

Shell Ocean Discovery XPRIZE

Blue Devil Ocean Engineering

Shell OCEAN DISCOVERY **XPRIZE**

Getting to the Bottom of Our Ocean.



Blue Devil
Ocean
Engineering

XPRIZE
FOUNDATION

Duke Modular Model of the Environment Duke Modular Model of the Environment

OCEANS GO DIVE gle

The Contest

- Prizes
 - First Place \$4M
 - Second Place \$1M
 - \$1M NOAA prize
 - Other prizes??? TBD
 - 10 teams going to round two each receive \$100K
- Two (2) rounds over 36 months (3 years)
- From the shore remotely produce:
 - A map of 500 km² of ocean floor (20% in round 1)
 - Images of biological, archaeological, and geological features of the ocean environment (one at 2000m in round 1 to prove you were there)
 - \$1M NOAA prize data for tracking chemical signal

Contest Timeline



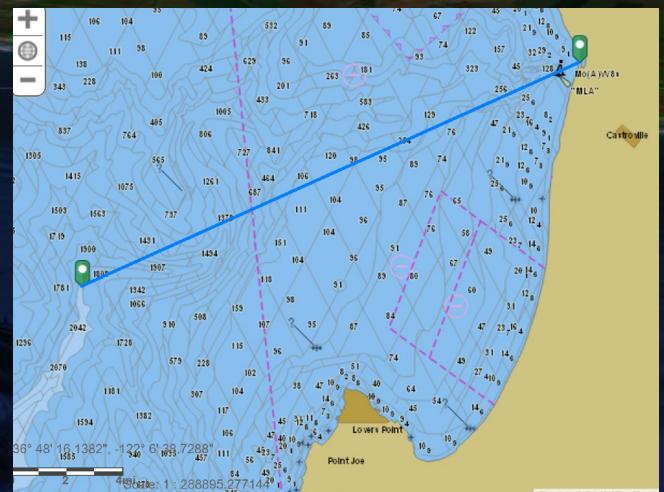
- Fall 2016, need to submit Technical Document
- If proposal is accepted can compete in Round 1
- Round 1 = Spring, Summer 2017
- Ocean Testing = Summer 2017
- Team Summit 13-16 November 2016, San Diego, California, USA.
- Work in [Foundry](#) / [113 A&B](#) Hudson
-

Possible Contest Sites?

- Round 1
- Monterey
- 31 km to 2000m



- Round 2
- Morro Bay
- 114 km to 4000m
- Hawaii Big Island
- 22 km to 4000m



Our Plan

- Synthetic Aperture Sonar Diving Pods
 - 28 kHz Sound system for SONAR
 - Variable Buoyancy Diving System
 - IMU + GPS based position sensors
 - WiFi + LoRa Data communication
 - Sensor for chemical signature
- Heavy Lift Drone
 - 12 Rotors / triply redundant / hybrid gas–electric
 - Automatic Imaging pod pickup system
 - WiFi + LoRa Data communication
- Offline Location and Mapping
 - Bathymetric SLAM algorithms
 - Match models of SONAR to ocean measurements

Six Fall 2016 Projects to choose:

Synthetic Aperture Sonar Diving Pods:

1. 28 kHz Sound system for SONAR (2-3 teams)
2. Variable Buoyancy Diving System (1-2 teams)
3. IMU + GPS based position sensors / WiFi + LoRa Data communication (1-2 teams)

X. Sensor for chemical signature (save for Spring)

Heavy Lift Drone:

4. 12 Rotors / triply redundant (2-3 teams)
 5. hybrid gas-electric Power (1-2 teams)
- Y. Automatic pod pickup system (save for Spring)
6. Offline Location and Mapping /Bathymetric SLAM algorithms / Match models of SONAR to ocean measurements

Six Fall 2016 Projects to choose:

- Projects **1-5** are all **Hardware** related and use microcontrollers extensively.
- Project **6** is **software** and will probably access Amazon Web Services
- I expect to have **more than one team** on each project, ideally I would like 3 teams on each project, but that will depend on enrollment.
- We will conduct a survey early in the class to assemble the teams based on skills / interests / and availability to work together outside of class time.
- The grading will be entirely attendance and project performance based.

