SeaFlight Glider Specifications

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Overview

This is a specification for a new class of underwater gliders designed to serve the needs of the scientific community to sample water carrying sensors, exploration and robotics research. The SeaFlight Underwater Glider will be designed to be robust, quickly repairable, easily refurbishable and built with mostly off the shelf, printed or machined parts.

The intention of this first version is to build a 'Model T' glider where robustness and repairability are more important than speed, steering agility or life at sea. Over time these can all be improved, but without a robust and repairable design as the foundation it will be difficult to move forward.

The entire glider design, hardware and software, will be open source, licensed so that all improvements need to be given back to the community.

This is an initial specification, an initial writeup of ideas meant to be discussed and to evolve. Please be forward with feedback and ideas.

Appendix 1: Design tenants.
Appendix 2: Why it is important that this is an open source project.
Appendix 3: Hardware Diagram

Goals:

Initial

1. Be 'deployed' in the open ocean
2. Get GPS location + heading + Navigate planned route
3. Dive and be able to change course under water
4. While diving sample data from an open CTD modified for use in a glider
5. Dive to a depth of 100m
6. Be able to sense if bottom is hit before 100m

7. Be able to track heading and steer underwater towards planned route
8. Drop weight in case of emergency

Long Term:

1. Be deployed in the open ocean for 6+ Months
2. Get GPS location + heading + Navigate planned route
3. While diving be able to sample a selection of 6 instruments (see Appendix 6)
4. Dive to a depth of 200m
5. Be able to track heading and steer underwater towards planned route
6. Be able to modify route based on sensor readings
7. Solar panels on top of glider to recharge batteries.
8. AIS Radio to detect if ships are close. If so then dive.
9. Audio processing to detect if ships are close. If so then dive.
10. Explore the possibility of having two gliders attached to each other for redundant or additional payload and redundant engines. Steering would be small differences in the pressure engines.

Mechanical Specifications

Depth + Diving

The goal of the first prototype is to be able to dive to 100m[1] in the open ocean. The intention is that the initial depth is something that is accessible and not a barrier for development.
A plan on how to dive deeper depths down to 1000' should be considered.

Buoyancy Engine

The buoyancy engine enclosure should be easily removable from the glider. This modularity will allow for separate refurbishment paths from the payload. The buoyancy engine will have its own batteries, mission computer, GPS, pressure sensors, Real Time Clock, emergency weight release, motion pack and watchdog computer.

The batteries will be rechargeable. In addition to the high cost of alkaline batteries for each mission it is utterly unsustainable to throw away batteries as a functional part of the operation of

[1] If designing a glider for 200m is possible with a bit more effort then 200m would be preferred.

a product we design. By using rechargeable batteries from the beginning it forces the design to be efficient. This will limit the duration of the missions in the beginning but make it easier to do more of them. The batteries are always in place.

The buoyancy engine will be able to operate on its own without a payload section, however when attached the payload section is available to transfer power to the buoyancy engine in an emergency, as well as get sensor readings like pressure. There will be a 16 pin electrical jumper from the buoyancy engine to the payload. This will include RS232, RS485 and wires for power sharing.

The goal is to design an engine that uses as many “off the shelf” parts with the possibility of multi-vendor sourcing for each part. The exact design of how the buoyancy engine will change volume to dive and surface is to be figured out. The idea of using off the shelf hydraulics is an ideal solution over a more mechanical approach of a custom made moving piston.

Payload

The payload section will be separate from the buoyancy engine. The payload will have its own batteries, computer and will connect to the engine. The payload section will be modular and easily modified to add sensors to.

The payload will be able to support 6 sensors with power, serial communications and software interfacing. It will be able to transmit collected data to the outside world.

The sensors the payload should be able to carry are combinations of these sensors:

Communications

Short burst iridium will be used for command and control. LoraWan has a 10k radius and can communicate to surface moorings to telemeter data home. Wifi will be used for local control and testing. If plastic housings are being used the antennas could be contained within.

Electronics

Buoyancy Engine

Engine CPU

The main CPU will be a standalone and will control and monitor the sequences of surface, diving, bottom of dive, surfacing. It will control the motor controllers based on input from an external pressure sensor, store flight logs and receive input from sensors.
There will be two SD Cards for writing the logs to for redundancy. FRAM memory can keep the state machine status so that in the event of a CPU reset it will immediately resume its existing mission.
For the prototype a lot of the electrics will be existing carrier boards tied together.

