

THE FEASIBILITY OF EXPANDING A REMOTE UNCREWED AIRCRAFT SYSTEM (UAS) INSPECTION & RESPONSE TEAM PROGRAM IN THE BERING STRAIT & OTHER REGIONS: A CASE STUDY

*A Technical Report developed in partial fulfillment of the requirements identified in the project,
“Remote Unmanned Aircraft System (UAS) Inspection and Response Team Development in the Bering
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Land Acknowledgement

The focus of this work is on the traditional lands of the Inupiat and Yupik people in an area that is known today as Unalakleet, Alaska.

The University of Alaska Fairbanks is located on the traditional land of the Lower Tanana Dene people in an area that is now known as Fairbanks, Alaska.

The Model Forest Policy Program's home base is Bonner County, Idaho, the traditional lands of the Kalispel, speakers of a dialect of Interior Salish.

Whistling Thorn Strategies is based in Montgomery County, Pennsylvania, lands traditionally inhabited by the Lenni Lenape people, an Algonquin speaking tribe.

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Cover Photo: Sunset over Norton Sound. Unalakleet AK (February 2022). *Photo Credit: Mike DeLue*

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EXECUTIVE SUMMARY

INTRODUCTION

Background

This document, *The Feasibility of Expanding a Remote Uncrewed Aircraft System (UAS) Inspection & Response Team Program in the Bering Strait & Other Regions: A Case Study* (Case Study), is part of *The Remote Uncrewed Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region* (UAS Project). Funding for both the project and this document comes from the Arctic Domain Awareness Center (ADAC), A Department of Homeland Security Center of Excellence. ADAC is housed at the University of Alaska - Anchorage. Funding was awarded in the fall of 2020. This ADAC project wrapped up in April 2022 while the Native Village of Unalakleet's UAS Program was taking off.

The project team is led by Dr. Jessica Garron, Principal Investigator - Research Faculty, International Arctic Research Center, University of Alaska Fairbanks (UAF). Co-Investigators are: John Henry Jr, Deputy Director, Native Village of Unalakleet (NVU); Margaret Hall, Associate Director, Model Forest Policy Program (MFPP); and CDR Jereme Altendorf, U.S. Coast Guard (USCG) Sector Anchorage. The Project Champion is CDR Chad Thompson, USCG HQ. Other University of Alaska Fairbanks (UAF) team members include: Andrew Wentworth, Mike DeLue, and Sam Jeffries. Two other team members are: Katie Daniels, Native Village of Unalakleet Pilot in Command, and Barbara Cozzens - Principal, Science-Based Economics, Whistling Thorn Strategies.

Approach

This Case Study draws on the current Remote Unmanned Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region project, building on work completed by much of the core team under a 2018-2020 Bureau of Indian Affairs (BIA) tribal resilience planning project. Further this study includes responses received and trends indicated in the spring 2022 Community Survey; the assessment of regional critical infrastructure and emergency response information; and finally, a cost analysis of UAS program implementation models in Alaska's Norton Sound Region. Together these different perspectives inform the recommendations found in this document.

ESSENTIAL OPERATIONAL COMPONENTS OF A UAS PROGRAM UNDER EVALUATION

The essential operational components under evaluation in this Case Study are the approach and outcomes for four key areas of a UAS program: Pilot Recruitment and Training, Equipment Management, Data Management and the development of a UAS Operations Center. Included in this section are the methods and outcomes of the team approach to pilot recruitment, pilot employment, training for their FAA Part 107 certification, and the hands-on training support for the UAS team. Also in this section is a thorough description of the hardware and the logic path for its selection, as well as for the selections of drone-captured imagery processing software, and the data products that can be created using the processing pipeline in place through this program. The components of a UAS program that are critical to its success, but often overlooked such as contracting mechanisms, secure storage, communications pathways and uncontrollable variables that can impact a UAS mission are highlighted. This section is the roadmap for future UAS team establishment programs.

SUMMARY OF LESSONS LEARNED

For each of the operational components evaluated, a set of descriptive lessons learned from the execution of these components are offered for consideration. These lessons learned are intended to go hand-in-hand with the UAS team establishment roadmap, to help stakeholders interested in establishing a UAS program like this one in either another community or USCG Sector, while taking advantage of the specific success and fail points that influenced the outcome of this UAS program. Of the larger lessons learned was that UAS program establishment must have at least one champion to ensure its establishment in the community. Included with these reflections are the results of a community survey highlighting community perceptions of need and placement for UAS support in rural Alaskan communities.

CRITICAL REGIONAL INFRASTRUCTURE & EMERGENCY RESPONSE INFORMATION SUMMARY

Prior to an actual emergency situation, key critical infrastructure and vulnerable (subsistence) assets located in NVU and other Bering Strait communities should be identified and prioritized for imaging during an ER event for situational awareness. In this section, a review of community plans and other document resources that identify critical infrastructure and/or emergency response information, for Unalakleet and other communities in the region are discussed, including Hazard Mitigation Plans (HMP) and Small Community Emergency Response Plan (SCERP) key components. HMPs can provide information on asset location (Lat/Long), estimated number of occupants, ownership type, type and value of assets, and vulnerability to certain risks. Other detailed community information can be found on the Alaska Department of Commerce, Community, and Economic Development - Division of Community and Regional Affairs (DCRA) website. Other information on critical infrastructure and ER assets came through discussion with local and regional decision makers and potential UAS data users, and via responses to a community survey. Survey respondents indicated the top three emergencies their communities were most capable of responding to were: storm surge; Search and Rescue – Land; and Search and Rescue – Marine. The three emergencies indicated that their community was least able to respond to were Oil Spills; Marine Infrastructure Damage (e.g. docks, piers, fuel distribution hook-ups, etc.); and Transportation Infrastructure (runway, bridges, roads).

COST ANALYSIS OF UAS PROGRAM IMPLEMENTATION MODELS IN ALASKA'S NORTON SOUND REGION

A cost analysis was undertaken to estimate and analyze the total and incremental costs of all resources required to implement a UAS program in practice. Cost inputs were obtained from expert sources, market research, and a document review. Costs were analyzed for three implementation scenarios. Each scenario assumed two sets of two UAS pilots utilizing two Skydio X2E drones. Scenario 1 analyzed costs for a community with a population of up to 1,000. Scenario 2 modeled costs for a community with a population between 1,001 and 5,000. Scenario 3 looked at costs for a regional service delivery program based in Unalakleet. No attempt was made to quantify the economic benefits of such programs, notably the impact of improvements in the frequency or efficacy of a UAS program compared to traditional approaches.

Total costs to operationalize a UAS program, incorporating both start-up and program delivery costs for 2 years, were \$205,390 (Scenario 1), \$268,072 (Scenario 2), and \$1,639,446 (Scenario 3). In all three scenarios, personnel accounted for a significant portion of program delivery costs: 81%, 86%, and 78% of the total, respectively. These results are based on a set of assumptions believed to be reasonable given available or known information, however many of these assumptions can be varied as the

scenarios are optimized. For example, the number of pilots can be reduced based on budget or mission demand. Further analysis and more data are needed to develop optimized programs for using UAVs at a local scale.

RECOMMENDATIONS

Synthesizing the Case Study, lessons learned, regional critical infrastructure resources and the cost analysis, a set of recommendations was developed for the implementation of this UAS program roadmap in other rural communities. The recommendations fall into the three broad categories, focused on Alaska, with specific and actionable components described therein: Develop Regional UAS Teams Throughout Coastal Alaska, Leverage Current Programmatic Structure Regionally, Develop Support Structure for Regional UAS Team Longevity. These recommendations highlight the crucial components of recruitment, training, program establishment and longevity support that are required for the successful implementation of this UAS program roadmap.

CONCLUSIONS

The conclusions of the study pivot around one central tenet, that the most significant outcome of this project is a well-trained, fully-functioning, UAS team in western Alaska with known capacity that can be contracted for their services to provide salient and legitimate near real time data for and from the region. This program provided far greater value and return on investment than the creation of the NVU UAS Team alone, but without the holistic development of that team, the resulting program establishment roadmap, lessons learned, and synthesis of recommendations for other communities and USCG Sectors would not have been possible.

REFERENCES/RESOURCES

References and resources included in this document are limited to, 1) The published materials used in the NVU Part 107 Training, and 2) Footnote References.

APPENDIX

Four appendices are included as part of this Case Study. Appendix A is the Native Village of Unalakleet (NVU) Uncrewed Aircraft Systems (UAS) Pilot Application that was created for pilot recruitment. Appendix B, Cost Analysis/Assumptions Related to Cost Ingredients, is the appendix that accompanies the Case Study's section 5. Cost Analysis of UAS Program Implementation Models in Alaska's Norton Sound Region, the summary report prepared by Barbara Cozzens, Whistling Thorn Strategies. Appendix C, Native Village of Unalakleet Uncrewed Aircraft Systems (UAS) Standard Operating Procedures. Appendix D is a compilation of the NVU UAS flight protocols as, Appendix D1: NVU UAS Infrastructure Inspection Protocol, Appendix D2: NVU UAS Oil Spill Detection and Monitoring Protocol, Appendix D3: NVU UAS Flood Delineation Protocol, Appendix D4: NVU UAS Search & Rescue Protocol.

ABBREVIATIONS & ACRONYMS

2D - Two-dimensional

3D - Three-dimensional

AQI - Air Quality Index

BVLOS - Beyond visual line of sight

COTS - Commercial off-the-shelf technology

DOM - Dissolved Organic Matter

DSM - Digital surface models

EO - Electro-optical sensor; RGB sensor; passive sensor

FAR - Federal Aviation Regulation

FLIR - Forward-looking infrared

GPS - Global positioning system

LIDAR - Light Detection and Ranging sensor; active sensor; uses pulses of light energy reflected off of a target to create a 3D map of surface characteristics

NDVI - Normalized Difference Vegetation Index; an indicator of plant community health and seasonal variability, through the relation of plant biomass to photosynthetic activity

Photogrammetry - Science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena.

RGB - Electro optical sensors operating in red, green and blue visible spectrum

RS - Remote-sensing; process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft)

SAR sensor - Synthetic aperture radar

SfM - Structure from Motion; a data processing methodology to create 3D maps from EO data.

sUAS - Small unmanned aircraft system, less than 55 lbs. gross take-off weight

UAS - Unmanned aircraft system; consists of aircraft, power source, payload, ground-controller station

UAV - Unmanned aircraft vehicle

Utilidors - Aboveground, insulated network of pipes and cables, used to convey water and electricity in communities situated in areas of permafrost.

VTOL - Vertical Take-Off and Landing; refers to a UAS that takes-off and lands vertically, but flies operationally horizontally

1. INTRODUCTION

1.1. BACKGROUND

1.1.1. Project Funding

Funding for *The Remote Unmanned Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region* (UAS Project), under which this document, *The Feasibility of Expanding a Remote Uncrewed Aircraft System (UAS) Inspection & Response Team Program in the Bering Strait & Other Regions: A Case Study* (Case Study) falls, comes from the **Arctic Domain Awareness Center (ADAC), A Department of Homeland Security Center of Excellence**. ADAC is housed at the University of Alaska - Anchorage. Funding was awarded in the fall of 2020. This ADAC project wrapped up in April 2022 while the Native Village of Unalakleet's UAS Program was taking off.



1.1.2. Project Team

Principal Investigators

- Dr. Jessica Garron, Research Faculty, International Arctic Research Center, University of Alaska Fairbanks (UAF)
- John Henry Jr, Deputy Director, Native Village of Unalakleet (NVU)
- Margaret Hall, Associate Director, Model Forest Policy Program (MFPP)
- CDR Jereme Altendorf, U.S. Coast Guard (USCG) Sector Anchorage

Project Champions

CDR Chad Thompson, USCG HQ

Other Project Team Members

- University of Alaska Fairbanks (UAF)
 - Andrew Wentworth
 - Mike DeLue
 - Sam Jeffries
- Katie Daniels, Pilot in Command, Native Village of Unalakleet
- Barbara Cozzens - Principal, Science-Based Economics, Whistling Thorn Strategies

1.1.3. Project Overview

Overall Project

For the northwestern coastal Alaska Native communities in Norton Sound and the Bering Strait, oil spills are of increasing concern and have grown in probability because of the reduction in sea ice and climate change. More on-the-ground monitoring of a community's infrastructure (e.g. bulk fuel tanks and water tanks) has become critical, especially for those structures that may be located in coastal inundation or flood zones or on thawing permafrost. Search and Rescue efforts have become more challenging because of the shifting climate in the region. The *Remote Uncrewed Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region* (UAS Project), is designed to develop the use of UASs to increase situational awareness with regards to oil spills, as well as the use of UASs in assessing critical community infrastructure and responding to Search and Rescue missions.

The project Principal Investigator is Dr. Jessica Garron, Assistant Research Professor at the International Arctic Research Center, University of Alaska Fairbanks (UAF). Project co-investigators include the Native Village of Unalakleet (NVU) Lead, John Henry Jr., NVU Deputy Director; Margaret Hall, Associate Director of the Model Forest Policy Program (MFPP); and Commander Jereme Altendorf, Arctic Emergency Management Specialist, USCG Sector Anchorage. John Henry was the Project Lead on the initial BIA-funded *Feasibility Study*, described below in the Prior Project (2018-2020) section.

The UAS Project has focused on accomplishing the following objectives:

Train pilot teams in the regional hub of Unalakleet to

- Acquire real-time/near real-time situational awareness.

Develop operational UAS protocols to

- Monitor infrastructure for compliance and potential oil discharge prevention by developing infrastructure inspection protocol, specifically bulk fuel tank farm; and
- Support emergency response through regional preparedness by developing Search and Rescue, oil spill detection and mapping, and flood mapping protocols.

Conduct Bering Strait regional feasibility assessment to

- Use as a possible case study by U.S. Coast Guard (USCG) and other interested stakeholders for additional implementation.



Figure 1.1. Provides a snapshot of the project components starting with “UAS Pilot

Case Study

This document, *The Feasibility of Expanding a Remote Uncrewed Aircraft System (UAS) Inspection & Response Team Program in the Bering Strait & Other Regions: A Case Study* (Case Study), is part of the larger *Remote Uncrewed Aircraft System (UAS) Inspection & Response Team Program in the Bering Strait & Other Regions* (UAS Project). This Case Study is designed to evaluate the current NVU UAS Program components and findings (lessons learned) for consideration prior to developing a regional program or team expansion, and to highlight critical regional infrastructure and emergency response information required for efficient emergency response support.

The *Case Study* also includes a cost-feasibility analysis (CFA) done by Barbara Cozzens of Whistling Thorn Strategies. The CFA component analyzes the following three scenarios/models, assuming a UAS program with two sets of two pilots:

- Population up to 1000 (e.g. Elim, Koyuk, Unalakleet, etc.)
- Population up to 5000 (e.g. Nome, Home, etc.)
- Regional Scenario

Costs for four main resource categories (Personnel, Materials and equipment, Facilities, and Other inputs) are analyzed through a Theory of Change lens.

The recommendation section discusses possible improvements to the program and/or how it might be expanded regionally.



Figure 1.2 (Above). NVU UAS pilot K. Daniels and Skydio trainer J. Garcia flying a 3D scan during on-site flight training. *Photo credit: MDeLue.*

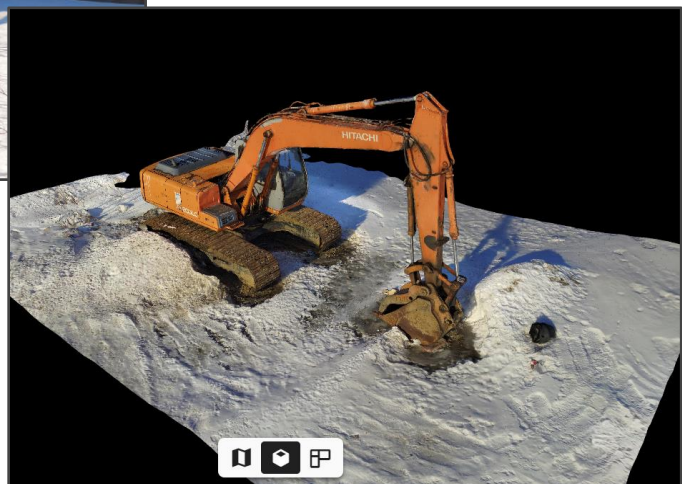


Figure 1.3 (Right). 3D image created by DroneDeploy.

1.2. APPROACH

In addition to the work that has been done under the current UAS Project, *The Feasibility of Expanding a Remote Uncrewed Aircraft System (UAS) Inspection & Response Team Program in the Bering Strait & Other Regions: A Case Study* builds on the prior 2018-2020 Bureau of Indian Affairs (BIA) project; the responses received and trends indicated in the Community Survey sent out the first part of 2022; the assessment of regional critical infrastructure and emergency response information; and finally, a cost analysis of UAS program implementation models in Alaska's Norton Sound Region. Together these different perspectives help to inform the recommendations found in this Case Study.

1.2.1. Prior Project (2018-2020)

The current UAS Project builds on a 2018-2020 BIA project, led by John Henry of NVU, *The Feasibility of Improving Local Decision Making in Alaskan Communities with Unmanned Aircraft Systems and Online Climate Data Tools (BIA Project)*,¹ a project that analyzed the feasibility of establishing a regional data collection program utilizing an uncrewed aircraft system (UAS) compared to other collection systems.

To address the climate risks that NVU and other Norton Sound Native Villages face, research was conducted under nine scientific study areas illustrated in the synthesis represented in Figure 1.2, created by Anne Jess of The Doodle Biz.

The study areas provided the framework for the project outcomes. Individual components included: UAS Operational Solutions Matrix, Online Tools Comparison Matrix, Environmental Monitoring with Unmanned Aerial Vehicles: Cost Estimating & Analysis, Integration and Applications of UAS and Online Climate Tools Data - Document Review, Partnership Options/Considerations template, and a related stakeholder survey summary.

Findings of this first project indicated that the development of a regional program was of high interest and it was worth taking steps toward implementation.

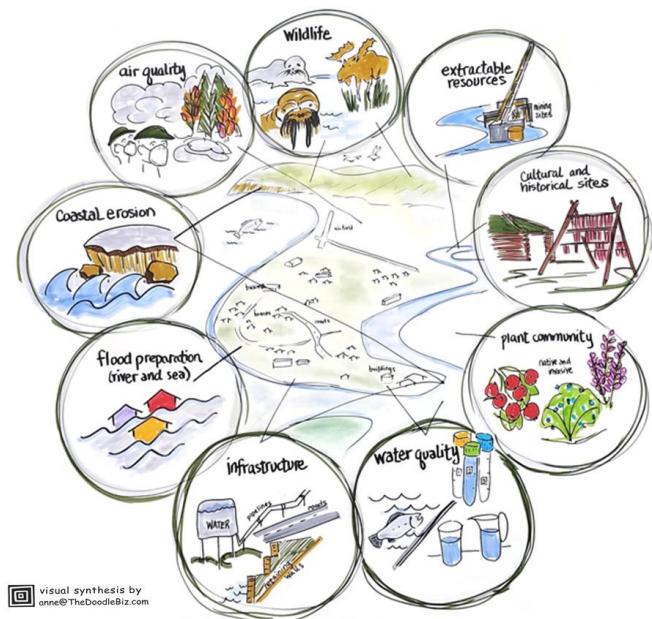


Figure 1.4. Graphic depiction of the nine scientific study areas examined as part of the precursor *The Feasibility of Improving Local Decision Making in*

¹ The final BIA Feasibility Study is online at: <https://drive.google.com/file/d/1fBel0tvS0rSP11Sf2o-WpvsXpHpXwPQ0/view?usp=sharing>.

1.2.2. Regional Community UAS Needs

In assessing potential expansion of the current UAS Project into a sustainable program, understanding the level of interest and relevancy of UAS-based infrastructure inspection and emergency response needs are important. To do so, a contact list of was developed that included potential stakeholders in such programs such as Bureau of Indian Affairs (BIA) Indian Environmental General Assistance Program (IGAP) coordinators, public works staff, emergency responders and communications technicians, plus regional, state, and federal organizations and agencies active in the region (e.g. Kawerak Incorporated, Alaska Native Tribal Health Consortium, Denali Commission, Norton Bay Inter-Tribal Watershed Council, EPA, and Federal Emergency Management Agency). During the first quarter of 2022, individuals on this list were invited to complete the *Bering Strait Uncrewed Aircraft Systems (UAS) - Regional Feasibility Study: Community Survey (April 2022) (Community Survey)*. People could fill out the Community Survey online or by filling in and returning an attached pdf via U.S. mail; most chose the online option.

The Community Survey included 19 questions falling under the 6 sections: Survey Recipient Profile; Community Concerns & Responses; UAS/Drone-Related; Community's Internet Service; Additional Information or Comments; and (general) Follow-up. Over 110 people were invited to respond to the survey via email; 21 responses were received with 13 being fully completed. Though a somewhat low response rate (19%), some general trends were apparent. Overall, the collected responses indicate an interest in using UASs for Infrastructure Inspection and Emergency Response flights outside of the NVU, not only in the Bering Strait region, but other areas across Alaska.

In the Survey Recipient section, approximately 81% of respondents indicated that they live in their community as opposed to being located in a larger hub location. The role of those responding fell primarily into 4 categories: Tribal or City Department/ Program Staff member (24%); City Council Member (19%), Elder (19%), Regional Organizational Support (19%). For both questions, people could choose more than one answer.

Table 1.1 indicates the key assets that people were asked to prioritize for inspection, monitoring, and protection.

Table 1.1. Key assets that survey respondents were to prioritize for inspection, monitoring, and

List of Key Assets		
Government Offices	Wind Towers	Roads
School Buildings	Satellite Dishes or Cell Towers	Bridges
Subsistence Harvest Locations	Fuel Distribution Pipelines	Solid Waste Disposal Sites
Cultural Resources	Water Distribution Pipelines	Contaminated Sites
Community Store	Electrical Distribution Lines	Other
Fuel Tanks	Phone Distribution Lines	
Water Tanks	Airport and Airport Runways	

Survey respondents were then asked to prioritize those assets based on the three actions of Inspect, Monitor, and Protect. Table 1.2, below, identifies the four highest prioritized assets reported under each action.

Table 1.2. The four highest prioritized assets under each action.

Four Highest Prioritized Assets		
Inspect	Monitor	Protect
Solid Waste Disposal Sites	Fuel Tanks	Subsistence Harvest Locations
Fuel Tanks + Contaminated Sites + Roads	Solid Waste Disposal Sites	Cultural Resources
-	Contaminated Sites	Fuel Tanks
-	Electrical Distribution Lines	Contaminated Sites

Under **Inspect**, Solid Waste Disposal Sites were the top priority for UAS inspection flights, followed by Fuel Tanks, Contaminated Sites, and Roads, all of which received the same rating. The subsequent highest asset was Bridges. With regards to **Monitor**, Fuel Tanks were ranked as the highest priority, with a bit lesser priority for the next three. The highest priority for community stakeholders under **Protect** was definitely Subsistence Harvest Locations, followed by Cultural Resources, with less prioritization on Fuel Tanks and Contaminated Sites.

Survey recipients were asked to rank their communities' capacity to respond to a set of emergencies (Table 1.3). Emergencies identified in the left column indicate the three that individuals felt their community most ready to respond to; those on the right were seen as least able to respond to.

Table 1.3. Ranked perceptions of community capacity to respond to different types of emergencies.

Type of Emergencies		
3 Most able to respond to	Some response capacity	3 Least able to respond to
Storm Surge	Flooding	Oil Spill
Search and Rescue - Land	Wildland Fire	Marine Infrastructure Damage (e.g. docks, piers, fuel distribution hook-ups, etc.)
Search and Rescue - Marine	Land-based Infrastructure Damage (disrupting electricity, water, fuel, or communications access)	Transportation Infrastructure (runway, bridges, roads)
	Disruption in Food Delivery or Access to Local Subsistence Sites	

The Community Survey also asked the extent of emergency response planning, hazard mitigation or Search and Rescue plans that were known to have been undertaken in the community. With regards to the top three plans or planning efforts undertaken, a majority (70%) indicated their community had done some type of Search and Rescue planning (conceivably a table top exercise); 62% indicated that Hazard Mitigation Plan (HMP) had been; and 42% indicated so for a Small Community Emergency Response Plan (SCERP). The survey did not ask how recent that any planning efforts might have been. Over 58% indicated that they were not sure that a SCERP had been done, and 31% indicated they were not sure about whether an HMP had been or not. Those who indicated that no Brownfield Remediation Plan, HMP or SCERP planning had taken place, or there was no plan, were 27%, 23% and 8% respectively. Some of these planning efforts or plans may not have been relevant to the person responding.

The Community Survey further inquired about the use of, interest in, and/or support of small UASs (or drones) and local pilots within the community, the results of which are reported in Table 1.4. The majority of those who responded indicated that their community does not currently use drones to respond to or assess emergencies. When asked if they had an interest in using drones, on a scale of 0 - 5 with 5 being Extremely Interested, all responses were above 3, with the majority being 5.

Table 1.4. Current use and interest in using UAS to support community planning and decision-making.

**Round error in this line.*

Survey Question	Yes	No	Maybe
Are you interested in setting up a local drone program for your community?	67% (8)	8% (1)	25% (3)
Would you rather subcontract for drone services?	33% (4)	50% (6)	17% (2)
Are there already drone pilots in your community?*	42% (5)	17% (2)	42% (5)

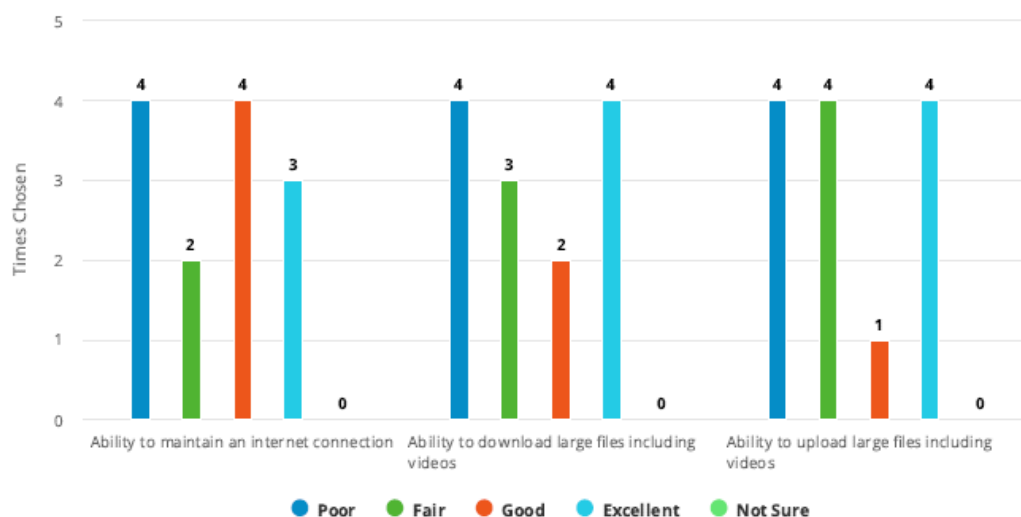
Regarding UAS/drone pilot training for respondents or their staff and whether they would participate in, or would support staff participating in such training, the majority of people responded “Yes”, especially if the training were held locally or regionally. People preferred that the local training were in-person but virtually, on a weekly basis, was acceptable. People had less interest in flying to Anchorage or Fairbanks for an intensive 2-day training.

