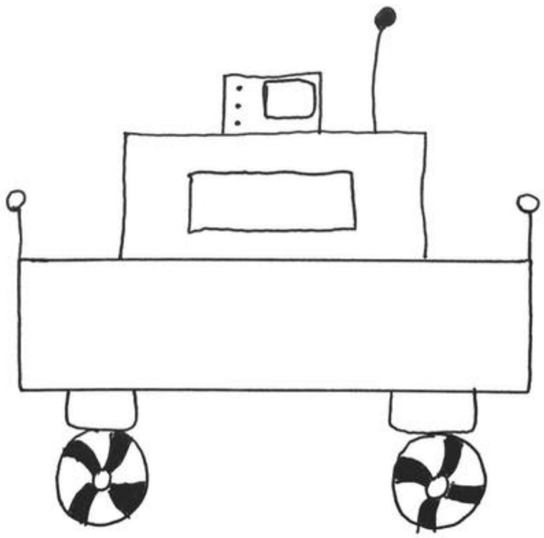
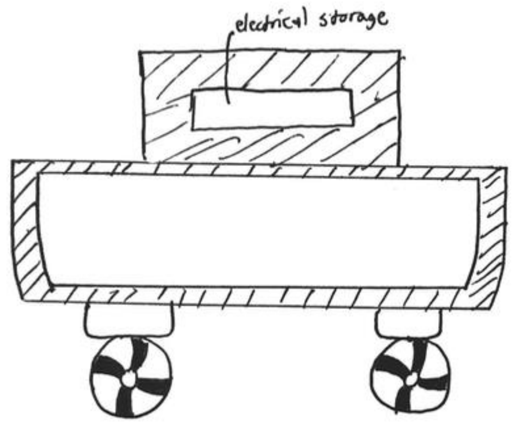


