presented by

ECHO TECHNOLOGIES

Proof of Concept

26 March 2019

MISSION
STATEMENT

ECHO Technologies seeks to **surpass industry standards** and **achieve excellence** as an engineering business by **promoting student-led discovery** in the development of technical solutions, education of communities, and the growth of individual persons.

VISION STATEMENT

To create **ideas worth hearing** that inspire the communities we serve, through the products we develop, and the leaders we cultivate.

EXECUTIVE SUMMARY

- Developing and testing UAV/UUV recovery vehicle technology
- Progress
  - heavy-lifting, waterproof, UAV/UUV prototype
  - passive intake for smaller UUV prototype
- Finishing prototyping and testing
- Project finances:
  current spending ≈ $9500
- Legacy

MISSION REVIEW

MISSION REVIEW

Megalodon (UAV/UUV Drone)

- Operate autonomously
- Fly in air & water
- Function without a tether
- Selectively jettison mildly radioactive objects and manipulate object retrieval articulation
- Detect Remora’s beacon and retrieve the Remora

Remora (UUV)

- Assist in locating wreckage with a live video feed
- Provide a beacon for Megalodon device
- Detect mild radioactivity with UV light
- Recover all radioactive items

MISSION REVIEW

- Fly 201.9 feet to the body of water
- Drop the Remora into the pool
- Retrieve & jettison...
    - All radioactive objects
    - Submarine wreckage
    - Remora
- Land on a floating quadcopter pad

YEAR AT A GLANCE

November 2018

System Performance Specifications

ECHO introduced their approach to the mission and broke down their design for the Megalodon and Remora, as well as individual components.

March 2019

Proof of Concept Presentation

ECHO confirms choice of design and hardware through testing. Demonstrations are shown in addition.

April 2019

First article/Technical Data Package

ECHO completes and gives the Technical Data Package for the Megalodon and Remora to the client.

May 2019

Mission Day & Expo

ECHO presents the Megalodon and Remora to the client. The Megalodon and Remora will complete the mission.

OUTREACH

As ECHO's Outreach team, our main goal is to educate communities about the possibilities in the STE(A)M fields and to inspire youth to pursue a career in them.

How?

- Hosting multiple STEAM events and workshops
- Interactive lessons
- Disney themed educational activities

Where?

- Boys & Girls Clubs
- CAMS Community Days
- Benjamin F. Tucker, Grant, Mann, Dooley, and Hickory Elementary schools
- Jane Addams Middle School

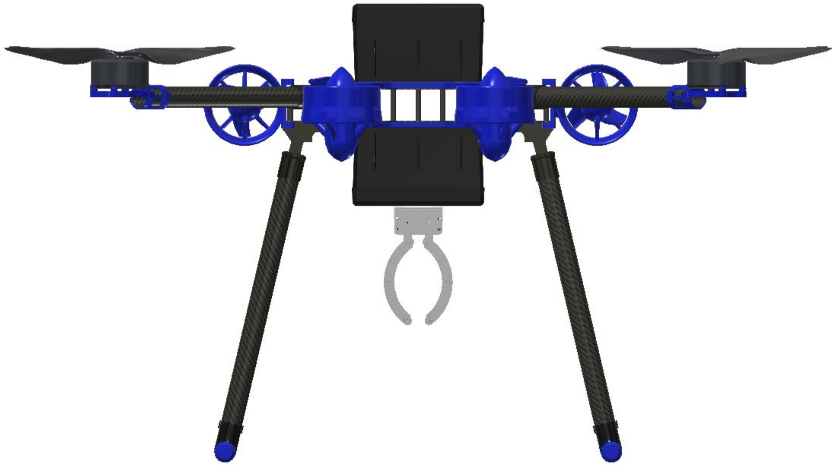
PRESENTATION OVERVIEW

1. Retrieval Mechanism
2. Programming
3. Communication
4. Remora
5. Prototype Testing and Data
6. Demonstration
7. Finance
8. Future Goals

MEGALODON

DESIGN OVERVIEW

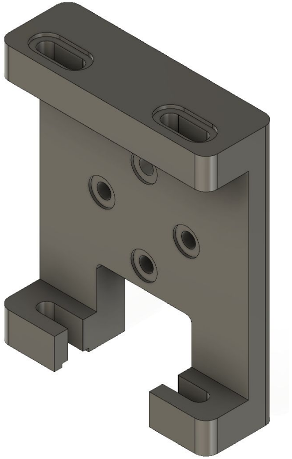
- Carbon Fiber Frame
- 4 Aerial Motors
- 6 Underwater Motors
- Two Watertight Enclosures
- Recovery Mechanism (Claw)



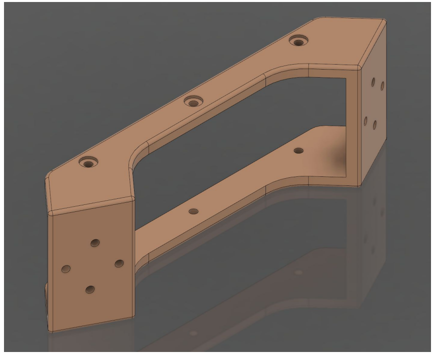
DESIGN OVERVIEW

Motor Mounts

- Designed specifically for the underwater motors
- Maximizes Stability
- Lines up flush against drone frame
- Made of ABS Plastic



Motor Mount for horizontal T200 underwater motors



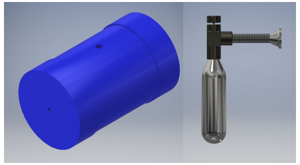
Motor Mount for vertical T200 underwater motors

PROTOTYPE VS. THEORETICAL

- 4 UUV thrusters vs. 6
- Piloted vs. autonomous
- Claw (retrieval mechanism) has not yet been attached to our prototype

DESIGN ALTERATIONS

1. Ballast System - **Removed**



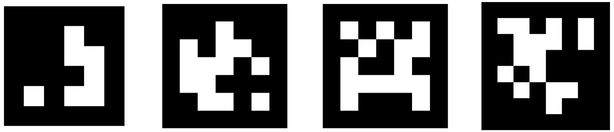
2. Cameras - **Replaced**

3. Flight Controller - **Replaced**

4. Aquatic Communication - **Replaced**

5. Power Distribution - **Replaced**

6. AprilTags



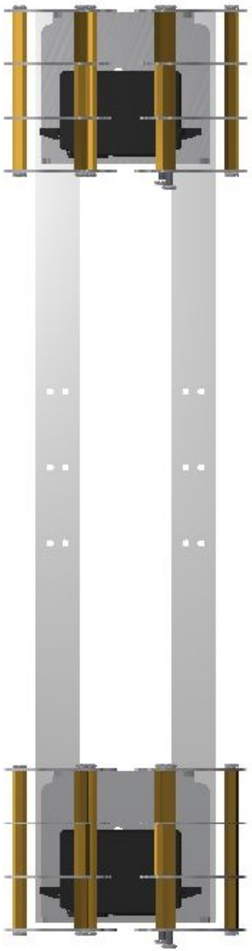
RETRIEVAL MECHANISM

THE CLAW

- Two mechanical standard gripper claws
- Attached to two 12in aluminum L-bars
- High-torque motor attached to geared joints

