Vertical Profiling Float

2024 MATE ROV Pennsylvania Workshop

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  - ◆ Research @ GRASP Lab — working on an origami-inspired robot that swims via jet propulsion!
- ➔ 6+ years in MATE!
  - ◆ 1st overall @ MATE PA (2021, 2022, 2023)
  - ◆ 2nd overall @ MATE World Championships (2023)

1

History of MATE Floats!

35/300 points

2022 MATE ROV (Task 3.1)

60/300 points

2023 MATE ROV (Task 3)

70/350 points

2024 MATE ROV (NEW — **Task 4!**)

2

The GO-BGC Project

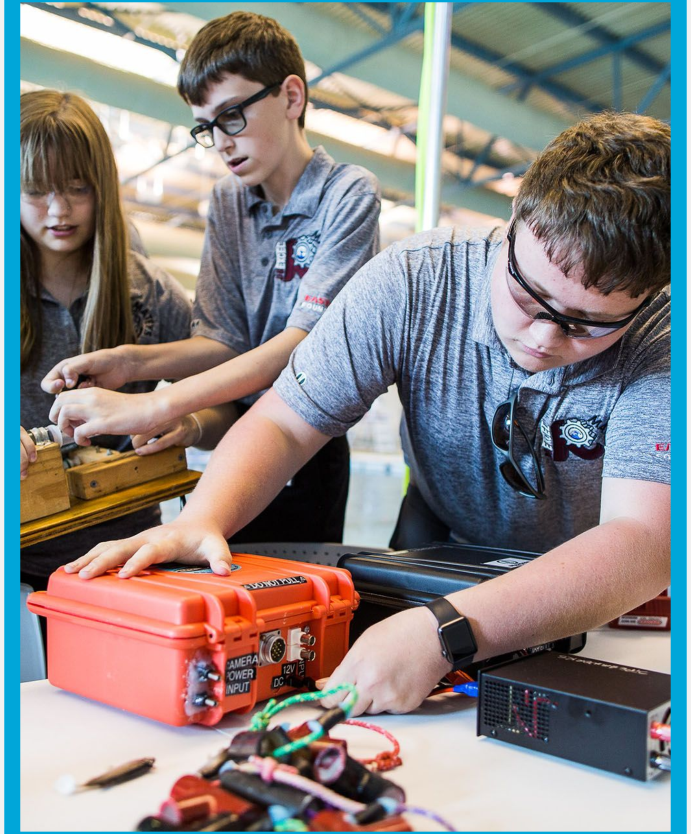
Scientific Context — GO-BGC

What does GO-BGC stand for?

Scientific Context — GO-BGC

An Industry Focus — GO-BGC

What are some challenges that GO-BGC engineers experience?



An Industry Focus

Power Management and Efficiency

Real-World Challenge: Ensuring the float can operate for extended periods in the ocean on limited power sources.

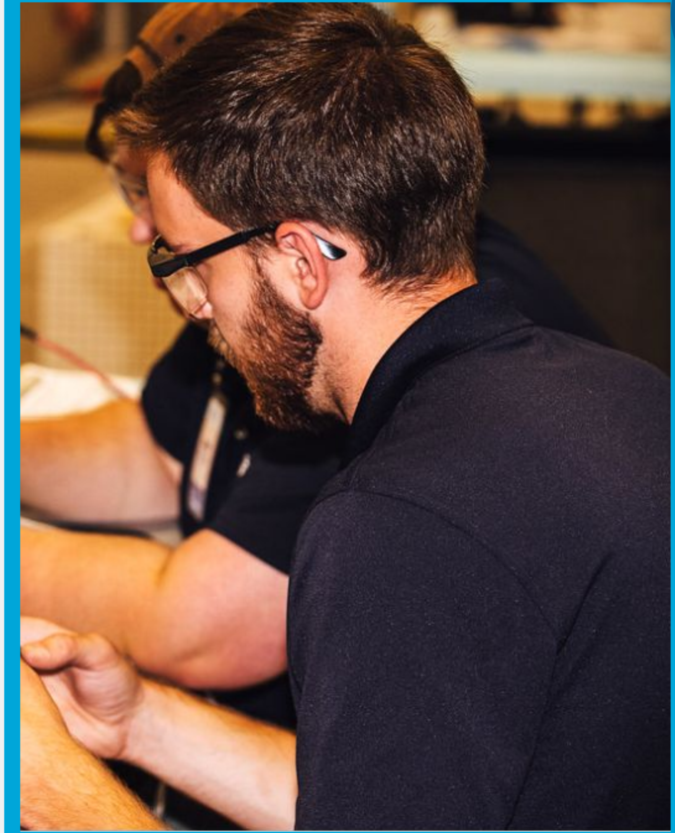
MATE Adaptation: Challenge students to design energy-efficient systems for their floats, focusing on optimizing battery life and power consumption. This could involve selecting energy-efficient sensors and propulsion systems or developing algorithms for efficient energy use.