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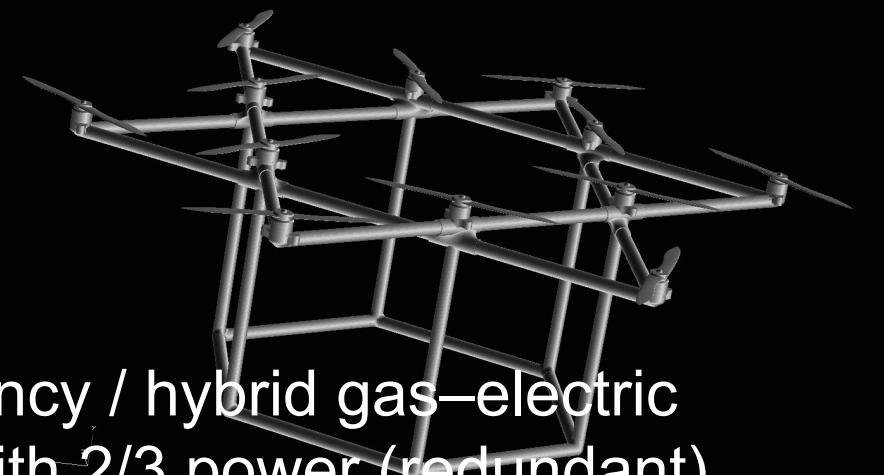
1. Compete Surveys to form Groups
 - o Do I have your email?
2. Arrange for Team photo (per XPRIZE)
3. Get everybody setup for collaboration
 - o Slack
 - o Sakai?
 - o Google Docs
 - o Box

Synthetic Aperture Sonar Diving Pods

- 28 kHz Sound system for SONAR
 - 192kHz 24bit audio
 - Sensor Technology SX28-02 transducers
- Variable Buoyancy Diving System
 - Like Seaglider and Argo floats
 - Cannot use pressure vessel (too heavy)
- IMU + GPS based position sensors
 - 9 DOF IMU sensors
 - pressure depth sensors
- WiFi + LoRa Data communication
- Sensor for chemical signature
 - Metal Rods (AKA our XPRIZE sensor)
 - Colorimetry? ECE 449 Design class

