ADVANCED UAS SENSOR DEVELOPMENT FOR MARINE MAMMAL MONITORING: PHASE II

Research to Operations Transition Plan

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NOAA FISHERIES
National Oceanic and Atmospheric Administration

NOAA
Uncrewed Systems
Research Transition Office

Approval Page

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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 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 in the column to the right may be omitted if the transition activity occurs internally within a single LO.

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

Build a customized uncrewed aircraft observation system mounted with an advanced multispectral sensor for population assessments of cryptic northern fur seals.

End User

The Marine Mammal Lab (MML) is coordinating with experts to build the advanced observation system which will be transitioned into operations for annual northern fur seal abundance surveys conducted by MML, Alaska Fisheries Science Center, and NOAA Fisheries.

Addressed Requirements

Develop a novel approach to survey northern fur seals to eliminate the need for the traditional ground-based method for surveying northern fur seals, which is costly, requires up to 22 people, poses potential risk to personnel, and total disturbance to the fur seals.

1.2 Anticipated Results

This observation system could revolutionize how we survey northern fur seals, as well as provide a novel approach for surveying more cryptic wildlife, using traditional methods of multispectral imaging in a novel way.

2. Research background

The northern fur seal is listed as a depleted species under the MMPA as the population dropped below 50% of its historical abundance (Towell 2006). The largest aggregation of northern fur seals used to be found in the Pribilof Island Archipelago, Alaska. In 2018, MML observed the lowest pup production in one hundred years (Towell 2019). The traditional mark-recapture method of shear-sampling has been used since 1963 for assessing pup production and population trends. Currently, MML uses this method to conduct biennial surveys of northern fur seals on St. Paul and St. George Islands (Pribilof Islands, Alaska; Buckland and York 2009). This method involves groups of up to 22 people walking through rookeries during the breeding season in order to clear adults from sections of the rookery to handle and mark pups. This clearing involves tactfully persuading adults to move off the beach section to allow MML staff and volunteers to have safe access to the pups (approximately 1 month old). MML personnel then handle pups to cut a small section of hair at the back of their neck thus providing a temporary mark that is used to count sheared and un-sheared pups during sampling counts to estimate pup production, which is used to estimate abundance. The teams typically shear approximately 10% of the pups (~10,000). This method is costly (requires up to 20 people to travel to the remote Islands for up to three weeks at a time); poses potential risk for injury of MML staff and volunteers (inherent risk when working with wild animals); and creates disturbance of all fur seals hauled out on land during the surveys.

Pursuing new technology to move away from the traditional survey method is important in order to reduce disturbance and increase efficiency, which will allow MML biologists to focus on other important NOAA priorities. Crewed aircraft surveys are not an option for this area because of logistical issues (e.g., remote airfield, fuel, and inclement weather). Naturally, this led to pursuing uncrewed aircraft surveys (UAS; e.g., drones) as an alternative. Fur seals blend in well with the background making the use of only a visual sensor inadequate for identifying individual fur seals in imagery.

Over the course of Phase I of this long-term effort, MML conducted imaging and sensor assessments, which elevated this this effort from an RL 1 to an RL 5. MML and partners assessed the spectral reflectance of fur seals and the background (rocks, sand, grass, etc.) to find the optimal wavelength bands that could be used to better distinguish fur seals from the background. This sort of “signature support” study is commonly used for calibrating satellite imagery and aerial imagery for land-use assessments (i.e., vegetation surveys; Zaman *et al.* 2011). Applying spectral signature support studies like this directly to wildlife has been conducted in preliminary ways however, the literature does not indicate previous studies taking this method the step further to developing a UAS imaging strategy (Schoonmaker et al. 2008, Leblanc et al. 2016,Chabot et al. 2019)

A total of 14 sensor options were evaluated for modeling and simulation studies. Remote sensing experts visually and spectrally modeled a virtual rookery environment to simulate UAS surveys with nine of the 14 evaluated sensors. Experts identified the optimal sensor for its resolution, capabilities, size, weight, and cost: the Tetracam MCAW6 with thermal sensor add-ons. This Phase II project of this long-term effort involves using the information gathered in Phase I to build the identified optimal observation system to survey, collect imagery, and confirm these virtual results. Phase III, not included in this Phase II project, is to use AI to develop a program to automate image processing and analysis of the imagery.

