Augmenting Steller Sea Lion Surveys in the Western Aleutians with Unmanned Aircraft

North Pacific Research Board – Project Number 1120

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Abstract

New techniques for counting Steller sea lions (SSL) using unmanned aircraft systems (UAS) were tested. These techniques were proven to be useful. The UAS and imaging technologies have several characteristics that may make them superior to previously used airborne survey methods. Additionally, it may be possible to conduct survey operations by UAS more frequently, more safely, at a lesser cost, and in a wider range of weather conditions than comparable surveys employing manned aircraft. Utilizing small UAS for aerial survey operations could increase the rate of SSL monitoring, and would thus lead to a better understanding of the animal population's vital rates and dynamics.

Key Words

AeroVironment – UAS manufacturer
Aeryon – UAS manufacturer
Aleutians – Western island chain of Alaska that is area of interest
DSM – Digital Surface Model
EDPS – Eastern Distinct Population Segment
EO – Electro Optical
FAA – Federal Aviation Administration
FAR – Federal Aviation Regulations
Georeferenced – A method of locating an image in a mapping system
Haulout –Terrestrial location where SLL rest
Infrared – Portion of the thermal spectrum invisible to the human eye
Loss of Link – When two-way communications between the aircraft and pilot is broken
Mosaic – Single image of large geographic extent created from many smaller individual images
NMFS – National Marine Fisheries Service
NMML – National Marine Mammal Laboratory
NTSC – National Television System Committee
Ortho – An image where all pixels are in their correct geographic coordinates
Puma – UAS manufactured by AeroVironment
Rookery – Terrestrial location where SSL pups are birthed
Scout – Small UAS manufactured by Aeryon
See and Avoid – Rules for pilot vigilance to see neighboring aircraft and avoid mid-air collisions
Sense and Avoid – Evolving sensor technology to sense neighboring aircraft and avoid mid-air collisions
SfM – Structure from Motion
SSL – Seller sea lion
Structure from Motion – Technique for constructing depth fields from overlapping images
Take – Disturbing an animal during a survey
UAF – University of Alaska Fairbanks
UAS – Unmanned Aircraft System
VTOL – Vertical Take Off and Landing
WDPS – Western Distinct Population Segment

Citation

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Study Chronology

The original Principal Investigator (PI) for NPRB Project 1120 was Gregory Walker at the University of Alaska Fairbanks (UAF), Geophysical Institute. Mr. Walker departed UAF in 2014 and Dr. Keith W. Cunningham assumed the role as PI, organized the data/metadata, and authored this report. Dr. Cunningham is with the UAF Scenarios Network for Alaska and Arctic Planning, which is part of the International Arctic Research Center.

Introduction

Counting the Steller sea lion (SSL) populations is important to understanding their declining population. Existing methods of counting SSL are difficult. Biologist on shore near rookeries and haulouts using high-power optics to make the counts is time consuming. Aerial surveys with manned aircraft are also problematic because of the harsh weather and distance between airfields, limiting where and when air photos can be collected for the animal counts. This research with unmanned aircraft systems (UAS), operating from a ship, demonstrated that the technology could greatly assist and improve the SSL surveys.

Objectives

Objective 1: Evaluate multiple unmanned aircraft platforms and imaging solutions to collect the necessary imagery.

We considered several unmanned aircraft systems that we believed could operate in the austere and harsh weather of the Aleutians. Two aircraft were selected for evaluation. The Aeryon Scout is a rotary-wing aircraft. The AeroVironment Puma is a fixed-wing aircraft. Both aircraft have optical imagers capable of transmitting streaming video, saving high-resolution images, as well as thermal-infrared imaging. More details on how this objective was accomplished can be found in chapters 3-5.

Objective 2: Conduct unmanned aircraft flights over both known SSL sites previously surveyed and un-surveyed coastline to demonstrate and evaluate the capability of the aircraft to equal or improve on the quality of data collected by manned aircraft surveys.

Both aircraft were launched from a ship. The Scout made hovering landings on the ship and the Puma, being marinized, utilized a splashdown recovery next to the ship. The Scout has a 20-minute flight operation and the Puma has a 3.5-hour endurance.

In practice, the ship would station about a mile from the Steller sea lion haulout or rookery. The aircraft were launched and loitered over the haulout/rookery to collect imagery. The aircraft then returned to the ship and the biologist could then count the animals from the images. More details on how this objective was accomplished can be found in chapter 6.

Objective 3: Engage with SSL scientists to compare benefits and drawbacks of manned and unmanned survey operations. This comparison will include as many factors as can be evaluated and include the potential benefits of decreased weather limitations and airfield requirements and compare to current observation practices.

The Aeryon Scout had sufficient flight endurance to ferry to the area of interest, collect the imagery, and return to the ship. The Puma's significantly longer endurance was useful for scouting beaches searching for unknown haulouts/rookeries.

The Puma's fixed-wing is much like a glider, making its performance in stiff and variable winds more problematic than the more stable quad-rotor design of the Scout. The Scout operated well in 40-knot winds. Both aircraft operated well in rain and snow. More details on how this objective was accomplished can be found in chapter 6.

Objective 4: Evaluate all collected data, including costs, and prepare and present a detailed report describing the expected and discovered outcomes. Present as part of this report a detailed estimate of the investment and operations costs of mounting a UAS operation to provide routine survey operations.

The imagery collected was adequate for counting the Steller sea lions. In some cases the resolution was good enough to read the brand uniquely identifying the animal. Another discovery was that both UAS operated quietly, thus did not appear to disturb the resting animals. On one occasion, a resting SSL was noticed looking up at the hovering Scout aircraft, which appeared to be the only disturbance. More details on how this objective was accomplished can be found in chapter 6.

Costs associated with operating the Scout and Puma are presently on par with manned aviation and traditional SLL survey flights in the Aleutians, which is expensive. The pricing for the Scout and Puma UAS is about the same pricing for military applications. However, this pricing will begin to decline rapidly as the Federal Aviation Administration (FAA) determines the rules for the safe integration of the technology into the National Airspace System (NAS). This will introduce price competition as additional companies vie for non-military applications of the UAS technology. For example, the list price of the Scout is approximately $80,000 with additional costs for equipment spares. Because that cost represents a barrier to affordable research, UAF developed a comparable UAS costing about $15,000 in 2014, and these prices are likely to continue to decline.

There are other costs that will decline and be eliminated. Standardization of UAS ground control stations will simplify UAS pilot training, reducing operations costs. Also the necessary permissions from the FAA for this research project will be waived with future FAA flight regulations, savings costs associated with the administrative paperwork to comply with Federal Aviation Regulations.

Chapter 1. Background

Steller sea lions range across the North Pacific and are divided into two distinct populations (Figure 1). Since the 1970’s, the population of Steller sea lion (*Eumetopias jubatus*) has declined dramatically. The Western Distinct Population Segment (WDPS) stock is currently listed as an endangered species in the Aleutian Islands, and the Eastern Distinct Population Segment (EDPS) is listed at threatened[1].

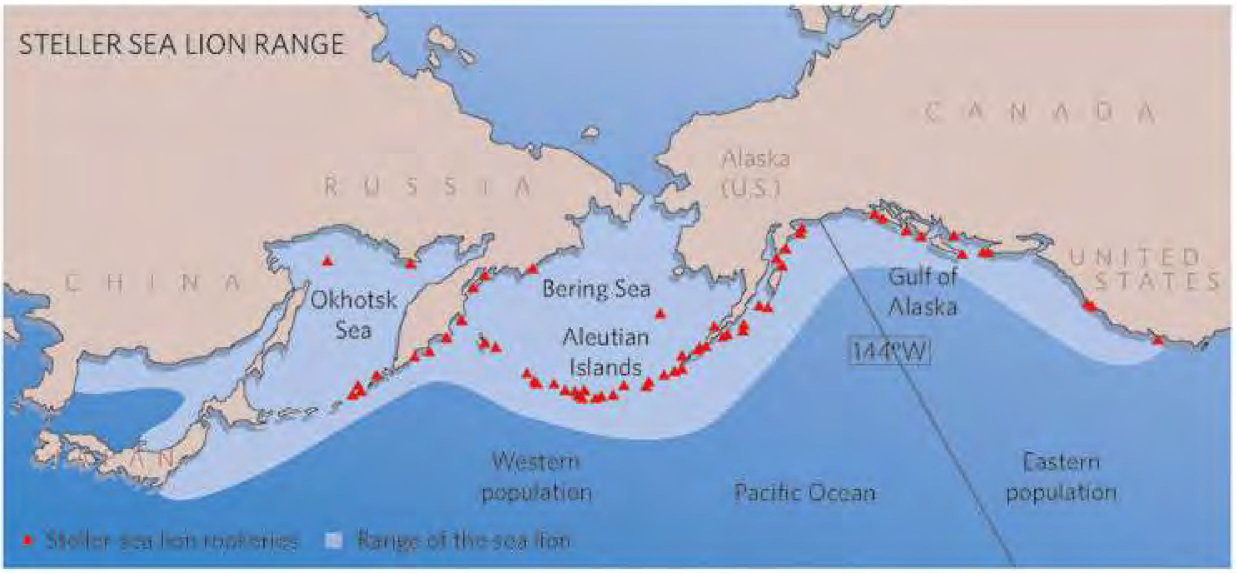

Figure 1: Range of Steller Sea Lions[2]

The SSL decline is unexplained. Commercial overfishing has been implicated in the species' population decrease because as, opportunistic marine predators, the SSL feed on a variety of fish. Another direct factor could be predation by orcas, and a variety of indirect factors such as pollution and climate change may also play a role. However, no definitive links have been established between any of these possible factors and the SSL decline.