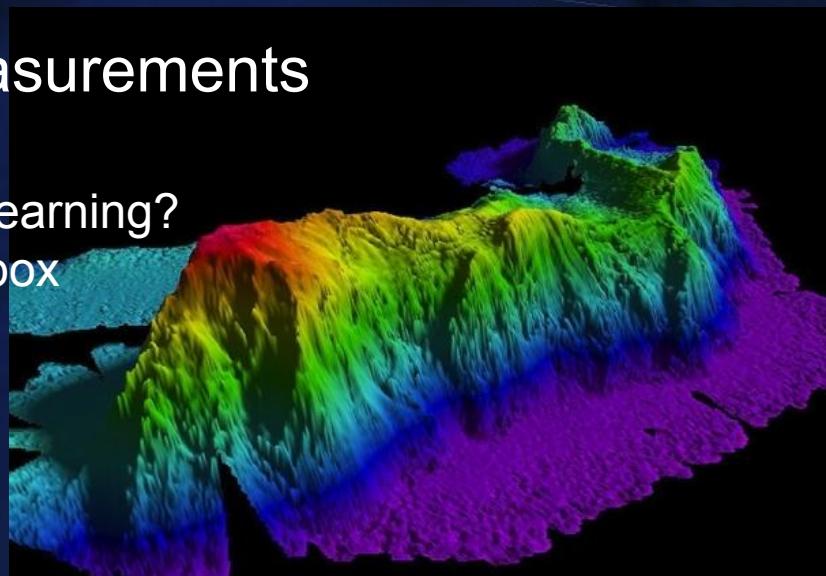
Heavy Lift Drone

- 12 Rotors / triple redundancy / hybrid gas–electric
 - Can lift ~10 lbs load with 2/3 power (redundant)
 - Based on open software [Pixhawk](#)
- Automatic Imaging pod pickup system
 - Spring 2017 ECE 496 Robotic Systems Design Topics?
- WiFi + [LoRa](#) Data communication
 - WiFi high data rate and close
 - LoRa long range 15 km??? Under water??



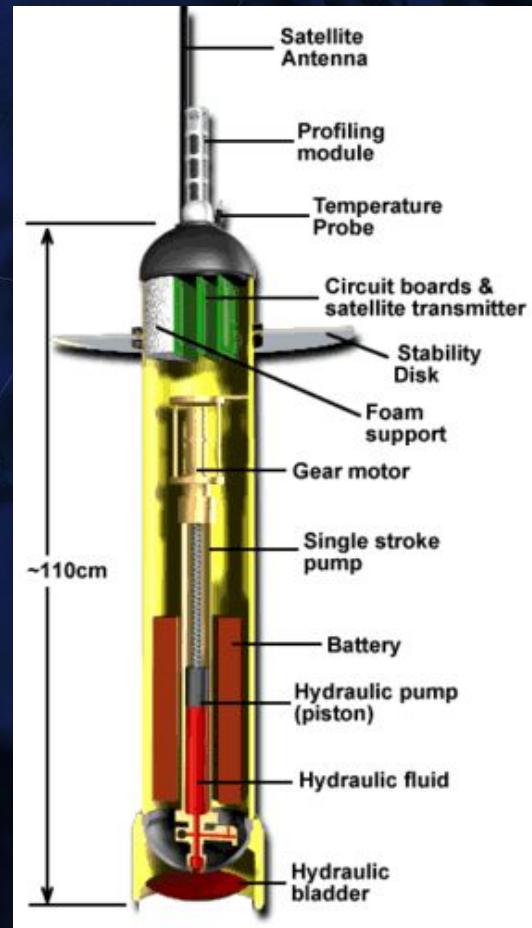
Offline Location and Mapping

- Match models to ocean measurements
- IMU data / Depth data / SONAR echo data
- 3D Ocean Map (0.5 meter voxel)
 - Bathymetric SLAM algorithms
 - Simulation using ocean acoustics models
 - KRAKEN: Normal Mode Model
 - RAM Parabolic Equation
 - Match Simulation to Measurements
 - Global Optimization
 - Error Guided Perturbation Learning?
 - MATLAB Optimization Toolbox
 - Amazon Web Services?



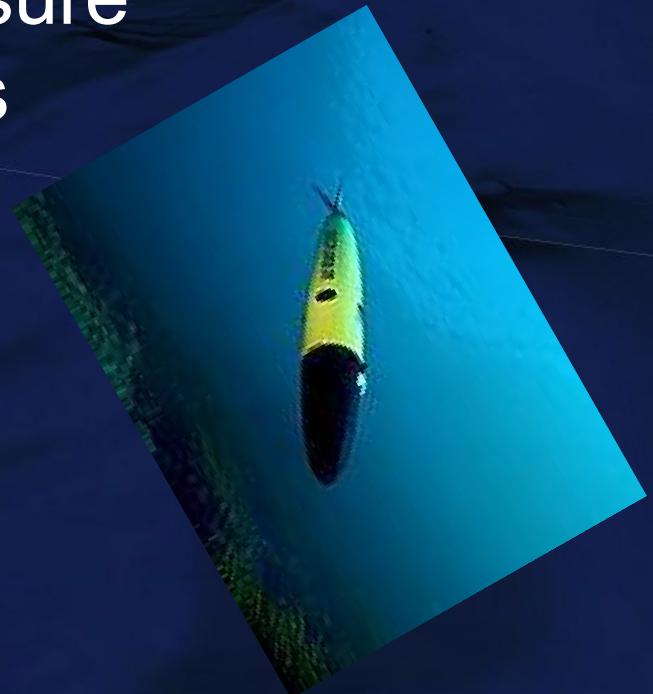
Synthetic Aperture Sonar Diving Pods (SAS Pod)

