Deep Sea Carbon Dioxide Separator Prototype

SCHULICH School of Engineering — University of Calgary

Introduction

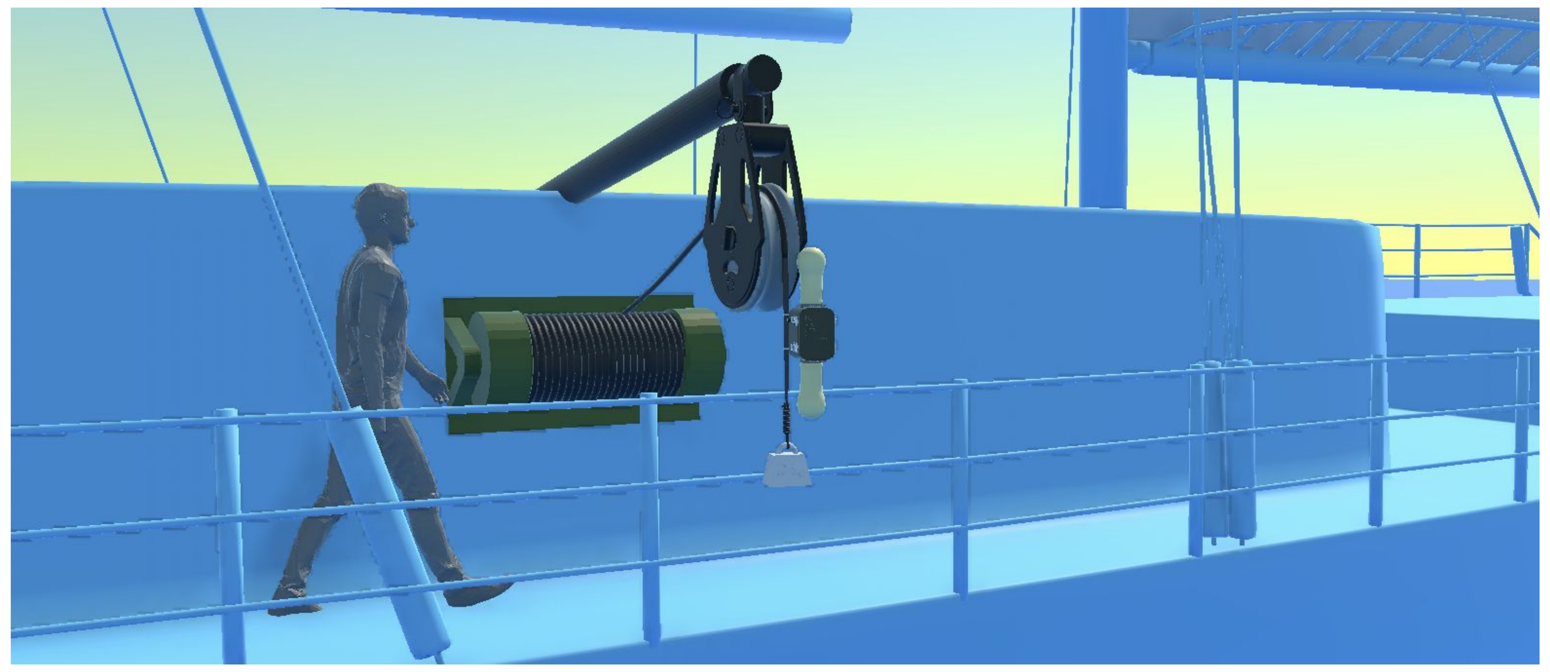
The Deep Sea Carbon Dioxide Separator Prototype (Fig. 5) is a device designed to remove CO2 from the air using deep-sea hydrostatic pressure. It is intended to sink 500 meters into the ocean, where pressure and temperature condense CO2 out of the air and into a liquid state. Within the prototype, this liquid can be isolated within a distinct chamber.

Our project builds upon the foundation established by Dr. Roman Shor[1] and it his previous sponsored capstone project, titled 'Subsea Buoyancy Energy Storage System and Direct Air Carbon Capture for Deep-Sea Energy Sources.' The initial project aimed to harness the buoyant force of air for underwater energy storage while also exploring the separation of CO_2 from the air.

