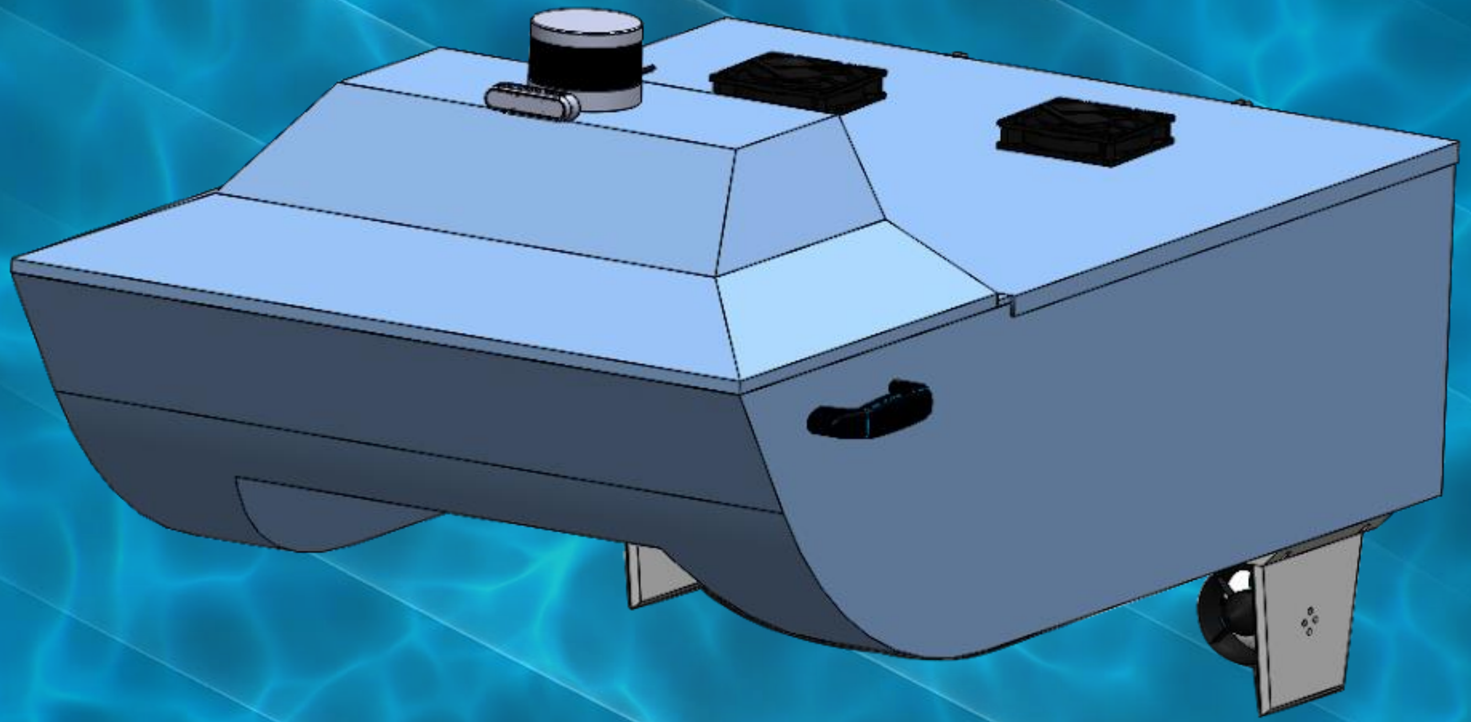


EML 4552/EEL 4915C: ROBOBOAT 2020

Final Presentation

Department of Mechanical Engineering
Department of Electrical and Computer Engineering

FAMU-FSU Engineering

Team Introductions

Brandon Bascetta
Mechanical Design Lead

Courtney Cumberland
Manufacturing Lead

Toni Weaver
Systems Lead

Team Introductions

Madison Penney
Electrical Design Lead

Mark Hartzog
Software Lead

Peter Oakes
Integration Lead

ADVISORS

EE Mentor/Academic Advisor
Dr. Geoffrey Brooks
Electrical Engineering,
FSU Panama City

ME Mentor/Academic Advisor
Dr. Damion Dunlap
Mechanical Engineering,
FSU Panama City

Peter Oakes

ADVISOR

<u>Technical Advisor</u>

Dr. Joshua Weaver

Senior Scientist of Autonomy,

Naval Surface Warfare Center (NSWC)

Peter Oakes

OBJECTIVE

Create a new boat for the 2020 RoboBoat competition.

Madison Penney

PROJECT SCOPE

The scope of this project is to manufacture and wire a competition ready boat. This project will also involve basic software for the future RoboBoat competition.

Madison Penney

WORK BREAKDOWN

- Sensor Design - Brandon
- Manufacture - Courtney
- Power – Madison/Peter
- Sensor Integration - Peter/Toni
- Software – Mark/Toni

Madison Penney

PROJECT INSPIRATION

Toni Weaver

Project Inspiration

Roboboat is an autonomous boat competition, created by Robonation and Sponsored by Office of Naval Research, Naval Information Warfare Center as well as by several corporations.

Toni Weaver

Project Inspiration

Last year, a team of FSU and Gulf Coast students participated in RoboBoat's 2019 competition

Toni Weaver

PROJECT BACKGROUND

Mark Hartzog

Project Background - ME

Beginning in the Fall 2019 semester, the Mechanical Engineering team began designing a new boat.

Their goal was to design and manufacture a boat suitable for the tasks required by the roboboat competition. The end product was to be a manufactured hull, with integrated sensor mounts and basic navigation.

Their team consisted of Brandon Bascetta, Courtney Cumberland and Toni Weaver.

Mark Hartzog

Project Background - EE

In Spring 2020, the electrical engineering team began their senior design project.

The ultimate goal of this team was to wire the components and sensors needed for the competition within the boat manufactured by the Mechanical Engineering Senior Design team.

Their end product was to be a completely powered boat, with accessible wiring integrating a previous teams power box. They were to also complete the software for basic autonomous behavior.

This team consisted of Mark Hartzog, Peter Oakes, and Madison Penney.

Mark Hartzog

Project Background - Combined Project

In June 2020, with the outbreak of Covid-19, the decision was made to bring both projects together and also move to a virtual platform.

The team then combined their projects to complement each other.

The team end product goal became a fully functioning boat capable of completing at least one task for the RoboBoat competition.

Mark Hartzog

PROJECT REQUIREMENTS

Peter Oakes

PROJECT REQUIREMENTS

- Boat shall be positively buoyant.
- Boat shall be manufactured to withstand normal use during testing and competition.
- Boat shall have all necessary sensors integrated into hull.
- Boat shall be wired up and competition ready.
- Boat shall contain custom power box.
- Boat shall have basic motor mixing and RC control.
- Boat shall be capable of basic waypoint navigation.

Peter Oakes

Design Decision Making

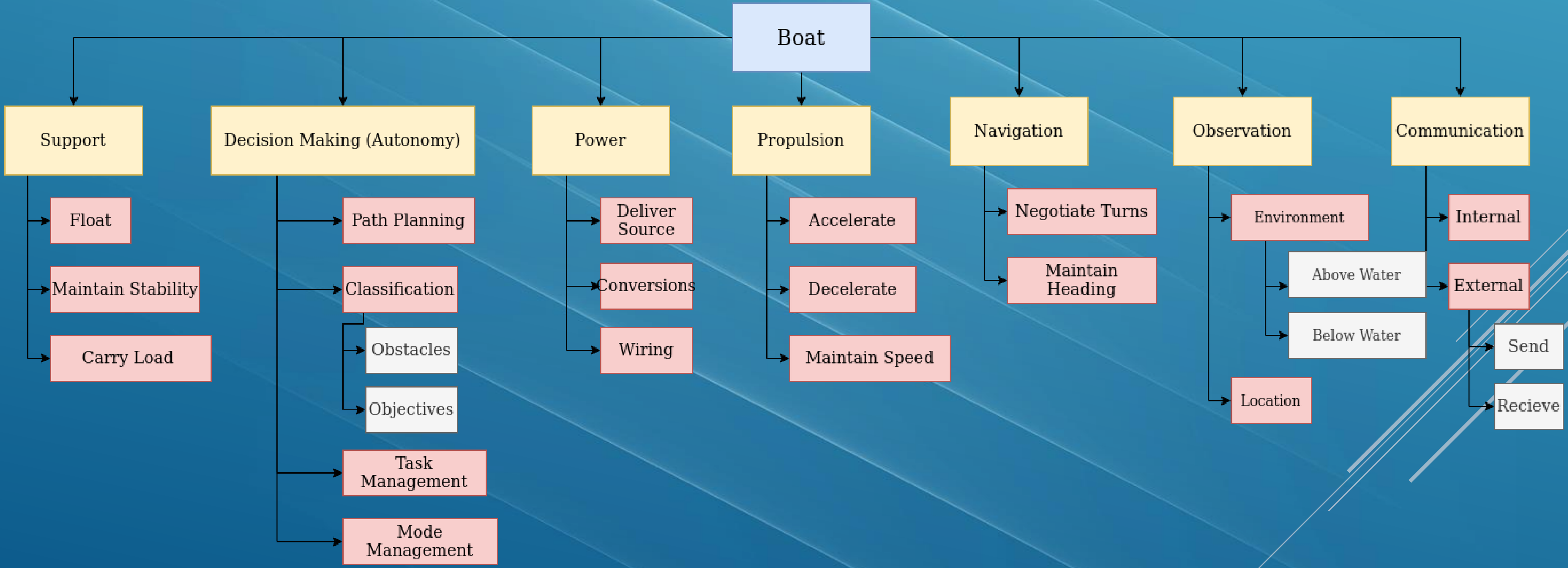
Brandon Bascetta

CUSTOMER NEEDS

Questions Asked	Need Statement
What features of the boat design are most important to you?	Provide adequate boat space for all components and enough space to work on.
Do you believe the boat should be modular, or an "all in one" design?	Able to easily change parts to the boat.
Given the required dimensions of 3 ft width, 6 ft length and 3 ft height, what features do you believe should be given the most priority/room in the boat?	Adequate space to work with components, air flow, and working space. Also, proper weight distributions.

Brandon Bascetta

FUNCTIONAL DECOMPOSITION



Brandon Bascetta

BOAT DESIGN INSPIRATIONS: MONO-HULL VS. CATAMARAN

Brandon Bascetta

BOAT DESIGN INSPIRATIONS: BOSTON FIREBOAT

Brandon Bascetta

CONCEPT DEVELOPMENT

Hull	Super Structure (Material)	Propulsion	Sensor	Cooling System	Connection
Catamaran	Cardboard	Differential Thrus	Spider Rail	Fans(Active)	Rail System
Monohull	Tuberware	2 vector Thrust	Tree Stump	Vents (Passive)	Grenade Pin
Round	Pelican Box	4 Vector Thrust	Narwhal	Water Cooling	Snap Down
Trimaran	Carbon Fiber	rudder	Hole-y Board	Mineral Oil	Clam Shell (Hinge)
Hovercraft	Same Material	Sail	Tower of Terror		Convertable (Corvette)
	Wood				

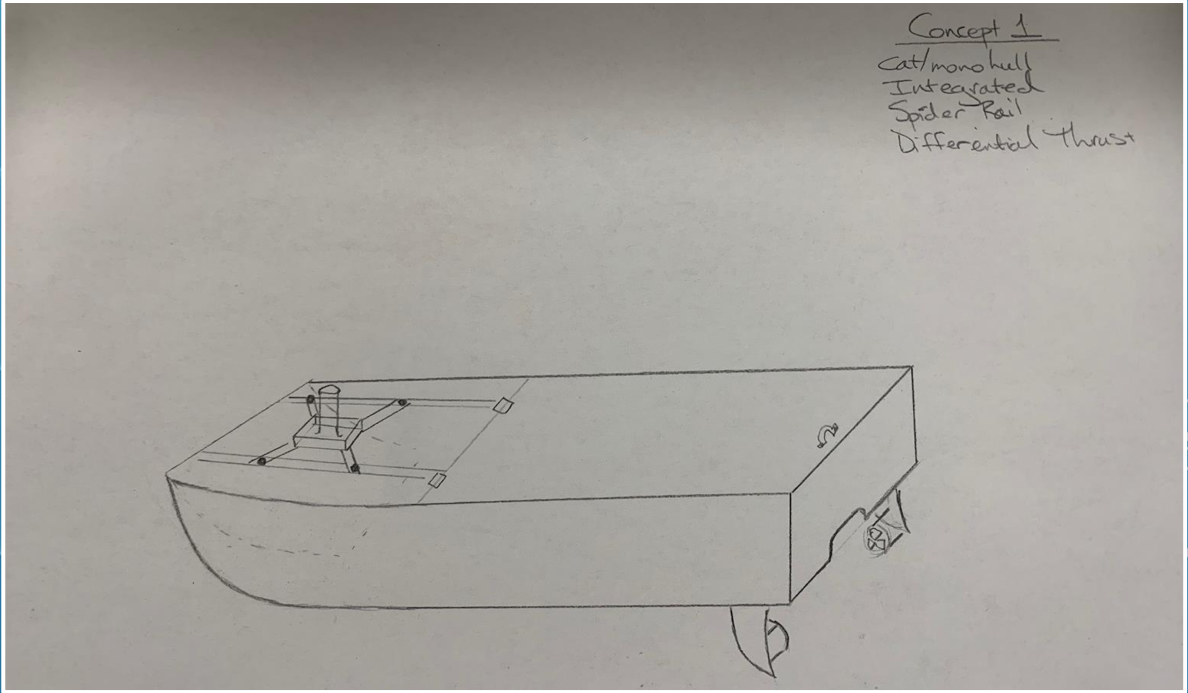
	Conept Assemblies					
Concept 1	Cat/Mono	Same Material	Differential	Spider Rail	Active	N/a
Concept 2	Cat/Mono	Modular	Differential	Spider Rail	Active	Grenade Pins
Concept 3	Long Cat	Same Material	Differential	Spider Rail	Active	N/a
Concept 4	Long Cat	Modular	Differential	Spider Rail	Active	Snap Down