Nonetheless, authorities are acting upon the assumption that overfishing is largely to blame for the SSL decline. The National Marine Fisheries Service (NMFS) is in the process of finalizing a biological opinion that would propose mitigation measures that would curtail the commercial fishery in the central Aleutians and eliminates fishing in the western Aleutians entirely[3].

1 http://www.nature.com/nature/journal/v436/n7047/full/436014a.html

2 http://www.nature.com/nature/journal/v436/n7047/fig_tab/436014a_F1.html

3 Fritz, 2005.

The National Marine Mammal Laboratory (NMML) annually conducts manned aerial surveys to monitor the SSL population. Animals resting at haulouts (Figure 3) and birthing at rookeries are counted by biologists using aerial photography. These counts provide the data that enables the NMML to count pups and non-pups, estimate age-specific survival and reproductive rates, and determine the age of animals at their first natality. The surveys also allow for the observation of marked (branded) animals, and may provide information on seasonal and inter-annual movements and emigration over longer time frames than are possible with satellite tagging and tracking methods.

These aerial surveys span the entire range of the SSL in Alaska from the southeast panhandle to the western Aleutians. This is an enormous distance, comparable to that between Florida and California. Flights are in the summer months of June and July, and typically employ a DeHavilland Twin Otter aircraft (Figure 2) carrying two pilots, three biologists, and a mapping camera.

Figure 2: DeHavilland Twin Otter aircraft

Undertaking these surveys can be extremely challenging. Aircraft crews routinely encounter adverse weather in the Aleutians: rain, fog, and gusty winds are the norm. Safety requirements for manned aviation must account for issues of visibility, ceiling, cloud decks, icing, and winds. Further, the distance between airports in the western Aleutians presents a major safety and logistics issue: airfields at Dutch Harbor, Atka, Adak, and Shemya may be hundreds of miles apart. These limitations inhibit the ability to consistently and adequately survey remote locations. Consequently, there are years in which known sites or entire segments of the survey are not inventoried.

Figure 3: Typical Steller Sea Lion Haulout in the Western Aleutians

The obstacles confronting manned aerial surveys of SSL habitat are such that assessment is sometimes impossible. From the 2009 through the 2012 breeding seasons, NMML was unable to survey a 300-mile stretch of the Aleutians that includes the endangered Western District Population Segment (wDPS). The primary reasons for this failure were fog obscuring the rookeries, poor aviation weather, and deficient airport logistics.

Further complicating manned aerial surveys are the stringent regulations that have been put in place because of environmental concerns regarding the SSL. The typical flight height above SSL haulouts and rookeries is 1,000 feet, and the lowest permissible altitude is 500 feet. These altitudes have been established in order that the aircraft's noise and moving silhouette are less likely to disturb the resting animals. SSL flee into the water when disturbed, reducing the accuracy of the population count.

Unmanned aerial systems (UAS) offer the potential to augment SSL population surveys and improve the collection of population data. Though UAS operations are an attractive option for aerial population surveys because they are comparatively less risky than manned flights, they offer the additional potential benefit of permitting a wider range of operations in narrower weather windows. Ship-deployed UAS could also enable opportunistic surveys in close proximity to haulouts and rookeries; they may also enable previously unknown sites to be located.

More frequent and complete surveys permit more accurate population counts, enabling better wildlife and resource management. More frequent and opportunistic surveys are likely best performed with smaller

UAS that require correspondingly smaller supporting systems. To test this hypothesis, small UAS weighing less than five kilograms were evaluated for flexibility, cost, and collection efficiency of imagery for population counts.

Research goals include:

- Effect of UAS on SSL Takes
- UAS Overview
- UAS Selected
- UAS Operations
- UAS Imaging & SSL Surveys
- Conclusions
- Outreach

Chapter 2. Effect of UAS on Steller Sea Lion Takes

The use of UAS as a survey platform is novel. Potentially adverse effects of employing UAS for population surveys are similar to those of manned aircraft, which have occasionally been known to disturb resting SSL. Because the SSL is classified as endangered, Marine Mammal Protection Act of 1972 regulations governing the “taking” of marine mammals applies to these surveys. The term “take” originally implied the lethal collection (intentional or unintentional) of an animal for the purpose of the science being conducted. The term has been broadened to include the harassment of the animals as part of the science, and may include disturbing the resting animals. In the case of SSL at rookeries and haulouts, a “take” also encompasses instances of animal behavior that would not have occurred if an aircraft were not present, including an alert behavior.

There are two ways a UAS may trigger a “take.” The sound of the UAS flying nearby could disturb SSL, and the silhouette of the aircraft could startle the animal. A “take” in the simplest case could be defined as an animal looking at the aircraft; a “take” in its most extreme case would occur when an animal is flushed into the sea.

Manned aircraft typically have a large profile, fly above 300 meters (1,000 feet) altitude, and their engines can be quite loud. While UAS will operate at lower altitudes and are significantly quieter, methods of mitigating their noise and profiles may be required.

Sound volume (intensity) decreases exponentially with distance, in accordance with the inverse square law. The DeHavilland Twin Otter flying at 1,000 feet has a sound level of 52 dBA. The ambient background sound of waves and winds is typically 55 dBA. If the Twin Otter were to drop in altitude for the aerial imaging, the sound would increase above the ambient background level and the SSL may be disturbed. It is anticipated that the small motors and propellers of UAS would allow significantly lower-altitude imaging surveys than manned aircraft without disturbing the SSL.

The Twin Otter's 65-foot wingspan creates a sizable profile. Because small UAS possess wingspans that are typically less than 15 foot, they may operate at much lower altitudes with comparable profiles. The Twin Otter flying at 700 feet has a similar profile to a fixed-winged UAS flying at 100 feet and smaller rotary-winged UAS flying at 75 feet.

Flying lower and slower with a quiet UAS should reduce the number of takes recorded by SSL aerial population surveys.

Chapter 3. Unmanned Aircraft Systems Overview

An unmanned aircraft system is typically considered to be an aircraft that can be programmed to fly itself; thus, the UAS requires an autopilot with a positioning and navigation system. The UAS also carries a payload that can also be programmed to perform a function – for example, a camera that collects an image every second. This is the significant distinction between a UAS and remotely operated or remotely piloted aircraft.

The "system" component of the term unmanned aircraft system describes all of the supporting people and equipment that are involved in operating the aircraft and payload. Larger UAS have specialized equipment to launch and recover the aircraft. Some UAS are so large that they require an airfield for operation, just like manned aircraft. There may also be equipment such as air traffic radar to manage the airspace in which the UAS is operating.

Completing the system are the pilot and other personnel supporting the UAS mission. The pilot monitors the aircraft and payload and is part of the "sense and avoid" process required by the Federal Aviation Administration (FAA) to avoid collisions with other aircraft. Manned aircraft follow comparable "see and avoid" procedures to prevent mid-air collisions.

Current FAA rules govern civilian operation of the UAS and there are several operational restrictions to ensure aviation safety, especially the safety of any manned aircraft that may be operating in the vicinity. These rules include requirements for ground observers and the restriction of UAS operations to the observers' line of sight. A telemetry link must be used to issue commands and control the aircraft, which requires a two-way radio system between the ground crew and the aircraft. Line-of-sight operation typically means a short telemetry link of only a few miles; thus, the radios are low powered.

Operationally, a UAS is also programmed to respond to a loss of communications with the pilot and ground crew. When the telemetry link is lost, the UAS may be programmed to fly to the "home" from which it was launched, to ascend in an attempt to reestablish the telemetry link, or even to descend in altitude and deploy a parachute so the UAS can be safely recovered. The FAA is working to establish standards and protocols related to recovery of these "lost" UAS, but there are drawbacks to all approaches.

Other personnel may be operating the aircraft payload, such as a real-time video camera and the sensors, which collect other data. Additional personnel may also have a role in the post-processing of the sensor data. Thus the “system” is not just the aircraft and payload, but all of the people and equipment supporting the mission. The system may thus include a biologist who uses the data collected to conduct the SSL population count.

The UAS considered in this research are small and do not require an airfield or the support facilities that are necessary for operating a manned aircraft. They can be launched and recovered from a ship at sea or by a team boated to shore near the haulouts and rookeries. Ship and shore operations of UAS provide a range of flight operations that would not be possible when employing a manned aircraft because of low cloud ceilings and intermittent weather conditions such as rain showers and fog. Shore operations with biologists also studying the sea lions have additional advantages discussed later.

UAS Considered

UAF has worked with many UAS in a variety of locations. These include several operations with the National Oceanographic and Atmospheric Administration (NOAA) aboard their research vessels in the Arctic and North Pacific. The graphics below show the launch of UAS while at sea on the NOAA research vessel *Oscar Dyson* in Puget Sound. The second graphic is of the recovery of a UAS on the NOAA research vessel *MacArthur II* in the Bering Sea (Figure 4).