People were further asked whether they would complete the training, or support their staff completing the training, if the FAA (Part 107) certification exam for UAS/drone pilots was available: Locally, Regionally, or Only in Anchorage or Fairbanks. Again, the majority of responses indicated that Locally or Regionally were the most preferred, though currently these are not options in Alaska.

Finally, in terms of current Internet Service, Graph 1.1 captures the level of service experienced for the respondent’s work location in the community. Data revealed that respondents were operating at the extremes of access, with either Poor connectivity, download, or upload capacity, or Excellent as the

Graph 1.1: Indication of level of current Internet service.

Number of responses: 13



dominant responses. As indicated, uploading and downloading data appear to be more challenging for internet access than maintaining a connection for more people, but it is unclear if these data are perception-based or if systematic network testing was included in their answer.

When asked if improvements in Internet connectivity and/or capacity in the community was expected in the next 2-3 years, out of thirteen (13) responses, the majority indicated Possibly (5), Likely (4), or Upgrade Pending (1). A shared comment stated, “Hoping Starlink will make a difference.”

1.2.3. Regional Critical Infrastructure and Emergency Response Information

To be better prepared for possible UAS missions that might be flown in the Norton Sound Area, this Case Study looks at identifying critical infrastructure, critical and vulnerable (subsistence) assets prior to going out on a UAS mission. In doing so, key community documents (e.g. Local Economic Development Plan, Hazard Mitigation Plans, and Small Community Emergency Plans) were reviewed and an online community asset matrix created. Initially, the process began with Unalakleet’s key community assets. In working to fill out the matrix, the NVU UAS pilot in command was concerned that the information being collected was culturally and security sensitive. To address this issue, with further investigation, it was determined that the same information of concern was actually highlighted in The City of Unalakleet Hazard Mitigation Plan (December 2015) under “Table 6-4. Unalakleet Critical Facilities & Infrastructure”. Hence, rather than “reinventing the wheel,” a recommendation was instead made to use the HMP as the initial resource for emergency response mission support.

Another community document, which a number of Alaska communities have completed, is a Small Community Emergency Response Plan (SCERP). This document outlines steps to be taken in case of an emergency and agencies and/or individuals to be contacted. For Unalakleet, its SCERP was last updated in July 2019. A third resource is the detailed community information found on the Alaska Department of Commerce, Community, and Economic Development - Division of Community and Regional Affairs (DCRA) website.

The above resources are complemented by additional information received during a roundtable discussion with local decision makers and potential users of UAS services on March 4th, 2022 during the project team visit to Unalakleet. Additional in-depth discussions held with regional organizations and responses received in the Community Survey conducted the first quarter of 2022 are also included.



Figure 1.5. UAS (Skydio X2E) scan of Unalakleet’s Bulk Tank Farm, March 2022. *Photo credit: MWHall.*

1.2.4. Cost Analysis²

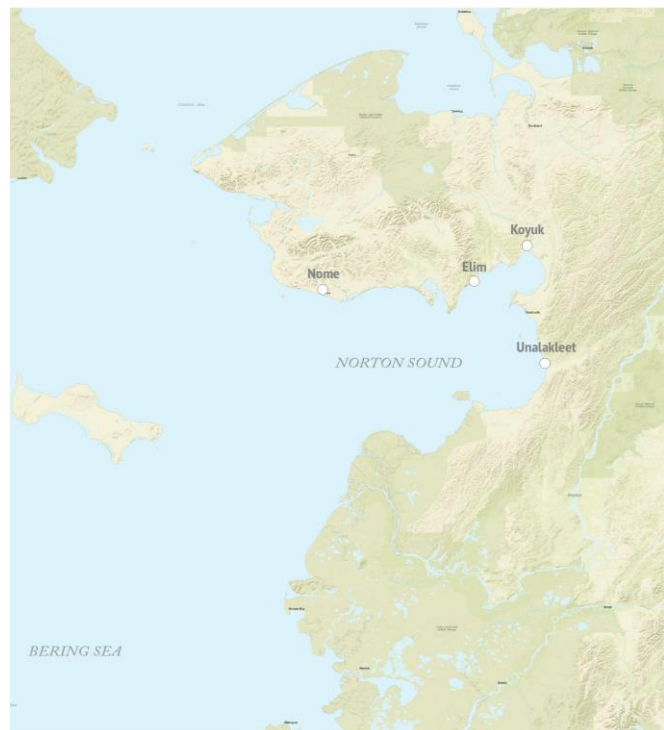
Barbara Cozzens of Whistling Thorn Strategies was commissioned to analyze the costs associated with the Case Study. Cost analysis is a systematic method for identifying and estimating the total and incremental quantity and economic value of all resources required to implement a program. Unlike a cost-effectiveness or cost-benefit analysis, a cost analysis strictly focuses on cost estimation, rather than return on investment. In the context of this study, no attempt was made to quantify the economic returns, namely the impact of improvements in the frequency or efficacy of a UAS program compared to traditional approaches.

Costs were analyzed for three implementation scenarios. Each scenario assumed two sets of two UAS pilots utilizing two Skydio X2E drones. Scenario 1 analyzed costs for a community with a population of up to 1,000. Scenario 2 modeled costs for a community with a population between 1,001 and 5,000. Scenario 3 looked at costs for a regional program based in Unalakleet.

The analysis incorporated four categories of cost inputs: personnel, materials, facilities, and other inputs. Data collected include: type, quantity, percentage of use, and price of all resources used to implement a UAS program over a 2-year period. Only costs directly related to the UAS program were included. For example, if a pilot spends two days per month on mission-related activities, only that percent -- 192 hours out of 2,040 working hours in a year, or 9.4% -- of his or her salary is included in final costs. The analysis assumed that the cost data collection and presentation both occur in 2022.

Outputs of this cost analysis include:

- Total costs by scenario
- Yearly estimated costs by scenario
- Cost per scenario by resource category
- Cost per tribal member



**Map 1.1. Map of Norton Sound/
Bering Strait Region.**

² The following Cost Analysis section is summarized from section 5. Analysis of UAS Program Implementation Models in Alaska's Norton Sound Region; the Case Study includes the full analysis prepared by Barbara Cozzens.

2. ESSENTIAL OPERATIONAL COMPONENTS OF A UAS PROGRAM UNDER EVALUATION

The following chapter discusses the individual components (Pilot Training, Data Management, and Essential Operational Components) that are critical for a successful drone program, and how to achieve them. These essential components and the methods used to achieve them as part of this project were part of the development of Unalakleet's community-based Uncrewed Aircraft System (UAS) response team program.

2.1. PILOT RECRUITMENT AND TRAINING

The most essential components to a commercially operating UAS program are qualified Part 107 Certified pilots. Without well-trained and certified individuals, there is not a program. Pilots acting as pilots in command must maintain their sUAS aeronautical knowledge currency (current licensure) per 14 CFR FAR 107.65, have a copy of their Part 107 on file with the UAS program, and have a copy of their Part 107 on the pilot's person during mission. Suggested qualifications for recruited pilots can be found in [Appendix A: NVU UAS Pilot Application \(Fnl 2-03-2021\)](#).

Salary information for pilots is contained in [5. Cost Analysis of UAS Program Implementation Models in Alaska's Norton Sound Region](#) and [Appendix B: Cost Analysis/Assumptions Related to Cost Ingredients](#).

Pilots must show proficiency in the following sUAS specific areas prior to becoming a crewmember:

- System Theory
- Assembly / Disassembly
- Operator Controls and interface
- Instrumentation Indications and Warnings
- Operating Procedures and Flight Dynamics
- Normal procedures
- Preflight
- Launch mission execution
- Recovery of the UAV
- Post Flight Procedures
- Emergency Procedures
- Mission Planning and Execution
- Basic Mission Types
- Payload Support
- Mobile Operations
- Airspace Coordination
- Frequency Coordination
- Collision Avoidance
- Two-Way Radio Communications
- General and Commercial Aviation
- Air Traffic Services

Pilots and other team members must demonstrate knowledge of the following regulatory areas prior to becoming a crewmember of an active mission. These can be found at: PART 91—General Operations and Flight Rules: <https://www.ecfr.gov/cgi-bin/text-idx?node=14:2.0.1.3.10>.

Subpart A - General

- [FAR 91.3](#) Responsibility and authority of the pilot in command
- [FAR 91.13](#) Careless or reckless operation
- [FAR 91.15](#) Dropping objects
- [FAR 91.17](#) Alcohol or Drugs
- [FAR 91.25](#) Aviation Safety Reporting Program

Subpart B - Flight Rules

- [FAR 91.101](#) Applicability
- [FAR 91.103](#) Preflight Action
- [FAR 91.111](#) Operating near other aircraft
- [FAR 91.113](#) Right-of-way rules: Except water operations
- [FAR 91.115](#) Right-of-way rules: Water Operations
- [FAR 91.117](#) Aircraft Speed
- [FAR 91.119](#) Minimum safe altitudes: General
- [FAR 91.121](#) Altimeter settings
- [FAR 91.125](#) ATC light signals
- [FAR 91.126](#) Operating on or in the vicinity of an airport in Class G airspace
- [FAR 91.127](#) Operating on or in the vicinity of an airport in Class E airspace
- [FAR 91.129](#) Operations in Class D airspace
- [FAR 91.130](#) Operations in Class C airspace
- [FAR 91.131](#) Operations in Class B airspace
- [FAR 91.133](#) Restricted and Prohibited areas
- [FAR 91.135](#) Operations in Class A airspace
- [FAR 91.137](#) Temporary Flight Restrictions (TFR's) in the vicinity of a disaster/hazard areas
- [FAR 91.141](#) Flight restrictions in the proximity of the Presidential and other parties
- [FAR 91.143](#) Flight limitation in the proximity of space flight operations
- [FAR 91.144](#) Temporary restriction on flight operations during abnormally high barometric pressure conditions.
- [FAR 91.155](#) Basic VFR Weather Minimums

2.1.1. Recruitment and Orientation Process

In early 2021, a framework was developed to provide remote training and to recruit UAS pilots living in the community of Unalakleet, AK for the UAS Program. Discussed below are the key elements of the framework, which are: Program Definition, Recruitment Webinar, Communications Tools, and NVU UAS Pilot Application.

Program Definition

During January and February 2021, the UAS Project Team mapped out and developed the Recruitment/Orientation process, identified the required instructional materials for trainees, and developed the UAS Part 107 pilot instructional content. During the organizational period, the UAS Project Team decided on several scenarios for class time, with the final decision made with input from the recruited pilots. During the Part 107 Training period, regular, remote, and weekly team meetings were held among core team members and the pilot trainees, with additional ad hoc meetings as needed for iterating on the program and completing deliverables. After the Training ended, the same weekly meeting schedule was continued in order to work on Standard Operating Procedures and Protocols for the program.

Recruitment Webinar

A two-hour Recruitment & Orientation webinar was developed by the project core team of Garron (PI), Henry (Co-I) and Hall (Co-I) and held over Zoom on February 25, 2021 to introduce the project to the community, stakeholders from around the state, and especially, potential pilots in Unalakleet. To engage key community members, and entice participation from a broad swath of the community, a set of formal invitation letters were sent to select members of the Unalakleet community specifically recruited for the program based upon current employment duties or expressed interest in UAS. In addition, webinar invitation letters were sent to community planners and managers, the local State of Alaska Troopers, the Village Public Safety Officer, members of the Kawerak regional tribal consortium, the Norton Sound Economic Development Corporation, the Alaska Department of Transportation (Aviation Division), and instructors of the Career and Technical Education program in the Bering Strait School District. The overarching objectives of the project, the methodology and roadmap for participation were shared with participants. The webinar was recorded and provided to all invitees and attendees at its conclusion. The entire project team was on-line to present and answer questions, as were project sponsors from the ADAC leadership team.

Communications Tools

With COVID making it impossible to meet in-person with either instructors or among community members, delivery of the Pilot Training program needed to take place remotely. In order to effectively train remotely, an investigation into available scheduled and non-scheduled content delivery tools was conducted. Two critical criteria of the communication tools identified were flexibility to support the needs of all project stakeholders (UAF, MFPP, NVU, USCG), and ability to work effectively with bandwidth constraints. The primary tools chosen for communication among the project team and partners were: **Zoom** for webinars, weekly meetings, and reporting to sponsors; **Google Drive** for archiving and sharing documents, presentations and other project content; **YouTube** for editing, archiving and distribution of project videos to pilots in training; **Facebook** for distribution of project

videos to pilots, and informal information sharing; text messaging and personal **phone** calls among team members is also utilized.

NVU UAS Pilot Application

The UAS Project Team developed a UAS pilot application for both program participation and as an employment application for the Native Village of Unalakleet, while simultaneously developing the recruitment webinar. The recruitment application highlighted the minimum requirements for employment with NVU, for the Part 107 certification, plus the general requirements and preferences for all aspects of the program, including familiarity with maps, and comfort using computers and radios. The application period lasted for three weeks and was a hard copy application that needed to be delivered in person to the tribal administration building. The position was described as a part-time, non-exempt, hourly, with a rate of \$39.49/hr. Posting for the application was circulated as other NVU employment opportunities plus included in the “Recruitment & Orientation” webinar that was held on February 25th.

The recruitment process resulted in three trainee pilot/co-pilot UAS teams (plus one back-up pilot/coordinator) identified in Unalakleet. Each person brought to the table diverse, but complementary, background and expertise that was anticipated to provide a strong support group for one another. A copy of the full application is available as **Appendix A. NVU UAS Pilot Application (Fnl 02-03-2021)**.

2.1.2. FAA Part 107 Pilot Training and Certification

The following section discusses the virtual FAA Part 107 Training delivered, issues related to the FAA Certification, and the co-production of Standard Operating Procedures (SOPs).

Remote Training

To conduct the remote training of the UAS pilots, the training materials were identified, developed, polished and then delivered. This effort incorporated reference materials, lessons learned and expertise from multiple UAS pilots that have been working in the industry for close to twenty years. This included the creation of a syllabus outlining the 8-week training program, the identification of hard copy and on-line resources for FAA Part 107 operations and exam certification preparation, a series of instructional PowerPoint Presentations, and the recordings of the training sessions which include personal lessons learned as well as multiple Q & A sessions that took place in an ad hoc fashion during training. The virtual platform used was Zoom. The sessions were recorded and made available through YouTube, Facebook, email and the Google shared folder to review as needed.



Figure 2.1. Hard copy FAA Part 107 study materials provided to each pilot trainee. Photo credit: MWHall.

Due to the delay in project establishment, project components that were intended to take place during winter months were shifted into the commercial fishing season, for which half of our NVU UAS pilots participated. The first virtual FAA Part 107 Remote UAS Pilot Training was held mid-April with six recruited trainees and one back-up/coordinator from Unalakleet. During the session, the group decided to hold regular, weekly team meetings for the training, with additional ad hoc meetings as needed for iterating on the program and completing deliverables. Besides covering the topics outlined in the syllabus below, pilot teams participated in six hours of collaborative review sessions about the laws and requirements for UAS flight in US airspace to pass the FAA certification exam independently. Additional instruction on lessons-learned during prior operations and specific instruction based upon the airspace and general conditions of the Norton Sound region were included.

The Part 107 8-week syllabus was broken down into the following topic areas (Lessons):

Week 1: Introduction

Week 2: Regulations General / Regulations Operating Rules / Regulations Certification /
Regulations Waivers

Week 3: Airspace Classification / Airspace Operating rules (Tom Elmer assisted)

Week 4: Weather Sources / Weather Effects on Performance

Week 5: Loading and Performance / Regulations 2021 alterations

Week 6: Operations Communications / Operations Airports

Week 7: Operations Emergencies / Operations ADM

Week 8: Operations Physiology / Operations Maintenance and Inspections

Seasonal employment opportunities impacted team cohesion as well as the timeline for pilot certification by the FAA. The part-time training program could not compete with full-time seasonal employment opportunities for some of the participants, and participants began to leave the program. The virtual meetings began as training sessions but became established work sessions used for all topics relating to team support and project execution throughout the lifecycle of the project.

Trainee Compensation

As indicated above, the position was described as a part-time, non-exempt, hourly, with a rate of **\$39.49/hr**. For a copy of the full application, please see: **Appendix A. NVU UAS Pilot Application (Fnl 02-03-2021)**.

Part 107 Certification in Alaska

Numerous logistical challenges were overcome to have the NVU UAS pilots Part 107 certified during the on-going COVID-19 pandemic, some of which are a direct consequence of the pandemic. Quarantine requirements for unvaccinated individuals traveling to Unalakleet from Anchorage caused added stress and complications to the logistics of testing. Of the three certified UAS pilots on the NVU UAS Team, one pilot was certified in April 2021, the second in August, and the third in November. No other potential UAS pilots were sponsored to travel for the Part 107 certification exam, only available in Fairbanks, AK or Anchorage, AK when testing in Alaska (Note: The individual certified in April was the only trainee able to take the test online because she already had her manned pilots license).

2.2. Hands-on Training for UASs

The following section discusses the training that took place as the NVU UAS Team transitioned from virtual training of the Part 107 to actual hands-on training with the Skydio UASs. Key components of the start-up and on-going operations of a successful program is to provide high quality, hands-on UAS flight training, including the use of sensors for inspections and different flight scenarios. Hands-on training was provided to the pilots after the successful completion of their Part 107 certification.

Simulator Training

Initially, two copies of RealFlight sUAS flight simulator software were purchased and delivered to Unalakleet for the pilots to use starting mid-2021 to maintain and hone their skills when weather was not conducive for live test flights. The aim was to have the simulators fill the gap while waiting for the delivery of the Skydio S2 and X2E UASs.

Hands-On S2 Training

The Skydio S2 UAS, outfitted with Electro-optical (EO) sensors, were purchased for the NVU UAS Team to train on during the first part of 2021, but due to global supply chain shortages were not available for program integration until Fall 2021. These small drones bridge the gap between the simulated flights and the operational aircraft, exposing the new pilot teams to the three-dimensional (3D) aspects of UAS flight and the specific operational components of the Skydio S2 system.

Due to the impacts of COVID-19, hands-on training was provided on the Skydio S2 in Fairbanks, AK during November of 2021. One-on-one hands-on training on the operation of the S2, the management of the sUAS collected data, processing of the data, and delivery of the data to end-users by PI Garron and UAF Pilot Jeffries was able to be provided to the NVU UAS pilot Katie Daniels throughout the month of October 2021. Ms. Daniels relocated to Fairbanks for the month of October to receive this training, to iterate on flight protocols and to coproduce the data management and processing protocols. The week of November 1 – 5, 2021, all NVU UAS pilots, Co-I Henry, and Co-I Hall, traveled to Fairbanks, AK for hands-on training, protocol coproduction, and project work sessions. PI Garron and UAF UAS Pilots Jeffries and DeLue, and NVU UAS Pilot Daniels provided basic operational training on the S2 sUAS, how to perform manual sUAS flights, how to perform autonomous 2D scans, how to perform autonomous 3D scans, how to archive data, and how to document all of these components for long-term recordkeeping. On the final day of this group training, the project team was joined by two representatives from Skydio who were on-site to demonstrate the operational features of the Skydio X2E for the project. All UAS pilots had the opportunity to fly the operational aircraft and receive preliminary training on the nuances of this more robust system. Two of the S2 aircrafts were sent to Unalakleet, AK with the trained pilots for additional flight training and testing.

Hands-on X2E Training

The Skydio X2E, a multi-rotor UAS outfitted with both EO and infrared (IR) sensors was purchased for operational use, and due to continued global supply chain challenges, were not delivered to Alaska until February 2022. The X2E aircraft include all the above features for the S2, with the addition of greater radio line-of-sight range, a longwave infrared sensor, and a more robust controller. The hands-on training for the Skydio X2E occurred during the week the entire project team was in Unalakleet, AK for

the Community Project Fair in March of 2022. Training flights included key linear infrastructure flights over water bearing infrastructure from the town water pump house, 3D modeling flights of the community tank farm and 3D modeling of key historical cultural resources. PI Garron, the NVU UAS Pilots (Co-I Henry and Ms. Daniels), the UAF UAS Pilots, Co-I Hall and one trainer from the Skydio team participated in this Unalakleet-based, hands-on training.

2.3. EQUIPMENT MANAGEMENT

Quality equipment and equipment management increases the likelihood of UAS team success and longevity. While the pilot training was underway, an investigation into the most robust and applicable USA-made UAS that should be used for this program was also taking place. Aircraft, the status and types of sensors integrated, and the type of processing required to create a useful product for decision-makers were all part of the matrix of potential equipment solutions for this program. Once the hardware solutions were identified, the supporting software and logistical management of both the hardware and software was developed for the NVU UAS Program.

2.3.1. Aircraft

A thorough investigation of different small UAS was undertaken to identify the quality equipment for use in this program that also could maintain the longevity required to support subsequent missions beyond the lifecycle of the project. The most important mandate that was to be met regarding the UAS selections was that the UAS had to be manufactured in the USA. This requirement limited the number of UAS that were eligible for use in the program, as well as the type of sensors that had already been integrated into those USA-made aircraft.

A multi-rotor vehicle was determined to be the most versatile of the different types of small unmanned aircraft hull types (multi-rotor, VTOL, fixed-wing), thus providing the greatest value to this program that needed to be able to perform area and volumetric analyses. Commercial-off-the-shelf (COTS) UAS were the only aircraft evaluated as part of this project as the long-term support structures needed to already be in place to support the NVU UAS Team, but also the project investigators, and future USCG end users. Among the COTS multi-rotor vehicles that were made in the USA, there were very few that had integrated multispectral sensors into their aircraft, and those aircraft with those sensors did not have any of the auxiliary capacity of the Skydio system, specifically 3D scan and 360° optical-based, obstacle avoidance. The Skydio does offer two the EO and IR sensor capacity, and those two sensors can be used to meet a large portion of the operational needs for emergency response and infrastructure inspections in rural Alaska.

Benefits of Skydio UAS

The benefits of the Skydio's UAS platforms are broader than its geographic manufacture point. The greatest benefits of these UAS include,

- Made and supported in the USA
- No geofencing built into the software (no physical limitations built into software)
- Optical-based situational awareness (no GPS blocking)
- Alternative GPS flight mode and required lighting for night missions

- 360° obstacle avoidance AI
- 2D and 3D scanning capacity
- Current and expanding integration with DroneDeploy and other post-processing software

It is important to recognize that there are alternative, small UAS, that are made in the U.S.A, that also are not reliant on GPS navigation. These alternatives did not offer all of the capacity that the Skydio systems already had developed at the time of UAS purchase for this project. The way in which this project chose and thus used the UAS for inspections and analyses is also not typical for most Skydio UAS users. As such, PI Garron spent considerable time with the Skydio development team to continue to improve and ruggedized data collection protocols that support the operational missions of remote, western Alaska. This continued working relationship between the project team and Skydio continues to benefit all members of the program through direct development requests and integration of software improvements to meet the research program's needs.

Testing

Most of the Skydio UAS flight testing was centered around basic operation and operational limitations in Arctic environments, as the recommended operational environment for Skydio equipment³ is a unique window rarely open in Alaska. Through these examinations, the UAF and Skydio team identified and improved a number of specific flight components supporting the 2D and 3D scanning capacity of the UAS, and defined boundaries for operations in the extreme Alaskan environment.

Cold Weather

The Skydio UAS were tested throughout the fall and winter in Fairbanks, AK. This testing also allowed the research team to understand that both the S2 and the X2E are capable of operating down to -20° F (-29° C) with little to no impact to the aircraft or battery life, if batteries were stored warm. There was some distortion when capturing data in video mode at these cold temperatures, but these distortions were not visible during operations at 20° F (-7° C) or warmer. It is unclear if this wavy video phenomenon will perpetuate into larger data sets collected at cold temperatures. No loss in flight time was experienced at cold temperatures on either the S2 or X2E.

Precipitation

The program team does not risk flights during precipitation. If rain or snow begins to fall during a mission, the UAS is returned home, and the mission rescheduled for another day. The risks to the equipment are not worth the risk of the damage to exposed electronics and aircraft operation. When needed for a search and rescue mission in inclement weather, the risk of flight will be the judgment of the pilot in command.

Wind

The S2 and the X2E collect data smoothly up until the upper wind limits of the aircraft are reached at approximately 20 mph sustained winds. If systematic data collection is the aim of the mission, postponing until wind conditions are 10 mph or less will result in more consistent data capture and end

³ Skydio Safety and Operating Guide, <https://support.skydio.com/hc/en-us/articles/360000586653-Skydio-Safety-and-Operating-Guide>

products. High wind warnings on the UAS hand-held controller inform the pilot of wind conditions at altitude, and extreme high winds will cause the UAS to stop data gathering until stability can be restored. When high winds warnings persist, pilots should return the UAS to home, and replan the mission for another time if possible.

Connectivity

The S2 loses connectivity with the controller when almost any obstruction presents itself, including distance. The program team was not able to maintain connectivity beyond 0.5 mile (1.6 km), though the advertised range was over 3 kilometers. Connectivity was also impacted by trees, low buildings, and metal structures passing between the aircraft and the controller. In discussions with Skydio, it was determined that these issues were a result of having the antenna internal to the hull, a choice made to increase robustness of the aircraft. The subsequent model of this UAS, the S2+, has the antennae on the outside of the aircraft, and it is reported that this connectivity problem has been greatly reduced.

The S2 is controlled via an app on a smartphone or tablet, the hardware not being designed for UAS operations. Tablet driven operations are limited by the tablet. If the tablet is too cold to operate, there is no mission. If the tablet gets wet, there is no mission. If the table was not charged, there is no mission. UAS controlled via smart devices can also experience time-outs when multiple apps are running, resulting in the loss of connection and control of the aircraft. Multiple connectivity problems ranging from app version, to distance, to charging cord varieties, also plagued the connection between the controller and the aircraft during testing. Operational solutions and acceptance support continued flights with the S2 today.

The X2E had almost no connectivity problems during testing. The X2E communication antennae are located on the exterior of the hull, and the signal to those antennae is coming from a dedicated controller, resulting in a more robust connection to the aircraft. Loss of connectivity to the X2E has only been experienced as a result of a building between the controller and the aircraft. No loss of connectivity within line-of-sight of the aircraft has occurred.

2D and 3D Scanning

One of the critical benefits of the Skydio UAS over other vehicles are the autonomous 2D and 3D scan capabilities. This capacity is acquired through additional licensing with Skydio and allows for simple boundary definition by the pilot, followed by an autonomous data capture flight, the results of which can be uploaded to DroneDeploy for automated 2D model (orthomosaic) and 3D model creation. Orthomosaics are a single orthorectified image that is composed of the individual georeferenced images collected by the EO sensor on the Skydio, stitched together, overlapped and referenced to a point on the earth. These orthomosaics can be overlaid on maps to provide high resolution detail when none was available before. Figure 2.2 is an example orthomosaic created using 2D scan collection mode on the S2 and uploading the images for automated processing in DroneDeploy.

