# Advancing Remote Marine Mammal Stock Assessment with Passive Acoustic Gliders

**Research to Operation Transition Plan**

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**April 6, 2022**

**Review/Approval Page**

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**Research to Operation Transition Plan**

*The below parties, by providing signatures, approve of the transition plan outlined in this document, which may be periodically reviewed and updated as needed.*

*It is acknowledged herein that transition projects have a specific set of performance metrics, milestones, and other gate conditions that must be achieved to advance the proposed capabilities into operations. Operational implementation of these new capabilities are subject to successful completion of the described research, development, and/or demonstration, review and approval through appropriate end user NOAA Line Office governance procedures, and availability of funding. Short of meeting these conditions, the transition project could be considered for divestment. Divestment from a transition project can occur in several ways, including termination of the project or transfer of the project to an extramural partner.*

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*Consult NAO 216-105B and check with the relevant Line Office (LO) for appropriate transition stage signatures. Until a project matures, new R&D efforts may only require approval from a division chief or other resource manager, who may serve as both the R&D and receiving LO transition manager. R&D LO signature lines and columns (above) may be omitted, as necessary, if the transition activity occurs internally within a single LO.

*This Plan is a dynamic document that will be revised as necessary to reflect changes. Modifications made to this Transition Plan are to be recorded in the Changes/Revisions record below. This record is to be maintained throughout the life of the Transition Plan.*

### *Document Version Table*

| Version Number | Date | Description of Change/Revision | Section/Pages Affected | Changes Made by Name/Title/Organization |
|---|---|---|---|---|
| | | | | |
| 1.0 | 12/31/21 | Rough Draft | | Erin M. Oleson, NMFS/PIFSC |
| 1.1 | 01/12/22 | Edits/Revised Approval Page | All Sections | Kenneth Vierra, UxSRTO |
| 1.2 | 04/05/22 | Final Draft | All Sections | Erin Oleson, NMFS/PIFSC |
| 1.3 | 04/06/22 | Edits | All Sections | Kenneth Vierra, UxSRTO |
| 1.4 | 7/1/22 | Signature Process Started | | Kenneth Vierra, UxSRTO |
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## 1. Purpose for Transition Effort

The intention of this document is to guide transition efforts for the proposed capability toward operations. It is a living document and will remain valid as long as the corresponding development project is completed successfully, satisfies end user-defined Line Office metrics for success and operational constraints, and clearly surpasses each of the associated gates for transition. The ultimate decision to transition this project to operations resides with the appropriate decision maker of the receiving Line Office.

### 1.1 Transition Product

Name of Proposed Product

Advancing Remote Marine Mammal Stock Assessment with Passive Acoustic Gliders

This project is intended to test the feasibility of routine operation of autonomous underwater gliders equipped with passive acoustic monitoring systems for monitoring occurrence and providing data for assessment of cetaceans in the Pacific Islands Region. This includes development and testing of a near-real-time system for reporting occurrences of specific species based on detection of their sounds by the glider, and for development of a MATLAB-based toolbox intended to assist with survey design, mission execution, and passive acoustic and glider data analysis.

End User

This project is intended to assess the feasibility of acoustic glider surveys as a tool for augmenting vessel-based surveys of cetaceans in the Pacific Islands Region. As such, the target office is the Pacific Islands Fisheries Science Center, though developments achieved during this project will likely have relevance to other Science Centers that undertake cetacean surveys, as well as other non-NOAA users of acoustically-equipped gliders.

Addressed Requirements

Marine mammal assessments are required under the Marine Mammal Protection Act (MMPA). Execution of assessment surveys is limited by available ship time and other vessel resources. Passive acoustic sensing has played an increasing role in marine mammal assessments, providing data where visual surveys are rare or impossible and also by providing key parameter inputs for rare species in traditional assessment frameworks. Autonomous Seagliders equipped with passive acoustic sensing, and especially with near real-time monitoring capability, are envisioned to significantly increase NMFS ability to fill survey gaps for unassessed or high priority species.