Brandon Bascetta

CONCEPT RENDERINGS: CONCEPT 1

Concept 1:

- Mono Hull/Catamaran Hybrid
- Integrated Hull
- Differential Thrust
- Active Air Cooling
- "Spider Rail" Sensor Mount

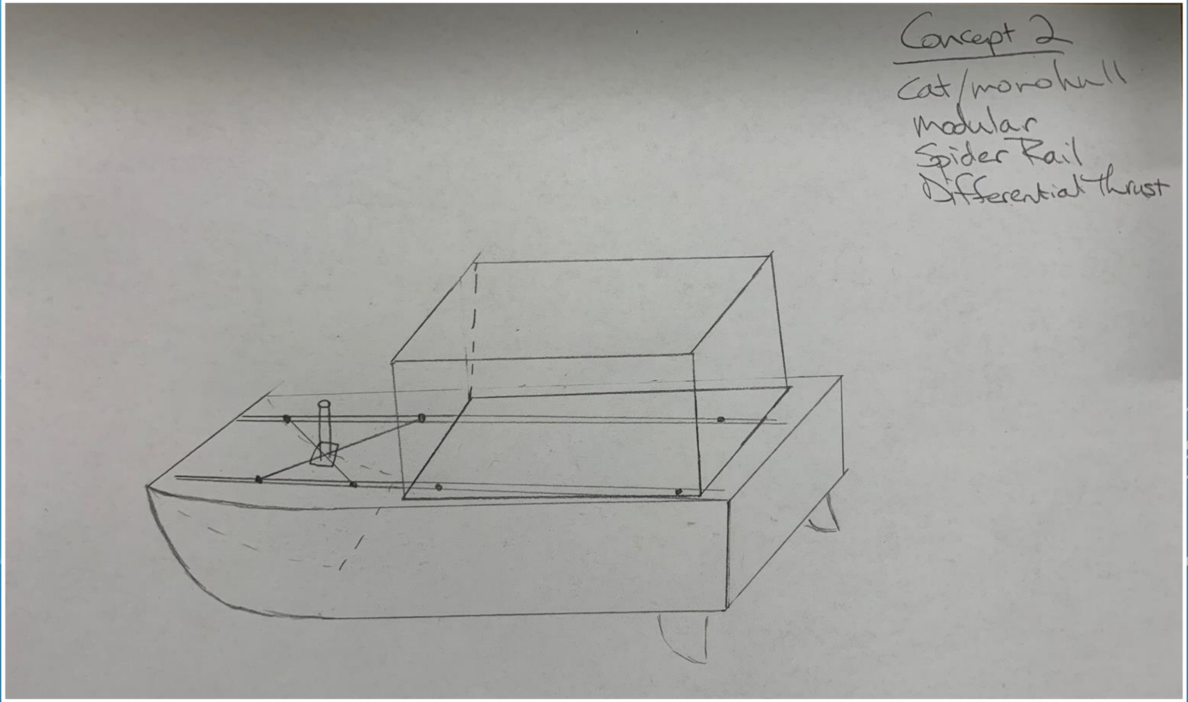


Brandon Bascetta

CONCEPT RENDERINGS: CONCEPT 2

Concept 2:

- Mono Hull/Catamaran Hybrid
- Modular
- Differential Thrust
- Active Air Cooling
- "Spider Rail" Sensor Mount
- "Grenade Pin" Connection

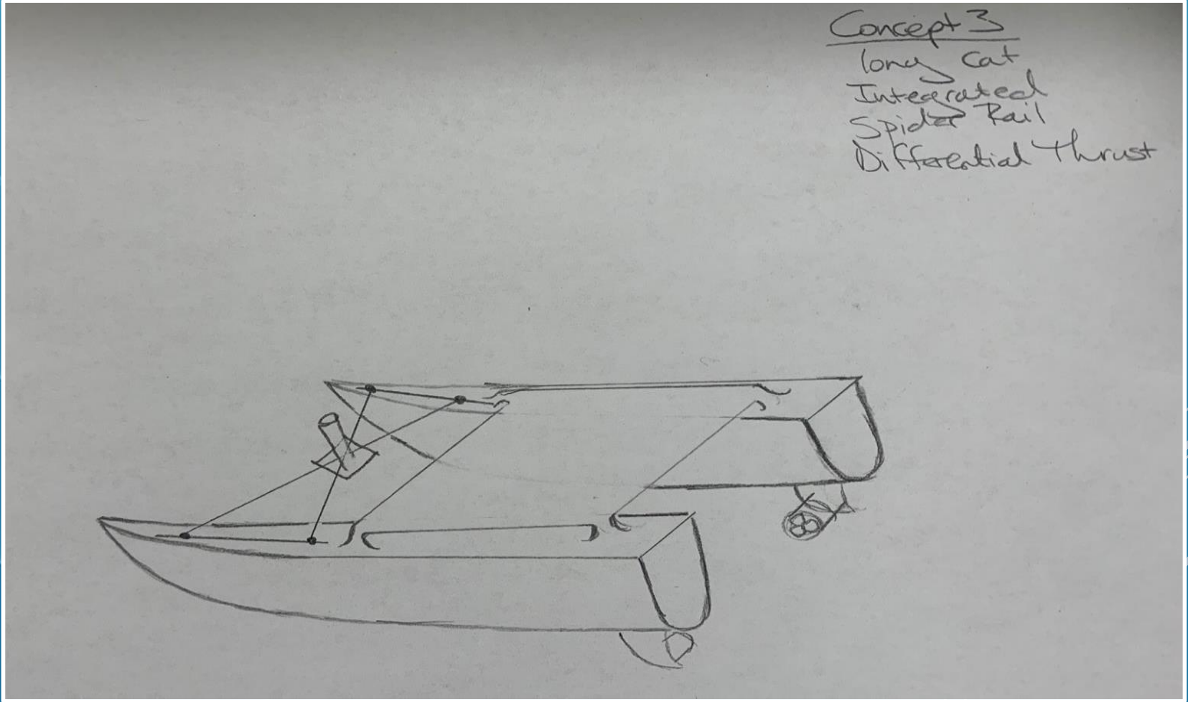


Brandon Bascetta

CONCEPT RENDERINGS: CONCEPT 3

Concept 3:

- Long Catamaran Hull
- Integrated Hull
- Differential Thrust
- Active Air Cooling
- "Spider Rail" Sensor Mount

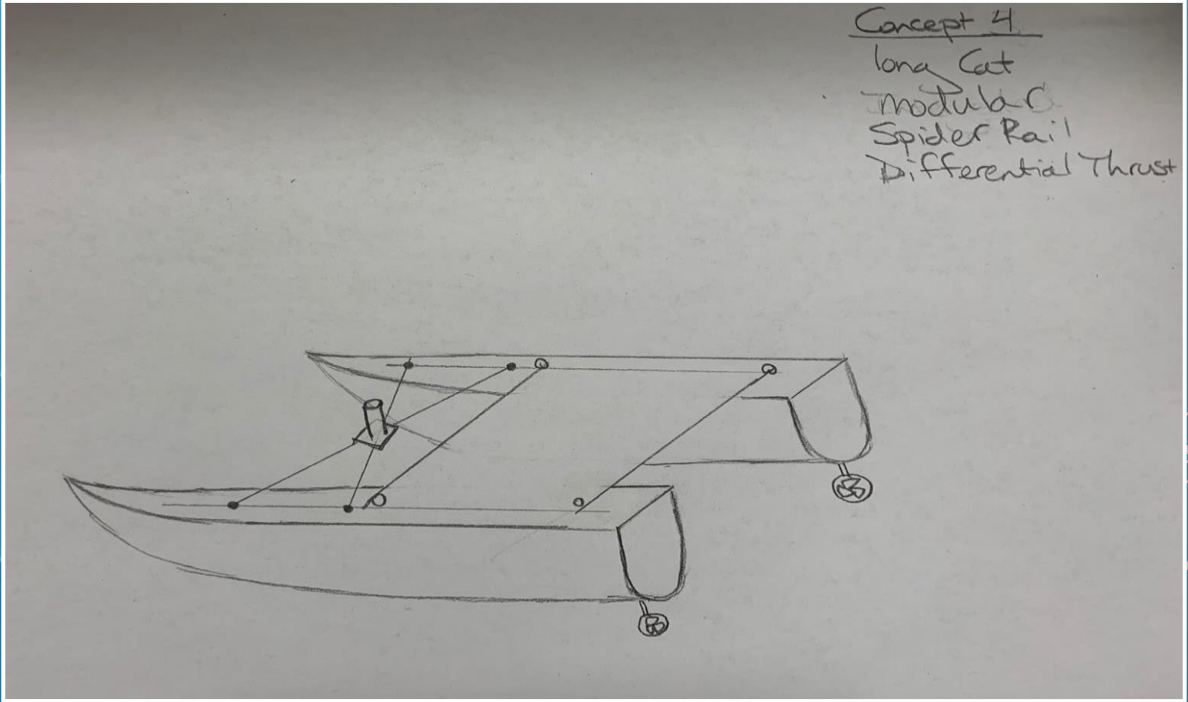


Brandon Bascetta

CONCEPT RENDERINGS: CONCEPT 4

Concept 4:

- Long Catamaran Hull
- Modular
- Differential Thrust
- Active Air Cooling
- “Spider Rail” Sensor Mount
- “Grenade Pin” Connections



Brandon Bascetta

PUGH CHART

Selection Criteria	DATUM (Wilson)	1	2	3	4
Stability		+	+	+	+
Aesthetics		+	+	+	+
Maneuvaribility		+	+	+	+
Modularity		S	+	S	+
Deck Space		+	+	+	+
Manufacturability		+	+	+	+
Speed		+	+	+	+
Number of +'s		6	7	6	7
Number of -'s		0	0	0	0

Selection Criteria	DATUM (Concept 4)	1	2	3
Stability		S	S	S
Aesthetics		S	S	S
Maneuvaribility		+	+	S
Modularity		-	S	-
Deck Space		+	-	S
Manufacturability		-	-	-
Speed		+	+	+
Number of +'s		3	3	1
Number of -'s		2	2	2

Brandon Bascetta

BINARY PIECEWISE COMPARISON

	1	2	3	4	5	6	7	Total
Stability	-	1	0	1	1	1	1	**5**
Aesthetics	0	-	0	1	1	1	0	**3**
Maneuvaribility	1	1	-	1	1	1	1	**6**
Modularity	0	0	0	-	0	1	0	**1**
Deck Space	0	0	0	1	-	1	1	**3**
Manufacturability	0	0	0	0	0	-	1	**1**
Speed	0	1	0	1	0	0	-	**2**