Rough 3D models are created from data captured as 2D scans, but highly detailed 3D models can be created from data captured as 3D scans, one of the unique features of the Skydio operational AI. The 3D models are discussed in more detail in Section 2.4.2, but the bottom line is that this automated

processing pipeline has exponentially increased the successful integration of data capture and processing for this program, and is highly suggested for future applications.

Every anomaly in operation that has been discovered on the Skydio UAS have been reported directly to Skydio. As a result of this rolling feedback loop, software improvements that subsequently increase the performance of the UAS are regularly released, and the program team's experience with the Skydio UAS and team remain positive.



Figure 2.2. Orthomosaic created from EO data collected by K. Daniels using the Skydio S2 and overlaid on Google Earth.

Comparison of the S2 and X2E

The Skydio X2 series, currently undergoing certification for Blue sUAS designation, was originally developed for military applications and is more robust than the S2 and more cybersecure. Two models of consumer X2 sUAS are available, one outfitted with an EO paired with an infrared sensor (IR), and one outfitted with an EO sensor only. The following table offers a brief comparison of all three Skydio aircraft commercially available.

Table 2.1: Comparison of Skydio Operational Aircraft (X2 series) and Trainer Aircraft (S2).

	X2E – EO/IR sensors	X2E – EO only	S2
Blue UAS (USA-made)	Yes	Yes	No
2D and 3D scan support	Yes, but currently only for EO	Yes	Yes
Electro Optical camera	4K 60p HDR, lower resolution (res) still images, narrow field of view (half the view of S2)	4K 60 HDR, high res still images, wide field of view	4K 60 HDR, high res still images, wide field of view
Infrared camera	FLIR 320p	No	No
3D scan distance from object	15 ft.	5 ft.	5 ft.

Operational frequency	5 GHz	5 GHz	2.4 GHz
Battery life	35 minutes	35 minutes	20 minutes
Range from ground control station (GCS)	8000 ft. +	8000 ft. +	1500 ft.
Strobe lights	Yes	Yes	No
Construction material	Carbon fiber	Carbon fiber	Plastic

Skydio is now selling and supporting the S2+ instead of the S2. The S2+ has increased range and more robust connectivity, but otherwise is the same aircraft as analyzed in this Case Study.

2.3.2. Laptops

Laptop computers are the primary supporting equipment for any UAS program. To narrow the field of choices for laptops, a review of geospatial processing and analytical software was first undertaken to ensure the laptop purchased would have the appropriate computing capacity to support the UAS program in the field and in Unalakleet. An additional requirement was for the laptop to have either a DVD player or be able to support an external DVD to allow the UAS pilots access to the RealFlight simulator software for “thumb skill” support.

The laptops chosen for use in this project was the Panasonic Toughbook. This laptop was specifically chosen for a number of its built-in attributes. Toughbooks are designed to be durable in rugged operational environments, like Alaska, they comply with the IP65 standard for protection against dust and water ingress. These laptops are powered by Intel Core processors, running a Windows 10 operating system, which facilitates out of the box compatibility with most geospatial processing programs. The Toughbook is outfitted with a wide variety of external ports to support auxiliary devices including USB, SDXC, VGA, HDMI, Wi-Fi, Ethernet, Bluetooth, and it has an internal dedicated GPS. The dedicated GPS allows for the Toughbook to be used as ground control point during data processing, supporting the calibration of the UAS-collected imagery to the land through that GPS point. The Toughbook has a built-in handle. Testing with this equipment is ongoing with no significant hurdles to its use identified so far.

2.3.3. Chain-of-Custody

Consistent chain-of-custody processes and documentation is important when trying to maintain equipment in a UAS program. In UAS programs, chain-of-custody is a process used to track the movement and control of a UAS and its accoutrements through its lifecycle by documenting each person and organization who handles the UAS and its components⁴. This includes sending parts or the UAS hull for repair at the manufacturer, sending the UAS to another community for another pilot to fly, or other activities in which the UAS is transferred from the NVU UAS office. Maintaining the chain-of-custody increases transparency and enables accountability for actions taken on the UAS or with the UAS. Chain-of-custody processes reduce program risk by ensuring only approved people can access the equipment. Maintenance logs are similar in that they document all known changes to the UAS or its components, but chain-of-custody is broader to include use and lack of control, circumstantial or otherwise.

⁴ Cybersecurity and Infrastructure Security Agency, Chain of Custody and Critical Infrastructure Systems, <https://www.cisa.gov/insights>.

The chain-of-custody is considered broken when there is a loss of control over the piece of controlled equipment. If chain-of-custody is broken, the integrity of the UAS and its underlying data can be questioned for reliability, accuracy, and security. As such, data collected by systems that have undergone a loss of chain-of-custody may be rendered inadmissible in a court of law. The inability to provide evidence that a system has not been compromised equates to saying the system is unreliable.

To ensure chain-of-custody of the UAS and supporting equipment in Unalakleet, a UAS office secured by a key code lock has been established within the NVU tribal administration building for the UAS equipment. Only the NVU UAS Team has access to this office. Flight logs and maintenance logs document activity with the aircraft, and those are maintained in hard copy with the UAS, and digitally in Google Drive. As the NVU UAS Team expands, additional chain-of-custody protocols addressing UAS movement in/out of the UAS office may need to be put in place.

2.3.4. Software Licenses

The equipment used in this program would be rendered useless without the supporting software to operate it. The NVU UAS Program relies on software to run the UAS, collect the data, and process that data into 2D and 3D models that reveal different components of the flown targets. Each of these pieces of software are commercially available, thus requiring licensing for them to operate, and for this project, education bundles were able to be leveraged due to PI Garron's university affiliation. Licenses can be paid for remotely, installed, and updated, over an internet connection. The three required licenses to run the NVU UAS systems as designed through this UAS program are the Skydio AEF, Skydio 3D Scan and DroneDeploy Teams software packages.

The Skydio AEF software is the software that runs the aircraft and allows for the sensors to capture data as images or video. The AEF software also supports the 360° avoidance artificial intelligence (AI) technology that allows the Skydio aircraft to avoid collision with anything larger than an average person's thumb. The AEF software also supports target tracking, a feature that is not as valuable for interrogation missions, and thus not integrated into any of the protocols produced as part of this project. The 3D Scan software from Skydio is what controls the UAS capacity to perform programmable 2D and 3D scans of targets on the landscape. The software bundle from Skydio that includes both of these services is available as either one-year or three-year licenses for operation.

To process the imagery collected with the Skydio hardware and software suite, this project decided upon DroneDeploy as the primary processing software, which operates exclusively in the cloud. The DroneDeploy Teams license provides access to all of the 2D and 3D processing required to support orthomosaic and 3D model creation. Licensing for software Team add-ons are also available, one of which was also included in this program, the Google Drive integration. This add-on allows for users to have processed output also be delivered to a Google Drive location for ease of sharing and archiving. The licensing for DroneDeploy is only available in one-year terms, and is limited in the number of seats available at the base Teams licensure rate; additional seats can be added to the license at a cost, otherwise the one-year term license comes with five seats.

These are the software solutions and supporting licenses required for what was employed for this UAS program using the Skydio S2 and X2E. There are no other software solutions that will support the Skydio aircraft operation other than what Skydio provides, and that is a cost that must be incurred to fly Skydio equipment to its potential. The DroneDeploy license is only one of a number of possible processing software solutions that could have been used for this work, but was the one chosen due to other variables besides licensing.

2.4. DATA MANAGEMENT

Discussed below are the three primary components of UAS mission data management: collection (protocols), processing and delivery. Auxiliary information and applications relevant to UAS data operations, especially conditions of data collection, in Unalakleet and other rural northwest Alaskan communities are included for consideration.

2.4.1. Data Collection and Protocols

Understanding the end product desired by the end user is critical to defining the proper UAS data collection mission. Additional considerations besides the ultimate application of the data include the constraints on its collection.

Background Considerations for Data Collection

Airspace Considerations in Rural Alaska

Critical to UAS missions is determining safe airspace within which to fly them. As is the case of many remote, rural Alaska communities, airstrips are often located in or very close to the middle of town. These airstrips tend to be designated as Class E airspace, requiring FAA authorization to fly near, or within, except for at very low altitudes. Some UAS operate with geofencing software that prevents UAS take-off within two miles of any airport. In these remote Alaskan communities, once the airport is closed for the day, the airspace will resort to Class G airspace, which is the least restricted airspace, allowing for UAS flight operations that follow the Part 107 guidelines. The challenge with waiting until the airport is closed for the day is that oftentimes the airport closes at dark, reducing the utility of this airspace access. During the summer in northwest Alaska where Unalakleet is located, light remains well after the hour of airport closure, allowing for UAS data collection flights in town, but requires the pilots to be flexible about the hours in which they typically fly the data collection flights.

The location of airstrips in the heart of rural Alaskan communities introduces challenges for almost all community-based infrastructure inspections such as electrical lines, phone lines, roof inspections, road inspections, and most obviously, airstrip inspections. In addition to these legal hurdles to safe operation in rural communities, there are many small airplanes operating in and around these communities, not all of which announce their location when traveling over a community, nor operate an ADS-B (automated beacon) system in their aircraft. The critical components to performing flights in areas where pilots are not mandated to report their aircraft is to have well trained, and ideally multiple, visual observers. Though these challenges exist, the identification of them and the safe ways to operate in and around

these regulations was critical to understanding the nuances and value of operating UAS for real-time data collection over infrastructure and other targets in rural Alaskan communities.

Weather

The impacts of weather on sUAS operations are exacerbated in Arctic and sub-Arctic environments by the physical conditions for pilots operating in these environments, robustness of the aircraft, and lack of communication infrastructure. Coastal Alaska has dynamic and extreme weather as the norm. These weather conditions reduce the flexibility afforded by using sUAS for emergency response and infrastructure inspection applications. Small UAS are all sensitive to the effects of wind, precipitation, and darkness, though darkness is not a component of weather, but instead latitude. The fixed-wing and VTOL style sUAS are more similar to manned aircraft, and thus are more resistant to wind and precipitation, but the use cases for a fixed-wing or VTOL UAS are more limited than a multirotor UAS.

Temperature is one of the largest environmental variables impacting UAS operations in cold climates. Temperature can reduce the efficiency of mechanical and electronic UAS components and may also impact sensors and the subsequent collected data. Most commercial off the-shelf sUAS are rated to operate from -10° C to 40° C (22°F to 104° F) with a few rated down to -20 C (-4° F). Batteries are a common limiting factor at cold temperatures, as flight times are reduced when batteries become cold soaked. Some UAS use “smart batteries” that do not allow the sUAS to fly outside of the defined temperature range of the battery as defined by the manufacturer.

Icing of UAS components in-flight changes the weight balance of UAS and can result in a loss of performance and control. Temperature combined with the humidity of the flight area will determine whether in-flight icing is a potential hazard. Wind reduces battery lifespan as the UAS uses more energy to maintain course, sUAS operations are limited by line-of-sight operations which can be easily impaired by fog, and precipitation as either rain or snow can easily damage exposed electronics. Though some solutions exist for weatherizing aircraft and increasing the operational temperature range of UAS, the need for more operational solutions for cold climate UAS flight is needed. These environmental factors also impact the UAS pilots and observers operating these aircraft. Health and human safety is paramount to every UAS mission, and if environmental factors are impacting the mechanics of UAS operations, they are likely impacting the human operators as well.

Cybersecurity

Cybersecurity concerns impact sUAS compatibility with various missions. For example, U.S. federal agencies do not want to use data collected with drones made in China due to known transmission of metadata and unknown transmission of other in-flight collected data, nor are federal agencies allowed to purchase sUAS manufactured in China. Cybersecurity of sUAS flights in remote Alaska are minimal due to the lack of communication infrastructure for information transmission. Communication infrastructure challenges at high latitudes are based on the lack of populace and thus a lack of investment in infrastructure. Cellular towers provide localized service, but are not uniformly distributed which prevents the use of these networks for data delivery beyond the local community. Similarly, without roads and railways extending from city centers to remote communities, utility corridors do not exist for installation of communication systems. Most UAS are controlled by line-of-sight radio communications using the frequencies 2.4 GHz and 5.6 GHz, accessed over localized WiFi networks

broadcast from the ground control station. These signals can be obscured by landscape features, atmospheric conditions and other frequency interferences, and are typically limited to a range up to 2 miles, thus causing little cybersecurity concern.

Data Archival

In addition to whatever end product the UAS team prepares as a result of the UAS missions, data collected from the UAS flights needs to be archived by the UAS Team each day according to data archiving and sharing protocols defined by the NVU SOPs or otherwise mandated by contractual obligations. Minimum archival will include preserving all summary reports (requirements below), manually recorded UAS Flight Logs (scanned as PDF or JPG), digitally recorded flight logs (T-logs and .DAT files from the aircraft), raw data files, and data products on two hard drives, to be stored with the UAS Team unless otherwise defined.

Summary information required specific to the UAS flights:

- Date;
- Description of mission;
- Crew members (UAS pilot and affiliation, UAS observer and affiliation);
- Description of UAS platform (Make, model, type);
- Description of the payload/sensor;
- Description of the ground control station (geographic location and land ownership status);
- Mission objectives (e.g. oil extent mapping, wildlife identification, air quality, etc.);
- Type of survey or sampling method (e.g. line/strip transects, sunburst patterns, etc.);
- Filename(s);
- Total time flown;
- Total distances flown;
- Weather or other factors affecting visibility and detectability of targets (i.e., fog/glare);
- Minimum (less take-off and landing) and maximum altitude of flights;
- Data products created;
- Data chain of custody;
- Environmental variables;
- Flight mishaps.

Co-Production of Standard Operating Procedures (SOPs) & Mission Protocols

Once the remote UAS pilot training was completed, the weekly training session turned into weekly work sessions with the entire project team, including remote UAS pilot and pilot instructor Wentworth. During these weekly sessions the comprehensive Standard Operating Procedures (SOPs) for the NVU UAS Team were developed. These SOPs define all components of the NVU UAS Team including roles and responsibilities of the UAS pilots, legal considerations, insurance requirements, equipment chain-of-custody procedures, UAS preflight/postflight and maintenance standards for the NVU UAS Team equipment. Several operational Appendices are included as part of the SOPs, that have been integrated into all mission operations by the NVU UAS Team, including Preflight Checklist, Postflight Checklist, Flight Logbooks, and Maintenance Logs. Additionally, each pilot was issued a Rite-in-the-rain field

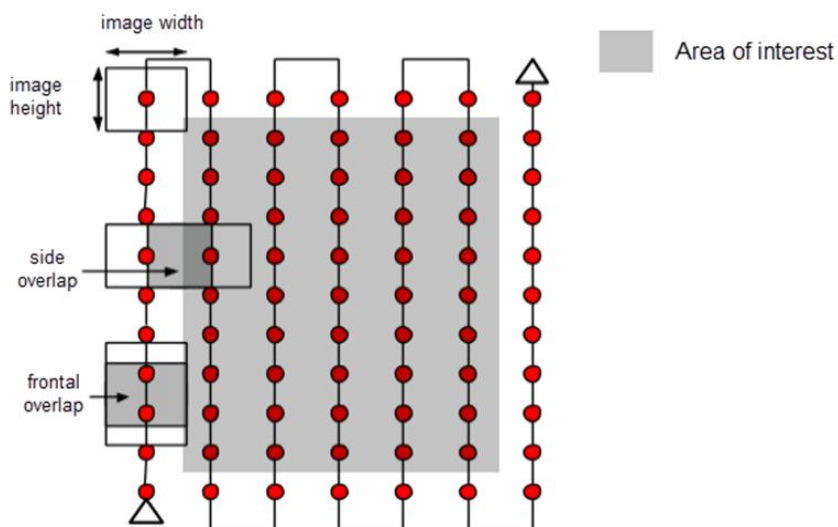
notebook for all other note taking needs in the field. General data management protocols were also developed.

Data Collection for Emergency Response

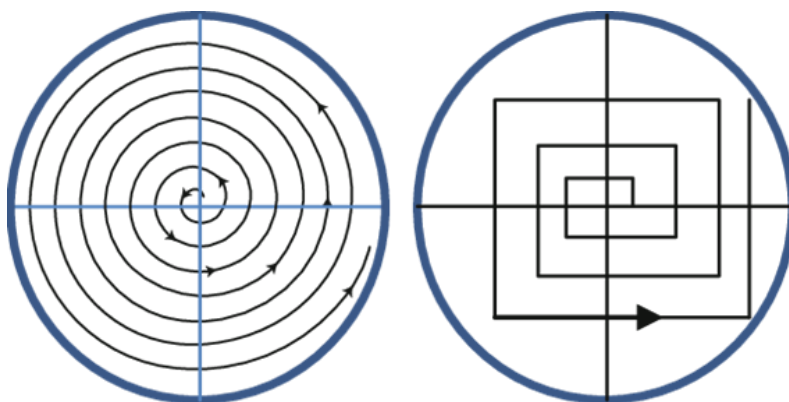
Being able to monitor key community assets and report on their condition is key for ER activities, as are search and rescue missions and other dynamic ER scenarios. Through discussions with project partners in the Norton Sound region, specific emergency scenarios were identified by the pilots for flight protocol support. These specific scenarios are 1) search and rescue actions over land, 2) flood delineation and 3) oil spill detection and monitoring. Being limited by line-of-sight operations, the integration of UAS into specific search and rescue activities over water was discussed but was not prioritized as a protocol for this program. The risk to the aircraft being flown over water by newly trained UAS pilots did not outweigh the benefits to the development of this protocol, especially considering the overarching integration of UAS into USCG operations at this time. It is suggested that only experienced UAS pilots perform operations like these over water, though the utility of these flights over high-powered binoculars in the conditions conducive to flight (no precipitations and winds less than 20 mph) remain unclear.

Using the general and specific co-produced ER flight protocols, the NVU UAS Team conducted preliminary test flights over swaths of tundra to practice the different flight patterns that would be used during situational awareness assessments after an emergency event, such as a SAR mission or flooding. These included the patterns of, “**mowing the lawn**” “**expanding spiral**”, **linear missions**, and lastly the **ad hoc** flights, such as those that may be required when under the direction of a search and rescue team. Test data products were produced as part of the effort and were analyzed as a team for lessons learned and protocol refinement. Baseline flights of areas that did not require airport closure to conduct, were processed as relevant to the target to learn and expand NVU UAS data processing skills. Examples of each of these flight patterns are illustrated below.

“Mowing the Lawn” - Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable SAR operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.



“Expanding Spiral” - Two types of spiral patterns that can be flown by UAS in support of SAR missions.



Linear Missions - Sample of linear flight pattern over road segment, but could be used for coastlines, pipelines, and other linear features. 75% frontal overlap and 75% side overlap is recommended change detection/linear orthomosaic operations. Segment stitching requires an additional 100' of overlap between segment ends.



Ad Hoc - The real-time site interrogation/ad hoc flight pattern is used when determining preliminary situational awareness. There is no predetermined flight plan, and the pilot is working directly with the SAR team to fly in specific locations as requested by the SAR team UAS coordinator.

The different flight scenarios above, choice of sensor, angle of collection, altitude settings and data capture models (e.g. video versus still image capture), are taken into account in developing the mission-specific protocols for different types of flights and different end user needs.

Data Collection for Infrastructure Inspection

The primary goal of flying regular infrastructure inspection missions is to identify structural and environmental anomalies before they become problems, and to allow for the inclusion of observable risk assessment in resource allocation decision-making. If the given infrastructure has already failed, UAS flights can support the documentation of those failures and other resulting impacts. Infrastructure inspection flights can be used for area-based, linear, and 3D data collections, to help interrogate infrastructure and cultural resources in support of decision-making. These missions can be flown as part of a one-time effort or be conducted regularly and systematically to perform change detection analyses.

For this Case Study, project investigators worked with the Environmental Protection Agency, USCG, and the State of Alaska to gain and understand documented requirements for the inspection and integrity of fuel carrying and fuel storage facilities in remote Alaska. The requirements and general inspection needs

were then translated into flight protocol components. The Infrastructure Inspection protocol paired 33 CFR 154 regulated bulk fuel facility integrity inspection requirements, State of Alaska (18 AAC 75) guidelines for reservoir/tank farm infrastructure inspections, and UAS operations, via the coproduction of an operational, infrastructure inspection protocol. Of note, during these discussions it was made clear to the project team that the most common point of failure during these infrastructure inspections is not the infrastructure, but instead the lack of consistent personnel in the remote Alaskan communities to maintain the community of practice required for the safe transfer and distribution of fuel throughout the community.

Additional infrastructure inspection applications besides inspections of fuel transportation and storage facilities were created from information gathered during testing in Fairbanks and training in Unalakleet. These additional applications focus on specific community needs such as monitoring available space in the landfill, performing inspections on the community wind farm turbines, identification of leaks in water pipes, and integrity inspections for electrical distribution lines. Ad hoc inspections like those for heat loss from buildings and pipes were also performed during testing, and have been incorporated into NVU UAS Infrastructure Protocols.

Infrastructure inspections can be performed as either ad hoc manual flights, 2D scans or 3D interrogations of the target infrastructure, the choice of mode being based on the specific inquiry. These types of missions are almost always recorded in some format for additional review later or for archival purposes. For quick point interrogations, an ad hoc flight pattern, switching between EO and IR to capture anomalies in real-time while simultaneously archiving video or still imagery is suggested. The 2D flight patterns for linear and area-focused infrastructure inspections as scans are similar to those described above, with the difference being that the orthomosaic is the desired product over the real-time observation.

The significant flight pattern that sets infrastructure inspections apart from other 2D scans is 3D capture in support of 3D model creation. The flight plan is automatically calculated by the Skydio aircraft's internal software when the UAS pilot defines the "pillars" that represent the extent of the area to be scanned. The 3D scan consists of a preliminary flight to identify the extent of the 3D scan and set the boundaries (pillars) of the scan, 2) a preliminary 3D scan during the "Exploratory Phase" of the scan, and after both processes the 3) data gathering scan will commence. Most 3D scans will require multiple batteries, and care needs to be taken to follow the proper data saving and UAS shut down procedure for the battery exchange to ensure no data loss.

The 3D structural models created from infrastructure targets allow for the localized, informed, prioritization of asset management. Analysis of these models can be used to identify weaknesses in structural integrity and other potential risks to that infrastructure function due to acute or chronic wear. Using 3D models, consistent observations of fuel bearing infrastructure located can support the identification of areas of concern resulting from subsidence of permafrost before there is an oil or diesel release into the environment. Regular 3D inspection of bridges is also possible using 3D capture.

One of the specific use cases for flying 3D capture of bulk fuel delivery and storage infrastructure in Unalakleet was to develop a UAS inspection protocol that can be used in Unalakleet and other

communities to prioritize inspection schedules for the Sector Anchorage Marine Safety Task Force (MSTF). By working with UAF to support the development of a trained UAS team that is local to the Bering Strait region, that has the skills to provide 2D and 3D models to the USCG, and that can be contracted to fly inspection missions throughout remote Alaska, MSTF has an increased capacity to prevent oil spills in Alaska. The MSTF can contract the NVU UAS pilots to perform annual flights in remote communities that can then be archived to support short and long-term change detection analyses, as well as allow the MSTF to prioritize inspection sites when resources are limited. These contracting discussions began immediately after the establishment of the NVU UAS Team with the MSTF, as well as with local and regional infrastructure managers looking to capitalize on the new regional UAS mapping capacity.



Figure 2.3 (Left). Photograph of Bus 142 inside the UAF Engineering Bay.
Figure 2.4 (Right). 3D model of Bus 142 generated from EO data collected by the Skydio S2 and processed in DroneDeploy.

2.4.2. Processing

While the NVU UAS pilots performed preliminary S2 flights in Unalakleet, the S2 was being tested at UAF to determine the operational range of the UAS and to streamline data processing nuances. Data gathered by the sensors during these test flights was processed using three post-processing software solutions to determine which software provided the highest quality data product for decision-making, while also being reasonably user friendly to support the success of data product creation by the NVU UAS pilots. Of these software solutions, the one selected for operational use was DroneDeploy. DroneDeploy offers the benefits of ease by only requiring EO images to be uploaded to their cloud processing environment. No processing selections are made, the data is just processed to the fullest capacity of the Drone Deploy software on the metadata of the imagery provided.

DroneDeploy supports the creation of orthomosaics when georeferenced 2D imagery is uploaded, and 3D models when 3D scan data is uploaded. For each set of sequenced uploaded images, DroneDeploy will create a Digital Surface Model (DSM) that describes the topography of the flight landscape, with the capability of making man made features from the DSM if necessary. Accuracy of the DSM is

approximately 0.5 cm in elevation, whereas accuracy of the EO orthomosaics is 1 cm/pixel. All data products are stored within DroneDeploy and are accessible through a series of intuitive toggle switches.

Orthomosaics and DSMs can be explored or exported from DroneDeploy as GeoTIFFs, JPG map, PDF and as point-cloud data (.las). These 2D orthomosaics can be further analyzed in GIS software environments and other 2D geospatial software programs. 3D models can be explored within DroneDeploy software or other programs that can consume and display .obj files; .obj is the only export format for the 3D models created in DroneDeploy. Ancillary metadata files for both the 2D and 3D products created in DroneDeploy are available via the Map Details selection. Metadata reports can also be generated and exported that contain key information about the size of the area modeled, the resolution of both the 2D and 3D components of the models.

2.4.3. Delivery

Data products created from UAS collected data processed in DroneDeploy can be exported for either digital display and manipulation, or for static printing as needed by the end user. The end users of these drone products range from USCG MSTF members needing to prioritize inspections of bulk fuel infrastructure, to city planners interested in volume remaining at the local landfill, to utility managers wanting to understand the impacts of thawing permafrost on their infrastructure, to cultural resource advocates interested in the identification of those resources and their preservation.

Each of the different UAS data end user communities have different data needs that are met by different data products. Tank inspectors are interested in 3D models, but can still prioritize inspections on UAS-collected images alone. As such MSTF inspectors would be interested in digital models and digital imagery of the tanks in EO and IR, and would want to be able to reference the images in reports, but not necessarily need to print them out. City planners would be interested in a DroneDeploy “cut and fill” product where volume estimates can be calculated from 3D data of the landfill landscape, but may be happy to have a numerical volume estimate with no imagery at all. Utility managers may be interested in 3D models of their infrastructure they can manipulate directly, but also value printed maps of their infrastructure that can be used to follow-up on anomalies observed in digital models. Understanding how these end users want to interact with the data products created from UAS data is critical to determining end product delivery to local end users as well as remote delivery to end users far afield.

Local data product delivery needs to include review of the products among the UAS team and the end user to highlight what the product is and what can be ascertained from it. A copy of the product should be provided via hard drive or link to a cloud storage environment, and due diligence needs to be performed to ensure the end user can access the product in their own computing environment. If the end user wants some type of hard copy product, that needs to be provided at the time digital copies are delivered. Hard copy products are unable to highlight all of the collected and processed data from the UAS due to their inherent 2D limitations, but sometimes hard copy products are the most tangible and intuitive end products that users can manage.