Figure 4: Prior UAS Missions on *Oscar Dyson* and *MacArthur II* in the Bering Sea

A variety of aircraft were considered for operations in the North Pacific and Aleutians (Table 1). These platforms were selected primarily because of their performance in a variety of weather conditions, especially in the rain and gusty winds which are typical of the Aleutians.

Table 1: Specifications of Selected UAS

Aircraft	Manufacturer	Airframe	Endurance	Weight
Scout	Aeryon	Rotary wing	25 minutes	1.3 kilograms
Puma A/E	AeroVironment	Fixed wing	2 hours	5.9 kilograms
Resolution	ATI	Fixed wing	2 hours	6.8 kilograms
ScanEagle	Boeing	Fixed wing	24 hours	20 kilograms

The Scout is manufactured by Aeryon, which is based in Waterloo Ontario, Canada. UAF has operated this UAS in -40 temperatures during the January 2012 fuel delivery in Nome, Alaska by the Russian fuel tanker Ronda. The Scout's operational specification also describes operating in winds as high as 50 kph and gusts up to 80 kph, which could be necessary for work in the Aleutians (Figure 5).

Figure 5: Scout in Flight in the Aleutians

AeroVironment of Monrovia, California manufactures the Puma All Environment. The large wingspan of the PUMA provides efficient flying with an electric motor, but becomes a liability when winds are high and variable. The Puma A/E has demonstrated flight in weather conditions that would be considered "good to fair" for the western Aleutian Islands (20 kph winds, rain, etc.). The Puma is hand launched (Figure 6) and because it will float it may be safely recovered from the water after a deep stall. NOAA considered purchasing six of these platforms for its own research; thus, this platform was selected for SSL surveys.

Figure 6: Puma ready for hand launch

The Resolution is under development by Airborne Technology Incorporated, based in Wasilla, Alaska. The Resolution has the advantage of being a marinized aircraft, and salt-water recovery would be useful while working in the Aleutians. Unfortunately the aircraft was not ready for deployment in the 2011 sailing or the 2012 campaign. Figure 7 shows the Resolution operating from a NOAA research vessel.

Figure 7: Resolution Catapult Launch

The ScanEagle is manufactured by the Boeing subsidiary Insitu, which is located in Bingen, Washington. The ScanEagle was originally designed to replace manned helicopters in the tuna fishing industry. UAF owns nine ScanEagle UAS. It supports a larger payload than the other UAS used in this study and has long endurance; thus, it is well suited for testing a variety of sensors. However, the ScanEagle's larger payload and longer endurance give it the drawback of a significantly larger operational footprint – it requires dedicated launch and specialized recovery equipment. Though an extremely capable UAS, its operational footprint is not efficient for the short surveys of rookeries & haulouts. Additionally, as the ScanEagle has been previously evaluated in the Bering Sea (Figure 8) in conditions similar to the Aleutian Islands, it was decided not to deploy the aircraft as part of this SSL survey research.

Figure 8: ScanEagle in Bering Sea Trials

The criteria used to select the UAS systems for SSL survey mapping are fairly straightforward. The systems must be commercially ready. The launch and recovery of the UAS must be possible from a ship at sea. The UAS should be capable of flight and data collection in the typical weather of the Aleutians. The UAS needs an endurance of about 20-30 minutes, which is the time required to launch, fly a few kilometers to the area of interest, observe the SSL and collect high resolution images, and return to the ship with a margin of time for safe recovery. Last, the UAS need both an optical and infrared camera with real-time video via the operational telemetry control. Thus the Scout and Puma were selected.

Chapter 4. Unmanned Aerial Systems Selected

Aeryon Scout

The Scout is classified as a small Unmanned Aircraft System (sUAS). It weighs 1.4 kilograms and is transported with the aircraft in one watertight case and the ground control system (GCS) in another (Figures 9 & 10). The UAS can be assembled and launched in less than a minute, though mission planning and programming using the tablet computer GCS is required.

Figure 9: Aeryon Scout and Ground Control Station

The Scout's quad-rotor design gives it vertical take-off and landing (VTOL) capabilities, which means that it does not require launch and recovery equipment. The Scout also permits hand-recovery, which worked well during the trails at sea. Operational ceiling is 500 meters, but lower flights will be flown to achieve the image resolution necessary to count SSL.

The operator can monitor flight details and see real-time video images with the GCS operated from the tablet computer. The UAS has self-stabilizing avionics to minimize image blur. This enables operators to navigate, search the area of interest, and record high-resolution imagery for the animal counts. Color and infrared cameras are mounted on a gimbal that the pilot/operator can point on an area-of-interest (AOI) while the aircraft is in flight.

Figure 10: Scout Ground Control Station and Spare Batteries

The Scout is battery powered and flies quietly. Flights are limited to the charge of the lithium polymer (LiPo) battery, which is approximately 25 minutes. As the telemetry link is line-of-sight, the Scout's battery life and communications system limits its operational range to about three kilometers. The Scout is weatherized and can operate in rain, as well as in sustained winds of 50 kph and wind gusts up to 80 kph.

Operational Narrative

The Scout is assembled in the ship's wheel house (Figure 11) and carried out to the deck. A self-check begins after it is turned on. The pilot monitors the system status via the GCS and if the operational parameters are satisfactory, the UAS is ready for launch. With the takeoff command, the Scout lifts off and follows a programmed course to avoid obstructions on the ship such as its crane, mast, antennae, etc.

Figure 11: Aeryon Scout in Ship’s Wheelhouse

The system climbs to a programmed altitude of 122 meters and begins flying a preprogrammed route. While routes can be planned with the GPC, the system can also navigate using waypoints, and can be programmed to fly a grid pattern to optimize the collection of imagery.

Because of the limited operational endurance of 25 minutes, routes were planned so that the UAS would return to the ship after a 16-minute mission so as to include a safety margin. Longer flights of 20-minutes were conducted when the UAS was operated from the shore. The UAS's battery may be swapped out with a charged spare after it has returned to base. Even with these limitations on endurance and safety, we were able to collect complete imagery of rookeries and haulouts from a ship one mile off shore.

Imagery was collected at altitudes of 30 meters without disturbing the animals (Figure 12). When another flight was conducted at 15 meters one animal did notice the UAS. Flights at the higher altitudes allow the operator to orient the direction of the camera searching for the animals. The altitude was decreased when the animals were located and high-resolution images were collected.

Figure 12: Beach Haul Out at Finch Point, March 23 2012, imaged by the Scout at 30 meters altitude.

The UAS lands itself at its base or other programmed location. The UAS descends to about two meters where the Scout's ultrasonic altimeter then assists to complete the landing, either on ground or the ship's deck. On contact, the system then powers down so that the pilot/operator may safely approach it.

The system can also be "snatched" from the air if there is too much heave or pitch in the ship deck for a reliable auto land. In this maneuver a ground operator wearing safety gear (gloves, helmet, and visor) grabs the aircraft from a hover about two meters from the deck. Once the two landing struts are held, the operator rotates the system 90 degrees to its side, which signals the UAS to power-off, the props. This method of recovery is also desirable if there are many obstacles on the flight deck, which could damage the propellers. This "snatch" maneuver has been part of the training with the system, but for safety reasons, the technique is only used when an autonomous landing is not possible (Figure 13).

Figure 13: Hand Recovery of Aeryon Scout during Aleutian Campaign

The Scout UAS was also operated from shore. On a small launch, the pilot, operator, and accompanying biologists went ashore some distance from a haulout. The biologist then approached the Steller Sea Lions to observe their behavior when the UAS was collecting imagery. This process is described later.

AeroVironment Puma AE

The Puma AE is also classified as a sUAS. Weighing almost six kilograms and with a 2.6 meter wingspan, it is essentially a hand-launched glider. Assembly is more involved than the Scout, with the fuselage carried in one case and the wings in another case. The GCS is also more complex than the Scout and possesses a longer-ranged encrypted communications and control system primarily because the system was designed for military, not civilian applications.

Puma AE system operations typically involve a two-person team. Being hand-launched, the operator holds the UAS while the pilot starts the electric motor. On command, the operator throws the aircraft forward, ideally into a head wind (Figure 14). The UAS autopilot then takes control.

The Puma has an operational altitude of 300 meters and its large wings allow for two-hour flight endurance with a range of 10 kilometers. This enables larger areas to be surveyed via live video than would be possible with the Aeryon Scout. During this mission, the average flight was only 36 minutes. Like the Scout, the Puma's electric propulsion allows it to operate quietly and without disturbing the animals. When images of animals need to be collected, the altitude is decreased to improve image resolution.

The Puma optics for this mission were inferior to the Scout's, and because the minimum altitude at which the aircraft could be comfortably flown was above 200 feet the imagery was inferior for animal counting and inadequate for brand identification. The infrared sensor proved adequate for simple and quick SSL animal counts, but high-resolution color camera will be a system requirement to produce high-resolution photomosaics.

Recovery of the Puma at sea utilizes a deep stall before the UAS splashes into the salt water. The recovery operator is in a small boat positioned off the ship and the pilot using the GCS specifies the location of the splash down relative to the ship. The splash down occurs about 10-20 meters from the launch. After splashdown the recovery operator motors to the Puma and lifts it out the water and places it in the boat.