The focus of our project is on developing a device to assess the practicality of CO_2 separation and provide a simulation detailing the process.

Abstract

- **Project Basis:** Aims to create a physical prototype (fig 4) to test concepts of $C0_2$ separation and a software based simulation(figs 1 and 2) of its use case.
- **Innovation:** We have developed a waterproof electronic housing for our prototype, enabling pool testing using electronic sensors. The internal electronic circuit utilizes sensors to detect $C0_2$ concentration, detect underwater pressure and close a valve separating chambers with different $C0_2$ concentrations at a specified depth. The electronics are designed to function in high-pressure environments and record data. Finally, a software based simulation demonstrates the real world application.
- **Methods:** The 3D modeling software Blender[2] was used to design the waterproof housing. The internal electric circuit was designed to work within the housing. The software simulation utilized Unity Game Engine[3].
- **Future Work:** Our electronic design (fig 4) would be used would be utilized in deep sea hydrostatic pressures at depths of 500 meters to condense atmospheric CO_2 into liquid form for efficient direct air capture. Expand on past work for for energy storage and $C0_2$ separation as a combined technology. Buoyant force of the air being used for $C0_2$ separation can also be used to store excess exergy for offshore wind turbines.
- **Objective:** Explore the feasibility of $C0_2$ separation and provide a simulation detailing its potential use case.



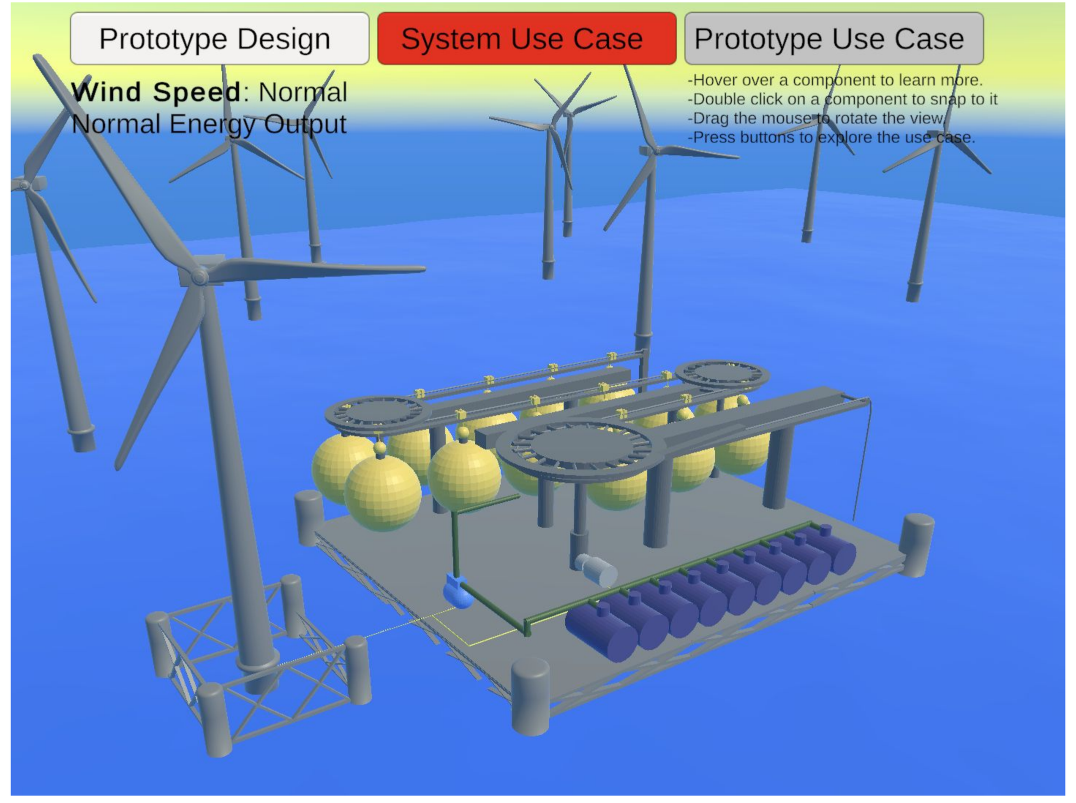


Fig 1 (top). The ideal use case for this project is to create a mini version of the internal gondola device, attach a weight to it, and sink it to a depth of 500 m from a ship deck.