Watchdog Computer

The watchdog computer will be a standalone CPU that will communicate with the main CPU and if it does not hear a response reset the CPU and then the entire drive circuit if escalation is needed. The watchdog timer will share the responsibility of dropping the dead weight off, both receiving input from their own external pressure sensors, in addition to failure escalations messages from the main CPU that when possible it will verify with its own separate sensor suite. The watchdog computer will be powered from the main batteries but have their own backup watchdog batteries that remain charged and functional the entire time in case the main batteries die, they can still release the drop weight.

Sensors

The buoyancy engine will have a minimal set of sensors. Because of high failure rates and low cost there will be two sensor packs, one talking to the main CPU and one talking to the watchdog CPU. Leak detect sensors will be at both ends of the engine pressure enclosure with 360 degree coverage in case the glider is upside down, giving it a rough approximation of water depth. Internal pressure, temperature, ground fault, humidity will all be duplicated with the second set connected to the watchdog cpu. These sensors will also not be soldered onto the computer boards. They will plug in to be easily replaceable.

Payload

Payload CPU

The payload CPU would handle power and serial communications with the sensors, reading internal sensor data (pressure, temp, humidity, leak detect, ground fault). The buoyancy engine watchdog would also monitor the payload CPU via the 16 pin connection and have the ability to reset the power if communication drops out.

Software

The goals of software are:

1. Robust
2. Testable
3. Low power

There is an opportunity here to design software that is first and foremost robust. It needs to be able to run on embedded processors and contain power saving sleep needed to conserve battery life. The CPU's will be asleep 95% of the time so going into and out of sleep needs to be reliable. Both external and timer interrupts will be able to wake the CPU's.

The state of the glider will be stored in non-volatile memory so that it can continue on without missing anything after a reset or deep sleep. Each dive the payload section will collect data from the sensors, make sure that they reflect the current state, if they do then log data to an SD card, see if anything needs to change, then go back to sleep until the next check (a few seconds).

In an effort to keep power consumption as low as possible the CPU should be a standalone embedded processor. Running linux and ROS (Robot Operating System) would most likely not be a good fit for the glider as the overhead of running an operating system is too power hungry, however it is possible that with a charging source like solar panels turning on a linux SBC (possibly running ROS) would be possible to do occasionally, perhaps to calculate new routes based on sensor feedback. This computer would be in the payload section, separate from the engine, and would make high level decisions.

Using open source software like the Arduino libraries will increase development time and make the glider more accessible - many millions of people know how to develop electronics with the Arduino.
There will be a built-in webserver and the glider can be controlled and programmed through a web interface from any phone or computer over wifi.

Appendix 1: Design Goals

The goals of an open source glider include a holistic approach to the design where sustainability, end of life plans for hardware and community building and outreach are considered in the design process.
The intention is to document and publish the design as well as explain the reasoning behind choices as they reflected on these design tenants:

1. Simplicity
    a. Use existing open source hardware and software projects as building blocks in the design. This helps the project to reach further than its existing resources.
    b. Build the “Model T” first. The goal is not the fastest glider, or most maneuverable. The goal is to build the most reliable and repairable and then iterate.
2. The design begins with robustness and reliability
    a. Design with failure in mind. i.e. The glider design and software will be robust to common failures (leaks, critical component failures). Design simplicity will support this goal.
3. Designed with available off the shelf parts
    a. When an existing part does not exist custom parts will be designed to be easily fabricated by commonly available resources such as local machine shops, 3D printers and PCB fabrication houses.
4. Kindness to humans
    a. Repairable: The entire glider should be able to be completely disassembled, fixed and refurbished in a finite amount of time by a scientist as stated in the Repair Manifesto[2]
    b. Reusable: Included in the design will be an end of life plan for all the parts in the glider. Disposal costs will be included in the upfront cost of the glider and its parts.
    c. Sustainable: Waste will be minimized when possible. i.e. The glider will use rechargeable batteries.
5. Modular
    a. The payload will be seperate from the glider ‘core’ so they can be refurbished separately.
    b. The glider cores will be interchangeable with the same mechanical, electrical and software interfaces. A glider core should be easily swapped out for another one.