THE CLAW

- Attached to the bottom center of the electrical box
- Two points of contact

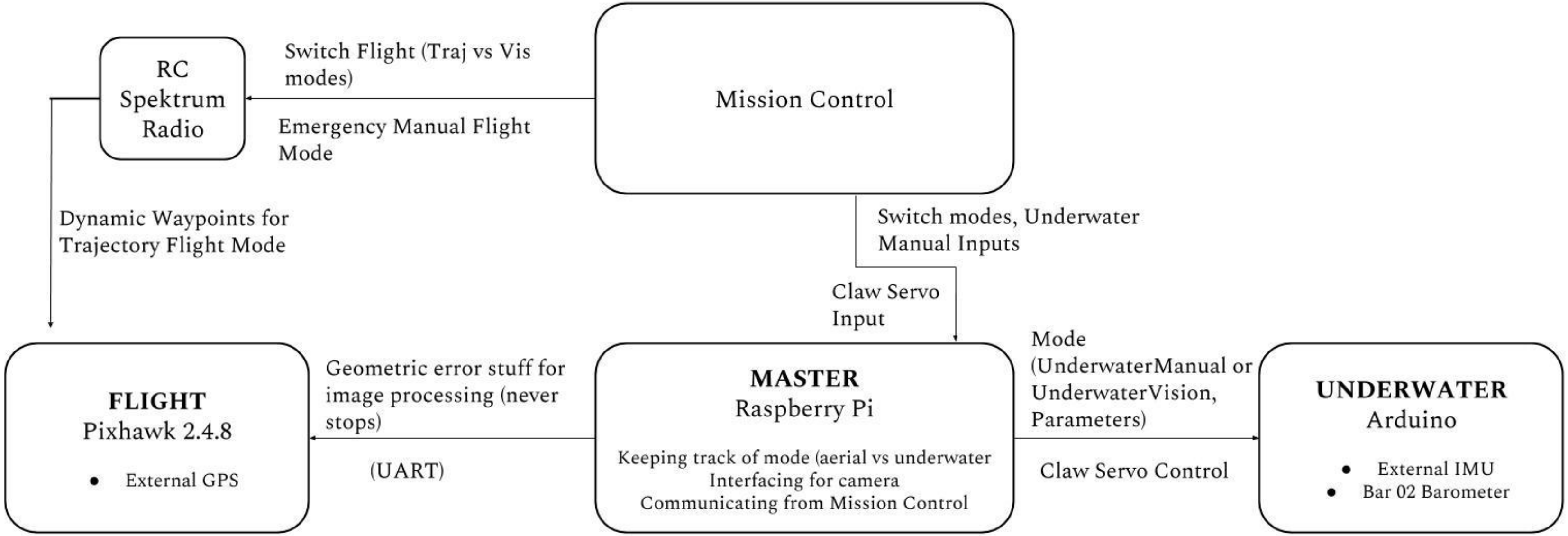


PROGRAMMING

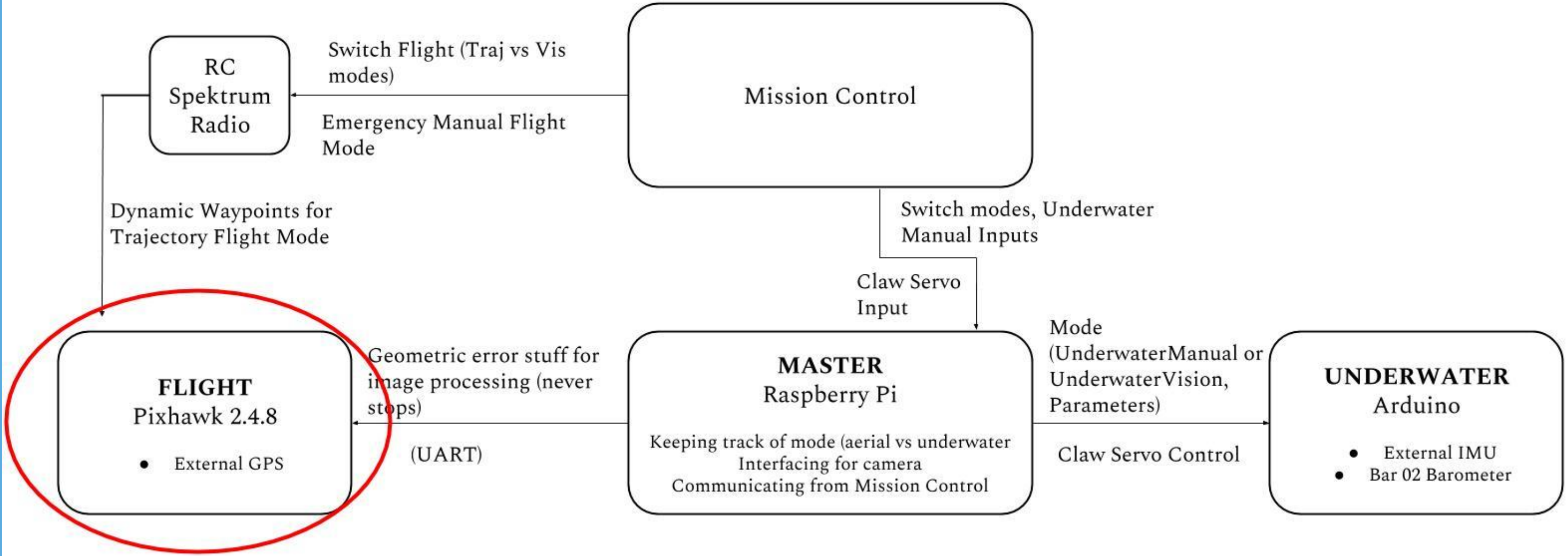
OVERVIEW

- **System Architecture**
  - 3 Raspberry Pis proposed in SPS
    - ➜ UPDATED: 1 Raspberry Pi + PixHawk + Arduino
- **Sensor Testing**
  - Barometer
  - GPS
- **Flight Control**
  - Pixhawk
- **Vision**
  - OpenCV
  - AprilTags

SYSTEM ARCHITECTURE



SYSTEM ARCHITECTURE



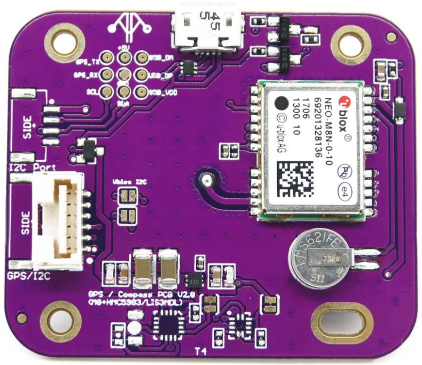
FLIGHT CONTROLLER

mRo PixHawk 2.4.6

- 32-bit Cortex® M4 core with FPU
- Micro 3-axis 16-bit gyroscope
- Micro 3-axis 14-bit accelerometer / magnetometer
- MEAS barometer