Fig 2 (bottom). The gondola platform explored in past projects for energy storage. Each one contains a device that can separate $C0_2$, as well as store energy underwater.

Discussion

- A physical model (fig 5) of the prototype was constructed using 3D printing, Flex Seal, latches, electronics and other waterproofing elements.
- Features a robust 3D-printed structure with attached air balloons.
- Internals are managed by an Arduino control system for precise depth and CO_2 capture regulation.
- Fitted with sensors to monitor CO_2 levels and depth, the system precisely controls the air balloons' descent and ascent, optimizing energy efficiency.
- Pool testing(fig 3) confirmed the prototype's operational capabilities and sets the stage for trials in the ocean after slight improvements to the waterproofing.

Fig 3. The final test for the prototype in a U of C pool. The depth sensor was able to trigger the valve to close at the depth we specified, 1.5 m. The trigger depth can be adjusted for a larger scale test. A weight was also taped on to help sink the device.

Methods and Materials

- **Deep Sea Pressure:** Large pressure will liquidize CO_2.
- **Prototype Housing:** 3D modelling software[2] to design the device and 3D printing to create a shell and some internal components (ex battery case).
- **Electronics:** Circuitry was design to utilize an Arduino UNO as the "brain" of the system.
- **Balloons:** Latex balloons were pumped with air, although the test depth we had access to was not high enough to condense CO_2.
- **Simulation:** Unity Game Engine[3] was used to create a interactive and user friendly simulation further explaining the use case and potential future system.
- **Testing and Validation**: The prototype was tested in the University of Calgary aquatic center (fig 3).
- **Materials**: Latches, gasket, flex seal and epoxy were used to waterproof the housing and protect the electronics as seen in figures 4 and 5.

Results

- **Pool Test**
  - The device maintained its waterproofing for multiple trials over the course of 30 mins.
  - The Depth Sensor was able to detect our set depth (1.5m) and the circuitry responded by closing the valve.
  - The Depth Sensor and $C0_2$ sensors were able to record data to an SD card during the trials.
  - Overall the test was a success and the electronic work as intended.
- **Simulation Features**
  - Animation and explanation of assembling the components of the prototype design.
  - A demonstration of the prototype use case showing the estimated $C0_2$ concentration in parts per million during the process.
  - A overall system use case detailing how the prototype could be integrated into the proposed energy storage system.