- like Argo pods and Seagliders
- Use bladder for dive and ascend
- SONAR ping and record as it dives



SAS Pod depths

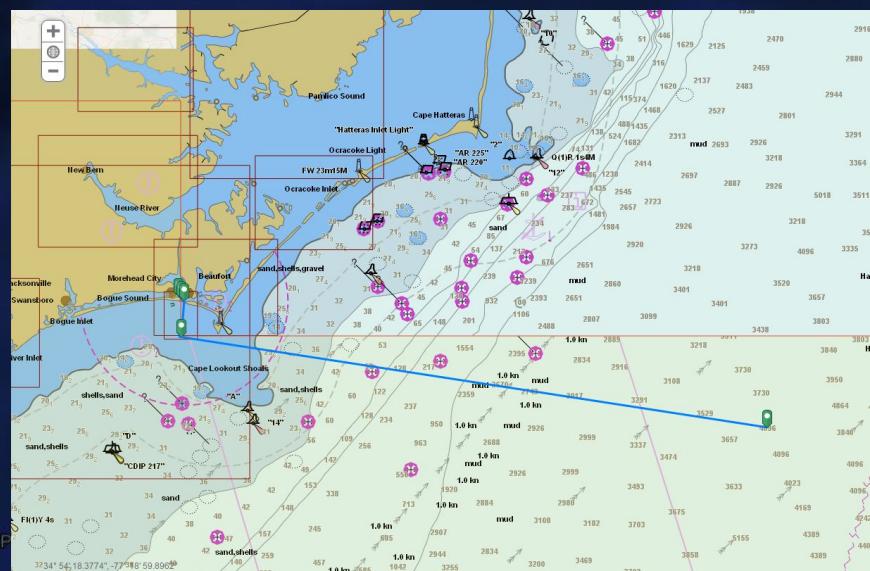
- Round 1 2000m = 20.2 MPa in Seawater
- Round 2 4000m = 40.3 MPa
- 50 MPa is a safe design pressure
- ~7000 psi ~ 500 Atmospheres



1890 ft

SAS Pod Pressure Testing Facility?

- Deepsea / University Labs (PennState?)
- Cold Water Pressure washers for test?
 - Easy-Kleen I-S7040G, 7000 PSI
 - Water Cannon 17H26, 7000 PSI
 - Pressure Chamber
 - High Pressure Equipment Company: R6-12-10
 - \$15-30K to set up
- Drop them in the ocean!
 - 2000m is 100 km from Duke Marine Lab
 - 4000m is 230 km



28 kHz Sound system for SONAR

○ 192kHz 24bit audio



Power Supply
1-30V 30A
B&K Precision
BK1694-ND



Turnigy nano-tech
5000mah 45~90C
HIGH DISCHARGE LIPO BATTERY
5000mah 45~90C (22.2V)
45~90C (225A) Lipo Pack



Class D Amp
Texas Instruments TPA3250D2EVM
(Digikey 296-43809-ND)



Digital-analog converter
FiiO D3 (D03K)
(Amazon)



Analog-digital converter
Texas Instruments PCM1864EVM
(Mouser 595-PCM1864EVM)



Raspberry Pi audio card
Cirrus Logic Audio Card
(Element14)

Stacked



Raspberry Pi

○ Sensor Technology SX28-02 and SX30 transducers



Transducer
Sensor Tech Ltd SX30
TVR 133dB@30kHz
Lower Cost (\$500)



Transducer
Sensor Tech Ltd SX28-02 TVR
173dB@28kHz
Best Sensor! (\$1.2K)