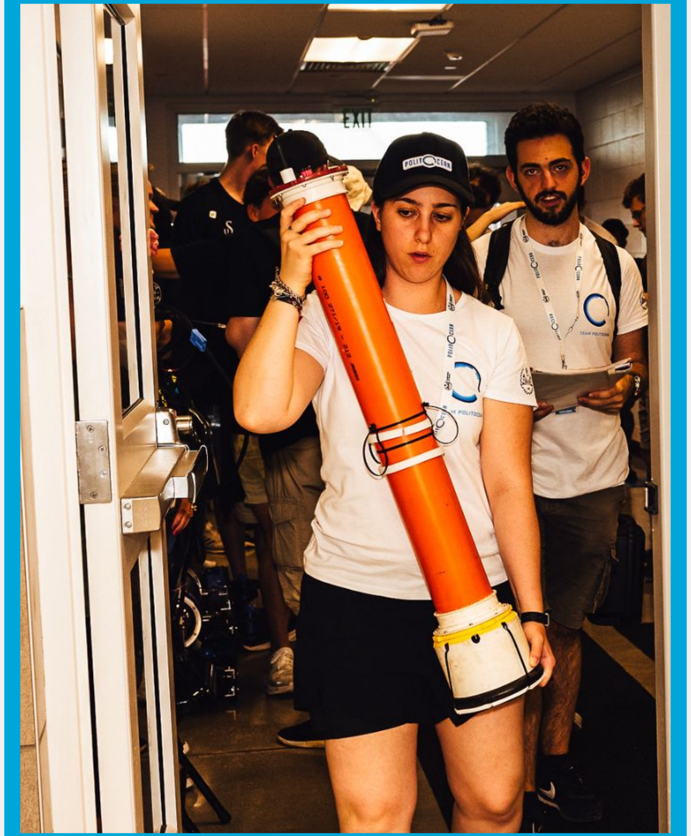
An Industry Focus

Data Collection and Transmission

Real-World Challenge: Collecting high-quality, accurate data under various ocean conditions and transmitting it back to researchers without data loss or corruption.

MATE Adaptation: Task students with integrating robust sensors into their ROVs that can collect depth and pressure data. They must also devise reliable methods for data storage and transmission to the surface, while accounting for a potentially noisy poolside environment.





An Industry Focus

Buoyancy Control

Real-World Challenge: Engineering a float that can adjust its buoyancy to descend to and ascend from deep ocean layers, enduring high-pressure environments.

MATE Adaptation: Encourage teams to develop a buoyancy control system for their ROVs, allowing them to precisely control the depth of their vehicle. This could involve using materials and mechanisms that can withstand pressure changes and accurately adjust buoyancy.

Resources

Adopt-A-Float

“This program creates a powerful opportunity for students of all ages to engage directly with world-class scientists and learn about their research by naming and tracking BGC (biogeochemical) floats. **There is no financial cost to adopting a float!”**

3

Task 4: MATE Floats!

See 2024 MATE Competition Manual (Ranger class) — pages 36 and 37.

This task involves the following steps:

4.1 Design and construct an operational vertical profiling float

- Prior to the competition, design and construct a vertical profiling float – 5 points
- Deploy the float into a designated area – 5 points
- Float communicates with the mission station prior to descending – 10 points
- Float completes up to two vertical profiles –
    - Vertical profile 1
        - Float completes first vertical profile
            - Using a buoyancy engine – 10 points
            - Using a different mechanism – 5 points
        - Float communicates data to the mission station – 5 points
        - Data is graphed as depth over time – 10 points
    - Vertical profile 2

- Float completes a second vertical profile
    - Using a buoyancy engine – 10 points
    - Using a different mechanism – 5 points
- Float communicates data to mission station – 5 points
- Data is graphed as depth over time – 10 points

