WHALEFALL ROV/DPV

FUNG Fellowship x WHALEFALL | 30 April 2024
Spring 2024 Final Presentation

WHALEFALL

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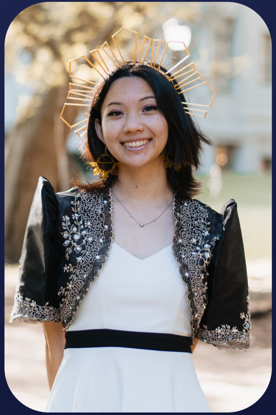
Fung Fellowship Team



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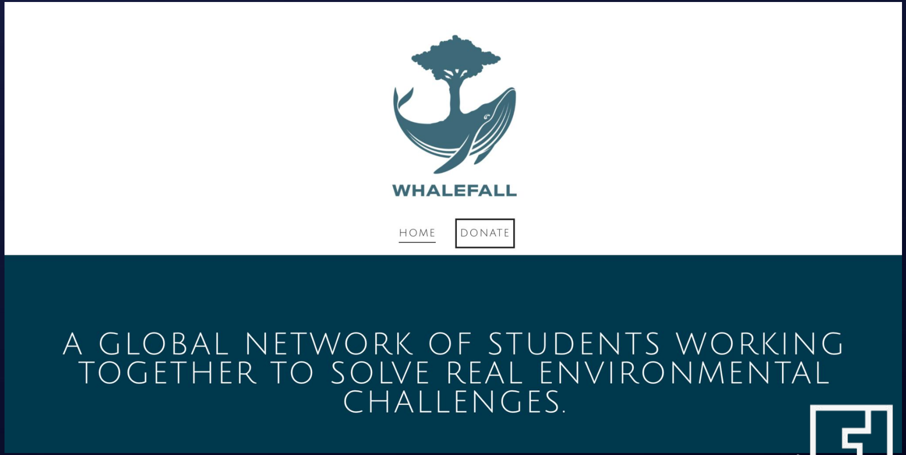
WHALEFALL (Blue Endeavors)

Spring 2024 Partner Organization

Non-profit organization dedicated to researching and developing solutions to ocean problems through:

- scuba diving education
- community outreach
- collaboration with international conservation groups.
- open source and open science data tools

Main Contact | **Vince Smith,** Founder & CEO



01 Problem Statement

The ocean, rich in biodiversity and vital to Earth's natural cycles (carbon/water cycle, etc.), remains one of the least explored frontiers.

Only "**5%** of the ocean is fully explored," (NOAA) and within that 5%, our understanding remains limited.

Why is this the case?

Problem Context

Physical Limitations (Research Diving)

- Excellent diving skills and buoyancy mastery
- Adequate knowledge on species identification
- Time/weather constraints, energetically demanding, and expensive
  - Each survey takes approximately an hour to complete
- Research diving is inaccessible to non-research divers (students, policymakers, general public) interested in participating

Digital Limitations

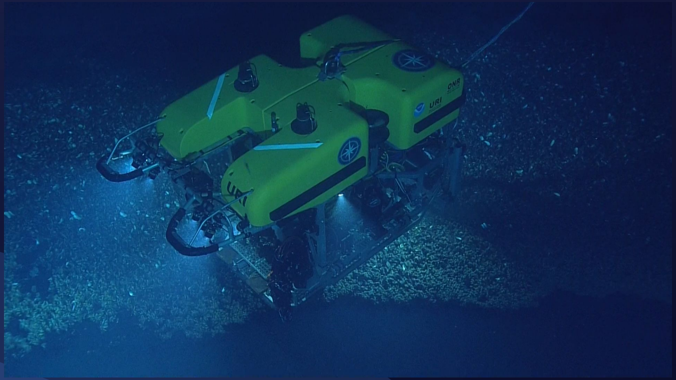
- Due to variations among human operators, achieving consistent and precise data quality becomes difficult
- Data is not always open sourced, leading to increased challenges in accessing data and advancing the field

Current Problem Solutions

Tools applied in the field today: ROVs enable access to areas unreachable to humans, while DPVs allow for more efficient data collection.