### 1.2 Anticipated Results

There are three objectives, and thus three anticipated results, for this project:

1) Assess the feasibility of acoustically monitoring cetacean species around the main Hawaiian Islands (MHI) using acoustically-equipped gliders. With inadequate shiptime to sufficiently survey all Pacific Islands Region waters to support cetacean stock assessments, acoustically-equipped gliders can provide valuable input to the stock assessment process, including at minimum, **information about cetacean distribution and occurrence**, if not appropriate encounter and survey information, to inform quantitative assessments. We begin in the MHI where we can draw upon the results of many prior visual survey efforts to ground our detection system and encounter rates for key species.

2) Develop **a real-time acoustic detection system**, and test with the detection and classification of false killer whales in Hawaiian waters. Integration of the WISPR-2 acoustic package into the Seaglider enables the use of onboard acoustic detectors and classifiers that can be tuned to report the occurrence of species of particular interest. Such near real-time reporting may have particular utility when glider surveys are paired with other survey modalities, enabling high encounter rates and additional data collection opportunities.

3) Build **an open-source toolbox for passive acoustics monitoring by uncrewed ocean gliders**.The toolbox will include four primary tool sets: glider piloting, post-flight glider flight processing, acoustic processing, and cetacean encounter processing, and will be made available to all acoustic Seaglider users through the U2G user group.

## 2. Research Background

Under the Marine Mammal Protection Act, NMFS is required to assess the status of cetacean stocks occurring within US waters every three years. While visual surveys are generally considered the ‘gold standard’ for collecting the data needed to assess cetacean stocks in many regions, these surveys are limited to daylight hours and good weather conditions when visual observers can see cetacean groups. Regions with significant annual allocations of ship time and ample personnel often struggle to maintain up-to-date assessments for all species, with many of those assessments including only the most basic biological and distributional information (Merrick et al. 2004).

The NMFS Pacific Islands Region (PIR) encompasses the U.S. Exclusive Economic Zones (EEZs) around each of the U.S. states, territories, and holdings in the central and western Pacific, from Hawaii to Guam and south to American Samoa, collectively the largest region under NMFS management and representing approximately 1.8 million nmi$^2$ of ocean. Like all NMFS Science Centers, the Pacific Islands Fisheries Science Center (PIFSC) invests considerably in fielding visual and passive acoustic (via towed hydrophone arrays) surveys for cetaceans in the region. PIFSC is presently responsible for assessment of over 120 cetaceans stocks in the region, with separate stocks of the same species variably using restricted island-associated spaces and broad pelagic ranges, complicating design of comprehensive ship-based survey efforts. At present only stocks in Hawaii have quantitative assessments of abundance, and many dozen stocks in other PIR areas are known only based on sporadic or opportunistic sightings during other research operations. In Hawaii, comprehensive survey efforts are carried out every 7-8 years. In other portions of the PIR, the area has never been surveyed or surveyed only partially. Over 500 days of ship time are required to conduct line-transect surveys of each PIR EEZ once. With limited ship time and resources this represents a significant challenge to meeting our assessment mandate using traditional ship-based methods, thus requiring new approaches and new technology to develop new assessment modalities.

The PIR is in a unique position to design and implement a more advanced, mobile, and flexible system for cetacean assessment, even during the first surveys of many of the region's EEZs. In addition to broad-scale cetacean survey efforts, regional management needs may require alternative types of data collection or monitoring to collect the data required to meet the management need. For example, in Hawaii, an Endangered Species Act (ESA)-listed population of false killer whales occurs in nearshore waters around the main Hawaiian Islands (MHI) and a pelagically-distributed population has a range extending from the islands to well beyond the EEZ boundary into the broad central Pacific. Both of these populations are thought to take bait and catch from commercial fisheries, with such interactions resulting in both hooking and entanglement of the whales and financial losses to fishermen. More flexible survey modalities are needed to provide detailed distribution and density data required to adequately assess these separate populations.

Passive acoustic monitoring (PAM) provides an alternative survey method that can be as or more effective than traditional visual surveys (Barlow and Taylor 2005, Mellinger et al. 2007). The Cetacean Research Program (CRP) has substantial experience using a variety of PAM modalities to contribute data toward cetacean assessments, from towed hydrophone arrays during ship-based surveys to autonomous drifting instruments and stationary long-term acoustic monitoring stations around the Pacific Islands. While our passive acoustic datasets have provided important insights into cetacean occurrence, distribution, seasonality, and habitat throughout the region, a more agile, mobile, and remotely operated survey option will be required to meet our assessment mandate.