3. Capabilities and Functions

3.1 Assessment of Current Capability

This project is currently at a Readiness Level (RL) 5: *Concept Validated in Laboratory* or “Controlled Environment.” Phase II of this project involves building the customized and optimal observation system (equipped with the optimal sensor identified in Phase I, the Tetracam MCAW6 sensor, with additional thermal sensor add-ons). MML will then be able to fly this system *in situ*—in the field on the Pribilof Islands, Alaska—to test and confirm that fur seals can be easily distinguished from the background from the co-registered multispectral imagery. MML will pilot the UAS for conducting surveys, and assess image outputs.

3.2 Assessment of Anticipated Operational Capability

By the end of Phase II, MML expects this project (and observation system) will be elevated to an RL 8, “Final System Demonstrated in Operational Environment.” Once MML confirms the observation system captures imagery that performs to identify fur seals from the background, MML will conduct numerous surveys of rookeries to collect as much imagery as possible. The operation of this sensor is a new challenge for MML, which is why we have contracted with experts in multispectral imaging and remote sensing to guide us in developing a robust survey protocol. The observation system will be operated by MML to conduct annual abundance surveys of northern fur seals during the peak pupping window in the end of July. This system will require the procurement of LiPo (lithium polymer) batteries every 1-2 years as they degrade over time. Additionally, the UAS will require regular monitoring and maintenance, as needed.

Future efforts beyond this Phase II project:

Not included in this Phase II project, the next step of this long-term effort will be to work with AI experts to develop a program for automating image processing and analysis. Given we will be collecting co-registered visual, near infrared, and thermal imagery, this is three times the amount of imagery of a regular survey. Additionally, northern fur seal pup estimates is almost 100,000 individuals and many more non-pups (adults and juveniles), which means counting by human eye will be impossible within a relevant timeframe for contributing to NOAA management decisions. This final Phase III will move this effort and the observation system to an RL 9 (*Final System Transitioned into Operations / Application Use).*

3.3 Acceptance Criteria for Transition

In order for this project to successfully reach an RL 8, MML must successfully build, operate, survey with the advanced sensor observation system and collect imagery that helps us better identify northern fur seals from the background. For this capability to be transitioned to operations at an RL 9 will require a next Phase III effort to use imagery and work with AI experts to develop a program to automate image processing and analysis. Phase III is estimated to cost approximately $250,000 to work with AI experts to develop an automated count program.

4. Transition Gates and Activities

4.1 Gates toward Transition

4.1.1 Gate 1: Analysis of Alternatives

The current traditional method used for estimating pup production for population estimates is a mark-recapture method called shear sampling. This method has been used since 1963 for assessing pup production and population trends. Currently, MML uses this method to conduct biennial surveys of northern fur seals on St. Paul and St. George Islands (Pribilof Islands, Alaska). This method involves groups of up to 22 people walking through rookeries during the breeding season in order to clear adults from sections of the rookery to handle and mark pups. This clearing involves tactfully persuading adults to move off the beach section to allow MML staff and volunteers to have safe access to the pups (approximately 1 month old). MML personnel then handle pups to cut a small section of hair at the back of their neck thus providing a temporary mark that is used to count sheared and un-sheared pups during sampling counts to estimate pup production, which is used to estimate abundance. The teams typically shear approximately 10% of the pups (~10,000). This method is costly (requires up to 20 people to travel to the remote Islands for up to three weeks at a time); poses potential risk for injury of MML staff and volunteers (inherent risk when working with wild animals); and creates disturbance of all fur seals hauled out on land during the surveys.

