MicroFloats: Progress Report

Ideation and Concept Generation

Swarmers

Dahrius Abdelnur, Will Jarman,

Terence Lui, Alex Olsen,

Vatsal Trivedi, Sidney Wise

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Team Structure

Role	Member	Description
Project Manager	Alex Olsen (ME)	Coordinates group meetings and scheduling; ensures all deliverables are completed on time; ensures project timeline is maintained
Controls and Fabrication Lead	Dahrius Abdelnur (ME)	Ensures manufacturability and viability of all designed components; works with electrical lead to develop electronic control system
CAD and Sourcing Lead	Will Jarman (ME)	Manages project CAD and computer-aided analysis like FEA; represents the team in supplier communications
Electrical Lead	Sidney Wise (CmpE)	Manages electronics and communications systems; responsible for developing electronics BOM and determining feasibility
Mechanical Lead	Terence Lui (ME)	Ensures that design meets engineering specifications; develops mechanical assembly
Software and Web Development Lead	Vatsal Trivedi (ME)	Responsible for developing project website; works with electrical lead when necessary on any custom software

Advisor	Faculty Member
Primary	Dr. Michael West, ECE
Secondary	Dr. Amit Jariwala, ME

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Presentation Outline

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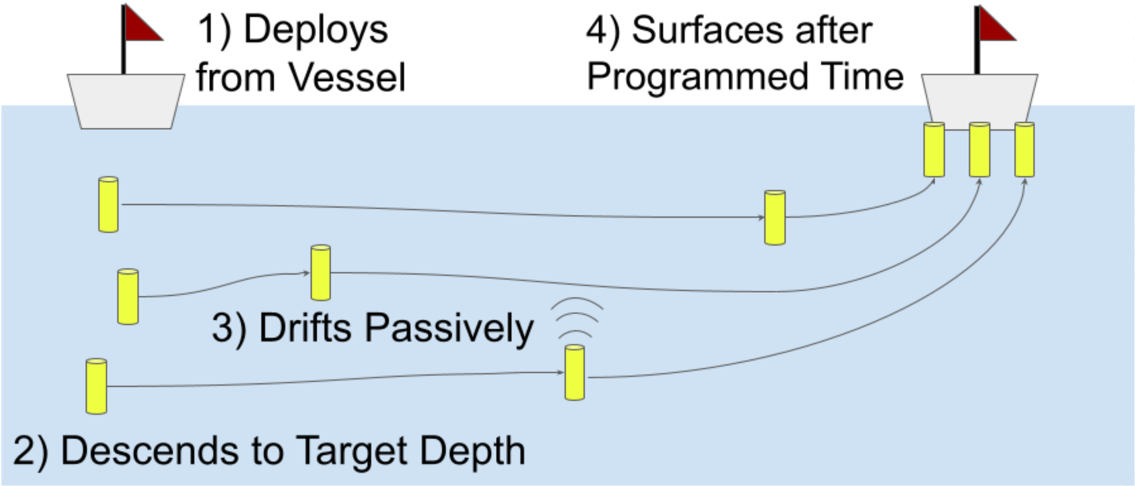
Project Overview

- Ocean scientists wish to better understand the effects of climate change on ocean chemistry
  - CO_2 in the atmosphere is absorbed by the oceans, a phenomenon commonly called “ocean acidification”
  - Measuring methane seeps is also a complementary goal, with the Gulf of Mexico serving as a rough, terrestrial analog for Titan

- Ocean chemistry will be best understood by surveying large areas of ocean waters
  - Multiple devices are needed to survey the vast areas needed for an accurate understanding; singular autonomous underwater vehicles are impractical and inefficient for this purpose
  - Instead, ocean scientists could better use a swarm of autonomous floats that communicate with each other and can blanket a large swath of water
  - Each float concentrates on a column of water, from the surface to a maximum depth
  - Aggregated swarm data can be used to create a 3D mesh of a volume of ocean water, with relevant measurements like carbon dioxide and methane taken at each node

Introduction - MicroFloats

- Small autonomous underwater device for oceanic monitoring
- Lateral Motion
  - Ocean currents will be utilized
- Vertical Motion
  - A buoyancy control device will be utilized
- Sensors
  - Pressure, methane, and conductivity
- Swarm Mechanics
  - Robots must have the ability to communicate with each other

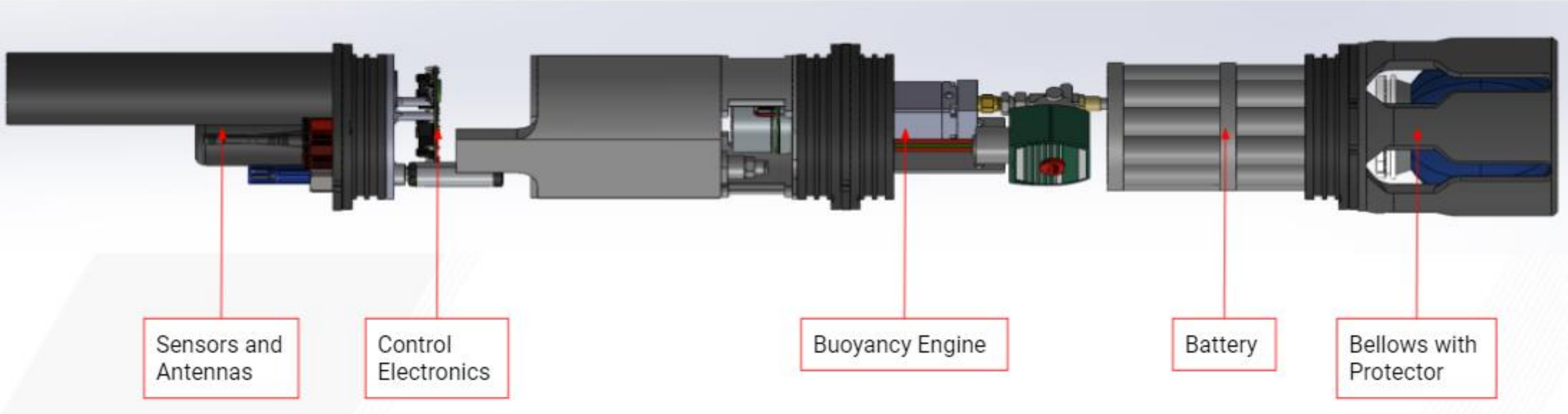


Stakeholders and Market Research

- Stakeholders
  - Dr. Mick West

- Market Research
  - Market size: Very small
  - Demographics: Oceanic researchers
  - Market research plan: Regular design meetings and continuous communication, with Dr. West as liaison
  - Price Range: $800 - $1000 per unit to start
  - No similar commercial product