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[2] https://www.ifixit.com/Manifesto

6. Openness
    a. We will build a community of users who are enabled to use and improve the design
    b. This community and project documentation will be accessible to high school, college, graduate and professional users.
7. Significantly reduce cost of collecting scientific data from the ocean
    a. The Cost Of Goods (COGS) of the glider without sensors is aimed to be below $5,000.

Appendix 2: Why open source?

I often compare open source to science. To where science took this whole notion of developing ideas in the open and improving on other peoples' ideas and making it into what science is today and the incredible advances that we have had. And I compare that to witchcraft and alchemy, where openness was something you didn't do. - Linus Torvalds

There has been feedback on this project questioning why it needs to be open source. The short answer is to prevent the stagnation of development that is happening now in the underwater glider market and to remove a dependance on a single company for long term support, service and parts. The science market is too small to support the interests of billion dollar companies.

The long answer is this is a chance to create something that will be owned by the public, a chance to design a solution that will benefit humanity. To build something that has a chance of becoming bigger than just those who created it, bigger than a capitalistic company who keeps secrets could develop it. The same way linux helped the internet grow in the late 90's open source robotics can help oceanography now.

Some of the benefits of open source projects[3]:

Transparency. Whether we're developing software or solving a business problem, we all have access to the information and materials necessary for doing our best work. And when these materials are accessible, we can build upon each other's ideas and discoveries. We can make more effective decisions and understand how decisions affect us.

Collaboration. When we're free to participate, we can enhance each other's work in unanticipated ways. When we can modify what others have shared, we unlock new possibilities. By initiating new projects together, we can solve problems that no one can solve alone. And when we implement open standards, we enable others to contribute in the future.

Release early and often. Rapid prototypes can lead to rapid discoveries. An iterative approach leads to better solutions faster. When you're free to experiment, you can look at problems in new ways and seek answers in new places. You can learn by doing.

Meritocracy. Good ideas can come from anywhere, and the best ideas should win. Only by including diverse perspectives in our conversations can we be certain we've identified the best

[3] from The Open Source Way

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ideas, and decision-makers continually seek those perspectives. We may not operate by consensus, but successful work determines which projects gather support and effort from the community.

Community. Communities form when different people unite around a common purpose. Shared values guide decision making, and community goals supersede individual interests and agendas.

Why do people prefer using open source software?[4]

People prefer open source software to proprietary software for a number of reasons, including:

Control. Many people prefer open source software because they have more control over that kind of software. They can examine the code to make sure it's not doing anything they don't want it to do, and they can change parts of it they don't like. Users who aren't programmers also benefit from open source software, because they can use this software for any purpose they wish—not merely the way someone else thinks they should.

Training. Other people like open source software because it helps them become better programmers. Because open source code is publicly accessible, students can easily study it as they learn to make better software. Students can also share their work with others, inviting comment and critique, as they develop their skills. When people discover mistakes in programs' source code, they can share those mistakes with others to help them avoid making those same mistakes themselves.

Security. Some people prefer open source software because they consider it more secure and stable than proprietary software. Because anyone can view and modify open source software, someone might spot and correct errors or omissions that a program's original authors might have missed. And because so many programmers can work on a piece of open source software without asking for permission from original authors, they can fix, update, and upgrade open source software more quickly than they can proprietary software.

Stability. Many users prefer open source software to proprietary software for important, long-term projects. Because programmers publicly distribute the source code for open source software, users relying on that software for critical tasks can be sure their tools won't disappear

[4] From The Open Source Way

or fall into disrepair if their original creators stop working on them. Additionally, open source software tends to both incorporate and operate according to open standards.

Community. Open source software often inspires a community of users and developers to form around it. That's not unique to open source; many popular applications are the subject of meetups and user groups. But with open source, the community isn't just a fanbase that buys in (emotionally or financially) to an elite user group, it's the people who produce, test, use, promote, and ultimately affect the software they love.

