Measuring the Ocean: A Plan for Open Source Underwater Robots and Sensors to make Ocean-Science more Accessible

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ABSTRACT
CHALLENGES
VISION
CONNECTIONS
OPPORTUNITIES
COLLABORATORS

Abstract

How a family of open source robots and sensors can expand Ocean Science

Fostering the global capacity to sample the ocean is critical to delivering accessible and actionable data for a broad range of needs, including understanding the ocean-climate system and predicting future change, identifying and tracking ocean health issues at local and global scale, and building resilience to climate changes. Oceanic profiles of physical, biological, and chemical properties are one essential source of information we need to understand, model, and predict ocean-climate interaction and planetary future. Obtaining these profiles is a complex and costly endeavor.

Ubiquitous and persistent sampling of ocean profiles using networks of steerable untethered autonomous robots equipped with sensors, while visionary, remains an impractical goal. Developing and deploying such valuable robots and sensors still requires specialized and highly-engineered, and expensive designs which are only manufactured in limited locations, and remain out of reach for too many potential users. This will fundamentally limit where and how data will be collected in the ocean.
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We propose that open-source technology is poised to expand development of robust, locally manufactured, repairable, and less-costly vehicles and sensors that can be used to obtain profiles anywhere, by researchers, students, and citizen-scientists alike. Open source development projects also broaden the visibility and availability of good design, construction concepts, and tools and and will result in libraries of standard, interoperable parts.

Open source robots that are simpler in design, cheaper to construct, and carry interoperable and similarly open-source sensors will be more broadly adopted. This will reduce the existing barriers to usage and will accelerate the explosion of profiling robots in research, education, and ocean monitoring.

A cornerstone of the effort is fostering an international community of users, building an ecosystem of low-cost local manufacturing resources, and fostering educational adoption of open-source tools and technologies. Innovative open-source projects will result in affordable profiling robots and sensors for professional scientists, colleges, and high schools and provide an opportunity to interact with and inspire the next generation of oceanographers and engineers.

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Challenges addressed

Expanding Access to Ocean Profiling via Open Source Robotic and Sensor Design

Oceanic profiles of physical, biological, and chemical properties are an essential source of vital information if we are to understand, model, and predict ocean-climate interaction and planetary future. While untethered autonomous robots directed by intelligent operators can deliver repeated profiles, free from tethers and virtually anywhere, such valuable robots remain dependent on specialized and expensive resources and thus remain out of reach for too many potential users.

Greater ubiquity of inexpensive and reliable profiling robots in coastal and ocean regions will deliver timely and actionable data to a broad collection of users. Increased profile distribution and frequency supports both highly localized research and monitoring efforts by citizen scientists as well as persistent globalized ocean observing systems. This is especially true for groups and regions where there may be limited expertise or other resource constraints, especially cost.

The open source revolution that transformed software development in the previous decade will also change how we design and use robots. We are proposing an open source effort to design families of lower cost, more reliable and repairable underwater robots and sensors. We believe that open source technologies can be adapted and deployed to address ocean challenges and more.

Challenge 5: Enhance understanding of the ocean-climate nexus and generate knowledge and solutions to mitigate, adapt and build resilience to the effects of climate change across all geographies and at all scales, and to improve services including predictions for the ocean, climate and weather.

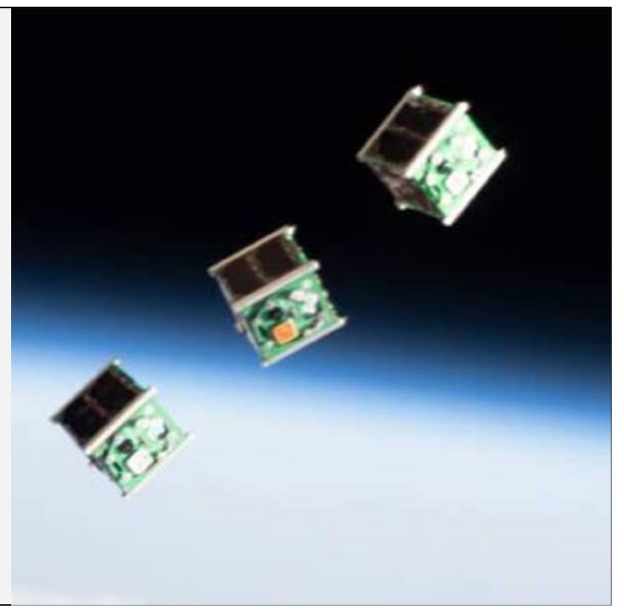
Challenge 6: Enhance multi-hazard early warning services for all geophysical, ecological, biological, weather, climate and anthropogenic related ocean and coastal hazards, and mainstream community preparedness and resilience.