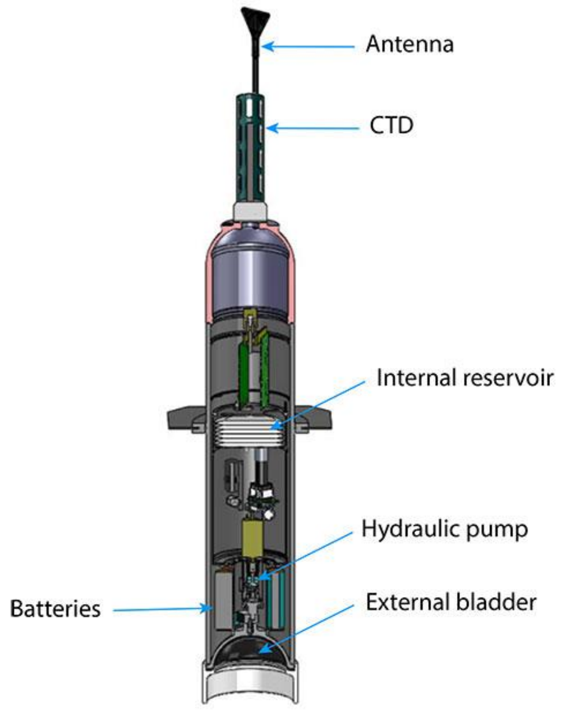
Previous Work - RUR

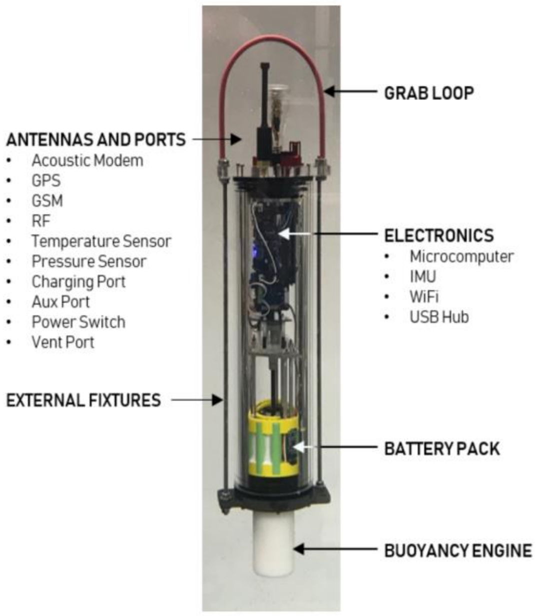


- Spring 2021 Capstone Team
- Utilized bellows to alter displacement and control depth
  - Bellows inflated with oil hydraulics
- Theoretically able to achieve 450 m underwater
- Tested for 15 feet descend
- 1 week battery life

Prior Art – Research Projects

- Argo Project
  - Satellite communication (after resurface)
  - Buoyancy control
    - Oil pumping piston pumping
    - Patented buoyancy engine
- µFloats
  - Design for lakes (low depth)
  - Constant communication
    - Only with buoys
  - Buoyancy control
    - Screw mechanism





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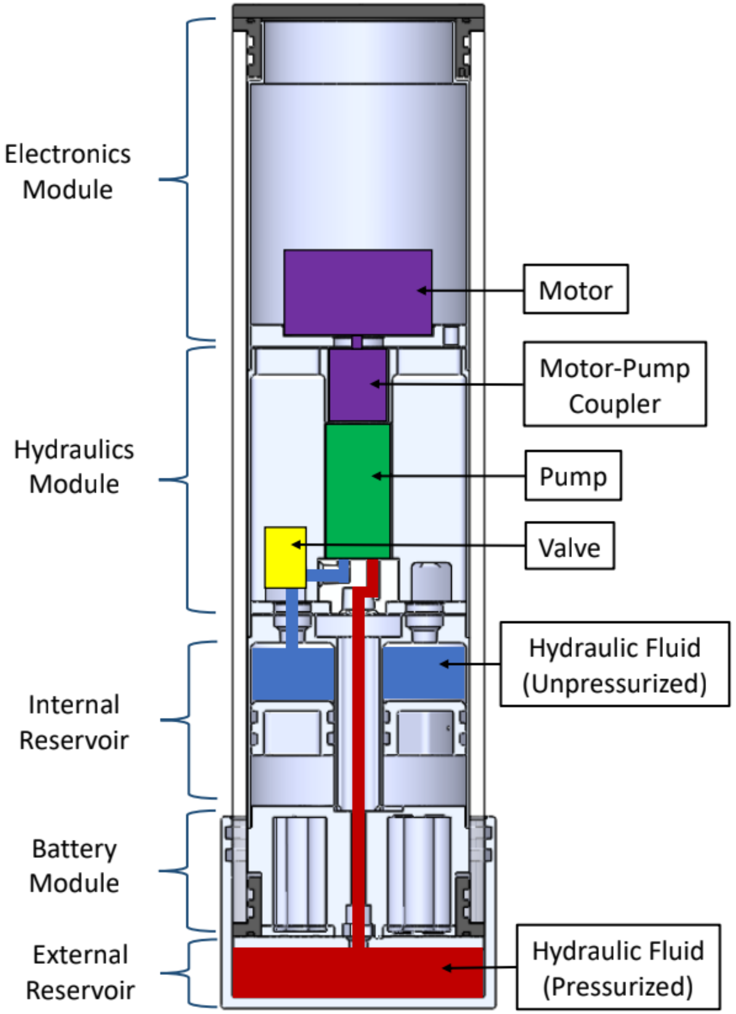
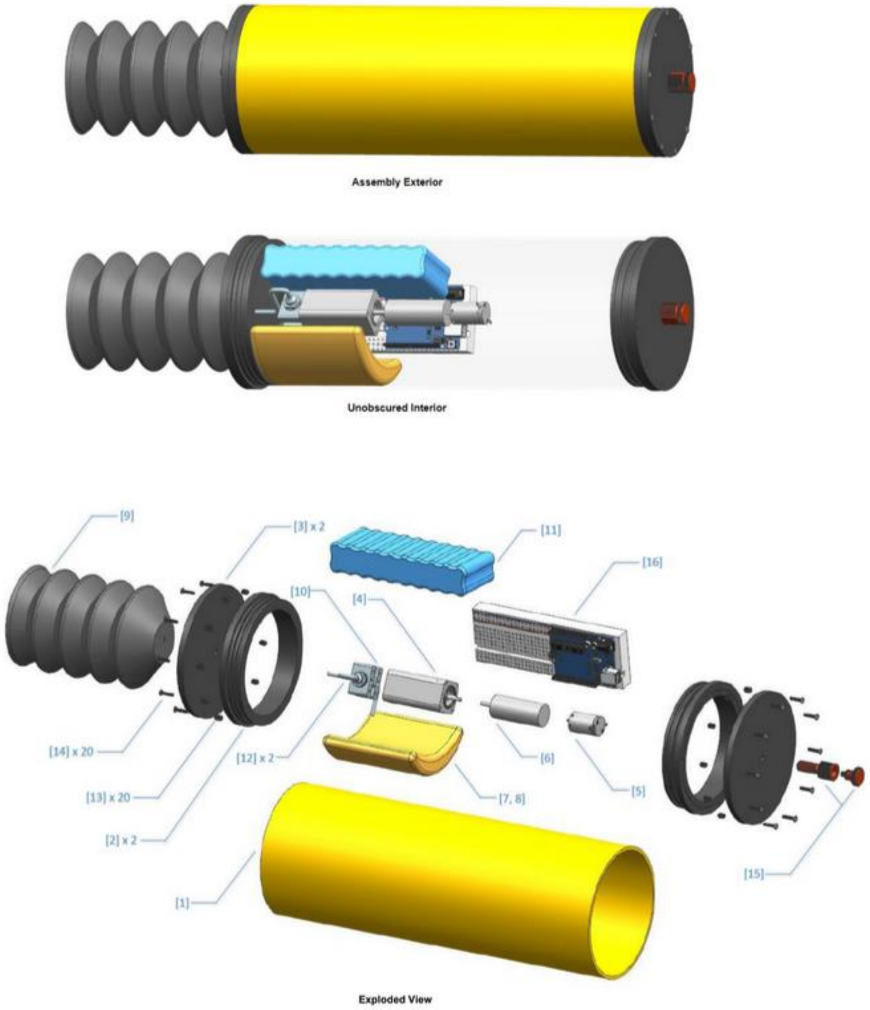
Prior Art – VIP Project