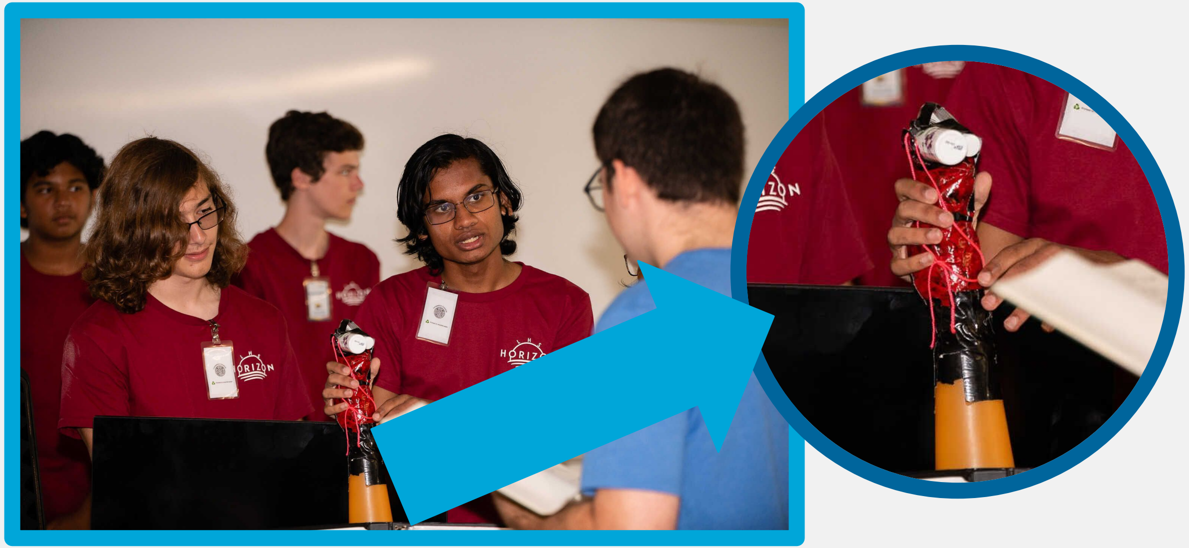
OR

Company does not design and construct a vertical profiling float or float does not communicate data to the mission station.

- MATE-provided data is used to graph depth over time – 10 points

Total points = 70 points

Attempt to build a float!



...even if it looks like this.

Build Components

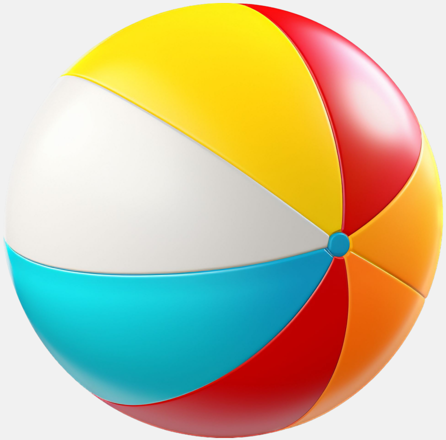
1. Buoyancy Engine
2. Vehicle Hull
3. Data Collection & Storage
4. Data Transmission

3.1

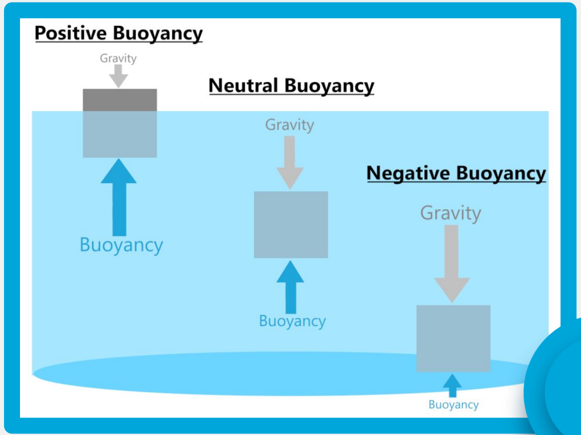
Buoyancy Engines

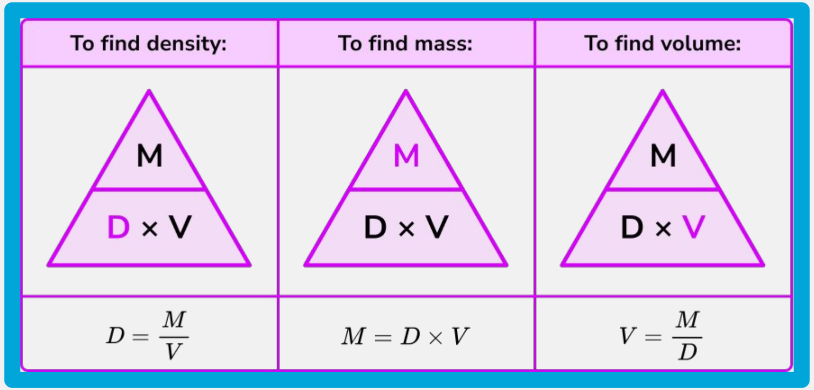
First of all...