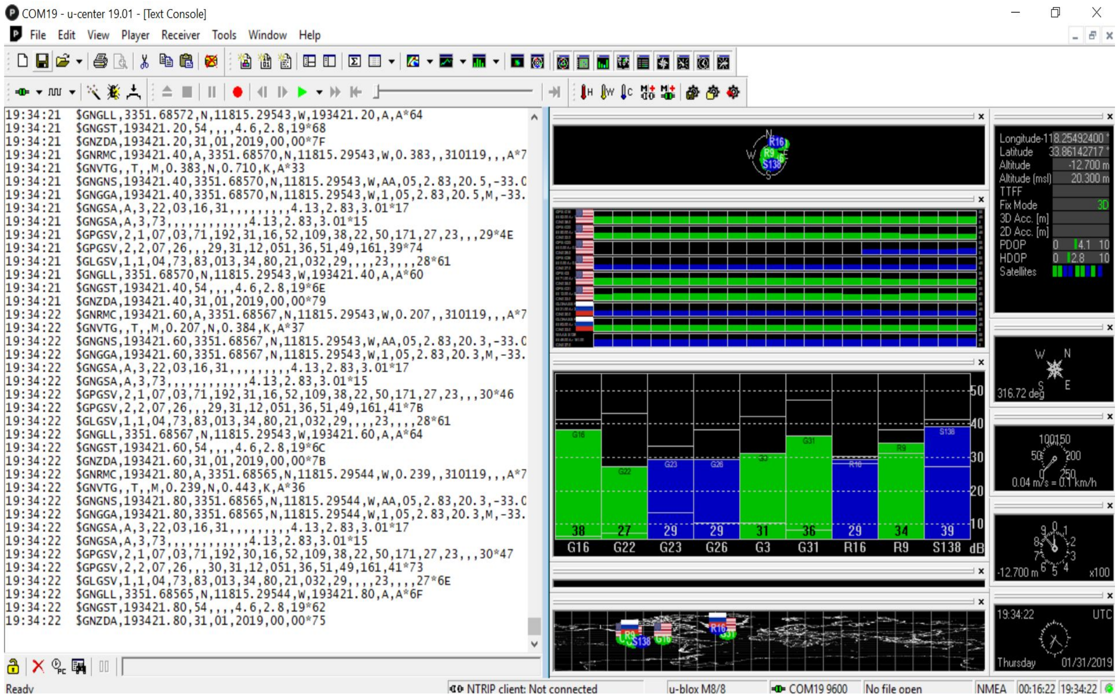
ECHO TECHNOLOGIES

SENSOR TESTING: GPS

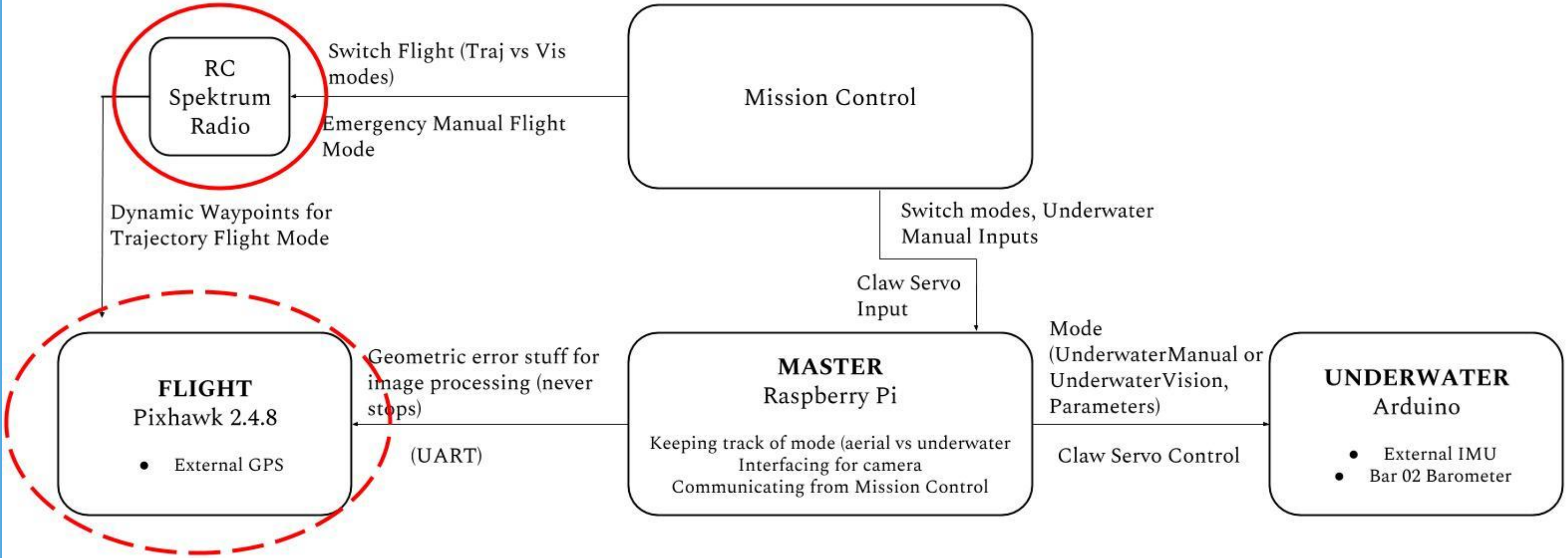


uBlox GPS Model BGP

mRo 6-Pins JST-GH to 6-Pins DF13



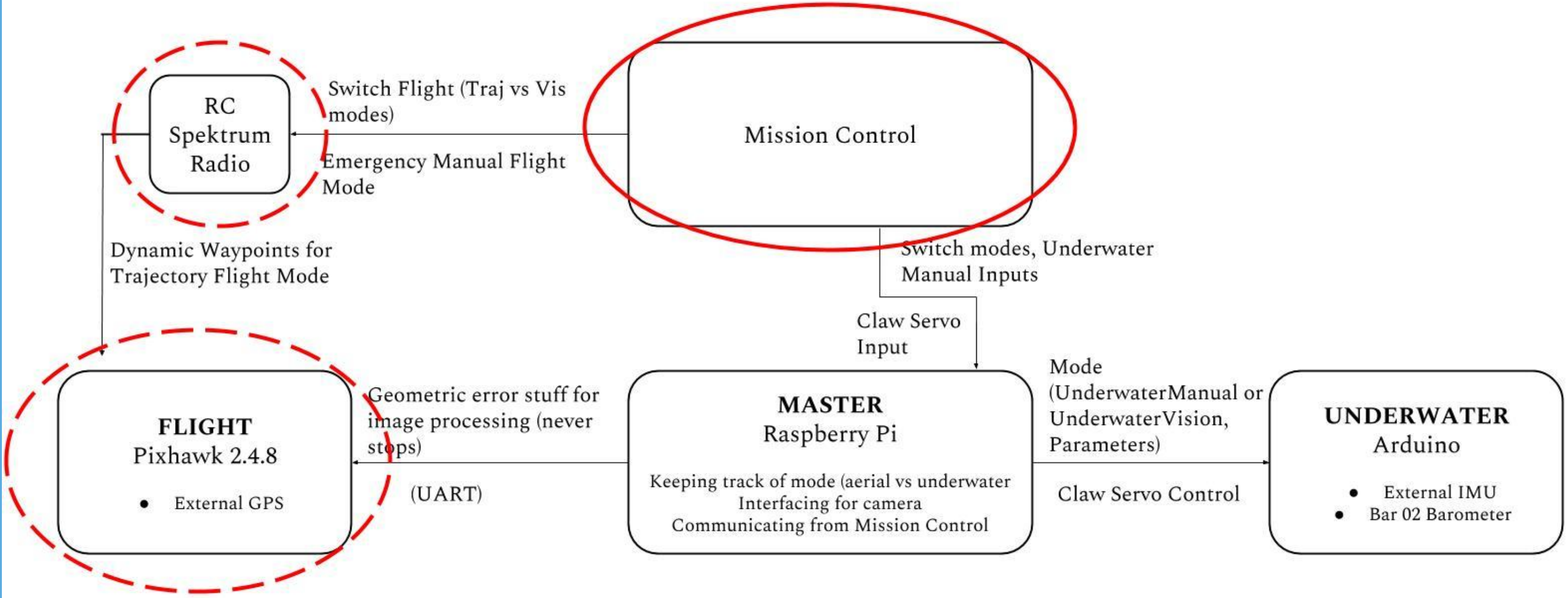
SYSTEM ARCHITECTURE



SENSOR TESTING: R/C Spektrum

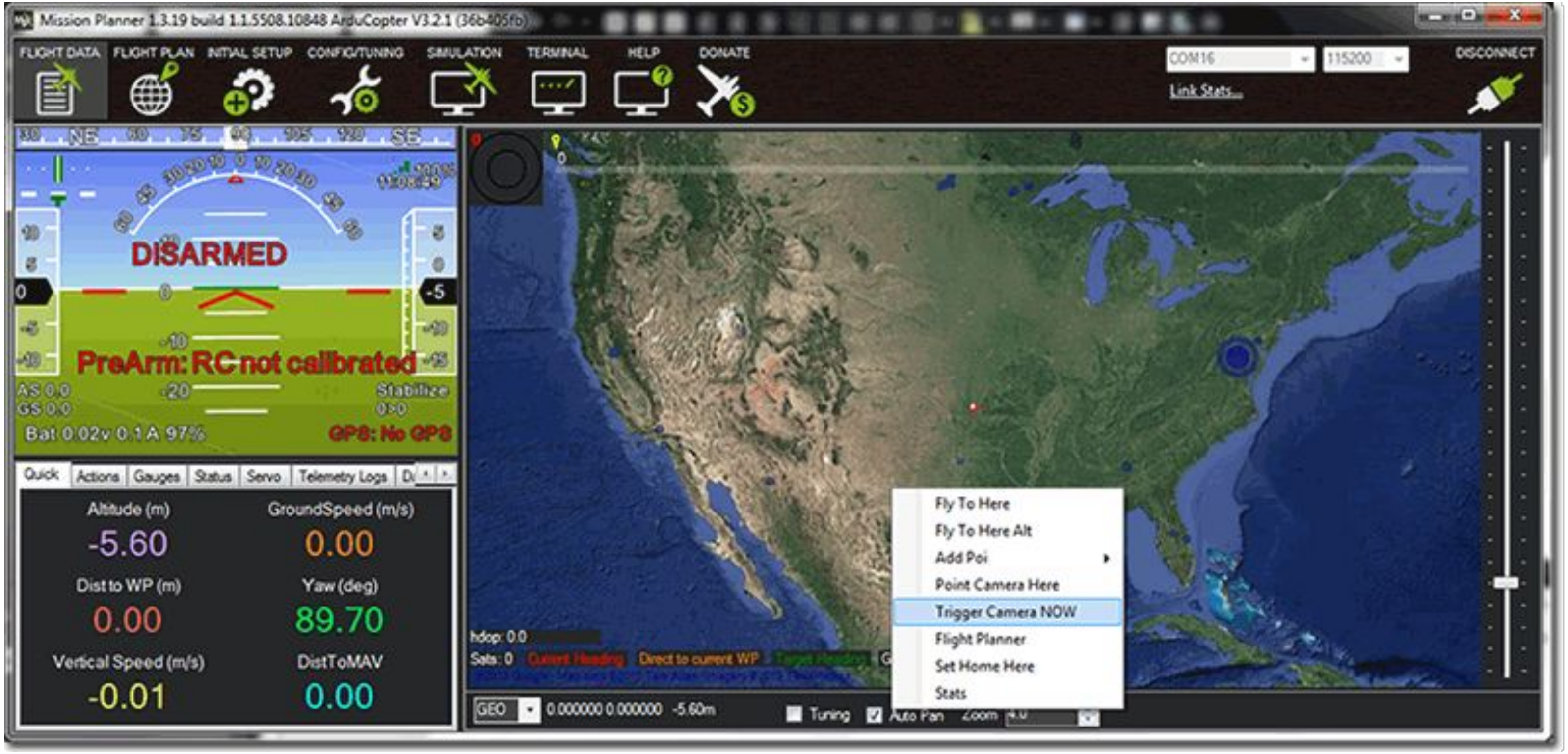
- Antenna Diversity
- Auto-bind
- Serial port supports SRXL or Remote/Satellite Receiver

SYSTEM ARCHITECTURE

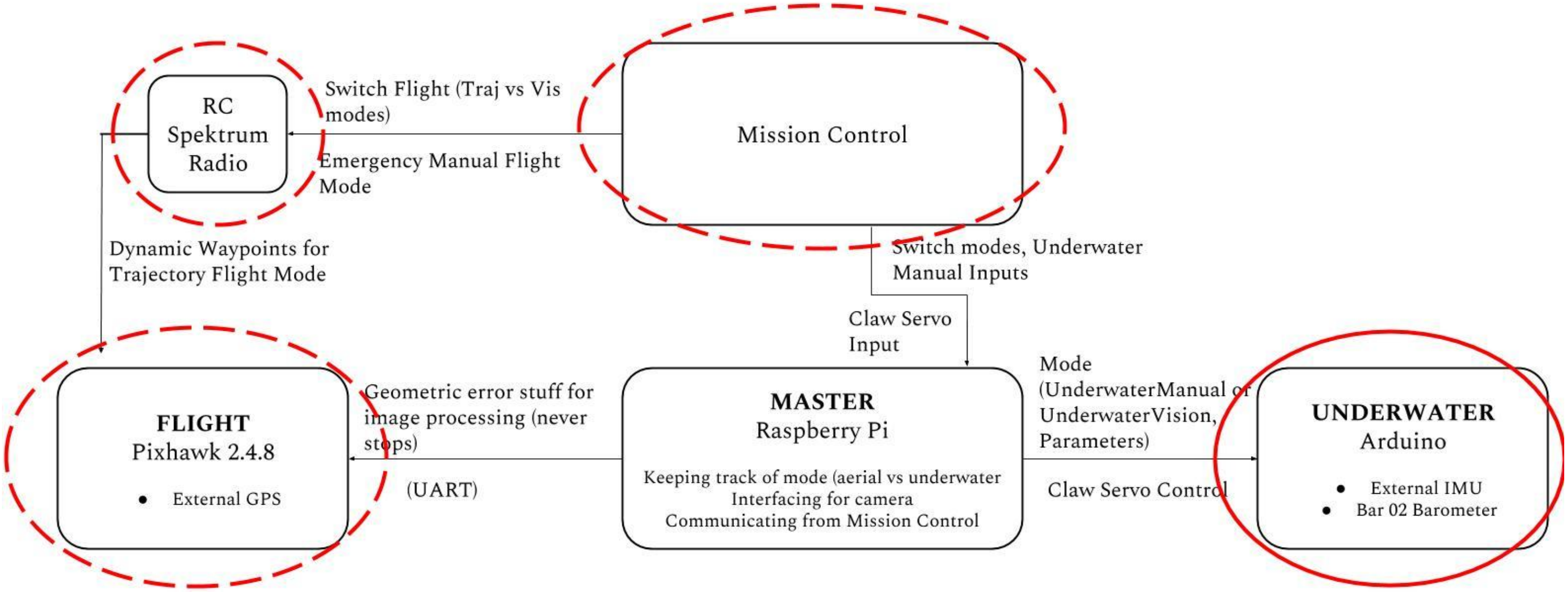


FLIGHT CONTROL

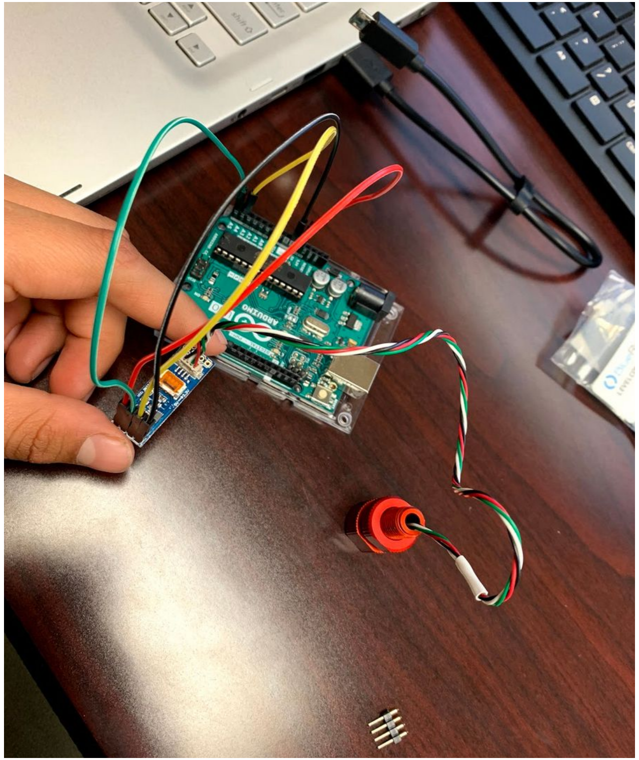
Mission Planner - Ground Control Station



SYSTEM ARCHITECTURE



SENSOR TESTING: PRESSURE ALTIMETER

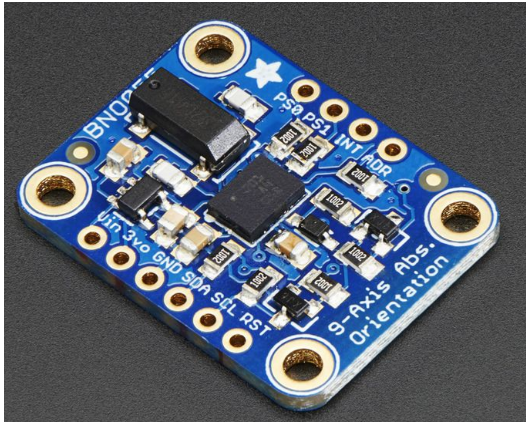


sensortest.ino

```
#include <MS5837.h>

#include <Wire.h>

MS5837 sensor;

void setup() {

  Serial.begin(9600);

  Serial.println("Starting");

  Wire.begin();

  sensor.setModel(MS5837::MS5837_02BA);
  sensor.init();

  sensor.setFluidDensity(997); // kg/m^3 (997 freshwater, 1029 for seawater)
}

void loop() {

  sensor.read();

  Serial.print("Altitude: ");
  Serial.print(sensor.altitude());
  Serial.println(" m above mean sea level");
```