- Lagrangian Profiler MK4
  - Surface communication
  - Buoyancy control
    - Oil displacement piston
    - External "shell" piston



Prior Art – Design Project

- Together We Swim
  - Buoyancy control
    - Oil pumping
  - Prototype validation failure
    - Unresolvable sealing issues
  - Created CAD concept



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Codes and Standards

- Standard Practice for Exposing and Evaluating Metals and Alloys in Surface Seawater
  - ASTM G52 – 20
  - Requirements and recommendation to evaluate corrosion and marine fouling behavior of materials exposed to a saltwater environment
- Standard Specification for Sealless Lube Oil Pump with Oil Through Motor for Marine Applications
  - ASTM F2798-09(2018)
  - Requirements applicable to design, construction and testing of sealless, rotary positive displacement pumps with oil-through motors for marine operations
- Antifouling paint
  - 304(a) of the Clean Water Act (CWA)
  - < 0.0074 µg/L on a 4-day average, or < 0.42 µg/L on a 1-hour average
- RoHS Standard
  - <0.1% by weight for lead mercury, hexavalent chromium and cadmium
  - States including California, New Mexico, New York and Rode Island

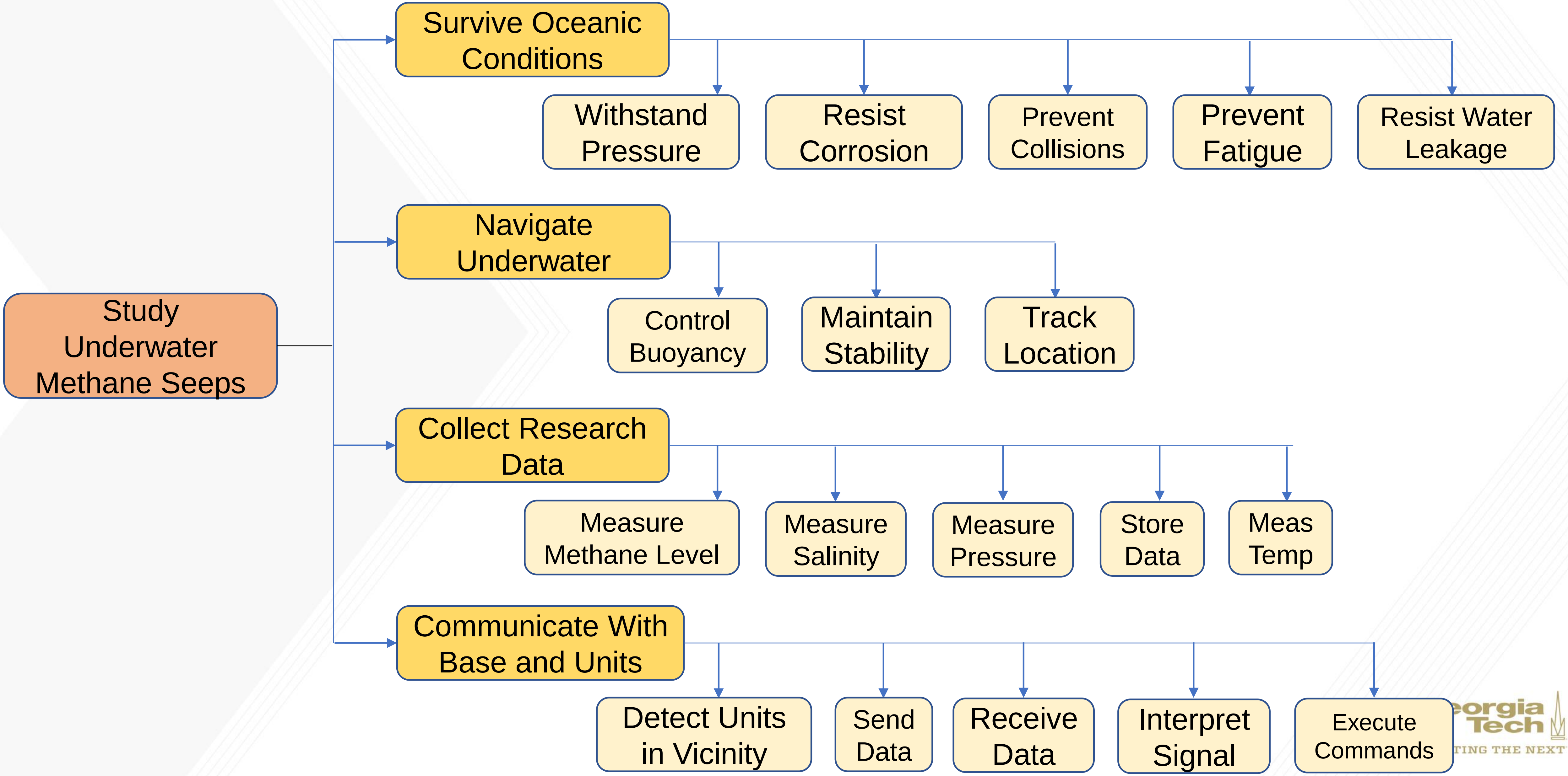
Requirements and Specifications

- Travel Vertically in Water
  - Detect depth (0 – 750 m)
  - Maintain stability
  - Alter buoyancy (0.5 m/s)
- Endure ocean conditions
  - Corrosion resistant (withstand two weeks submerged in sea water)
  - Withstand 750 m water pressure
- Collect measurements
  - Store two weeks of sensor data
  - Support multiple sensors
  - Support flexible sensor mounting
- Convey position and sensor readings upon surfacing
  - Send and receive signals
  - Localization (latitude, longitude and depth)
- Needs to have standard buoy size: 4.875” diameter, 36” length
- Needs to have at least two-week battery life
- Needs a visual marker upon resurfacing for visibility (LED Flasher)
- Must be able to release internal pressure upon returning to sea level
- Must be able to independently switch sensors on or off

QFD: House of Quality

Category	Weight	Customer Requirements (Explicit and Implicit) / Engineering Requirements	Tensile Strength (Mpa)	Compressive Strength (Mpa)	Sensing Range (m)	Motion Range (# cycles)	Mass (kg)	Cost ($)	Battery Life (weeks)	Resolution
		Column #	1	2	3	4	5	6	7	8
		Direction of Improvement	▲	▲	▲	▲	▼	▼	▲	◇
Sensing	10	Measure Methane Seeps								●
	8	Identify Pressure upto 1500 psi								●
Size	5	As Small as Possible	▽	▽		○	●	●	○	
Longevity	10	Withstand Ocean conditions 1000m deep	●	●				○		
	7	>2 week battery life			▽	●	▽	○	●	
Budget	4	<$800 budget	▽	▽		○	○	●	○	
Primary Applications	2	Swarmability			●			○	▽	
	10	Alter buoyancy	▽	▽		▽	▽		○	
	6	Easy to Operate			○	○	▽		▽	
	8	Easy to Fabricate	▽	▽			○			
		Target	15	15	1000	1000	75	800	2	1/10R
		Max Relationship	9	9	9	9	9	9	9	9
		Technical Importance Rating	117	117	43	118	104	138	128	162
		Relative Weight	13%	13%	5%	13%	11%	15%	14%	17%
		Weight Chart								
		Column #	1	2	3	4	5	6	7	8