Figure 14: Hand Launch & Water Recovery on 2012 Aleutian Campaign

Chapter 5. Unmanned Aircraft Systems Operations

For both manned and unmanned aircraft there are other mission components that must be planned before the surveys can be conducted. These include a variety of management functions and operational logistics. However, UAS operations face some unique issues that are specified by the Federal Aviation Administration's (FAA) guidelines for operating UAS.

This includes working with the SSL biologists to identify the locations of the known haulouts and rookeries. In this study the area of interest encompassed the chain of Aleutian Islands from False Pass to Attu Island (Figure 15). This AOI includes 50 islands with 54 SSL haulouts. Supporting mapping data of the AOI are collected for the Western Distinct Population Segment. These locations are used to acquire the flight permissions required from the FAA.

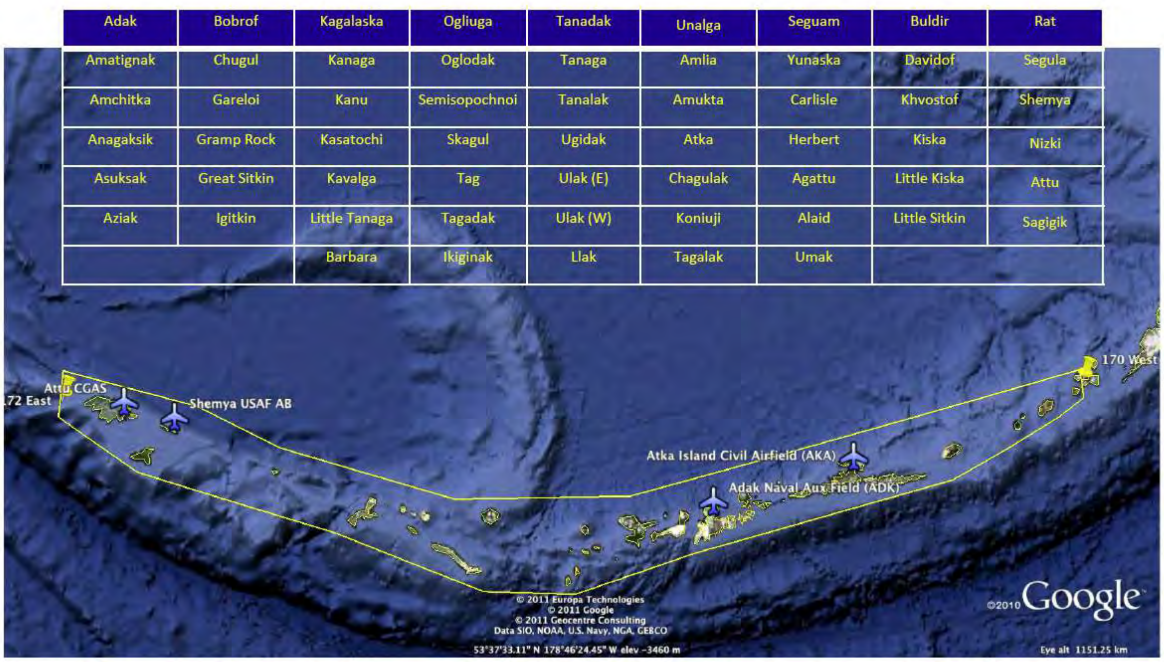

Figure 15: Western Aleutian Islands for 2012 Survey Campaign

The FAA considers aviation safety one of its most important missions. The Federal Aviation Regulations (FAR) are the specific rules all pilots follow to ensure safe aviation. These rules work when the pilot is onboard the aircraft, but in the case of the UAS, the pilot is not onboard. With the pilot on the ground, it is not possible to follow the vigilant "see and avoid" rules that may prevent collisions with other aircraft. Thus the UAS pilot must remain in visual line of sight control of the UAS while watching the airspace. Spotters on the ground are also used to monitor the airspace to better manage potential aviation emergencies.

UAS technology is rapidly evolving, and in the future sensing systems that enable "sense and avoid" rules may augment the "see and avoid" rule. Sense and avoid technology that would allow UAS to detect encroachments from other aircraft and steer clear of potential collisions. However, this technology is only now in development and will not be operationally ready until at least 2016.

Certificate of Authority

To safely manage the National Air Space (NAS), the FAA only grants permissions to operate UAS in certain circumstances. The process of receiving this permission requires filing with the FAA paperwork that specifies the mission, operation, and safety systems that will be used. After public comment and the FAA's approval, which may take some time to be granted, a certificate of authority (COA) is issued.

There are many rules for acquiring a COA. First, UAS has to be classified by the FAA as a "public aircraft," which essentially means that the UAS cannot be operated for any commercial purposes. Therefore the entity operating the UAS has to be a public organization conducting non-commercial, non-profit research. Further, a COA can presently only be issued for operations in restricted or segregated airspace that is not available to normal air traffic. UAS are currently banned from all commercial applications for these reasons.

UAF is a public, research institution and these aerial surveys of the Steller sea lions are classified as research. The COA for the sea lion surveys was more complex in that it includes a very large geographic region and that two types of UAS were to be utilized from both ship and shore.

One requirement of the COA is that the UAS will always be flown at a maximum altitude of 122 meters over the open water and 160 meters maximum altitude when over the shore scouting and imaging the animals. These maximum altitude restricts are for the safety of manned aircraft flying nearby.

UAF has a long history of working with the FAA to receive COA for a wide range of applications and locations. One of the tools UAF possesses to help the FAA understand the risk of UAS to nearby manned aircraft is a small, portable air traffic monitoring radar. UAF has also developed its Portable Airspace Surveillance System (iPASS) to supplement the requirement of visual observers (Figure 16).

Figure 16: The iPASS Radar to Monitor Airspace

During this survey campaign, a representative from the FAA Alaska Region participated as an observer and spotter. This allowed the FAA to better understand UAS technology and this particular application of SSL surveys.

Communications Loss of Link

The COA specifies the area and time of operations, the certifications (training and licensing) of the pilot, two-way-communications systems, and the rules to be followed in the event of communication failure (loss of link) with the ground control station (GCS). The two selected UAS follow programmed rules in the event that they lose communications.

In the case of the Puma, the loss of link emergency procedures are: 1) Land Now, by which the UAS immediately follows an auto-land program, 2) Go-to-Rally, by which the program flies to a prior-specified landing waypoint and executes the auto-land program, or 3) Finish Flight, by which the aircraft continues the mission according to the programming and then executes the auto-land program. Because the Puma is watertight and floats, a water landing is a satisfactory emergency recovery.

In the case of the Scout, the emergency procedures for loss of link are: 1) Land Now, by which the program lowers itself at its current position, and 2) Rally to the take-off position and land. Note that in the case of the Scout, if the UAS attempts to land over water the aircraft will sink and be lost.

Chapter 6. UAS Imaging & SSL Surveys

Two groups – NMML biologists and UAS researchers – received research grants from the North Pacific Research Board. The NMML biologists from the Alaska Ecosystem Program were to investigate the relationship between SSL population trends and the animals' winter diet. The UAF unmanned aircraft group received the research grant in order to determine how unmanned aircraft systems could be used to augment the Steller sea lion population surveys. The biologists needed to visit each SSL rookery and haulout in order to conduct a visual count of the animals and collect scat to analyze their winter diet. The UAS researchers also needed to travel to each haulout and rookery in order to conduct the UAS survey flights.

The joint-research campaign began March 4, 2012. Starting in Dutch Harbor, over the course of three weeks the cruise traveled 650 nautical miles west to Adak and back. The *R/V Norseman*, a ship originally built for crab fishing in the Bering Sea, was chartered for the cruise (Figure 17). The craft was refit for extended research expeditions in the North Pacific and Arctic, and its accommodations and large bridge allowed the UAS pilot/operator to work in coordination with the biologists and the ship's crew.

Figure 17: R/V Norseman

March weather in the Aleutians is windy, wet, and cold (Figure 18). Temperatures are below freezing at night and warm to just above freezing during daylight hours. On average, the sky is cloudy or overcast three-quarters of the time. Though precipitation is not typically heavy, rain, freezing rain, and snow are common and the air is humid – the dew point averages 21° F. Sea ice is not unusual.

Figure 18: Ice Floe & Deck Ice near Atka on March 11 (left) and March 14 (right), 2012.

Eleven operational staff were onboard the *R/V Norseman*, including two NOAA Corps officers, five NMML biologists, three UAS pilots, and an observer from the FAA (Table 2).