- **ROVs**: Remotely Operated Vehicle
  - Unmanned water vehicles with cameras + sensors → collect visual + environmental data

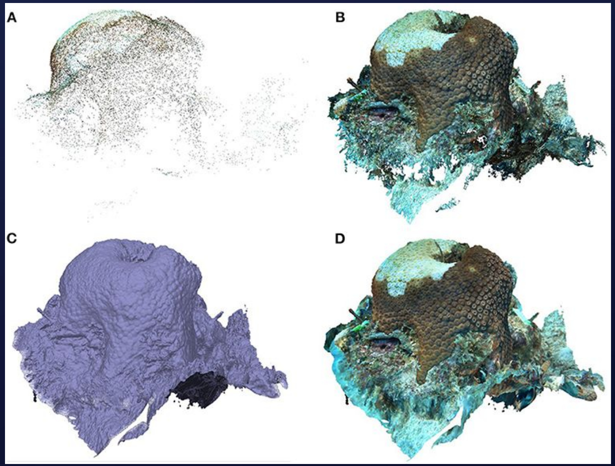
- **DPVs**: Diver Propulsion Vehicle (aka "underwater scooters")
  - Enhance driver mobility → cover larger areas in less time + collect more data



Current Problem Solutions

- **Photogrammetry**: the process of creating dimensional models from photographs
  - Stitching together images captured during underwater surveys → creation of detailed underwater compositions → comprehensive data collection
  - Researchers can gain deeper insights into biodiversity, habitat complexity, ecosystem dynamics, etc.

The lack of a standardized protocol for photogrammetry in oceanic contexts presents a challenge...



Building a 3D model of a coral with Stony Coral Tissue Loss Disease (Meiling S, et. al. 2020)

How might we develop a **streamlined protocol** for **ROV and DPVs** to guide users in capturing optimal photos for photogrammetry during underwater surveys?

How might we ensure **compatibility** of an **ideal 3D photogrammetry software** and **data collection protocol** to create detailed ecosystem representations while maximizing accuracy, usability, affordability?

02 Insights & Development

Research Timeline

January

Partnered with **WHALEFALL**!

February

Initial **user research** and early stage prototypes

March

Midpoint Presentation & **Redirection**

April

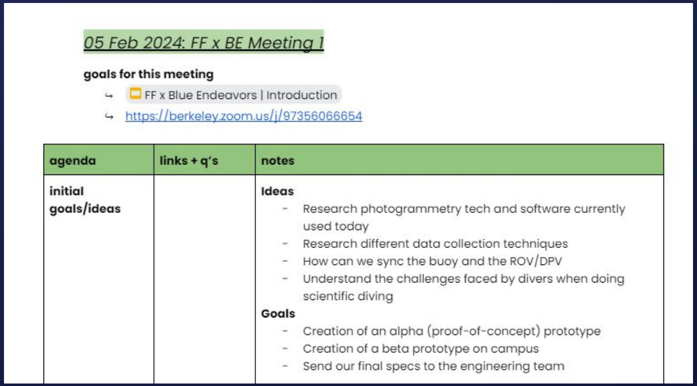
Modified research steps, **finalizing deliverables**, prototype review

May

Final Prototype Demonstration

Team Organization

- Communication with team members & Vince
- Meeting Notes
- Research Organization

