Design and Development of an Autonomous Underwater Vehicle

Final Presentation
Team 23
April 14th, 2016

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Sponsor: Dr. Shih, NEEC

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The Competition

- AUVSI International Robosub Competition

- Objective of the competition:
  - Design an autonomous underwater vehicle to perform a series of tasks

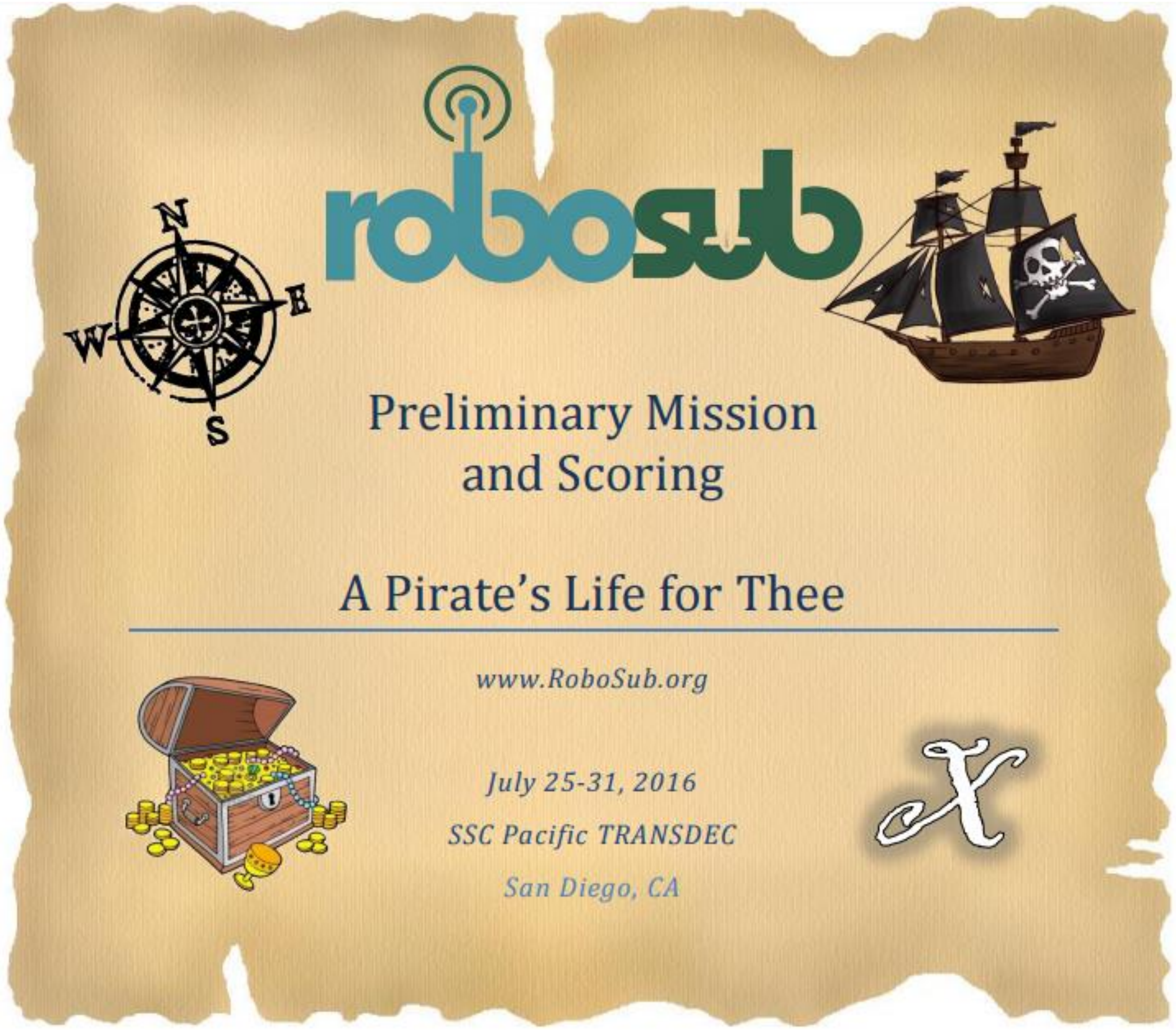


Figure 1: Robosub Competition Rules Cover Image

Competition Tasks

1. Follow path markers between tasks
2. Interact with colored buoys
3. Pass over an Obstacle
4. Drop markers at a specified location
5. Fire Torpedoes through a specific target
6. Locate an object and pickup and move to a specified location

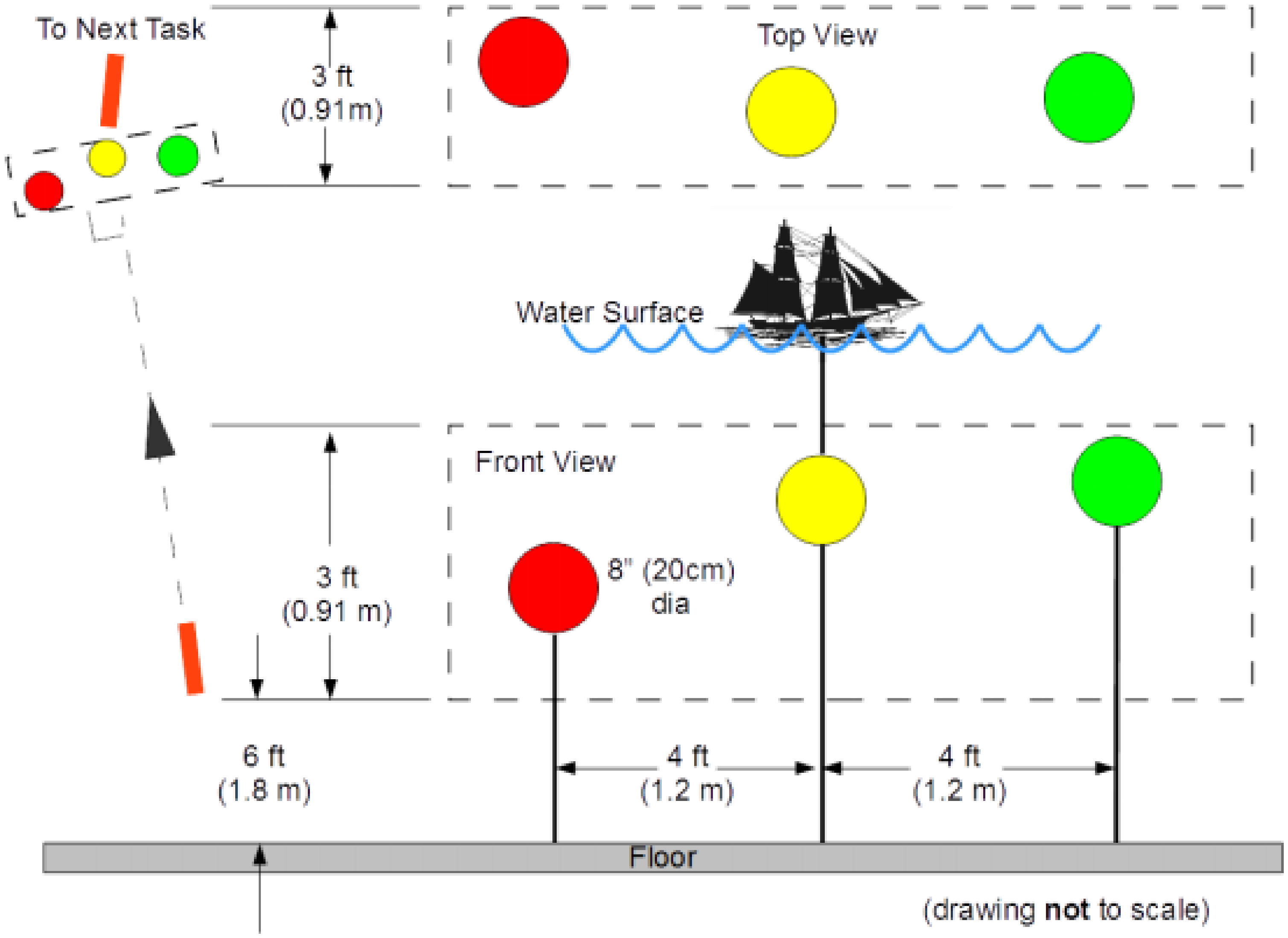


Figure 2: Buoy Interaction Task

Team Robosub Breakdown

- ME Project Objectives
  - Design, Fabricate, and test new hull and frame
  - Design and integrate air system for torpedoes and gripper
  - Physical subsystems integration
  - Troubleshoot and Debug final design to ensure robust functionality of mechanical and electronic components
- ECE Project Objectives
  - Optimized the image processing software
  - Software integration
  - Parse through the inherited code and modularizing for efficiency
  - Development of the gripper

Project Background

- The Previous AUV
  - Designed and Built in 2013
  - Components
    - 6 Seabotics thrusters
    - Zotac Mini Computer (CPU)
    - Arduino Mega and Uno
    - 3 Motor Controllers
    - Inertial Measurement Unit (IMU)
    - 2 Cameras
    - Depth Sensor
  - Drawbacks
    - Positively buoyant
    - Inefficient for inside access