Table 2: Survey Team for Aleutian Campaign

Individual	Affiliation	Duties
Gregory Walker	UAF	UAS Principal Investigator Pilot-in-Command (both Aircraft) Radar Operator
David Giessel	UAF	Radar Lead Aeryon Scout Operator Alternate Flight Observer
Jay Skaggs	FAA	Project Observer
Taylor Nobles	AeroVironment	Puma AE Operator Alternate Flight Observer
CDR Nancy Hamm (formerly Ash)	NOAA Corp.	Aircraft Support Project Observer Alternate Flight Observer
LTJG Van Helker	NOAA Corp.	Aircraft Support Project Observer Alternate Flight Observer
Lowell Fritz	NOAA NMML	Diet Study Principal Investigator Cruise Principal Investigator Harassment Permit Co-Investigator
Sara Finneseth	NOAA NMML	Mammal Technician
Cary Kuhn	NOAA NMML	Mammal Technician
Vladimir Burkanov	NOAA NMML & Consultant	Camera Technician & Mammal Technician
Yura Burkanov	Vladimir’s son	Support Staff

The procedure for conducting the SSL count and winter diet analysis follows these general steps:

1. The research ship approaches the known SSL haulout or rookery.
2. The ship maintains a distance that will not disturb the resting Steller sea lions.
3. A shore party of biologists and NOAA Corp officers prepares the small boat launch.
4. The shore party lands at a sufficient distance from the SSL that the animals are not disturbed.
5. Attempting to remain unnoticed by the animals, the biologists approach the SSL.
6. The biologist then observes, counts, and classifies the SSL (Figures 19 & 20).
7. The UAS is prepared for operations –the Puma is used in calm winds and the Scout in strong.
8. The UAS flies over the haulout while biologists observe and report via radio with the pilot.
9. The UAS surveys the haulout with live streaming video to confirm the presence of SSL.
10. The UAS collects high-resolution images of the area of interest.
11. The biologist monitors the SSL to determine if they are disturbed by the UAS operation.
12. The UAS returns to the ship and the high-resolution imagery is downloaded.
13. The biologists then approach the SSL to look for and capture images of branded animals.
14. The biologists then flush the animals into the water so that scat can be collected for later analysis.
15. At three locations, solar-powered time-lapse cameras were set up:
16. Attu/Cape Wrangell
17. Agattu/Cape Sabak
18. Agattu/Gillon Point
19. The shore party returns to the ship.
20. The UAS imagery is processed for aerial SSL counts.
21. The biologist counts the SSL from the UAS imagery and compares this to the field count.
22. Field notes regarding disturbed animals are compared to imagery of disturbed animals.
23. Notes from the day's mission are recorded in a journal.

Figure 19: Biologists Ashore Observing SLL on Haulout with R/V Norseman in the Background

The biologists count the sea lions from shore and boat as well as collecting supporting images to verify SSL numbers on March 9, 2012 (Figure 20).

Figure 20: Image of SSL Collected from Boat by Biologists. This image was collected from the boat.

The biologist then opens this image in Adobe Photoshop and clocks on the image of an individual SSL, leaving a symbol that classifies the animal into one of nine categories (Table 3). A script within the program totals each classification according to the following symbols:

Table 3: Codes for SSL Classification Counts

Symbol	Code	Description
*	1TF	Male defending territory
*	2TN	Male not defending territory
*	3AN	Male (just another male)
#	4Sa	Sub adult male
+	5F	Female
+	6J	Juvenile
#	7U	Too little imaged to determine
+	8P	Pup
x	9DP	Dead pup

Even in foul weather, the biologists attempted to perform field counts with observations from land and sea. But poor weather conditions can interfere with accurate and complete counts. High sea swells can prevent the boat launch from approaching the haulout at a sufficient distance for the biologists to camera images. Worse weather even can prevent the shore party from landing. It was not possible to survey all the SSL haulouts and rookeries that were chosen for the project during the three-week campaign.

Aerial images were to be collected in order to confirm the biologist's counts from ship and shore. As with the manned aircraft used in previous aerial SSL surveys, UAS operations can be adversely affected by weather. Of the planned 49 missions to image 54 haulouts, the weather was satisfactory to operate the UAS in only 19 of these missions. But on a positive note, this was actually more missions than the team originally expected to fly.

Because of the risk of icing, neither UAS would be flown if temperature were near or below freezing. Wind was another significant issue, and neither platform was flown when the winds in excess of 30 knots were recorded. Further, the Puma could not be flown if the seas were too rough for a boat launch because the aircraft requires a splashdown recovery.

Both the Scout and Puma proved able to fly in rainy conditions provided the rain was not heavy. However, water on the camera lens degraded the quality of the streaming video and high-resolution images (Figure 21).

Figure 21: Raindrop on the UAS camera lens

Table 4 lists the UAS missions at 19 separate survey sites. In March 2012, the Puma flew nine missions over nine sites, while the Scout flew 30 missions over 15 sites. The survey site field is the haulout or rookery surveyed by the biologists where scat was collected and the UAS operated. Wind is in knots and flights are the number of missions flow with each respective UAS; in the case of the Scout, the UAS returned to the research vessel between flights to swap batteries and download images.

Table 4: UAS Operations, Locations, Weather, and Notes

Date	Survey Site	Wind	Precipitation	Scout Fights	Puma Flights	Biologist & Pilot Flight notes
6	Ulak – Hasgox Pt	25	None	1	1	Silent flights
8	Semisopochnoi – Pochnoi	25	None		1	
9	Amchitka – East Cape	20	None	3	1	Silent flights
9	Amchitka – Column Rock	20	Snow & Rain	1		Silent flights
9	Amchitka – St Makarius	25	None		1	Silent flights
10	Kiska – Cape St Stephen	Light	None	2	1	
13	Agattu – Gillon Pt	20	Snow		1	Excellent scouting tool
14	Agattu – Gillon Pt	10	Snow	2		Poor illumination
14	Attu – Cape Wrangell	10	None	1		
15	Attu – Cape Wrangell	10	Snow	6		
16	Attu – Cape Wrangell	Light	None	2	1	Wrong haulout – UAS identified correct one
18	Rat	20	None	2	1	UAS operated on shore
19	Kavalga	5	Snow	1		
19	Kanaga – Ship Rock	10	None	4		Collected high-res stills for 3D photomap
21	Atka – North Cape	10	Snow	1		
21	Salt	5	None	1		
23	Seguam – Finch Pt	20	None	2		
23	Seguam – Saddleridge	25	None	1		
24	Adugak	5	None		1	

Note that strong winds were typical. In general, the Scout performed better in the higher winds than the Puma, primarily because of the difference in the aircraft designs. The Puma's large wings make it behave more like a glider, and its flight characteristic is more like a hover when it is pointed into the wind. The Scout's quad-rotor design is better suited for flying into the wind than the Puma, but it is only effective in wind speeds below 30 knots.

Over 3,000 Steller sea lions were identified and counted by the biologist. On top of these numerical population counts, the biologist attempted to determine the sex and age of the individual animals, i.e. bulls, sub-adult males, females, and juveniles. The UAS helped collect imagery used to count 1,797 animals.

Table 5: SSL Survey Locations, Counts, and Notes

Date	Survey Site	Biologist Count	UAS Count	Takes	UAS Count & Take Notes
6	Ulak – Hasgox Pt	52		0	No reaction to UAS
8	Semisopochnoi – Pochnoi	1		0	
9	Amchitka – East Cape	196	192	0	No reaction to UAS
9	Amchitka – Column Rock	8	9	0	No reaction to UAS
9	Amchitka – St Makarius	50		0	No reaction to UAS
10	Kiska – Cape St Stephen	18		0	
13	Agattu – Gillon Pt	3		0	Scouted for other SSL
14	Agattu – Gillon Pt	0		0	
14	Attu – Cape Wrangell	100		0	Animals spooked by shore party – no UAS imagery
15	Attu – Cape Wrangell	30		0	No reaction to UAS
16	Attu – Cape Wrangell	28	32	0	New haulout located
18	Rat	96	79	5	20 SSL on offshore rocks, not on imagery
19	Kavalga	103	96	0	No reaction to UAS
19	Kanaga – Ship Rock	163	157	0	No reaction to UAS
21	Atka – North Cape	100	191	0	Camera gimbal issue – poor images: Age & sex impossible
21	Salt	175	106	0	60 SSL on offshore rocks, not on imagery
23	Seguam – Finch Pt	700	635		65 SSL on offshore rocks, not imaged
23	Seguam – Saddleridge	20		8	UAS flushed 8 SSL
24	Adugak	250	300	0	Low resolution image – could not assign age & sex

The number of “takes” - that is, occasions during which the SSL were disturbed by or became attentive to the UAS – seems to have been very modest. The sound of the UAS did not appear to cause the animals to take note of the aircraft; even at low-level flights of 50-75 feet, the noise signature of either UAS is comparable to that of ambient sound such as wind and waves. The animals did not appear to notice the aircraft provided that the UAS continued to move (not hover).

There was one notable occurrence of a near-take during the project: on March 19 at Krysi Point, Rat Island, a male SSL vocalized when the Scout flew over the haulout at 50 foot. The roar alerted the entire group of 56 animals (4 adult males, 4 sub-adult males, 20 adult females & 28 juveniles). All the animals rose up, some approached the water, and five entered the water. However, the biologists on the shore team determined that this reaction was not a response to the hovering Scout, although they did radio the UAS pilot to increase altitude to 75 feet. After the aircraft climbed, the animals seemed to become less active and they returned to a resting posture. The Scout finished collecting high-resolution imagery, and the biologists then spooked all of the animals off the beach in order to collect scat.

Optical and Infrared Imaging

Both UAS are equipped with cameras and radios to transmit real-time video. The electro-optical cameras operate in both color and thermal infrared. Figure 22 shows the Puma’s real-time video; the image to the left is in color, while the image to the right is thermal infrared (black assigned to hot). The pilot-operator can switch among all modes in order to better inspect the area of interest.