ECHO TECHNOLOGIES

SENSOR TESTING: IMU



Adafruit BNO055 Absolute Orientation Sensor

imu_test

```
*/
/**************************************************************************/
void loop(void)
{
  // Possible vector values can be:
  // - VECTOR_ACCELEROMETER - m/s^2
  // - VECTOR_MAGNETOMETER  - uT
  // - VECTOR_GYROSCOPE     - rad/s
  // - VECTOR_EULER         - degrees
  // - VECTOR_LINEARACCEL   - m/s^2
  // - VECTOR_GRAVITY       - m/s^2
  imu::Vector<3> euler = bno.getVector(Adafruit_BNO055::VECTOR_EULER);

  /* Display the floating point data */
  Serial.print("Roll: ");
  Serial.print(euler.x());
  Serial.print(" Pitch: ");
  Serial.print(euler.y());
  Serial.print(" Yaw: ");
  Serial.print(euler.z());
  Serial.print("\t\t");

  imu::Vector<3> linearAccel = bno.getVector(Adafruit_BNO055::VECTOR_LINEARACCEL);
    /* Display the floating point data */
  Serial.print("X: ");
  Serial.print(linearAccel.x());
  Serial.print(" Y: ");
  Serial.print(linearAccel.y());
  Serial.print(" Z: ");
  Serial.print(linearAccel.z());
  Serial.print("\t\t");

  // Quaternion data
  imu::Quaternion quat = bno.getQuat();
  Serial.print("qW: ");
  Serial.print(quat.w(), 4);
  Serial.print(" qX: ");
  Serial.print(quat.y(), 4);
  Serial.print(" qY: ");
  Serial.print(quat.x(), 4);
  Serial.print(" qZ: ");
  Serial.print(quat.z(), 4);
```

Done Saving.

UNDERWATER - MOTOR TESTING

- Pulse-Width Modulation (PWM) signal to a Blue Robotics ESC

- Effective range of input was from 1100 to 1900

- Wrapped (1100, 1900) to (-1.0, 1.0)

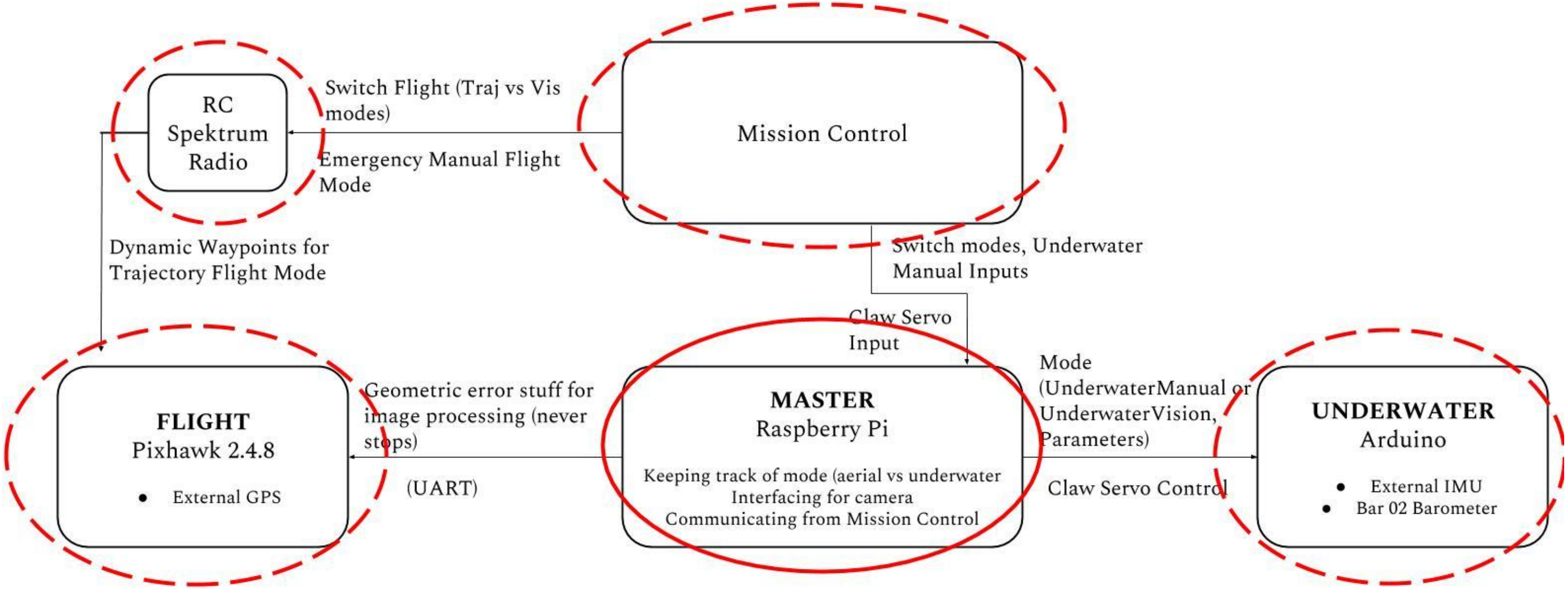
single_motor_test

```
#include <Servo.h>

byte servoPin = 9;
float throttle = 0;
Servo motor1;

// set power from -1.0 to 1.0
void setThrottle(float motorThrottle) {
  float input = motorThrottle * 400 + 1500;
  motor1.writeMicroseconds(input);
  Serial.print("Motor 1 Throttle: ");
  Serial.print(motorThrottle);
  Serial.print(" || Motor 1 input: ");
  Serial.print(input);
  Serial.println();
}

void setup() {
  Serial.begin(9600);

  motor1.attach(servoPin);
  setThrottle(0);
  delay(7000);
}

void loop() {
  setThrottle(0.3);


}
```

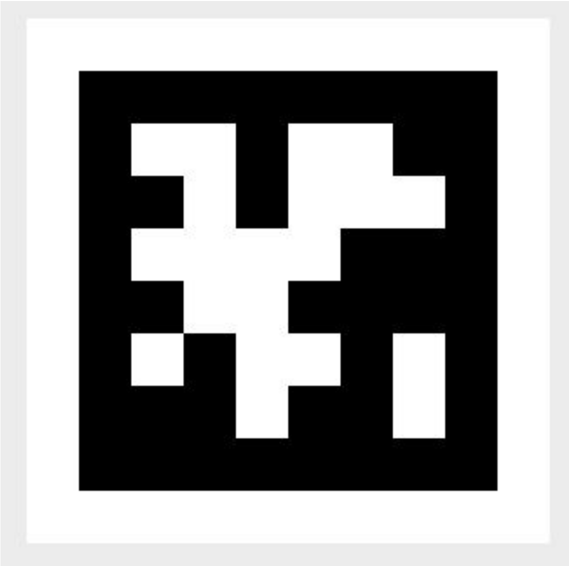
UNDERWATER - CONTROL SCHEME

- Dependent on **IMU** and **barometer** for feedback
- 3 proportional controllers on rotation about each major axis
    - Add the differential outputs of controllers to calculate base throttles for each motor
- Open-loop translation on y-axis (forwards and backwards) and P-controlled translation on z-axis (depth) of the vehicle

SYSTEM ARCHITECTURE

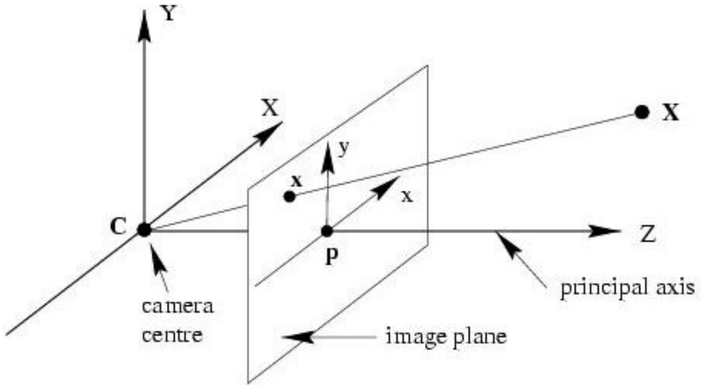


VISION - APRILTAG DETECTION



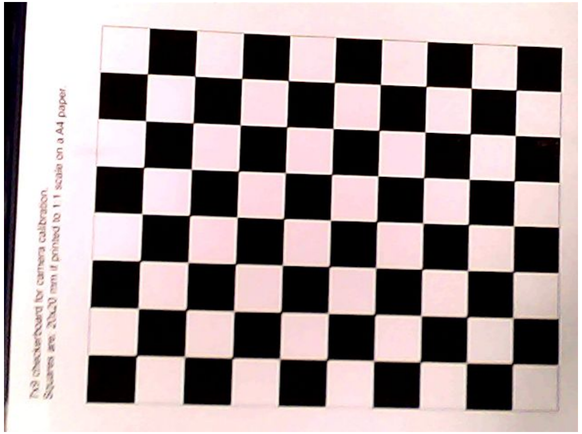
- QR code-like fiducial markers
- Detection robustness
- Accurate corner detection
- Estimate the full 3D pose by solving the Perspective-n-Point problem

VISION - CAMERA CALIBRATION



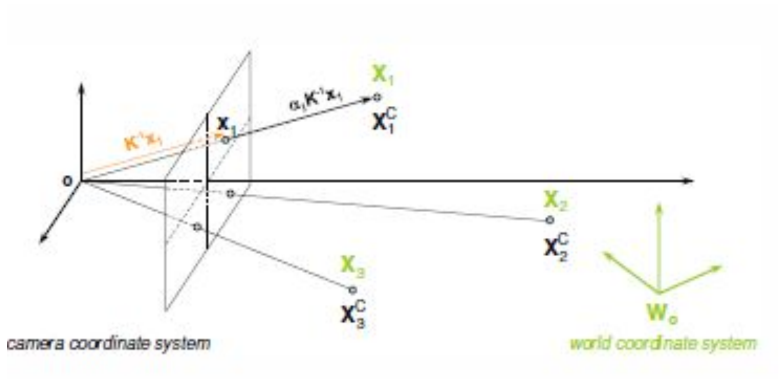
$$K = \begin{pmatrix} f_x & s & x_0 \\ 0 & f_y & y_0 \\ 0 & 0 & 1 \end{pmatrix}$$