End users outside of the local community will need their data delivered to them. The most straightforward way to deliver data that is bandwidth independent is to save the raw and processed

imagery onto a hard drive that can be shipped via small airplane through the U.S. Mail system. Other end users and partners will only want the products delivered electronically. Raw UAS imagery and processed data can be voluminous, thus electronic delivery typically incorporates a component of cloud storage for both the UAS team and the end user to access. The most common end products besides the raw imagery are 2D orthomosaics as GeoTIFFs. GeoTIFFs can be compressed and delivered electronically fairly easily, but when large volumes of data can be anticipated, establishing a direct delivery pipeline with the end point is important. NOAA's interface ERMA is the primary repository for scientific information about Alaska that can be accessed by the USCG, and thus is a key endpoint for UAS mission data collected in Unalakleet that is not culturally sensitive. ERMA is also the primary interface where geospatial data is acquired for decision-making during federal emergency response actions taking place in Alaska, such as some oil spills and search and rescue efforts. Additional data delivery models for cooperative science and regional planning are being developed but all focus on the utilization of actionable data, not delivery of data just for the novelty of the capacity. The NVU UAS Team has the ability to provide data via all of these local and remote delivery mechanisms, the exploitation of which is contract dependent.

2.5. UAS OPERATIONS CENTER

Logistical requirements for supporting a community-based UAS program are scalar. A UAS operations center could be run out of the trunk of a car, or from an aircraft control tower. As this program formally established a team, thus establishing the logistical framework to support that team's Operations Center was also required.

2.5.1. Office

The synthesized graphic, done by Anne Jess of TheDoodleBiz, captures the essence of what a local office might look like and how it might function. In short, having a designated office that can be secured is important especially if the equipment includes the Skydio X2E or something equivalent. There needs to be places for such things as charging stations, a computer, radios, walkie talkies, supplies, field equipment, storage area for supplies, as well as Internet connection.

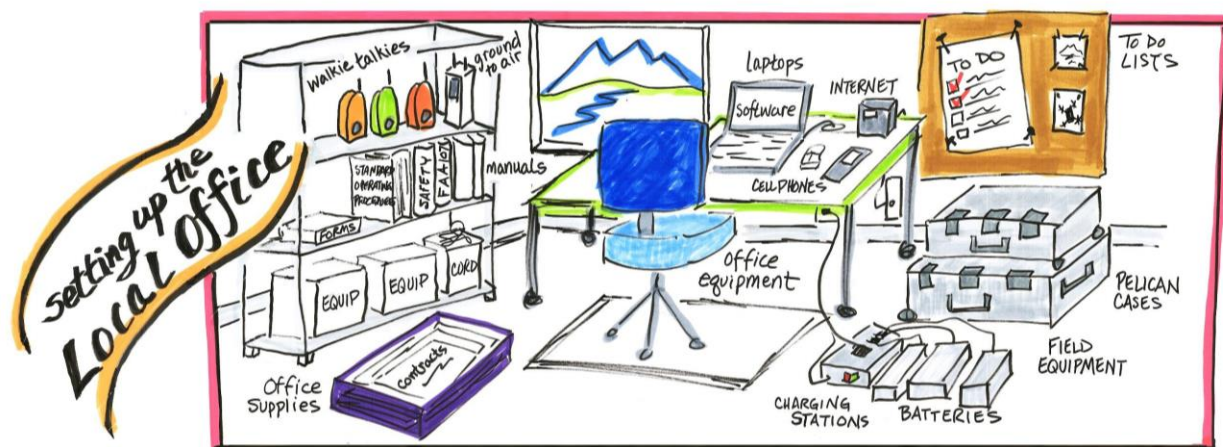


Figure 2.5. Graphic depiction of a UAS operation center (office) with set-up and needed equipment. Synthesis by Anne Jess, TheDoodleBiz.

In Unalakleet, this office was established in the NVU Tribal Administration building. The office has a key code lock, as do the exterior building doors, allowing pilot access to equipment 24-hours a day. The room has electricity to support charging stations, and space for storage of all UAS, laptops, radios, and other ancillary equipment. There is an area for pilots to perform computer work, though no dedicated phone extension at this time.

2.5.2. Mobile

Reciprocal support is common among remote Alaskan communities. This program was developed to be able to support UAS applications in other rural Alaskan communities as well as Unalakleet, as such attention to what is needed for mobile UAS operations was paid. When operating away from home, what you take with you out in the field may change slightly with the type and location of the mission and prep time to leave. A good place to start though is with the following list which is from the NVU UAS Standard Operating Procedures - Go Bag. A copy of it should be printed and kept in the UAS notebook and also in your own Go Bag.

Non-UAS Items

- Small pack (fanny pack, fancy S&R satchel)
- Headlamp
- Compass
- Extra batteries in waterproof case
- Gloves (fingerless gloves, gloves that can be used with iPad)
- Carabiner
- Ankle Gators
- Double-sided tarp (silver heat side/solid color side)
- First Aid Kit
- Leatherman
- Parachute cord
- Benadryl
- Aspirin or other pain reliever
- Fire starter
- Lighter/safety matches
- Toe warmers
- Snow pants/Rain pants
- Heavier gloves/mittens
- Wool hat
- Toilet Paper
- Webbing
- Flare
- Waterproof boots
- Water bottle
- Snacks - non-perishable (Nuts, crackers, trail mix, etc.)

UAS Materials

- UAS
- Anemometer
- Pens and pencils
- Rite in the Rain Notebook
- Ground-to-air radio
- Walkie talkies
- Small generator (no fuel or oil)

Note: Try to have compatible batteries across devices, like headlamps and radios.

2.5.3. Insurance

When undertaking commercial ventures/flights, hull insurance and liability insurance is available under Part 107 for certified pilots for little cost for recreational flying. In a commercial setting, additional flight insurance should be acquired by the UAS pilot or their supporting organization. During contractual

discussions, evidence of insurance or indemnification clauses may become relevant depending on the size, the target, and the duration of the mission.

2.5.4. Communications and Marketing

Communications: In communicating with the public regarding the UAS program, it is important to have a designated contact person (e.g. UAS Program Manager) and contact information including phone number (landline, cell and/or fax), email address, and physical address. The personal contact information for pilot(s) in command should not be circulated. Hours of operation, if known, should be published. For NVU, this information is contained in its UAS Standard Operating Procedures (SOPs).

Marketing: Information regarding the overall project and the NVU UAS Program as it has developed, has been through four newsletters, various presentations, circulation of a press release by UAF about the project in June 2021, which caused a flurry of inquiries about the project and several radio, newspaper and TV interviews; and briefings to key funders/partners.

Currently, the biggest form of marketing for the program has been through various presentations that have been made, especially over the last 3 months. Inquiries directly to John Henry regarding the NVU UAS services and capabilities are a direct result of these various opportunities. Another source is word-of-mouth. Business cards for the program have been created and printed.

2.5.5. Contracting⁵

In setting up a UAS program, it is important to have in place some type of memorandum of agreement (MOA), contract or cooperative agreement in place. The following Table 2.2 outlines the types of relationships that could exist between parties. The Table was created during the work done for 2018-2020 BIA Project by Hal Shepherd of Water Policy Consulting and Meghan “Sigvanna” Topkok, Staff Attorney at Kawerak, in their research of different types of agreements (general contract, service agreement, subscription, MOA, other) for UAS services rendered. The research took into account that the UAS service may not be provided by Unalakleet but that another Alaska Native Village may entertain the possibility of setting up a similar UAS program. From the research, the following table was created.

Table 2.2. Types of Agreement Identified during the 2018-2020 BIA Project.

Types of Agreements for Future Uncrewed Aircraft Systems Data Collection Services		
Contractee (Retention of Services) or Funding Entity	Contractor (Provides Services) or Funding Recipient	Type of Agreement (Memorandum of Agreement (MOA), Contract, Cooperative Agreement)
e.g. Native Village of Unalakleet	Consultant providing the service	Can be MOA or contract
Community XYZ or Regional Non-Governmental Organization (NGO)	NVU - to collect data	MOAs or contract
Agency XYZ	NVU - to collect data	MOAs or contract

⁵ Henry, John, Garron, J., Hall, M., Cozzens, B., Gilliam, N., Griffith, G., Shepherd, H. Feasibility of Improving Local Decision Making in Alaskan Communities with Unmanned Aircraft Systems and Online Climate Data Tools. Pp. 42-43, 89-91, Appendix E.1-13.

Partnership	Partnership Agreement (Formal business structure, generally registered)
Multiple Parties	Cooperative Agreement - Generally based on government-to-government collaboration (Typically an MOA, depending on number of parties and what is being agreed to)

The MOA structure was chosen because it was considered less formal and potentially a more appropriate agreement. From this decision, a MOA partnership template was developed and is Appendix E. Contractual Considerations - Example of Professional Services Language of the 2018-2020 BIA Project. The template is for Example Purposes ONLY. Before finalizing any document, Contractor should seek legal advice to ensure all sections are legally applicable.

Key aspects of the template are that it:

- Defines (UAS) terminology, data-to-be-collected and analyzed, and protocol(s) needed for specified region or location.
- Identifies parties (Contractor (UAS service provider) and Contractee (e.g. Community, federal or state agency, and/or other entity).
- Clearly spells out obligations and ownership/ custody of raw and analyzed data.

Project discussions related to the contractual template acknowledged that some data collected may be culturally sensitive, and ideally should not be disclosed. However, in the case of emergency response, exceptions for the community's health and safety may need to be made. Cultural sensitivities over collected data need to be acknowledged and appropriate data management protocols put in place to ensure all parties are being respectfully supported during the UAS operation.

As part of the contracting discussion, it is essential to coordinate the operational components of the proposed mission with the end-users. These discussions are critical for the UAS team to understand the detailed needs of the mission or set of missions, end-product(s) desired, and any complications to be taken into consideration. Capturing these details in a contract where they are spelled out, is highly recommended, especially if major work is being commissioned. Deliverables or analysis of deliverables should not be promised unless the expertise of that analysis resides directly with the UAS team or through specific partnership agreements they may have with other experts. Overpromising any component of the UAS team capacity can create a liability issue the consequences of which could be significant. If any doubts are expressed about any of the contracting language for a given mission, legal review should be sought.

3. SUMMARY OF LESSONS LEARNED

This section reviews significant Lessons Learned (LL) from throughout the *The Remote Uncrewed Aircraft System (UAS) Inspection and Response Team Development in the Bering Strait Region* program. These LL are organized to reflect the essential operational components of a UAS program that were evaluated as part of this Case Study, but are not a one-to-one evaluation as additional LL were revealed at each step of the program.

3.1. PILOT RECRUITMENT AND TRAINING

After completion of the Part 107 Training, a survey was developed and shared with pilots-in-training, instructors and others who supported delivery of the program. It included questions that applied to the initial set-up and Recruitment & Orientation Process that are reported below. Additional LL from the project investigators are also included.

3.1.1. Recruitment and Orientation Process

Recruitment Webinar

Holding a recruitment webinar allowed for the project team to reach out with real-time information and enthusiasm about the program, and was a critical recruitment tool during the pandemic. This webinar was also attended by community leaders, increasing buy-in for the program beyond the potential pilots. Holding an in-person or on-line recruitment session, with roles and objectives clearly defined will manage expectations and aid in identifying the inspired folks that want to be part of a program like this one. *LL: Hold in-person or on-line recruitment/orientation sessions when establishing a new UAS program.*

Alternative Recruitment Pathways

Though a critical component of the recruitment process, not all NVU UAS pilots came to the program via the recruitment webinar. Project investigators also reached out to regional and local program coordinators that may have direct benefit from having a UAS pilot on staff to share this opportunity within their teams. Other word of mouth interest caused project investigators to reach out directly to interested individuals in the community to invite their participation. Through these direct recruitment methods delivered either face-to-face or over the phone, four of the original seven pilot recruits were identified and engaged. *LL: Do not rely on one method of program recruitment alone; recruit broadly, creatively and with intent.*

Recruitment Stagnation

The recruitment methods used at the beginning of the NVU UAS Program yielded a team of seven UAS pilot trainees, and was considered successful. What the project team failed to take into account at the inception of the project was the potential attrition of pilots, and how they would be replaced. It was decided that new pilots would not be sought to fill the spaces vacated throughout the program, so as not to disrupt team cohesion, and to maintain forward momentum. One of the specific aims of this prototypical project was to create a roadmap for the creation of UAS teams like these in other communities, which we have. But to see this program continue to succeed, new UAS pilots need to join

the NVU UAS Team ASAP using the lessons learned from this Case Study. *LL: Communities where this UAS program roadmap is applied need to actively recruit new pilots as others leave the program to maintain a consistently sized team of UAS pilots.*

Communication Tools

Survey feedback on the methods of internal communications between the trainers/project investigators and the pilot trainees indicated that emails and phone calls were most preferred by the pilot trainees, and that the level of communications was just about right. Further response indicated that Facebook was not the preferred method of communications but it did not negatively impact the program. *LL: Focus internal communications with remote project participants to email, phone calls, and texts.*

NVU UAS Pilot Application

To establish commitment to the program and the trainees, potential participants were asked to fill out an employment application with NVU for the role of UAS Pilot. All applicants that filled out an application were admitted into the UAS training program and were paid employees of NVU for the duration of their involvement in the program. This formal application process may have eliminated potential trainees that were not fully committed to complete the program, which was a benefit for those that were accepted into the program and received more individual attention for their training. In terms of the UAS Pilot Job Announcement, one comment received stated that the Duties and Responsibilities language was possibly a bit confusing or that they had not read the description carefully. They were a bit surprised to learn that part of the work was to help coproduce parts of the program. This was not seen as a bad thing but just unexpected. *LL: Use clear language to describe all components of the program you are recruiting for and confirm the commitment to those components upon acceptance of employment/program participation.*

3.1.2. FAA Part 107 Pilot Training and Certification

The lessons learned summarized in this section reference the implementation of the remote training program and the FAA UAS pilot certification process.

Remote Training

Remote training was the only option for this project due to the Covid-19 pandemic. We chose to move forward with the model of having one of the highly experienced ACUASI pilots provide the training for the Part 107 certification exam, and to only meet once a week for two hours in an effort not to impinge on pilot trainees other employment. The training program lasted approximately 12-weeks, during which there was a fair bit of attrition on our pilot team. Starting with seven, only three ended up completing the program through until certification. *LL: Reduce training time for Part 107 certification by condensing the content to fewer and longer remote sessions; consider leveraging commercially available in-person or on-line training courses instead.*

Trainee Compensation

Providing compensation to the UAS pilot trainees during the Training Program was critical to both the project investigators and participants. The part-time hourly rate was reasonable (\$39/hour) for the area

and was distributed based upon weekly timesheet submission. Direct participant compensation based upon formal program participation provided an easy way to distribute funds fairly and throughout the lifecycle of the project. *LL: Compensate program participants appropriately for their time and efforts. By establishing a job description and rate, trainees recognize the level of commitment to the program by all members of the project team, and have a preliminary cash value to assign to their participation.*

Project Delay

Many residents of Unalakleet perform numerous roles, and often have multiple modes of employment depending on the time of year. Due to the delay in project establishment, project components that were intended to take place during winter months were shifted into the commercial fishing season, for which half of our NVU UAS pilots participated. These seasonal/multiple roles impacted team cohesion as well as the timeline for pilot certification by the FAA. The part-time training program could not compete with full-time seasonal employment opportunities despite the core Team and Instructors working hard to accommodate the various needs of pilots-in-training. The impacts of this unanticipated delay likely influenced the number of pilots that did not complete the program. *LL: Avoid holding required program components during key subsistence and seasonal employment windows, i.e. May-August.*

Part 107 Certification in Alaska

The only two communities in Alaska in which a person can take the test to become an FAA certified Part 107 UAS pilot are Anchorage and Fairbanks. As such, the pilot trainees were required to travel outside their community in the middle of a pandemic to sit for a two-hour exam. Though funding existed for this effort, the complications associated with travel to and from Alaska Native communities during the pandemic instigated travel protocols that caused pilot trainees to need to be away from Unalakleet, and thus their primary employment and family, for a minimum of three days. The required quarantine time after their return from the city to Unalakleet caused the duration of the experience to be significantly longer, greater than 11-days for one trainee. This process may have contributed to some of the pilot attrition in that people were not ready to sacrifice such a long period of time away from their regular lives to travel for the certification exam. It is worth noting that the testing requirement in itself may have been intimidating to potential UAS pilots that were interested in the program, but due to test anxiety or other extenuating circumstances, were not inclined to follow through with the last component of the training, the testing for FAA certification. *LL: Part 107 certification is a larger hurdle than just a test for residents of rural Alaska.*

3.1.3. Hands-on Training for UASs

The LL from the hands-on training portion of the UAS program are straightforward and primarily logistical. Identifying these LL and implementing strategic solutions to address them will enhance the programmatic outcomes for future UAS training programs.

Simulator Training

Though the RealFlight UAS flight simulator software was readily available for purchase and shipment to the pilot trainees in Unalakleet, there were no computers available that the NVU UAS pilots had access to that also had a DVD player to run the simulator software. The solution to this was to purchase team laptops that had a DVD drive. This solution also became problematic due to the global supply chain

shortages on electronics as a result of the Covid-19 pandemic. Due to the delays in equipment provision due to the supply chain shortages, the laptops that could be used to host the simulator software were not available for use until after the NVU UAS Team already had the S2 and the X2E aircraft in-hand for test flying. The software is still valuable for training future pilots as well as for maintaining NVU UAS pilots' skills throughout the winter when UAS missions are few. *LL: Hardware requirements to support UAS program software is required in-hand to be able to use the software; order supporting equipment like laptops 6-10 weeks before it is required for program use.*

Hands-On S2 Training

The primary training with the S2 took place in Fairbanks in October and November, both indoors and out in the field. The indoor sessions provided an introduction to the Skydio S2s, proper inspection of the aircraft and accessories before going out into the field, other preflight preparations, post debriefs, flight and maintenance logs, etc. The outdoor sessions provided the team opportunities to see and/or practice different types of flight scenarios to better understand the S2s capabilities and operating parameters in real time. Scenarios included pre-programmed scanning of the historic 300' Chatanika dredge, real-time site interrogation utilizing a lawnmower pattern, and flights at varying altitudes and distances. *LL: Having the S2 in hand to train on, prior to the arrival of the X2E, provided the opportunity for pilots to build confidence in their flight abilities and practice different flight scenarios. S2 works well in tight indoor space though not the design intention.*

Hands-On X2E Training

The primary hands-on training for the X2E took place in Unalakleet in late February/early March 2022. The Skydio trainer traveled to Alaska for the training, worked closely with Katie Daniels, the NVU pilot in command, so that she became highly familiar and proficient with flying the X2E under different flight scenarios and environmental conditions including high wind speeds and dusk to dark lighting. UAF pilot Mike DeLue had been learning in the X2E independently throughout the fall, and was able to work with the Skydio trainer to dissect detailed and nuanced issues encountered with the aircraft and software throughout testing. Both PI Garron and Co-Is Henry and Hall were also on-site for the training, but did not spend time using the controller as much as observing and documenting the instruction and resulting training flights. Training flights included key linear infrastructure flights over water bearing infrastructure from the town water pump house, 3D modeling flights of the community tank farm and 3D modeling of key historical cultural resources. *LL: Hands-on, one-to-one or small group training is extremely valuable for instilling confidence and nuances for UAS skills training. Ensure that all pilots train on all equipment, regardless of anticipated time flying missions in the future.*

3.2. EQUIPMENT MANAGEMENT

3.2.1. Aircraft

The discussion of lessons learned about the Skydio UAS refers to both the S2 and the X2E unless expressly differentiated. Similarities and differences in these aircraft are discussed in detail in Section 2.3.1., whereas this section is dedicated to discoveries about project specific and relevant components of the Skydio UAS during testing and operation.

USA-Made UAS

This program was mandated to use UAS made in the USA. This directive forced researchers to identify equipment that would not have otherwise been utilized for this research. As such, the team was exposed to the rapidly growing USA drone market. Though none of the USA-made UAS possessed all of the desired components originally designed for integration into the program (i.e. multispectral sensors and imagery), many new capabilities were revealed and explored that were previously unknown to the research team. Besides being USA-made and supported, some of the additional benefits realized by identifying the Skydio platform included,

- No geofencing built into the software (no physical limitations to flight locations)
- Optical-based situational awareness (no GPS blocking)
- Alternative GPS flight mode and required lighting for night missions
- 360° obstacle avoidance AI
- 2D and 3D scanning capacity
- Current and expanding integration with DroneDeploy and other post-processing software

LL: USA-made UAS companies are rapidly expanding the capacity of their equipment to offer advantages that DJI products cannot.

3.2.2. Testing

Cold Weather

Cold weather testing is critical for understanding the operational limitations of equipment in Alaska. This testing took place throughout the winter of 2021-2022 in Fairbanks, Alaska. Results for both aircraft showed both the S2 and the X2E are capable of operating down to -20° F (-29° C) with little to no impact to the aircraft or battery life, if batteries were stored warm. No loss in flight time was experienced at cold temperatures, and no significant impacts to the collected data were observed on either the S2 or X2E; the greatest impact of cold was on the S2 iPad controller. *LL: The Skydio UAS are well suited for regular operation in the cold temperatures experienced in Alaska; limitations on aircraft operational temperatures are similar to their human pilots.*

Precipitation

The program team does not risk flights during precipitation. When needed for a search and rescue mission in inclement weather, the risk of flight will be the judgment of the pilot in command. *LL: Do not operate UAS when it is raining or snowing; return to home if precipitation begins midflight.*

Wind

All aircraft are sensitive to wind in one way or another. Most commonly, wind causes a lack of stability and an increase in energy use as the UAS tries to maintain that stability, which in turn reduces flight time. Testing the Skydio UAS in different wind conditions showed no notable reduction in battery life, and the only reduction in performance associated with wind was lack of stability causing the collection procedures to be paused until stability was regained. *LL: The Skydio UAS are more functional in wind up to 20 mph than most UAS with built in warning features.*

Connectivity

Connectivity between the S2 controller and the aircraft can be influenced by trees, low buildings, and metal structures passing between the aircraft and the controller. This is most heavily influenced by the internal antenna design of the S2. *LL: External antennas are more effective at maintaining connectivity between the controller and the aircraft than internally mounted antennas.*

Tablet driven UAS operations are limited by the tablet, creating an additional point of failure when not using a dedicated controller to fly the UAS. The S2 has significantly more connectivity problems than the X2E, some of which pivot around controller design. *LL: Controllers made exclusively to control the UAS are more robust in connectivity than tablet or phone-based controllers.*

2D and 3D Scanning

One of the critical benefits of the Skydio UAS over other UAS are the autonomous 2D and 3D scan capabilities. This automation reduces the UAS data flow to flight boundary definition, autonomous data capture flight, imagery upload to DroneDeploy, automated 2D model (orthomosaic) and 3D model creation. The level of quality in the EO sensors on the Skydio UAS allows for the collection of 2D points in 3D space, allowing for one-click orthomosaic and 3D model creation. *LL: Automated processing pipelines for 2D and 3D data exponentially increases the successful integration of data capture and processing.*

Every anomaly in operation that was discovered on the Skydio UAS was reported directly to Skydio. As a result of this rolling feedback loop, software improvements that subsequently increase the performance of the UAS are regularly released, and the program team's experience with the Skydio UAS and team remain positive. *LL: Maintaining strong and productive relationships with your equipment manufacturer will cause your problems to be elevated for solution.*

3.2.3. Laptops

Laptop computers are the primary supporting equipment for any UAS program. Many different makes and models can be used to support a UAS program, they just need to be compatible with the data management and protocols required as part of the program. The laptops chosen for use in this project was the Panasonic Toughbook. This laptop was specifically chosen for a number of its built-in attributes. Unfortunately for program delivery, the impacts of the Covid pandemic on the global supply chain caused a seven-month delay in the delivery of the laptops for this project, limiting their utility to support the program during the program. *LL: Required hardware should be ordered as soon as funding is available for purchase so as to reduce the impacts of supply side delays in delivery on the program.*

3.2.4. Chain-of-Custody

The introduction of chain-of-custody processes and documentation was one of the detail-driven attributes implemented as part of the NVU UAS Program. This effort was undertaken to reduce equipment loss and to ensure quality documentation in case of any subsequent liability discussions. It is hoped that the reduction of risk inherently delivered by practicing chain-of-custody procedures will support increased longevity of the equipment and the program. Chain-of-custody protocols are in place now, but have not yet been used as supporting documentation in liability discussions. *LL: Chain-of-*

custody processes are not intuitive and need to be expressly taught and maintained as part of a successful UAS program.

3.2.5. Software Licenses

The three required licenses to run the NVU UAS systems as designed through this UAS Program are the Skydio AEF, Skydio 3D Scan and DroneDeploy Teams software packages. The software bundle from Skydio that includes both of these services is available as either one-year or three-year licenses for operation. Software to operate the Skydio UAS is non-negotiably required. The DroneDeploy Teams license provides access to all of the 2D and 3D processing required to support orthomosaic and 3D model creation, and is exclusively operated in the DroneDeploy cloud environment on one-year terms. There were two LL from the investigation into software and software licensing for the UAS Program. *LL: Software compatibility with equipment is not a problem when most processing is done in the cloud. Cloud-based software licensing and access is simple and only limited by time as a result of bandwidth, and LL: Educational and tribal discounts exist for all of the supporting software used in this project; do not rely only on what is posted on-line.*

3.3. DATA MANAGEMENT

3.3.1. Data Collection and Protocols

There are basic components of every UAS flight that need to be considered prior to executing the mission. These LL have come from years of UAS experience from the research team and are stated here as basic ground rules of UAS mission planning that need to be regularly addressed.

- *LL: Always know why you are flying a mission so that you can perform appropriate mission planning to get the end product you want.*
- *LL: Always charge all batteries, even if you think the mission will be short.*
- *LL: Always assume everything will take twice as long as budgeted; bring extra supplies such as food, water, batteries and generator gas.*

The following LL focus on the nuances that were learned or reiterated during the UAS Program that are specific to missions in rural Alaska.