Brandon Bascetta

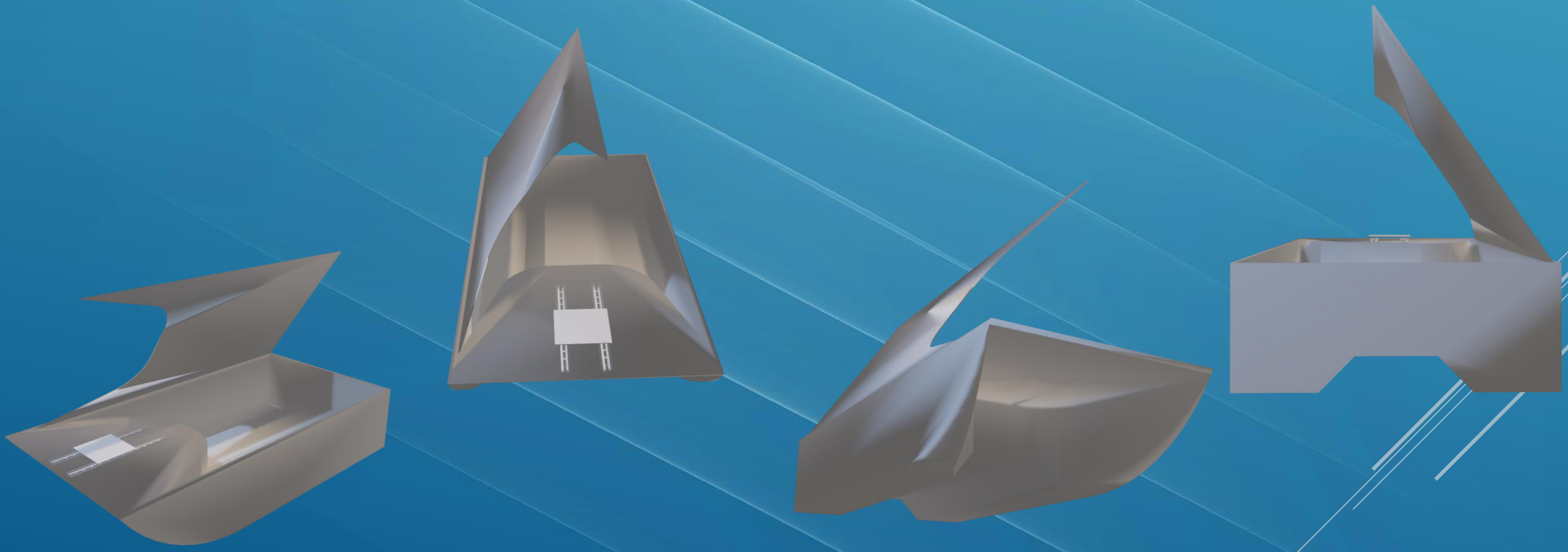
CONCEPT SELECTION

Customer Requirements	Importance Weight Factor	Concept 1	Concept 2	Concept 3	Concept 4
Stability	5	3	3	3	3
Aesthetics	3	3	3	3	3
Maneuverability	6	1	1	3	3
Modularity	1	0	9	0	9
Deck Space	3	9	3	1	0
Manufacturability	1	3	3	9	9
Speed	2	3	3	1	1
Raw Score:	189	66	57	56	62

Concepts	
1	monocat integrated
2	monocat modular
3	long cat not integrated
4	long cat modular

Brandon Bascetta

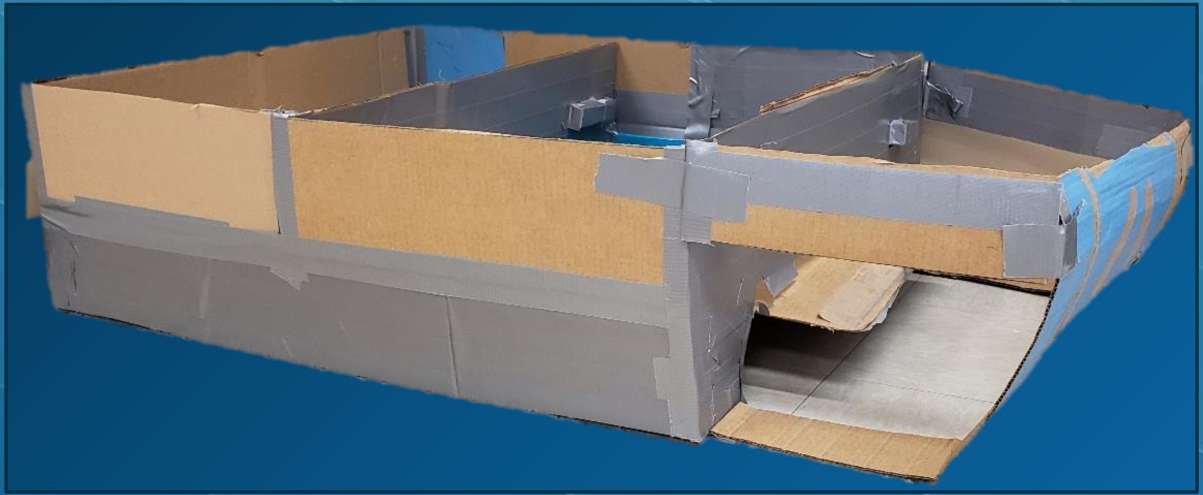
CONCEPT RENDERINGS: HIGHER FIDELITY DESIGN



Brandon Bascetta

FIRST BOAT DESIGN

- The original dimensions were 32” x 60”
- Physical boat was modeled out of cardboard



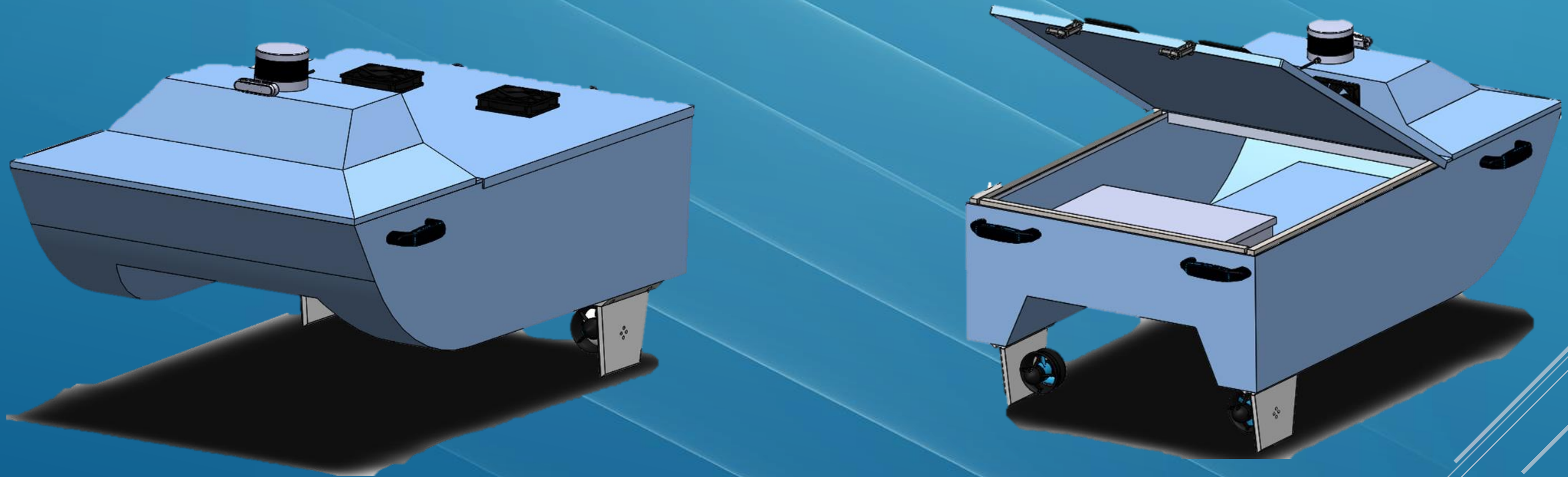
Brandon Bascetta

SECOND BOAT DESIGN

- It was decided that the first boat design was too large.
- Physical mockups of the sensors/components being used to create a layout the space needed.
- The boat was then reduced to 30" x 50"

Brandon Bascetta

FINAL BOAT DESIGN



Brandon Bascetta

BOAT MANUFACTURING PLAN

Courtney Cumberland

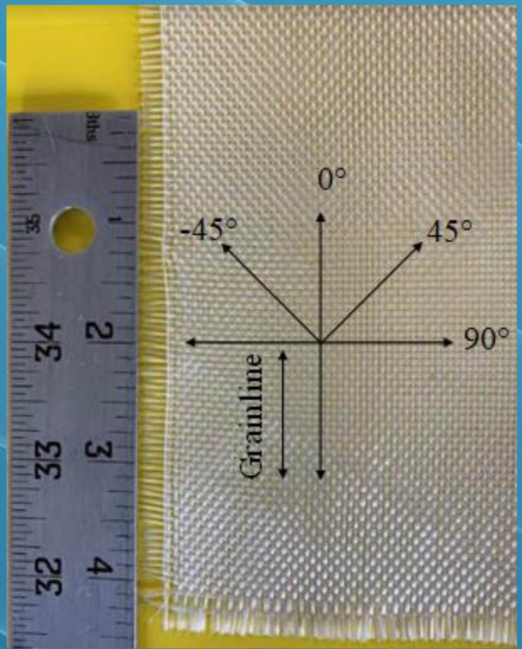
Manufacturing: Previous Work

Material Selection

Composite Chosen: 6 oz Plain Weave Fiberglass Cloth, Fiberglass Mat and Epoxy Resin!!

Reasons:

- Low Cost
- Easy manufacturability
- Anti-Corrosive
- High strength to weight ratio



Plain Weave Description:

- Weight : 6 oz per square yard
- Thickness: 0.0093"
- Weave: 1 over-1 under

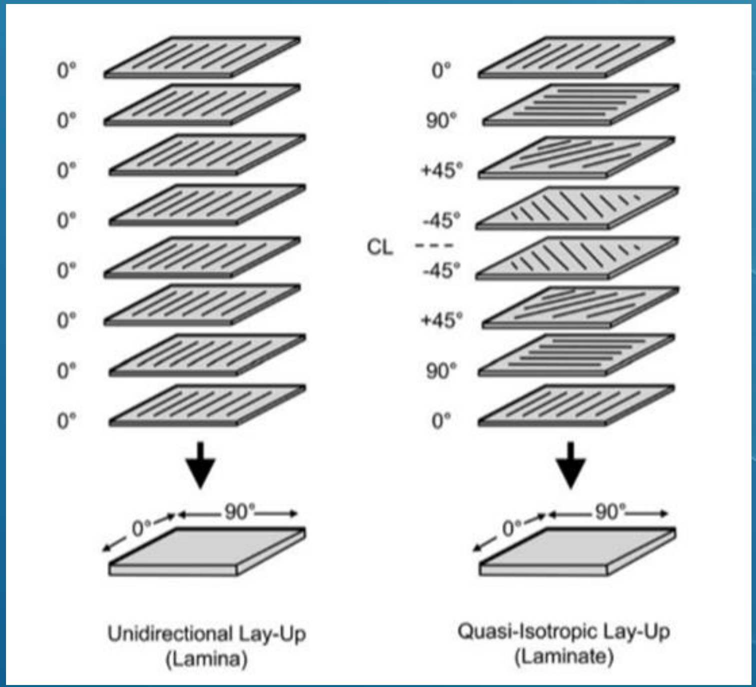
Mat Description:

- Weight : 13.5 oz per square yard
- Thickness: 0.013"
- Weave: omnidirectional

Courtney Cumberland

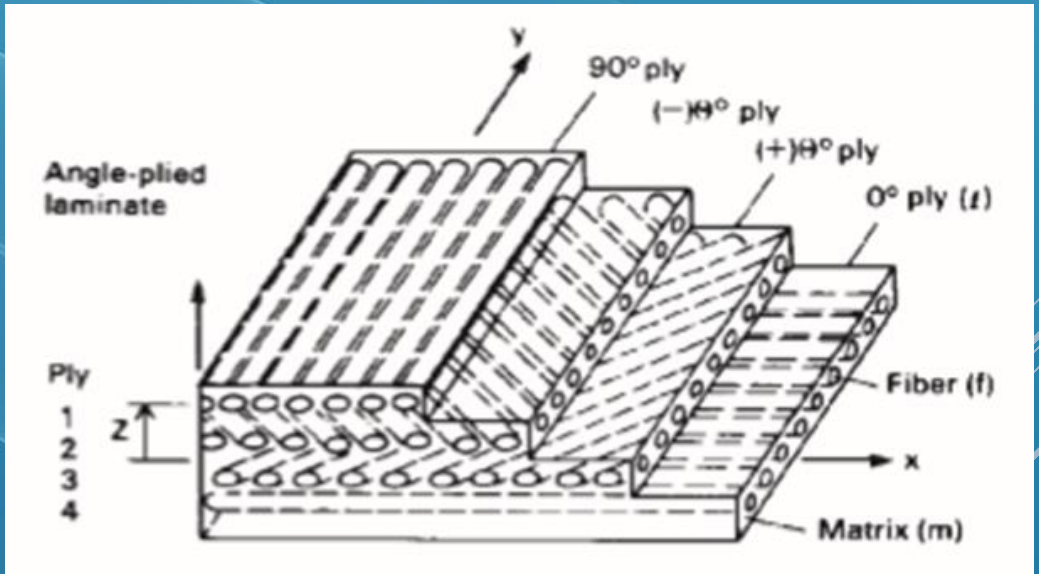
Manufacturing: Previous Work

Fiber Orientation



"Because the fiber orientation directly impacts mechanical properties, it seems logical to orient as many of the layers as possible in the main load-carrying direction. While this approach may work for some structures, it is usually necessary to balance the load-carrying capability in a number of different directions, such as the 0°, +45°, -45°, and 90° directions."