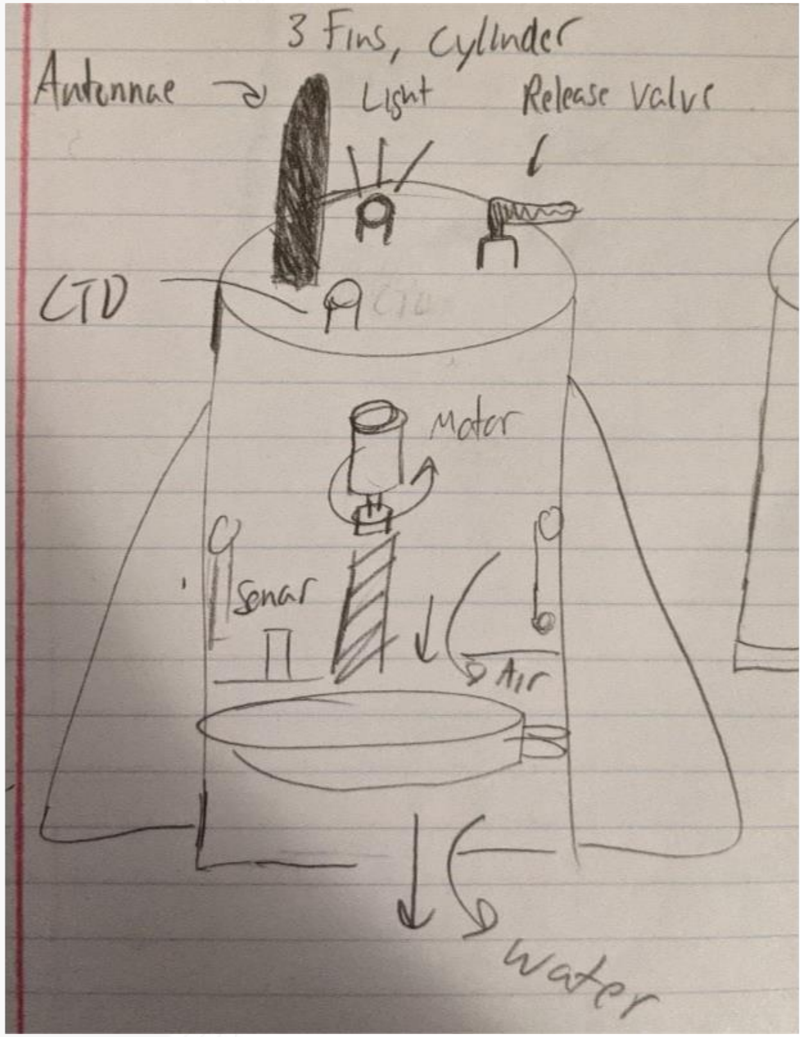
Function Tree



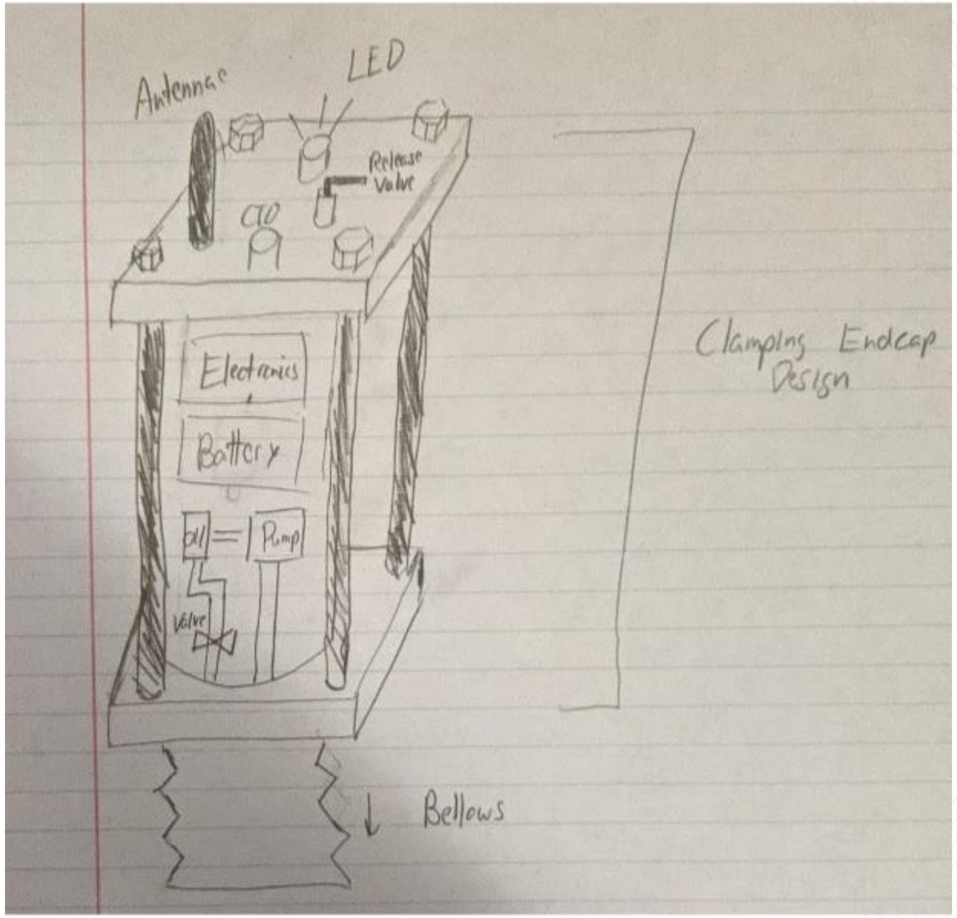
Functions	Concept 1	Concept 2	Concept 3	Concept 4	Functions	Concept 1	Concept 2	Concept 3	Concept 4
Maintain Stability/ Orientation	Fins	Hang Mass from Float	High Internal COM	Low internal COM	Resist Corrosion	Corrosion Resistant Material	Barrier Coating	Anodized surface	Hot-Dip Galvanization
Control Buoyancy	Ballast System (Air, Water)	Screw Driven	Pressurized Piston	Bellows	Withstand Pressure at 750m	Properly Sized Body	Pressurized Cylinder (Outlet Port, Inlet Port)	Flexible frame	Spherical vessel
Track Location	Use GPS	Use Sonar for Depth Sensing	Communicate with other units	9-axis imu (gyroscope, accelerometer, compass)	Resist Water Leakage	Capped Cylinder	O-Ring/Gasket	Use Sealant	Weld the seam

Functions	Concept 1	Concept 2	Concept 3	Concept 4	Functions	Concept 1	Concept 2	Concept 3	Concept 4
Store Sensor Data	Save to SD card	Save to usb-drive	Save to micro-computer storage		Send and Receive Signals	RF module + Antenna	Sonar Module	Wi-fi Emitter	
Support Multiple Sensors	Multiple inputs on controller	Sufficient Cap Space	Integrate additional sensors onto pcb	Universal connector port	Convey Position and Sensor Readings	Read Stored Data and Send it	Get current sensor readings and Post	Transmit data when surfaced	Storage device retrieved by scientists
Support Universal Mounting	Interchangeable Sensor Nodes	Standardized waterproof connectors			Prevent Collisions	Light to Signal Status	Sonar to Detect Floor	Thrusters for X and Y movements	

Integrated Concept Designs (1-2)