Challenge 7: Ensure a sustainable ocean observing system across all ocean basins that delivers accessible, timely, and actionable data and information to all users.

Challenge 8: Through multi-stakeholder collaboration, develop a comprehensive digital representation of the ocean, including a dynamic ocean map, which provides free and open access for exploring, discovering, and visualizing past, current, and future ocean conditions in a manner relevant to diverse stakeholders.

Related Precedent:

In the same way that the CubeSat satellite has revolutionized space-based research by providing a cheap, open source satellite platform accessing low-earth orbits, an open source robust robotic platforms can become the lower-cost vehicles for carrying ocean sensors, and will deliver ubiquitous profile data that supports challenges



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Vision & transformative impact

Open Source Initiative

The vision is to support accelerated development of autonomous, long-range, open-source underwater robots and sensor designs, ones that will make ocean science more accessible to the world. This multidisciplinary effort will span the Decade of Ocean Science for Sustainable Development, creating an international fellowship of students, scientists, and engineers to design, build, and test a new family of interoperable underwater robots and sensors.

This effort has already begun. A group of professionals in ocean-science started in 2019 building an open source glider that is repairable, built with easily machined and off the shelf parts, and expect to have a glider designed and tested by the end of 2021. The advantage of this approach has naturally sprouted several similar efforts (see Resources).

International Fellowship and Cooperation

In the next decade we need wild evolution in shape and configuration of lower-cost robots and sensors that will be capable of carrying sensors into the water column and telemeter the data home. With low cost comes low risk, which favors novelty and encourages creators in any country to invent solutions that address local or global concerns.

Coordinated efforts at national and international levels will be needed to develop a design culture following these design tenets: Open source, repairable, sustainable with local resources, interoperable, and adhering to the principles of zero waste. The advantages of lower-cost tools is lowering the barriers to experimentation and risk taking.

Education

It is imperative that the teaching of the next generation of engineers and scientists includes the following design tenants: open source, repairable, sustainable, interoperable and zero waste. This family of long range robots and sensors will be used in high schools and colleges and act as a gateway for students to be more involved in ocean-science, and will include in the design open source technology already taught in schools worldwide.

Design Tenets

Built on open source

Using existing open sources to build upon speeds up development and can lead to evolution of good design. Using readily available open source tools that are already a part of curriculums around the globe increases the number of people who can modify and improve the design.

Repairable

A modular, easily repairable design turns consumers into creators. The right to repair is a crucial part of this proposal. Assemblies should be easily disassembled. Plans, schematics and tools will be included in each device to ensure its use can continue if found ashore. Designs will deliberately favor off-the-shelf or easily machined parts.

Sustainable with local resources

Through deliberate design choices, seek to maximize the use of components that can be fabricated and repaired with resources found in local and non-specialized machine shops and by using common tool sets.

Interoperable

Designing a standard electrical, mechanical, and software interfaces will enable reuse, repurposing, sharing ,and upgrading.

Zero waste

Refuse what we don't need and change the way we produce and consume by redesigning business models, goods, and packaging in order to reduce resource-use and waste. Encourage full circle designs, choose materials with end-of-life recycling for broken or aging parts, and incorporate these factors into design and fabrication costs from the start. Designs with standardized parts will create a large market for used parts.

Risk/Reward

Encourage experimentation and risk taking by designing underlying robustness, stability and accessibility.

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Connections to existing infrastructure, technology, and partnerships

Global Manufacturing Resources

Global partnerships will be fostered to deliver lower-cost and more readily available manufacturing resources. We will build on and expand the global network of small-scale manufacturing resources, including 3D printing, machining and injection molding, and support their ability to service a growing community of ocean roboticists.