~https://www.asminternational.org/documents/10192/1849770/05287G_Sample_Chapter.pdf



~www.shipstructure.org/pdf/403.pdf

Courtney Cumberland

Manufacturing

Manufacturing Plan

To manufacture the boat hull, a foam mold was created for the top and bottom sections. It was tested for buoyancy in a pool and floated while supporting 12 pounds of weight. Next, the fiberglass cloth and fiberglass mat layers were applied with epoxy resin. Three layers of cloth and one layer of mat were used. The cloth will have grainline directions of 0º, 45º, 90º, one layer each. The fiberglass mat does not have a grainline direction. The fiberglass hull was removed from the mold and sanded down to a smooth finish. The final step was applying a moisture resistant paint.

Courtney Cumberland

Boat Hull: Testable Requirements

Requirements:

- Will the boat hull float or sink?
- How much weight will it be able to carry?
- Will the boat hull take on water at any location?
- The fiberglass will have limited deflection
- The hull will be as lightweight at possible.

What will constitute a passing score?

- The boat floats.
- The boat will carry 15 pounds.
- There will be no leaks in the hull
- Deflection will be less than ⅛"
- The boat will weigh less than 20 pounds

Courtney Cumberland

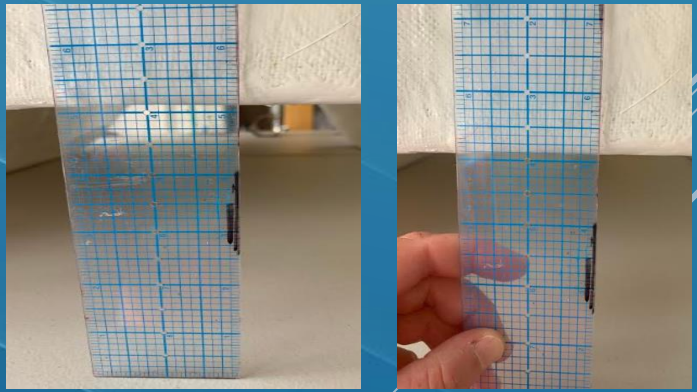
Boat Hull: Results

IT PASSED!!

After testing the hull in the hot tub, it floated for 30 minutes carrying a load of 24 pounds with no leaks at the end.

Hull Weight: 17.8 pounds

Deflection at center: 0 inches



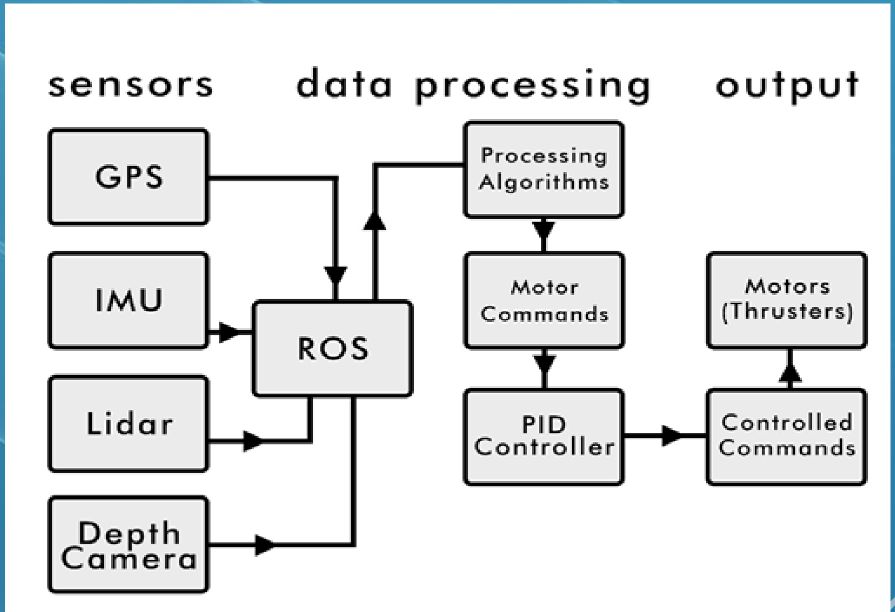
Courtney Cumberland

BOAT WIRING AND DEVICE INTEGRATION

Peter Oakes/Madison Penney

Hardware: Previous Work

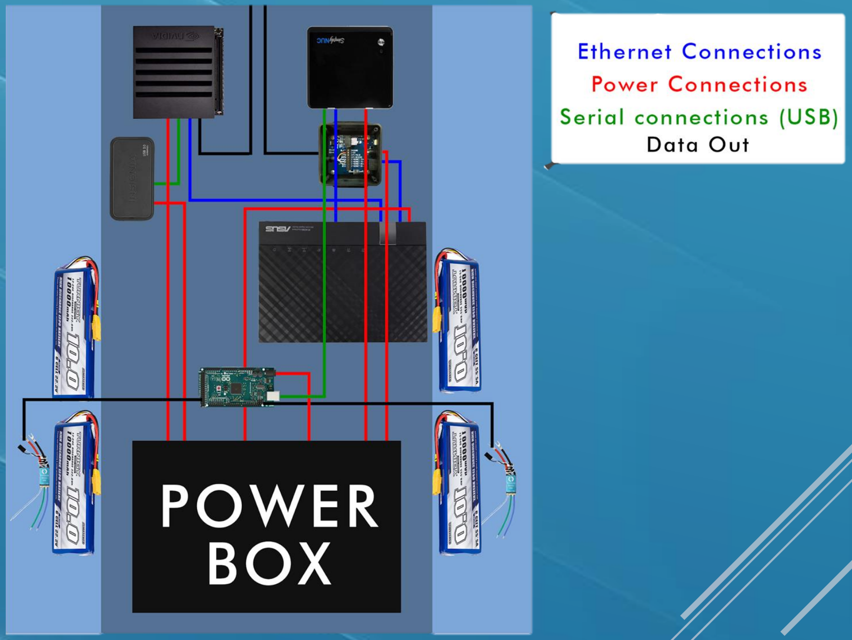
To begin the testing and prototyping of the software, the hardware needed to be assembled. For our team the hardware specifically consisted of sensor devices, networking devices, microprocessors, and computers. These sensors needed to be wired to the computer using USB and network connections.



Peter Oakes

Hardware: Previous Work

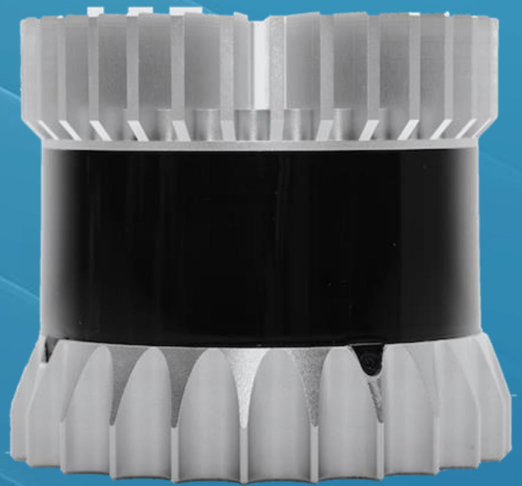
Device
Computer #1 (Simply NUC)
Computer #2 (Jetson Xavier)
LiDAR
Router
ESCs (x2)
Arduino Mega (x2)
DC Fan
USB Hub (includes RealSense camera)



Peter Oakes

Sensors: LiDAR

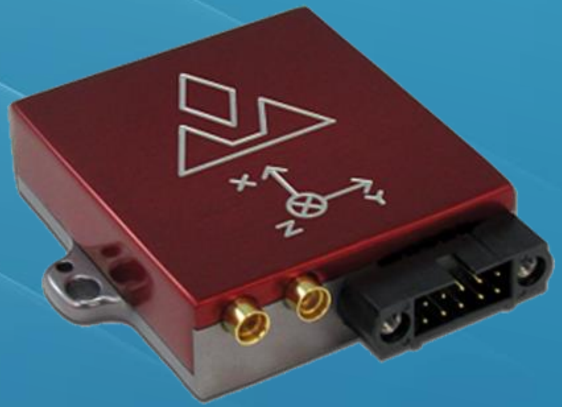
This device constantly rotates during runtime while simultaneously firing infrared lasers. It allows us to map our environment in real time and is helpful in object detection. We used an Ouster OS1 LiDAR.



Peter Oakes

Sensors: VectorNav VN-300

This device provides extremely accurate readings for heading, position, velocity, and acceleration from satellites so that it is not dependent on the vehicle dynamics.



Peter Oakes

Components: Networking

For our uses, we needed to establish a connection to our computers onboard, our ground station computer and our LiDAR. To do this, we used a NETGEAR N900 wireless router which provided very high speeds over Ethernet and Wi-Fi connections. Components with higher priority (i.e. computer, LiDAR) that required faster connections were connected via Ethernet.

Madison Penney

Components: Computer

To run our more processing intensive tasks like vision and path-planning algorithms, we decided to use a mobile station called a Simply NUC developed by Intel. It uses an x86 architecture and consumed a small amount of battery which worked out perfectly for our uses.

Madison Penney

Components: Microprocessor

To run the tedious tasks that usually requires constant input like motor drivers or a digital killswitch we used the open source Arduino Mega boards because we could directly code in C++.

Madison Penney

Components: (ESC) Electronic Speed Controls

The device used to send motor commands from the Arduino was an electronic speed controller. This device takes in a pulse width modulation (PWM) signal. The width of the pulse of the signal will be related to a particular current to bias the motors for thrust. We used Blue Robotics Basic ESCs for our project, as seen to the right.

Madison Penney

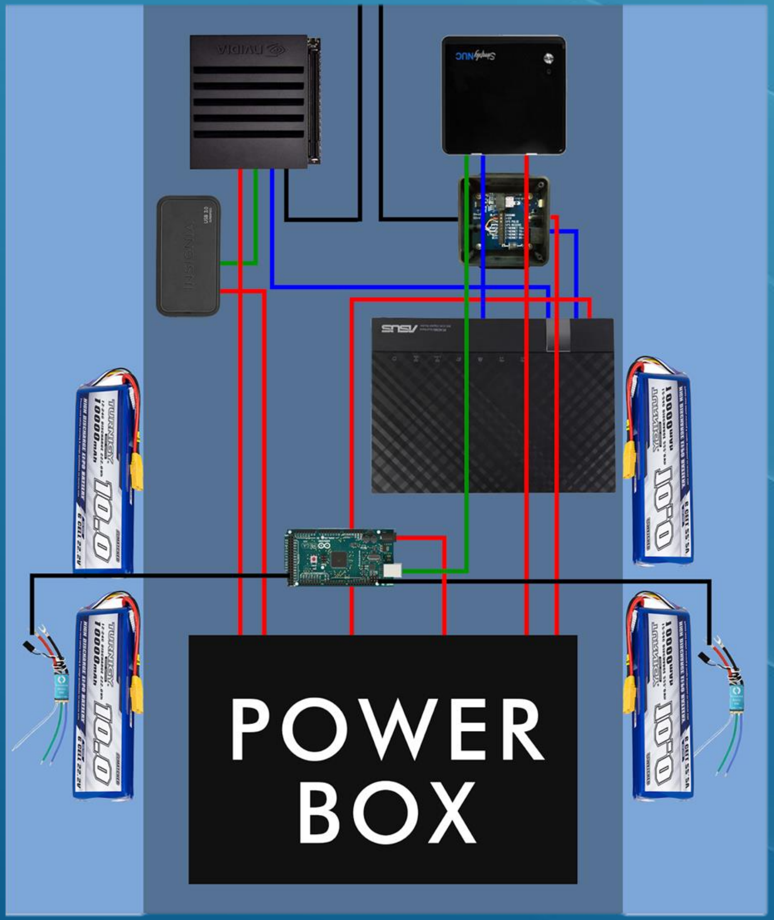
Hardware Changes

Device
Computer #1 (Simply NUC)
Computer #2 (Jetson Xavier)
Ouster OS1 LiDAR
NETGEAR N900 Router
Blue Robotics Basic ESCs (x2)
Arduino Mega (x2)
USB Hub (includes RealSense camera)