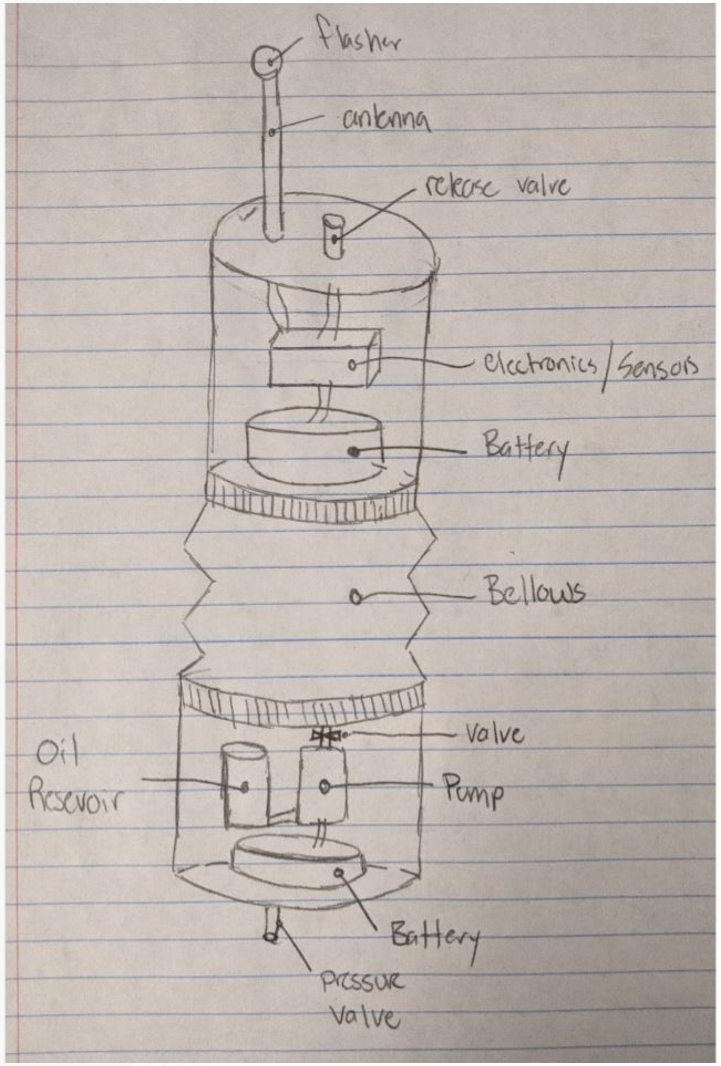


Bottom piston concept

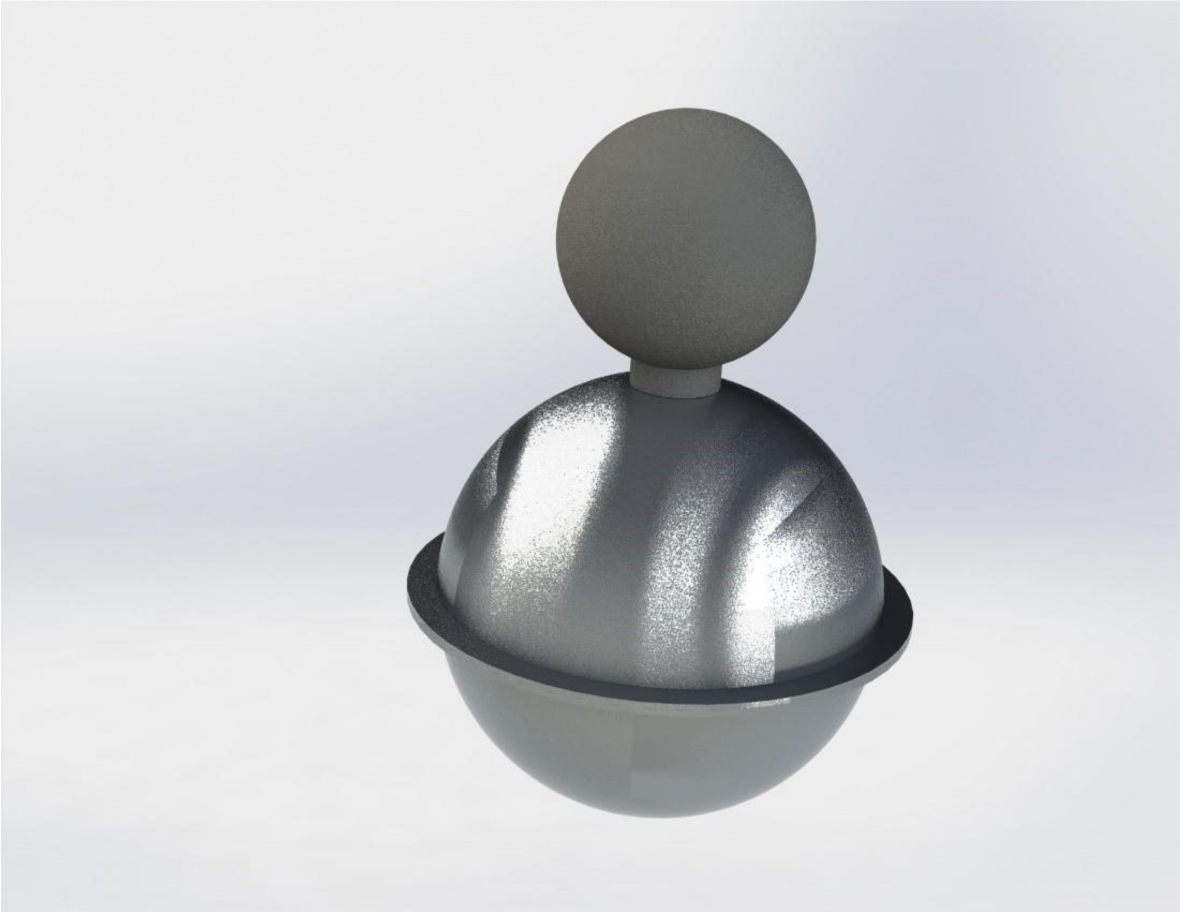


Bottom bellows concept
with clamped endcaps

Integrated Concept Designs (3-4)