Variable Buoyancy Diving System

- Unlike Seaglider and Argo floats we cannot use a pressure vessel (too heavy)
- Probably need a gas bladder that inflates as needed to change rate of ascent
- We need 7000 psi (3000 psi at 2000m)
- Option 1 45 CI 4500 psi Paintball cylinder
- OK for round 1?
- weight <2 lbs empty
- We will probably have trouble with the regulators at depth



Variable Buoyancy Diving System

- Option 2 gas generation from solids/liquids
- Hydrogen peroxide
- Hydrazine
- Chlorates and perchlorates
- Sodium azide
- Solid rocket propellants - electronic ignition
 - Ammonium perchlorate composite propellant
 - E20 \$15 35 Ns thrust
 - G76G \$95 Reusable 115 N
 - will these fire at depth?
 - how much gas? how hot?



IMU + GPS based position sensors

- We have Adafruit 10 DOF sensor breakout
 - L3GD20H / LSM303
 - AHRS generates Altitude & Heading
 - Motion tracking need assumptions about motion to remove drift, pressure sensor altitude, average loc. from GPS could work.
 - BMP180
 - does -500 m below sea level, >> if in EPOXY?
- We have Adafruit Version 3 GPS breakout
 - MTK3339 only works on surface!
-

WiFi + LoRa Data communication

- SAS Pod use
- WiFi high data close range
 - Used for sending sonar data to drone on pickup
 - Used for pickup signaling of GPS location
 - May be used for triangulation for pickup
- LoRa long range 15 km??? Under water??
 - Could allow for better range GPS location signaling to drone for pickup
 - Communication between pods on surface
 - Maybe drop LoRa only Pods for communication back to shore for drone?

WiFi + LoRa Data communication

I have a lot of different options for this most of which are meant to be for more general user access.

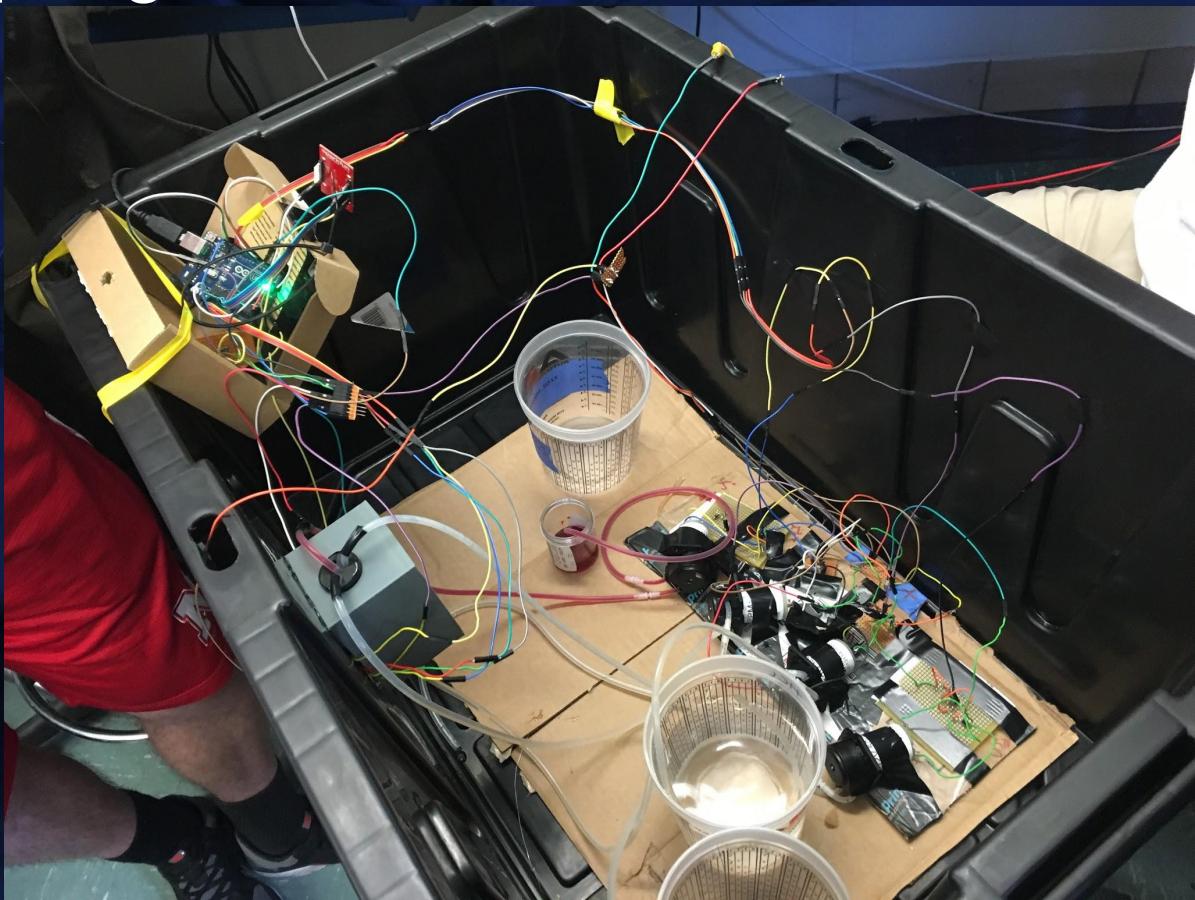
So you do not *have* to be a computer engineer or much of a programmer to work on this!