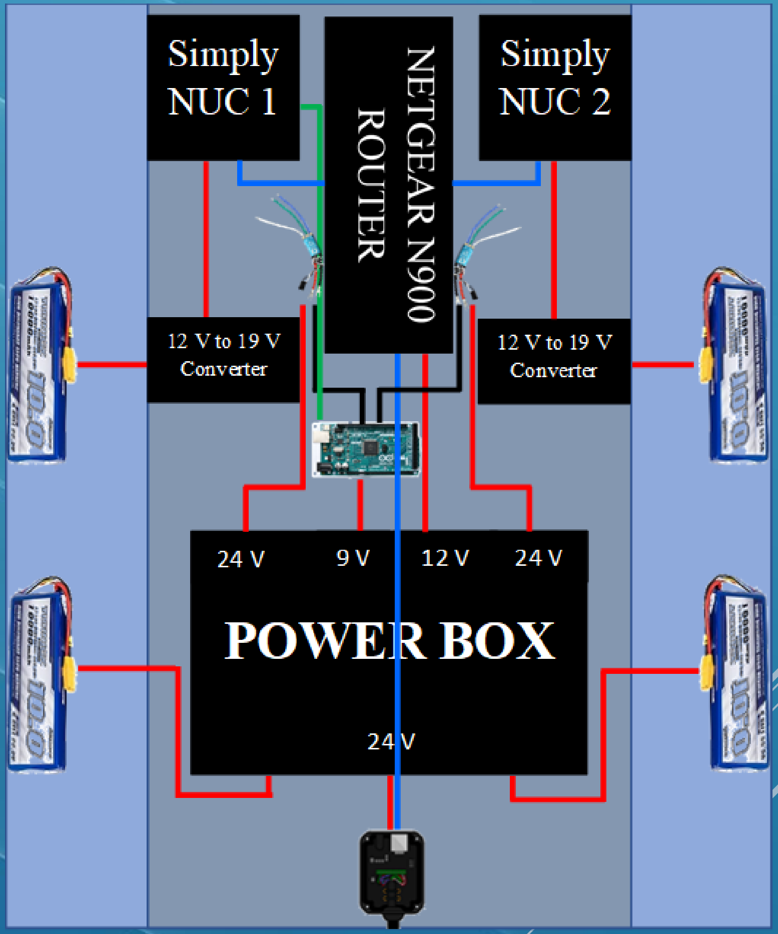
Device
Computer #1 (Simply NUC)
Computer #2 (Simply NUC)
Ouster OS1 LiDAR
NETGEAR N900 Router
Blue Robotics Basic ESCs (x2)
Arduino Mega
None

Madison Penney

Schematic Layout Changes

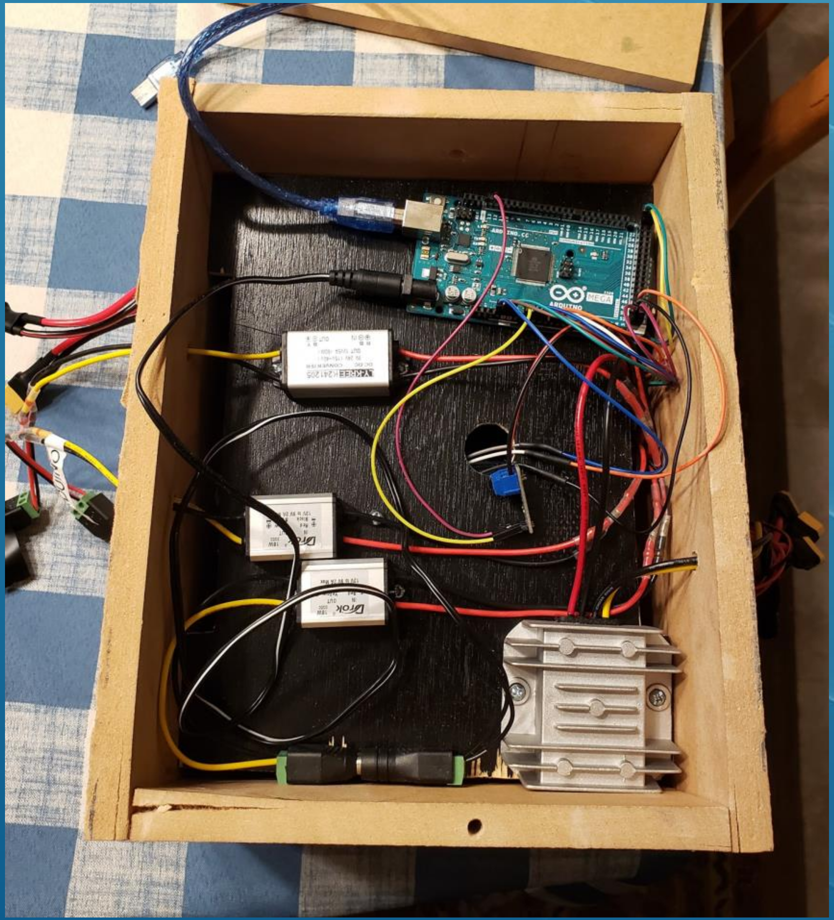


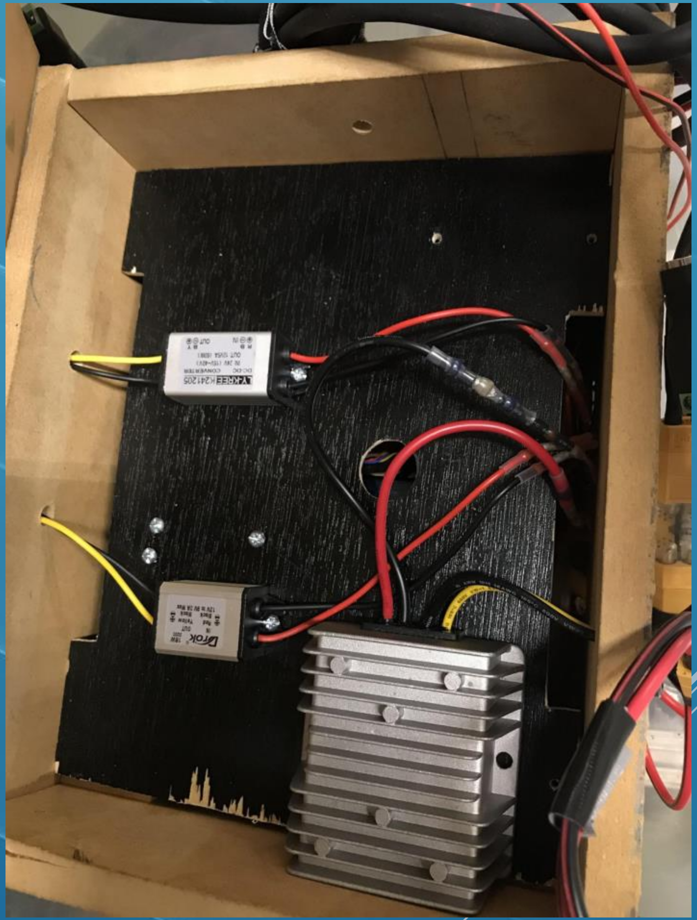
Ethernet Connections
Power Connections
Serial connections (USB)
Data Out



Madison Penney

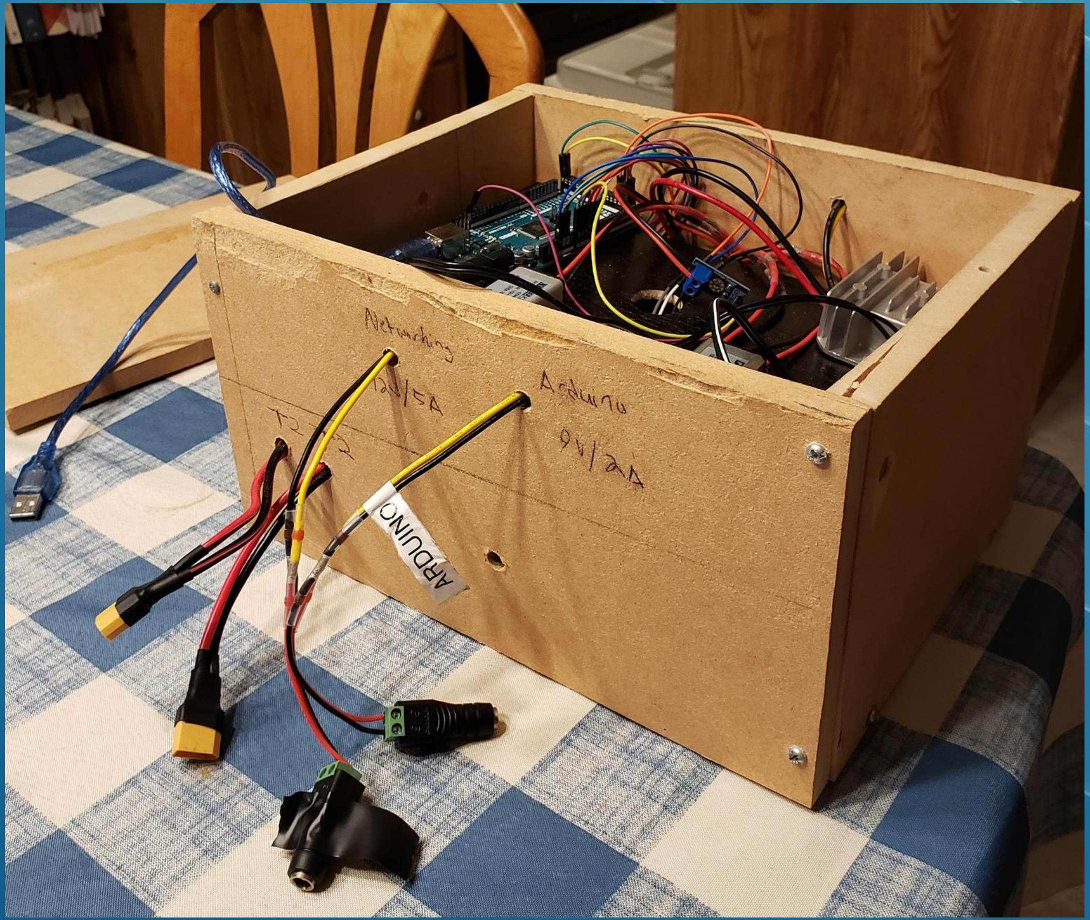
Power Source Changes

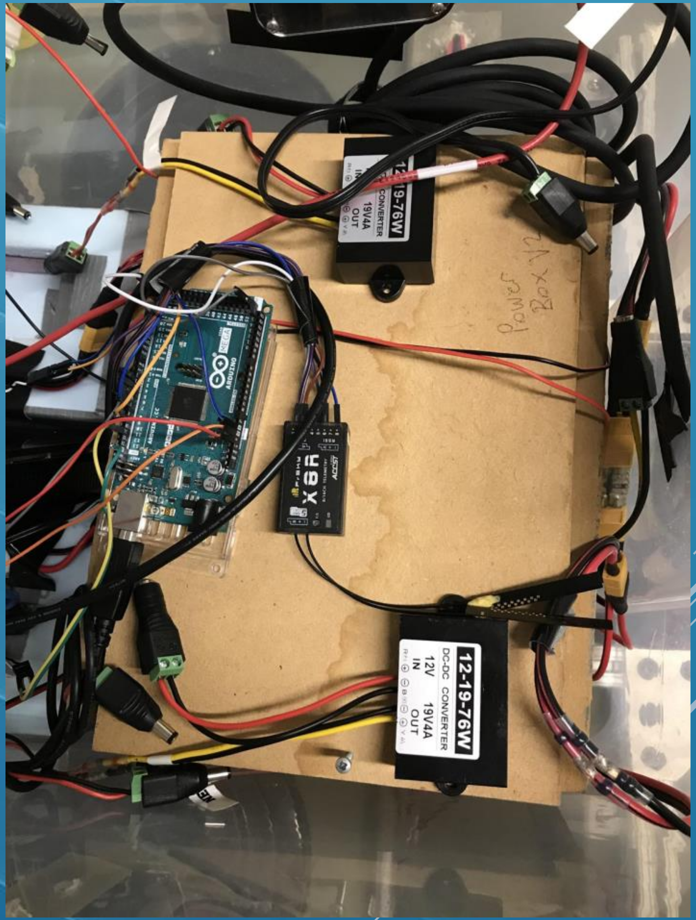




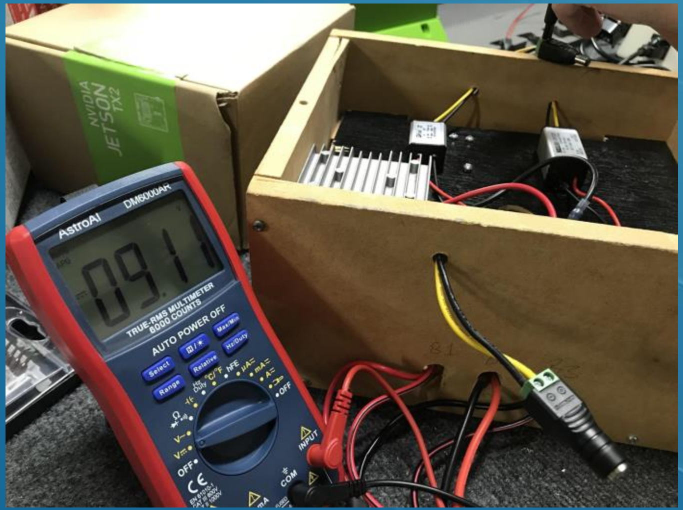
Peter Oakes

Power Source Change

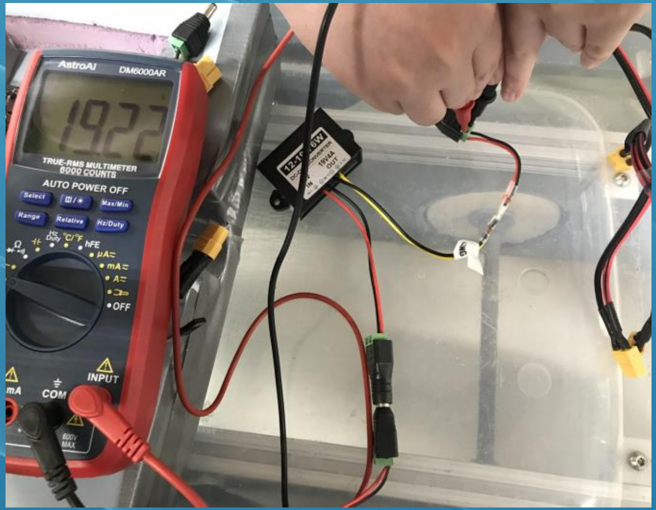




Peter Oakes



Arduino Mega



Simply NUC

Peter Oakes

Hardware: Future Work

- Incorporate every used component onto one circuit.
- Redesign power box to be lighter and take up less room.
- Add even more safety features to protect components and users
- Remove unnecessary wires, converters, and connectors
- Add a digital monitoring system to monitor current and voltages leaving the system
- Add power system and components onto new boat