Figure 3: Concept 3 Front View

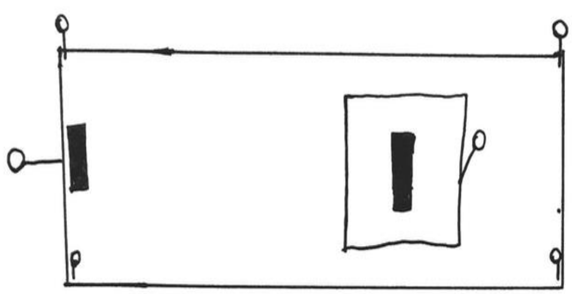
Figure 3: Concept 3 Additional Views



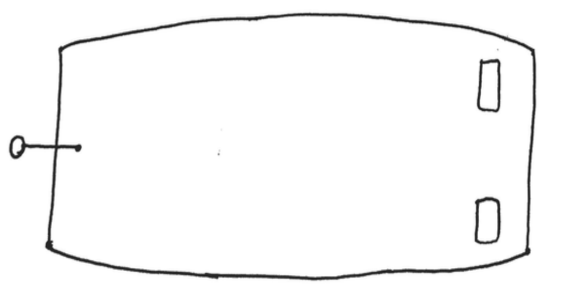
Rear View



Cross-Section View



Top View

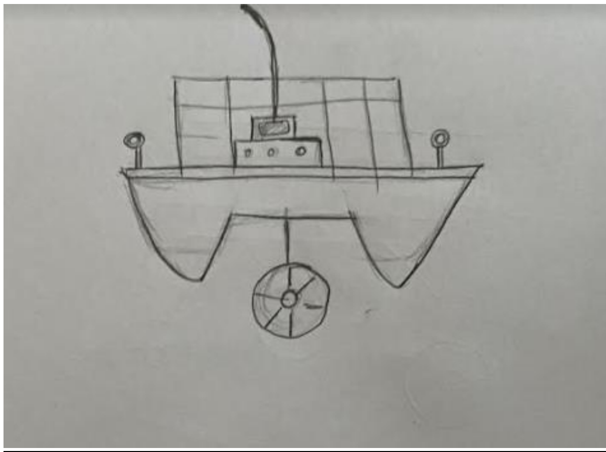


Bottom View

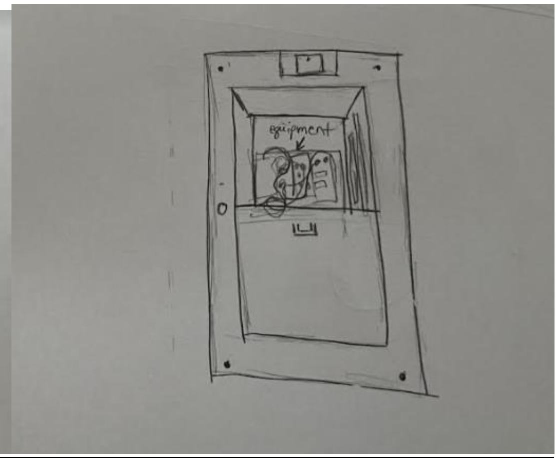
Concept 4

Figure 4: Concept 4 Perspective

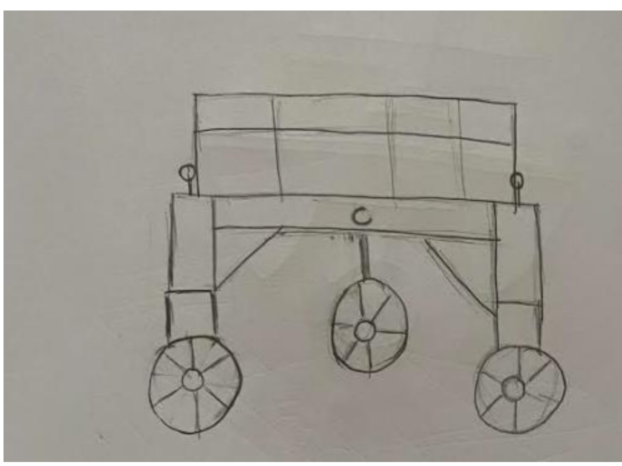
Figure 4: Concept 4 Additional Views



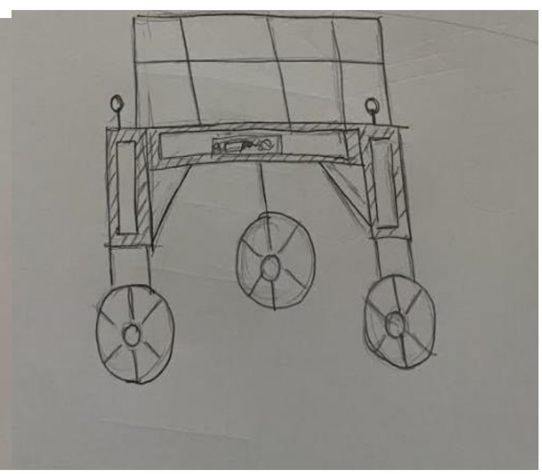
Front View



Top View