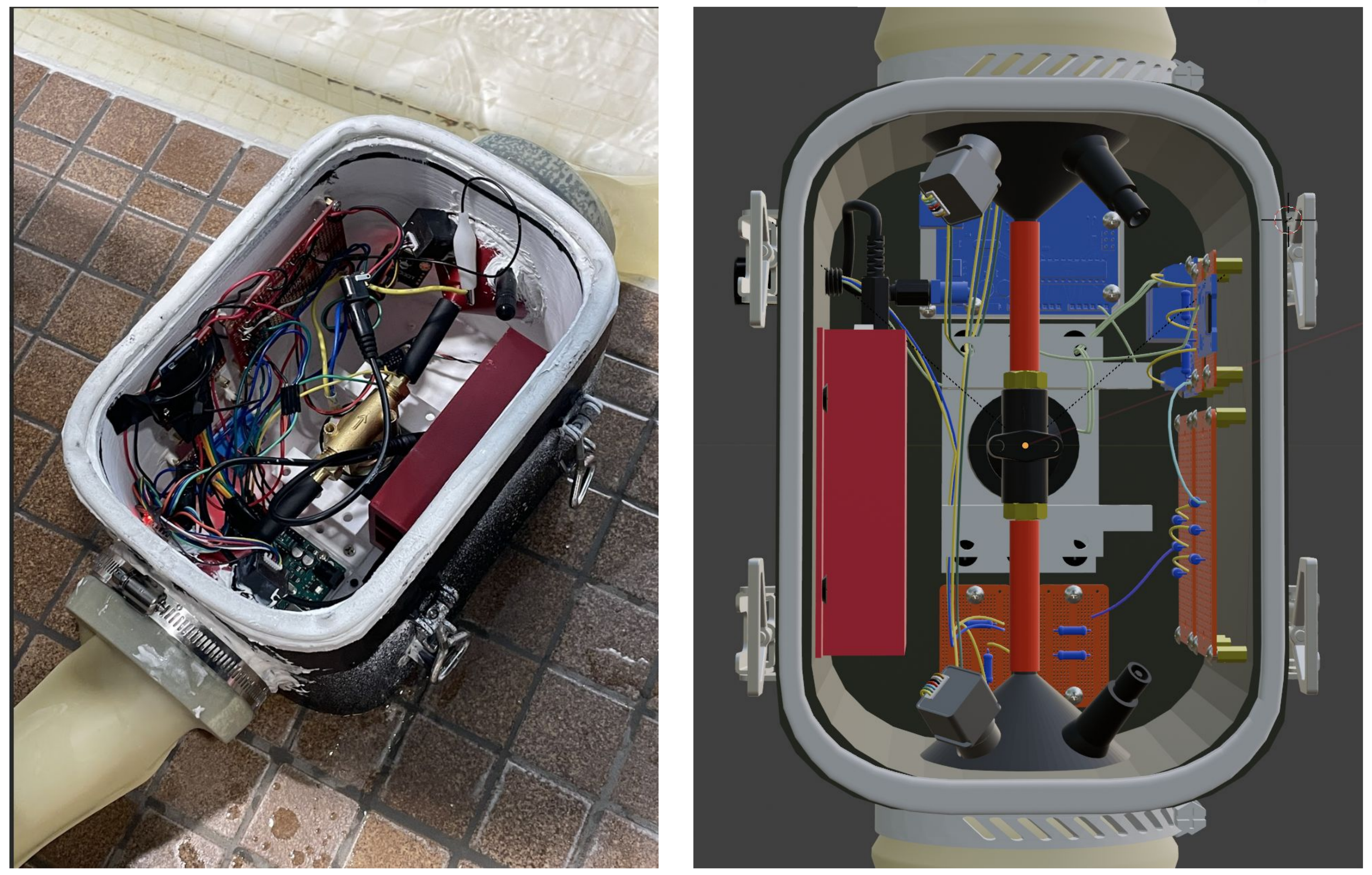


Fig 4. The physical prototype (left) and its 3D modeled counterpart (right). The physical device has the electric circuit fully incorporated. The wiring connect multiple sensors to an arduino including, The depth sensor, two CO_2 sensors, and the valve. The 3D model version served as a blue print during construction of the physical device.

Conclusion

The Deep Sea CO_2 Separator project demonstrates a method for separating $C0_2$ from the atmosphere. While this prototype type needs further testing to show its capabilities it is a promising design for future groups to use furthering this project. This prototype type can be a stepping stone to implement $C0_2$ separation in combination with deep sea energy storage.

The simulation provide a clear picture of the use case and hopeful final version of this project through successful iterations by other engineering disciplines.

While further optimization is necessary for commercial deployment, the initial outcomes highlight the project's potential to help advance renewable energy reliability and CO_2 reduction.

Fig 5. The design of the outside of the prototype. The latex balloons are pumped up using the air valve located on the inside of the device.

References

[1] Shor, R., Hands, G., Truong, K., Unico, Y., Ashar, A., & Al-Saiedy, A. (2023). Energy Storage and Direct Air Carbon Capture Solution for Offshore Sources of Energy. Proceedings of the ASME 2023 42nd International Conference on Ocean, Offshore and Arctic Engineering. OMAE2023. Melbourne, Australia.

[2] Blender, Home of the Blender project - free and open 3D creation software, blender.org. Available at: https://www.blender.org/.

[3] Unity Technologies. (2022). Unity - Game Development Platform. [Software]. Available: https://unity.com/.

Authors:
Roman Shor (Sponsor)

Claes Medrano
claesjared.medrano@ucalgary.ca

Nabeel Amjad
nabeel.amjad@ucalgary.ca

Cale Morash
cale.morash1@ucalgary.ca

Fahad Yasin
fahad.yasin@ucalgary.ca

Chace Nielson
chace.nielson1@ucalgary.ca