Peter Oakes

SENSOR DESIGN

Brandon Bascetta

Department of Mechanical Engineering
Department of Electrical and Computer Engineering

FAMU-FSU Engineering

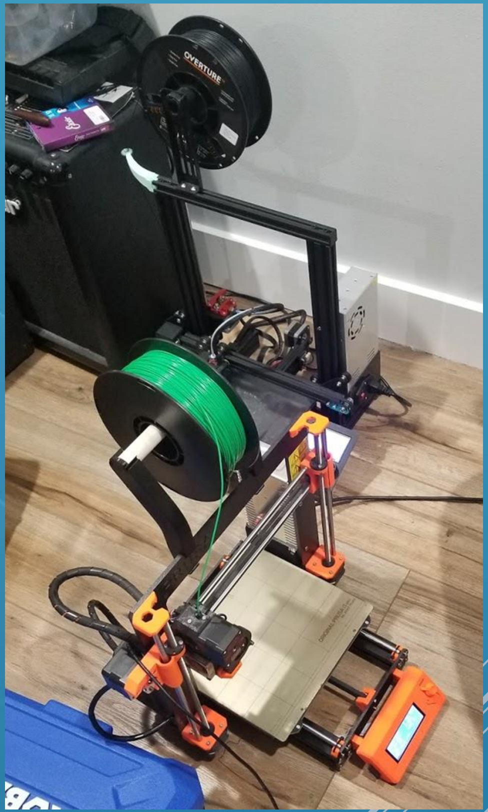
Sensor Design: Semester Work

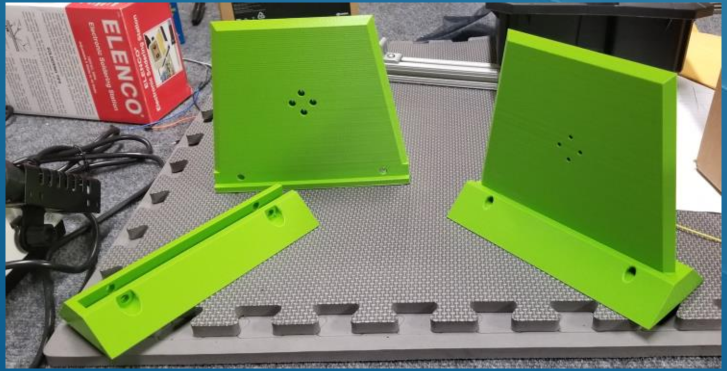
- Mounts created during the semester:
  - Modular Fin Mount.
  - Ouster OS1 Lidar Mount.
  - Computer Separator.
  - Visual Feedback and VectorNav Mount.

Brandon Bascetta

Sensor Design: Semester Work

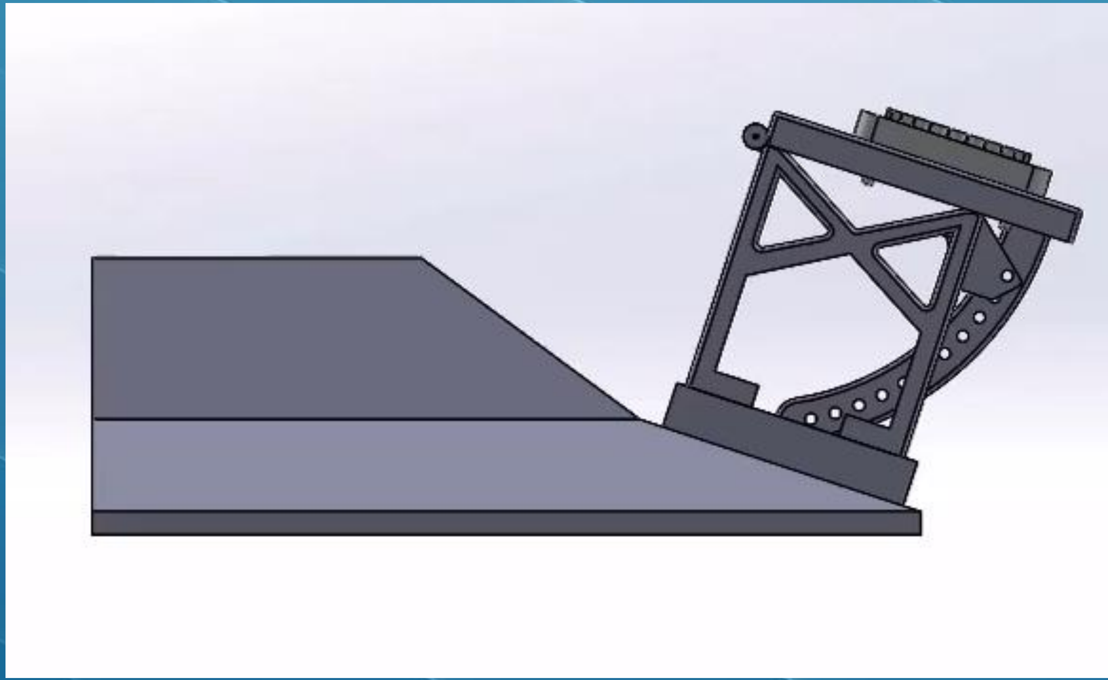
- Manufacturing process:
  - Fins were outsourced to be printed.
  - Bought a 3D printer (Ender 3) and also brought in an additional printer (Prusa i3 Mk3) to speed up production.
  - Both printers broke
    - Nozzle clogged and destroyed thermistors.
    - Bowden tube adapter broke off.





Brandon Bascetta

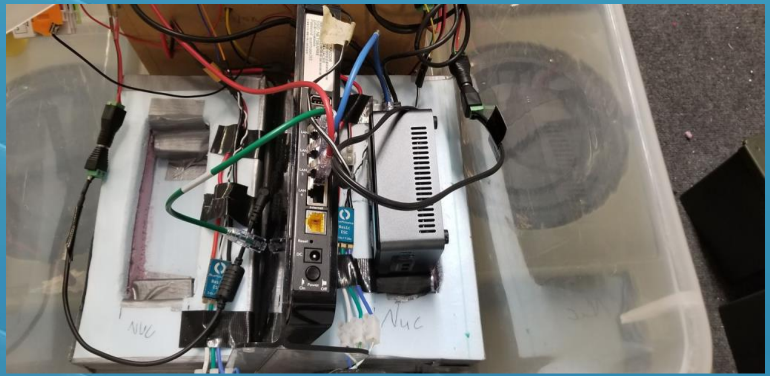
Sensor Design: Semester Work

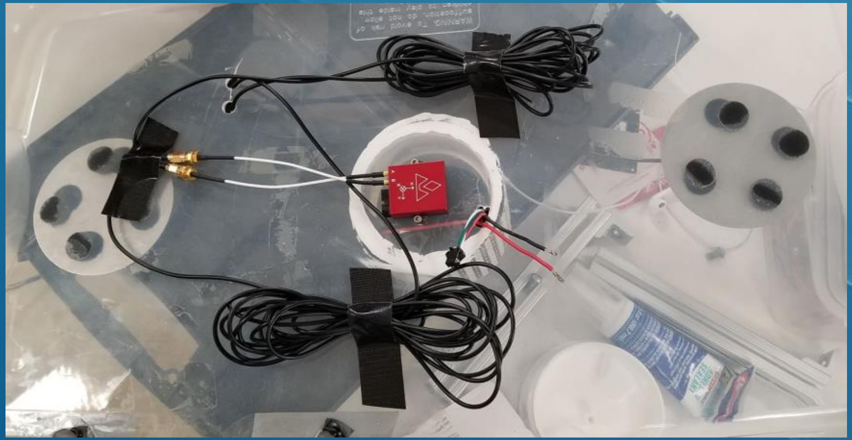


Brandon Bascetta

Sensor Design: Semester Work

- Testing Boat Renovation:
  - Computer and router mounts.
  - VectorNav and visual feedback mounts.

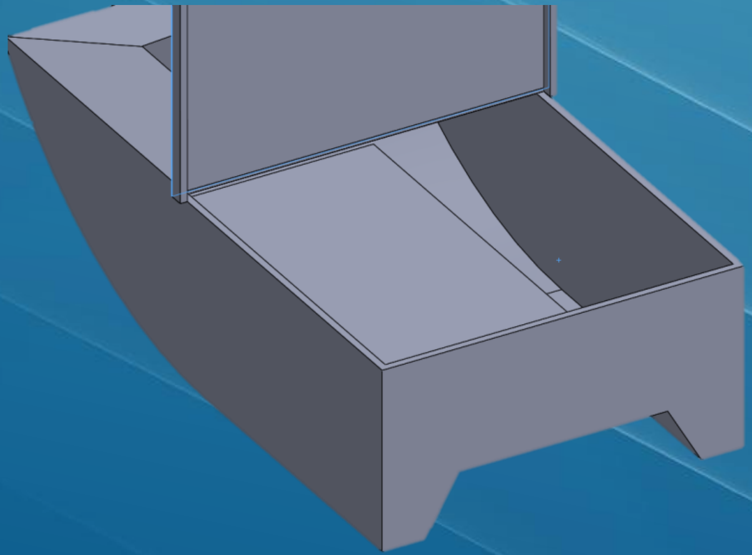


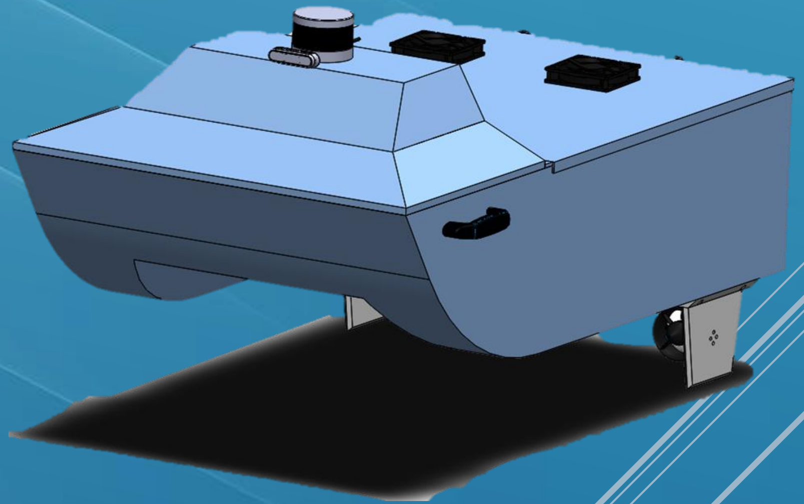


Brandon Bascetta

Sensor Design: Future Work

- Finish manufacturing mounts for Lidar.
- Finish manufacturing Visual Feedback.
- Create a new mount for RealSense camera.
- Create a platform for internal hardware to stay on.