$f_x = 782.4328288970378$
$f_y = 775.4785896345137$
$x_0 = 348.44041423071474$
$y_0 = 192.40481442590067$

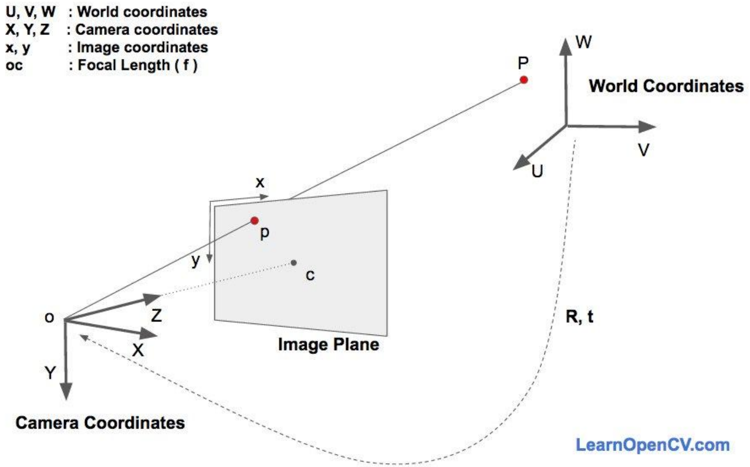


VISION - PnP Problem

- Givens
  - camera intrinsics matrix
  - real-world 3D locations of n points on the object of interest
  - corresponding coordinates of those points in the 2D image
- Solve for
  - 3D pose of object of interest



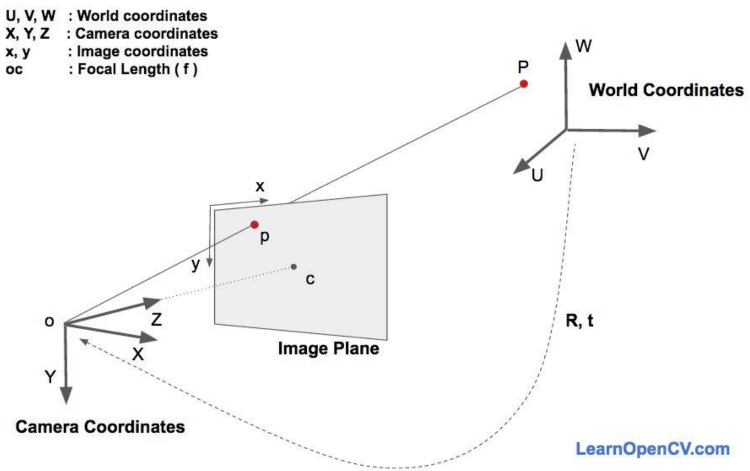
VISION - PnP Problem



$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \mathbf{R} \begin{bmatrix} U \\ V \\ W \end{bmatrix} + \mathbf{t}$$

$$\Rightarrow \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = [\mathbf{R} \mid \mathbf{t}] \begin{bmatrix} U \\ V \\ W \\ 1 \end{bmatrix}$$

VISION - PnP Problem



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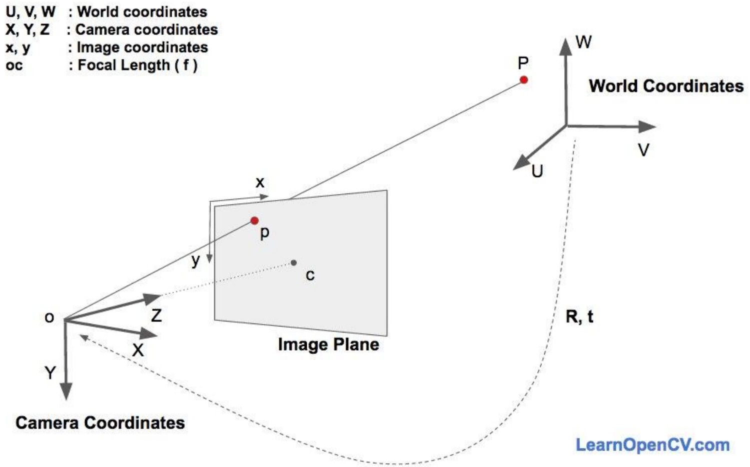
$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = s \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

VISION - PnP Problem



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$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = s \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

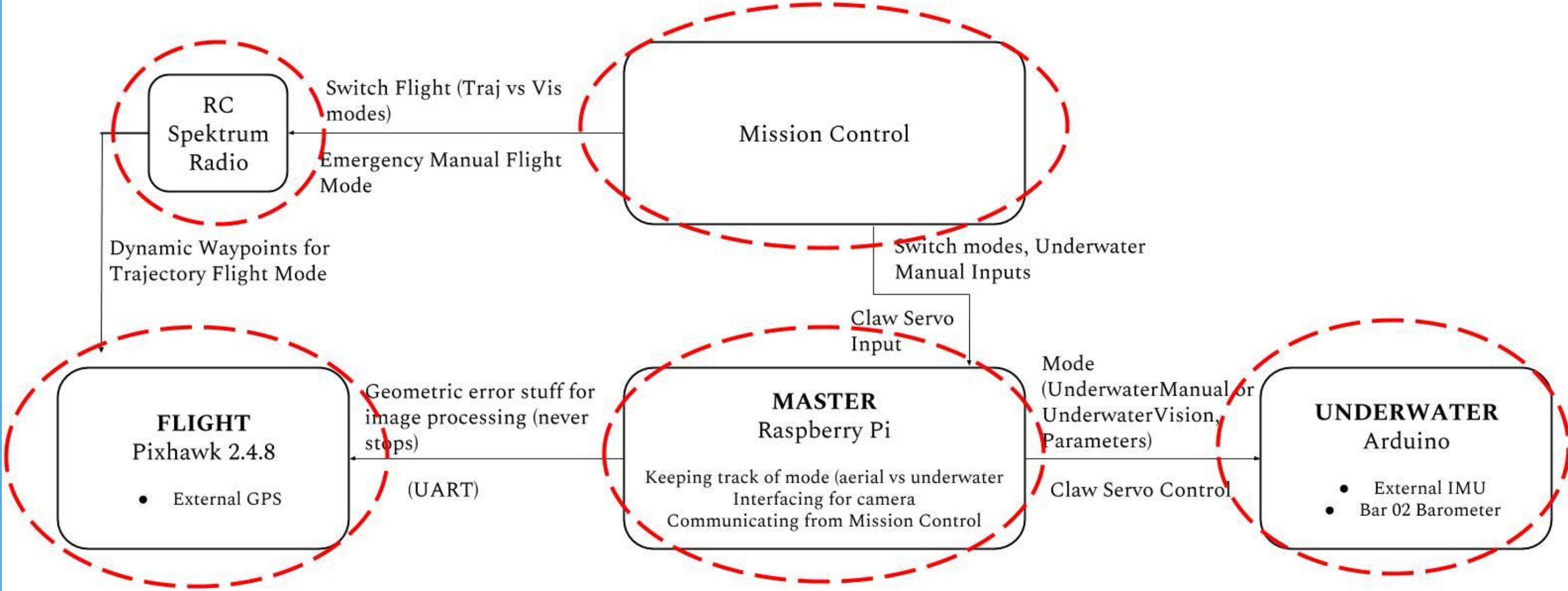
$$s \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} r_{00} & r_{01} & r_{02} & t_x \\ r_{10} & r_{11} & r_{12} & t_y \\ r_{20} & r_{21} & r_{22} & t_z \end{bmatrix} \begin{bmatrix} U \\ V \\ W \\ 1 \end{bmatrix}$$

VISION - PnP Problem

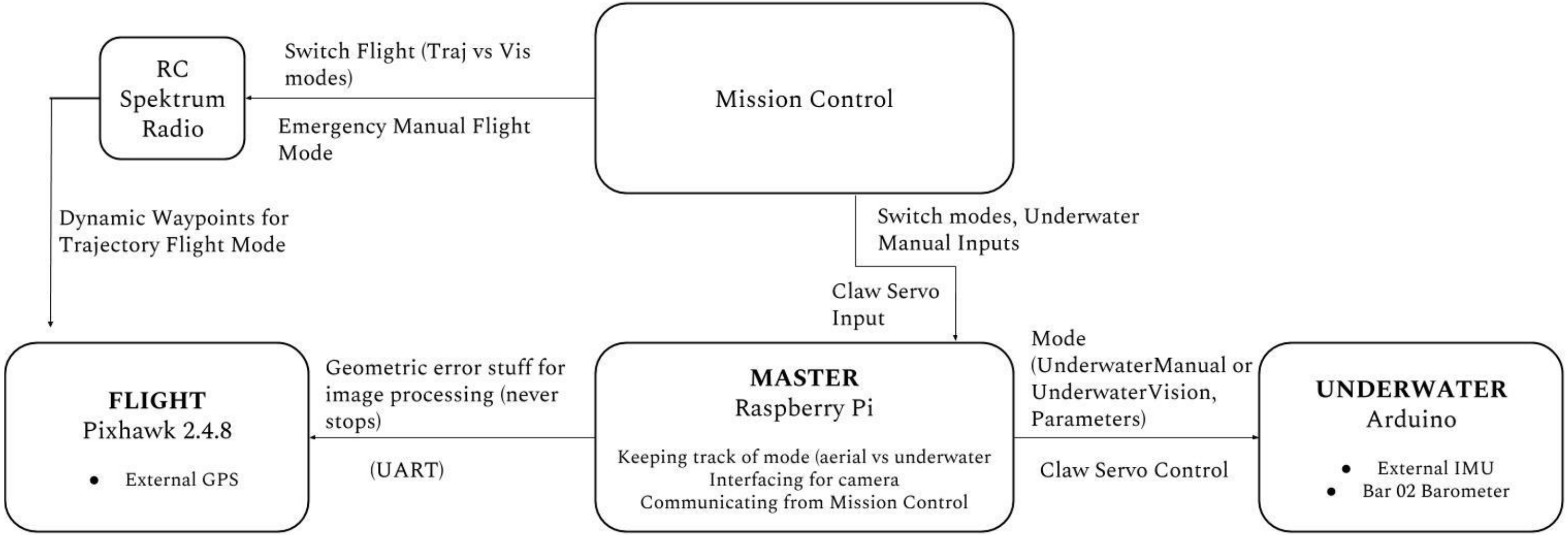
$$s\begin{bmatrix}X\\Y\\Z\end{bmatrix}=\begin{bmatrix}r_{00} & r_{01} & r_{02} & t_x\\ r_{10} & r_{11} & r_{12} & t_y\\ r_{20} & r_{21} & r_{22} & t_z\end{bmatrix}\begin{bmatrix}U\\V\\W\\1\end{bmatrix}$$