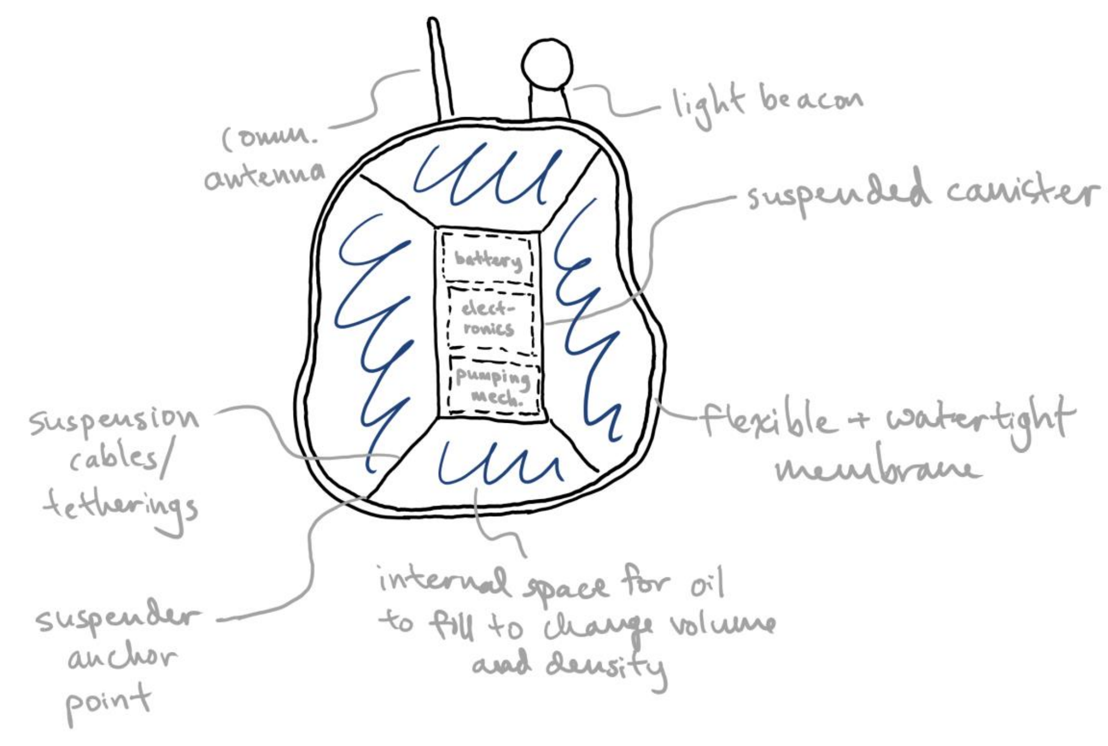


Middle bellows concept

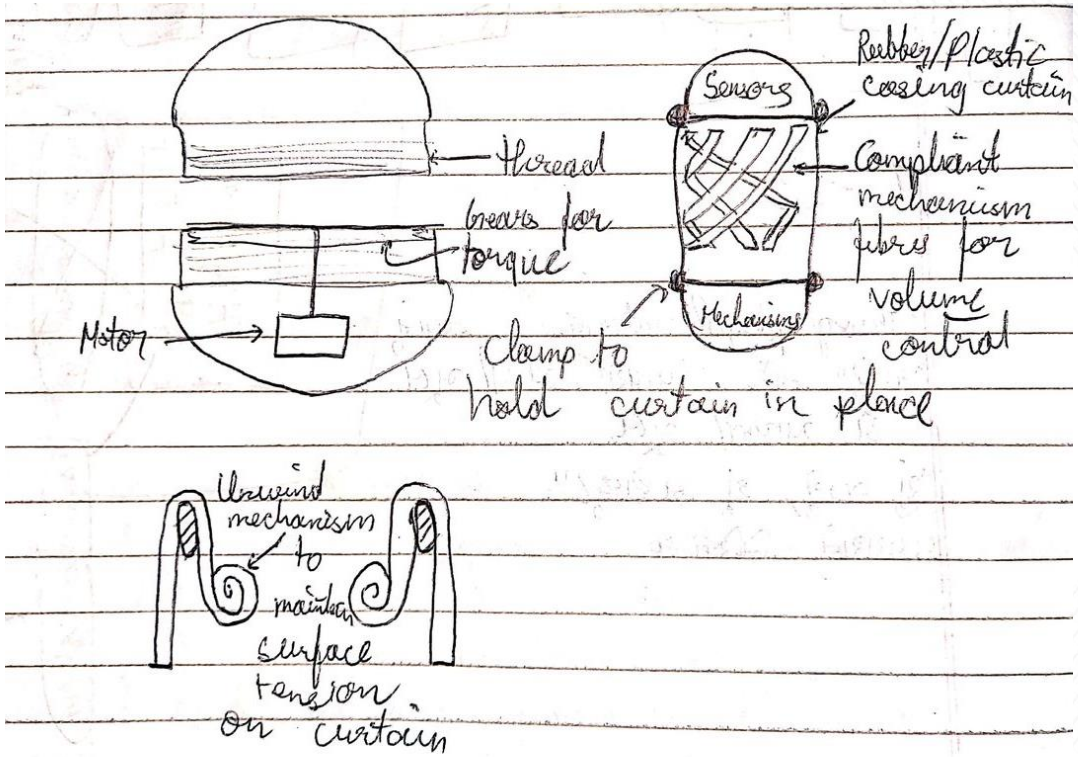


Flanged sphere concept with oil sack

Integrated Concept Designs (5-6)



Soft balloon concept



Compliant sphere concept

Evaluation Matrix

- Criteria for ranking concepts developed from revised function tree and each assigned a relative importance value
    - Ability to measure methane seeps, altering buoyancy, and withstanding ocean conditions at 750 m are the core functions of the vehicle and thus the most important criteria; not successfully completing any one of these would be a design failure
- Each concept was given a fair discussion to reach a consensus on rating for each criterion
- Swarmability is a desired but secondary feature, partially outside the scope of this project, and relies on a communication protocol and internal electronics, so it is not impacted significantly by the mechanical design

Evaluation Matrix

Criteria	Importance	Bottom Piston		Bottom Bellows		Middle Bellows		Sphere Sack		Soft Balloon		Compliant Sphere	
		Rating	W. Total	Rating	W. Total	Rating	W. Total	Rating	W. Total	Rating	W. Total	Rating	W. Total
Measure methane seeps	10	10	100	10	100	10	100	10	100	10	100	10	100
Identify pressure up to 1500 psi	8	10	80	10	80	10	80	10	80	10	80	10	80
As small as possible	5	6	30	6	30	6	30	8	40	9	45	8	40
Withstand ocean conditions at 1000 m	10	7	70	8	80	7	70	10	100	10	100	9	90