Crewed aircraft surveys are not a viable survey option because of remoteness (e.g., remote and sparse airfields), logistics (e.g., fuel, etc.), and inclement weather. Since MML began to use UAS to augment Steller sea lion surveys in 2014, we also assessed the same observation system (mounted with a standard point and shoot digital camera) to collect visual imagery and found it to be inadequate for identifying northern fur seals. Northern fur seals, especially pups, are small and black and blend in well with the black volcanic rock substrate. Other imaging methods had to be assessed to find the best alternative for distinguishing fur seals from the background to collect complete counts. During Phase I, MML evaluated thermal and multispectral imaging resulting in the selection of the components to build an optimal observation system with the Tetracam MCAW6 (with thermal sensor add-ons) mounted to the Aerial Imaging Solution's APO-42 heavy lift octocopter.

The Aerial Imaging Solutions APO-42 UAS octocopter was selected for the building the first version of the observation system. This system was chosen as it is already approved for NOAA operations and meets our requirements for payload allowance and flight time. Given the current uncertainties of UAS manufactured in foreign countries or built with foreign-made components, the AIS systems are designed and manufactured in the USA. Most, if not all, parts are made in the U.S. Many other platforms are either not approved by AOC at this time, or could potentially not be allowed for government operations in the near future. Finally, MML has several APH-22 and APH-28 systems which are interchangeable with the same ground control station and radio controller components making it ideal to stay within the AIS family.

4.1.2 Gate 2: Data Impact Assessment

The custom UAS-based observation system will enable MML to capture co-registered imagery (visual, near infrared, and thermal imagery) of cryptic northern fur seals on land. These imaging capabilities will allow for the capture of imagery at customized wavelength bands where there is the greatest separation between fur seals and their background. This will enable MML to distinguish fur seals from the background, which is similar in size and color to animals. This long term effort is a revolutionary approach using traditional multispectral remote sensing capabilities applied to wildlife, which has not yet been reported in the scientific literature. The traditional method currently used for surveying fur seals is costly, hard manual labor, poses potential risk to personnel and animals (intrinsic when handling and working with wildlife), and causes disturbance to the animals. A UAS based approach would reduce cost, eliminate risk to personnel and animals, as well as virtually eliminate disturbance to this sensitive population.

4.1.3 Gate 3: Cost-benefit Analysis

Implementing a UAS-based approach will significantly reduce the number of personnel required for surveys from up to 22 to only a flight team of two (Table 1). The timeframe for surveying would be shorter by one week and therefore the subsequent travel costs and premium pay would be significantly reduced. In total, the UAS-based method would cut field costs by approximately 82% from the traditional method. These calculations do not account for maintenance of the observation system (which would occur as needed and updates/upgrades that may become necessary or available). The UAS is an electric system which will also require purchasing new batteries (~$150 each) every one to two years to ensure maximum flight time and efficiency. What is not quantifiable is the benefit to personnel and fur seals—this transition to a UAS-based approach will virtually eliminate the risk to personnel and disturbance to this protected and sensitive population.

Table 1—Estimated cost comparison of traditional shear-sampling survey method to the Phase II UAS-based approach.

Method:	Shear-sampling (Traditional Method)	UAS-based method (Phase II project)
Number of Personnel	Up to 22	2
Field survey timeframe	Up to 3 weeks	2 weeks
Estimated Travel Costs	22 people * $3,200	2 people * $3,200
Total Premium Pay	$12,000	$4,000

Supplies/Shipping	$5,000	$5,000
Total Cost	**$84,400**	**$15,400**

4.1.4 Gate 4: Regulations, Access, and Approvals

The selected UAS platform (the Aerial Imaging Solutions APO-42 octocopter) has already been approved for flight operations by NOAA OMAO UxS Operation Center (UxSOC) though the Tetracam MCAW6 is a new sensor for this platform. Therefore, we will be required to coordinate with the UxSOC for airworthiness evaluation and approval prior to any operations. MML will work closely with the UxS to complete this imperative step prior to testing or field survey flights. The Tetracam MCAW6 sensor is designed and built in California, USA and will not be integrated into the UAS flight navigation system—the system will simply be mounted to the UAS and wired to power the sensor and trigger it to capture imagery.