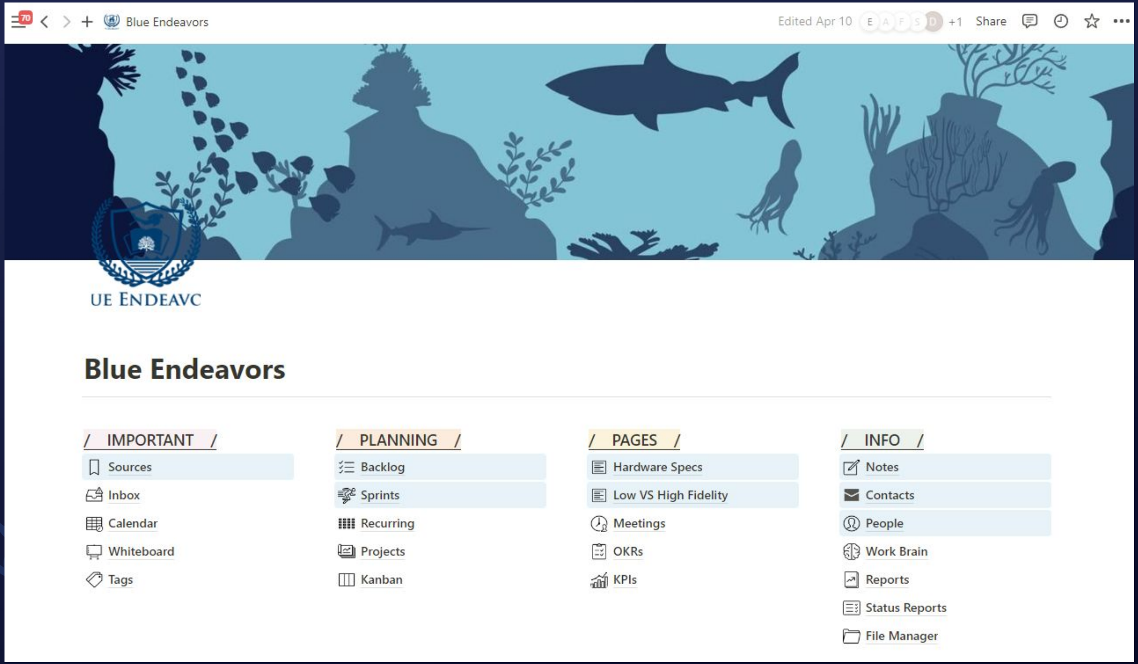


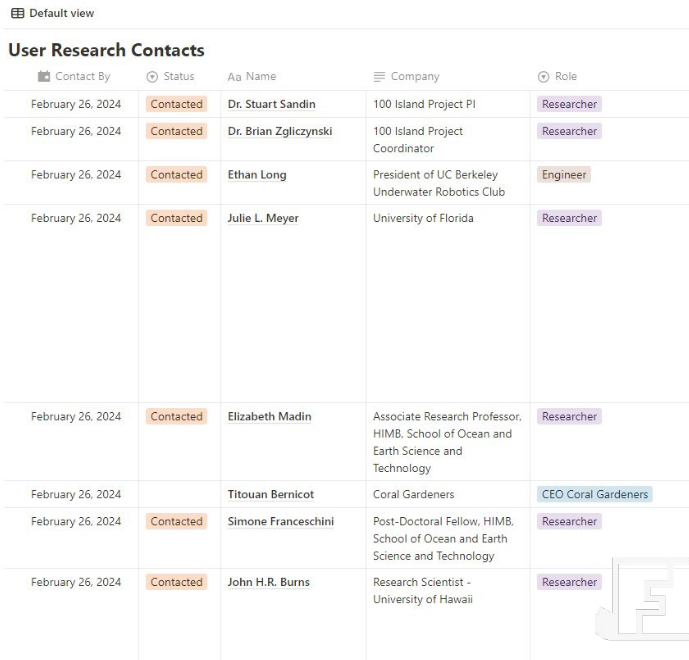
05 Feb 2024: FF x BE Meeting 1

goals for this meeting

↪ FF x Blue Endeavors | Introduction
↪ https://berkeley.zoom.us/j/97356066654

agenda	links + q's	notes
initial goals/ideas		**Ideas** - Research photogrammetry tech and software currently used today - Research different data collection techniques - How can we sync the buoy and the ROV/DPV - Understand the challenges faced by divers when doing scientific diving **Goals** - Creation of an alpha (proof-of-concept) prototype - Creation of a beta prototype on campus - Send our final specs to the engineering team





Default view

User Research Contacts

Contact By	Status	Name	Company	Role
February 26, 2024	Contacted	Dr. Stuart Sandin	100 Island Project PI	Researcher
February 26, 2024	Contacted	Dr. Brian Zgliczynski	100 Island Project Coordinator	Researcher
February 26, 2024	Contacted	Ethan Long	President of UC Berkeley Underwater Robotics Club	Engineer
February 26, 2024	Contacted	Julie L. Meyer	University of Florida	Researcher
February 26, 2024	Contacted	Elizabeth Madin	Associate Research Professor, HIMB, School of Ocean and Earth Science and Technology	Researcher
February 26, 2024		Titouan Bernicot	Coral Gardeners	CEO Coral Gardeners
February 26, 2024	Contacted	Simone Franceschini	Post-Doctoral Fellow, HIMB, School of Ocean and Earth Science and Technology	Researcher
February 26, 2024	Contacted	John H.R. Burns	Research Scientist - University of Hawaii	Researcher

Researchers

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Caren Eckrich
Marine Biologist

Brian Zgliczynski
Scripps 100 Island Project

Pim Bongaerts
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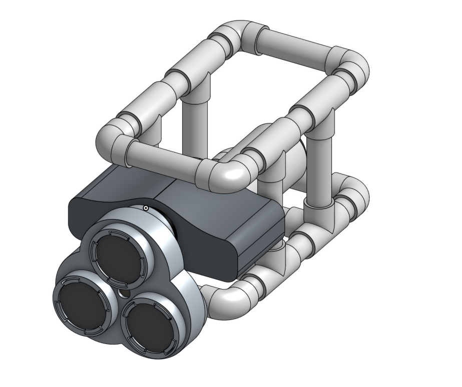
Sciences