What is buoyancy?



Buoyancy is the ability or tendency to float in water or air or some other fluid!





Buoyancy depends on **density**.

→ Density (ρ) = mass / volume

→ ρ_{H20} = 1 gram per mL

If $\rho_{obj} > \rho_{H20}$...an object sinks.

If $\rho_{obj} < \rho_{H20}$...an object floats.

What if $\rho_{obj} = \rho_{H20}$?

What IS a buoyancy engine?

“A buoyancy engine **moves fluid from inside the float to outside the float**, displacing seawater and changing the density of the float.”

What is NOT a buoyancy engine?

- → Thrusters
- → Water jet propulsion

Options for Buoyancy Engines

What kind of “fluid” is transferred?

- Option 1: Water

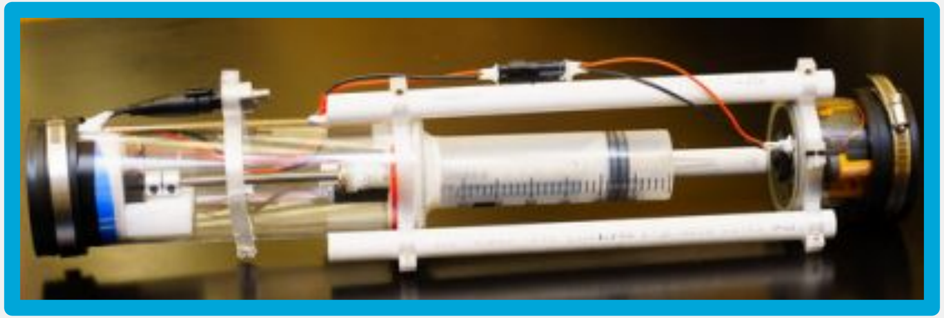
- Option 2: Air

Option 1: Water-Based

E.g. a servo-powered syringe...

- ➔ Takes in water...
  ↑ Mass, = Volume
  ↑ Density
  Object sinks.
- ➔ Expels water...
  ↓ Mass, = Volume
  ↓ Density
  Object floats.

Servo-powered syringe
Credit: MTL Horizon



Vertical profiling float assembly
Credit: Geneseas

Vertical profiling float assembly
Credit: WhaleTech Robotics

You don't have to use a servo-powered syringe to take in and expel water!

This team used a **hydraulic cylinder** and a **stepper motor** to pump water.

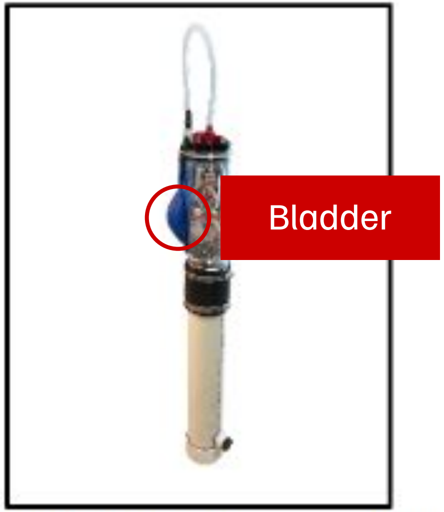
Pros? This system can more easily compress the air inside the buoyancy engine. Therefore, it can let more water in! The system achieves a greater **change in density** without changing the volume.

Cons? The system is more complex.

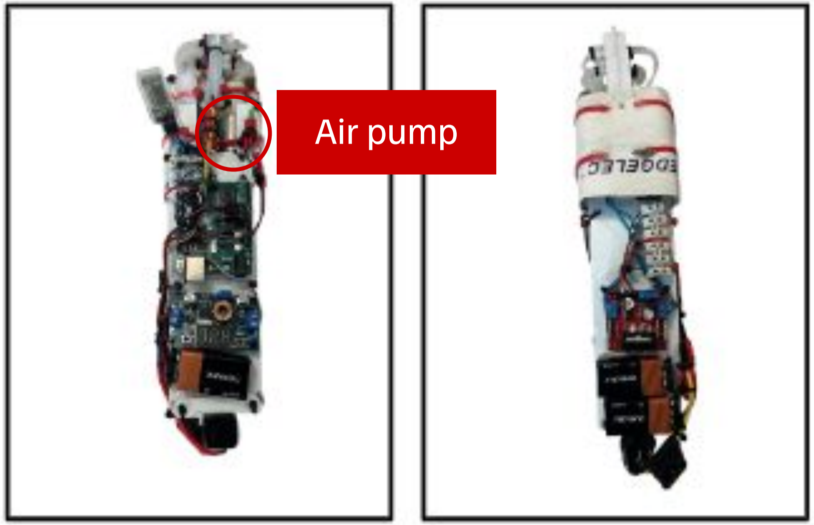
Option 2: Air-Based

E.g. air pump(s)...