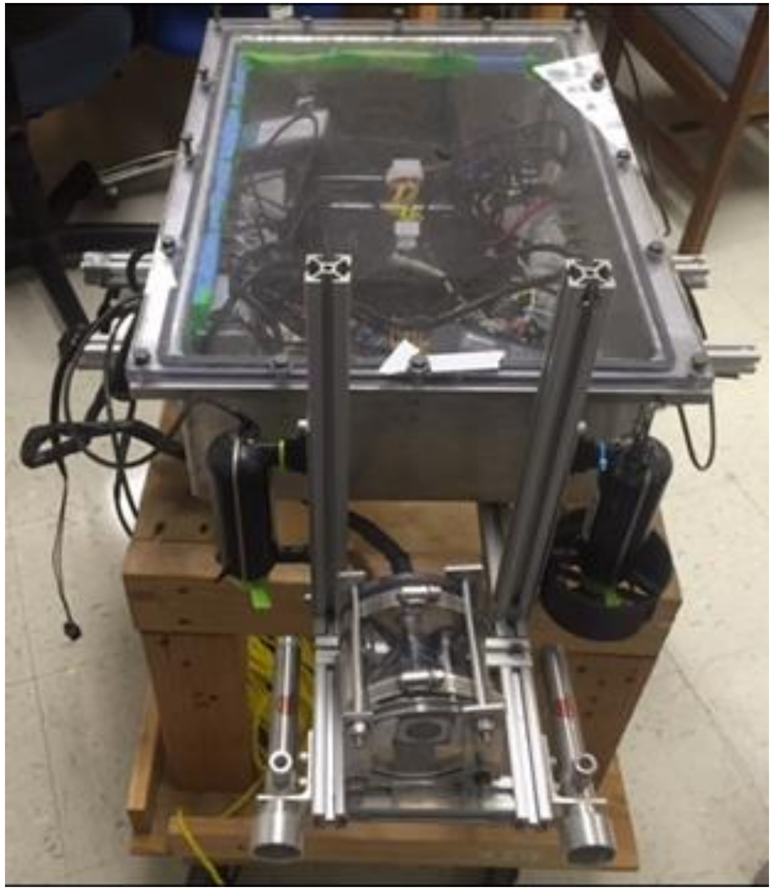


Figure 3: Old AUV

Robosub Signal Diagram

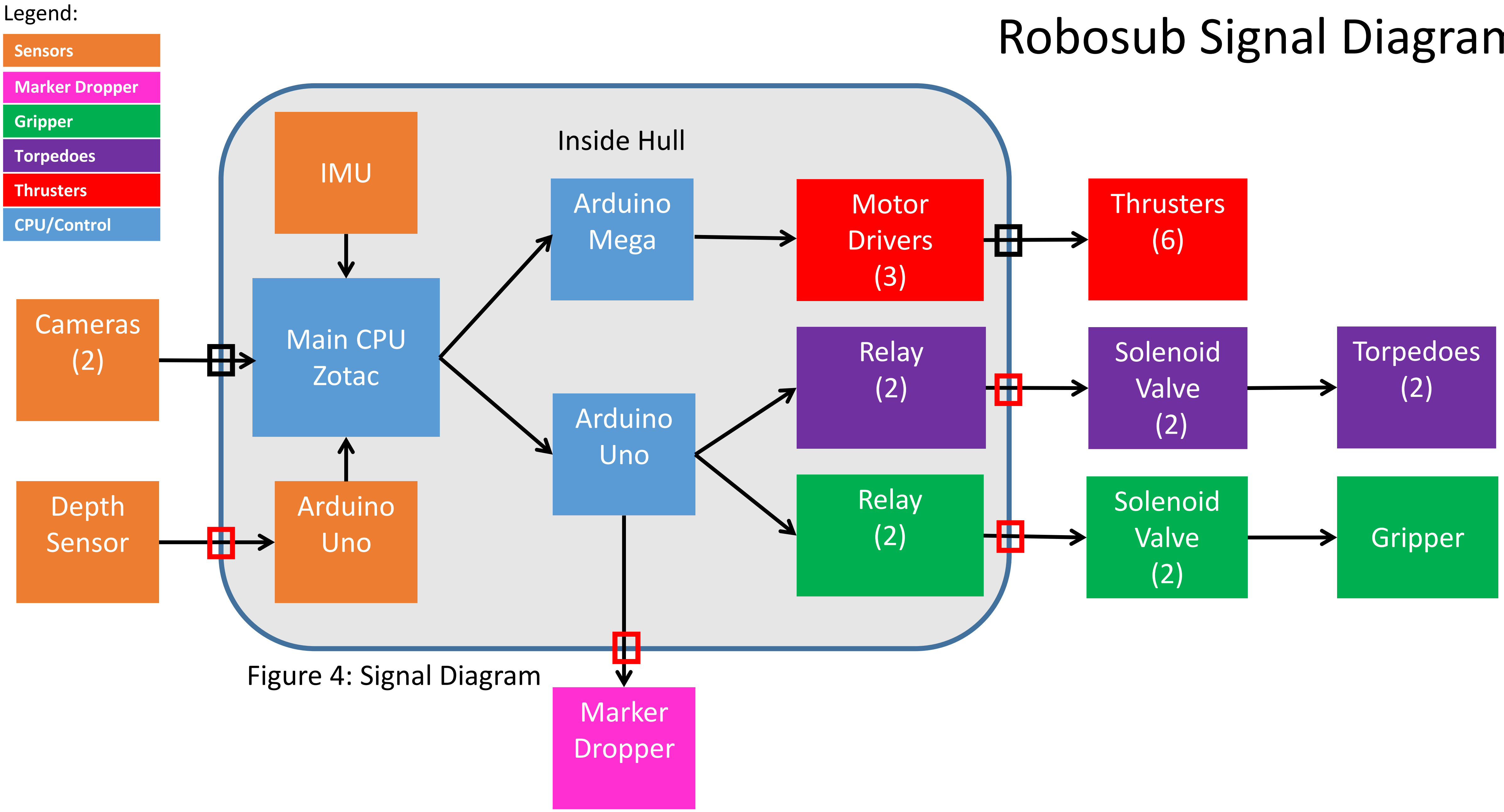
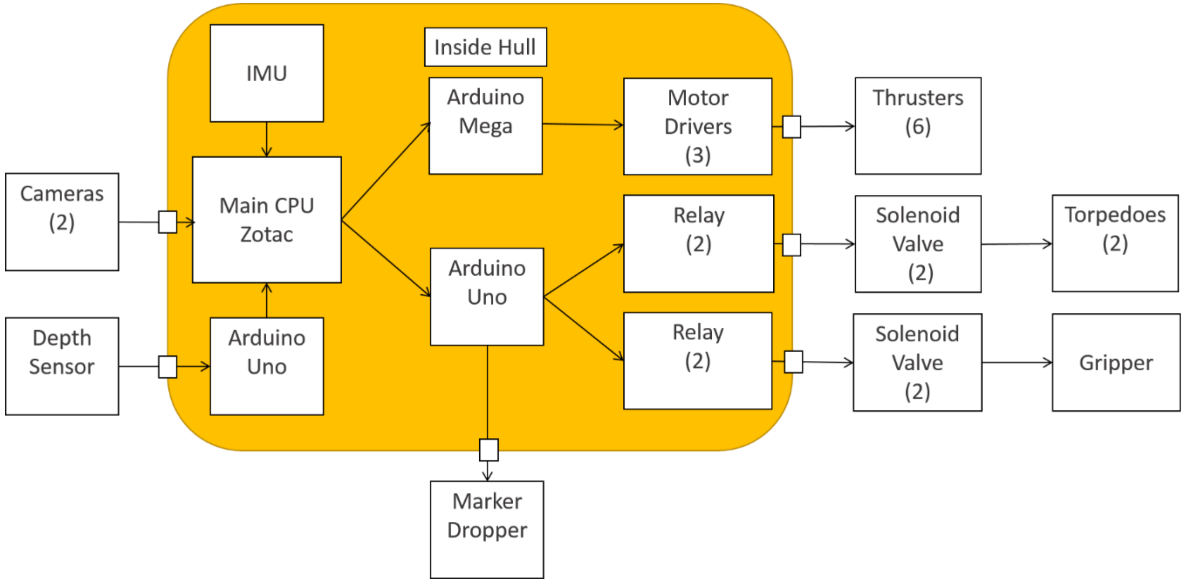


Figure 4: Signal Diagram

The Hull



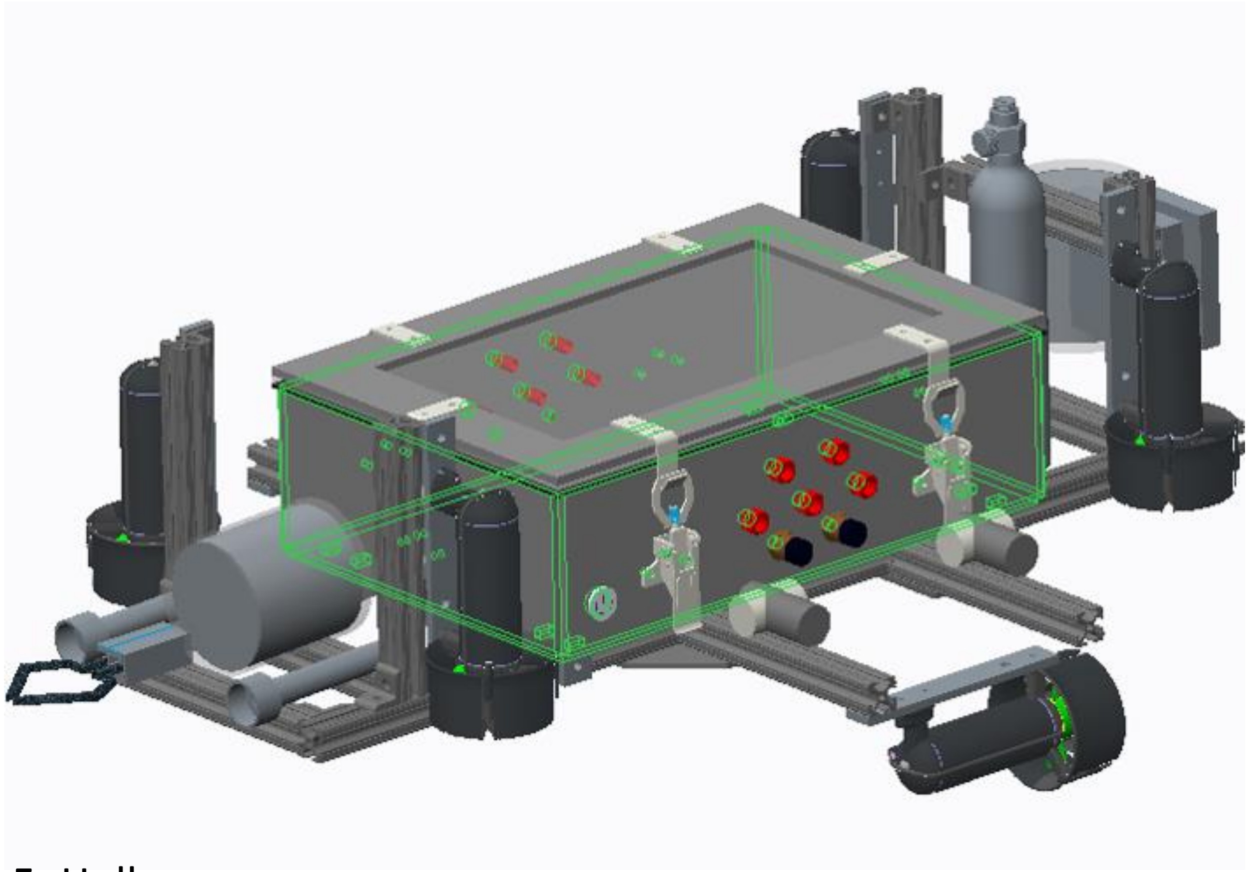


Figure 5: Hull

The Hull

- From old to new
  - Decrease weight by 13 lbf
  - Decreased buoyancy by 28 lbf
  - Decreased volume by 900 in^3
- Switched from aluminum to stainless steel for higher density
- 6 toggle latches instead of 16 nuts and bolts for easier access
- Electrical insulation for inside hull
  - Reorganization of internal electronics

Table 1: Hull Properties

Property	Equations	Old Hull	Revised Hull
Material Density (lb/in3)	m/V	0.0975	0.2781
Dimensions (inches)	*L x W x H*	22x15x6	12x18x5
Weight (lbf)	*m* x *g*	84	71
Buoyancy (lbf)	ρ_{water} x $V_{displaced}$ x g	100	72