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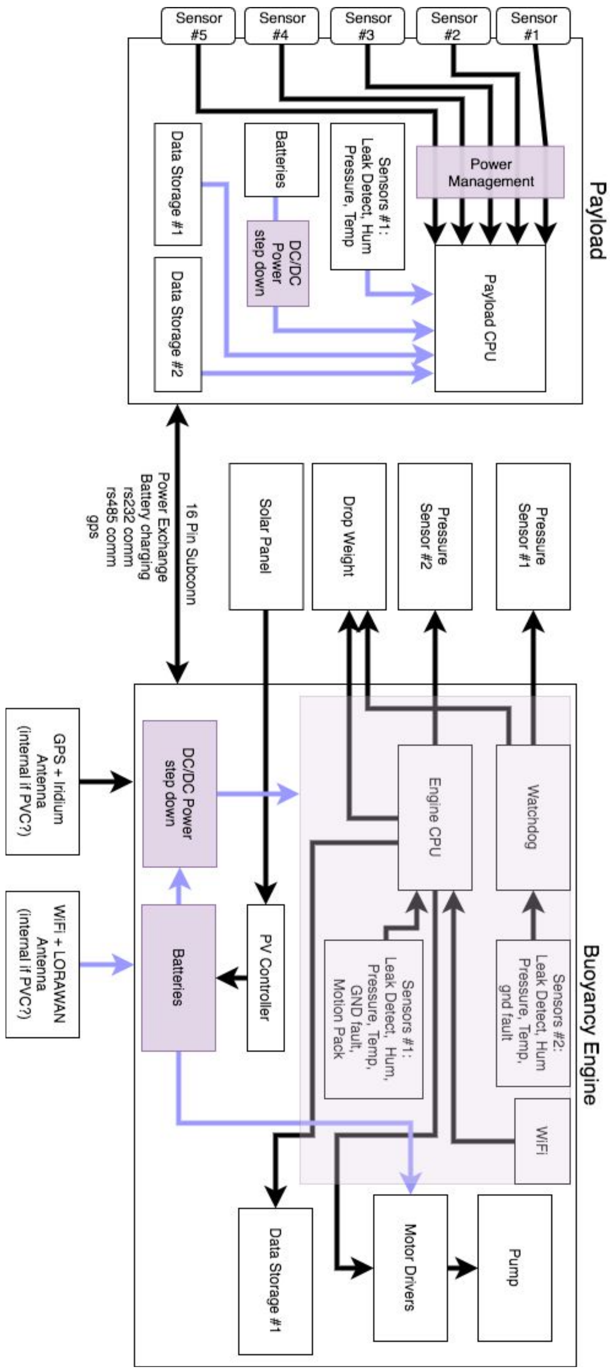
Appendix 3: Hardware Diagram



Appendix 4: Sensor suites on OOI Gliders

Table C-3
Coastal Glider Calibrated Instrument Suite

Instrument (Class-Series)	Make/Model	Vendor
Conductivity, temperature, depth sensor (CTDGV-M) CGSN P/N: 1331-00001-00013	Sea-Bird Slocum Glider Payload CTD TWR P/N:G-1451 (current revision)	Sea-Bird Electronics, Inc. 13431 20th Street Bellevue, WA 98005-2010 USA www.seabird.com
Oxygen sensor (DOSTA-M) CGSN P/N: 1331-00002-00013	Aanderaa Optode 4831 TWR P/N:G-4663 (current revision)	Aanderaa Data Instruments AS AADI. P.O. Box 34 Slåtthaug N-5851 Bergen, Norway www.aadi.no
Photosynthetically available radiation sensor (PARAD-M) CGSN P/N: 1331-00005-00013	Biospherical QSP-2155 TWR P/N:4333 (current revision)	Biospherical Inc 5340 Riley Street San Diego, CA 92110-2621 USA www.biospherical.com

Chlorophyll-a fluorescence, optical backscatter, and CDOM fluorescence sensor (FLORT-M) CGSN P/N: 1331-00003-000 13	WET Labs ECO Puck, FLBBCD-SL C TWR P/N:301771 (current revision)	WET Labs P.O. Box 518 620 Applegate Street Philomath, OR 97370 USA www.seabird.com