Open Source Sensor Interoperability

The design of standard electrical, mechanical and software interfaces has long been desired. Several previous and ongoing efforts to unify sensor interfaces are hinting at a future where robotic design choices can be independent on mis-matching sensor configuration, leading to novel applications. Open source sensors, such as the OpenCTD, promise to give designers lower-cost options to complement or substitute for research-grade instruments.

Open Source Software

Robot and sensor designers can tap into a well developed ecosystem of open source software which will accelerate future development. As this project is also open source, in turn the benefits will cascade throughout this decade and beyond.

Open-Source Submersible Profiling Glider

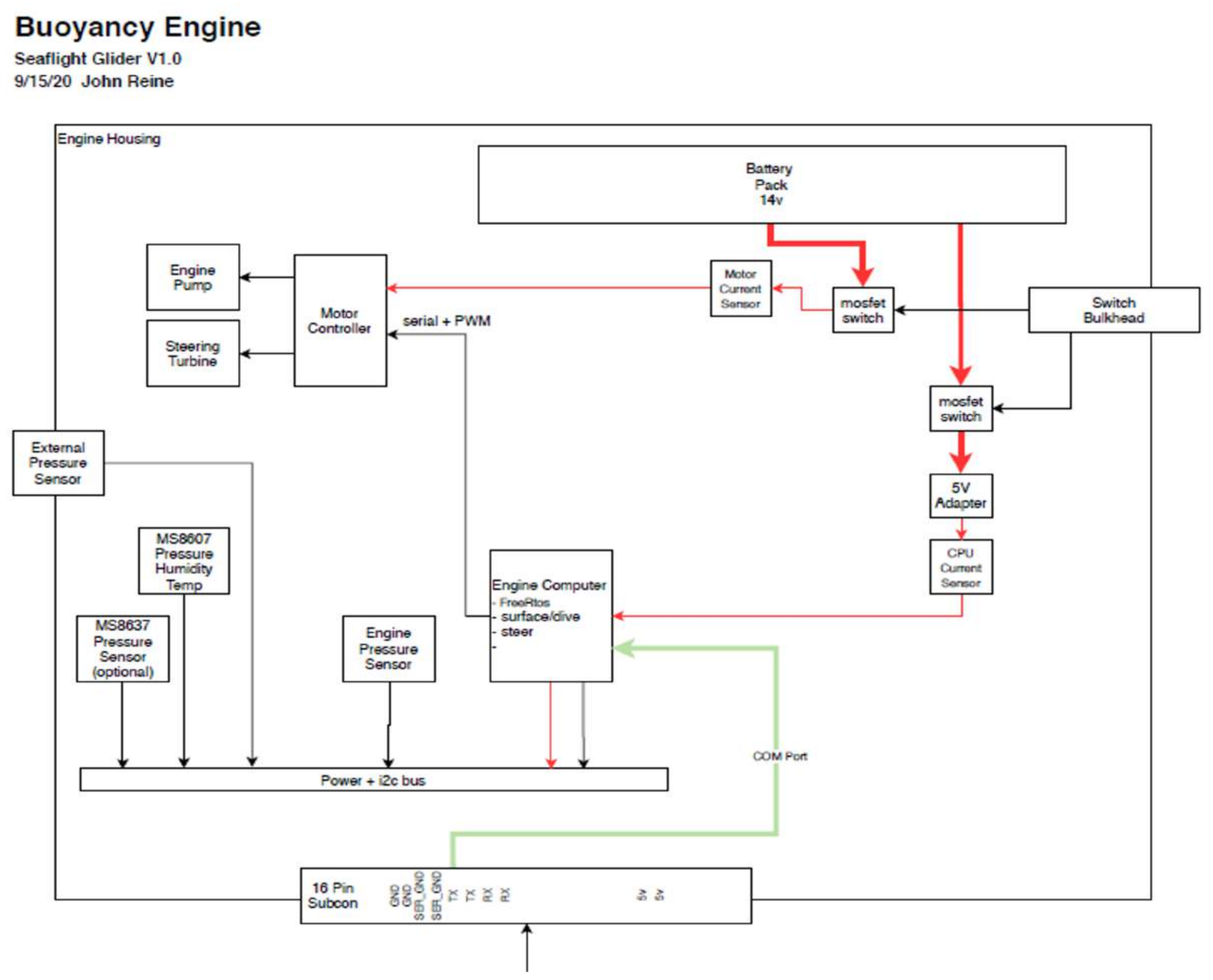
As a proof of concept we are developing an open source steerable ocean glider for shallow water operation. The design of this autonomous glider is fully open to adaptation and improvement by users and employs many off the shelf components and open source software.