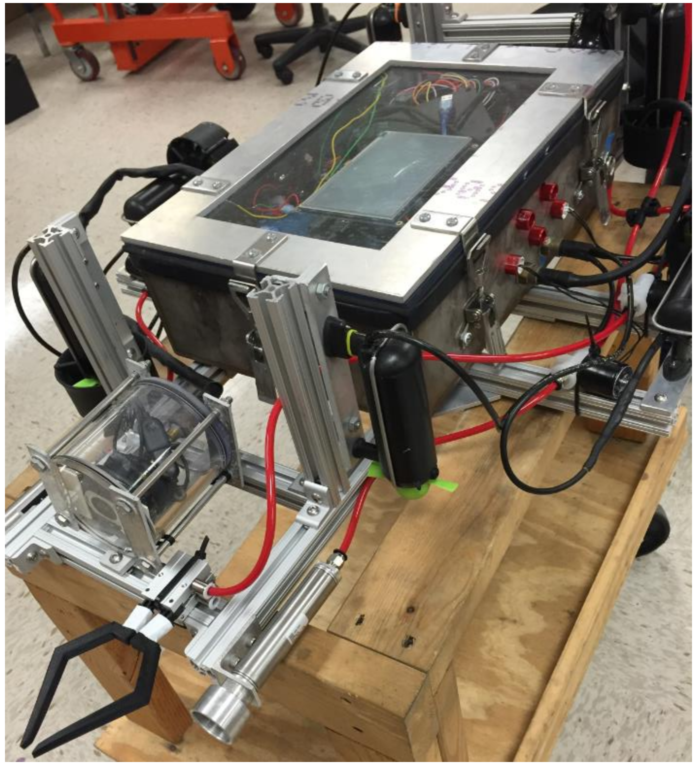
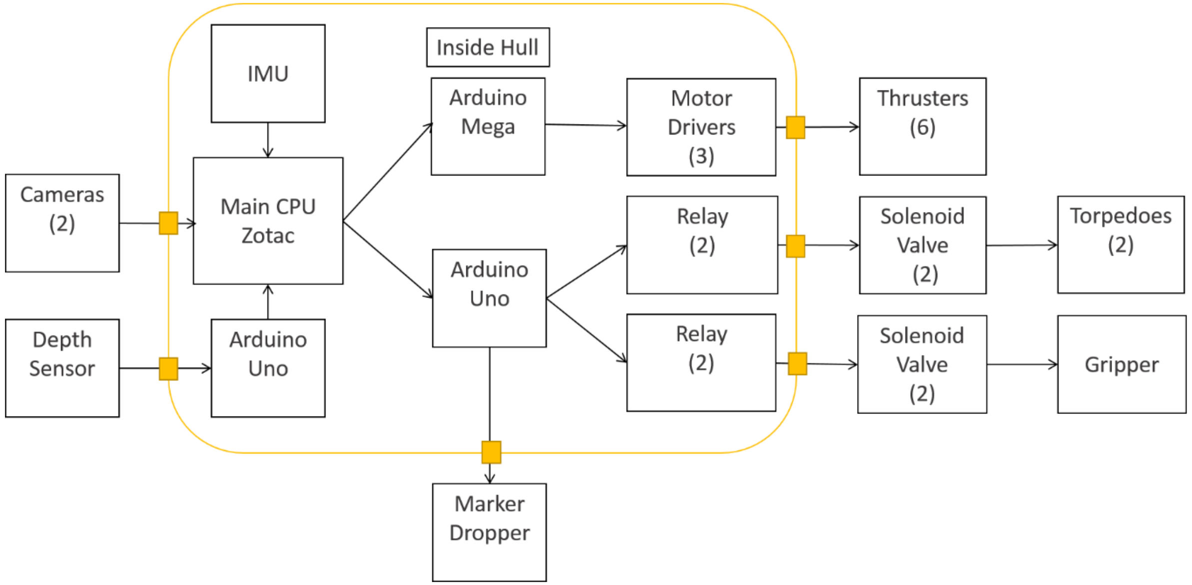


Figure 6: Redesigned AUV

Waterproof Electrical Connectors



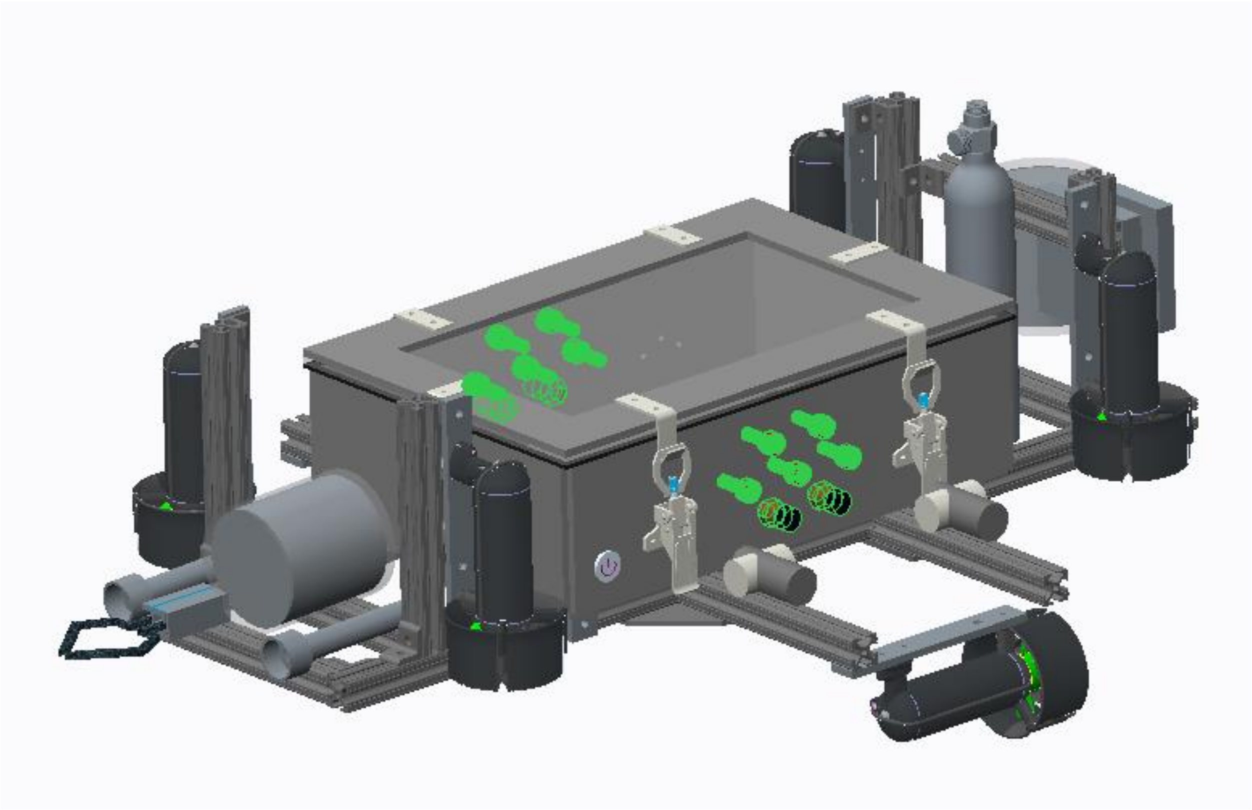


Figure 7: Waterproof Connectors

Waterproof Electrical Connectors

- Decision was made to keep some existing ports and replace others
- 4 Seacon heavy duty ports will be salvaged from old hull to accommodate thrusters and cameras
- 10 new cable penetrators will replace remaining Seacon ports
  - Pros: Cheap, Corrosion resistant
  - Cons: Held with permanent marine epoxy

Table 2: Port Comparison

Item	Old hull	New hull
Seacon ports	$100 X 16	$100 X 4
Cable penetrators	$4 X 0	$4 x 10
Total Cost	$1600	$440