Airspace

Airstrips in most rural Alaskan communities are often located in or very close to the middle of town. Unalakleet's airport and runways are no exception. Additionally, in the hub community of Unalakleet local airspace is Class E during the day and Class G after the Unalakleet Airport closes, limiting all flights over town to after airport closure or to those flown with the use of a waiver. This heavily restricted airspace is juxtaposed by unrestricted airspace immediately outside of the city boundaries, a major benefit for all other missions. Operational UAS missions in rural Alaska need to account for these airspace restrictions in remote locations by performing rigorous flight planning in advance of the mission, inclusive of waiver application if needed. *LL: Airspace restrictions and securing operational waivers in rural Alaska are as critical and complex as they are in more populated locations.*

Weather

The impacts of weather on sUAS operations are exacerbated in Arctic and sub-Arctic environments by the physical conditions for pilots operating in these environments, the robustness of the aircraft, the lack of communication infrastructure, and the extremes experienced in all of these categories in coastal locations of Alaska. Weather is an uncontrollable force that will influence UAS missions. The only realistic solution for weather management is to plan for extra time in the field ideally at times of the year when the success of the mission is greater. *LL: Weather is variable. Always leave extra windows of time to perform the mission and to travel around the Bering Strait region to perform those missions.*

Cybersecurity

U.S. federal agencies do not want to use data collected with drones made in China due to known transmission of UAS metadata back to China regardless of where it is being collected, and unknown transmission of other in-flight collected data. For the same reasons, federal agencies are not allowed to purchase UAS manufactured in China. This UAS Project is funded by Department of Homeland Security dollars so falls under this directive. Other cybersecurity concerns revolve around GPS manipulation and data interception during transmission. UAS operators can only control a certain number of these risks and should make every effort to do so to reduce nefarious data use. *LL: Delivering UAS data from Unalakleet to regional and federal partners via hard drive delivery is the most cyber secure data delivery method and should be employed if security concerns are high for a particular mission.*

Coproduction of SOPs and Protocols

The NVU UAS Standard Operating Procedures (SOPs) working document was uploaded to Google Drive where it could be shared and edited in real time by those who participated in the sessions, as well as suggest edits and/or pose questions in between sessions. These SOPs were available to all members of the program from the moment of their inception, but were not added to, edited or manipulated by a member of the NVU UAS unless it was during one of the weekly working sessions. This was an important discovery as previous assumptions by the research team included having support of the co-production of these SOPs beyond the work sessions.

Similarly, the four protocols covering different components of emergency response and infrastructure inspection data capture flight were not able to be holistically co-produced due to the lack of background knowledge of the NVU UAS Team, and the amount of time remaining in the project after the completion of training. As such, the production of these four protocols relied heavily on the technical knowledge of PI Garron, who ultimately produced them for delivery and iteration by the NVU UAS Team and USCG pilots capable of flying these missions directly. These working documents will be altered through time as the NVU UAS Team leverages them for future mission support. *LL: Coproduction relied heavily on the technical knowledge of PI Garron; true coproduction of flight protocols was not possible because of the timeline available to produce required deliverables and the limited background UAS knowledge of the NVU UAS Team.*

The entire concept of co-production was new to some members of the team, and though is designed to empower team members in the process of program creation, may have been intimidating or poorly placed in the framework of the UAS program due to the required background knowledge of UAS that

was just being introduced at the time. This lack of understanding likely impacted the co-production process, leaving much of the document creation on the primary research team. *LL: Co-production does take time and may be unfamiliar to some. Clearly explaining the intent of the process and discussing how best to work together as a team will increase the benefits associated with program co-production.*

Though there is a deep sense of trust among all of the members of the project team, the intent of developing Unalakleet specific flight protocols was also to integrate local knowledge to support risk prioritization of flights during emergencies. This small protocol addition would have required either having the pilots canvas community members directly for information, or to have the project team develop relationships with a broad swath of the community to gain their perspectives on what culturally sensitive resources should be prioritized for observation during emergency response and infrastructure inspection flights. Both of the efforts, led by either the pilots or the research team, required time and knowledge that the program team was not afforded, as the time allotted to gain this community trust and gather this information was woefully underestimated. *LL: Due to a lack of time to develop deeper trust-based relationships within the community at large, Traditional Ecological Knowledge (TEK) was not integrated into UAS protocols.*

Data Collection for Emergency Response

The three emergency response missions for which protocols were developed were, oil spill detection and monitoring, flood delineation, and search and rescue (SAR). Each of these protocols has similarities based upon time sensitivities and coordinating with a response team during the active phase, and differences that were minimal but focused on time series documentation of the event.

Emergency response missions over water should focus on the real-time observation of the UAS flight path by a member of the response operation. Video over the ocean or river can still be recorded and viewed, but it cannot be reliably geospatially referenced without at least some anchor image to the land, ideally a formal ground control point. Response missions over land do not have these limitations.

SAR missions are the most time critical, and represent the major components that make emergency response missions different than other inspection or observation missions. SAR team/response team coordination is key to all SAR/response supporting UAS missions. Working directly with SAR/response coordinators increases efficiency as UAS teams can be directed to targeted areas and can work in tandem with foot-based operations to increase the depth of coverage over a given search area. If UAS teams are not embedded within the SAR/response operation, direct coordination with the SAR/response coordinators is necessary prior to UAS mission execution so that the most valuable UAS product can be collected for the SAR/response operation. *LL: Strengthening connections with the local SAR team is critical for future SAR and general response team support in Unalakleet.*

Data Collection for Infrastructure Inspection

As is the case for NVU, most community- supporting infrastructure is located in highly congested areas in controlled airspace, thus considerable coordination and planning needs to take place in order to execute those missions. Such flights can be used for area-based, linear, and 3D data collections, to help interrogate infrastructure and cultural resources in support of decision-making. These missions can be flown as part of a one-time effort or be conducted regularly and systematically to perform change

detection analyses. *LL: There is a high probability that a community's infrastructure falls into regulated airspace. In addition to following legal airspace guidelines, all efforts should be made to respect and protect people's privacy when flying in more congested areas and/or over people's home and/or seasonal camps.*

As contracting discussions begin for the NVU UAS Team, an additional issue is emerging. There is a lack of defined data products that should be resulting from these infrastructure inspection missions. End users want to have the information, but are unclear in how they want to receive that information, nor if they have the capacity to receive that information in any other format than hard copy. If these end products are not clearly defined prior to mission execution, confusion, disappointment and distrust could result. *LL: Manage expectations of end users by agreeing to a reasonable end product for the mission together.*

3.3.2. Processing

DroneDeploy was determined to be the software which provided the highest quality data product for decision-making, while also being reasonably user friendly to support the success of data product creation by the NVU UAS pilots. DroneDeploy offers the benefits of ease by only requiring EO images to be uploaded to their cloud processing environment. No processing selections are made, the data is just processed to the fullest capacity of the Drone Deploy software on the metadata of the imagery provided. The resulting 2D orthomosaics and 3D models are of high quality and are exportable for external end users. *LL: Not all geospatial processing needs to be painful. Identify the software solution that will provide you and your team with the product that is most useful for decision-making or the observation needed.*

3.3.3. Delivery

Different UAS data end user communities have different data needs that are met by different data products. It is essential to clarify and agree to in writing what the desired end products are to be. Data products created from UAS collected data processed in DroneDeploy can be exported for either digital display and manipulation, or for static printing as needed by the end user. Local data product delivery needs to include review of the products among the UAS team and the end user to highlight what the product is and what can be ascertained from it. End users outside of the local community will need their data delivered to them. Direct digital delivery is limited by bandwidth, but can be accomplished through cloud sharing services like Google Drive or DropBox. Other digital delivery mechanisms reliant upon opening a connection to a remote server or delivery of large files is still problematic in rural Alaska. To deliver data from these locations, data needs to either be converted to a lightweight format like JPG or it needs to be delivered in discrete chunks. The most straightforward way to deliver data outside of the community that is bandwidth independent is to save the raw and processed imagery onto a hard drive that can be shipped via small airplane through the U.S. Mail system. *LL: Though digital delivery is preferred, bandwidth limitations in rural Alaska persist.*

3.4. UAS OPERATIONS CENTER

3.4.1. Office

Given that Unalakleet was to store the project's UAS equipment (e.g. Skydio X2Es, S2s, charging stations, computer(s), radios, walkie talkies, supplies, field equipment), identification and preparation of a secure office space was critical. An office space, approximately 25' sq. ft., was identified in the NVU Tribal Office building. The space that had been used for storage more recently, needed to be cleared, and a secure lock installed; and internet connection and landline phone made available. In order to get the right lock and tools to install it, plus lining up someone to do the work, took lead time. *LL: Designated office space is essential for a certain level of program functionality, security of UAS equipment, supplies, and mission records, and to maintain realistic equipment chain-of-custody and maintenance logs. Provide adequate time to identify and prepare a location.*

3.4.2. Mobile

In preparing for a mobile mission, whether responding to an emergency and/or providing UAS service locally or to another community, upfront planning and readiness are critical. Preparing for mobile missions includes having a personal bag ready or a checklist to reference to prepare one, and a clear idea of what UAS team equipment should be taken to run mobile operations in different types of weather and locations. Equipment may have to change depending on whether access to a mission location is by vehicle, boat and/or plane. The *NVU UAS Standard Operating Procedures* includes a "Go Bag" list broken into "Non-UAS Items" and "UAS Materials" to support this requirement. *LL: Prepare for mobile missions systematically using the guidance in the NVU UAS SOPs, including always having a Go Bag or checklist available to prepare for a mobile mission in a short amount of time.*

3.4.3. Insurance

One of the critical components to a local UAS program is to carry sufficient insurance to cover the pilots, and the equipment, and also for any accidents that may result from UAS operations. The UAS Project was led by UAF, thus operated under UAF insurance policies for travel and UAS operations. With the project transitioning to the NVU UAS Program, NVU is required to carry their own insurance to maintain the NVU UAS Program, as is the case for any UAS service provider. *LL: Ensure all commercial UAS missions are covered under insurance.*

3.4.4. Communications and Marketing

External Communications

In communicating with the public regarding the UAS program, it is important to have a designated contact person (e.g. UAS Program Manager), their contact information, hours of operation, and other general UAS program information available via websites and other listings. It is also important to respond in a timely fashion to any inquiries received through those contact mechanisms. For NVU, the guidance and listing of this information is contained in its UAS SOPs, and should be disseminated more broadly through a dedicated webpage. *LL: Consistent, reliable and multiple pathways of communication should be actively leveraged to maintain program access by stakeholders.*

Internal Communications

After the pilot training ended, the same weekly meeting schedule was continued in order to work on Standard Operating Procedures, Protocols and to support each other for presentation preparations. Having this designated weekly meeting time was crucial for the continuity of the program throughout its duration, and because it was at a consistent time each Monday, there were very few scheduling conflicts preventing folks from joining. This practice is recommended for all UAS programs to maintain team cohesiveness and designated problem-solving time *LL: Create consistent space for UAS team members to connect each week to discuss and solve issues and identify opportunities.*

Marketing

Information regarding the overall project and the NVU UAS Program was successfully relayed to many different stakeholders throughout the project resulting in an on-going level of interest and support for the program. News outlets, scientific conferences, project newsletters, sponsor report-outs, ad hoc discussion and phone calls were the primary modes of project marketing. Though inquiries directly to John Henry regarding the NVU UAS services and capabilities, a direct result of these marketing actions, continue, a succinct, future-looking marketing plan has not been developed for the NVU UAS Team at this time. *LL: Consistent and frequent presentations about the program cause long-lasting program support.*

3.4.5. Contracting and Costs

Synthesizing the broad capacity and cost components of a community-based UAS program into a cost structure allows for streamlined contracting discussions with potential clients. However, the consideration of those components and collecting the different scales of information required to develop a clear contract cost structure took a large amount of time that was not properly budgeted for in the program. The Cost Analysis, section 5 of this Case Study, reports cost structures for a slightly larger sized program and regional programs, but the cost analysis specific to the longevity of the Unalakleet program was not budgeted for in the workplan and became essentially a volunteer effort on part of the project team to coordinate the information to develop the cost structure for immediate contracting needs in Unalakleet. *LL: Provide time to support program longevity when developing contracting mechanisms.*

3.5. CONCLUSION OF LESSONS LEARNED

Each project offers a multitude of lessons learned, and this one was no exception. The complexities of working through a DHS Center of Excellence, combined with working with an Alaska Native community, and critical research partners across America, throughout a pandemic, provided a large window of opportunity for lessons learned. Some of the original plans to co-produce most of the components of the program were idealistic, and the objective of analyzing different sensor combinations was scientific. These two preliminary aims of the project were replaced with program components that provided what was actually needed: a regional team with known capacity to provide salient, legitimate, near real time data from remote Alaska for decision-making. The primary lesson learned is to be flexible with program components to reach the overarching end goal successfully.

4. REGIONAL CRITICAL INFRASTRUCTURE & EMERGENCY RESPONSE INFORMATION

Bering Strait communities, like NVU, are remote, subsistence-based communities, off the road system in Western Alaska. As such, environmental compartments (e.g. air, water, soil, and flora and fauna), and community support mechanisms, like the airport, power plant and school, are key assets for the survival of the community. Being able to monitor these assets and report on their condition is key for ER activities, as are search and rescue missions and other dynamic ER scenarios. Through discussions with project partners in the Norton Sound region, specific emergency scenarios that the pilots have identified for their community were identified for flight protocol support. These specific scenarios are search and rescue actions over land, flood delineation and oil spill detection and monitoring.

In real time, UAS pilots need to have readily available resources to help prioritize key components of their UAS data collection flights as part of their emergency response missions. Hence, prior to an actual emergency situation, a necessary step is to identify key critical infrastructure and vulnerable (subsistence) assets located in NVU and other Bering Strait communities that should be prioritized for imaging during an ER event for situational awareness. During NVU UAS working sessions, the question of how to identify these resources and how best to incorporate such information into emergency response (ER) were discussed.

As part of the NVU UAS working session, a matrix with key assets for Unalakleet was initially established. In working to fill out the matrix, the NVU UAS pilot in command voiced a concern that the information being collected in the matrix could be culturally and security sensitive. Listening to this concern, project investigators considered other options that drew on various resources, which are described below.

4.1. COMMUNITY DOCUMENTS

Over the course of several prior BIA projects, including the 2018-2020 BIA Project mentioned earlier, the project co-investigators had become familiar with a number of key documents (e.g. Local Economic Development Plan, Hazard Mitigation Plans, and Small Community Emergency Plans) for NVU and other Norton Sound communities. After another review of such documents, it was determined that much of the same information related to key community assets and infrastructure was actually available in The City of Unalakleet Hazard Mitigation Plan (December 2015) under “Table 6-4. Unalakleet Critical Facilities & Infrastructure”. The recommendation is for the NVU UAS Team to use Unalakleet’s HMP as an initial resource to identify critical community assets for emergency response mission support. The information contained in the HMP Table 6-4 is invaluable and provides critical information including location (Lat/Long), possible number of occupants, ownership type, type and value of assets, vulnerability to certain risks.

A number of communities in the region have HMPs since the document is a criterion for receiving certain types of mitigation funding. Though some HMPs may be older than others, reviewing a community’s document would be valuable when the NVU UAS Team is preparing for an ER mission.

The following table, Table 6-4 Unalakleet Critical Facilities & Infrastructure⁶, is from the City of Unalakleet Hazard Mitigation Plan, December 2015. Generally, HMPs are updated every 5-7 years.

Table 4.1. City of Unalakleet Hazard Mitigation Plan (HMP), December 2015, Table 6-4.

Table 6-4 Unalakleet Critical Facilities & Infrastructure											
Facilities	Number of Occupants	Facilities	Address	Latitude	Longitude	Estimated Value	Building Type	Earthquake	Flood	Severe Weather	Tundra/ Wildland Fire
Government	3	City Hall	28 Beach Road	63.87662	-160.79333	\$1,000,000	W1	X	X	X	X
	3	Native Village Offices	Main Street	63.87191	-160.78527	\$2,000,000	W1	X	X	X	X
	NA	IRA Office Native	NA	63.8795	-160.78926	NA	W1	X	X	X	X
Emergency Response	4	Memorial Community Hall/ State Troopers	Airport	63.87516	-160.78685	\$4,000,000	W1	X	X	X	X
	2	Emergency Operations Center/Police station	Main Street	63.87739	-160.78906	\$3,000,000	W1	X	X	X	X
		National Guard Building	Airport	63.87979	-160.79422	\$1,000,000	W1	X	X	X	X
Educational	150	BSSD- Unalakleet School	Beach Road	63.87726	-160.79301	\$20,000,000	W1	X	X	X	X
	0	OLD BIA School abandoned	Undefined	63.87252	-160.78502	Undefined	W1	X	X	X	X
	12	School Offices	Beach Road	63.87733	-160.79124	\$5,000,000	W1	X	X	X	X
Medical	12	Health Clinic	Airport Road	63.87776	-160.79111	\$30,000,000	W1	X	X	X	X
Community	1	Library Building	Pond Road	63.87851	-160.79249	\$200,000	W1	X	X	X	X
	3	UNC Office Building Store	Pond Road	63.8753	-160.78702	\$3,000,000	W1	X	X	X	X
	2	Post Office	Main Street	63.87301	-160.78502	\$6,000,000	S2L	X	X	X	X
	24	Fish Cannery	By the dock	Undefined	Undefined	Undefined	W1	X	X	X	X
	2	Teachers Quarters	Main Street	63.87784	-160.7937	\$500,000	W1	X	X	X	X
	2	Teachers Quarters	Main Street	63.87812	-160.7939	\$500,000	W1	X	X	X	X
	2	Teachers Quarters	Main Street	63.87781	-160.79005	\$500,000	W1	X	X	X	X
	6	AC Store	Main Street	63.87277	-160.78347	\$500,000	W1	X	X	X	X
	0	Fuel Storage Tanks (>500gal) Northwest 15 tanks	Undefined	63.87961	-160.78673	\$25,000,000	OTF	X	X	X	X
	0	Radio Transmitter	Undefined	63.87662	-160.79333	\$20,000	CBO	X	X	X	X
	1	Generator	Undefined	63.8775	-160.78796	\$15,000	EPPS	X	X	X	X
315	Estimated Occupants				Estimated Total Value	\$168,495,000					

(Unalakleet 2015, DHS&EM 2009)

⁶ City of Unalakleet Hazard Mitigation Plan (HMP), December 2015. Prepared by City of Unalakleet Hazard Mitigation Plan Team and Hazard Mitigation Planning Team.

Another key document, which could be used as a reference and a number of Alaska communities have completed, is the Small Community Emergency Response Plan (SCERP). This document outlines steps to be taken in case of an emergency and agencies and/or individuals to be contacted.

Both the City of Unalakleet's HMP and Unalakleet's July 2019 SCERP are available to the team on the NVU UAS Program Drive. Unalakleet's SCERP is referenced in the NVU Uncrewed Aircraft Systems (UAS) Standard Operating Procedures (SOPs) to assist the UAS pilot in command craft an emergency response plan for the mission and to help ensure appropriate action at the appropriate time by the crew. In the SOPs it is recommended that a copy of the most current *Unalakleet Small Community Emergency Response Plan for Unincorporated Area* should be kept in the NVU Drone Team Office. Another copy should be available to take in the field on missions.

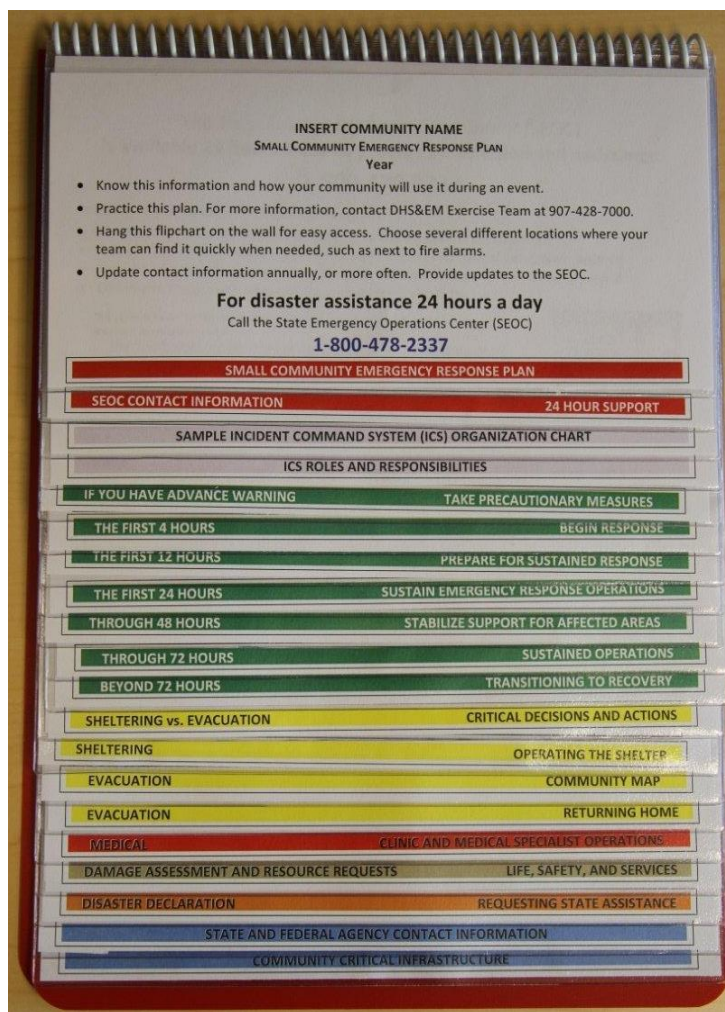


Figure 4.1 (Upper right): SCERP template.

Figure 4.2 (Right). Cover page of Unalakleet's SCERP.



A *Small Community Emergency Response Plan* template is available online at: <https://drive.google.com/file/d/1vVMF8uNKNGfwMrLFa-rnvzon97zI87AC/view?usp=sharing>. More information about SCERPs is available on the Alaska Division of Homeland Security and Emergency Management - Planning Section website at: <https://www.ready.alaska.gov/Plans/SCERP>.

Critical community information can also be found by searching individual communities on the Alaska Department of Commerce, Community, and Economic Development - Division of Community and Regional Affairs (DCRA) website at: <https://dcra-cdo-dccd.opendata.arcgis.com/>, organized by community name.

An example of some of the Unalakleet information available on the DCRA site is found at: <https://dcced.maps.arcgis.com/apps/MapJournal/index.html?appid=acffb5f1e31c4061a8e74ea2a98aa79b#>. Information on the Bulk Fuel

Inventory can be found in the Utilities section on the left. The site also includes an ArcGis map for exploring via geographical points. By clicking on the items on the map (e.g. pink dot (bulk fuel tank storage) or pale yellow dot (electric utility company)), a pop-up screen shows up with additional information. The caveat being that there is access to the Internet.

Figure 4.3 (Upper right) and Figure 4.4 (Lower right). Examples of Community Detail Information found on the DCRA site for Unalakleet.

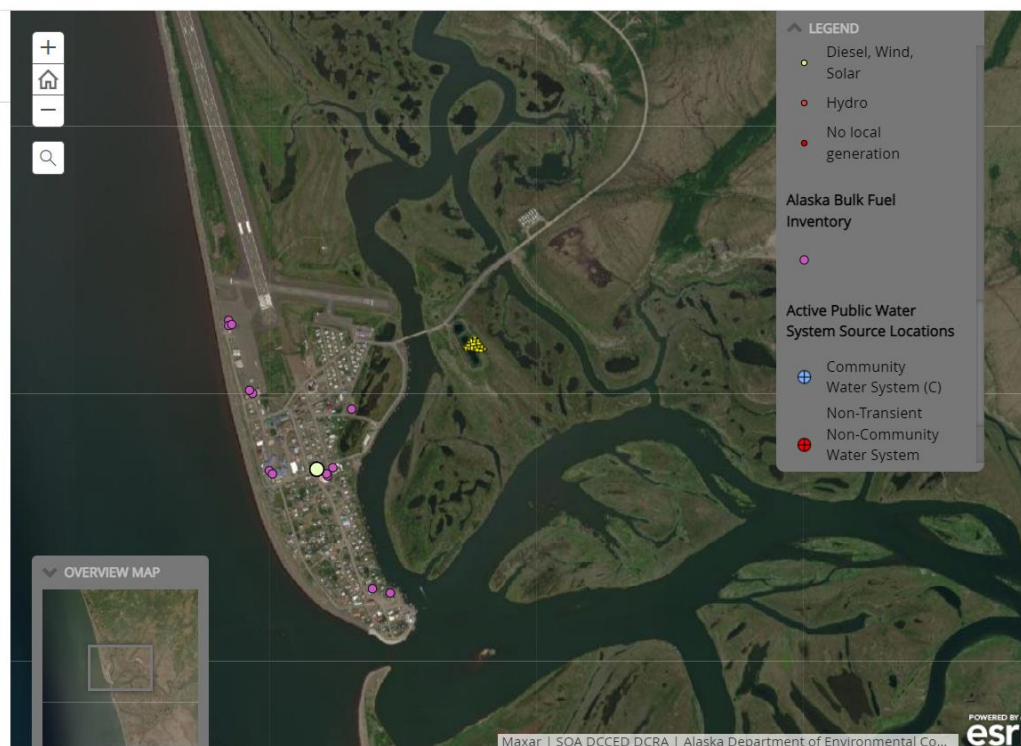
Return to DCRA Information Portal

Unalakleet, Alaska

Heating Fuel Vendor
Unalakleet Native Corporation

Bulk Fuel Inventory:

Owner	Owner Contact	Number of Tanks	Gasoline Capacity	Diesel Capacity	Total Capacity
West Coast Aviation Service	None	None	None	None	7200
Alaska Village Electric Cooperative	None	None	None	None	358000
Unalakleet Native Corporation	None	None	None	None	261900
City of Unalakleet	907-625-3531	None	None	None	23000
Peninsula Airline and ATS	None	None	None	None	1900



4.2. COMMUNITY INPUT

March 2022 Roundtable Discussion

In addition to resources mentioned above, in conjunction with the March 2022 Community Fair, local decision makers and potential users of UAS-collected data were invited to a discussion with project investigators and the NVU UAS Team. The emphasis of the discussion was to share with those attending what types of data can be collected, data processing steps, and possible formats that information can be received. The goal was to better understand what types of reports or “End Products” the City Public Works Department, electric utility, SAR members, and others might need.

Out of the discussion, the emergency response scenario that resonated most within the community was for search and rescue support by a UAS. The value of the infrared sensor was much higher for members of the Unalakleet search and rescue community than it was for decision-makers monitoring the integrity of infrastructure because of the sensor capacity to clearly delineate body heat from the surrounding landscape. Access to infrared sensors in rural Alaska is not common, hence this added capacity for the community and region is significant. In contrast, folks interested in UAS applications for infrastructure inspections were more interested in the EO data for infrastructure inspection efforts, as that data is more intuitive for integrity analyses. These community members simultaneously recognized the importance of infrared sensors for specific infrastructure applications, such as transformer integrity, but the value of having the infrared sensor in the community was higher for the support of search and rescue activities.

Community Survey Responses

As discussed above in the **Regional Community UAS Needs** section, those responding to the Community Survey were asked to prioritize a list of 19 Key Community Assets to Inspect, Monitor and /or Protect. The top 4 assets that people indicated a need to Protect during an emergency were: Subsistence Harvest Locations, Cultural Resources, Fuel Tanks, and Contaminated Sites. Fuel Tanks and Contaminated Sites can be identified through the documents mentioned above. However, the Subsistence Harvest Locations and Cultural Resources information are much more sensitive and the information not readily available outside of the community. To incorporate subsistence and culturally sensitive assets into flight plans, the NVU UAS Team will have to work with Tribal Historic Preservation Officers (THPOs), elders and others knowledgeable about such information, and determine the most culturally appropriate way to analyze the resulting data over those sensitive areas.