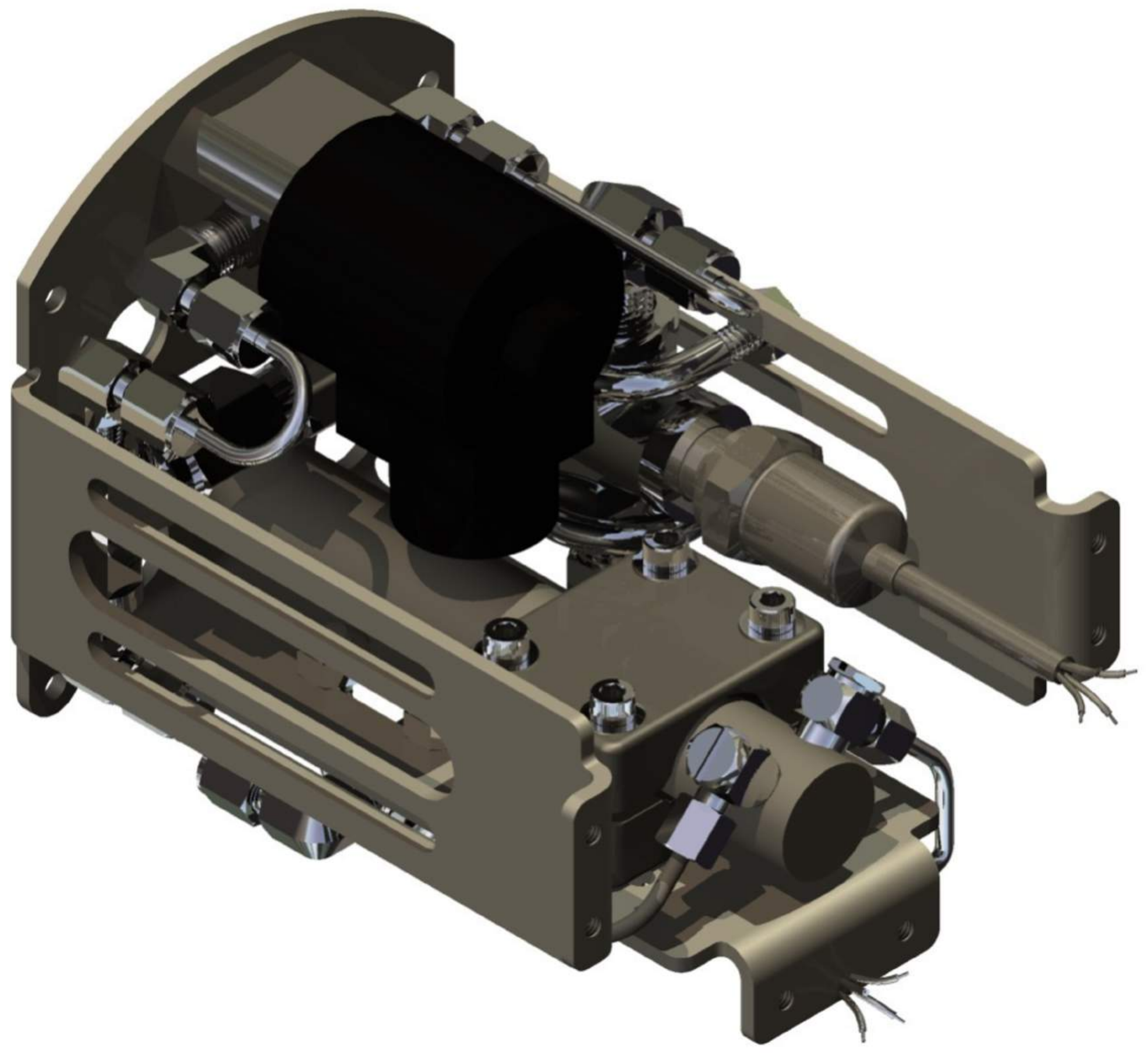
- Broadly available and low-cost mechanical components
- Flexible micro-electronics built for mobility applications
- Architecture for both research-grade and open source science sensors
- Open source software libraries for command, communication, navigation, and data logging

Prototyping was accelerated using off-the-shelf components and open source control electronics and software, taking less than 200 person-hr. to achieve bench-top operation. A closed-cycle hydraulic buoyancy engine using readily available components was designed and built in < 200 person-hr. Given this, we believe that fleets of open-source underwater robots carrying an array of open-source sensors and instruments are quite realizable in the future.