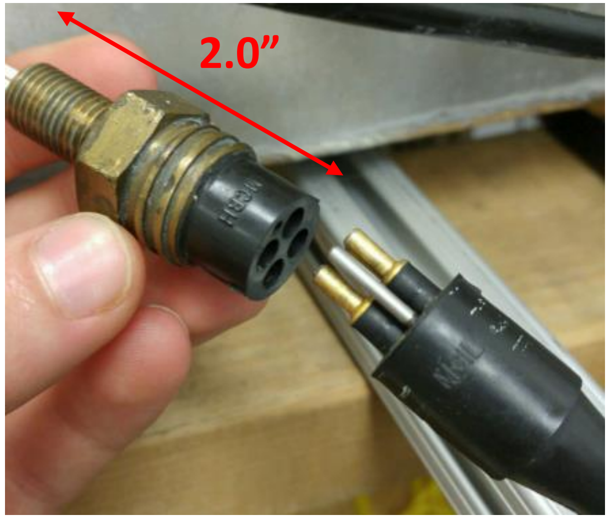


Figure 8: Seacon Port

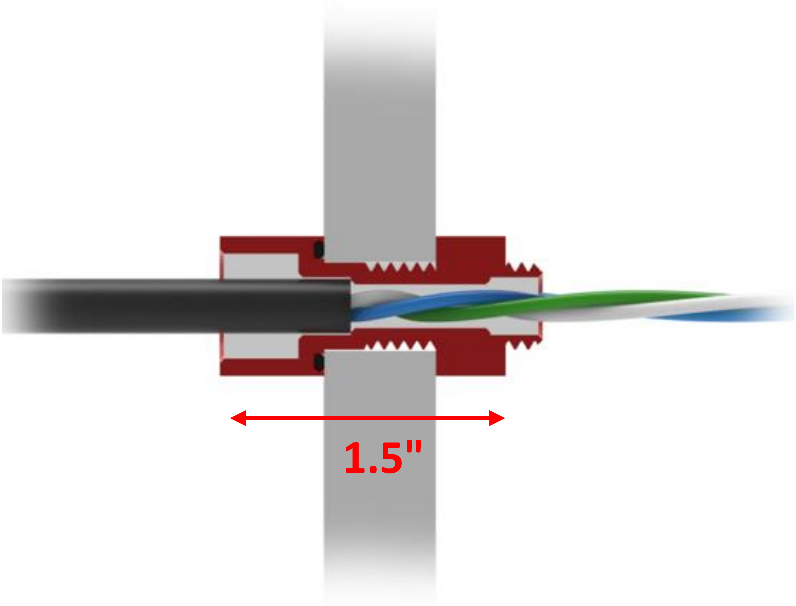


Figure 9: Cable Penetrator Cross Section

Internal Electronics

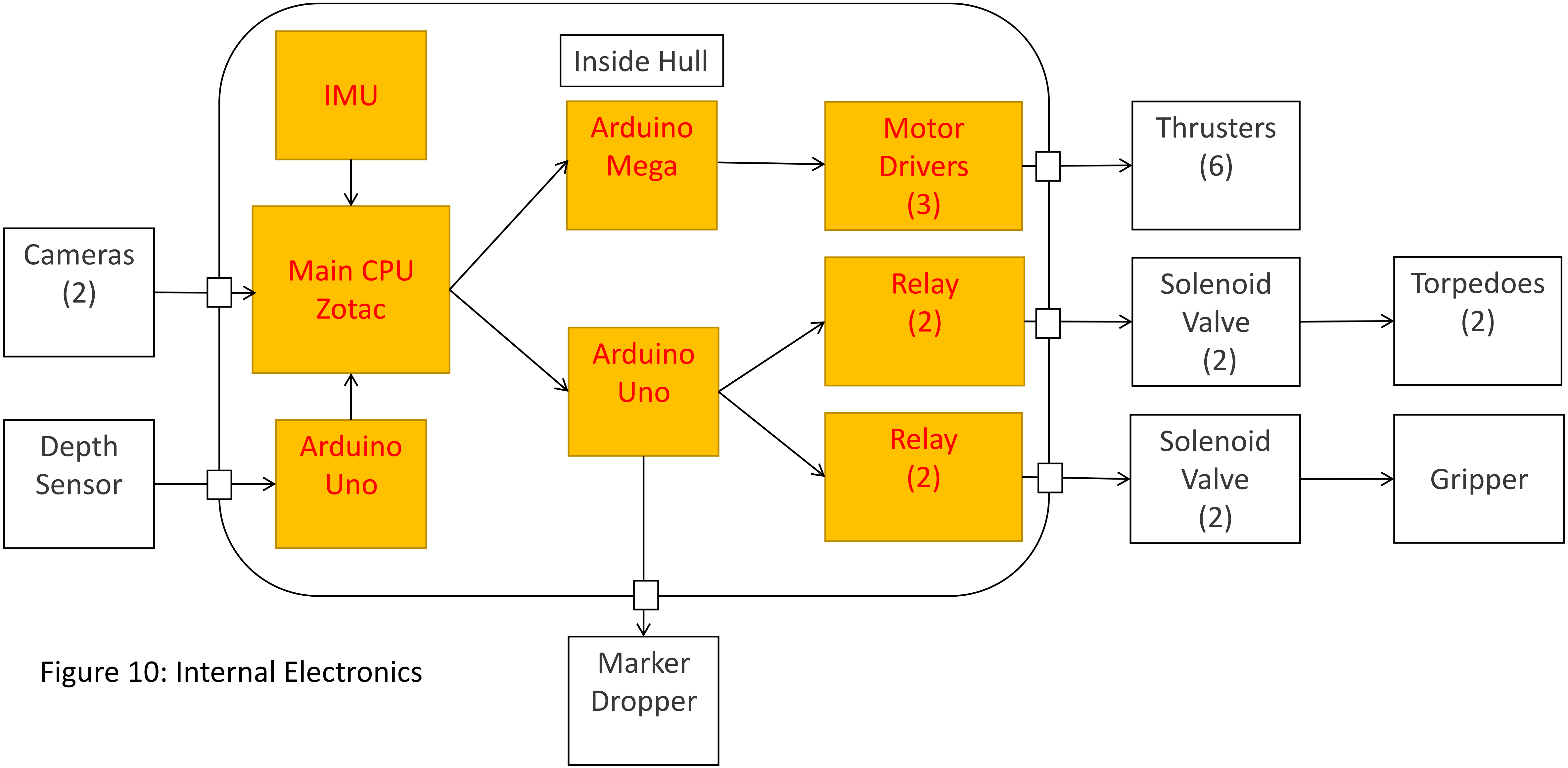


Figure 10: Internal Electronics

Power Systems

- 12V, 9Ah lead acid battery
  - Two identical batteries put in series to achieve 24 V
  - Max Discharge: 2.7 A
  - Weight: 4.5 lb
- Voltage regulators used to step down voltage to the different components
- 12V, 5Ah lead acid battery to power smaller components
  - LED Strip
  - Blue LED ring on kill switch
  - Cooling fans
  - Common port for relays to open valves

Table 3: Component Requirements

Components	Max Current (A)	Ave. Current (A)	Voltage Required (V)
Zotac PC Board	3.5	1.5	19.0
Arduino UNO	0.75	0.5	7.0 - 12.0
Arduino Mega	0.75	0.5	7.0 - 12.0
Motor Controllers	2.0	1.5	5.0
IMU	0.075	0.060	3.5 - 16.0
Thrusters	12.0	3.0	19.1
Depth Sensor	0.020	0.012	8.0 - 11.0

Figure 11: 12V Lead Acid Battery

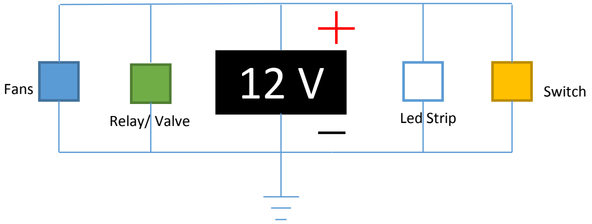


Figure 12: 12V Battery Circuit

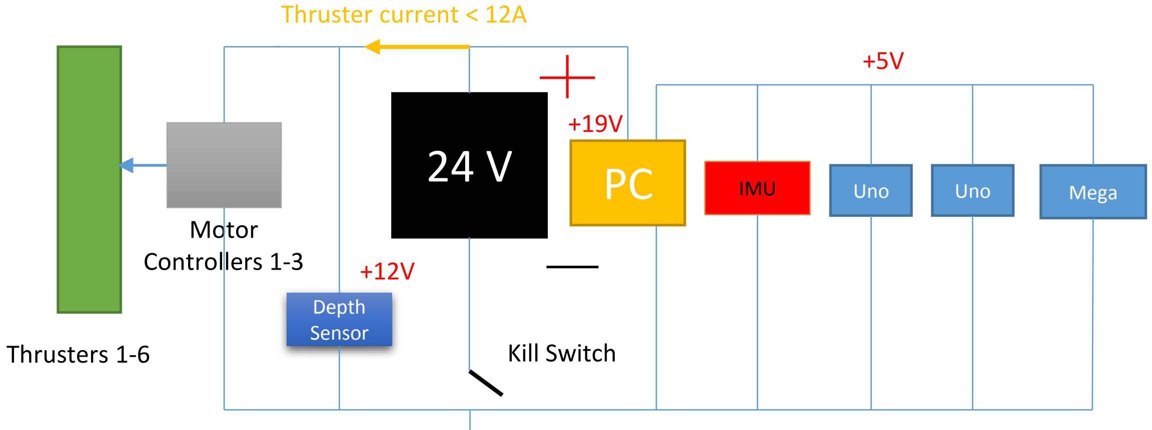


Figure 13: Main Battery Circuit

Reorganization of Internal Electronics

- Original layout
  - Motor controllers in breadboard
  - Arduinos laying around
  - Wires everywhere
- Messy
- Not organized

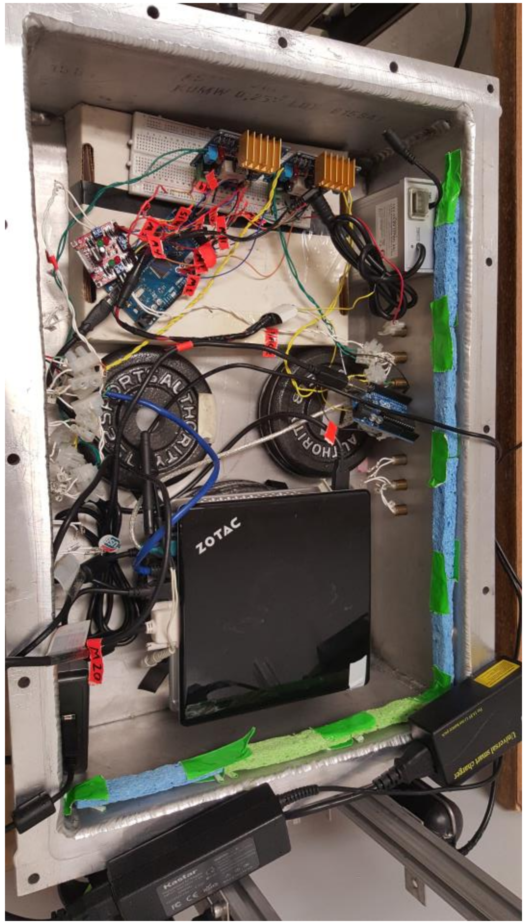


Figure 14: Original Hull Interior

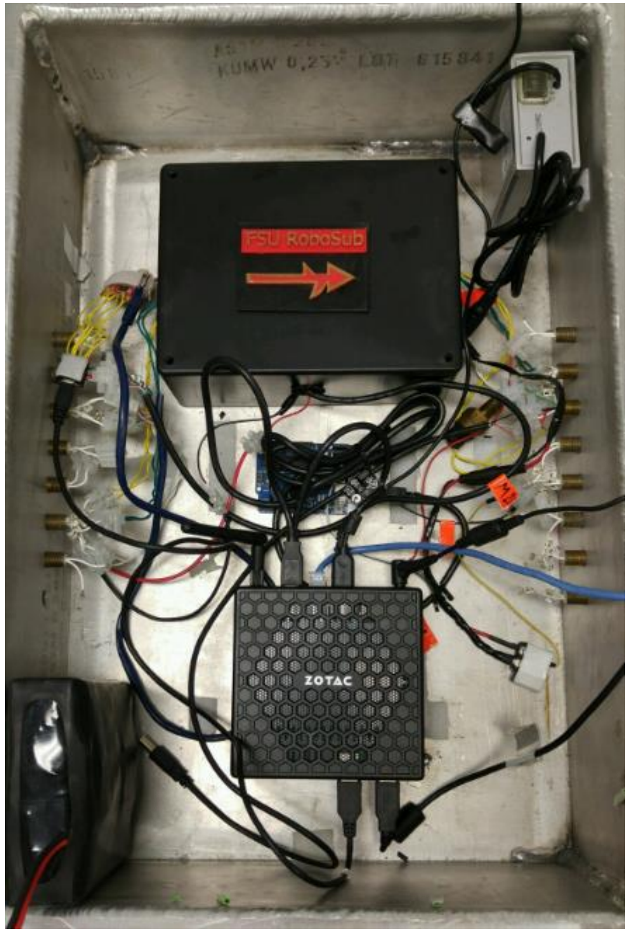
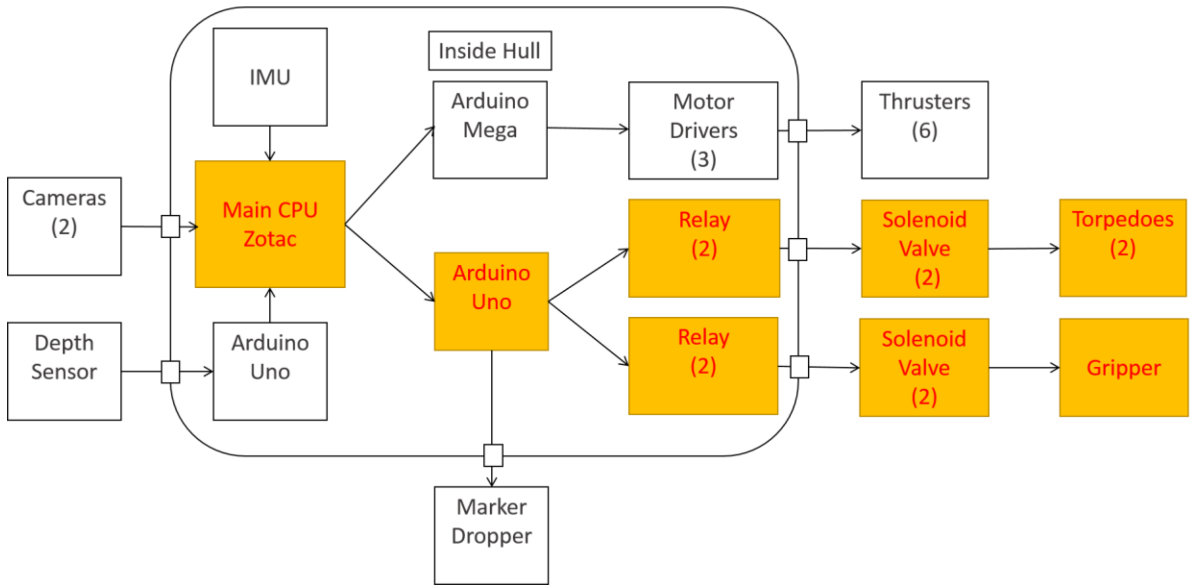


Figure 15: Updated Hull Interior

- Eliminated breadboard
  - Reorganized in black box
    - 3 Motor controllers
    - 1 Arduino Mega
- Further improvements
  - Implement cooling fans
    - Ensure electronics do not overheat