Direct Linear Transform => Levenberg-Marquardt Optimization

SYSTEM ARCHITECTURE



SYSTEM ARCHITECTURE



COMMUNICATIONS

COMMUNICATIONS

3 Communication Systems: In-air AV, In-air RC, and Underwater

AV

- For FPV (first-person view)
- 5.8 GHz, radio waves
- Camera -> transmitter -> receiver -> monitor at base
- PWM (pulse-width modulation) signals

RC

- For drone control
- 2.4 GHz, radio waves
- Remote input -> transmitter -> receiver on drone -> Raspberry PI #1 (signal processing)
- PWM

Underwater

- For aquatic ROV control
- Light Communication
- Laser and photoresistors
- Joystick input -> optic transmitter topside -> Laser -> receiver on ROV (photoresistors) -> Raspberry PI #1

REMORA

DESIGN OVERVIEW

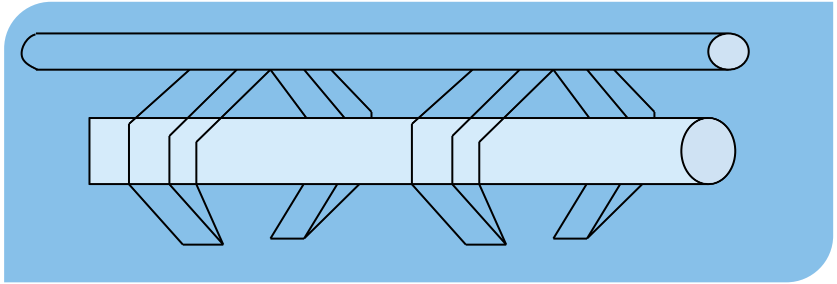
Frame Structure Design

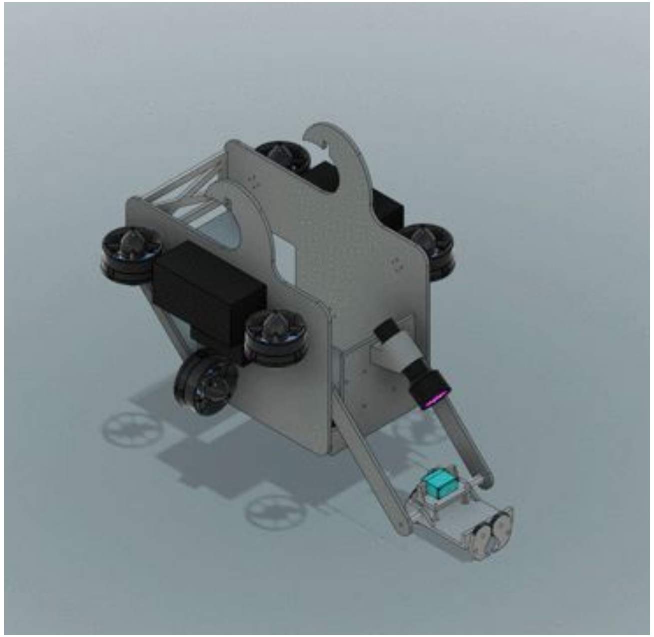
- ABS plastic
- 3D printed gussets
- Based around a center receptacle

DESIGN OVERVIEW

Intake Analysis

- Arm
  - 2 sets of claws extended at the front with a servo-motorized joint





DESIGN OVERVIEW

Motors

- 6 T-200 Blue Robotics Brushless Motors, with motor mounts
    - Each create 5 lbs of thrust
- Angled to enable full control of movement

DESIGN ALTERATIONS

Frame Structure Design

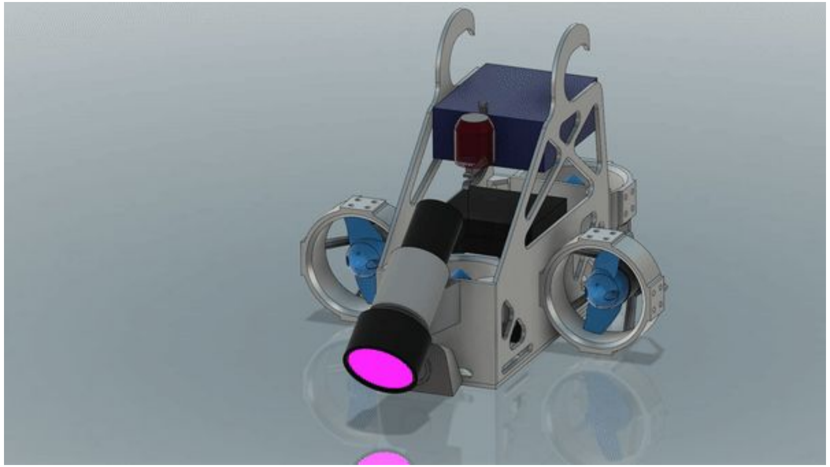
- Polycarbonate
- 3D printed gussets
- Overall size is smaller

No arm

- Replacing with passive intake to reduce weight

Motors

- 4 M100 Blue Robotics Brushless Motors, with motor mounts



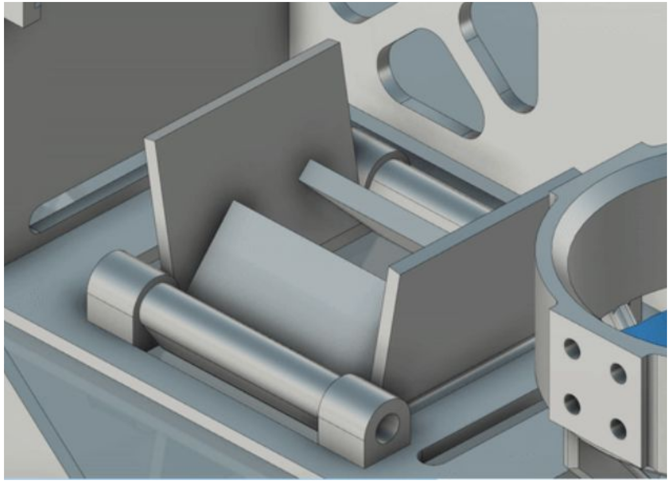
DESIGN ALTERATIONS

New Intake System

- Passive
- Lightweight
- Easily modifiable

Previous Design

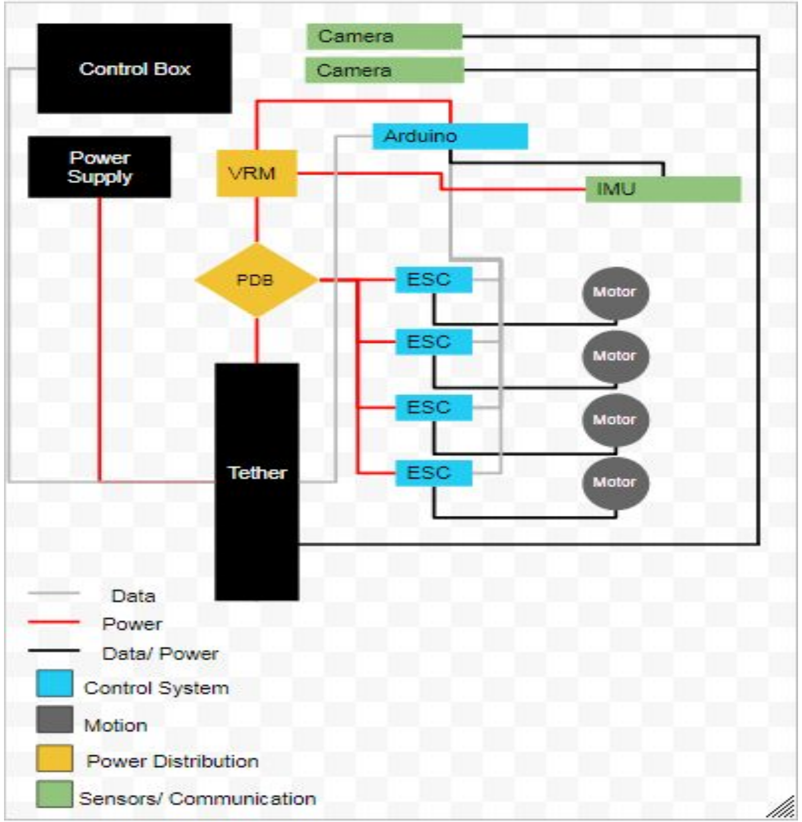
- Claw uses servo - added weight + cost
- Required too much accuracy



DESIGN ALTERATIONS

Electrical

- External Control Box to Tether
  - Power & Data
- Pi replaced with Arduino Uno
  - ESC/Motors
- USB camera through tether



RISKS, TESTING, & DATA

RISKS AND ASSUMPTIONS

- Main Causes of Risk
  - Environment
  - Manufacturing
  - Testing
- Accessing the Largest Risks
- Actions Taken to Prevent Risk
- Safety Protocols and Procedures
  - Flight
  - Diving
  - Manufacturing
  - Removal and Reduction of Hazardous Objects
- Risks Relation to the Timeline

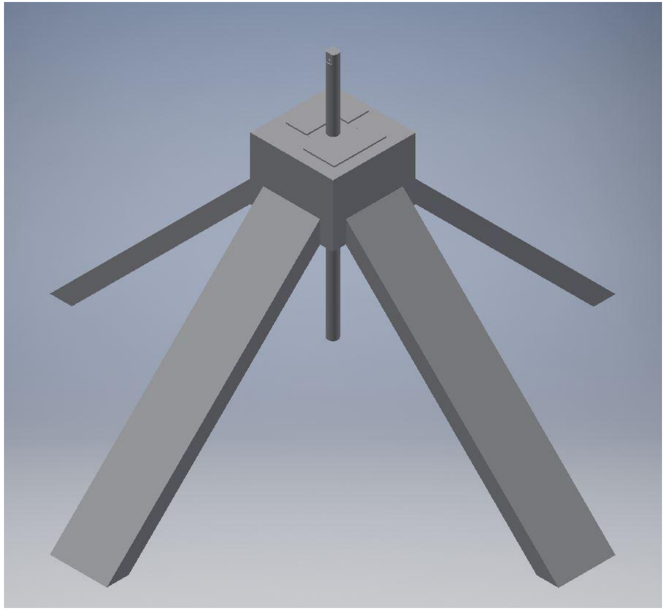
Risk Scales	Severity			
Likelihood	Inconsequential	Insignificant	Noteworthy	Dangerous
Anticipated	Moderate	High	Unacceptable	Unacceptable
Possible	Acceptable	Moderate	High	Unacceptable
Improbable	Acceptable	Acceptable	Moderate	High
Unrealistic	Acceptable	Acceptable	Moderate	High