Rear View



Cross-section View

Concept 5

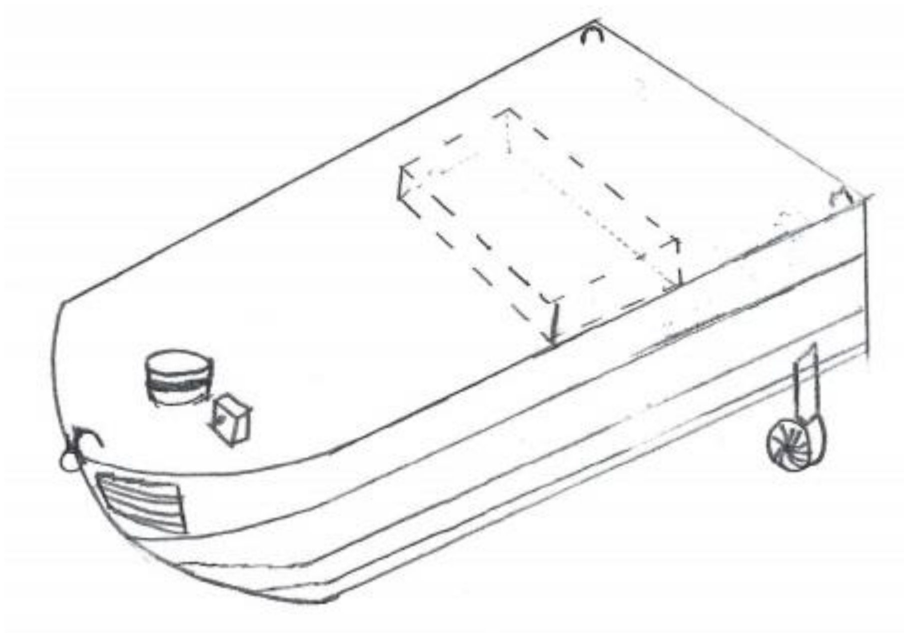


Figure 5: Concept 5 Perspective VIew

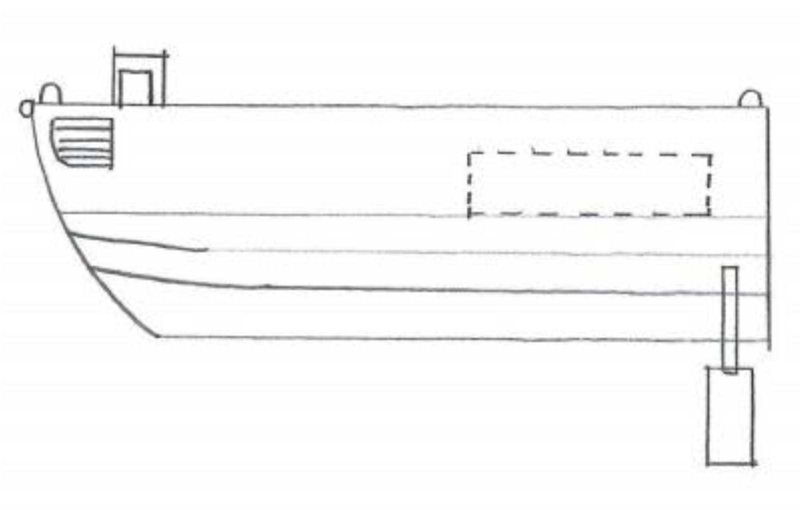
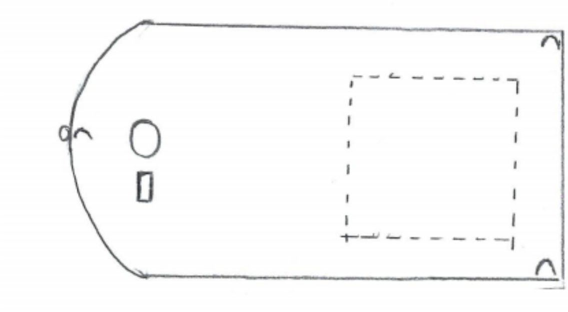
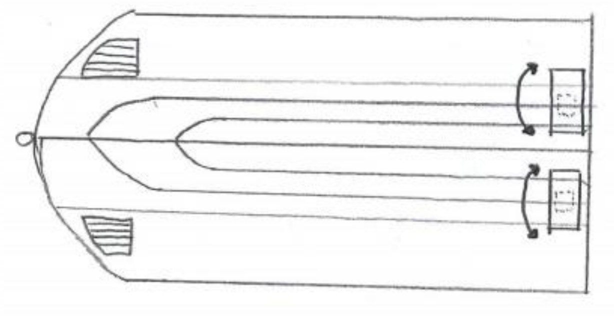


Figure 5: Concept 5 Side View

Figure 5 : Concept 5 Additional VIews



Top View



Bottom View

Front View

Back View

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

Reciever 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