Air System



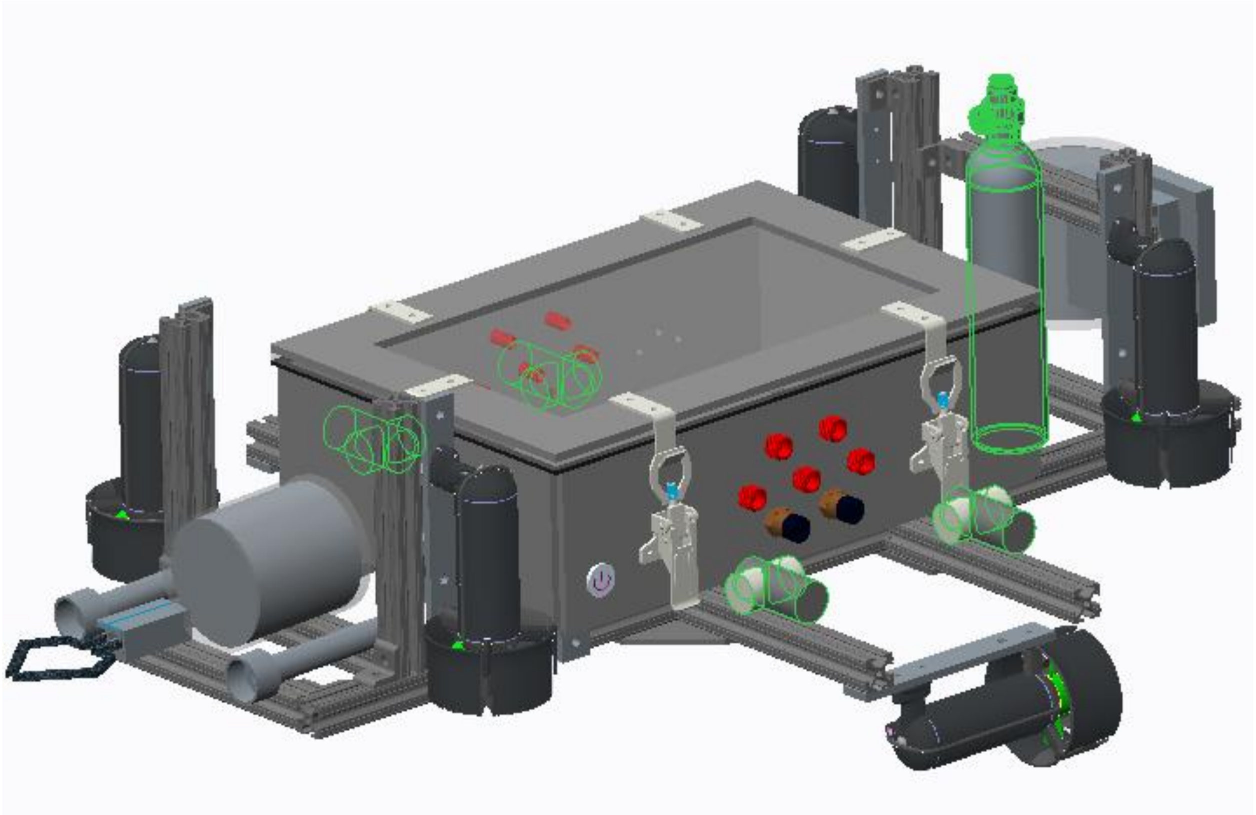


Figure 16: Air System

Air System

- Updated and assembled
  - Actuators
  - Tubing
  - Airtight and waterproof seals
  - Electronic relays for actuators
  - 12v battery
- Functioning code
  - Can launch left and right torpedo based off of keyboard input
  - Future team task is changing keyboard input to identifying image

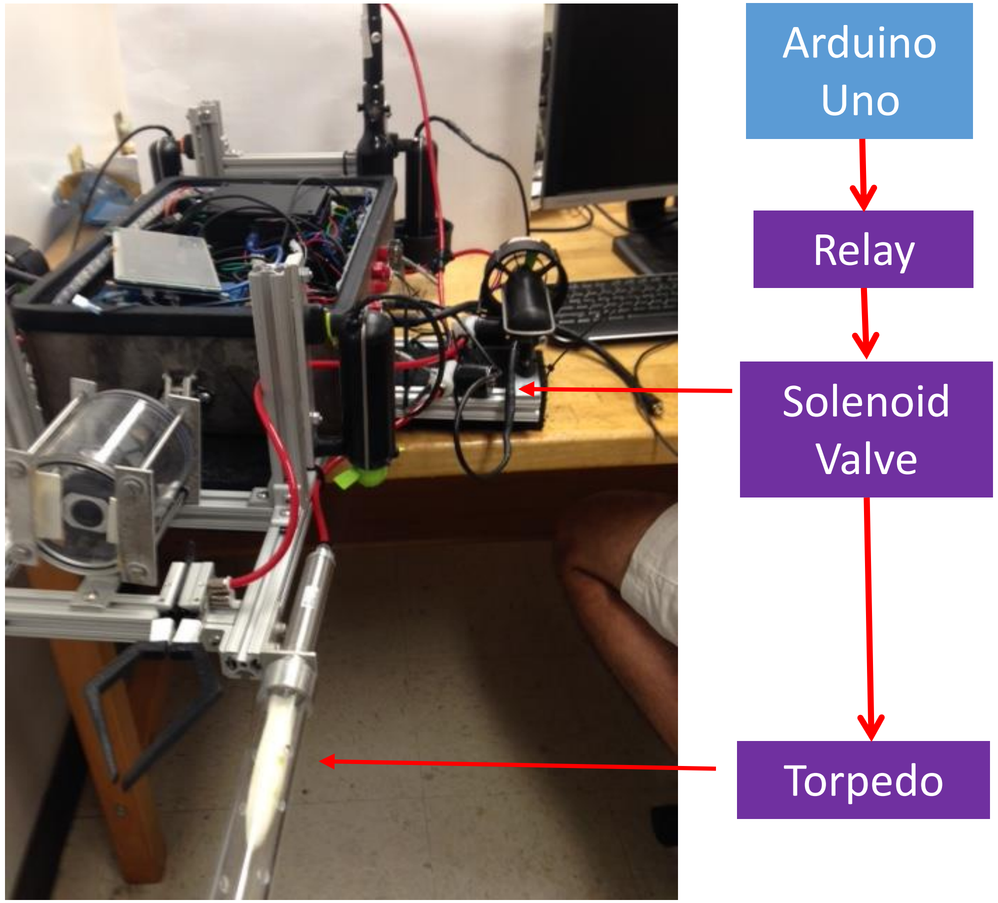
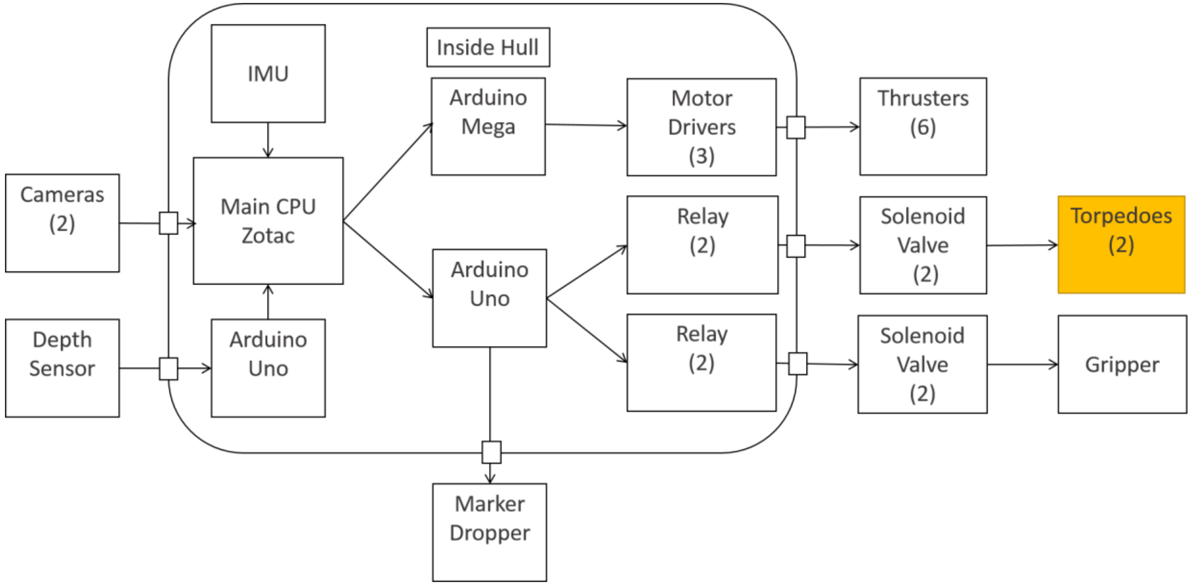


Figure 17: Air System Configuration

Torpedoes



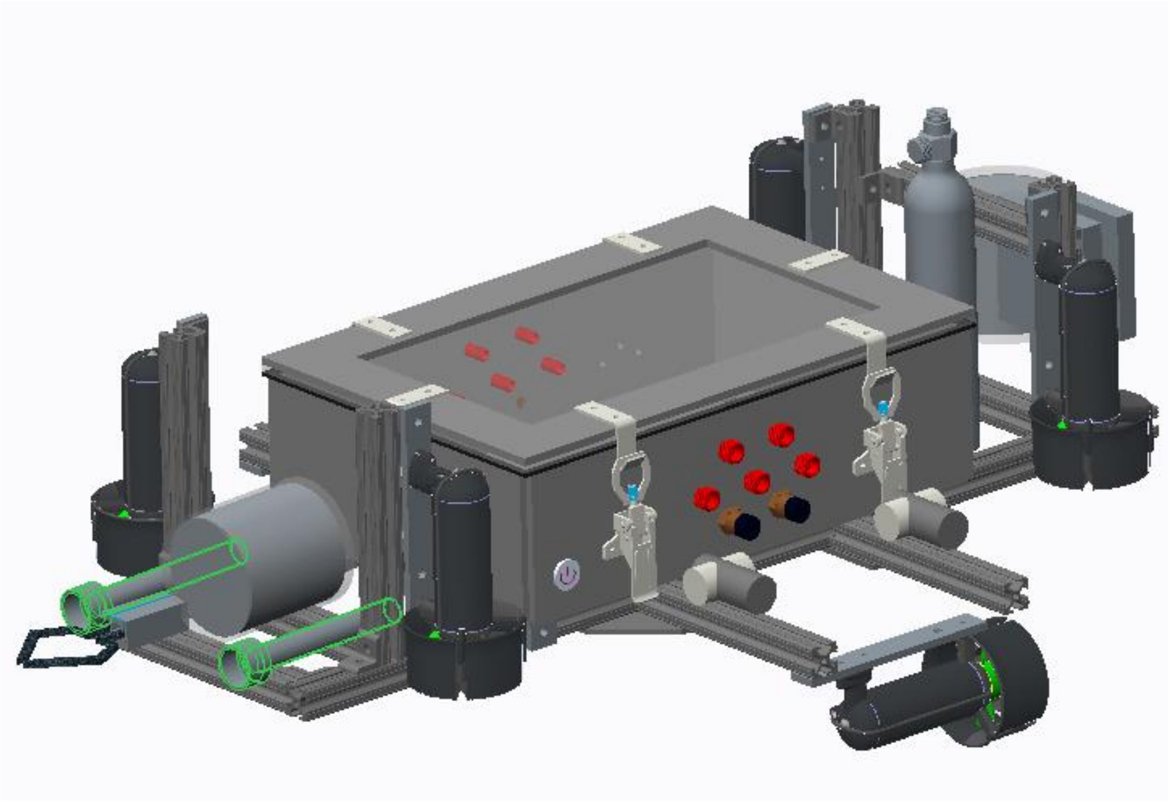


Figure 18: Torpedoes

Torpedo Development

CAD design

- Small fins for easy mold release
- Small diameter to ensure piston fit

3D printed torpedo

- High buoyancy abs plastic
- Rapid prototyping

Plaster mold

- Plaster of Paris
- Mold around 3D printed torpedo
- Recoverable molds

Simpact 85A urethane rubber

- Relatively high density rubber (sinks in water)
- Easy pour but short pot life for rubber positive mold