In-depth Discussions

Additional in-depth discussions continue to be held with staff of regional organizations in the Bering Strait. These conversations provide insight into infrastructure priorities that these organizations have, and have aided in the refinement of data management procedures and contracting language. Some areas of interest that have come out of those discussions include mapping of coastal erosion for certain communities in the region, taking elevations of the utilidors, as well as determining areas of permafrost subsidence to better determine where communities can be built.

5. COST ANALYSIS OF UAS PROGRAM IMPLEMENTATION MODELS IN ALASKA’S NORTON SOUND REGION

5.1. INTRODUCTION

In Alaska’s remote and sparsely populated Norton Sound region, there are major barriers to the timely and efficient inspection of key infrastructure facilities. Conducting hands- and eyes-on tests requires costly transportation across difficult terrain with variable and often severe weather. Delays in completing these inspections or assessing damages can lead to multi-faceted disasters with potentially significant economic, social and environmental costs to the surrounding communities. Unmanned aircraft systems (UAS) — or drones — can mitigate some of these limitations and are increasingly used to support both routine and emergency maintenance inspections and disaster response needs.

A growing body of evidence suggests that substantial savings in time and cost can be achieved by utilizing UAS for monitoring natural and other resources. Applications range from infrastructure and oil and gas pipeline inspections to cultural heritage site inventories, coastal erosion assessments, and fish, wildlife, and plant surveys. Some of these studies suggest that UAS are cost-effective and may offer more accurate, faster, or safer results compared with traditional land-based or air-based inspections⁷.

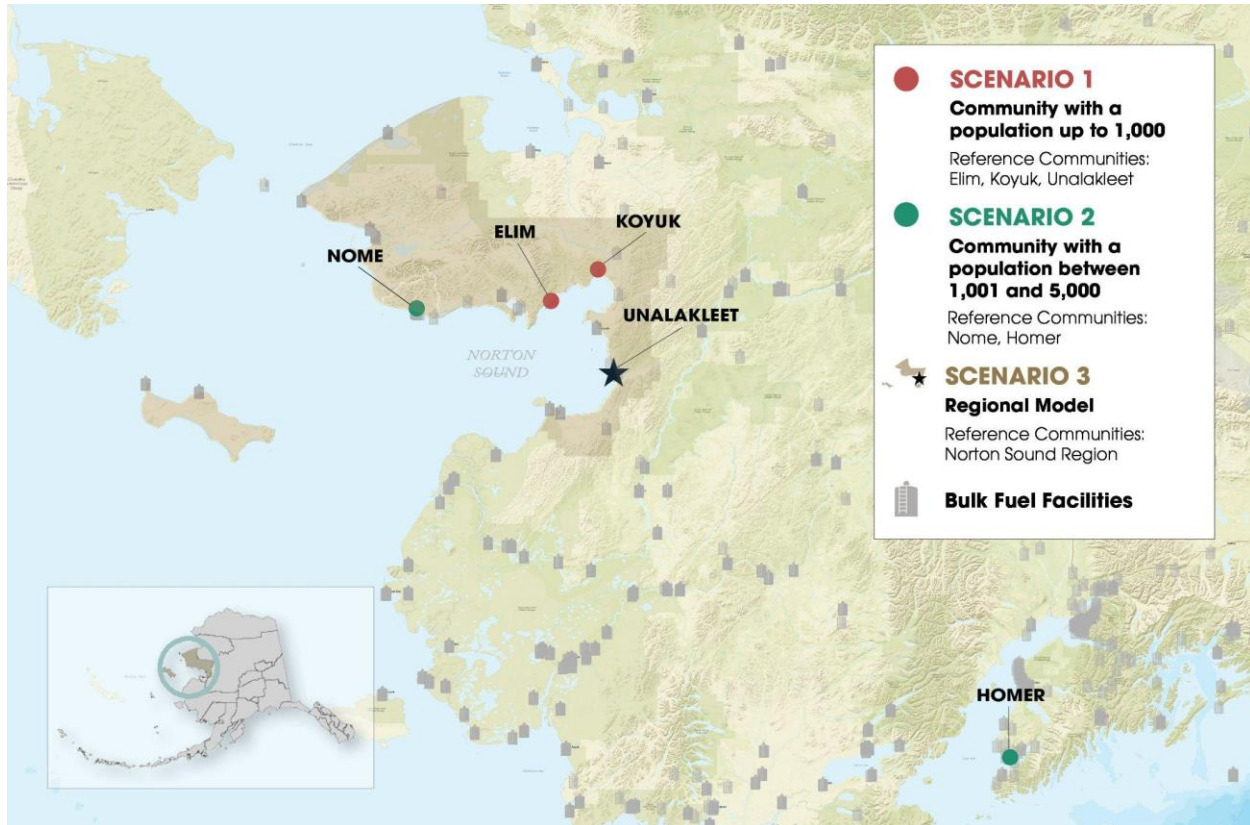
However, few studies detail the full costs of the deployed systems, the amortization used in the analyses, or other technical and economic assumptions. Likewise, most do not account for costs related to personnel, program management, UAS training and certification, computer systems, software and licenses, insurance, travel, and fleet replacement or upgrades. Based on these studies alone, it remains unclear whether UAS are useful substitutes or complements to traditional monitoring approaches.

Barb Cozzens of Whistling Thorn Strategies carried out a cost analysis to estimate and analyze the costs associated with establishing UAS programs in the Norton Sound region at three scales:

- **Scenario 1:** A community with a population of up to 1,000
- **Scenario 2:** A community with a population between 1,001 and 5,000
- **Scenario 3:** A regional model

⁷ See: Cozzens, B. (2021) Environmental Monitoring with Unmanned Aerial Vehicles: Cost Estimating and Analysis in: Henry, John, Garron, J., Hall, M., Cozzens, B., Gilliam, N., Griffith, G., Shepherd, H. *Feasibility of Improving Local Decision Making in Alaskan Communities with Unmanned Aircraft Systems and Online Climate Data Tools*. pp. D.1 - D.19.

UAS Program Implementation Models



Map 5.1. UAS Program Implementation Models map [1:11990561] produced by Barbara Cozzens. Utilities Bulk Fuel Inventory dataset: The Alaska Department of Commerce, Community, and Economic Development (DCCED), accessed on May 22, 2022.

This report details the methods used in this analysis and results related to the costs of establishing these programs. This analysis aims to contribute to the knowledge base and inform the ongoing dialog about the use of UAS in rural and remote Alaskan communities.

Outputs of this cost analysis include:

- Total costs by scenario
- Yearly estimated costs by scenario
- Cost per scenario by resource category
- Cost per tribal member

While this analysis provides important insights into the costs of establishing a community-based or regional UAS program in the Norton Sound region, it should not be seen as an accurate estimate of the definitive costs if a UAS program were to be implemented at scale. Because the UAS technology is still relatively early in development, and community requirements for its capabilities are uncertain, costs represent current best estimates, and will likely change significantly as community needs, staffing requirements, and technical capabilities become clearer.

Additionally, this analysis only estimated the costs of each scenario; it did not attempt to quantify the impact of improvements in the frequency or efficacy of a UAS program compared to traditional approaches. It also did not explore scenarios for program optimization, which should be examined closely to define use cases and implementation plans in the future. In any program, policy, or action, the preferred alternative is not chosen simply based on cost, but rather on cost-effectiveness. Decisionmakers ultimately select the alternative that achieves the required level of service at the lowest cost.

The results of this analysis can be used to inform the design of future studies to determine if UAS technology can improve the frequency and reliability of key facilities inspections and disaster response times, and if a sound case can be made for integrating UAS into the community, either directly or through a regional service delivery model.

5.2. METHODS

This analysis looked at the costs of establishing a UAS program in two-sized communities and at a regional scale. The geographic scope of this cost analysis was limited to the Norton Sound Region. Transportation costs are likely to vary across Alaska based on season, demand for services, fuel prices, geography, and availability of services. Although the results of this cost analysis are not necessarily representative of state-wide costs, they provide initial estimates to inform the next steps in exploring and better defining the potential deployment of a community-based or regional UAS program.

The analysis incorporates four categories of costs: personnel, materials, facilities, and other inputs. Only costs directly related to the UAS program are included. For example, if a pilot spends two days per month on mission-related activities, only that percent -- 192 hours out of 2,040 working hours in a year, or 9.4% -- of his or her salary is included in final costs.

The model uses 2022 as the base year and uses a discount rate of 3% for analyses over a 2-year time horizon. Where local salaries were not known, wages from other areas were used as proxies and adjusted using regional price parities. Table 1 details the input parameters used in this analysis:

Table 5.1. Cost Inputs and Sources

Data Element	Value	Source	Notes
Parameters & Rates			
Regional Price Parity	1.03	BEA	Alaska Nonmetropolitan Area
Interest Rates (2022)	Treasury Bond Rates, with the exception that interest rates for 1 year are set to zero (0)	Federal Reserve Bank of St. Louis Economic Data	For amortizing the prices of ingredients that last more than one year

Data Element	Value	Source	Notes
Consumer Price Index (CPI-U) 2022	287.504	U.S. Bureau of Labor & Statistics	For inflation adjustments
Personnel			
Salaries for pilots	\$61,430 annually	Salary.com	Average salary for a drone operator with 1 to 2 years of experience in nonmetropolitan areas of Alaska
Salary for project coordinator	\$60,530* annually	Salary.com	The average salary for a UAS Program Manager in Raleigh, NC
Salary for GIS technician	\$31* per hour	Jessica Garron/Univ. of Alaska	Average hourly rate for a GIS technician in Fairbanks, Alaska
Fringe Rate/Alaska	86%		MCSAP
Materials			
Cost of Skydio X2E drone	\$14,999	GRESCO Technology Solutions	
Usable life of a drone	2-4 years	Drone U	
Cost of drone imagery computer	\$2,445	LSU Ag Center	
Usable life of computer	3 years	IRS	
Software & Licenses	\$492 per year	Jessica Garron/UAS Solutions Matrix	Adobe Photoshop, Adobe Premiere Pro, & ESRI Drone2Map (free with Tribal license)
Reference Books	\$18, \$18, \$24	Amazon.com	Books and other materials suggested by Andrew Wentworth
Fleet Renewal	33% per year after year 1	Coastal Drone	
Facilities			
Size of facilities	25 square feet	Jessica Garron/Univ. of Alaska	
Cost of Commercial Office Space	\$1.8/sq foot (UNK) \$2.154/sq ft (Homer)	Statewide Lease List: Alaska Department of Transportation	
Other Inputs			
Initial Pilot Training	\$1397 per pilot	<u>Props</u>	Online program: Part 107 Drone License Test Prep, Don't Crash, Practice Drills & Exercises, Comprehensive Mapping, 3D Interactive Modeling
Internet Costs	\$50/month	ViaSat	Prorated based on personnel time

Data Element	Value	Source	Notes
Commercial Air Travel (Flight 107 Certification, Mission)	\$219 - \$531	Ravn Air or Bering Air	See Supporting Materials: Travel Cost Calculations
Per Diem (M&IE, Lodging)	\$101 - \$125 (M&IE) \$175 - \$229 (Lodging)	Federal Register	See Supporting Materials: Travel Cost Calculations
Taxi	\$21 per person (assuming a group of four rides together)	Taxi Fare Calculator (Anchorage, AK)	Anchorage Airport to Flight 107 Testing Center (32 miles roundtrip)
Rental Car	\$100	Dredge Inn	
Gasoline in Alaska	\$5.19/gallon	AAA Fuel Calculator	Extracted May 15, 2022
Flight 107 Certification Exam	\$175	FAA	
Insurance	\$2500 + \$2400 per drone/team	SkyWatch.AI	\$5M Liability and Hull Coverage

**Input values before RPP adjustments*

Technical assumptions and additional details related to the inputs collected for each scenario are described in **Appendix B: Cost Analysis/Assumptions Related to Cost Ingredients**.

5.2.1. Scenarios

Costs were analyzed for three scenarios. Characteristics of each are described in Table 2 below:

Table 5.2. Cost Scenario Characteristics

Scenario	Description	Reference Communities	Land Area	UAS Mission Assumptions
1	Population up to 1,000	Elim, Koyuk, Unalakleet	2.6 – 5.1 square miles	Mission travel within the community in company vehicles: two missions per month
2	Population up to 5,000	Nome, Homer	12.5 – 15 square miles	Mission travel within the community with company vehicles: three to four missions per month

Scenario	Description	Reference Communities	Land Area	UAS Mission Assumptions
3	Regional Model Norton Sound region has 9,492 residents (2010 Census Bureau Report)	Based out of Unalakleet	Region	Mission travel within the community with company vehicles: two missions per month To smaller communities by air: two missions per month To mid-size communities by air: three missions per month

5.3. RESULTS AND DISCUSSION OF COST ANALYSIS

This section describes findings regarding costs associated with each UAS implementation scenario. Detailed assumptions and model parameters are contained in **Appendix B: Cost Analysis/Assumptions Related to Cost Ingredients**.

The model costs program implementation, from start-up to program delivery, over a 2-year period. The approach incorporated the cost of personnel time and is comprehensive including costs of hardware, software and licenses, other materials, fleet renewal, facilities, training and testing, and travel.

Note: Report results are based on a set of assumptions believed to be reasonable given available or known information, however many of these assumptions can be varied. For example, the number of pilots can be reduced based on budget or mission demand, or prices can be increased or decreased based on what is negotiated with vendors.

Table 5.3. Total Costs Implementation Model

Metric	Total Costs Using Local Prices	Cost per Community Member (Average)
Scenario 1: Small Community	\$205,390	\$205
Scenario 2: Mid-Size Community	\$268,072	\$54
Scenario 3: Regional Model	\$1,639,446	\$173

Figure 5.1. Total Costs by Year in Local Prices

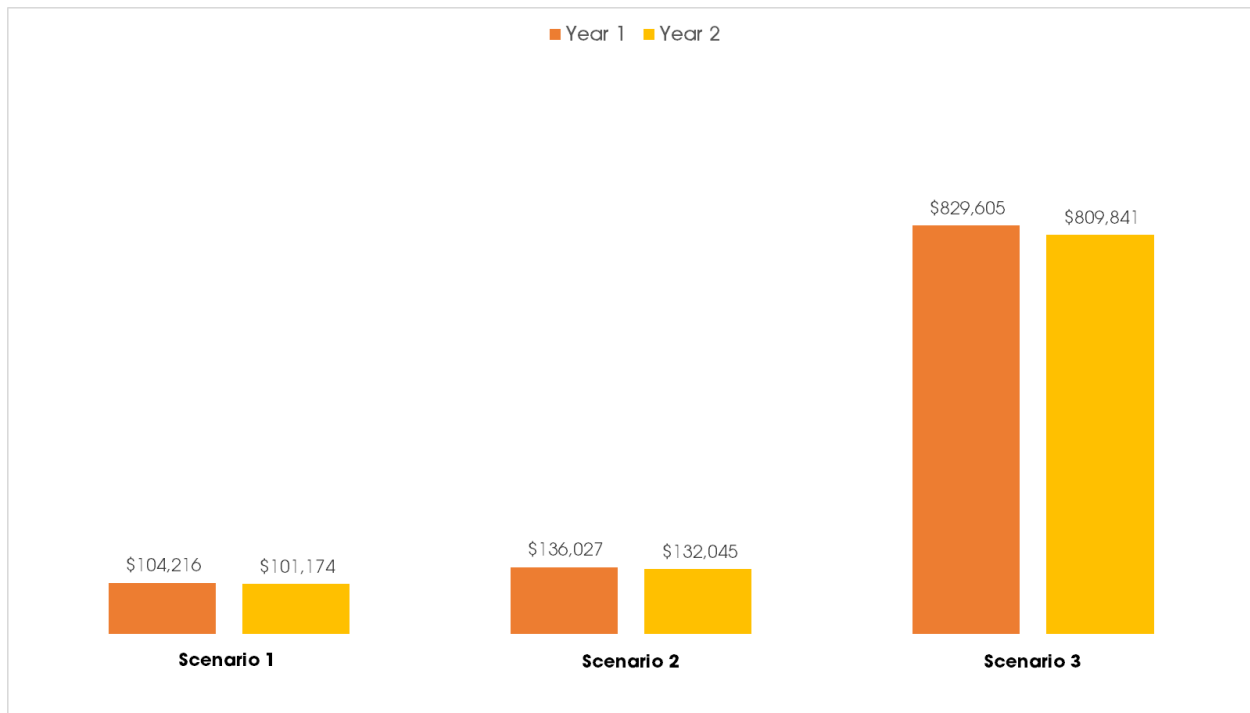
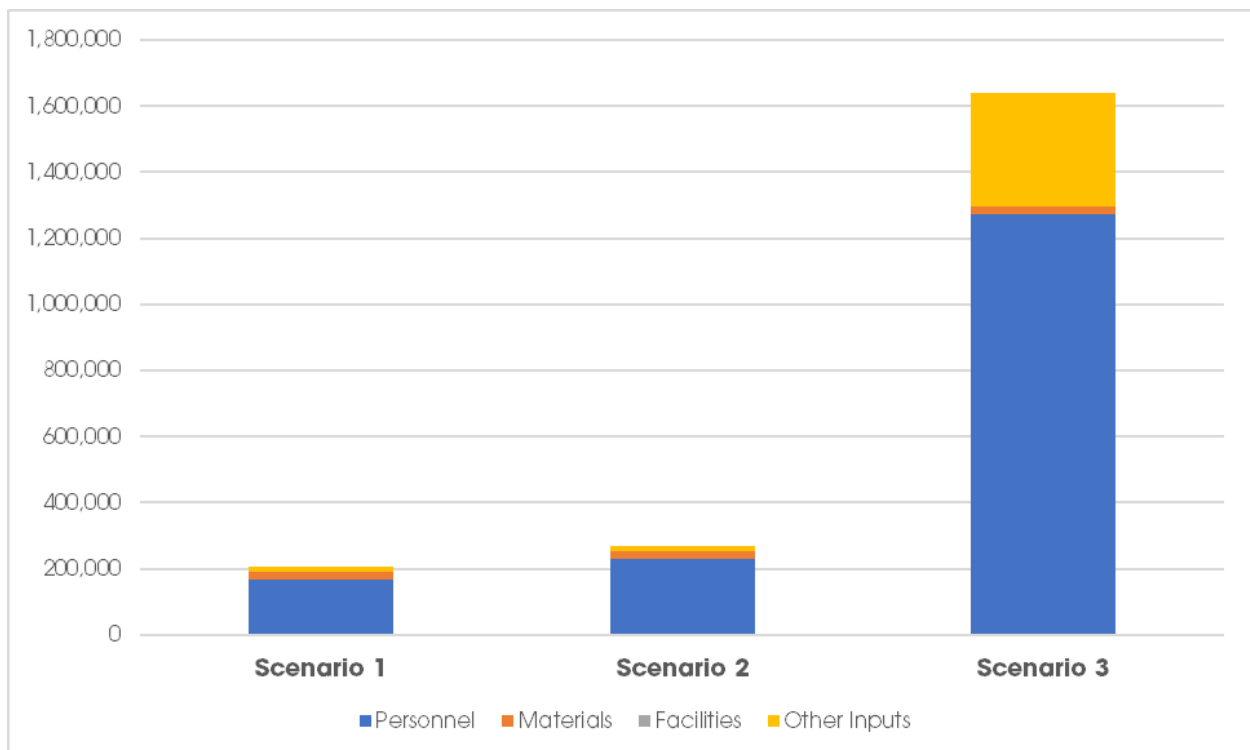


Figure 5.2. Total Costs by Resource Category



The major cost category for all three scenarios is personnel: 81%, 86%, and 78% of the totals, respectively. Reducing the number of pilots in the community-based implementation scenarios would significantly reduce the total costs.

It is important to remember that the scenarios analyzed in this report have not been optimized. Two sets of two pilots, two drones, and the selected drone model may not be optimal for small or even mid-sized communities. Further analyses and more data are needed to develop optimized programs for using UAVs at the local scale.

5.4. CONCLUSION OF COST ANALYSIS

This cost analysis has several limitations. The results are based on a set of assumptions believed to be reasonable given available or known information. However, there are significant uncertainties associated with program configurations – namely mission demand and the personnel and equipment required to support these demands.

In spite of these limitations, the cost analysis does contribute to a small and growing body of work quantifying the costs of implementing a community-based UAS program. Any decisions to deploy such a program should be informed by further economic analysis that optimizes program delivery to best serve the geographical areas and needs. Such analyses should also quantify the expected programmatic benefits – both downstream and temporal – in relation to costs.

6. RECOMMENDATIONS

The critical outcome of the overarching UAS Program, from which this Case Study resulted, was defined to be: a research knowledge product of the UAS Program for USCG consideration; a set of trained pilots; and flyable UAS staged in the Bering Strait region. The latter two prepared to efficiently support community and USCG maintenance inspection and emergency response needs as desired by USCG or the NVU. That critical outcomes were met, but have fallen short of what is required to fully realize the potential of this work in practice. The following set of recommendations was developed to ensure that the successful and ground-breaking application of these remote-sensing tools in a cooperative way to support emergency response and infrastructure inspections capacity in the Bering Strait region will be utilized to their fullest capacity both in Alaska and USCG Sectors across the nation.

6.1. DEVELOP REGIONAL UAS TEAMS THROUGHOUT COASTAL ALASKA

Though the below set of recommendations are described specifically in reference to coastal Alaska, they should be used as proxy recommendations for any region of interest in the U.S. that is considered remote, with poor communications bandwidth, and a lack of overarching government-based structure for monitoring the physical environment in support of decision-making.

6.1.1. Make the Investment

Address the regional need for infrastructure inspections and emergency response by leveraging a shared service arrangement to deploy cross-municipality UAS teams. The fundamental establishment of this UAS team in the NVU fell within the projected cost analysis of approximately \$205,390 for the establishment of one team in a community of up to 1000 people. The estimated \$1.6-million cost to establish a regional UAS program based in Unalakleet is offset by the potential benefits of a shared service agreement. In many cases, sharing municipal services allows local communities to lower transaction costs, increase efficiencies through economies of scale, and achieve a higher level of service overall. Research suggests these effects are most pronounced in municipalities with small populations⁸. Additionally, shared services and inter-municipal cooperation (IMC) promote innovation in service delivery, improve cross-jurisdictional service coordination, and increase competitiveness for outside funding.

6.1.2. Recruitment

One of the concerns that became apparent toward the end of the project was that there was no express mechanism for on-boarding new UAS pilots into the NVU UAS Program. The UAS Program was prototypical and focused only on this initial cohort of pilots and did not actively recruit new pilots when individuals dropped out of the cohort. As such, there is a risk that this current effort may not be sustained unless new pilots are added to the NVU UAS Team, and replaced to maintain a minimum of four Part 107 current UAS pilots for the team. It is recommended that communities and USCG Sectors

⁸ Bel G, Sebó M. Does Inter-Municipal Cooperation Really Reduce Delivery Costs? An Empirical Evaluation of the Role of Scale Economies, Transaction Costs, and Governance Arrangements. *Urban Affairs Review*. 2021;57(1):153-188. doi:[10.1177/1078087419839492](https://doi.org/10.1177/1078087419839492).

where this UAS program roadmap is applied **actively recruit new pilots as others leave the program to maintain a consistently sized team of UAS pilots**. The recruitment methods used in this Case Study were effective and are recommended as a guide to this rolling recruitment process.

6.1.3. UAS Pilot Training

The UAS pilot training provided in this program was custom designed and delivered by a UAS pilot that had been working in the field for over twenty years. His instruction was supplemented by lectures and guidance from an FAA airspace expert to answer policy questions with extreme detail. The training was stretched out across the spring of 2021 to facilitate trainees other employment requirements, instead of being concentrated as an in-person one-week long training program that was scheduled to take place in Unalakleet, which was the plan prior to the program being modified due to the pandemic. One hypothesis about the pilot attrition from this program was that the training portion of the program just lasted too long. Not knowing if this was a contributing, primary or not applicable variable in the attrition rate, **it is recommended that a commercial training program be employed by communities interested in providing this training for potential community pilots instead of developing a customized UAS training program**. These commercially available trainings are optimized for efficient delivery and training exclusively to pass the FAA Part 107 certification exam. They can either include having a trainer travel to the community to provide in-person training, or training can be offered remotely. These programs range from an eight to 24-hour commitment, and put more of the onus on the student to prepare for the Part 107 exam with practice tests. Either on-line or in-person, a commercial training program followed with a series of group study sessions is worth the investment.

If the UAS trainer is a highly specialized expert or a hired trainer to conduct Part 107 certification training in 16-hours, the training is only the first piece in the development of a UAS program. To guide the UAS team trainees through the components of training and ultimately program establishment, there **needs to be at least one motivated individual in the community to motivate the other trainees and encourage follow through on all of the requirements of UAS program establishment**. This person will likely serve as the UAS team coordinator throughout team establishment and the POC with any outside support needed for the effort. This coordinator needs to be recognized for the extra time and responsibility they are contributing to the program throughout their tenure.

6.2. LEVERAGE CURRENT PROGRAMMATIC STRUCTURE REGIONALLY

It was the intention throughout the UAS Program lifecycle that the results of this co-production project needed to be able to serve as a roadmap for other Alaskan communities and USCG Sectors. This objective drove the project team to identify and prototype the project components holistically so that they could be applied beyond Unalakleet as well. The below recommendations are focused on leveraging the established tangible components of the UAS Program in the establishment of future UAS community or sector-based UAS teams.

6.2.1. Skydio UAS

The Skydio UAS chosen for use in this program were well-suited for the applications the UAS Program was developed to support. We **recommend that the USCG and the NVU continue to use Skydio products in an operational setting** due to a number of specific capabilities that they provide:

- Made and supported in the USA
- No geofencing built into the software
- Optical-based situational awareness
- Alternative GPS flight mode and required lighting for night missions
- 360° obstacle avoidance AI
- 2D and 3D scanning capacity
- Current and expanding integration with DroneDeploy and other post-processing software

UAF, NVU, and USCG HQ now have established partnerships with Skydio, making the continuous use of their product easy, and that support infrastructure needed for future applications is already in place.

6.2.2. SOPs, Protocols, and Operational Components

The UAS Program team spent a considerable amount of time over the program lifecycle co-producing the NVU UAS standard operating procedures to include, preflight protocols, post flight protocols, how to manage the logbooks that comprise the chain-of-custody documentation for the NVU UAS Team. Similarly, the emergency response and infrastructure inspection protocols were developed for the four use cases identified, and weeks were spent compiling the operational components of the NVU UAS Program and establishing the working team office in Unalakleet, AK. It was the intention throughout these co-production processes that these policies, protocols, and operational guidelines were to be the template for other communities in Alaska and across the U.S.A. to follow in order to establish future UAS teams. It is recommended that **other communities, USCG Sectors, and cooperative partners use the UAS programmatic team documents developed as part of this program to establish UAS teams** and programs to support situational awareness around emergency response and infrastructure inspections for risk prioritization.

6.2.3. NVU UAS Team

The NVU UAS Team is an established, contractable, UAS service provider in the Bering Strait region of western Alaska resulting directly from this program. This team was trained by experts in unmanned aircraft operations, FAA policies and guidelines, remote-sensing, communications and science co-production. The NVU UAS Team is FAA Part 107 certified, and employ their full skill set when flying UAS. It is recommended that the USCG and its local, regional, statewide and federal partners **take advantage of the new found capacity of having a UAS team on-site in the Bering Strait** that can provide near real-time situational awareness via imagery, maps, and models all across Alaska and the U.S.A.