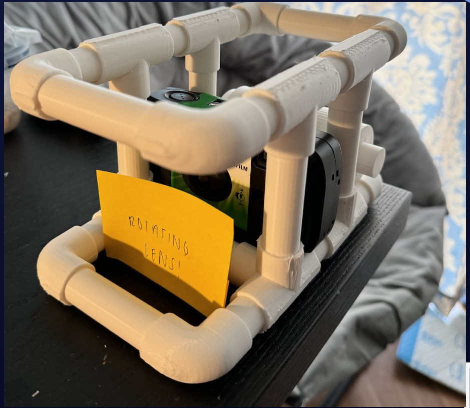
Current Technologies

Wide Angle Lens: allows for high overlap between adjacent images, which results in higher quality photogrammetry models. Source	
Macro Lens: Increased detail in images results in more accurate taxonomic identification. Source	

Core Features for Enhanced Data Collection

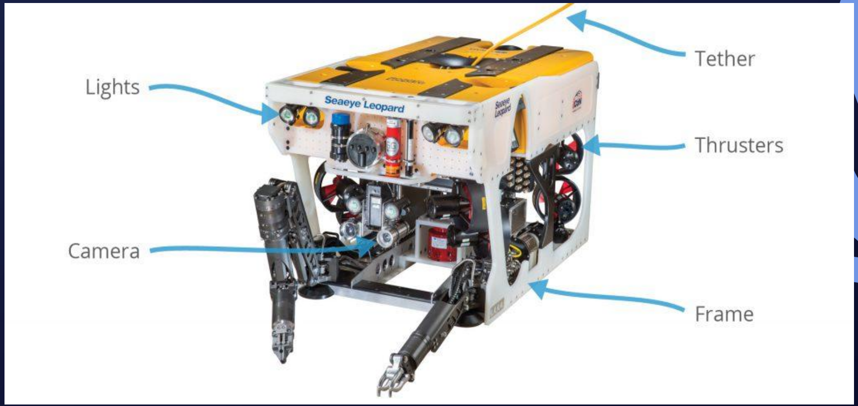
- **Advanced Camera Systems:**
  - High-resolution cameras with adjustable settings for depth and clarity, essential for detailed underwater imaging and photogrammetry.
- **Integrated Sampling Tools:**
  - Capabilities for water sampling and sediment collection, allowing for comprehensive environmental assessment.
- **Extended Battery Life and Range:**
  - Increased operational time and range to cover larger survey areas without frequent recharges or recalls.
- **Robust Data Storage and Transmission:**
  - Efficient onboard data storage with real-time data transmission capabilities for immediate analysis.



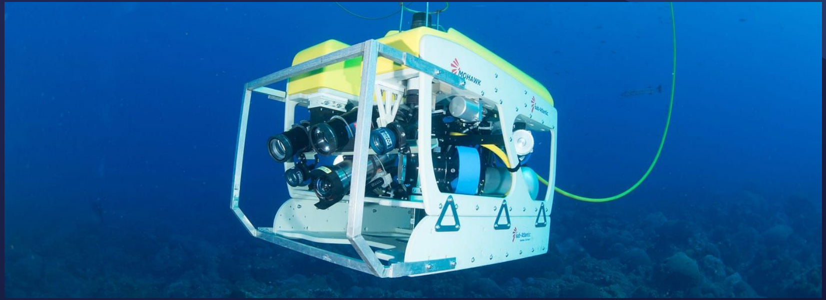


Integrating Cutting-Edge Technologies

- **DNA-Based Detection:**
  - Incorporation of molecular analysis tools for onsite pathogen and biodiversity assessment.
- **AI and Machine Learning:**
  - Utilization of artificial intelligence for real-time data processing, analysis, and decision-making support.
- **Autonomous Navigation:**
  - Advanced navigation systems for precise movement control and obstacle avoidance in complex underwater terrains.