Data and Inventory

The Roundabout DB database, an open source database developed at WHOI custom made to track lifecycle management of deployed assets can be used to manage inventory and evolve to facilitate a global manufacturing catalog of local manufacturers making interoperable parts and services.





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Opportunities for international collaboration and capacity-building

Open Source Initiative

The vision is an accelerated development of a family of open source underwater robots and sensor designs, an effort that will increase the availability of low cost tools for doing ocean science around the world. This multidisciplinary effort will span the Decade of Ocean Science for Sustainable Development, creating an international fellowship of students, scientists, and engineers to design, build, and test families of autonomous, steerable, underwater robots and sensors in support of ocean exploring and monitoring.

International Support

We will collaborate internationally with funding partners to support development of open source, networkable robots and sensors.

- International and private agreements for lower cost satellite telemetry service for networks of ocean robots.
- Open data sharing through the World Meteorological Organization (WMO) Global Telecommunications System (GTS).
- Partner with United Nations Technology Innovation Labs to expand programs focused on underwater robotics and sensors.

Local Self-Reliance

A global marketplace will be created for parts, services and assembly fabrication by small independent businesses, stimulating local economies. This is paired with online systems for training, vetting and qualifying manufacturers, assemblers, refurbishment and technical support vendors. Open source designs give local control over ocean-science programs and initiatives enabling diverse and equitable community engagement.

Education

Making ocean science accessible to high schools and colleges is a necessary part of including early stage scientists and engineers and enabling them to participate in this effort.

- Expand range of resources addressing the ocean challenges
- Encourage and fund engineering courses in open source robotic design specific to applied to ocean challenges
- Encourage partnerships between educators, students, and public/private design efforts
- Teach zero waste and full-lifecycle design concepts

Equitable Access to Ocean-Science

Small university programs often do not have the funding or expertise to engage in long term ocean monitoring projects.

The goals of this Ocean Shot is to provide a more equitable access to Ocean Science, available to all countries, all colleges, all research institutions, all governments, all high schools, and all people.

Copyright and Proprietary Interests

In choosing the MIT License for the SeaFlight Glider development we are advocating for unrestricted rights for anyone to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the design.

We believe this maximizes the growth potential for new robots, both non-profit and for-profit designs, encourages both collaboration and competition, and limits proprietary claims. This means small companies and individuals will all have equal access to resources to machine parts, to assemble, calibrate, refurbish, repair, deploy, pilot and recover.