Torpedoes Completed

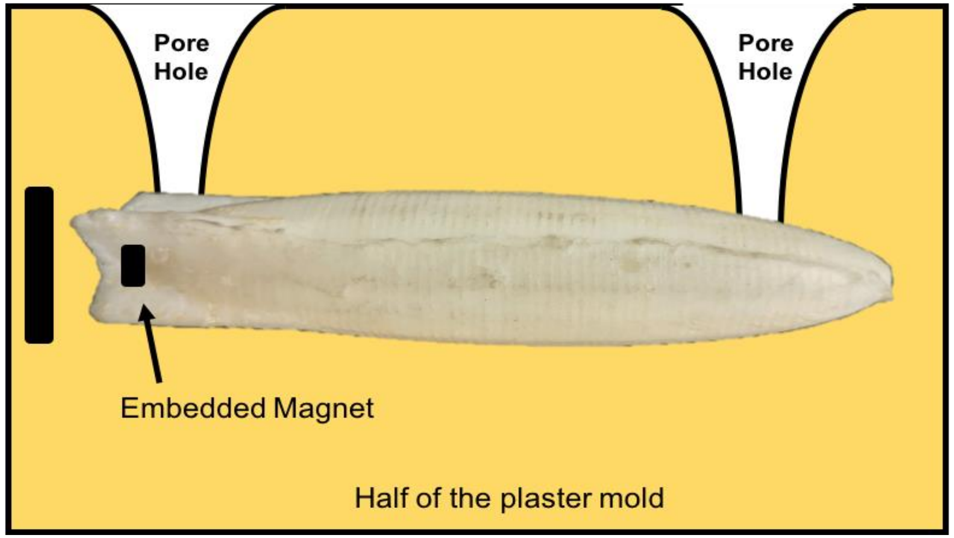
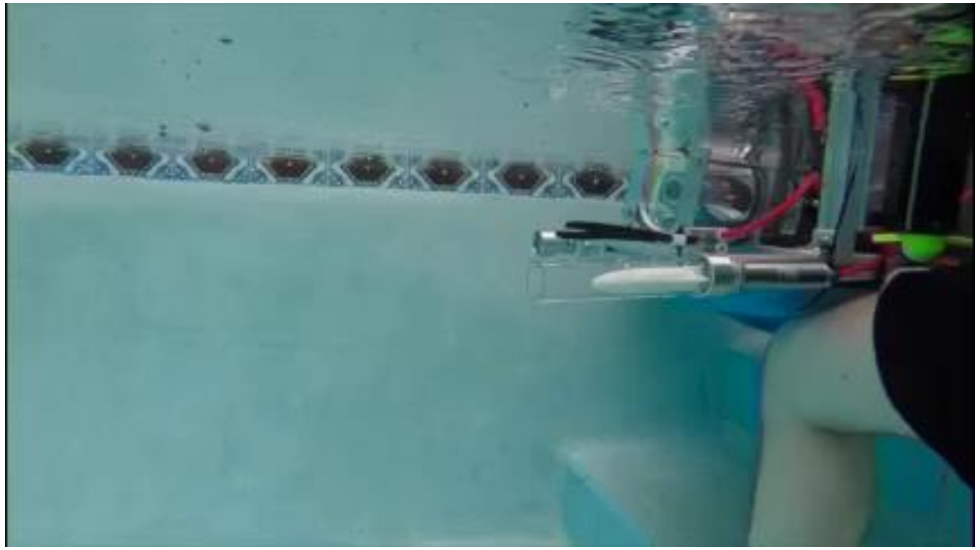


Figure 19: Magnet Embedded Torpedo Process



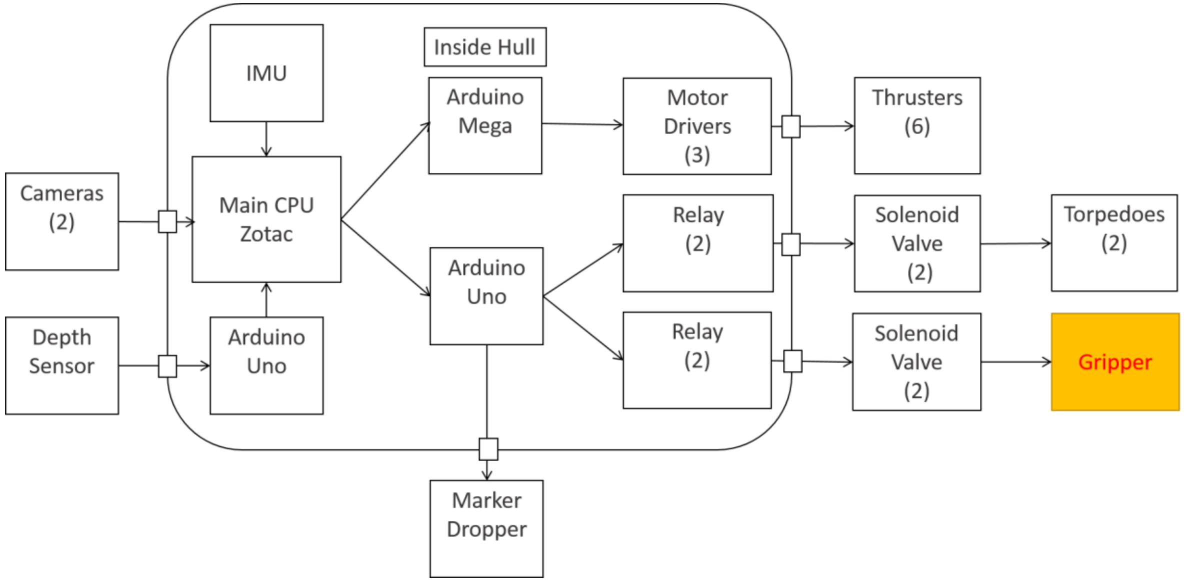
Updated Design

- Embed surface magnets to the torpedo back to ensure hold in tube
- Smoothing body to improve hydrodynamics

Successful Testing

- Rubber torpedo negatively buoyant
- Improvement over old design

Gripper



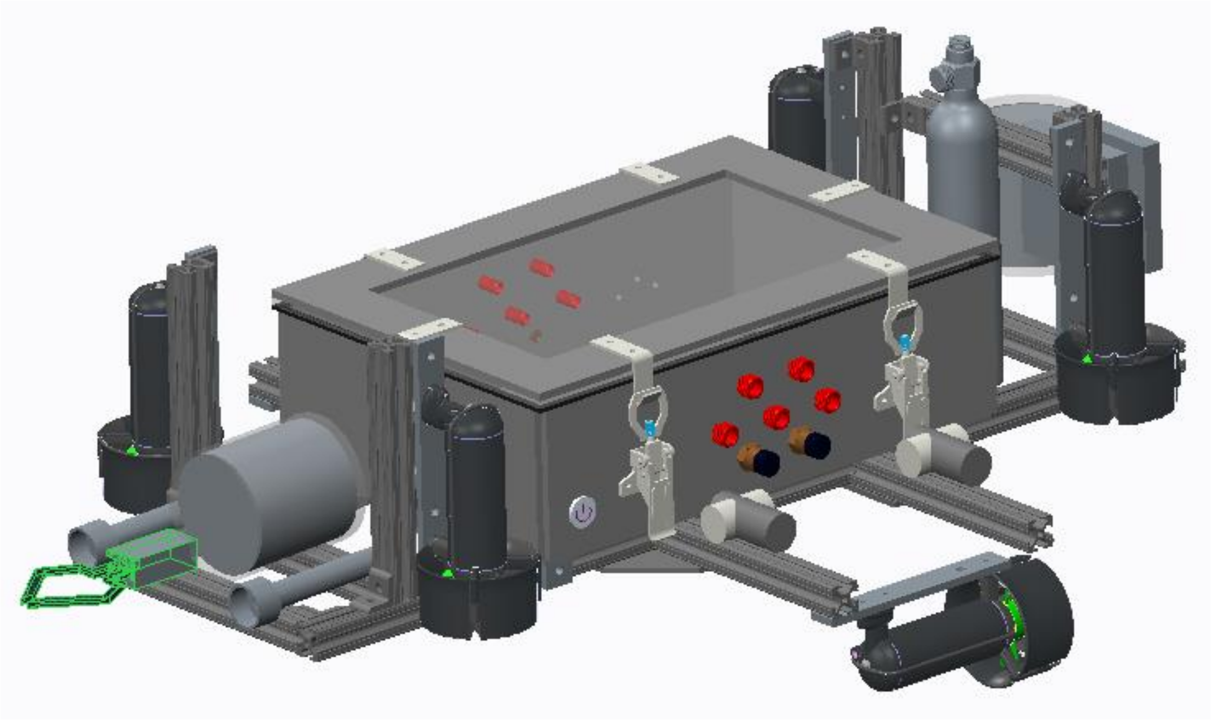
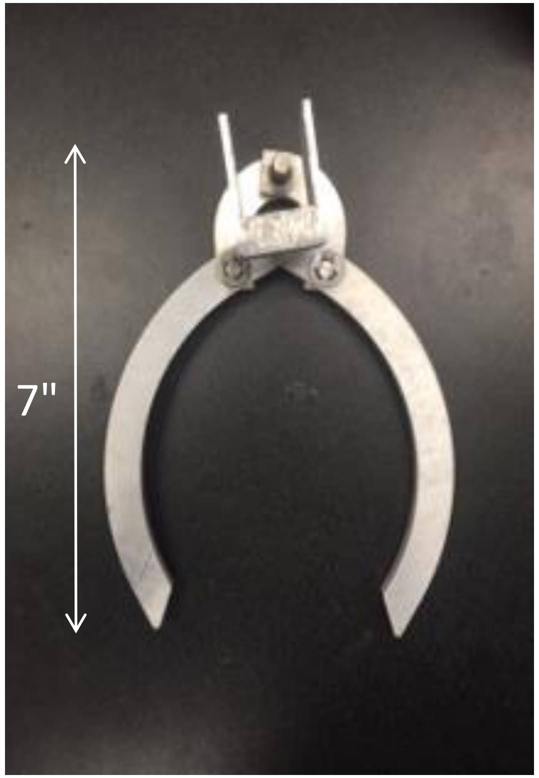