WiFi + LoRa Data communication

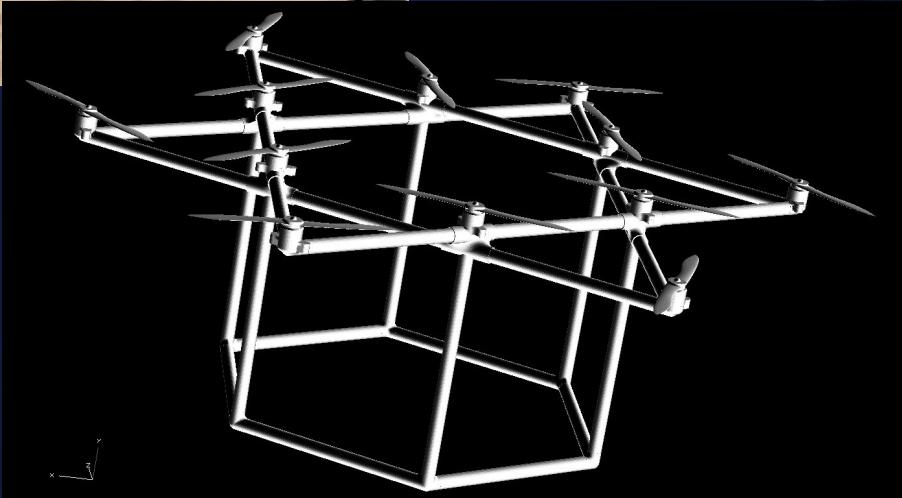
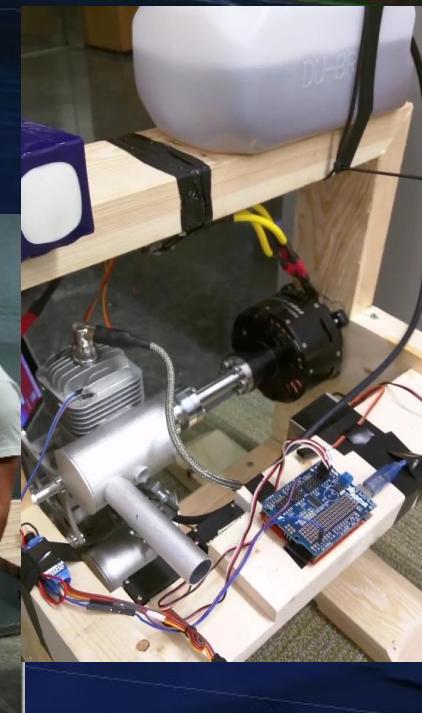
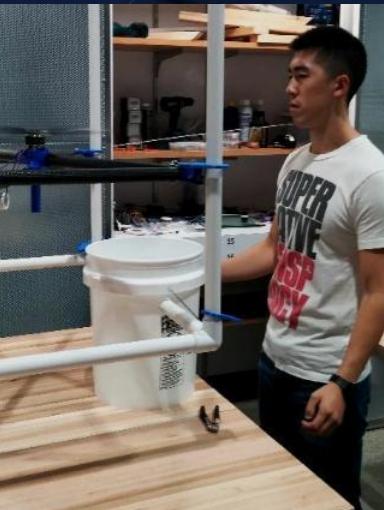
- LoPy Modules I have:
 - [HopeRF RFM95W](#) 915Mhz models and Dev Sys
 - [LoPy](#) = LoRa version of WiPy (due any day)
- WiFi Modules I have:
 - [WiPy](#)
 - [Onion Omega](#) Wifi Microcontroller
 - based on Qualcomm Atheros AR9331 SOC
 - Pine64
 - what is 64 bit good for?
 - Beaglebone Green
 - ESP8266
 - We used this last Fall and Spring semesters
 - Arduino
 - Already used for generator and last XPRIZE
 - Raspberry Pi
 - Already using for the SONAR