User Journeys



1. ROV Users

Learn & understand equipment → Hands-on training, sampling methodology → Field work (operating ROV) → Process imagery into 3D models → Analyze & Repeat

↕

2. Divers

Learn & understand equipment → Hands-on training, diving methodology → Field work (diving) → Relay imagery to ROV users (e.g. researchers) → Analyze & Repeat

03

Demonstrations & Solutions

Insights from Research to Design

Hardware Insights:
- lenses for photo/video capture
- reduce time for divers doing surveys

Hardware Design:
- Rotating lens attachment, account for many lens at once

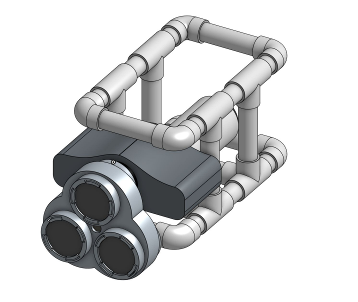
Software
- Photogrammetry requirements and limitations

Software
- Agisoft Metashape or 3Df Zephyr
- Automated interval camera code

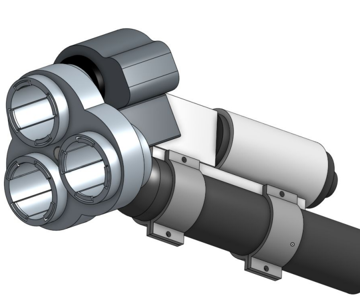
Protocols
- Research Diving protocols
- Photogrammetry protocols

Protocols
- A user manual that details the correct research diving and photogrammetry protocols using ROV/DPV

Redirection Through this Process



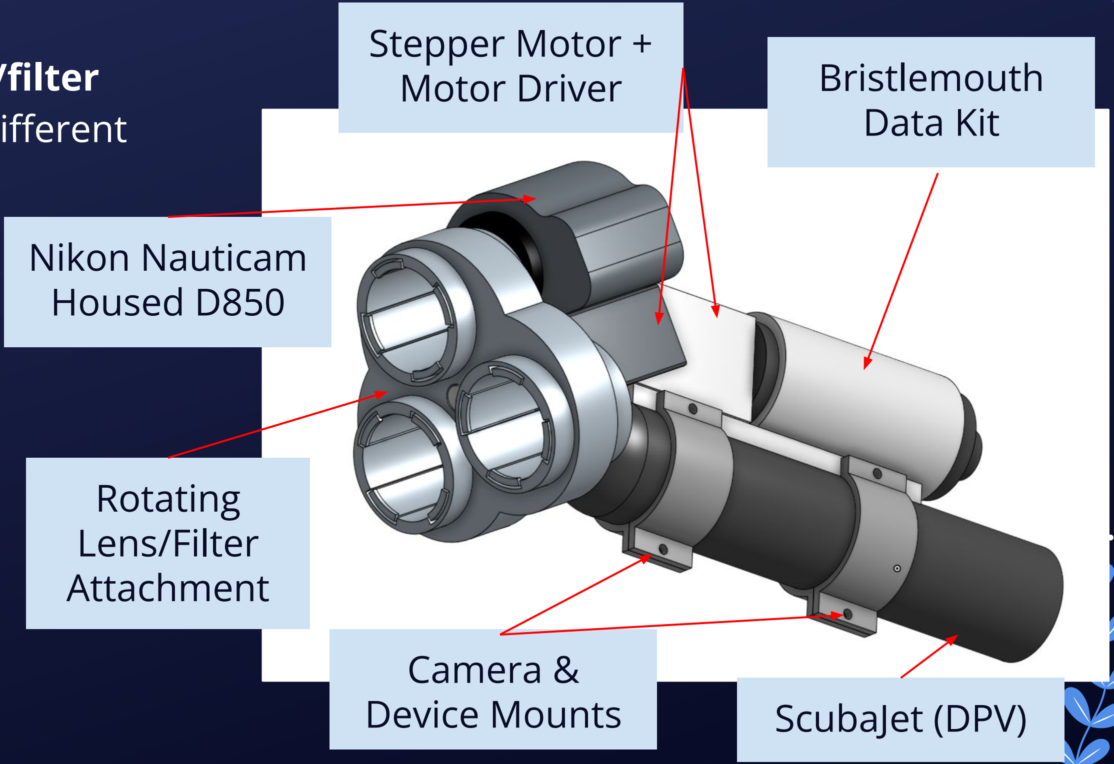
Initial Prototype	Final Deliverable
1. Design and manufacture an ROV & DPV prototype 2. Research ideal hardware (cameras, lenses) and software for photogrammetry 3. Survey protocols for Stony Coral Tissue Loss Disease (SCTLD) 4. Present open-source data to be used by community members	**1. Hardware:** A camera attachment system for multiple lenses and filters **2. Software:** Ideal software for 3D photogrammetry and data analysis steps **3. User manual:** survey protocols for different environmental conditions or survey goals **4. Product Recommendations**



Solutions – Hardware

We propose the idea of a **rotating lens/filter attachment** for users to secure three different lenses onto the ROV/DPV.