Ocean gliders equipped with passive acoustic recorders can now be used for PAM of a variety of cetacean species (Verfuss et al. 2019) and provide distinct advantages over ship-based acoustic surveys. Underwater gliders are low-power, buoyancy-driven systems that can be deployed for weeks to months and follow a specified survey path that allows them to traverse bathymetric and oceanographic features and management boundaries (e.g., Burnham et al., 2019; Silva et al., 2019). They are controlled remotely via satellite by a pilot on shore and collect temperature, salinity, and sound speed data. This type of spatial coverage is traditionally only available through costly vessel surveys or extensive stationary arrays. Further, gliders can survey in remote, otherwise inaccessible areas in all seasons (Baumgartner et al., 2014; Burnham et al., 2019; Nieukirk et al., 2016). Efforts are ongoing to enable estimating population density from gliders (Fregosi 2020, Gkikopoulou 2018, Harris et al. 2017) and to utilize gliders in near real-time monitoring studies (Baumgartner et al. 2020, Klinck et al. 2012).

## 3. Capabilities and Functions

### 3.1 Assessment of Current Capability

*Seaglider platform:* The overall Readiness Level of acoustic gliders for cetacean monitoring depends on the exact glider type and acoustic system. Acoustically-equipped Seagliders (RL 6) have been flown in the Pacific Islands region and elsewhere along the US east and west coast several times, providing demonstration that the platform can accomplish 4-6 week-long missions with archival passive acoustic recording of cetacean sounds over the duration. For this project we are partnering with the Cooperative Institute for Marine Ecosystem and Resources Studies (CIMERS) at NOAA PMEL and Oregon State University (OSU). This team has extensive experience at conducting glider surveys and analyzing collected recordings for marine mammals, having conducted over 30 acoustic Seaglider flights, including several 4-to-6-week-long surveys for cetaceans funded by the U.S. Navy and the Bureau of Ocean Energy Management.

The partnership with CIMERS is critical to the current phase of this work, as neither PIFSC nor other Centers within NMFS own or have long-term access to Seagliders. The NEFSC and SEFSC and other NOAA Offices have used similar glider platforms (e.g., Slocum, WaveGlider) for survey work in their regions, though this has also been undertaken with a university or industry partner providing the gliders and critical piloting and technical support. We anticipate that partnerships like this will be required to continue development and use of acoustically-equipped gliders for cetacean survey work within NMFS for the foreseeable future, and at least until there is sufficient usage of Seaglider or a similar vehicle for ecosystem and cetacean survey work across NMFS. The University of Hawaii at Manoa (UHM) also maintains a fleet of Seagliders, though at present they are not equipped for passive acoustic monitoring. Such advancement may be possible with dedicated partnership in the future.

A few different passive acoustic recording systems have been used with the Seaglider during prior studies including the DMON, PMAR-XL, and WISPR. The PMAR-XL can be purchased from and installed by the Seaglider manufacturer and is fully integrated within the Seaglider controls so acoustic monitoring parameters can be modified during a glider mission. The DMON system was integrated into a Seaglider by UHM (Van Uffelen et al. 2018), though at present it is not possible to control the DMON platform through the standard Seaglider glider controls. The CIMERS Seagliders have used both PMARXL and the WISPR 1.0 system during many previous missions in the PIR and elsewhere. Although WISPR-2 is a new system, the primary technical advantages over existing systems are related to inclusion of onboard detection and classification systems that enable near-real-time reporting for signals of interest, as well as lower power and more data storage. The WISPR itself is presently at RL 5, while the real-time aspects have not yet been validated onboard a Seaglider and as such would be considered RL 4.

### 3.2 Assessment of Anticipated Operational Capability

In the near- to medium-term, we feel it is most realistic to continue partnering with academic and industry partners to accomplish marine mammal monitoring with autonomous glider surveys. This will be most effective if appropriate funding can be provided to maintain the partnerships in a stable way. However, the ideal end-state would be ownership and operation of autonomous gliders by a NOAA entity, either within a Science Center or as part of the operations at NOAA's uncrewed maritime systems center, currently under construction in Gulfport, MS.