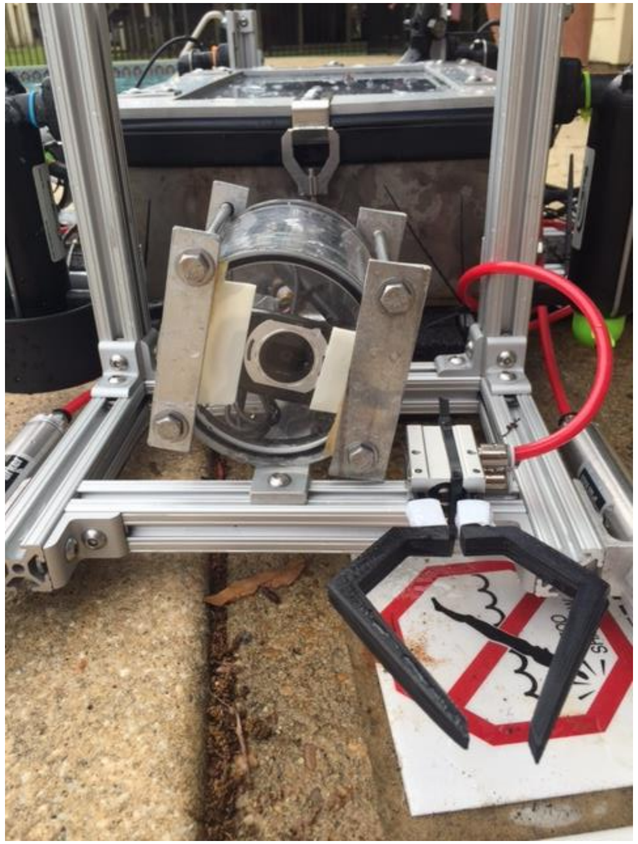
Figure 20: Gripper

Gripper Development



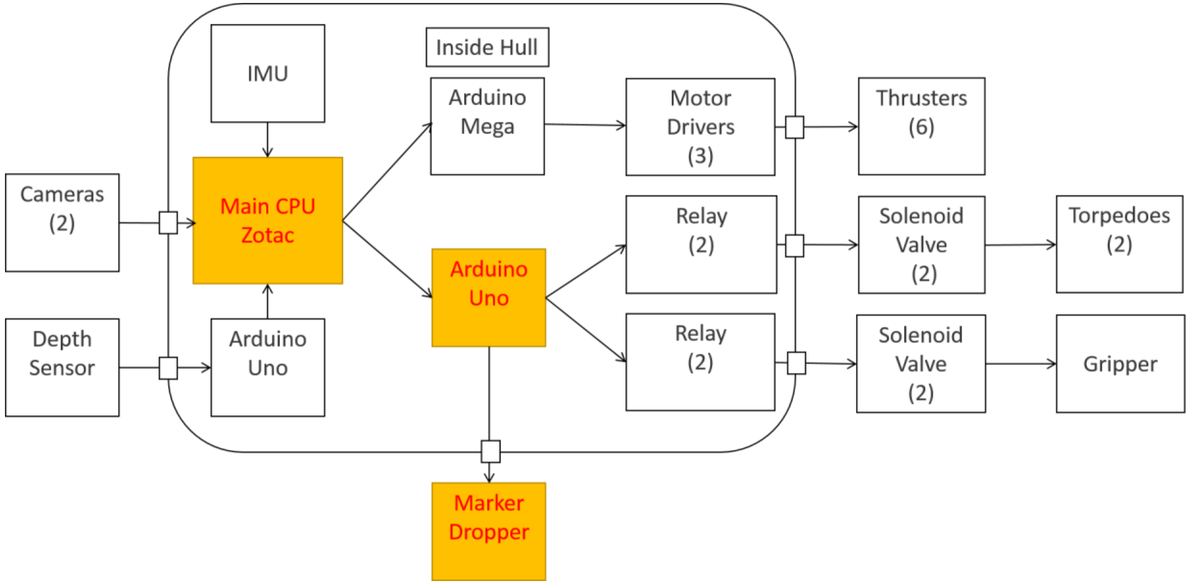
Old mechanism
- Lack of actuation mechanism
- Large ineffective claws

Gripper prototype
- Purchased pneumatic actuator
- 3D printed gripping mechanism



Prototype mounted
- Mounting platform for gripper on submersible frame
- Integrated with air system

Marker Dropper



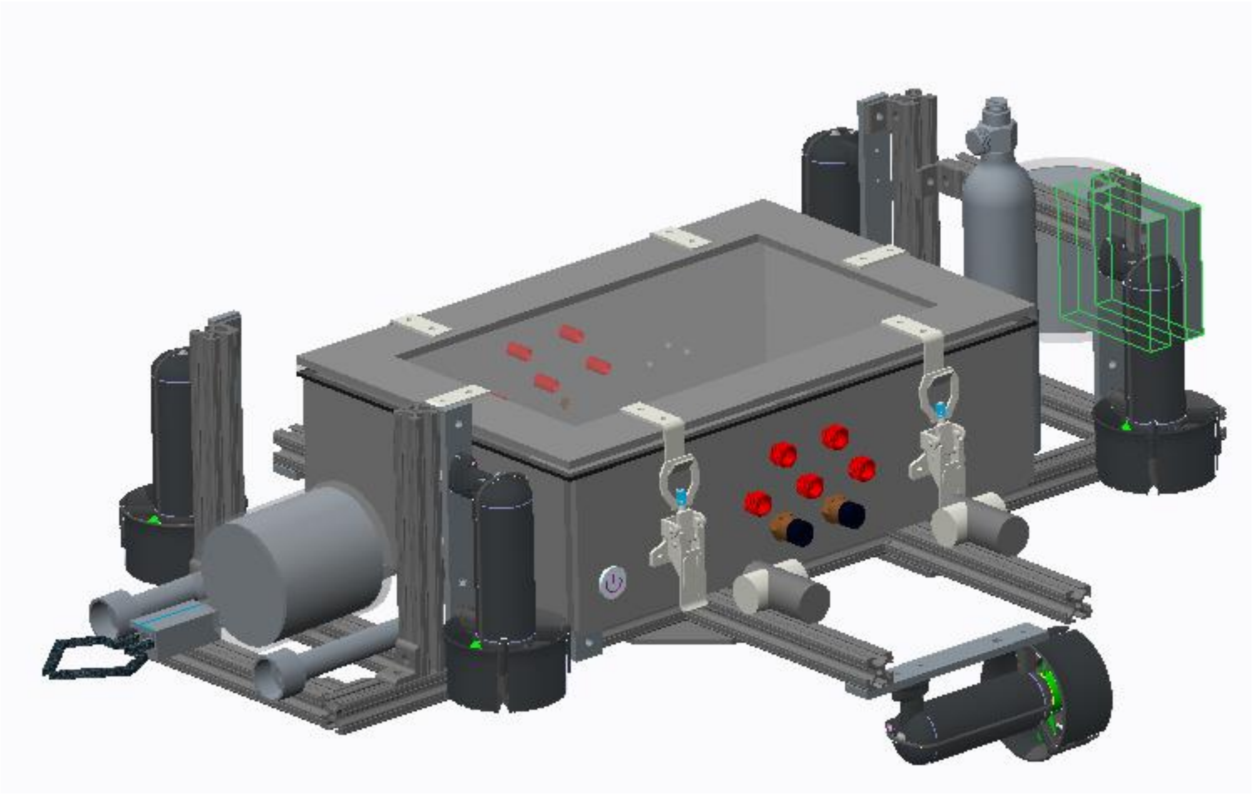
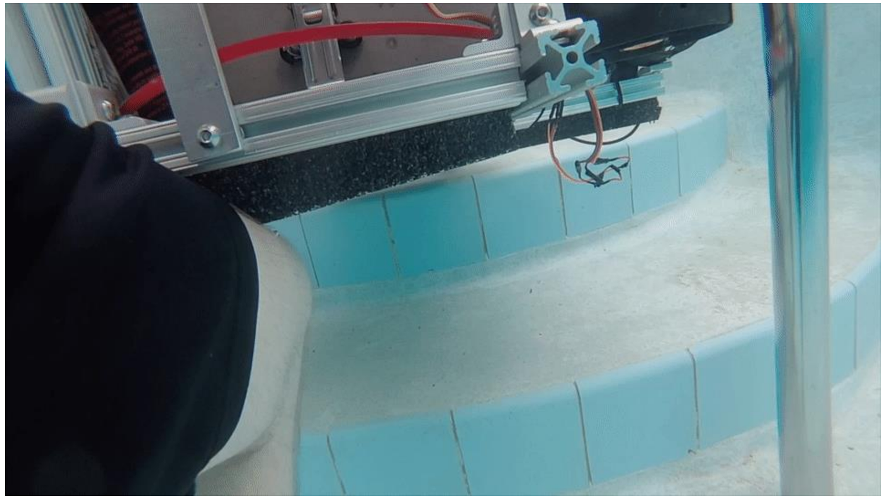


Figure 23: Marker Dropper

Marker Dropper Development



Old system

- Normal DC motor
- Poor waterproofing
- Usable frame

New actuator

- Waterproof servo
- Adjusted bracket positioning to allow the servo arm enough space to move

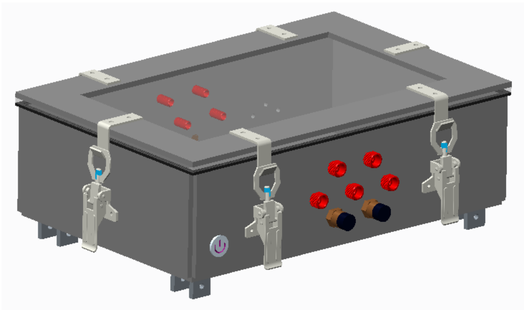
Tested servo underwater

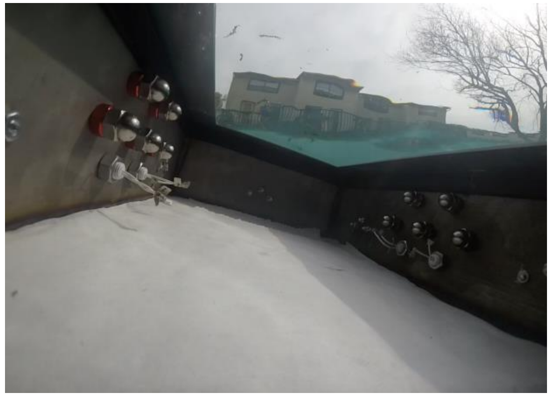
- Markers successfully drop when prompted by user
- Mounted to frame

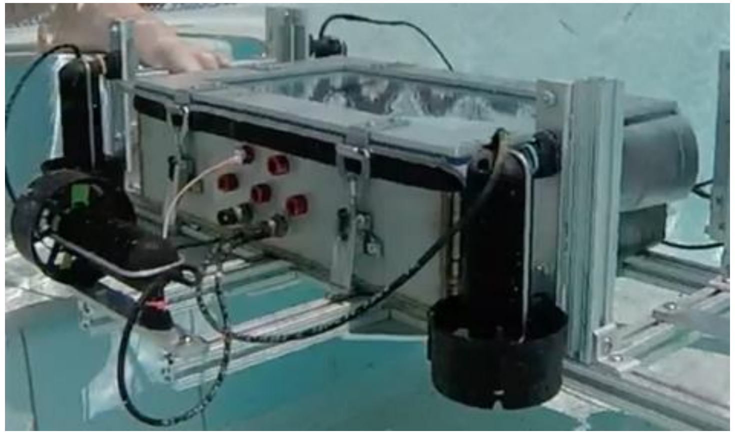
Testing Summary

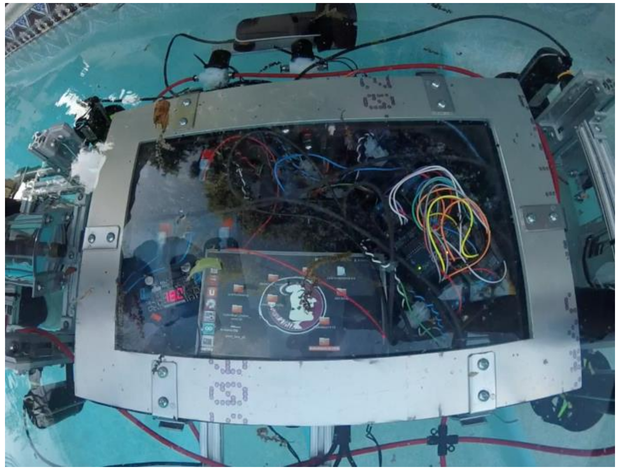
Test	Date	Notes
Gate Navigation	Incomplete	Computer malfunction
✓ Marker Dropper	January 22	Success
✓ Torpedoes	February 1	Success
✓ Gripper and Air Systems	February 1	Success
✓ Testing of New Hull	March 31st	Success
✓ Systems Integration	Monthly	Success

Waterproof Testing









Hull initial fabrication

- Parts direct from machine shop
- Assembled as initially planned
- Waterproofing from rubber gasket and nuts