1. Eliminates the need to switch lenses/filters above and underwater
    a. **saves time & reduces motion for surveys**
2. Reduces the need for multiple cameras on an ROV/DPV
    a. **conserves weight and bulk**



Demonstration – Hardware

Solutions – Software

Options for video or photo-based photogrammetry for higher versatility → Software for automatic interval-based photo capture, promoting ease of use for divers

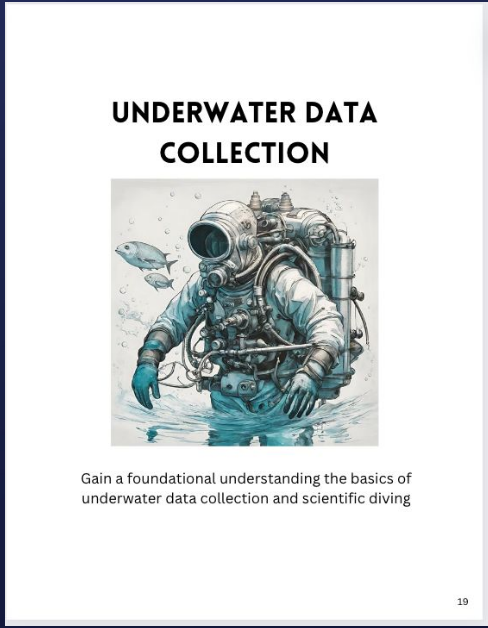
Model Variations to Test:

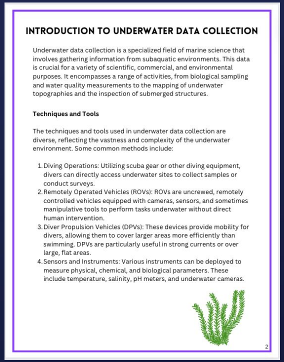
1. Angled vs. Straight-down (helpful in ROV implementation)
2. 20mm lens from height of 1.5m vs. 30mm lens from further up (as comfortable)
3. Macro lens and photogrammetry of specific object or target coral
4. Fewer passes at 1.5m distance
5. Higher vs. lower frames per second extraction

Demonstration – Software

Sample developed using 5-second footage from David:
<u>3D Mesh</u>

Solutions – User Manual





INTRODUCTION TO UNDERWATER DATA COLLECTION

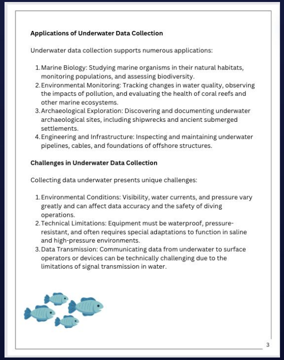
Underwater data collection is a specialized field of marine science that involves gathering information from subaquatic environments. This data is crucial for a variety of scientific, commercial, and environmental purposes. It encompasses a range of activities, from biological sampling and water quality measurements to the mapping of underwater topographies and the inspection of submerged structures.

Techniques and Tools

The techniques and tools used in underwater data collection are diverse, reflecting the vastness and complexity of the underwater environment. Some common methods include:

1. Diving Operations: Utilizing scuba gear or other diving equipment, divers can directly access underwater sites to collect samples or conduct surveys.
2. Remotely Operated Vehicles (ROVs): ROVs are uncrewed, remotely controlled vehicles equipped with cameras, sensors, and sometimes manipulative tools to perform tasks underwater without direct human intervention.
3. Diver Propulsion Vehicles (DPVs): These devices provide mobility for divers, allowing them to cover larger areas more efficiently than swimming. DPVs are particularly useful in strong currents or over large, flat areas.
4. Sensors and Instruments: Various instruments can be deployed to measure physical, chemical, and biological parameters. These include temperature, salinity, pH meters, and underwater cameras.

2



Applications of Underwater Data Collection

Underwater data collection supports numerous applications:

1. Marine Biology: Studying marine organisms in their natural habitats, monitoring populations, and assessing biodiversity.
2. Environmental Monitoring: Tracking changes in water quality, observing the impacts of pollution, and evaluating the health of coral reefs and other marine ecosystems.
3. Archaeological Exploration: Discovering and documenting underwater archaeological sites, including shipwrecks and ancient submerged settlements.
4. Engineering and Infrastructure: Inspecting and maintaining underwater pipelines, cables, and foundations of offshore structures.

Challenges in Underwater Data Collection

Collecting data underwater presents unique challenges:

1. Environmental Conditions: Visibility, water currents, and pressure vary greatly and can affect data accuracy and the safety of diving operations.
2. Technical Limitations: Equipment must be waterproof, pressure-resistant, and often requires special adaptations to function in saline and high-pressure environments.
3. Data Transmission: Communicating data from underwater to surface operators or devices can be technically challenging due to the limitations of signal transmission in water.