Within this effort we include training for PIFSC personnel in the use of gliders for marine mammal passive acoustic monitoring. Technicians within the CRP and Science Operations Division at PIFSC will be trained by the Seaglider manufacturer on glider refurbishment and piloting, and those technicians will also support this project through joint piloting with our expert Seaglider pilot, Selene Fregosi. Such training will ensure that Seaglider operations can continue beyond the scope of the proposed effort, both in support of cetacean assessment needs as well as other ecosystem and fisheries surveys using Seagliders at PIFSC. This proposal does not include PIFSC purchase of Seagliders, which cost approximately $152,000, as the hope is that such resources will become available at the maritime systems center. In the future, funding may be sought through other initiatives if Seaglider purchases at PIFSC are required to maintain future operations.

Data management and archiving for this project will be conducted in collaboration with the National Centers for Environmental Information (NCEI) Passive Acoustic Data Archive. This group already manages and archives passive acoustic data recorded by several NOAA line offices, including data from CRP, and for organizations outside of NOAA conducting research relevant to NOAA goals. Work is in progress by NCEI to expand archiving capabilities for mobile recorders so we anticipate that archiving of data following a transition to operations would continue in collaboration with NCEI.

### 3.3 Acceptance Criteria for Transition

The survey activities outlined in this project will be considered successful if

1) The Seaglider is able to maintain a survey track, allowing completion of a mission within the time allotted,
2) The passive acoustic system integrated into the Seaglider successfully records cetacean sounds, and
3) The real-time acoustic system is capable of detecting marine mammal sounds and sending notification of those detections.

# 4. Transition Gates and Activities

## 4.1 Gates toward Transition

### *4.1.1 Gate 1: Analysis of Alternatives*

Current survey methods: Most cetacean stock assessments are conducted using line-transect ship-based visual and passive acoustic surveys. NOAA Research vessels survey along predetermined tracklines with a team of visual observers maintaining a watch for cetaceans ahead of the ship. Concurrently, most surveys also include a towed hydrophone array that can collect cetacean encounter data through detection of sounds produced by the animals. This approach has been used by NOAA since the 1980s and the statistical approach to analyzing the encounter data for cetacean abundance is well-understood and quite advanced. Although most assessments use only the visual survey data, assessments in some regions and for some species are increasingly leveraging the typically much higher passive acoustic detection rates during the survey to increase assessment precision. An autonomous glider survey likely cannot fully replicate the data that are collected during these ship-based survey efforts; however, for those species that are reliably detected and classified to species, glider surveys offer increased flexibility and reduced cost for surveying remote regions where ship time is inadequate.

Other autonomous acoustic platforms: Several autonomous acoustic monitoring platforms exist and are in use throughout NOAA offices, including fixed-site long-term recorders and drifting acoustic recorders. Fixed-site monitoring provides long-term records of cetacean occurrence in a region, a valuable dataset for examining long-term trends in distribution or for surveilling a region for the occurrence of specific species over a long period. Because they are fixed in space, inferences may be biased by site-specific variables, such as deployment depth or location near an island. Similarly, most fixed-site acoustic recorders have only a single sensor such that it is not possible to locate the detected group, limiting their use for quantitative assessments.

Drifting acoustic recorders are not limited by their deployment location, as they move freely on ocean currents after deployment. In this way, a network of drifting recorders can provide information about cetacean occurrence without deployment site bias, providing a survey of a broader area, similar to ship-based surveys. The freely drifting nature of these instruments does require a capable vessel to chase down the recorder before its Iridium transmitter battery expires, potentially meaning a large investment in ship time to recover the network of drifting recorders. Such recorders have become a standard part of cetacean survey operations in the Pacific Islands and off the US west coast, often in association with ship-based line-transect surveys. These datasets complement each other nicely, with much higher detection rates of cryptic marine mammal species commonly missed by visual observers, and adequate opportunity to deploy and recover a large network of drifting recorders to survey a large area.

Acoustically-equipped autonomous underwater gliders complement the use of other autonomous acoustic systems. The ability to survey along a trackline provides a similar study design to ship-based surveys, and the ability to pilot the glider to a specific end-point reduces the need to chase down recorders, such that fewer vessel resources, and often small vessels form nearby ports can be used to deploy and recover the gliders at much lower cost than use of NOAA platforms.