6.3. DEVELOP SUPPORT STRUCTURE FOR REGIONAL UAS TEAM LONGEVITY

One of the LL that became clear during the later stages of the UAS Project was that not enough time was budgeted to holistically develop the components needed for the long-term success of the NVU UAS Team. Though this project provided training, compensation, equipment, and the programmatic structure within to operate, no time was defined in the approved project work plan to prepare for the continued success of the team after the conclusion of the project lifecycle. The below set of recommendations were developed as the final steps that should be taken when establishing a community-based UAS team in rural Alaska.

6.3.1. MOU Establishment

The longevity of regional UAS teams will initially be dependent on their utilization. If the teams are not contracted for flights, the overarching cost of maintaining pilot and technological currency may be too great for the community to maintain the program. One of the ways that known stakeholders can invest in the continuity of this and future community-based UAS teams is through partnership agreements that reduce the friction and time associated with UAS mission contracting.

USCG

USCG needs to make a direct effort to connect with UAS operators in the Bering Strait region that can support their mission, and integrate UAS operations into regular workflows. Integrating UAS operations into emergency response workflows in western Alaska has already been defined and implemented in the *Arctic and Western Alaska Area Contingency Plan*. This effort, completed by PI Garron and CDR Jereme Altendorf of Sector Anchorage in 2019, identifies how to integrate UAS teams and UAS-collected data into the incident command post of a hazardous substance response for informed decision-making. In Alaska, additional efforts are underway to integrate UAS flights and data into training activities for oil spill response (oil spill detection and tactical response observations) and for the validation and modernization of Geographic Response Strategies for oil spill response for the entire coast of Alaska. These are only a few of the many different operational areas in which the USCG can benefit from the integration of UAS flights and data. **Establishment of MOUs between the NVU UAS Team in the Bering Strait region and the USCG, specifically the USCG Sectors within District 17, will allow for long-term support of USCG integration of these UAS tools and methods** while the USCG determines if UAS operations will be established within the USCG operational units, or if it will be contracted out through local service providers, such as the NVU UAS Team.

NOAA

During emergency response activities, NOAA serves as the USCG scientific advisory team through their Scientific Support Coordinators (SSC). These SSC rely on the rich datasets available for visualizations and decision-making through their Environmental Response Management Application, or ERMA interface. ERMA is an online mapping tool that integrates static and real-time data, to help emergency responders and environmental resource managers better understand incidents that may adversely impact the environment, including oil spills, chemical spills, and vessel groundings. Arctic ERMA is a version of ERMA that is specific to the Arctic, and is focused on Alaska.

During the course of the UAS Program, UAS data was collected, processed into orthomosaics, and provided to NOAA for display in Arctic ERMA. This process was clear and straightforward, and did not require any special post-processing beyond data delivery as a GeoTIFF to the ERMA team. This prototypical delivery identified the data products that were needed to have UAS data collected by the NVU UAS Team available through ERMA for decision-making during an emergency response. It is recommended that this **UAS data product delivery pathway from rural Alaska to NOAA ERMA be codified through an MOU between NOAA and NVU, and that additional baseline environmental data sets be collected by the NVU UAS Team and shipped to NOAA using this pathway to increase familiarity with the process** prior to an emergency response in the region.

State of Alaska

The State of Alaska operates the Alaska Geospatial Office (AGO), a group that coordinates with public and private stakeholders across Alaska to develop and manage geographic information. Preliminary discussions with AGO have focused on the delivery of NVU UAS-collected data relevant to the State of Alaska to the AGO team for long-term archive. It is noted that not all data sets collected by NVU would be appropriate to send to the State of Alaska archive, and there is no mandate for those deliveries to happen. Regardless, **it is recommended that an MOU for data archive be established between NVU and the AGO to ensure long-term access and archive of raw UAS data.** The AGO also hosts the State of Alaska Open Data Geoportal⁹, where stakeholders can access a multitude of geospatial data from across the state. Once UAS data is ingested into the AGO archive, if desired it can be displayed through the Geoportal for other stakeholders to incorporate into their analyses, such as the Alaska Division of Geological and Geophysical Survey, the state group charged with documenting coastal and community change.

UAF

High quality data processing and preliminary analysis can be performed by the NVU UAS Team using the Skydio-collected EO data processed in DroneDeploy as either 2D or 3D models, but the interpretation of the data products will be limited by the knowledgebase of the NVU UAS pilot team's experience. Experts capable of interpreting the end products created from the NVU team collected data are distributed throughout UAF, as are experts that can help provide additional programmatic and scientific guidance on other components of the NVU UAS Program. Establishing an **MOU between NVU and UAF will provide the framework for systematic and ad hoc support of the NVU UAS Team** that is not predicated on the formal proposal process typically required for UAF researchers. These agreements need to have enough flexibility to allow for open-ended discussion and discovery among all parties to further the success of the NVU and other UAS programs that may be developed among these partners in the future.

6.3.2. Development Of Contracting Language

There was no language in the DHS approved workplan for the UAS Program that described the development of contracting language or long-term cost structures in support of the NVU UAS Team outside of the lifecycle of this project; the objectives of developing a UAS team in the Bering Strait

⁹ State of Alaska Open Data Portal, <https://gis.data.alaska.gov/>

region and to coproduce operational protocols applicable in rural Alaska and other USCG Sectors across the nation was paramount. This lack of foresight is understandable in light of the main project objectives, but in reality, the **baseline contracting language and cost structure must be developed to ensure that the co-produced protocols and the retention of a well-trained team in the Bering Strait region**. Local, regional and federal entities began to reach out to the NVU UAS Team during the lifecycle of the UAS Project to conduct missions in support of infrastructure inspections, which is how this oversight was brought to the project team's attention. It is critical that if future UAS programs are developed in rural Alaska that time and funding is allotted to formalizing how those UAS teams can be contracted for work to maintain the program.

6.3.3. Marketing

Advertising the capacity of the NVU UAS Team has been by word of mouth, quarterly newsletters, scientific presentations, public webinars, press releases, quarterly reports to project sponsors and stakeholders. These modes of communication about the team have been effective during the UAS Project lifecycle, but long-term marketing is needed to maintain knowledge of the program and ideally attract new UAS missions to support. Included in a reasonable marketing campaign would be the establishment of a UAS team website with contact information, listings of available UAS-based services, and samples of prior projects or data products created from them. During the pandemic, the entire world became accustomed to gathering information from the internet as a primary source, including people in rural Alaska. **Establishing a UAS team website is recommended for all community-based UAS teams**. Additional marketing that could be effective in rural Alaska is the distribution of informational flyers to nearby community leaders, regional organizations, radio stations, and other industry operators in the area that could benefit from UAS support. In this case, it would be assumed that those agencies recommended for MOU partnership above would already have an established relationship.

7. CONCLUSIONS

The most significant outcome of this project is a well-trained, fully-functioning, UAS team in western Alaska that can be contracted for their services. Through this project the NVU UAS Team was empowered by the scaffolding of this program to build with the tools of the UAS industry. The NVU UAS Team is actively leveraging the scaffolding of the UAS Program built as part of this effort. Being the first team in the Bering Strait to have developed a UAS pilot team, fully fleshed set of SOPs, operational flight protocols, contracting mechanisms, and the roadmap for continued success and expansion, the NVU UAS Team is at an advantage to fulfill stakeholder needs in the Bering Strait Region, including those of the USCG. This roadmap, though only implemented once thus far, and within the costs estimated in the cost analysis performed as part of this work, can also be adopted by other communities in other USCG Sectors across Alaska and the nation to support the near real time observational needs of the USCG.

The long-term partnerships among NVU, UAF, and MFPP were leveraged to develop and execute this project. Those same partners are committed to seeing the long-term success of the program, but recognize that success is reliant upon UAS program implementation plans being executed as designed. Part of this design was specifically to support the USCG infrastructure inspection needs across western Alaska. To execute this component, the NVU UAS Team needs to be contracted by USCG on a regular basis in support of regular infrastructure inspections in the Bering Strait region, and in support of situational awareness during emergency response actions. Having a regional UAS team with known capacity reduces response time by contacting them directly for the provision of salient and legitimate near real time data from the region. First attempts at this contracting are taking place during the summer of 2022, facilitated by PI Garron and UAF, as part of the relationship establishment between USCG Sector Anchorage inspectors, responders, and the NVU UAS Team.

Throughout the project, the effort became less and less about sensor testing and more about operational implementation of UAS to support the immediate needs of the USCG and the NVU. Though this transition was one of the clear objectives of the workplan, and supports the needs of both the USCG and NVU, the project was an exercise in boundary spanning from academia to local and federal agencies more than a scientifically driven study about UAS, which may be a more crucial application of the information in the short-term.

8. REFERENCES / RESOURCES

Published Materials Used in the NVU Part 107 Training:

- FAR/AIM 2021: Federal Aviation Regulations/Aeronautical Information Manual. Aviation Supplies & Academics, Inc.. Newcastle WA. 2021.
- Airman Knowledge Testing Supplement for Sport Pilot, Recreational Pilot, Remote Pilot, and Private Pilot. U.S. Department of Transportation, Federal Aviation Administration, Flight Standards Service. 2018. FAA-CT-8080-2H.
https://www.faa.gov/training_testing/testing/supplements/media/sport_rec_private_akts.pdf.
- Gardner, Bob, and David Ison. The Complete Remote Pilot. Aviation Supplies & Academics, Inc.. Newcastle WA. 2018.
- Remote Pilot 2020 Test Prep: Study & Prepare. Aviation Supplies & Academics, Inc.. Newcastle WA. 2019.

Footnote References:

- Bel G, Sebő M. Does Inter-Municipal Cooperation Really Reduce Delivery Costs? An Empirical Evaluation of the Role of Scale Economies, Transaction Costs, and Governance Arrangements. Urban Affairs Review. 2021;57(1):153-188. doi:10.1177/1078087419839492.
- City of Unalakleet Hazard Mitigation Plan (HMP), December 2015. Prepared by City of Unalakleet Hazard Mitigation Plan Team and Hazard Mitigation Planning Team.
- Cybersecurity and Infrastructure Security Agency, Chain of Custody and Critical Infrastructure Systems, <https://www.cisa.gov/insights>.
- Henry, John, Garron, J., Hall, M., Cozzens, B., Gilliam, N., Griffith, G., Shepherd, H. (2020). Feasibility of Improving Local Decision Making in Alaskan Communities with Unmanned Aircraft Systems and Online Climate Data Tools. <https://drive.google.com/file/d/1fBel0tvS0rSP11Sf2o-WpvsXpHpXwPQ0/view>.
- Skydio Safety and Operating Guide, <https://support.skydio.com/hc/en-us/articles/360000586653-Skydio-Safety-and-Operating-Guide>.
- State of Alaska Open Data Portal, <https://gis..data.alaska.gov/>.

APPENDIX A: NVU UAS Pilot Application (Fnl 2-03-2021)

Job Title: UAS PILOT/OBSERVER
Reports to: Deputy Director
Status: Part-time, Non-exempt, Hourly
Wage: \$39.49/hour
OPEN: February 15, 2021
CLOSE: March 5, 2021



JOB SUMMARY

The unmanned aircraft systems (UAS/drone) Pilot/Observer will work within the bounds of the NVU Personnel Policies and Procedures to participate in the NVU UAS Pilot Training Program. Trained pilots/observers will become FAA certified to fly small UAS (provided), perform UAS recordkeeping, coproduce (co-create) flight protocols to perform inspections of bulk fuel containers and in support of emergency operations (i.e. search and rescue, oil spill detection, flooding events) and conduct UAS flights and data deliveries as needed. Training will be conducted remotely until the cessation of the COVID-19 pandemic, with exceptions for travel to sit for the FAA certification exam in Anchorage or Fairbanks, AK.

ESSENTIAL QUALIFICATIONS

- High School Diploma or GED.
- Must have a valid Alaska Driver's License.
- The duties and responsibilities are not an all-inclusive list, but rather a general representation of the duties and responsibilities associated with this position. The duties and responsibilities will be subject to change based on organizational needs and/or deemed necessary by the supervisor.

SKILLS AND ABILITIES

- Detail oriented and possess strong organizational skills for recordkeeping.
- Self-motivated with ability to work with minimum supervision, yet able to adapt and work in a team environment.
- Strong written and oral communication skills.
- Ability to comprehend topographical maps.
- Basic computer literacy and capacity for learning new software.
- Capable of working outdoors for extended periods of time.
- Must be able to multi-task.
- Preferred familiarity with radio communications and communication infrastructure in remote Alaska.
- Prior experience with unmanned aerial systems preferred, but not required.
- Limited travel is required.
- Able to lift and move medium to heavy objects and bags (less than 50 lbs.).

DUTIES AND RESPONSIBILITIES include, but are not limited to the following:

- Participate in UAS Pilot Certification course.
- Acquire FAA Part 107 certification.
- Coproduce operational flight protocols operations in support of infrastructure inspections (bulk fuel facility/tank farm) and emergency response surveys.
- Conduct UAS operations in support of infrastructure inspections and emergency response surveys.
- Perform UAS data archive and delivery protocols.
- Become familiar with National Incident Management System/ Incident Command Structure.
- Become familiar with Unalakleet Small Community Emergency Response Plan.
- Coordinate with local, regional, federal entities as required for data collection and delivery.
- Acquire and sustain radio communication skills.
- Other duties as assigned.

Please submit an application to be considered for this position.

Application may be submitted via mail, fax, in person, or by email.

Native Village of Unalakleet
PO BOX 270
Unalakleet, AK 99684

Deputy Director John Henry
EMAIL: john.henry@unkira.org

Phone: (907) 624-3622
FAX: (907) 624-3621

NVU recognizes Alaskan Native and Native American preference in its hiring and employment policies.

BACKGROUND INFORMATION ON JOB

Project Summary: The Department of Homeland Security has funded a project to train a set of UAS pilots in Unalakleet, Alaska, to conduct infrastructure inspections and emergency response actions in support of local and/or regional crisis, using small unmanned aircraft systems (UAS). Applicants accepted to the program will be expected to complete all above listed duties and responsibilities in partnership with the project team led by the NVU, University of Alaska Fairbanks and the Model Forest Policy Program.

Partners: The University of Alaska Fairbanks, the Alaska Center for Unmanned Aircraft Systems Integration, Model Forest Policy Program, USCG Sector Anchorage, Arctic Domain Awareness Center (a DHS Center of Excellence house at the University of Alaska Anchorage), Kawerak, Inc., Unalakleet Bulk Fuel Tank Farm.

Trainers' Background: The Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) will be providing the pilot training for this program. ACUASI was established at the University of Alaska Fairbanks in 2001, and subsequently has become a FAA Center of Excellence, is the manager of the Pan-Pacific FAA UAS test site, and is an active participant in the FAA Beyond program. Project scientists from ACUASI specialize in remote sensing applications in Alaska, and will be supporting the UAS pilots throughout.

NVU recognizes Alaskan Native and Native American preference in its hiring and employment policies.

APPENDIX B: Cost Analysis/Assumptions Related to Cost Ingredients

	Scenario 1 Community of ~1,000	Scenario 2 Community of ~5,000	Scenario 3 Regional Program
Operational Parameters			
Flight Time (per team)	• 12 flying days per year • 12 backup days for weather per year	• 18 flying days per year • 18 backup days for weather per year	• Within community: • 12 flying days per year • 12 backup days for weather year • Servicing small communities: • 12 flying days per year • 12 backup days for weather per year • 24 travel days per year • Servicing mid-size community: • 18 flying days per year • 18 flying days per year • 36 travel days per year
Other Time (per team)	• 12 days of data processing and analysis per year	• 18 days of data processing and analysis per year	• 42 days of data processing and analysis
Dedicated Program Time (per team)	= 288 hours per year	= 432 hours per year	2080 hours per year (FTE)
Personnel			
Number of Personnel	Includes only personnel directly involved in UAS operations and data analysis		
	Two sets of two pilots and a project coordinator to oversee the operational status of the program, assign equipment and staff, and develop policies		Two sets of two pilots, a project coordinator, and a GIS specialist to manage data and maps
Amount of Time Spent on the Program	Default: 2080 hours for a regular job 8 hours per day, 5 days per week, 52 weeks per year		
Pilot	• 288 hrs/year (13.8%) • Estimated based on operational parameters above	• 432 hours (20.8%) • Estimated based on operational parameters above.	2080 hours (100% of their total time is spent on the program)
Initial Pilot Training	• Assumes 40 hours of training time and deducted from total hours in Year 1 • As training is used initially to set up the program and does not recur each year, costs are spread over 5 years.		
Coordinator	• 416 hours (20%) for a two-drone program. • Based on the assumption that managing a 10-drone program is a full-time position)		• 2080 hours (100% of their total time is spent on the program) • Assumes additional time spent administering a regional, fee-for-service program
GIS Technician			1,040 hours (50% FTE)

Salaries for Personnel			
Coordinator	- As there is no reliable baseline data for Alaska, used the low estimate for the same position with the state of North Carolina - Adjusted to local values using Regional Price Parities		
GIS Technician			- Estimate from Fairbanks (e.g., Metropolitan) - Adjusted for Alaska/Nonmetropolitan portion using Regional Price Parities
Materials			
UAV	- The model uses the cost of a Skydio X2E and assumes two drones per scenario. - Costs are spread (amortized) over an assumed usable life of 3 years.		
Drone imagery computer	- The model uses a configuration recommended by LSU Ag Center and assumes two systems per scenario. - Costs are amortized over an assumed usable life of 3 years (per IRS).		
Software and Licenses	Annual license fee, one per system		
Books and Reference Materials	One each per pilot		
UAS Maintenance or Fleet Renewal	Set aside for fleet renewal (repairs or replacement of damaged parts, batteries, blades, etc.): 33% in Year 2		
Facilities			
Size of facilities	25 square feet of commercial space		
Cost of facilities	Utilizes average cost of commercial space in UNK	Utilizes average cost of commercial space in Homer	Utilizes average cost of commercial space in UNK
Other Inputs			
Initial Pilot Training	- Assumes use of an FAA-compliant, fully-online drone training platform to manage, train, and test pilots - Courses include Part 107 Drone License Test Prep, Don't Crash, Practice Drills & Exercises, Comprehensive Mapping, 3D Interactive Modeling - Startup cost: spread over 7 years		
Internet for Training	25% of a month attributable to the program assuming 40 hours of online training - Startup cost: spread over 7 years		
Flight 107 Certification	- Travel to Anchorage for Flight 107 Certification: flights, per diem travel and full-day (M&IE), one-day lodging, and Flight 107 certification test fee per pilot, as well as a taxi for the group of four (See Supplementary Materials) - Flight 107 Certification test fee		
Insurance	\$5M Liability and hull Coverage for two Skydio X2Es		
Mission Travel	Per mission: Pilots spend one day flying with a travel day on either end		

Number of Missions	Two missions per month = 24 missions per year (12 per team)	Three missions per month = 36 missions per year (18 per team)	Assumes a mix of internal and external missions: Two internal missions per month, two external missions to small communities per month, and three missions to mid-sized communities per month.
Per Mission Costs	Assumes travel within the community, calculated based on the size of the community UNK = 4.95 square miles or 9.9 miles roundtrip per mission	Assumes travel within the community, calculated based on the size of the community Nome = 12.5 square miles or 25 miles roundtrip per mission	Internal: - Assumes travel within the community, calculated based on the size of the community - UNK = 4.95 square miles or 9.9 miles roundtrip per mission External (see <i>Supplementary Materials: Mission Cost Calculators</i>): To Small Community: - Per pilot: Flight, two per diem travel days (75%) and one full day (M&IE), two days of lodging - Per diem based on Delta Junction (pop. 943) - Per team: Rental car, rental car fuel - Fuel estimate assumes roundtrip across max. length of the community, UNK at 4.95 sq miles. To Mid Community: - Per pilot: Flight, two per diem travel days (75%) and one full day (M&IE), two days of lodging - Per diem based on Nome - Per team: Rental car, rental car fuel - Fuel estimate assumes roundtrip across max. length of the community, Nome at 12.5 sq miles. <i>Note: The model can accommodate variable mission-support configurations based on the mix of internal and small- and medium-sized external missions. The two mission types are assigned a unit cost based on the incremental, mission-related travel costs described above. Using the Supplementary Materials: Mission Cost Calculator, costs can be updated if the number, type, and frequency of missions is changed.</i>
Internet Access for Program Delivery	- Follows breakdown of pilot time - Adjusted for 11 months in Year 1		
	Assumes 23.1% of monthly internet use is attributable to the program		

APPENDIX C: Native Village of Unalakleet Uncrewed Aircraft Systems Standard Operating Procedures



Native Village of Unalakleet

Uncrewed Aircraft Systems (UAS)

Standard Operating Procedures

This document was developed in partnership with:

The University of Alaska Fairbanks International Arctic Research Center and
the Alaska Center for Unmanned Aircraft Systems Integration

Native Village of Unalakleet,

Model Forest Policy Program,

USCG Sector Anchorage,

Arctic Domain Awareness Center, a DHS Center of Excellence
housed at the University of Alaska Anchorage.

April 2022

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The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

Front Cover Photo Credit: Michael DeLue (2022)

Log of Revisions

Name of Revision	Date of Revision	Revision Highlights	Pages Effected	Approver Signature
Rev 1	12 July 2021	Original Issue	All	N/A
Rev 2	30 April 2022	NVU UAS Original Issue	All	

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Abbreviations & Acronyms

2D - Two-dimensional

3D - Three-dimensional

AQI - Air Quality Index

BVLOS - Beyond visual line of sight

COTS - Commercial off-the-shelf technology

DOM - Dissolved Organic Matter

DSM - Digital surface models

EO - Electro-optical sensor; RGB sensor; passive sensor

FAR - Federal Aviation Regulation

FLIR - Forward-looking infrared

GPS - Global positioning system

LIDAR - Light Detection and Ranging sensor; active sensor; uses pulses of light energy reflected off of a target to create a 3D map of surface characteristics

NDVI - Normalized Difference Vegetation Index; an indicator of plant community health and seasonal variability, through the relation of plant biomass to photosynthetic activity

Photogrammetry - Science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena.

RGB - Electro optical sensors operating in red, green and blue visible spectrum

RS - Remote-sensing; process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft)

SAR sensor - Synthetic aperture radar

SfM - Structure from Motion; a data processing methodology to create 3D maps from EO data.

sUAS - Small unmanned aircraft system, less than 55 lbs. gross take-off weight

UAS - Unmanned aircraft system; consists of aircraft, power source, payload, ground-controller station

UAV - Unmanned aircraft vehicle

Utilidors - Aboveground, insulated network of pipes and cables, used to convey water and electricity in communities situated in areas of permafrost.

VTOL - Vertical Take-Off and Landing; refers to a UAS that takes-off and lands vertically, but flies operationally horizontally

1. Introduction

1.1 Purpose

The goal of this document, Native Village of Unalakleet Uncrewed Aircraft Systems Standard Operating Procedures (SOPs), is to collect all the specific techniques, practices, and procedures related to flight of small uncrewed aircraft systems (sUAS) by the Native Village of Unalakleet (NVU) Drone Pilot Team into one easily referenced document. Where established procedures already exist, they are referenced in this document rather than restated.

1.2 Unalakleet Community Overview

The Native Village of Unalakleet is located 148 miles from Nome on the southeast side of Norton Sound at the mouth of the Unalakleet River, its adjacent shorelines, and subsistence hunting and fishing grounds. Combined, these areas, based on the total aggregated acres from the Alaska Native Claims Settlement Act, are approximately 17,573.42 acres.

Unalakleet has a history of diverse cultures and trade activity. Archeological finds date as far back as 200 B.C. to 300 A.D. On the upper river, nearby Athabaskans were considered "professional" traders with a monopoly on the Indian-Eskimo trade across the Kaltag Portage. Unalakleet was once a major trade center as the terminus for the Kaltag Portage, an important winter travel route connecting to the Yukon River. During the 1830's, the Russian-American Company built a post in Unalakleet. In 1898, reindeer herders from Lapland were brought to Unalakleet, by Sheldon Jackson who was head of the Bureau of Indian Affairs, to establish sound herding practices. In 1901, the Army Signal Corps built over 605 miles of telegraph line from St. Michael to Unalakleet, over the portage to Kaltag and Fort Gibbon. The city was incorporated in 1974. The local economy is the most active in Norton Sound, along with a traditional Unaligmiut Eskimo subsistence lifestyle. Fish, seal, caribou, moose, and bear are utilized.¹

The Native Village of Unalakleet ("IRA"), represented by the Unalakleet IRA Council, is a federally recognized Alaska Native Tribe organized pursuant to Section 16 of the Indian Reorganization Act of 1934, as amended, and derives its organization and authority from its Constitution and Bylaws, as amended. The IRA manages the Tribal affairs and administers several federal programs for roughly some 750 Tribal members.

The Bering Strait region of which NVU is a part of, has been identified by the U.S. Coast Guard (USCG) as having a gap in analyses for emergency response strategies that have otherwise been identified for Pacific and Atlantic shipping routes. Coupled with reduced and inconsistent sea ice coverage in this region, there is more vessel traffic navigating this only passage between the Arctic and Pacific Oceans, highlighting the need for effective strategies to prevent and address marine disaster response in the Bering Strait region. Populations and communities are sparse in the Bering Strait, thus there is an increased reliance of decision-makers on remote sensing tools for detection of conditions out of the line

¹Native Village of Unalakleet. (2021). Retrieved from <https://www.nativevillageofunalakleet.org/>.

of sight of the human eye. Weather in this part of Alaska often limits optical observations to below the cloud ceiling, or to satellite-based radar-based observations. A localized remote sensing solution that is inexpensive, designed for low altitude flights (below cloud ceiling), and that can create intuitive data products, are UAS. UAS are ideal for the dirty, dull, dangerous and hard to access jobs associated with research and operational observations in remote Alaska.

Safely integrating UAS-based remote sensing tools into remote Alaskan communities for emergency response activities is a critical component of this document. Increasing community capacity to perform more frequent inspections of oil containing and transporting infrastructure, and the need for rapid damage assessments over communities impacted by crises of various intensity is supported through the NVU UAS program as described in this document. This document is designed to support daily UAS operations in Unalakleet, AK and to support emergency operations in the Norton Sound region as defined in the Arctic and Western Alaska Area Contingency Plan (USCG 2018).

1.3 NVU UAS Program Mission

- Support the use science-based knowledge for decision-making, locally, regionally, and statewide, primarily through the use of UAS.
- Expand the workforce in the region to encompass new technology, in specific UAS expertise for supporting decision-making.
- Provide a UAS data collection service.
- Coordinate NVU's UAS program with other tribal, local, regional, state and federal agencies for situational awareness and emergency response support.