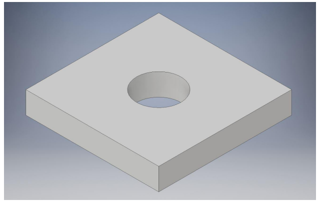
Largest Risk Management

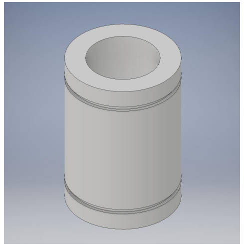
Risk	Consequence	Rating (S/L)	Risk Factor	Action
(Testing/Corp.) Possible Injuries	Personnel may need medical attention which may affect the timeline	3/2	High	Personnel are required to follow many procedures for safety, using protective equipment, and being well informed
(Mission) Retrieving the Submarine and Missiles	Dropping the missiles and being unable to complete this mission this way	3/2	High	Take extreme care and caution when retrieving the portion with the missiles inside, ensure they do not get disturbed and they are stable.
(Electrical) Water Damage	Timeline is delayed and systems may need to be rebuilt	3/2	High	Test containment and ensure no water leakage before testing with electronics
(Testing) Live Testing of Complete Mission	Damage to any important components or personnel	3/2	High	Testing procedures using nets to protect personnel are in place and properly practiced in order to prevent injury or damage to project
(System) Underwater Communication	Inability to communicate with the Megalodon	4/2	Undesirable	Ensure there are precautions in place in case communications are lost and that we have a few modes for communication underwater
(Corporate) Little Outside Investments	Echo Tech will be unable to pay for anything we require	3/1	Undesirable	Assure investors that the projects is very well thought out and prove our claims through presentations

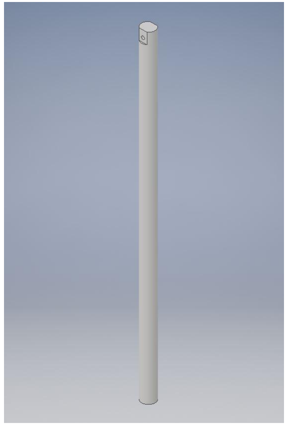
FLIGHT TESTBENCH

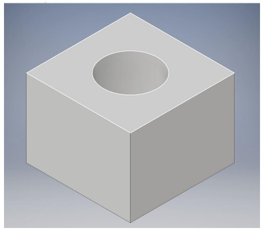
- Purpose: To provide a safe and easy way to test flight-related capabilities.

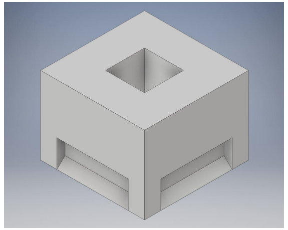


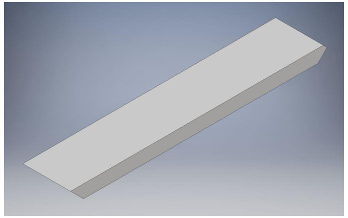


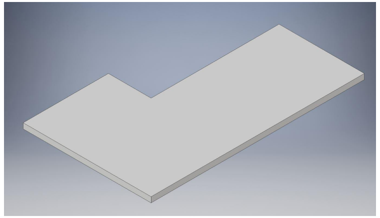










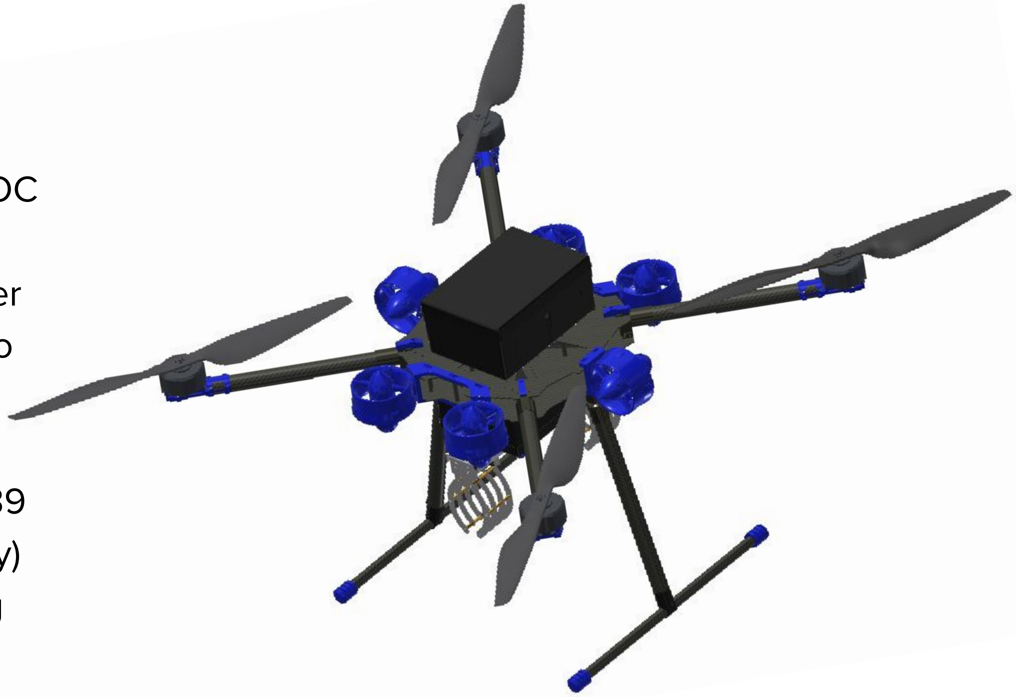


MEGALODON TESTING AND DATA

MEGALODON TESTING AND DATA

Weight and Buoyancy Estimation

- Estimated Weight of 12.4 kg (see weight breakdown in POC doc)
- Displaces about 11 kg of water
- ECHO Technologies needs to displace another 1.4 kg estimated
- Current prototype weighs 7.39 kg vs 8.37 kg (without battery)
- Power system puts out 27 kg of thrust



MEGALODON TESTING AND DATA

Purpose: Validate claim that we can

carry heavy payloads

Method

1. Record battery voltage
2. Preflight Inspection
3. Add weights appropriately
4. Record each flight on video
5. Check ESC temperatures

MEGALODON TESTING AND DATA

Results

- 12 flights completed
- Demonstrated ability to fly at 15.9 kg of flying weight (about 4 kg payload)
- Ability to fly at a heavier weight than expected
- Good flying characteristics
- Voltage drop on battery up to 1V for less than a minute of flight time

MEGALODON TESTING AND DATA

Motor Mount Modifications

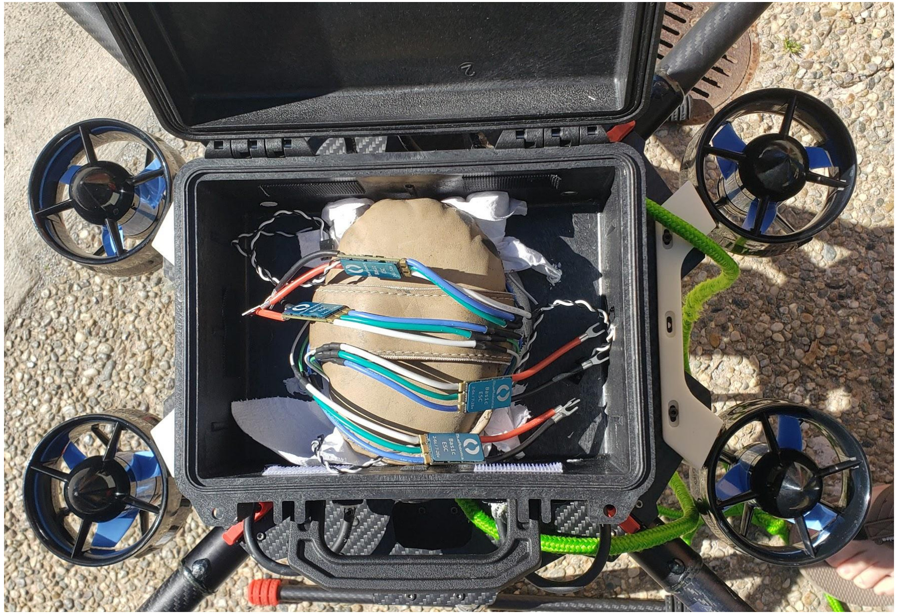
- Friction fit mounts by tightening four screws onto the arms of frame
- Stock mounts with Tarot X4 frame

MEGALODON TESTING AND DATA

Motor Mount Modifications

MEGALODON TESTING AND DATA

MEGALODON TESTING AND DATA



Purpose: Insure the drone's waterproof capabilities

Method

1. Place paper towels
2. Place into pool (3 ft.)
3. Record observations and time
4. Recover Megalodon and check paper towels
5. Repeat at depths 5 ft. and 7 ft.

MEGALODON TESTING AND DATA

Results

- Reveal areas of potential leakage
- Determine the Megalodon can survive at depths of 3 ft., 5 ft., and 7 ft.
- Record how the Megalodon sinks underwater
- Document the weight of the Megalodon while transitioning
- Find a strategy for transitioning from water to air

MEGALODON TESTING AND DATA

Transitioning from Water to Air

- Testing to determine if drag or suction from water added any weight
- Used a fishing scale to weigh the Megalodon being pulled out of the water
- No difference between dry weight of the Megalodon and maximum weight being pulled out of the water

ECHO TECHNOLOGIES

MEGALODON TESTING AND DATA

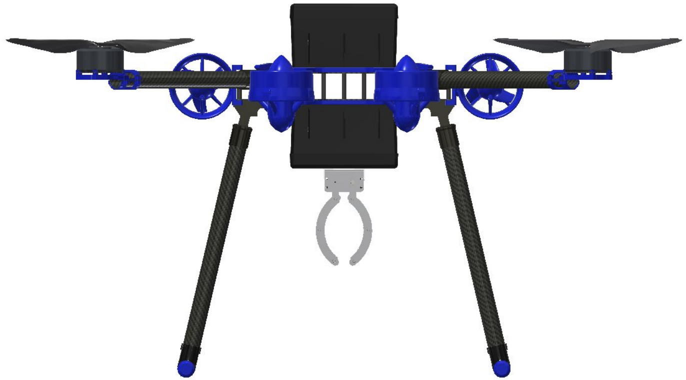
- Aerial power system must therefore provide thrust greater than the dry weight of the Megalodon to fly out of the water
- Aerial power system can only do this in the air