- ➔ Inflate an external bladder...
  = Mass, ↑ Volume
  ↓ Density
  Object floats.
- ➔ Deflate the bladder...
  = Mass, ↓ Volume
  ↑ Density
  Object sinks.



Our Vertical Profiler: *Cousteau*
Photo Credit: A. Selvakumar



Cousteau's Buoyancy Engine
(front and back)
Photo Credit: A. Amarnath

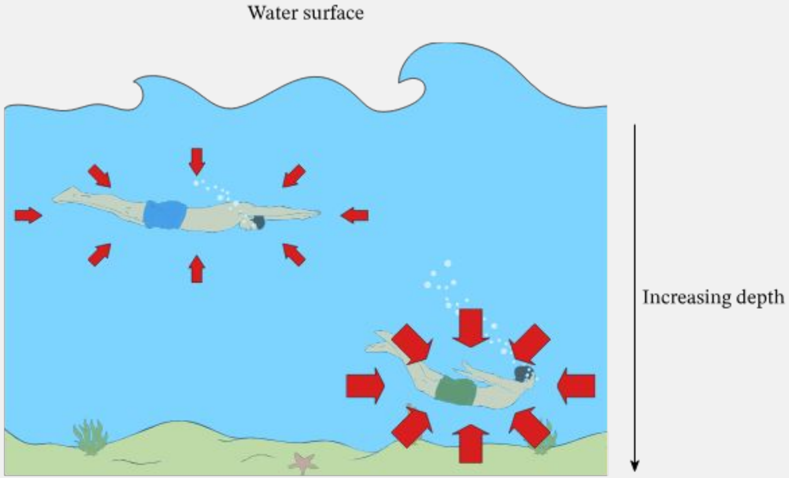
Figures from Non-ROV Device Design Document
Credit: MTL Horizon

An issue with air-based buoyancy engines!

"Pressure due to the weight of a liquid of constant density is given by...

$$p = \rho g h$$

...where p is the pressure, h is the depth of the liquid, ρ is the density of the liquid, and g is the acceleration due to gravity."



Pressure increases linearly with depth! Water pressure causes the external bladder to compress, decreasing the device's volume.

3.2

Vehicle Hulls

Minimize two things!

1. **Cross-Sectional Area**

Drag force increases linearly with cross-sectional area!

Minimize the horizontal cross-section of your device.

$$F_D = C_D A \frac{\rho V^2}{2}$$

where
F_D is the drag force
C_D is the drag coefficient
A is the reference area
ρ is the density of the fluid
V is the flow velocity relative to the object

Minimize two things!

2. **Hull Volume**

Pictured to the right is my team's first hull prototype.

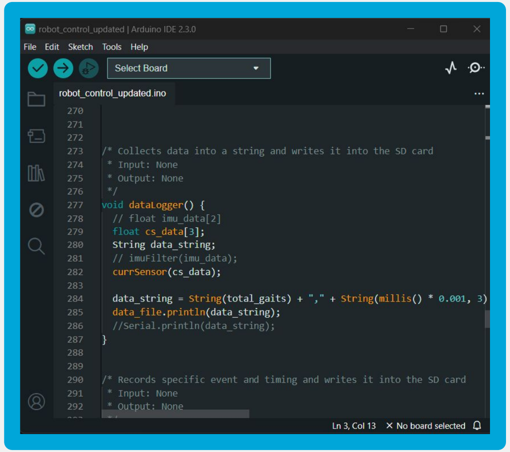
Cons? **Because the hull volume is so much larger than the volume of the buoyancy engine inside**, changes made to the buoyancy engine's density make a minimal impact on the density of the device as a whole.

3.3

Data Collection & Storage

Necessary Components

- Microcontroller (e.g. Arduino Uno/Nano)
- Storage device (e.g. micro SD card + adapter module)
- Sensor (e.g. BlueRobotics Bar02 or Bar30)



Sample Data-logger Program (Arduino)

Credit: Sung Robotics Group (GRASP Lab)

3.4

Data Transmission

Innovation in Software! **Cousteau's Mobile App**
Cousteau uses an Arduino and a Bluetooth module to communicate with the mission station. To prevent wireless interference, the Arduino requires a password to pair with the mobile app.

Figures from Technical Documentation
Credit: MTL Horizon