Table C-4

Open Ocean Glider Calibrated Instrument Suite

Instrument (Class-Series)	Make/Model	Vendor
Conductivity, temperature, depth sensor (CTDGV-M) CGSN P/N: 1331-00001-00 013	Sea-Bird Slocum Glider Payload CTD TWR P/N:G-1451 (current revision)	Sea-Bird Electronics, Inc. 13431 20th Street Bellevue, WA 98005-2010 USA www.seabird.com
Oxygen sensor (DOSTA-M) CGSN P/N: 1331-00002-00 013	Aanderaa Optode 4831 TWR P/N:4663	Aanderaa Data Instruments AS AADI. P.O. Box 34 Slåtthaug N-5851 Bergen, Norway www.aadi.no

Chlorophyll-a fluorescence and optical backscatter (FLORD-M) CGSN P/N: 1331-00003-00015	WET Labs ECO Puck, FLBB-SLC TWR P/N: 301770	WET Labs P.O. Box 518 620 Applegate Street Philomath, OR 97370 USA www.seabird.com

Table C-5

Profiling Glider Calibrated Instruments (Combined)

Instrument (Class-Series)	Make/Model	Vendor
Conductivity, temperature, depth sensor (CTDGV-M) CGSN P/N: 1331-00001-00013	Sea-Bird Slocum Glider Payload CTD TWR P/N:G-1451 (current revision)	Sea-Bird Electronics, Inc. 13431 20th Street Bellevue, WA 98005-2010 USA www.seabird.com
Oxygen sensor (DOSTA-M) CGSN P/N: 1331-00002-00013	Aanderaa Optode 4831 TWR P/N:4663	Aanderaa Data Instruments AS AADI. P.O. Box 34 Slåtthaug N-5851 Bergen, Norway www.aadi.no

Dissolved nitrate sensor (NUTNR M) CGSN P/N: 1331-00014-00013	Satlantic SUNA 2000M TWR P/N:G-1837	WET Labs P.O. Box 518 620 Applegate Street Philomath, OR 97370 USA www.seabird.com
Photosynthetically available radiation sensor (PARAD-M) CGSN P/N: 1331-00005-00013	Biospherical QSP-2155 TWR P/N:4333 (current revision)	Biospherical Inc 5340 Riley Street San Diego, CA 92110-2621 USA www.biospherical.com
Chlorophyll-a fluorescence, optical backscatter, and CDOM fluorescence sensor (FLORT-M) CGSN P/N: 1331-00003-00013	WET Labs ECO Puck, FLBBCD-SLC TWR P/N:301771 (current revision)	WET Labs P.O. Box 518 620 Applegate Street Philomath, OR 97370 USA www.seabird.com
Fluorometer three wavelength (FLORT M) CGSN P/N: 1331-00003-00013	WET Labs ECO Puck, BB3-SLC TWR P/N: 302378	WET Labs P.O. Box 518 620 Applegate Street Philomath, OR 97370 USA www.wetlabs.com

Appendix 5: Open source sensors

1. Open source CTD
2. Open source Oxygen - paper

Appendix 6: Sensors to Carry

For now we will specify that this glider should be able to carry all the sensors that a Slucom glider can from Appendix 4, Profiling Glider Calibrated Instruments.

The total volume of all of these sensors is _____

Conductivity, Pressure + Temperature sensor
GPCTD Sea-Bird Slocum Glider Payload CTD TWR P/N:G-1451
Housing: Standard: Plastic, 350 meters (1150 feet)
Dimensions: width: 3” height: 4.58” Length: 10.10” Volume: 138.7 cubic inches
Standard Plastic Housing – In air: 1.0 kg (2.2 lbs), In water: 0.2 kg (0.4 lbs)

Oxygen sensor
DOSTA-M Aanderaa Optode 4831 TWR P/N:4663
Housing: Epoxy coated Titanium, PA
Dimensions: width: 1.4” height: (circular) Length: 4.4” Volume: 7.8”
Weight: In air: 217g (7.65oz), In water: ?

Dissolved nitrate sensor
NUTNR M Satlantic SUNA 2000M TWR P/N:G-1837

Photosynthetically available radiation sensor
PARAD-M QSP-2155 TWR P/N:4333

Chlorophyll-a fluorescence, optical backscatter, and CDOM fluorescence sensor
FLORT-M WET Labs ECO Puck, FLBBCD-SLC TWR P/N:301771

Fluorometer three wavelength
FLORT-M WET Labs ECO Puck, BB3-SLC TWR P/N: 302378