Two-week battery life minimum	7	8	56	8	56	9	63	6	42	6	42	6	42
<$800 budget	4	9	36	8	32	8	32	4	16	2	8	6	24
Swarmability	2	0	0	0	0	0	0	0	0	0	0	0	0
Alter buoyancy	10	4	40	8	80	8	80	8	80	8	80	5	50
Easy to operate	6	6	36	8	48	9	54	5	30	2	12	5	30
Easy to fabricate	8	7	56	9	72	6	48	5	40	2	16	4	32
Total		504		578		557		528		483		488	
Relative Total		0.160611855		0.184193754		0.177501593		0.168260038		0.153919694		0.155513066	
Rank		4		1		2		3		6		5	

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Evaluation Matrix

Criteria	Importance	Bottom Piston		Bottom Bellows		Middle Bellows		Sphere Sack		Soft Balloon		Compliant Sphere	
		Rating	W. Total	Rating	W. Total	Rating	W. Total	Rating	W. Total	Rating	W. Total	Rating	W. Total
Measure methane seeps	10	10	100	10	100	10	100	10	100	10	100	10	100
Identify pressure up to 1500 psi	8	10	80	10	80	10	80	10	80	10	80	10	80
As small as possible	5	6	30	6	30	6	30	8	40	9	45	8	40
Withstand ocean conditions at 1000 m	10	7	70	8	80	7	70	10	100	10	100	9	90
Two-week battery life minimum	7	8	56	8	56	9	63	6	42	6	42	6	42
<$800 budget	4	9	36	8	32	8	32	4	16	2	8	6	24
Swarmability	2	0	0	0	0	0	0	0	0	0	0	0	0
Alter buoyancy	10	4	40	8	80	8	80	8	80	8	80	5	50
Easy to operate	6	6	36	8	48	9	54	5	30	2	12	5	30
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Total		504		578		557		528		483		488	
Relative Total		0.160611855		0.184193754		0.177501593		0.168260038		0.153919694		0.155513066	
Rank		4		1		2		3		6		5	