#### *4.1.2 Gate 2: Data Impact Assessment*

Acoustically-equipped underwater gliders are a complementary approach to a variety of other cetacean assessment survey modalities. Cetacean assessments require information on population range and seasonality, abundance, population trend, and human-cause impacts, such as by catch from fisheries, ship strikes, or more diffuse impacts such as exposure to anthropogenic noise. While standard ship-based surveys are well-designed to provide the data required to develop abundance estimates, they are infrequent and often limited in their geographic scope, particularly in the Pacific Islands Region. Further, most cetacean species in the PIR occur at relatively low density, such that encounter rates of any individual species during most multi-species ship surveys are low, resulting in abundance estimates with low precision. For example, it takes ~180 days of ship time to carry out a cetacean survey of the entire Hawaiian Archipelago with adequate transects to enable abundance estimates for most species. Within a given survey 15-20 species will be encountered, with 1-20 sightings of each of those species. While abundance estimates are generally unbiased, the coefficient of variation (CV) around the abundance estimates for each species often ranges between 0.4 and >1.0.

Various acoustic approaches can increase the sampling frequency. The PIFSC uses fixed-site acoustic monitoring to examine seasonality across the monitored region, and with sufficiently long time series could use these data sets to examine population trends. However, fixed site monitoring is just that, limited to the region around the recorder. Many fixed site systems are constrained in depth, such that they are commonly monitoring locations relatively closer to shore or on seamounts, regions that may not be representative habitat for many cetacean species. Drifting acoustic recorders are not constrained in their location, providing more representative sampling across an area; however, their passive drifting reduces the ability to plan for a specific monitoring area, limiting their usefulness in some cases, and their recovery locations can be wide-ranging, potentially requiring significant vessel time to retrieve them if they have been deployed for more than several days. In this way, drifting recorders are an excellent complement to ship-based surveys, where a network of recorders can be deployed and recovered during the survey to provide more intensive sampling of the overall study area. Recent statistical advancements have provided an approach for estimating abundance of deep-diving beaked whales from drifting recorders. When the study area is well-sampled, the resulting estimates are thought to be unbiased, and the relatively high encounter rates provide abundance estimates with much greater precision. Barlow et al. (2021) estimated abundance for Cuvier's beaked whales off the U.S. west coast with CV of 0.27.

In contrast to visual and other autonomous acoustic sampling approaches, acoustically-equipped underwater gliders afford the advantage of directed movement throughout a study region. In this way they may fill several important sampling gaps common to cetacean surveys. First, the autonomous nature means surveys can be repeated more frequently, resulting in higher encounter rates and more precision around abundance estimates, but also a greater understanding of how distribution and abundance may change seasonally or under various oceanographic conditions, some of which can also be measured *in situ* by the glider. Second, the ability to direct the glider allows for sampling more remote regions, including regions that may never be sampled by ship due to lack of ship-time resources. And third, if glider can report detections in real-time, as is presently possible for baleen whales using the Slocum glider, and will be tested during this project for false killer and sperm whales with Seaglider, a variety of monitoring and mitigation options become available to better sample, possibly respond to, and potentially mitigate human-caused impacts on cetaceans.

#### *4.1.3 Gate 3: Cost-benefit Analysis*

The success of a survey, whether ship- or glider-based, is dependent on the survey area and the number of encounters. There have been no comparable surveys by ship and acoustic gliders. To facilitate a reasonable comparison, we compare recent ship-based and drifting recorder surveys within the Hawaiian Islands and Mariana Archipelago to previous glider missions in those same regions. Mission endurance is measured as the amount of time the platform can provide survey coverage without returning to port or retrieved for maintenance. The average number of encounters per day is a proxy for assessment precision, and a guide for examining the number of missions (e.g., successive ship-based survey legs or glider redeployments) would be required to acquire an adequate sample for quantitative assessments. Per-mission costs for all modalities exclude vessel and travel costs, as well as costs of durable equipment, assumed to be available for multiple missions. The separate per-mission costs for Seaglider represent the cost of a skilled in-house technician maintaining and preparing the glider (~$6,000) versus manufacturer maintenance costs (>$14,000).

| *Survey modality* | *Single mission endurance (DAS)* | *Average track length / day* | *Average encounters / day* | *Survey staff required* | *Per mission cost* |
|---|---|---|---|---|---|
| Ship-based line-transect | 30 | 90 nmi | 2.1 | 10-12 | ~$200,000 |
| Drifting acoustic recorder | <25 | 10 nmi | 4.6 | 2 | ~$1,200 |
| Acoustically - equipped Seaglider | ~60 | 12 nmi | 6.1 | 2 | ~$6,000* ~$14,000+ |

Seagliders are capable of longer missions with much higher per-day cetacean encounter rates. Although per mission the cost is higher than the use of drifting recorders, the glider has the advantage of being piloted to specific monitoring and retrieval locations, reducing staff and vessel costs when conducted independent of ship-based survey efforts.