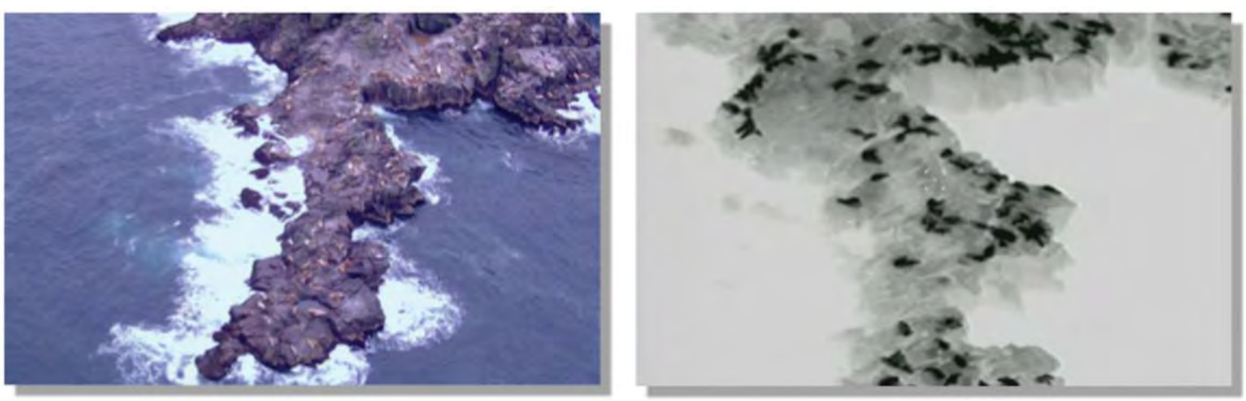

Figure 22: Color Video and Thermal Infrared Video from Puma

The infrared imaging allows the animals to be easily identified and counted. However, the resolution and quality of the real-time video from the Puma was insufficient to determine sex, age, and other characteristics. Also, working with the infrared camera requires that there be sufficient contrast between the warm animal and a cool background of the haulout. This was not an issue with imaging the SSL in March, but could become problematic during the summer, the season in which seal pups are born and counted by biologists. Seasonal molt of the SSL could also affect the infrared imaging quality.

With its two-hour endurance, infrared imaging, and effective altitude of 75-400 feet, the Puma is a very good tool for scouting the presence of SSL. It provides a wide field of view and does not disturb the animals.

Metadata is embedded in the collected images (Figure 23). The metadata provides unique details such as the time and GPS coordinates of the aircraft when the image was collected. Metadata may also include compass navigation data indicating the direction the UAS is traveling. Camera metadata also includes the make of the sensor, and the camera's orientation on the gimbal when the image is captured. The thermal infrared image below shows the metadata "branded" onto the still image.

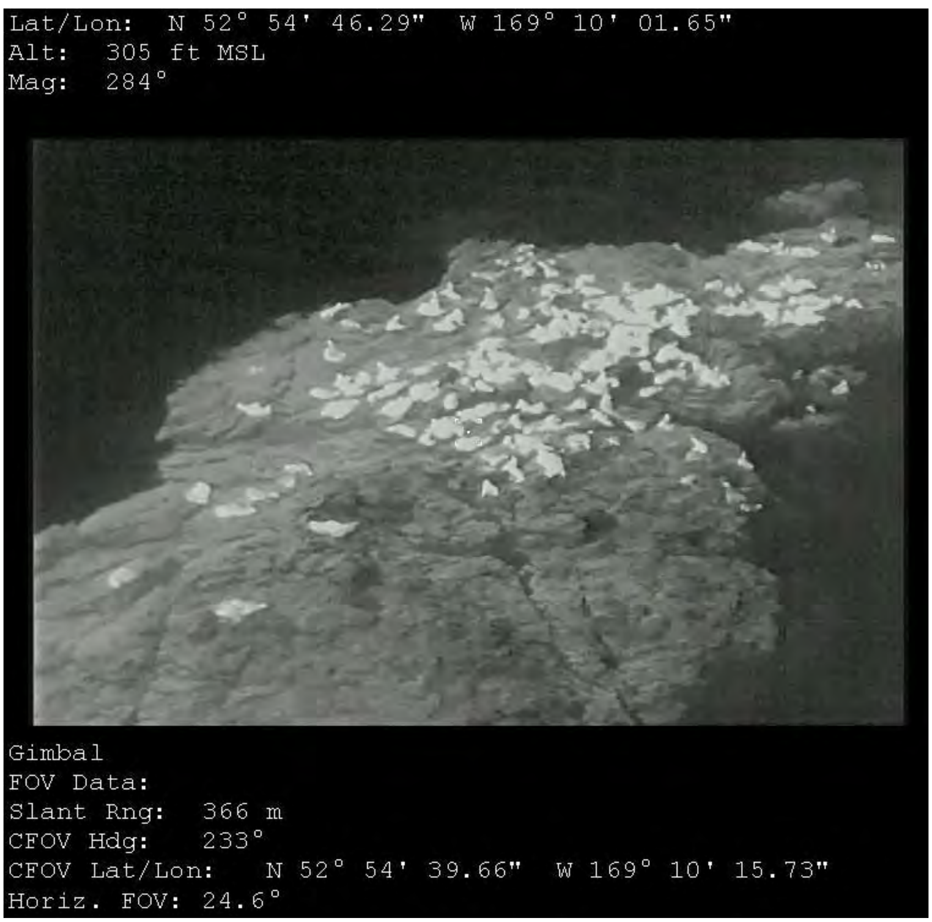

Figure 23: Thermal Infrared Image with Metadata Branded in the Image Collar

The warm Steller sea lions are shown as white in this example of an infrared still-image from Adugak. The infrared camera can be switched between representing hot targets as either white or black, which assists biologists in discerning the animals against the background.

Hi-Resolution Still Images

High-resolution images of the animals were taken with the Scout, which carries a 5 megapixel GoPro camera with a fisheye lens. The camera is gimbal mounted and the pilot can point the camera in various directions. In Figure 24, several animals are shown hauled out on a beach at Rat Island with some recent snow. The image quality here is sufficient to classify the animals' age and sex. The image also shows two of the four legs on the Scout aircraft.

Figure 24: Typical High Resolution Image from Scout – Note the Image Distortion from Fish Eye Lens

Some Steller sea lion individuals can be identified by a unique serial number branded on its flank (Figure 25). These brands are made to the animals at their natal rookeries when they are one to two month old pups. The first letter in the serial number identifies the rookery at which the SSL individual was born. The original brand is two or three inches tall and grows in size with the growth of the animal.

The serial numbers are used to create a “resight” database. The seasonal and annual resighting of an individual animal helps to determine its regional movements and it’s mixing among other SSL populations. Identifying unique animals by branding also helps to assess maternal activity and age-specific survival rates.

Figure 25: Branded Animal – The Number 16 is Visible on its Flank

The same method was used by the biologists to count and classify the SSL using Adobe Photoshop software and a counting script (Figure 26, Table 6). The airborne imagery collected with the UAS can be used to count and classify the animals. Figure 26 is of a haulout imaged by the Scout; the single scene can be used for the survey.

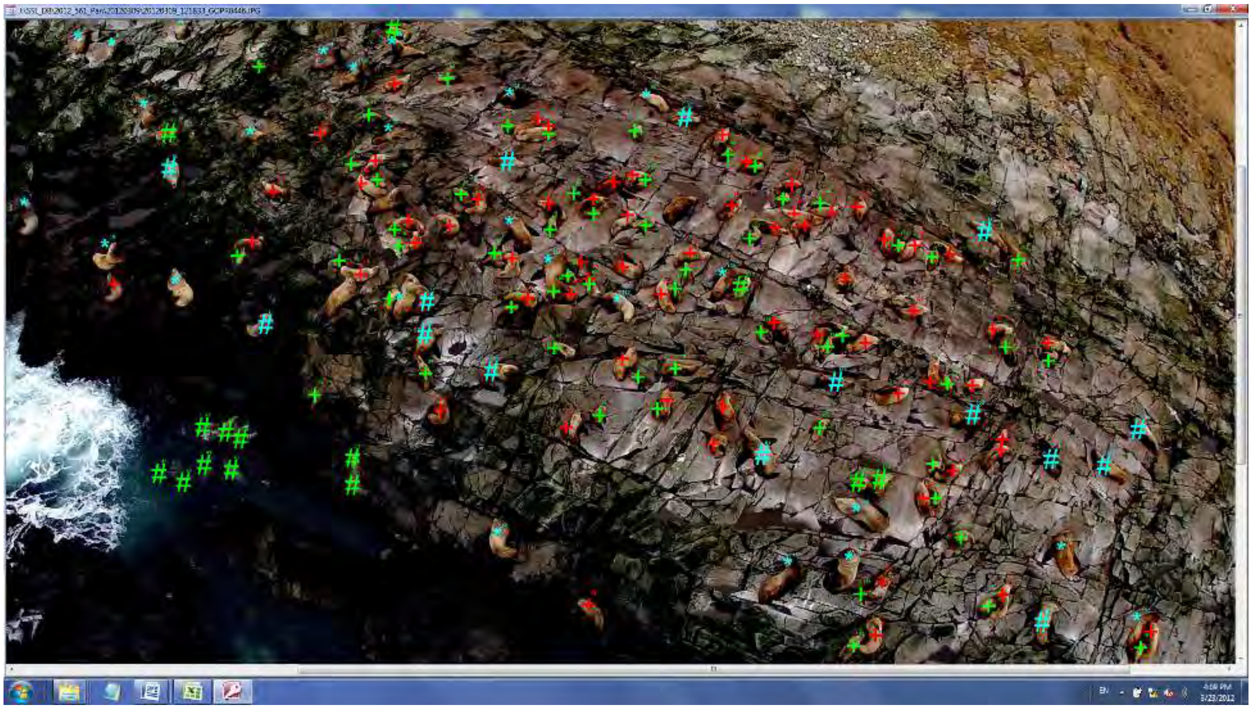

Figure 26: Aerial Image Used Counted by Biologists

The classification scheme here is the same for the counts performed with the non-airborne imagery.