Brandon Bascetta

SOFTWARE DEVELOPMENT

Toni Weaver/Mark Hartzog

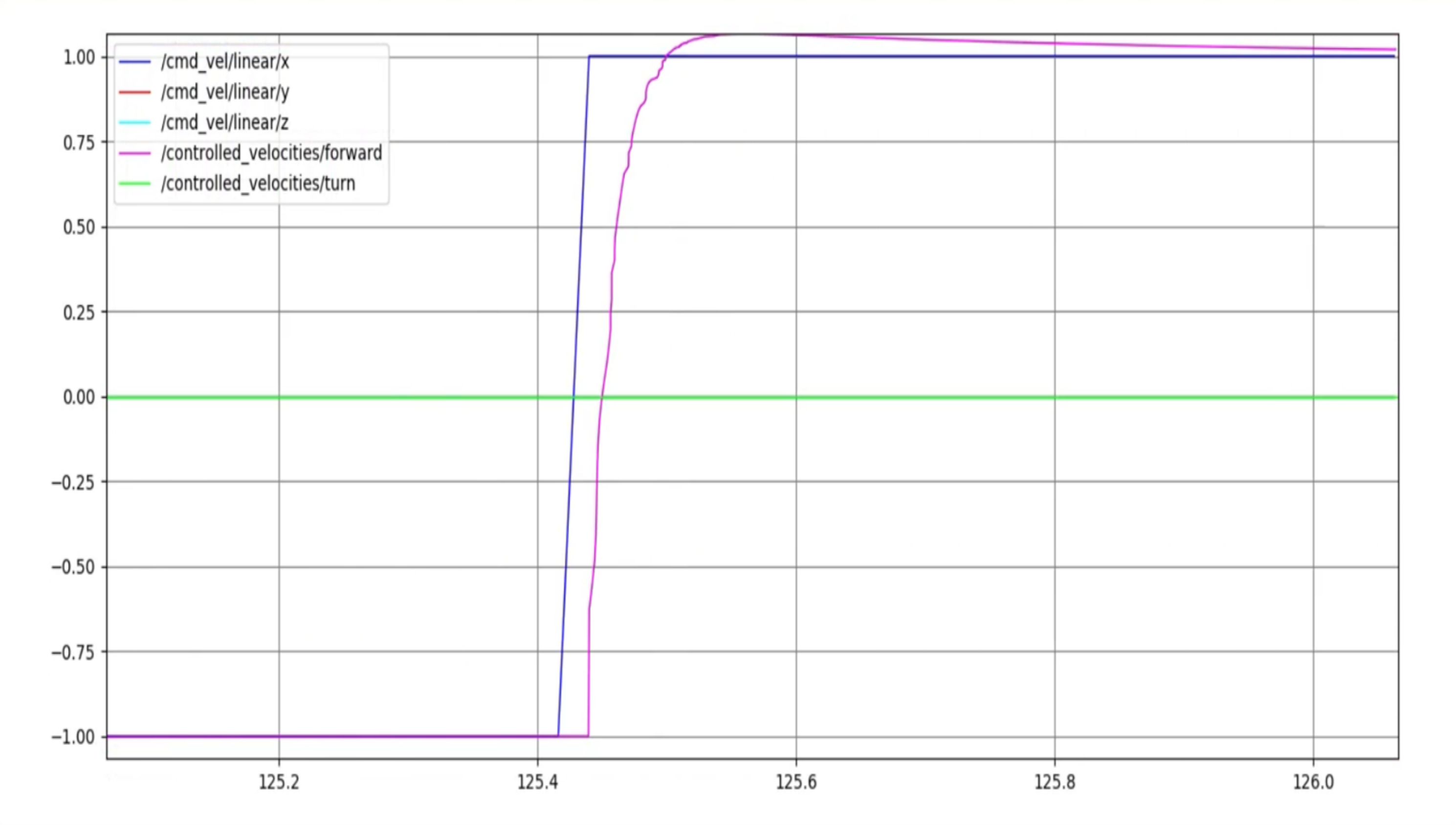
SOFTWARE ENVIRONMENT: ROBOTIC OPERATING SYSTEM

All of our code was developed for use within ROS, or the robotic operating system. This system environment is open source. In our case we used much of the ROS namespace, classes and syntax. This includes functions that exist only in ROS, sensor manufacture packages that allow ROS to use various devices and open source ROS packages like Movebase, or Navigation that make our jobs easier so we can focus on the path planning aspect and vehicle control.

ROS.org

Mark Hartzog

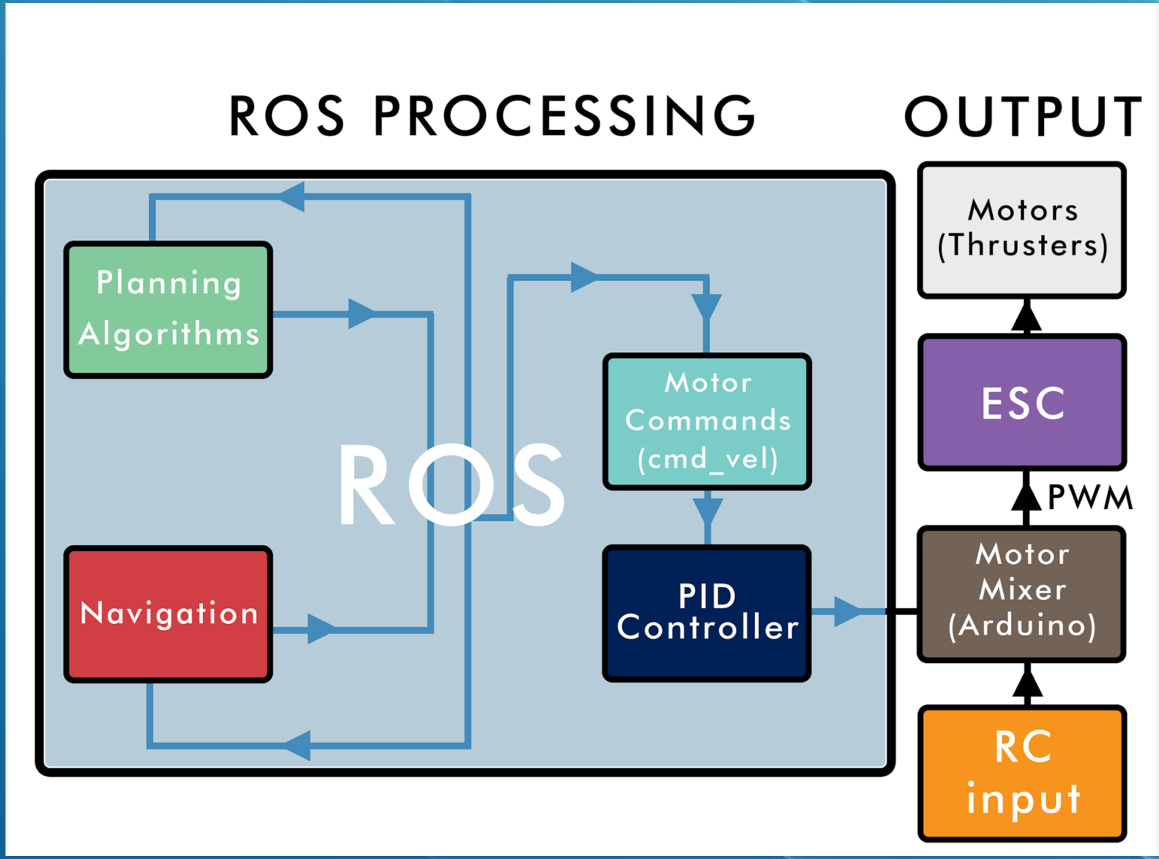
BOAT TASKING: CONTROL SYSTEM (PID)



The PID implemented last semester was updated with new gains which allow the vehicle to perform much better under conditions with water current. The gains can be manipulated at the testing location without recompiling the code which allows easy and efficient testing.

Mark Hartzog

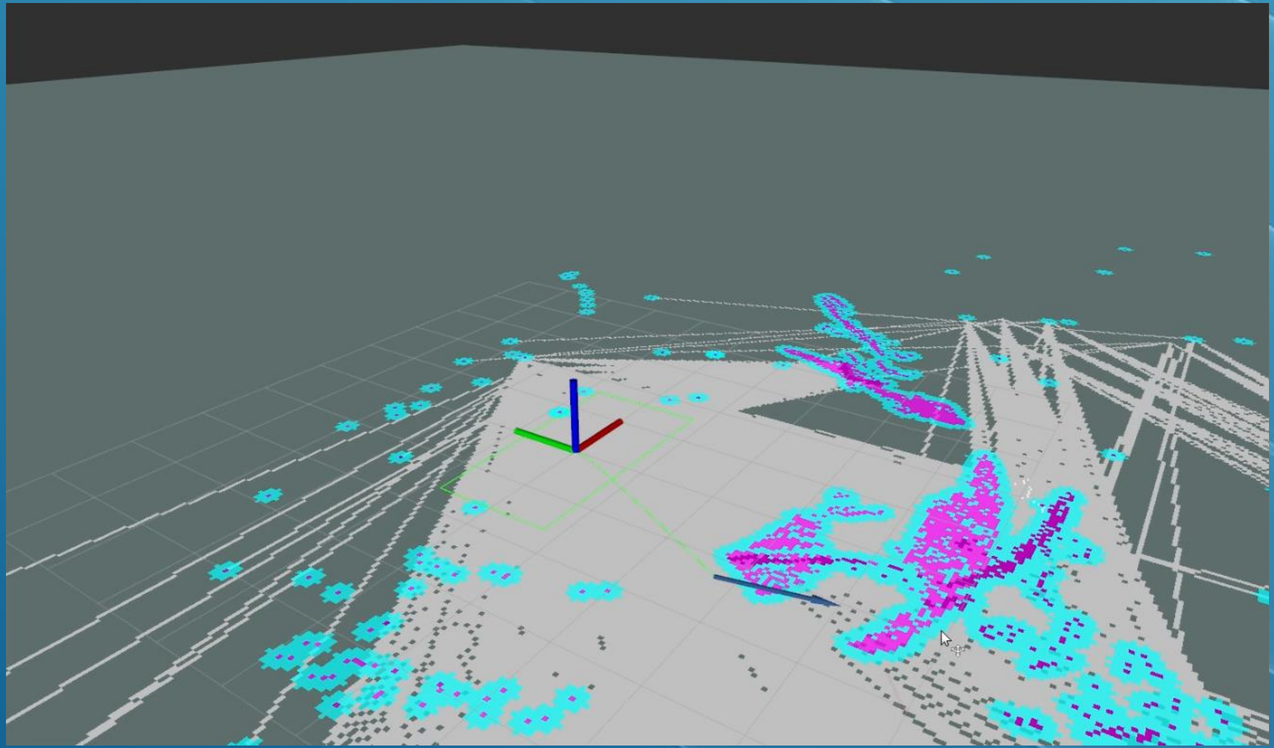
BOAT TASKING: DATA PATH



Much like the flow chart from earlier, this one specifically illustrates the way that ROS takes in data from the sensors, then distributes it to the software executables. After this is done, the modified data is sent from the planning algorithms back to ROS. Finally, ROS takes that data and sends it through the controller which distributes them to the microcontroller which sends PWM signals to the electronic speed controllers. It is important to note that the RC control is agnostic of ROS entirely, but is used to toggle the different modes of operation: Locked, Manual, and Autonomous.

Mark Hartzog

BOAT TASKING: LOCALIZATION

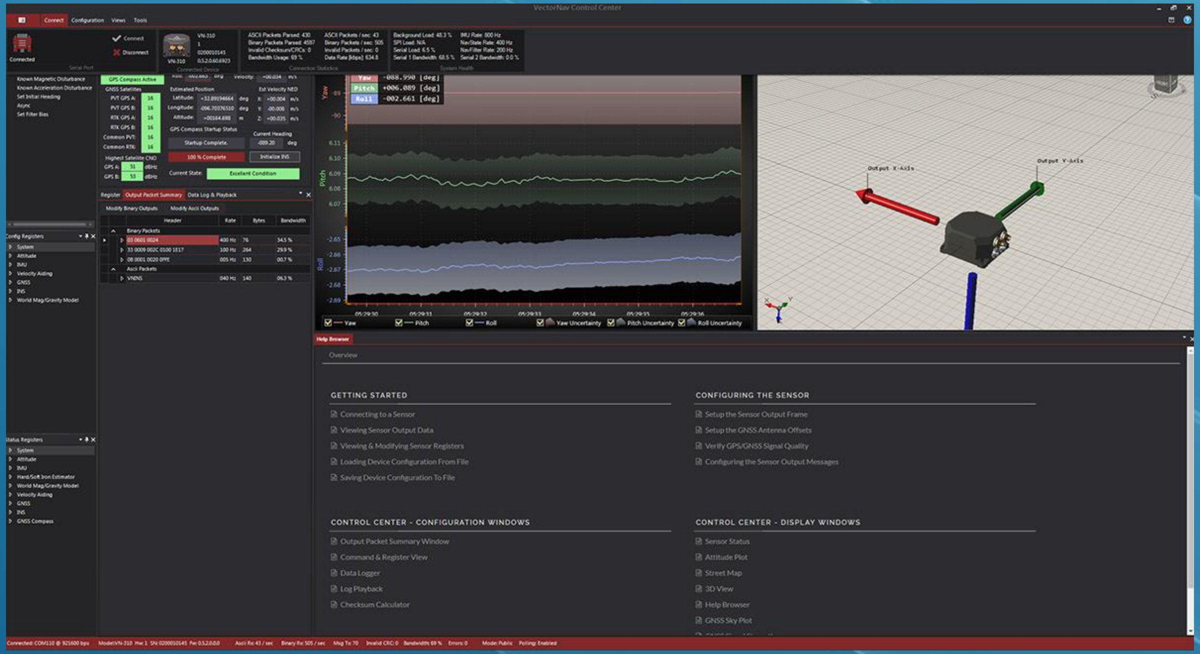


Taken from test on July 25 2020

The two sensors needed for localization, the IMU and LiDAR, were mapped in the coordinate frame. As seen in the image, ROS detected obstacles (purple voxels) with a region of high cost (teal voxels) using the transforms established in the software environment. Additionally, a footprint, or dimensional outline of the vehicle, was measured and inputted into the configuration settings. Then using the visualizer tool, (RVIZ) allows the user to detected the footprint which is represented by the green outline. Also, the blue arrow indicates a waypoint, or goal, set for the vehicle. The Vehicle the calculates a path (the green line) and follows that as closely and safely as possible.