As with all UAS flights, MML will work closely with UxSOC for approval to conduct operations with this new system in the Priblof Islands. Flying UAS in this area is commonly done by MML in this area and flight restrictions and the reduced weather minimum FAA waiver are well understood and will be followed accordingly.

There is a potential risk that operations could be delayed or halted due to an impending legislation on UAS for security purposes and of course, COVID-19.

4.1.5 Gate 5: Statistical and Scientific Considerations

Imagery MML collects will have to be evaluated and assessed in order to understand how well the sensor performs at creating imagery we can distinguish individual northern fur seals from the background. MML contracted with Remote sensing/multispectral experts to develop a robust survey protocol for this new sensor and image collection challenge, as well as to help assess imagery.

By the end of this Phase II project, this long term effort will require a third and final Phase. Phase III will be necessary in order to elevate this observation system to an RL9—transitioned fully into operations. AI-based solution for processing and analyzing aerial imagery. MML will generate a massive amount of imagery with this sensor that cannot reasonably be evaluated and analyzed by the human eye. Additionally, to continue the historical time series of shear sampling estimates, MML statisticians will have figure out a correction factor to continue the time series of population abundance and trends.

4.2 NOAA Testbeds, Proving Grounds, and Test Demonstrations

Once the observation system is deemed airworthy by UxSOC and MML personnel have completed manufacturer training, MML will conduct initial test flights on the NOAA Western Regional Center (Seattle, WA) prior to shipping the system to Alaska for July 2021 field operations.

4.3 New or Existing Technology Development

This effort employs traditional remote sensing methods for a novel application—to detect wildlife—that has never been reported in the scientific literature. This method uses commercial off-the-shelf sensor (Tetracam MCAW6 + thermal sensor add-ons) customized to our species, as well as a commercially available custom UAS platform (Aerial Imaging

Solutions APO-42 octocopter). A system with these commercially available components has not been built for this sort of application for wildlife.

5. Implementation Strategy

NOAA Fisheries' MML is the entity carrying out this effort and is also the intended end user of this observation system. Therefore, transition will be swift into a long term and sustainable operations into the future. This system could also be used to test its efficacy for other marine mammal species within the NOAA Fisheries line office. Beyond NOAA Fisheries, this technology could be used for coastal surveys to map out marine debris and vegetation of coastlines and how they change over time.

5.1 List of Milestones

1. *Sensor, UAS, and Accessories Procurement:* Contract with vendors to acquire the sensor, UAS, calibration tarps and remaining equipment necessary for remote field surveys. *(All completed by April 2021)*
2. *Sensor and UAS Integration:* Work with UAS manufacturer (Aerial Imaging Solutions) and Tetracam to integrate the sensor with the UAS. *(March 2021)*
3. *MML UAS Training:* Train up biologists in the APO-42 operation to be designated Pilots in Command of this new platform. *(April 2021)*
4. *MML Evaluation of UAS Options for Secondary System:* The APO-42 was selected as a pre-approved aircraft that had the payload capabilities to carry the Tetracam MCAW6 sensor. This relatively 'small' UAS is ideal for surveying smaller rookeries on the smaller island however, for the larger and more numerous rookeries on the larger island, it would be optimal to find a larger UAS with longer flight time endurance. MML will conduct research into alternative UAS options for secondary system development. *(By June 2021)*
5. *Alaska Image Collection Surveys:* MML will use the observation system to conduct surveys of fur seals hauled out on land during the peak pupping window. MML and remote sensing experts will assess this imagery to confirm modeling and simulation results: if this sensor can adequately identify fur seals from the background. MML will fly surveys to collect as much imagery as possible during field collection trips. *(July 2021)*
6. *Survey Protocol Development:* Collaborate (i.e., contract) with remote sensing experts to guide and assist with the development of a robust survey protocol, and training on operating and optimizing the Tetracam MCAW6 sensor. *(July 2021)*
7. *Build Secondary System with New UAS*: MML will identify an optimal UAS and coordinate with NOAA AOC UAS Section for airworthiness approval. (By April 2022)
8. *Finalize and Submit Phase III Proposal for Funding to Reach RL9*: MML will require further funding support in order to complete the final phase of this long-term effort to fully transition UAS-based abundance survey methods of northern fur seals to operations (RL9). *(FY22 RFP opportunities)*
9. *Conduct Second Round of Alaska Field Image Collection:* MML will conduct another Alaska field collection survey with the secondary system during the 2022 field season. This imagery will be included in the efforts for Phase III. *(July 2022)*
10. *Conduct Phase III Effort:* MML will us imagery collected during the Phase II Alaska field collection efforts to work with AI experts to develop a program to automate image processing and analysis and elevate this effort to an RL 9. *(By 2025; beyond the scope of this Phase II project)*
11. *Statistical Modeling to Continue Historical Data:* MML statisticians will develop a correction factor or method for continuing the historical data series with this new UAS-