Table 6: Same Count Classification Scheme as used earlier

Symbol	Code	Description
*	1TF	Male defending territory
*	2TN	Male not defending territory
*	3AN	Male (just another male)
#	4Sa	Sub adult male
+	5F	Female
+	6J	Juvenile
#	7U	Too little imaged to determine
+	8P	Pup
x	9DP	Dead pup

Many airborne images may be required to complete the count of the haulout or rookery is extensive, or there are a large number of animals present. Though it was not a stated research goal of the project, the investigators wanted to determine if image-processing software could be utilized to generate single mosaics from tens or even hundreds of individual images. They also felt that it would be desirable to georeference the mosaics, which would make them more useful when integrated into a geographic information system.

30 individual images were stitched together to create the mosaic (Figure 27) from Rat Island. Significant image overlap – of about 80% or more – is required for the software to make this process work. The mosaic process also reduces the image distortion of the fish-eye lens.

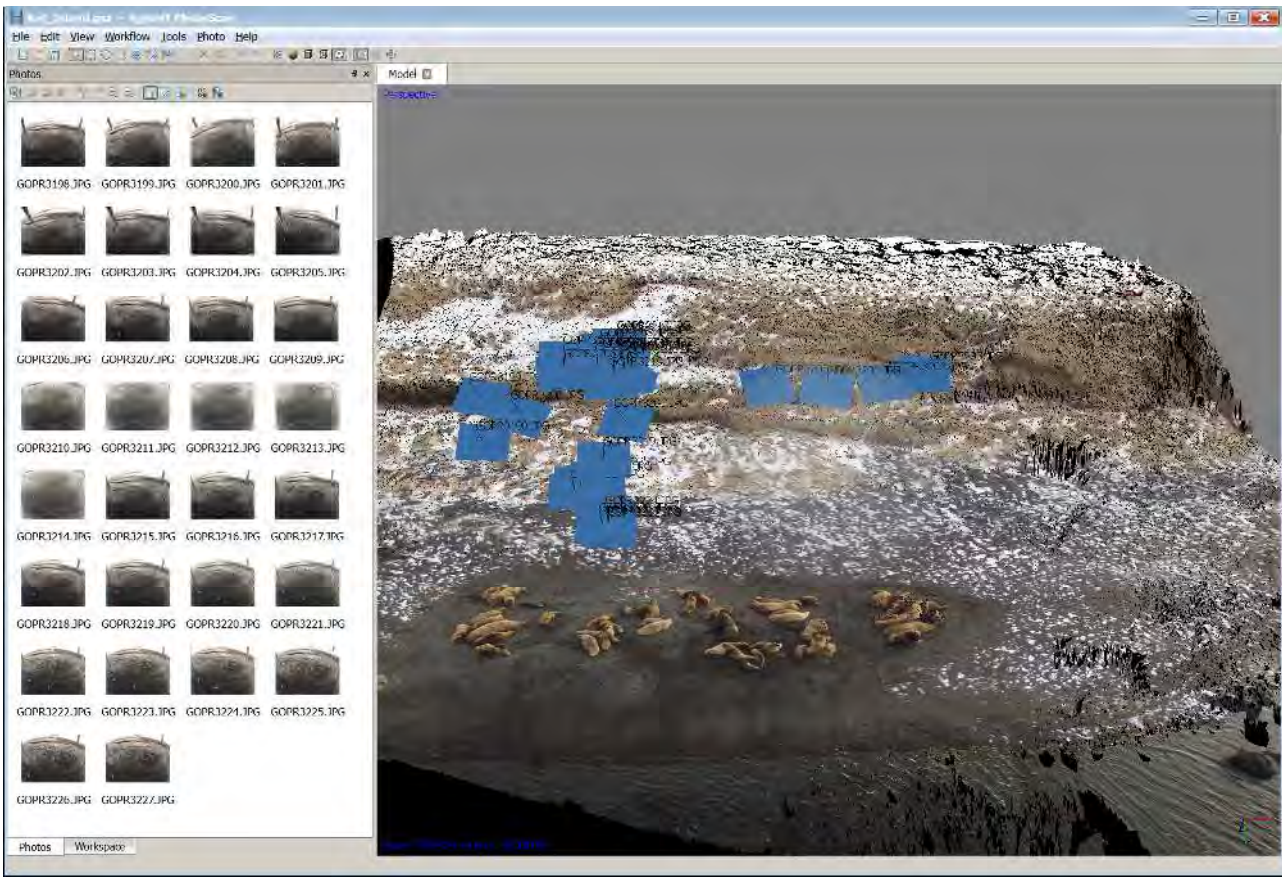

Figure 27: Mosaic Created from 30 Individual Still Images. Camera Position is represented by Blue Squares

The mosaic software calculates the position and orientation of the camera on the UAS. Figure 27 shows the resulting mosaic viewed from an oblique angle. The camera positions are represented by a blue frame that shows its position and orientation. This perspective can be changed so that the observer can look at this photo-model from any desired location. If the image metadata has position coordinates, the software will utilize the information to embed georeference data into the mosaic.

This technology is called structure from motion because it uses the moved location (motion) of the camera to reconstruct the image as a depth field (structure) from all of the images. The concept is that the parallax from many images at changing locations can render the three-dimensional depth of features in the overlapping images. Every pixel in every image is mathematically repositioned into its near-true coordinates relative to every other pixel's coordinate.

A very helpful discovery relevant to mosaic-making was made in the course of this project: the camera does not need to be pointed straight down at the ground (nadir) to collect imagery that can be mosaicked. As mosaic can still be created with oblique imaging, the UAS does not have to fly or hover directly over the animals.

A digital surface model upon which images are draped is another interesting data product which is native to the structure from motion technology (Figure 28). The surface model is a wireframe with a height (Z) coordinate for each XY map coordinate. In the example below, the SSL appear as hummocks on the smooth beach. Note that the spikes are the water surf – because the surf changes position in each image, it creates noise in the structure from the motion process. This noise can be removed with some manual data processing but is irrelevant to the SSL counts.