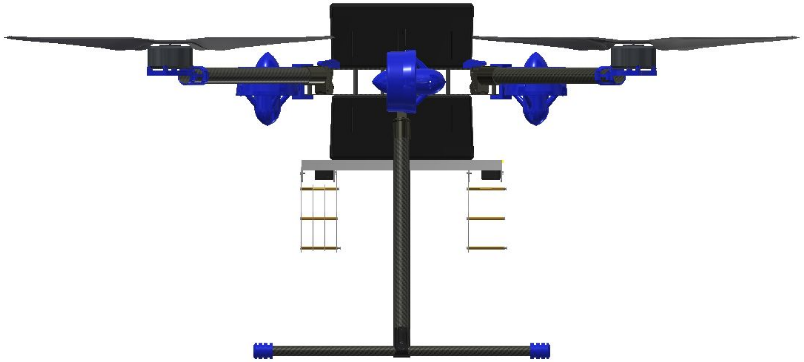
MEGALODON TESTING AND DATA

- Each T200 UUV thruster can provide 3.55 kg of thrust (12 V)
- 14.2 kg total thrust with four vertical facing motors
- Theoretically enough thrust to lift entire Megalodon out of the water if placed in the right location

MEGALODON TESTING AND DATA

- UUV motors could therefore lift top half of the Megalodon out of the water
- UAV motors could then take over and lift the Megalodon out of the water





BEACON TESTING AND DATA

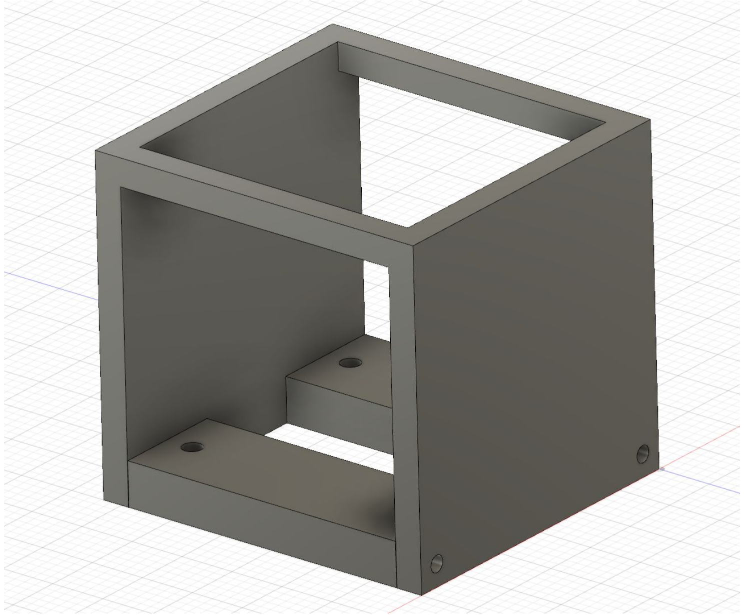
- Visible when water wasn't disturbed
- When water was disturbed, beacon was undetectable
- Isn't viable option unless surface of water is still

Pelican Mini Flasher
2130 LED

INTAKE TESTING AND DATA

Challenges

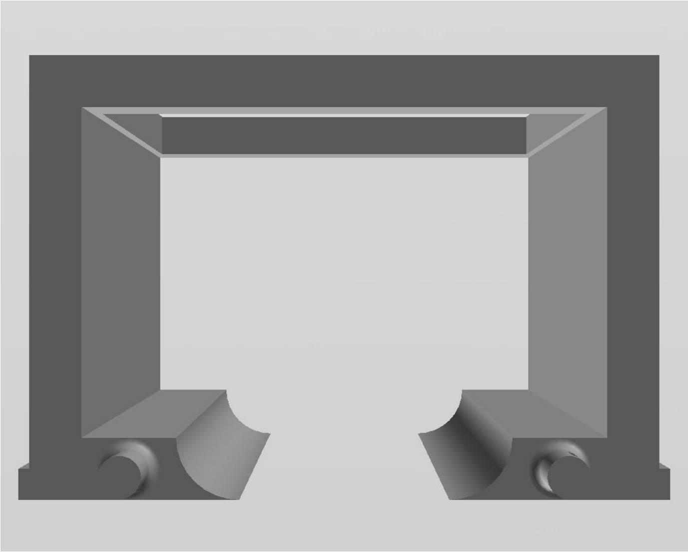
- Doors did not open wide enough for warhead
- Rubber bands angled the doors
- Doors could not keep warhead fully contained



INTAKE TESTING AND DATA

Improvements

- Move hooks closer together
- Round edges of doors
- Changed rubber band placement
- Wider, thicker frame
- Includes hinges instead of rods



VISION TESTING AND DATA

- Equipment:
  - Two (2) USB Standard ROV cameras from openROV
- Capabilities
  - OpenCV in python
    - Live stream video feed
    - Color Identification

DEMONSTRATIONS

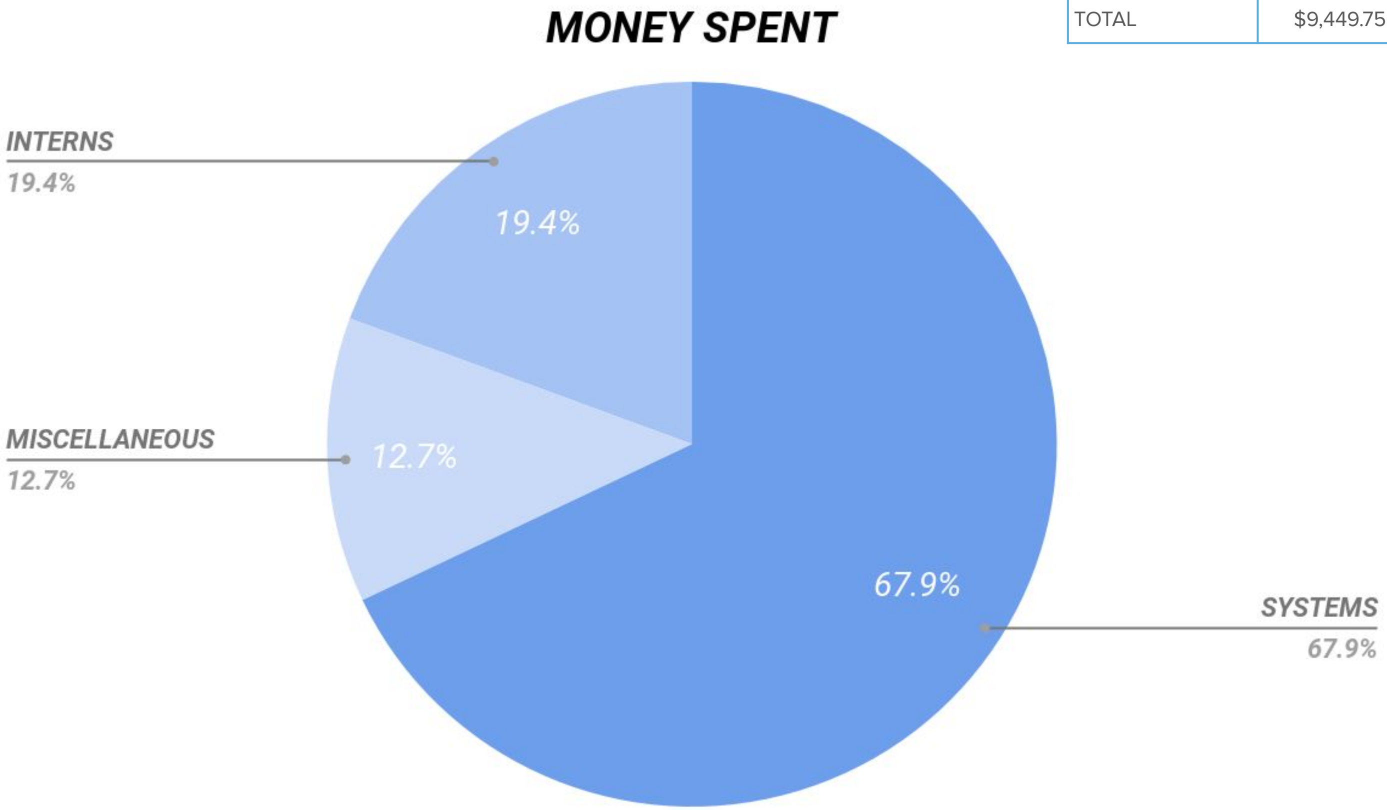
TONIGHT'S DEMONSTRATIONS

1. Megalodon **Waterproof Test**
2. Megalodon **Piloted Flight**
3. **Altitude** Detection
4. **Vision**
5. **Retrieval**
6. Remora **Radioactivity Detection**
7. Remora **Intake Prototype**

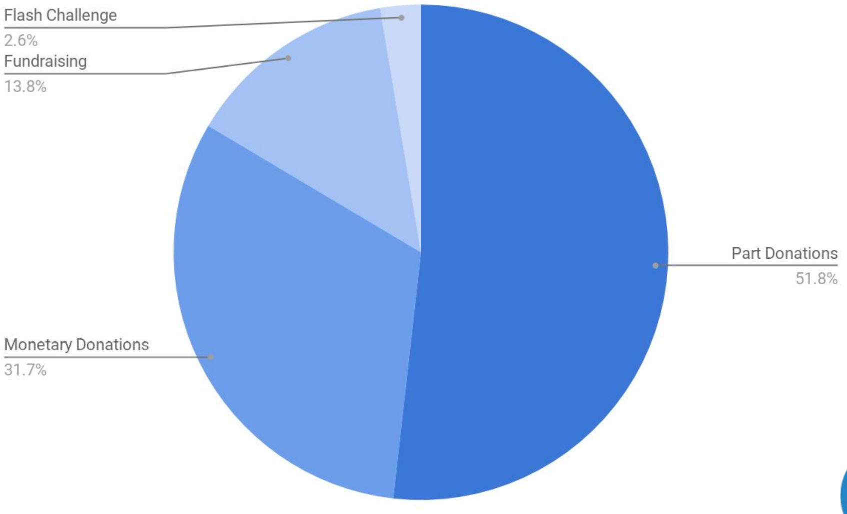
FINANCE

FINANCE

SYSTEMS	$6,418.47	67.9%
MISCELLANEOUS	$1,201.46	12.7%
INTERNS	$1,829.82	19.4%
TOTAL	$9,449.75	



FINANCE


Flash Challenge
2.6%
Fundraising
13.8%
Part Donations
51.8%
Monetary Donations
31.7%

FUTURE GOALS

THE MEGALODON

- Aquatic subsystems testing
  - UUV to ESCs
- Claw
- Test Bench
- Mission Simulation

THE REMORA

- Buy a Control Box
- Finish Assembling Robot
- Finish Code
- Testing
  - Vision Code Underwater
  - Intake System
  - Electrical System
  - Robot as a whole

ECHO TECHNOLOGIES

- Outreach events
- Mentor Ripple Technologies
- Future EDD fund
- ECHO Technologies Legacy
- CARPA Initiative Legacy

QUESTIONS, COMMENTS, & CONCERNS?

THANK YOU!

ECHO
TECHNOLOGIES