based approach elevating this effort to an RL9. *(By 2025; beyond the scope of this Phase II project)*

5.2 List of Deliverables

1. Delivery of APO-42 UAS mounted with the Tetracam MCAW 6 sensor and components
2. Final report from Alaska field collection and protocol development
3. *Final Report, Project Mission Review and Transition Plan to OARs USRTO*: MML will submit final versions of the final report and transition plan to OAR's USRTO to end Phase II of this long-term effort. *(December 2022)*

6. Roles and Responsibilities

NOAA Entity	Roles and Responsibilities
NOAA Fisheries / MML	MML will coordinate with sensor and platform vendors to build the observation system. MML will also contract remote sensing experts to develop a robust multispectral survey protocol. MML will then conduct field efforts annually to collect imagery for the final Phase III of this long term effort: use AI to automate image processing and analysis.
OAR / USRTO	Subject to availability of funds, the NOAA Uncrewed Systems Research Transition Office (USRTO) in OAR will fund the research, development, demonstration, and transition of the corresponding Phase II project toward RL 8 status. If and when funded the Phase III will result in a Readiness Level 9 as MML implements during normal operations. The USRTO will also provide management oversight for the project and serve as the UAS technology/research resource to facilitate these activities.
OMAO / UxSOC	As needed, the Office of Marine and Aviation Operations, UxS Operations Center (OMAO UxSOC) will coordinate airspace access and review UAS operations to ensure that safety and compliance with regulations and policy is maintained.

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 NOAA Uncrewed Systems Research Transition Office in OAR at a cost of $282,230 over 1.5 years (55 months) starting in June 2020. MML has paid the labor costs of federal employees and Joint Institute affiliates involved in this project.

7.2 Cost of Transition Activity

The transition cost provided in this section is subject to availability of appropriated funds. The cost to transition this capability from a final RL8 in Phase II to an RL 9 will require a third and final Phase III. This Phase III is estimated to cost approximately $250,000 to work with AI experts to develop an automated count program.

7.3 Cost of Operational Capability

The cost provided in this section is contingent upon NOAA Fisheries' decision regarding operational implementation of this capability, and is subject to availability of appropriated funds. The cost of implementing this observation strategy will be those associated with regular maintenance and upkeep of the UAS over the years ($0-2,000 annually), as well as the purchase of new batteries every 1-2 years ($4500) to ensure efficient surveys. Finally, over time, the calibration tarps will likely need to be replaced (~$5,000) as they will be used outdoors in rugged terrain and environmental conditions.

8. Risks and Mitigation

The APO-42 octocopter has proven to be a reliable platform and MML does not anticipate issues with flying or acquiring this platform. Additionally, the sensor identified is not integrated into the UAS flight system and is made in the U.S. This sensor has been integrated with small UAS for other applications. MML will be working with remote sensing experts to develop a robust survey protocol for this new technology. The COVID pandemic could cause delays in acquisition of materials and field work, which would postpone field work and could endanger funding this project through completion.

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