### *4.1.4 Gate 4: Regulations, Access, and Approvals*

Basestation for glider control: An internet-connected "basestation" computer is required in order to test and pilot the glider in real-time. At present this capability is being provided by partners at OSU that already have a basestation set up for controlling their gliders. Replicating similar capability within a NOAA office may be particularly challenging, as it requires real-time access via unencrypted channels from a NOAA computer to an autonomous platform at sea. We have mitigated this risk through partnership with OSU at present, but any long-term transition of autonomous glider operations to NOAA will require resolution of this relatively new IT concern. This a significant barrier to NMFS operation of Seagliders given current cyber-security policies.

Navy coordination: Some regions within our overall survey areas fall within Naval operations or training areas. Although NOAA has an MOU with Navy on data sharing and shares information on mission planning to avoid sensitive areas, continued coordination will be required for autonomous glider surveys to ensure both the safety of the glider (not flying through a region with explosives training) as well as to avoid excessive redaction of NOAA datasets due to colocation with sensitive signals. We will need to establish communication with/identify a contact at the Navy to share deployment plans as a safety precaution.

As part of the MOU between NOAA and the Navy, any data that NOAA wants to provide publicly (e.g., through NCEI) must be screened and sensitive signals redacted. A fully unredacted dataset is maintained by NOAA when the missions are executed by NOAA. Datasets collected by partners (as the Navy may view the data for this mission, given the use of OSU gliders) are typically returned to the PI without the redacted data. We will need to coordinate with NMFS OST (who manages the MOU) to ensure we have access to the full dataset and adapt (as needed) the MOU to account for the nature of glider data.

### 4.2 NOAA Testbeds, Proving Grounds, and Test Demonstrations

This project provides a test of several aspects of using acoustic Seagliders for cetacean assessments.

1. This effort will provide a more comprehensive test of cetacean encounter rates compared to what we expect from visual surveys in the main Hawaiian Islands. Habitat-based density maps are available for several species in Hawaiian waters, including for false killer whales and sperm whales, such that we can evaluate glider detections and encounter rates within the context of those known habitat affiliations.
2. A demonstration of the real-time reporting system. If the onboard acoustic detection system can provide reliable reports of false killer whale or other species occurrence, other types of sampling, as well as monitoring actions may be considered and implemented in the future, increasing the research and management utility of the platform.

### 4.3 New or Existing Technology Development

Seagliders and the acoustic recorders that go on them are commercial off-the-shelf (COTS) technology. Similarly, laboratory analysis of the recorded sound data is a field that has been well developed over the last two decades. One technology component in this project is new to PIFSC, namely real-time detection of targeted marine mammal species and communication of the detection information to land in near-real time. The hardware in this system is not new, but the use of that hardware on a Seaglider is new, as is the detection system being implemented. This system is being tried on an experimental basis in this project to see (a) how well it works and (b) the extent to which it enhances NOAA's ability to fulfill its mandate to manage marine mammal stocks. If successful in this instance, the technology will be transitioned to PIFSC by supplying the software and associated instruction documentation, and training PIFSC personnel in its use.

## 5. Implementation Strategy

PIFSC and OSU are collaborating to execute this project. The collaboration is necessary, as PIFSC presently does not own or have dedicated access to any underwater gliders. OSU has been carrying out acoustically-equipped underwater glider missions using Seagliders for several years, and as such brings the operational capability and expertise required to demonstrate the utility of gliders for cetacean surveys in the PIR. OSU is also providing technical and training assistance to PIFSC staff with the goal of enabling PIFSC use of this technology in the future.