Mark Hartzog

BOAT TASKING: SENSORS - IMU

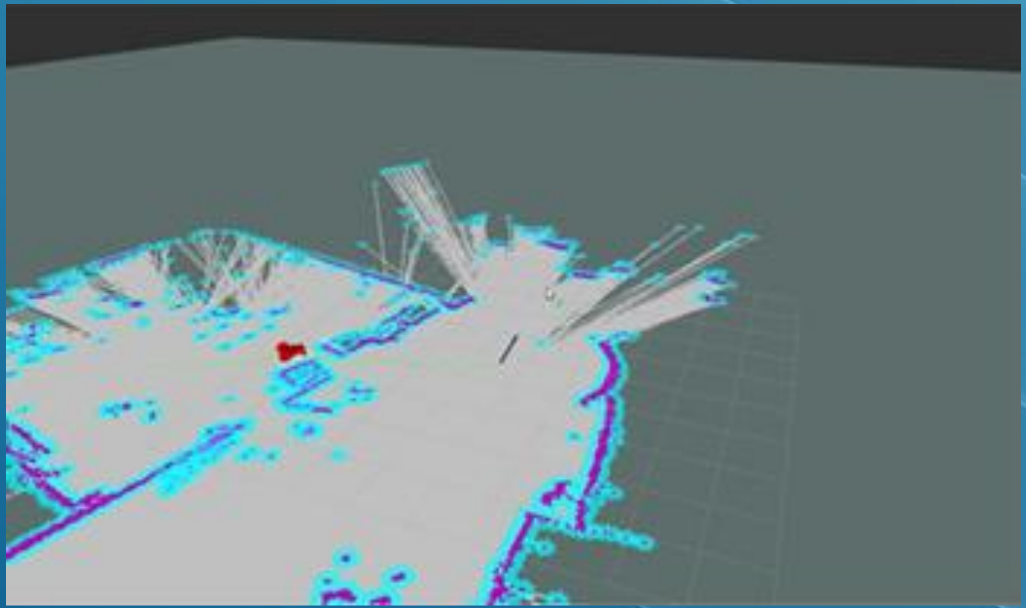


Using the software provided by the manufacturer, the sensor was calibrated before being used in ROS. The sensor was then integrated into ROS using a ROS wrapper.

This wrapper allowed us to take the data from the vectornav and use it with the navigation software to help create the costmap

Toni Weaver

BOAT TASKING: SENSORS - LiDAR

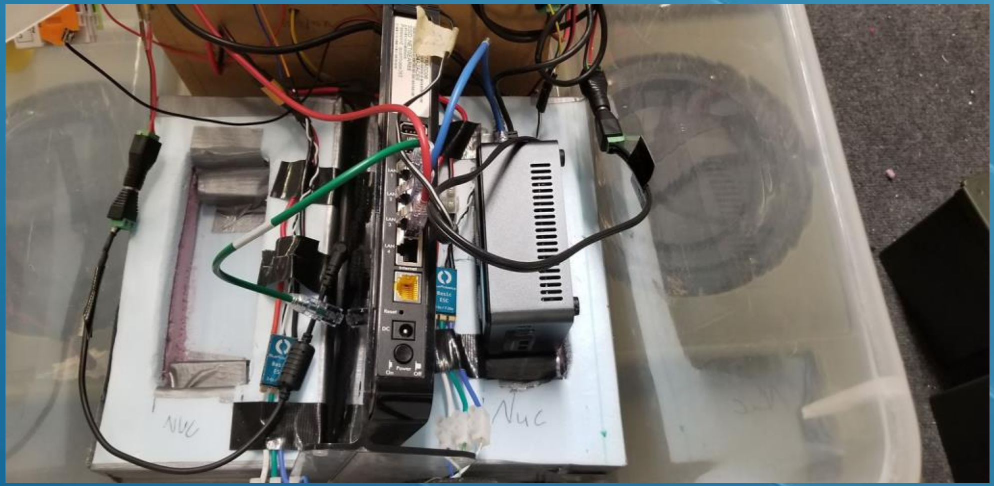


A photo of our LiDAR mapping out the Holley building in real time.

The Ouster lidar was integrated into ROS to use with our navigation algorithms. Due to an out of synch clock, the clock of the LiDAR ran faster than that of the computer. This caused an issue in ROS because the data used by the navigation package was timestamped much earlier than of that being requested. Simply put, that data was old and could not be used. This was fixed by altering the firmware of the LiDAR to force its clock to synchronize with the computer's clock. After, that data synchronized and was usable in ROS.

Toni Weaver

BOAT TASKING: POINT CLOUD PROCESSING



Because all of the processing for the ROS algorithms, IMU data collection and signal distributions were being handled by a single computer, computational constraints were encountered. Therefore, to split some of the load and redistribute resources, another computer was introduced. This computer was delegated to only handle the generation and distribution of point cloud data to the original, master computer. This greatly improved runtime of the vehicle and reduced other runtime errors.

Mark Hartzog

SOFTWARE DEVELOPMENT: FUTURE WORK

- Calibrate IMU Magnetometer (requires 5+ personnel)
- Reconfigure ROS transforms to more accurately localize.
- Reconfigure the costmap parameters to create more stability and force the vehicle to navigate more quickly.
- Incorporate the GPS of the IMU and fuse its data with a Kalman filter.
- Calibrate the LiDAR IMU and fuse its data with the corresponding IMU data generated by the IMU sensor.
- Mount a camera and incorporate it into the transform tree.

Mark Hartzog

Testing Procedure

Brandon Bascetta

Testing Procedure

Hull			
Requirement	**Testing Method**	**What is Success?**	**Passed (Y/N)**
Hull Floats	Place completed hull in a swimming pool.	The hull does not sink, it floats.	**Y**
Hull Carries 15 lbs	While in the swimming pool, dive weights will be added incrementally until 15 lbs is reached (dive weights are 3 lbs each).	The hull will carry 15 lbs with the pontoons only be submerged less than 4 inches.	**Y, it can carry 24 lbs**
Hull weighs <25 lbs	Place hull on scale and read weight.	Weight is < 25 lbs.	**Y, it weighs 13.8 lbs**
Hull doesn't leak	Place hull in pool carrying 15 lbs for a minimum of 30 minutes.	Hull has no water in the interior.	**Y**
Minimal Deflection	Place 9 lbs on the center section and measure deflection with a ruler.	The measured deflection will be less than ⅛".	**Y**

Courtney Cumberland

Testing Procedure

Sensor Design				
Requirement	**Testing Method**	**What is Success?**	**Passed (Y/N)**	**Exceptions**
Sensor mounts articulate	Sensors will be placed on the mount and the angle will be adjusted by raising and lowering the mount.	Mount is able to adjust to different angles.	**N/a**	**SolidWorks motion study shows that the sensor mount does articulate, although no physical testing proves.**
Sensor mount will be adaptable	Mounts created will be modular to fit onto two 80/20 rails.	Mount will fit on the 80/20 rail showing that the sizing is correct and other mounts can be made using these sizings.	**N/a**	**The bolts that were going to be used for mounting fit the 80/20 adapters but testing actual mounts has not been done**
Mounts are easily replaceable	The mounts will be 3D printed and spares will be made.	Print can be made on most 3D printer beds with common filament (PLA or PETG).	**N/a**	**2 3D printers were damaged during testing**

Brandon Bascetta

Testing Procedure

Hardware			
Requirement	**Testing Method**	**What is Success?**	**Passed (Y/N)**
While the components are not connected, the voltage output for all components are correct	Using a multimeter, measure the voltage output from the power to each component.	The voltage output for each component is within their specific acceptable range.	**Y**
While the components are connected and ON, the power output for all components are correct	Using a multimeter, measure the voltage output and current draw to each component.	The power output for each component is within their specific acceptable range.	**Y**
While the components are connected and ON, the components run without any issues	Each component will be turned on and observed for 3 minutes.	Each component runs smoothly without any brownouts, shutting off, malfunctioning, or overheating.	**Y**
Turnigy High Capacity 10000mAh 4S LiPo batteries remain within acceptable voltage range during testing	During testing, the voltage output from the batteries will be checked periodically.	The voltage range is maintained at 14.8-16.3 V.	**Y**

Madison Penney

Testing Procedure

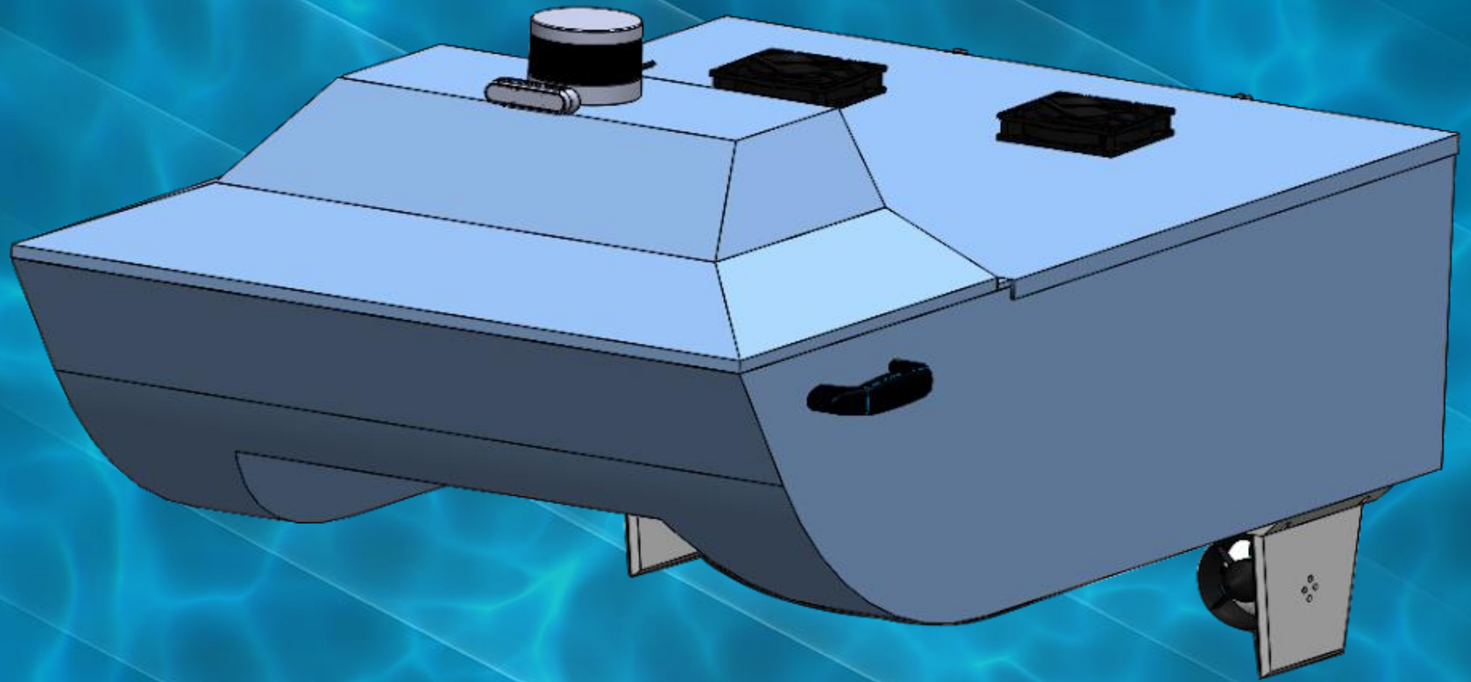
Device	Voltage	Current
Simply NUC (x2)	19 V	(max) 3 A
Ouster OS1 LiDAR	22-26 V	0.6-0.8 A
NETGEAR N900 Router	12-19 V	(max) 2.5 A
ESCs (x2)	7-26 V	(max constant current) 30 A
Arduino Mega	7-12 V	(max) 1 A

Madison Penney

Testing Procedure

Software			
Requirement	**Testing Method**	**What is Success?**	**Passed (Y/N)**
Confirm that software commands trigger the motors.	Use keyboard inputs to drive the vehicle.	If the motors accurately follow commands.	**Y**
Vehicle detects obstacles	Obstacles will be introduced in a controlled manner and the data will be logged.	Software accurately and repeatedly identifies obstacles.	**Y**
PID controller is capable of creating smooth continuous motion.	System will be driven using PID controller.	System moves in a smooth and continuous manner.	**Y**
Basic Waypoint Navigation Completed	System will be tasked with a waypoint within ROS.	System arrives at the waypoint within a reasonable amount of time (30 s).	**Y**
Boat Localized	System will be traveled around a specific path several times and the data logged.	The data points gathered at each point will agree with each other (within a 10% margin of error).	**Y**

Toni Weaver



ANY QUESTIONS?

Thank you for your time