Leak testing

- Rapid water entry from bolts
- Slow water entry from lid

Corrections

- Teflon tape Screw wrapping
- New washers and O-rings
- Foam addition to lid
- Marine epoxy and super glue touch-ups

Success

- Held underwater for over 20 minutes with electronics, moved, and reoriented
- No water entry

Completed Submersible

Figure 20: Forward Movement of Surface

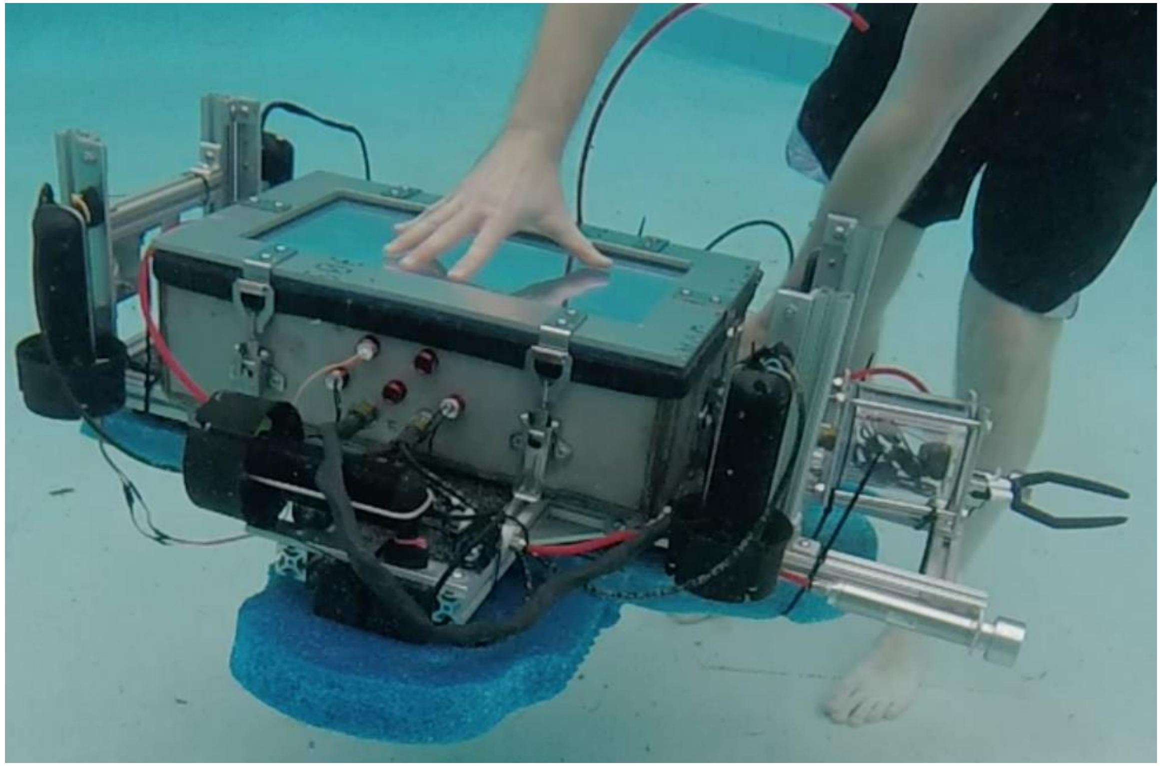


Figure 21: Moving while Fully Submerged

Challenges Faced

- Team Management
- Broken components throughout the year dividing project focus
- Hull and air system waterproofing
- Code integration
- Issues with final systems integration

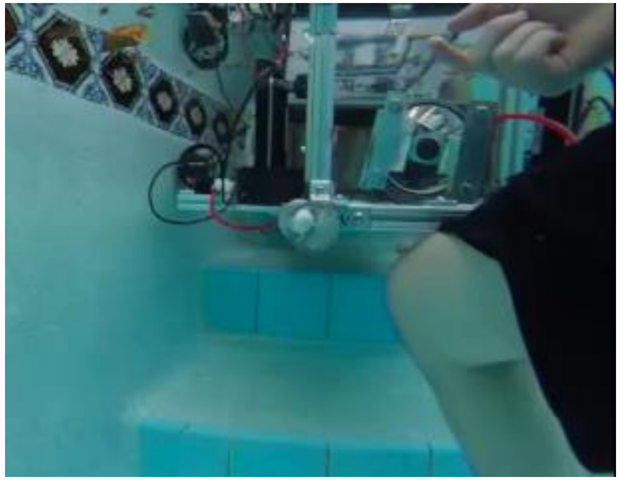


Figure 22: Leaks in the Air System

Lessons Learned

- Team organization and delegation over a long term project
- The merits of early prototyping, independent work, and flexibility of design corrections.
- Better familiarity with electromechanical systems
- Utilizing scheduling and creating deadlines as guides rather than hard set fixed orders

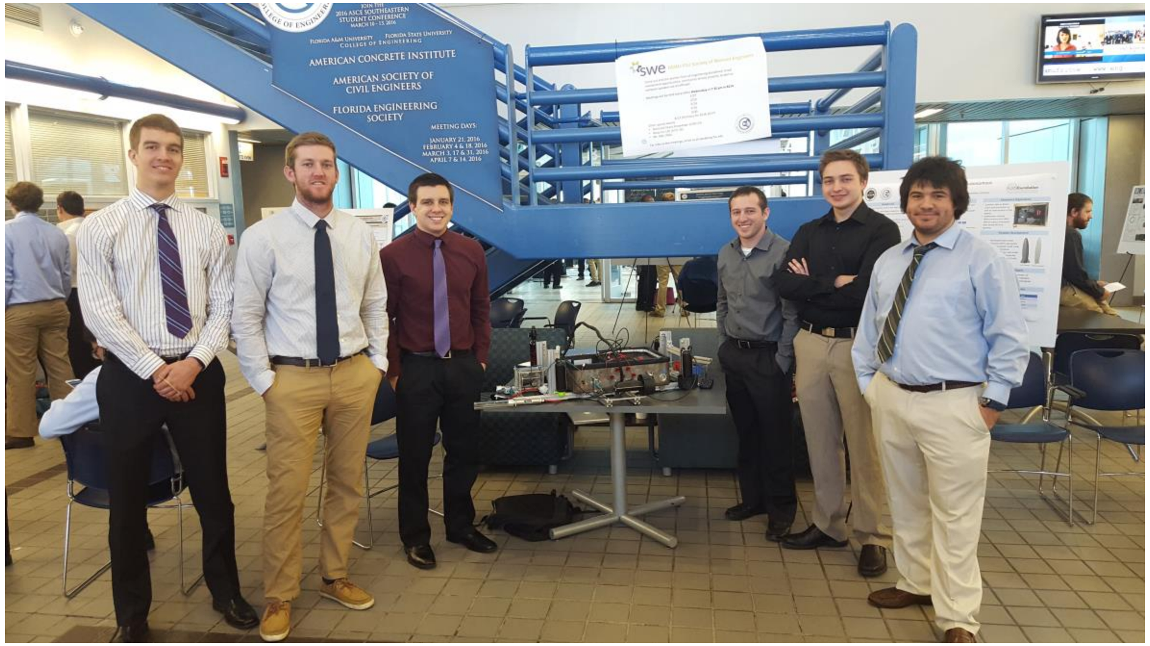


Figure 23: Team Photo

Gantt Chart Spring 2016

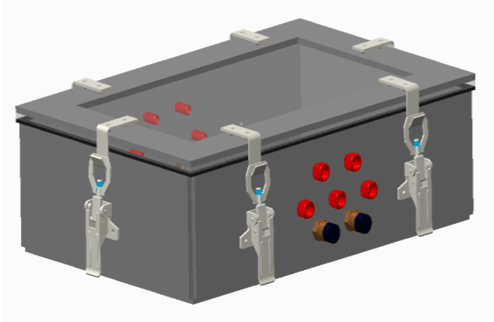
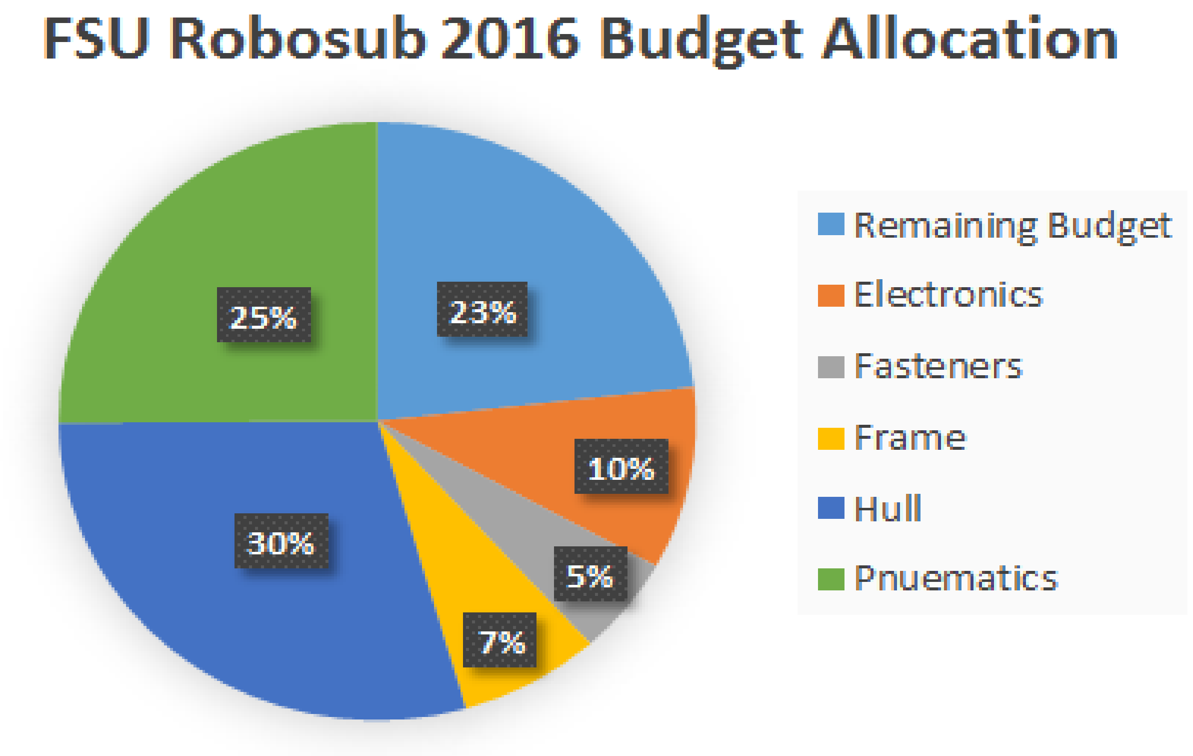


Figure 24: Time Allocation and Scheduling for Spring 2016 Semester

Resource Allocation

Initial Budget
$2000



Remaining Budget
$460

Project Summary

- New hull fabrication completed and waterproofed
- Fully assembled and tested torpedos and marker dropper
- Reorganized, electrically insulated, and modularized hull electronics
- Pneumatics system fully operational
- Code created to control sub remotely to test systems
- Frame fully assembled and systems integrated into single body

References

- [1] Auvsifoundation.org, "Home - Foundation", 2016. [Online]. Available: http://www.auvsifoundation.org/home. [Accessed: 16- Feb- 2016].
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- [3]F. Engineering, "FAMU-FSU College of Engineering :: Welcome", *Eng.fsu.edu*, 2016. [Online]. Available: http://www.eng.fsu.edu/. [Accessed: 16- Feb- 2016].