### 5.1 List of Milestones

***This project:***

1. Acoustic package procurement: Contract with vendor to acquire the WISPR-2 acoustic system (January 2022)
2. Prepare glider for spring deployment: Plan glider flights: detailed maps and waypoints, dates, travel plans, glider insurance, vessel charters, communications, glider configuration, etc. Integration of WISPR-2 acoustic system. (February 2022)
3. Deploy, fly, and recover two gliders during the first mission in the main Hawaiian Islands. The spring mission provides a test of our ability to pilot the glider along a specified trackline, providing representative sampling of the study region, and also provides a test bed for the new WISPR-2 acoustic system. (Mission complete May 2022)
4. Preliminary analysis of data from first deployment. Detect target species in acoustic data. Analyze false-positive and false-negative detection rates. Examine glider performance along the predetermined trackline. (September 2022)
5. Develop a real-time detection system. Adapt existing detection software to run on embedded Raspberry Pi system added as an accessory to WISPR-2 acoustic system. (September 2022)
6. Prepare gliders for fall deployment. Refurbish gliders. Install real-time systems (Raspberry Pi processor and software) onto existing WISPR-2 systems. Plan glider flights: detailed maps and waypoints, dates, travel plans, glider insurance, vessel charters, communications, glider configuration, etc. (September 2022).
7. Deploy, fly, and recover two gliders during the second mission in the main Hawaiian Islands. The fall mission provides a test of the real-time detection system and to adjust our piloting approach in response to the success of the first deployment. (Mission complete November 2022).
8. Preliminary analysis of data from second deployment. Detect target species in acoustic data. Analyze false-positive and false-negative detection rates. (May 2023)
9. Evaluate effectiveness of glider-based cetacean surveys for fulfilling PIFSC assessment needs (June 2023)

***To achieve RL 9:***

10. Develop and submit proposals to transition glider operations from OSU to PIFSC (FY’25, beyond the scope of this project).
11. Develop statistical approaches for integrating glider-based acoustic detections into quantitative cetacean assessments (FY’26, beyond the scope of this project).

### 5.2 List of Deliverables

- Toolbox user manual
- Glider piloting training manual
- Glider refurbishment training manual
- WISPR-2 installation and operation manual

- SOPs, including :
    - Example deployment and recovery plans
    - Shipment packing lists
    - Example insurance paperwork
    - Pre-deployment checklists (testing, basestation prep)
    - Post-deployment checklists (data offload, gear cleaning, repairs)
- Final report, project mission review, and transition plan to OMAO UxSOC on the success of pilot surveys in the main Hawaiian Islands (summer 2023)

## 6. Roles and Responsibilities

| NOAA or Other Entities | Roles and Responsibilities |
|---|---|
| *NOAA Fisheries / PIFSC* | PIFSC will acquire training for key staff in glider piloting and refurbishment, and will ensure CRP acoustic staff become familiar with mission planning and proficient in glider data analysis. PIFSC will work closely with CIMERS/OSU to ensure gliders are available for the two project missions. |
| *OMAO / UxS Operations Center* | Subject to the availability of funds, the OMAO UxS Operations Center will fund the research, development, demonstration, and transition of the proposed work toward RL 7 or 8 (for different components of the platform). Additional funds to support staff, glider purchases and regular use and maintenance costs in order to fully transition use of acoustic gliders to operations at PIFSC. |
| *Oregon State University / CIMERS* | OSU will provide two acoustically-equipped Seagliders and provide the technical expertise required to fly and maintain the gliders during this project. They may remain a long-term partner as PIFSC integrates gliders into cetacean survey operations. |

## 7. Budget Overview

### 7.1 Cost of Current Capability

Subject to availability of appropriated funds, the “pre-transition” research, development, and demonstration phase of this project is funded by the OMAO / UxS Operations Center at a cost of $831,749 over 3 years starting in June 2021. Salary support for Federal and University of Hawaii Cooperative Institute employees involved in this project is covered by PIFSC.

### 7.2 Cost of Transition Activity

The transition cost provided in this section is subject to availability of appropriated funds. Additional costs beyond the current project include procurement of up to 4 acoustic gliders for PIFSC use ($152,200 ea.), manufacturer training for additional glider pilots and technicians ($9,000 per person for pilot + maintenance training), procurement of a base station to support glider communications ($8,000). In addition, during a transition to PIFSC operations, continued partnership with OSU will be required, including the cost of maintaining and ensuring their gliders for PIFSC missions ($30,600 per glider per year) and their technical assistance in mission planning, glider deployment and recovery, glider piloting, and data analysis (~$130,000 per mission, reduced over time as PIFSC operations increase).