3

Key Features

Content

1. What is Underwater Data Collection
   a. How to collect data underwater
   b. How to Analyze Data
   c. Protocols (diving)
2. What is an ROV/DPV
   a. Parts of ROV/DPV
   b. How to use for specific ROV
   c. Protocols for surveying (steps to conducting surveys)
   d. Acoustic gps system
   e. Knowing the altitude above substrate

Product Recommendations

Document Link

1. **Research Summary**
   a. Includes important insights from researchers we interviewed
   b. Specific DPV protocols and preparation for conducting in-depth photogrammetry surveys
      i. Ideal conditions for when surveys should be conducted

2. **Software Specifications**
   a. Photogrammetry – **Agisoft Metashape or 3Df Zephyr** Software

3. **Hardware Specifications**
   a. List of items for ROV/DPVs

4. **Data Analysis & Protocols**
   a. Procedures for analyzing photogrammetry data
      i. How to organize large data sets and clean data directly from data collection

The Fung Fellowship 2023-2024 Team x WhaleFall (prev. Blue Endeavors) has compiled extensive research from scientists, university researchers, and community members dedicated to the future of standardized underwater research and data collection. Through user interviews and research papers, we provide WhaleFall with an extended document of product recommendations to further improve hardware specifications for underwater remotely operated vehicles (ROVs) and diver propulsion vehicles (DPVs).

We thank **Vince Smith** at WhaleFall, **David McGuire** at Shark Stewards, the entire WhaleFall team, and all of the researchers and community members who made this document possible:

Cynthia Becker, University of Florida	**Elliot Hazen**, NOAA/UCSC	**Diana Watters**, NOAA	**Tom Laidig**, NOAA	**Caren Eckrich**, Marine Biologist
Rodrigo Sanchez-Grez, Foundation Capital Azul	**Zach Randell**, Research Scientist at Seattle Aquarium	**Brian Zgliczynski**, Scripps 100 Island Project	**James Conrad**, NOAA/U.S. Geological Survey	

For further questions, please contact the Fung Fellowship 2023-2024 Team!

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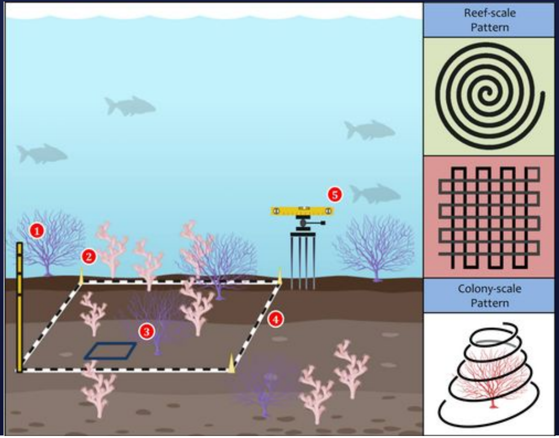
Faith Miller	Research + Software Lead + Research/Specs Team	Molecular Environmental Biology, Data Science	faithmiller@berkeley.edu
Sophie Simon	Team Liaison + Research Team	Conservation & Resource Studies	sophiesimon@berkeley.edu

Product Recommendations

Table of ROV/DPV Components

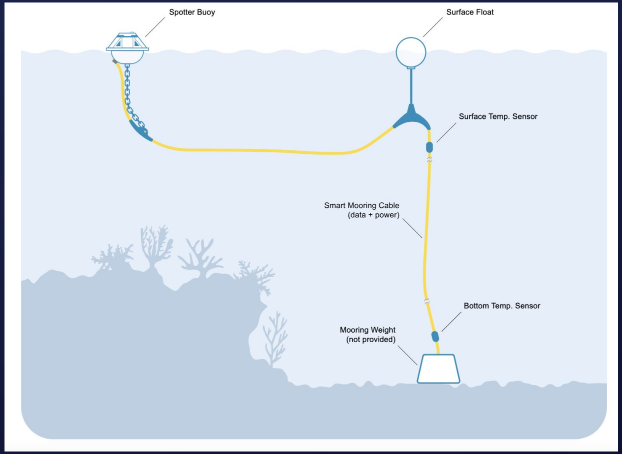
Component	Vendor	Model/Type	Specs
ROV COMPONENTS			
Camera	Nikon, Canon, Sony	*See above*	*See above*
Camera Lens	Nikkor	1. **Fisheye** 16mm 2. **Rectilinear** 18-200 mm 3. **Macro** 105mm	
Rotating Lens/Filter Attachment	*CAD Model, see above*		
High-Torque Stepper Motor & Driver	OrientalMotors	Various Stepper Motors & Drivers	
ROV Frame	Blue Robotics	BlueROV2	Thrusters (T200) (6) Acrylic Tube Configuration, 100m Fathom ROV Tether, 100m Lumen Subsea Light Ping360 Scanning Imaging Sonar Fathom Spool, Standard 150m Xbox Wireless Controller
Strobe Light	Ikelite	DS160 II 160Ws TTL Underwater Strobe	