Sensor for chemical signature

- Metal Rods? (AKA our XPRIZE sensor)
- Colorimetry? Spring 2016 ECE 449 Class



Heavy Lift Drone



1890 ft

12 Rotors / triple redundancy / hybrid gas electric

- Can lift ~10 lbs load with 2/3 power
- Based on open software [Pixhawk](#)
- 3D printed joints and Carbon fiber rods
- Commercial RC drone parts
- Needs some work!

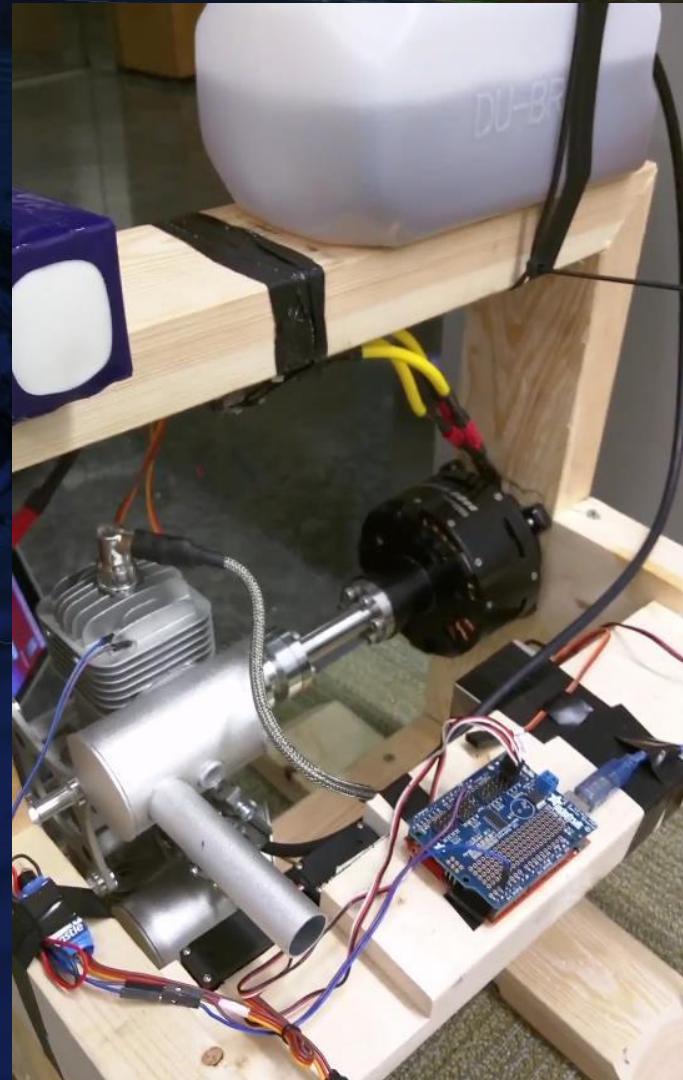


1890 ft

Hybrid Gas Electric

 [Generator Control Documentation.pdf](#)

- 3 x Generators to Charge Batteries
- To enable long range flights
- Arduino Control
- Needs integration into flight system



Pod Ocean pickup system

- ECE 496 Robotic Systems Design Topics?
- Need working Drone and Pods first?
- Flashing LEDS + Camera for fine location
- There are automatic and remote hooks
- But we may need ring and grapple pickup?

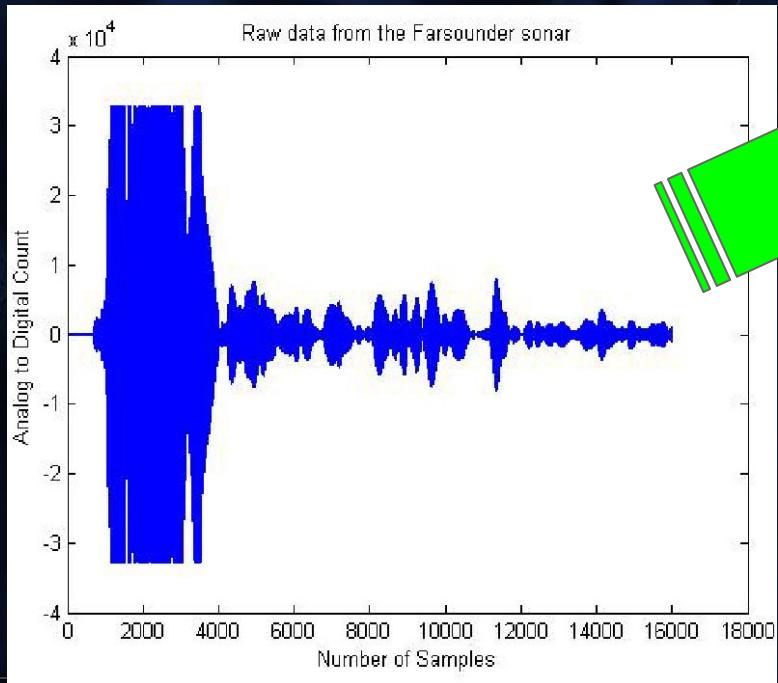


WiFi + LoRa Data communication

- Drone use
- WiFi high data close range
 - Used for sending sonar data to drone on pickup
 - Used for pickup signaling of GPS location
 - Maybe used for triangulation for pickup
- LoRa long range 15 km??? Under water??
 - Not sure we will use in the pod
 - Could allow for better range GPS location signaling
 - Could communicate back to shore???

Offline Location and Mapping

- Getting from SONAR to 3D Maps
- Want 0.5 meter voxel, Very Hard!
- Use Matlab + AI + Amazon Web Services



Match models to measurements

- Simulate dive and ascent path of pod
 - Make best guess at path using IMU / GPS / depth data
- Simulate SONAR with ocean acoustics models
 - KRAKEN: Normal Mode Model
 - RAM Parabolic Equation
 - use best available maps
- Assume that when the simulation matches the measurement the map is correct
- Refine map and path of pod to improve match
- This is very hard!

Global Optimization

- MATLAB Optimization Toolbox
- Error Guided Perturbation Learning?
- Amazon Web Services?
 - I imagine us spinning up many parallel AMS servers to generate the map from our data in the 48 hours provided by the XPRIZE