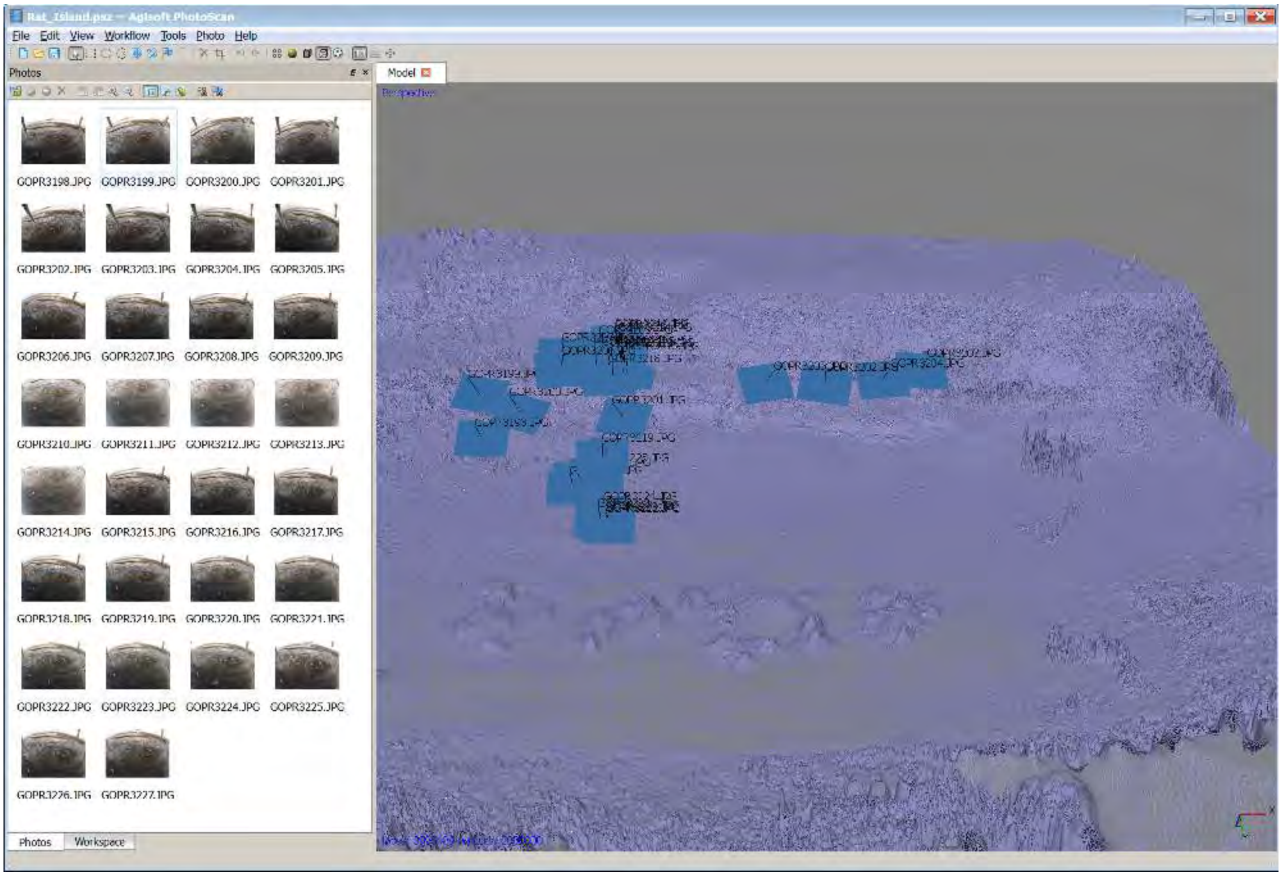

Figure 28: Three-Dimensional Wireframe Model Used in the Ortho-Mosaic Process

This image-draped three-dimensional wireframe allows the photo model to be rotated, panned, and zoomed. As this may make it possible to estimate the actual size of individual animals, we are currently considering how this capability could be of use to NMML biologists. UAF is continuing research into the structure from motion technology, paying considerable attention to determining optimum camera, lenses, and focal lengths, as well the optimal UAS altitudes that would maximize the accuracy of the three-dimensional depth field.

The data products created by these mosaic and wireframe techniques are very large. But geographic information systems technology can readily use the two-dimensional mosaics and ortho images. The structure from motion software used is called Photoscan and is produced by Agisoft in St. Petersburg, Russia. While other users such as biologists can purchase and use the Photoscan software for their own analysis, the three-dimensional photo models can be exported in many other formats, including Adobe PDF. Even as a PDF, the user can rotate, pan, and zoom in the wireframe and photomodel.

Conclusions

The goal of this research project was to determine the ways in which the use of UAS could augment the counting of endangered Steller sea lion populations in the Aleutians western district population segment (WDPS). As part of this broader objective, the team investigated the following: the components of UAS survey operations; the appropriate UAS to select for the Aleutian environment; the performance of each UAS selected for the project during the March NMML diet study; the way in which the UAS may effect SSL “takes”; and how the research findings may be disseminated through public outreach.

UAS Components

Integrating UAS into the NMML assessment mission required several considerations. First, the UAF team coordinated with the NMML biologists – who were to study the SSL winter diet and perform the manual survey counts – in order to define the area of interest for the airborne surveys. The lengthy process of obtaining an FAA certificate authority for operating UAS in commercial airspace helped the team to develop procedures for safe aviation and airspace management; understanding the iPASS radar system was critical in this regard. The other components of the UAS mission – including pilots, observers, and data processing support – would be determined after the selection of the UAS platforms to be evaluated. Determining and chartering a suitable research vessel for the cruise was another important factor in the planning stage.

UAS Selection

The team only considered small UAS for the project in order to preclude the specialized equipment needed to launch and recover larger aircraft. Thus, the Boeing ScanEagle was ruled out on account of its large footprint. The ATI Resolution was also excluded because the prototype was not operational at the time of the cruise. The team was thus left to select the AeroVironment PUMA and the Aeryon Scout. The Scout's vertical take-off and landing capability make it particularly suitable for launch and recovery from a ship's deck. The Puma, on the other hand, is hand launched and must be recovered at sea after splashdown. Standard electro-optical cameras capable of streaming video and high-resolution images in both color and infrared were fitted to the UAS.

UAS Operations

Both the Puma and Scout were employed when adverse weather conditions did not preclude their operation; however, conditions were sufficiently calm to allow for flights in only nineteen of the potential forty-nine missions. In calm winds, the Puma's longer endurance made it an effective tool for locating SSL haulouts. The Scout operated better in brisker winds and its ability to hover ensured that adequate numbers of high-quality images could be collected. The Scout’s ship-based recovery had advantages over the Puma’s water recovery, but the fact that the Puma is marinized is an important consideration given an emergency scenario in which a splashdown recovery may be the only option.

UAS Evaluation

Both the color and infrared imagery allowed the team to make accurate counts of the animals. However, the biologists' classification of individual sea lions according to sex and age required high-resolution still images. When counts required more than one image, mosaicking software made it possible – provided there was sufficient image overlap – to process many images into a georeferenced mosaic.

Neither UAS was found to be an ideal match for the mission of surveying SSL populations in the Aleutians. While each aircraft supplemented the assessment team's ability to locate and produce imagery of SSL populations, the animal counts collected by the flights are speculated to provide more complete and accurate counts, especially after the individual aerial images have been mosaicked into a single image of the SSL resting place. A more reliable and effective UAS design that is better able to withstand Bering Sea winds will be required if the NMML is to justify the operation of UAS for wildlife population assessments. For example, a slightly heavier hexacopter airframe would likely provide better performance in winds than the quad-rotor design of the Scout.

Such a hexacopter airframe was developed by UAF in 2014 anticipating that the airframe design with two extra rotors would provide enhanced stability in gusting winds, thus meeting the challenges of the Aleutian operating environment. The hexacopter is also slightly heavier because of larger batteries, thus provides improved image stabilization. The costs for building the UAF hexacopter are $15,000, about one fifth the cost of the off-the-shelf Scout. This new airframe would be a prime candidate for additional testing for SSL imaging in the Aleutians.

Management & Policy Implications

Two important conclusions can be made from this research.

First, unmanned aircraft systems can significantly augment the survey methods of Steller sea lions by providing biologists a tool to collect imagery of haulouts, rookeries, and beaches to count the animals. We demonstrated that the aircraft could be easily deployed and operated from ships and shore, in a variety of weather, including circumstances that would limit manned aviation for safety concerns.

Second, the small UAS operate quietly. The low noise profile made it possible for the team to operate at a much lower altitude than manned aircraft; this in turn allowed the UAS to collect a greater quantity of detailed imaging data. Flights were typically conducted at an altitude range of 50-75 feet above the animals. Biologists on shore who monitored the behavior of the animals when the UAS were overhead could not conclusively determine if any disturbances occurred that were attributable to the presence of aircraft.

There are policy implications from these findings that can be applied to the improved management of the Steller sea lion population.

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Outreach

Unmanned aircraft systems are essentially flying robots, and as such project a particular charisma that is attractive to experts and laypersons alike. Additionally, UAS' high-profile military applications, along with the privacy concerns that have arisen concerning their use, have put the machines in the public eye. The UAS technology used by the NMML and UAF in the Steller sea lion assessments may thus serve to make the project a high-profile draw among the general public. Presenting the project in public venues could serve the dual functions of informing the public about SSL population decline, and highlighting the as-yet under-appreciated civilian applications of UAS technology. Featuring the project at science and nature centers worldwide may excite public interest and raise awareness of the research activities of the North Pacific Research Board and the National Marine Mammal Laboratory, and the University of Alaska Fairbanks' leadership in UAS technology.

The outreach element of the SSL assessment intended to generate an awareness of both the project and the NPRB, and to stimulate interest in its work. It will also attempt to incorporate audience feedback about the project to the greatest extent possible. Though educational in nature, the outreach incorporates an exciting story calculated to efficiently and effectively reach multiple audiences. The outreach strategy only requires slight adjustments to account for the varying interests and understandings of the target audience and venue, whether that be schoolchildren, the general public, interest groups, commercial organization, scientists, or lawmakers.

Aside from the project's obvious "wow factor," it is attractive to the public for two reasons. First, the assessment project's concerns – endangered species and commercial fishing interests – are highly visible public interests. Second, the high-resolution mapping products created by the project are fairly easy to interpret.

The outreach plan includes three elements, each of which contributes to the presentation's goal of developing a succinct narrative that can be easily digested by general audiences.

Written: The storyline for this project is newsworthy, innovative and accessible, thus creating a compelling message.
Graphical: The visual nature of the UAS in flight, the images captured, and the charismatic Steller sea lions all contribute to the creation of interesting posters and graphical presentations.

Video: The research story is easily “told” in the form of a news story or a short educational video (three-to-five minutes) that may be easily distributed via the internet.

Following initial planning phase, the “show” went on the road. First, the written story was shared with the press, and the video with TV news programs. The graphic presentation material was taken to multiple meetings and venues at which the audience had an interest in the research findings. The specific ways in which the story was shared depended on the venue and audience. Presentation sites included the following:

<u>2012 Outreach History</u>

Science for Alaska lecture series, with public lectures held in Nome (January 11, 2012), Fairbanks (January 31, 2012), Juneau (April 18, 2012), and Anchorage (April 24, 2012).

Unmanned Aircraft Drone Test Flights in the Western Aleutian islands for Potential Use in Steller Sea Lion Surveys, March 26, 2012. Public outreach to the community of Dutch Harbor at the Museum of the Aleutians.
http://www.aleutians.org/Lectures.html

Presentation to the science class at the Dutch Harbor High School on March 26, 2012.

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