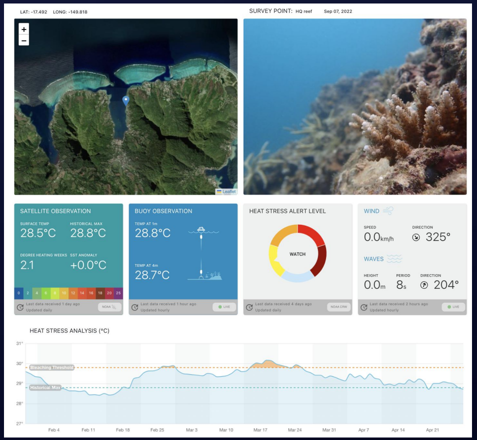


1. Place the camera in 1-second interval mode while swimming 1.5 meters above the substrate
2. Hold the camera frame level to face directly underneath towards the ground.
3. Swim in the gridded, “lawn mower” and zigzag pattern, while taking consecutive images throughout. For a 10 x 10 plot, make at least 10 passes in each direction.
4. Swim at a slow pace, ensuring that there is at least a 90% overlap with each consecutive image

Aqualink and Open Source Use

- **Aqualink:** An engineering organization dedicated to building and improving ocean conservation technology, while developing an open source network for data monitoring.
- **Solar powered buoy**: Measure temperatures in real-time at various depths.
  - These measurements transmitted via satellite connection to online servers and displayed on a user-friendly web interface,
- Open Source and Accessible:
  - User accessible web page: anyone can add/extract ocean data as a csv file. All monitored sites contain important information regarding real-time ocean temperature, wave and wind data
- Further Recommendations After completing data processing from prototype surveys:
  - Download all surveyed data and upload it to Aqualink as csv files. Continue to survey benthic ocean substrate near the buoys.





Success Metrics

Efficacy

- Does our design make photogrammetry more efficient?
  - It is intended to make the process of changing lenses and streamlining photogrammetry easier.
- Does the user manual help those with no experience understand more?
  - The user manual is a introduction to research diving, photogrammetry and the usage of ROV/DPV intended for those new to the subject.

Effectiveness

- Is our design compatible with the ROV/DPV?
  - Does the hardware mount to the scuba jet DPV?
- Does our design deliver desirable photographic data in the field?
  - Testing in Monterey Bay soon and comparing the model to what is seen in real time

User Accessibility

- Does the intended user find the user manual complete?
  - Pim said that the user manual would be great for everyone, but especially for those that don't know much about ROV/DPV or research diving
- Is our design useful for people doing photogrammetry surveys?
  - Pim said that having multiple lenses will help with the resolution if you want to get closer to the subject.

04 Future Goals

Next Steps & Future Goals

Planned Prototype Testing: Monterey Bay Underwater Test

- Test prototype with ScubaJet and underwater photogrammetry protocols

Future Research and Next Steps:

1.) **Bristlemouth-enabled survey time sensor:** Stage an acoustic transmitter on ROV/DPV and a receiver on the buoy mooring line

   a.) Use Bristlemouth Technology to connect both Ocean Data and Photogrammetry surveys

   b.) Develop prototype that could connect Buoy with ROV

2.) Incorporation of AI and Acoustic GPS systems

3.) **Finalized Product** that incorporates necessary requirements to survey ocean floor and build photogrammetry models all across the world

Next Steps & Future Goals

Further Automation:

1. Photogrammetry struggles with moving objects, so how do we capture wildlife data?
   a. For photos, either extracted from video automatically by the program or taken on site, AI software can be used to flag images where a fish is detected. These photos can then be analyzed by those experienced in species identification and recorded.
   b. For video, you can purchase or pay to develop an AI model that will extract every frame in which a fish is detected, which again can be analyzed later for species identification.
2. AI Coral species identification softwares can be implemented, such as those in use by the 100 Islands Challenge.

Thank You!

Questions? Comments?

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