### 7.3 Cost of Operational Capability

The cost provided in this section is contingent upon NMFS's decision regarding operational implementation of this capability, and is subject to availability of appropriated funds. Once purchased, gliders require periodic manufacturer maintenance ($9,000 per system per mission) that may be reduced as skilled technicians are trained at PIFSC. Gliders are periodically lost at sea or damaged beyond reasonable repair and require replacement ($152,200 ea. in FY22) in order to maintain operational capabilities. Beyond periodic maintenance and glider replacement, the bulk of the cost to maintain glider operations in the PIR is technician time to pilot and maintain gliders and research staff time to analyze the acquired data and integrate it into cetacean assessments. These are expected to be new FTE or CI positions rather than incorporating these duties into existing staff work plans given the specialized nature of the technology and datasets.

## 8. Risks and Mitigation

- *Lack of sufficient training and experience at refurbishing and piloting gliders*. The Seaglider manufacturer, Huntington Ingalls Industries (HII), provides training classes in both refurbishing Seagliders and in piloting. In addition, HII also provides refurbishment as a service, so PIFSC can use that if its own personnel are unavailable.

- *Basestation operation*. As mentioned above, gliders require a base station for communication while the gliders are operating, and this base station needs relatively open communication with the internet outside NOAA. This is difficult in the NOAA security environment. In the near future, this will be mitigated by using a base station at OSU for glider communication. Later on, it is hoped that such communication can be done via NOAA's Uncrewed Systems Center.

- *Glider loss or damage*. Gliders used by OSU are typically insured via a commercial insurer against loss during shipping, deployment, or operation. For gliders used by PIFSC and owned by OSU, this insurance will continue to be purchased. When PIFSC acquires its own gliders, such insurance will be purchased by PIFSC.

## 9. Data Management Plan

Approximately 2 months (60 days) of nearly continuous passive acoustic and basic oceanographic data will be collected from each glider during each survey effort. In total, approximately 7.4 TB of raw passive acoustic data must be processed to usable form (from flac to wav files), which will then be approximately 16 TB. Processing includes downsampling data to enable analysis of both low- and high-frequency cetacean sounds and generating a .json formatted metadata file with glider location and time associated with each acoustic file. Oceanographic data (temperature, depth, salinity, and sound speed) are processed in real time during the glider survey but must be checked for quality assurance upon glider recovery.

Glider track and environmental data will be deposited in the Integrated Ocean Observing System (IOOS) National Glider Data Assembly Center (NGDAC) in the standard NetCDF format. These processing steps generally take 2 weeks before data analysis can begin. OSU will be responsible for acoustic data processing and metadata creation during the proposed project. Acoustic data will be archived at NOAA's National Center for Environmental Information (NCEI). OSU personnel will work closely with PIFSC acoustic data managers to ensure these steps are documented and understood, as part of the intended transition to PIFSC operations.

Prior to public release, passive acoustic data must be reviewed by the Department of Defense to ensure that sensitive national security information is not released to the public. This screening process will follow the procedures outlined in the Memorandum of Agreement between the Department of the Navy and NMFS. Following screening, the metadata generated through the proposed work will be compiled and provided with the publicly-releasable passive acoustic data to NCEI. From NCEI the data will be available for public review and download.

## 10. List of List of Acronyms

| | |
|---|---|
| CV | coefficient of variation |
| CIMERS | Cooperative Institute for Marine Ecosystem and Resources Studies |
| CRP | Cetacean Research Program |
| EEZ | Exclusive Economic Zone |
| ESA | Endangered Species Act |
| IOOS | Integrated Ocean Observing System |
| MHI | Main Hawaiian Islands |
| MMPA | Marine Mammal Protection Act |

| | |
|---|---|
| MOU | Memorandum of Understanding |
| NCEI | National Center for Environmental Information |
| NGDAC | National Glider Data Assembly Center |
| NEFSC | Northeast Fisheries Science Center |
| NMFS | National Marine Fisheries Service |
| OSU | Oregon State University |
| PAM | passive acoustic monitoring |
| PIFSC | Pacific Islands Fisheries Science Center |
| PIR | Pacific Islands Region |
| PMEL | Pacific Marine Environmental Laboratory |
| SEFSC | Southeast Fisheries Science Center |
| SOP | standard operating procedure |
| UHM | University of Hawaii at Manoa |

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