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Collaborators and Resources

Collaborators

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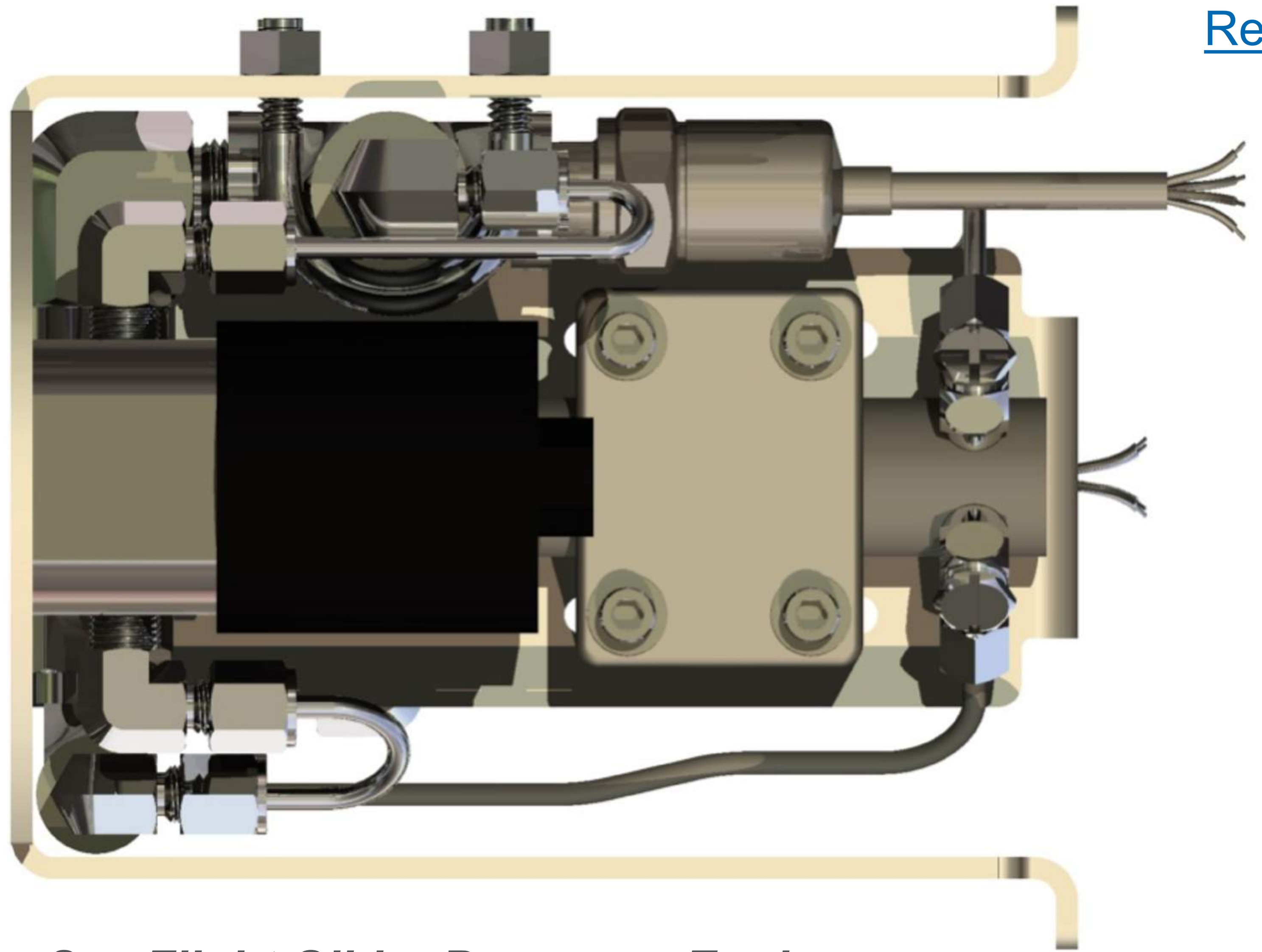
Peter Brickley
Jeremy Paulus
Matthew Palanza
Colin Dobson

Oregon State University
Ian Black
Stuart Pearce

Resources

- Sea Flight Glider
- Open Source CTDizzle
- OpenCTD
- Blue Robotics (open source ROV)
- Development of a Low-Cost Sonde
- Inlinino: Datalogger for optical oceanographic sensors
- The Cave Pearl Project
- Huliwai Underwater Data Logger
- Robot Operating System
- Roundabout DB (WHOI)
- Open Source Robotics Foundation
- Oceanography For Everyone
- United Nations Technology Innovation Labs
- Institute for Local Self Reliance
- Zero Waste Masterplan
- Reuse Public Policy



Sea Flight Glider Buoyancy Engine

SeaFlight Glider Design

Open Source resources used to build buoyancy engine:

- Arduino PCB
- BME280 Humidity Sensor
- RV-1805 Real Time Clock
- NEOM8U GPS
- HMC6343 Compass
- SD Card
- PWM Motor Control
- VL6180 Time of Flight Sensor
- FreeRTOS

Off the shelf parts used to build buoyancy engine:

- Hydraulic Pump (best)
- Hydraulic Pump (good)
- Standard Hydraulic parts
- Check Valve
- Brushless Motor Driver
- Pressure Sensor

Buoyancy engine designs (prototype):

Mechanical Files (send to machine shop)
Software

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