- Unique strengths for the top three designs are highlighted

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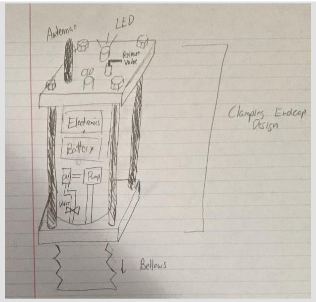
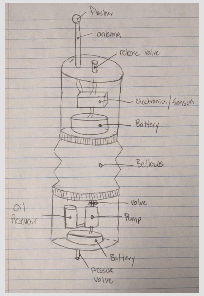
Concept Selection

	Bottom Bellows (1)	Middle Bellows (2)	Flanged Sphere with Oil Sack (3)
Sketch			
Pros	Easiest to fabricate of all concepts; practical	Easiest to operate and service; built-in modularity	Most compact and space-efficient
Cons	Not hydrodynamic; threaded rods exposed to corrosion	Not significantly different in function from (1) but more complex	Difficult to manufacture; potentially less stable underwater; packaging
Potential Countermeasures	Circular endcaps, larger diameter casing around threaded rods	Tradeoff between complexity and modularity	Off-the-shelf spherical casing; self-righting system
Comments	May investigate alternative bellows design based on compliant mechanism	May investigate alternative bellows design based on compliant mechanism	Will run preliminary design calculations but ultimately may prove impractical

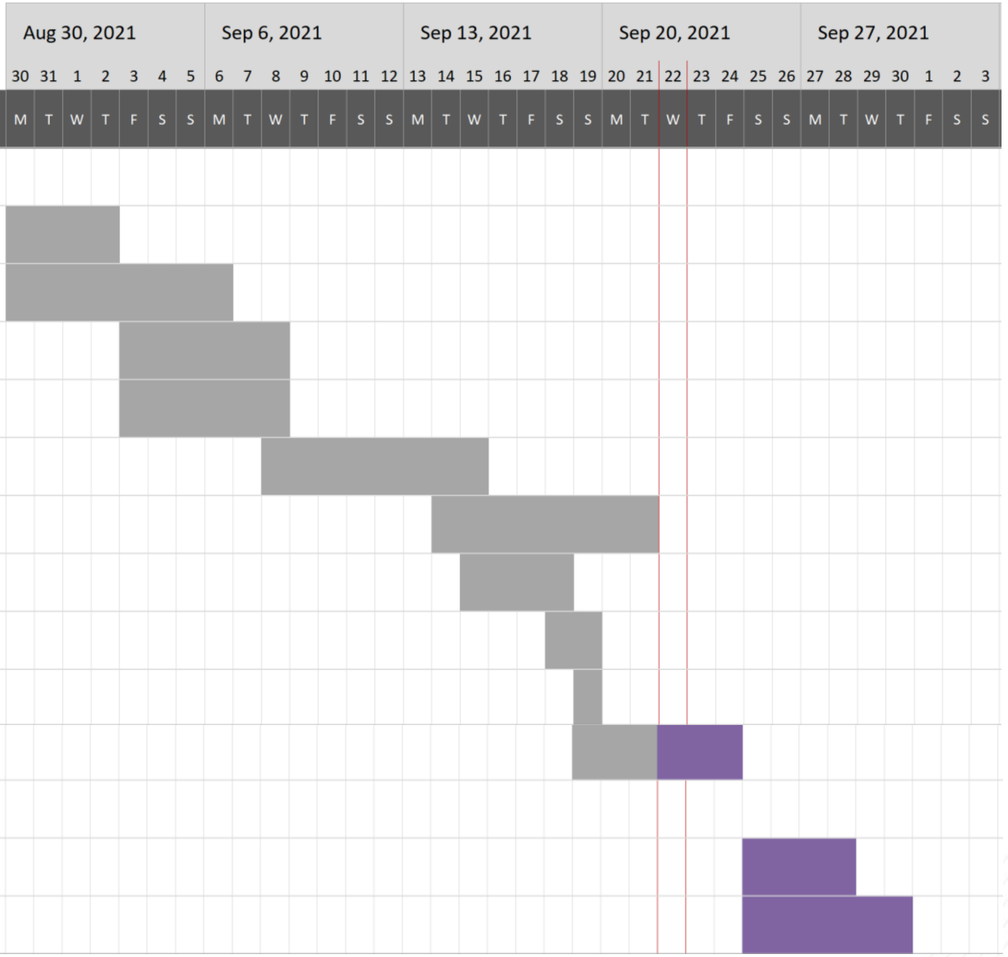
Project Timeline

MicroFloats

Swarmers
Project Manager: Alex Olsen

Project Start: Mon, 8/30/2021
Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Ideation and Concept Generation				
Compile available meeting times	Vatsal Trivedi	100%	8/30/21	9/2/21
Review previous team's work	All (async)	100%	8/30/21	9/6/21
Create house of quality	All (sync), Vatsal to digitize	100%	9/3/21	9/8/21
Create function tree	All (sync), Terence to digitize	100%	9/3/21	9/8/21
Create morphological chart	All (async)	100%	9/8/21	9/15/21
Update prior art search	Terence Lui, Sidney Wise	100%	9/14/21	9/21/21
Create concept sketches	All (sync)	100%	9/15/21	9/18/21
Discuss evaluation matrix	All (sync)	100%	9/18/21	9/19/21
Review prototype hardware and	lex Olsen, Dahrius Abdelnur, Sidney Wis	100%	9/19/21	9/19/21
Complete Report 1	All (async)	55%	9/19/21	9/24/21
Detail Design and Specifications				
Timeline for CAD and electrical de	Alex Olsen	10%	9/25/21	9/28/21
Begin hand calculations	lex Olsen, Dahrius Abdelnur, Terence Lu	10%	9/25/21	9/30/21



Future Work

- Plan timeline for CAD and electrical design
- Begin detailed design sketches and initial CAD
- Complete hand calculations for initial design validation
- Draft preliminary BOM and decide what components to reuse from RUR’s design

Questions?

Thank you!