1.4 NVU UAS Program Objectives

In 2021, the Department of Homeland Security funded a project to train a set of UAS pilots in Unalakleet, Alaska, to conduct infrastructure inspections and emergency response actions in support of local and/or regional crisis, using small uncrewed aircraft systems (sUAS). Applicants who are accepted into the program will be expected to complete and/or follow all listed duties and responsibilities below developed in partnership with the project team led by the NVU, University of Alaska Fairbanks and the Model Forest Policy Program. These developed protocols are specific to USCG and the Native Village of Unalakleet Tribal needs, but are not exclusive to other agency requirements.

The **NVU UAS Program Objectives** are to:

- Establish framework for safe UAS operations in the community of Unalakleet, Alaska in direct relation to 14 CFR Part 107 regulation by the Federal Aviation Administration;
- Establish a legitimate UAS team inclusive of recruitment and retention strategies;
- Define requirements for UAS team mobilization throughout the Norton Sound region;
- Develop Standard Operating Procedures (SOPs) as guiding documents for the long-term operation of the NVU UAS program;
- Define flight protocols that adhere to the Endangered Species Act, the Migratory Bird Treaty Act, Marine Mammal Protection Act, and Bald and Golden Eagle Act and are compatible with the Incident Command System, including but not limited to:

- Infrastructure Inspection
- Search and Rescue (SAR)
- Flood Delineation
- Oil Spill Detection and Monitoring
- Coastal Erosion Monitoring
- Collect standardized, high quality, reproducible, geospatial data sets using established coproduced protocols;
- Establish archival requirements for the NVU UAS team, which include archiving data, flight records, and maintenance records in a way that is accessible to decision-makers in the short and long-term;
- Provide a usable data-based product for decision-makers, such as a map or a summary report; and
- Define how the NVU UAS program integrates partners, and supports the local, regional, state and federal agency teams.

1.5 Facility Location and Mailing Address

Physical Location of the NVU UAS team

The NVU UAS Team (equipment) is located in a secured room within the NVU Main Office on 270 Main St. Unalakleet, Alaska.

Mailing Address:

Native Village of Unalakleet
P.O. Box 720
Unalakleet, AK 99684
Phone: (907) 624-3622 x. 28
FAX: (907) 624-3621
EMAIL: john.henry@unkira.org or sUAS@unkira.org

Business Hours: Due to this department's operational status, office hours can vary. Core hours are usually 8am-5pm Monday through Friday. The office is closed on all Local, State, and Federal Holidays.

1.6 Contact Information NVU UAS Program

NVU UAS Program Director:	John P. Henry, Jr. / (907) 624-3622 (office) / (907) 625-1588 (cell)
Pilot-in-Command/Observer:	Katie Daniels / (907) 624-3622 (office) / (907) 625-1224 (cell)
Pilot/Observer: TBD	(907) 624-3622 (office)

NVU Tribal Administration	(907) 624-3622
City of Unalakleet	(907) 624-3531
NVU IGAP Coordinator	(907) 624-3622
AK State Trooper/UNK S&R	(907) 624-3073 Community Bulk Tank Farm (907) 624-3531
UNK Airport Manager	(907) 451-2200
UNK Police Department	(907) 624-3008 or 911, if an emergency.

UVEC (Unalakleet Valley Electric) (907) 907-624-3474 (Main #)
National hotline for reporting oil spills if there is oil in the water or on the land:
Sector Anchorage POC (907) 428-4200
Weather Forecast 1-800-WX-BRIEF (1-800-992-7433) or
<https://www.1800wxbrief.com/>
UNK automatic weather station (907) 624-3051
For Emergency Response Contacts, please see Section 2.4 Emergency Response Checklist and Plans.

1.7 NVU UAS Team Employment Requirements

The following are the required qualifications for UAS crew team members flying for the NVU.

All members of NVU UAS team must at a minimum have:

- High School Diploma or GED, and
- Valid Alaska Driver's License.

All NVU UAS pilots are required to have or obtain:

- FAA Part 107 Certificate (Current).

The preferred employment Skills and Abilities for members of the NVU UAS team include:

- Detail oriented and possess strong organizational skills for recordkeeping.
- Self-motivated with ability to work with minimum supervision, yet able to adapt and work in a team environment.
- Strong written and oral communication skills.
- Ability to comprehend topographical maps.
- Basic computer literacy and capacity for learning new software.
- Capable of working outdoors for extended periods of time.
- Must be able to multitask.
- Preferred familiarity with radio communications and communication infrastructure in remote Alaska.
- Prior experience with unmanned aerial systems preferred, but not required.
- Able to lift and move medium to heavy objects and bags (less than 50 lbs.).

The Duties and Responsibilities of members of the NVU pilot team will be subject to change based on organizational needs and/or deemed necessary by the supervisor. They include, but are not limited to the following:

- Conduct UAS operations in support of infrastructure inspections and emergency response surveys.
- Perform UAS data archive and delivery protocols.
- Have familiarity with National Incident Management System/ Incident Command System.
- Have familiarity with Unalakleet Small Community Emergency Response Plan.
- Coordinate with local, regional, federal entities as required for data collection and delivery.
- Possess and sustain radio communication skills.

2. Flight Standards

The following crew standards are defined for UAS operations in accordance with the NVU UAS Program.

2.1 Pilot Training, Education, and Record Keeping

2.1.1 Onboarding New Pilots

The NVU Program Director will ensure that new pilots are FAA Part 107 certified and trained on how the crew operates on mission, and will confirm that all crew members are up-to-date on their certification before flying operational or training missions. The training program will consist of initial hands-on training, data chain-of-custody protocols as well as on-going, regular training during every recurrent training cycle, not to exceed a 12-month interval between initial training and recurrent training or between subsequent recurrent training sessions. Also, a copy of the RealFlight UAS simulator software will be kept on-site and made available for pilots to maintain skills when not actively flying UAS missions.

2.1.2 Aeronautical Knowledge Currency and Team Requirements

Pilots acting as PIC will maintain their sUAS aeronautical knowledge currency (current licensure) per 14 CFR FAR 107.65, have a copy of their Part 107 on file with NVU, and have a copy of their Part 107 on the pilot's person during mission.

Pilots must show proficiency in the following sUAS specific areas prior to becoming a crewmember:

- System Theory
- Assembly / Disassembly
- Operator Controls and interface
- Instrumentation Indications and Warnings
- Operating Procedures and Flight Dynamics
- Normal procedures
- Preflight
- Launch mission execution
- Recovery of the UAV
- Post Flight Procedures
- Emergency Procedures
- Mission Planning and Execution
- Basic Mission Types
- Payload Support
- Mobile Operations
- Airspace Coordination
- Frequency Coordination
- Collision Avoidance
- Two-Way Radio Communications
- General and Commercial Aviation
- Air Traffic Services

Team members must demonstrate knowledge of the following regulatory areas prior to becoming a crewmember of an active mission.² The requirements below are also found in **Appendix A: Federal Aviation Regulation Part 91 Requirements**.

Subpart A - General

- FAR 91.3 Responsibility and authority of the pilot in command
- FAR 91.13 Careless or reckless operation
- FAR 91.15 Dropping objects
- FAR 91.17 Alcohol or Drugs
- FAR 91.25 Aviation Safety Reporting Program

Subpart B - Flight Rules

- FAR 91.101 Applicability
- FAR 91.103 Preflight Action
- FAR 91.111 Operating near other aircraft
- FAR 91.113 Right-of-way rules: Except water operations
- FAR 91.115 Right-of-way rules: Water Operations
- FAR 91.117 Aircraft Speed
- FAR 91.119 Minimum safe altitudes: General
- FAR 91.121 Altimeter settings
- FAR 91.125 ATC light signals
- FAR 91.126 Operating on or in the vicinity of an airport in Class G airspace
- FAR 91.127 Operating on or in the vicinity of an airport in Class E airspace
- FAR 91.129 Operations in Class D airspace
- FAR 91.130 Operations in Class C airspace
- FAR 91.131 Operations in Class B airspace
- FAR 91.133 Restricted and Prohibited areas
- FAR 91.135 Operations in Class A airspace
- FAR 91.137 Temporary Flight Restrictions (TFR's) in the vicinity of a disaster/hazard areas
- FAR 91.141 Flight restrictions in the proximity of the Presidential and other parties
- FAR 91.143 Flight limitation in the proximity of space flight operations
- FAR 91.144 Temporary restriction on flight operations during abnormally high barometric pressure conditions.
- FAR 91.155 Basic VFR Weather Minimums

A recent version of the FAR/AIM Rules and Procedures needs to be kept on-hand with the UAS for quick reference.

² PART 91—General Operations and Flight Rules: <https://www.ecfr.gov/cgi-bin/text-idx?node=14:2.0.1.3.10>.

2.2 Visual Observers

2.2.1 Visual Observer Role

The Visual Observer (“Observer”) plays a critical role in assisting the PIC in maintaining situational awareness and complying with their “see-and-avoid” duties. Observers must maintain enough proximity to the PIC and to the flight operation to exercise “see-and-avoid” activities by scanning the area around the UAS for potentially conflicting traffic or other hazards to the safety of the flight.

The visual observer utilizes reliable and timely communication mechanisms between themselves and the pilot during operations. A visual observer shall communicate information to the pilot in a timely manner, during the operation, whenever the visual observer detects conflicting air traffic, hazards to aviation safety or hazards to persons on the surface. No visual observer shall perform visual observer duties for more than one remotely piloted aircraft at a time. No visual observer shall perform visual observer duties while operating a moving vehicle, vessel or aircraft.

Per **107.33, Visual Observer:**³ If a visual observer is used during the aircraft operation, all of the following requirements must be met:

- (a) The remote pilot in command, the person manipulating the flight controls of the small unmanned aircraft system, and the visual observer must maintain effective communication with each other at all times.
- (b) The remote pilot in command must ensure that the visual observer is able to see the unmanned aircraft in the manner specified in §107.31.
- (c) The remote pilot in command, the person manipulating the flight controls of the small unmanned aircraft system, and the visual observer must coordinate to do the following:
 - (1) Scan the airspace where the small unmanned aircraft is operating for any potential collision hazard; and
 - (2) Maintain awareness of the position of the small unmanned aircraft through direct visual observation.

2.2.2 Visual Observer Qualifications

All NVU Observers must understand applicable parts of Title 14 of the Code of Federal Regulations (14 CFR). Observers are considered crewmembers; therefore, shall meet the currency and proficiency requirements outlined above in Section 2.1.2 Aeronautical Knowledge Currency and Team Requirements. Observers will not perform crew duties for more than one UAS at a time. Observers are not allowed to perform concurrent duties as both UAS pilot and observer. Observers will be briefed and have a thorough understanding of normal, abnormal, and emergency operational aspects of the UAS.

Medical: NVU UAS Observers shall have a valid driver’s license meeting the medical requirements of the state or country of issuance without restriction or waiver.

³ Part 107 Subpart B § 107.33: <https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-107/subpart-B/section-107.33>.

Training: NVU UAS Observer training consists of sufficient training to communicate to the pilot any information required to remain clear of conflicting traffic, terrain, and obstructions; maintain proper cloud clearance; and provide navigational awareness. This training, at a minimum, includes knowledge of:

FAR 91.111 Operating near other aircraft;

FAR 91.113 Right-of-way rules: Except water operations;

FAR 91.115 Right-of-way rules: Water operations;

FAR 91.119 Minimum safe altitudes: General;

FAR 91.155 Basic VFR weather minimums;

FAR 107 Small Unmanned Aircraft Regulations; and

Air Traffic and Radio Communications, including the use of approved air traffic control (ATC)/pilot phraseology.

NVUNVU UAS Observers will have a working knowledge of air traffic and radio communications, including the use of approved air traffic control (ATC)/ pilot phraseology. Observers will familiarize themselves with the appropriate sections of the Aeronautical Information Manual (AIM). Publications can be viewed at www.faa.gov. The Program Director will confirm the Visual Observer is knowledgeable and qualified.

The following are requirements regarding Observer training certificates and certificate records:

- Copies of Observer training certificates need to be on file with NVU, and on the observer's person during the UAS mission.
- Certificates will be kept on file for as long as the Observer is employed.

2.3 Crew & Equipment Logs

2.3.1 Individual Flight Records Tracking

Each pilot is expected to rigorously track their individual UAS flight time in a personal flight log. This log needs to be up-to-date, available on request, but is not necessary to have on site during all missions, though it is suggested. Personal flight logs should include the type of UAS that was flown, amount of time it was flown, type of mission and if data was collected for other uses. Ancillary information such as lessons learned or anomalies to flight should be noted in the personal flight log.

2.3.2 Equipment Log

Equipment logs must include maintenance records, training records and flight logs to be kept on file with NVU, specifically with Lead Pilot, to consistently track the flight status of their pilots and UAS. Paper copies of these records are required; archived digital copies are also suggested.

2.4 Crew Duty

The following are the general requirements for crew duty day.

- Crew duty begins when employees arrive onsite to conduct operations and doesn't end until employees depart.
- The baseline crew duty period is 8-hours.
- Crew duty can be impacted by community events and the crew should remain aware of potential conflicts.
- Environmental factors can also be used to shorten the crew duty day.
 - Please see **Appendix B. Seasonal Environmental Factors**
- Extensions
 - The individual seeking must dialog with all crewmembers to achieve buy-in before seeking an extension.
 - The NVU UAS Program Manager or approved delegate can grant an extension up to 10 hours.
 - The NVU General Manager or approved delegate can grant an extension up to 12 hours.
 - Extensions may only be granted in the cases of operational priority, weather, unforeseen delays, and traffic management.
- After any duty period, crew must be allowed a minimum of 10 hours of rest.
- Time spent in travel between rest location and work location isn't part of rest period.

2.5 Site Survey

A site survey shall be conducted prior to deployment to a mission at a specific geographic location. A survey is a sequence of questions identifying unique characteristics and regulations of the mission that need to be addressed by the Team to the best of their abilities prior to travel to a site and/or start of a mission, if local. A new site survey needs to be done only if the Team has not visited a site recently and no known significant changes have taken place. The site survey form is located at **Appendix C1. Site Survey Form**.

2.6 Pre-Mission Activities

2.6.1 Equipment Health and Functionality

All mission equipment must be checked for functionality prior to departing for a mission. If any damages are visible, repairs will be conducted and noted in the maintenance log prior to use of the equipment. If significant repairs are required, the equipment shall not be used until those repairs have been completed and documented in the maintenance logs. (Please refer to **Appendix C: Critical Mission/ Flight/ Maintenance Forms**.)

Examples of this equipment are handheld radios, sUAS, ground support equipment, logbooks, checklists, and PPE.

Individual tasks will be assigned to respective crew members as responsible parties.

Prior to mission deployment, crews will conduct a full system checkout to include utilizing the checklist specific to the aircraft of the mission, demonstrating system knowledge.

Before the beginning of any mission a full test flight of the system is required. During this flight, the crew will demonstrate proficiency by safe execution of the flight parameters. Upon completion of this flight the crew is considered “current”.

NOTE: At the completion of each mission, any damage to any piece of the equipment needs to be noted on the flight log and maintenance logs for that piece of equipment (if in existence) and addressed as soon as reasonable. (See **Appendices C5a. Aircraft Flight Log** and **C8. Maintenance Operations Log.**)

2.6.2 Equipment Inventory

Complete inventory of the packout and ensure all equipment is packed in a manner that will allow it to be transported without damage.

Logbook of UAS team inventory check-in/check-out will remain on site at the Tribal Administration building. All items removed from the NVU must be noted on the check-out log book, and recorded once returned.

2.6.3 Emergency Response Plans

Prior to any flight operations at a new location, the PIC must craft a written emergency response plan that takes local authorities into account. This plan must be socialized with the remainder of the crew to ensure appropriate action at the appropriate time. The plan must, at a minimum, have the sequence of external and internal NVU contacts that are notified. Referencing the Small Community Emergency Response Plan (SCERP) can be useful for crafting the UAS Emergency Response Plan. **Refer to Appendix C12. Emergency Response Plan** for a link to the Unalakleet Small Community Emergency Response Plan (SCERP) as well as links to a SCERP template and the Alaska Division of Homeland Security and Emergency Management - Planning Section website.

2.7 Mission Brief - PIC Preflight Checklist

Prior to each day’s flight activities, the PIC will lead a mission brief laying out the objectives and scope for the flight for all members of the mission. All crew members will utilize the checklist specific to the aircraft of the mission. The PIC shall solicit input from every member of the crew during this brief. The following list of suggested topics should be used by the PIC as a guide. (See **Appendix C3. Preflight Checklist.**)

- Weather
- Waiver (special requirements) (See **Appendix D. FAA Airspace Authorization and Waiver Resources.**)

- Airspace and Controlling Authority (contacting requirements)
- ATC Frequencies
- NOTAMs (filed?)
- Crew Assignments
- System Maintenance Status (Logbooks)
- Purpose of Flight/Objectives
- Success Criteria
- Anticipated flight duration and potential flight delays
- Flight Profile Locations
- Contingency Procedures (Lost Link, GPS Fail, Ditch)
- Crew Communications Plan
- Communications Technology Test Report
- Handoff Procedures and Positive Transfer of Controls
- Sterile Cockpit and non-Mission Essential Personnel
- Safety (PPE, procedural logistics e.g. where first aid kit is)
- Emergency Procedure of the Day (nearest EMT, emergency call number locations)
- Final Q&A

2.8 Debrief

After each day's flight activities, the PIC will lead a mission debrief laying out the results of the flight. The PIC shall solicit input from every member of the crew during this debrief. The following list of suggested topics should be used by the PIC as a guide. (See **Appendix C4. Debrief Checklist.**)

- Weather
- Takeoff Time, Flight Duration, Landing Time, Delays
- Flight Profile Locations
- Purpose of Flight/Objectives
- Were Flight/Objectives met?
- What went well
- Communications success/failures
- Safety issues or abnormalities encountered
- Risk reduction plan
- Maintenance required before next flight
- Next steps for data (downloading, processing, archiving, delivery)
- What (if any) external follow-up will be required and by whom
- Plan for next operation

2.9 Shift Change Briefings

At the end of each shift, or if an alternate PIC needs to be identified during the mission, a full disclosure of the mission needs are to be shared with the new PIC and crew, as well as a description of work that

has been accomplished thus far as part of the mission. A review of the Mission Brief and discussion of mission highlights to date are suggested, in addition to any formal shift change documentation.

2.10 Post Mission Activities

At the completion of each mission, any damage to any piece of the equipment needs to be noted on the flight log and maintenance logs for that piece of equipment (if in existence) and addressed as soon as reasonable.

- Inventories
- Maintenance
- Storage

2.10.1 Daily Mission Report/Packet

While on mission, each day's activities and documentation will be compiled into a daily mission report/packet to track elements such as duty time, flight times, weather conditions, maintenance status, etc. These reports are to be retained for no less than three years to allow for later reference.

2.11 Checklist Procedures

Procedures specific to each UAS is found within each system's respective Pilots' Operating Handbook.

2.12 Sterile Cockpit

Unlike manned aircraft, the 'cockpit' or 'control station' of a UAS can be accessed during flight by bystanders. Therefore, controlling entry to the control station is of paramount importance. During the mission brief, the PIC will determine who and how the sterile cockpit will be maintained.

2.13 Air Traffic Services & Radio Communication

Standard radio communications will be conducted in accordance with the guidance of the Airmen [Aeronautical] Information Manual Chapter 4 Section 2.⁴ Specific radio communications will be conducted in accordance with instructions from air traffic service providers. Flight plans will be submitted at the discretion and direction of the local air traffic service provider. [**Note:** During UAS operations, ensure that ATC is informed as early as practical of a malfunction or abnormal occurrence that affects the operation of the UAS or interaction with ATC.]

⁴ For reference, see *Aeronautical Information Manual (AIM), Chapter 4. Air Traffic Control, Section 2. Radio Communications Phraseology and Techniques*:
https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap4_section_2.html.

3. Maintenance Standards

3.1 Scheduled Maintenance

The scheduled maintenance for each UAS (E.g., Skydio S2 and X2E) shall follow the manufacturer's recommended service schedule indicated in the manufacturer's equipment manual. The most current manuals shall be uploaded to the NVU UAS Drone Program Drive, subfolder - Equipment Manuals, found at: <https://drive.google.com/drive/folders/1T9zmZr0tBISbP8JO8hZCzG137RnnuxOs?usp=sharing>. More details regarding scheduled maintenance is not provided here because additional equipment and/or newer equipment may be purchased that would require change to this section.

3.2 Safety and Accuracy Checks

To ensure accurate position and altitude reporting, NVU Drones will be tested to maintain safety and accuracy following manufacturer protocols available. Equipment which falls under the regulatory authority of the FAA will be tested according to the relevant Federal Aviation Regulations (FARs) for that equipment.

3.3 Maintenance Records

NVU will maintain aircraft records based on the framework of the applicable sections of FAR 91.417(a)(1) and (2) and 43.9, which are part of Title 14 of the Code of Federal Regulations (CFR).⁵ Ad hoc repairs to system components will also be recorded in the Maintenance Records. Records will be kept with the log books in a secure location and a pdf copy kept on the laptop that is used during missions, as well as uploaded to the Drone Team folder on the NVU server.

⁵ § 91.417 -- Maintenance records: <https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-91/subpart-E/section-91.417>; and 14 CFR 43.9 - Content, form, and disposition of maintenance, preventive maintenance, rebuilding, and alteration records (except inspections performed in accordance with part 91, part 125, § 135.411(a)(1), and § 135.419 of this chapter): <https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-43/section-43.9>.

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Appendix A: Federal Aviation Regulation Part 91 Requirements

Following are the FAR Part 91 requirements that Team members must demonstrate knowledge of the prior to becoming a crewmember of an active mission.⁶ These links are also included above in **Section 2.1. Pilot Training, Education, and Record Keeping.**

Subpart A - General

- [FAR 91.3](#) Responsibility and authority of the pilot in command
- [FAR 91.13](#) Careless or reckless operation
- [FAR 91.15](#) Dropping objects
- [FAR 91.17](#) Alcohol or Drugs
- [FAR 91.25](#) Aviation Safety Reporting Program

Subpart B - Flight Rules

- [FAR 91.101](#) Applicability
- [FAR 91.103](#) Preflight Action
- [FAR 91.111](#) Operating near other aircraft
- [FAR 91.113](#) Right-of-way rules: Except water operations
- [FAR 91.115](#) Right-of-way rules: Water Operations
- [FAR 91.117](#) Aircraft Speed
- [FAR 91.119](#) Minimum safe altitudes: General
- [FAR 91.121](#) Altimeter settings
- [FAR 91.125](#) ATC light signals
- [FAR 91.126](#) Operating on or in the vicinity of an airport in Class G airspace
- [FAR 91.127](#) Operating on or in the vicinity of an airport in Class E airspace
- [FAR 91.129](#) Operations in Class D airspace
- [FAR 91.130](#) Operations in Class C airspace
- [FAR 91.131](#) Operations in Class B airspace
- [FAR 91.133](#) Restricted and Prohibited areas
- [FAR 91.135](#) Operations in Class A airspace
- [FAR 91.137](#) Temporary Flight Restrictions (TFR's) in the vicinity of a disaster/hazard areas
- [FAR 91.141](#) Flight restrictions in the proximity of the Presidential and other parties
- [FAR 91.143](#) Flight limitation in the proximity of space flight operations
- [FAR 91.144](#) Temporary restriction on flight operations during abnormally high barometric pressure conditions.
- [FAR 91.155](#) Basic VFR Weather Minimums

⁶ PART 91—General Operations and Flight Rules: <https://www.ecfr.gov/cgi-bin/text-idx?node=14:2.0.1.3.10>.



Appendix B: Seasonal Environmental Factors

Date: _____ Location of Work: _____
 Name: _____ Work Type (circle): Light Moderate Heavy
 Time: _____ AM PM Temperature (F): _____ *Work Cycle(min): _____
 At Location Time Start: _____ AM/PM Time End: _____ AM/PM Time Difference: _____

Work Task: ☐ PIC ☐ Observer ☐ Other

☐ *Monitor heart rate (30 seconds): _____ (bpm) Greater than 110 bpm? ☐ Y ☐ N

If Yes, then cut down next work cycle by 1/3 of calculated work time based on temperature

*Signs and Symptoms

Heat Cramps

- ☐ Muscle spasms
☐ Pain in the hands, feet,
 and abdomen

Heat Exhaustion

- ☐ Pale, cool, moist skin
☐ Heavy Sweating
☐ Dizziness
☐ Nausea
☐ Fainting

Heat Stroke

- ☐ Red, hot, usually dry skin
☐ Lack of or reduced respiration
☐ Nausea, dizziness, and confusion
☐ Strong, rapid pulse, and coma

*Work Cycle for Working Outside

ADJUSTED TEMPERATURE ^b	NORMAL WORK ENSEMBLE ^c	IMPERMEABLE ENSEMBLE
90°F (32.2°C) or above	After each 45 minutes of work	After each 15 minutes of work
87.5°-90°F (30.8°-32.2°C)	After each 60 minutes of work	After each 30 minutes of work
82.5°-87.5°F (28.1°-30.8°C)	After each 90 minutes of work	After each 60 minutes of work
77.5°-82.5°F (25.3°-28.1°C)	After each 120 minutes of work	After each 90 minutes of work
72.5°-77.5°F (22.5°-25.3°)	After each 150 minutes of work	After each 120 minutes of work

*The Seasonal Environmental Factors come from the 2019 BAPP Daily Logs_update.docx provided by John Henry.
 [BAPP: Behavioral Accident Prevention Process]*



Appendix C: Critical Mission/Flight/Maintenance Forms

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c1. Site Survey Form

Location of Proposed Operations: _____

The following document is a series of questions that should be answered during a site survey for NVU UAS operations. It is not an exhaustive list of knowledge areas, but should be used as guidance for discussions that need to take place prior to arriving with any equipment. Answers and notes from discussions should be annotated on this form to serve as a record for operations at the named site.

A copy of this Site Survey Form should be kept in the UAS Notebook and printed out and filled in for each different site location.

Operational Factors

Runway length, width, direction, slope, and surface type: (Absolute minimum length & tire size: N/A)
Runway obstructions: (Ends / Sides)
GCS Location: (Line of sight and visibility from GCS to runway, ease of access, can GCS be left in place?)
Airfield manager: (Who operates airfield and what local responsibilities exist?)
Range control: (In the case of operating on military installations.) (Contact information for liaison)
Airspace Profile: (Coordinates of designated airspace for operation and feasibility of operating within it)
Other operations at same location: (Either UAS or manned)
Other air traffic: (Frequency, busy times, types, traffic patterns)
Airspace deconfliction: (Airspace type, contact info, radio frequencies, and special procedures, issued radios?)

Frequency deconfliction: (Area frequency manager) (approval to radiate) (approved frequencies)
Accessibility for vehicles: (GCS/truck/tow vehicle/parking)
Proposed flight times: (Time on station/takeoff/landing, crew rest possibilities, manning for deployment)
Weather Patterns: (Are expected patterns hazardous or unfriendly to operations? Seasonal differences?)
Weather Reports: (Where do we obtain weather and how often can it be obtained?)

Logistic Factors

Access: (What special permissions are required for flight crew to access flight operations area?) (Private property?)
Escorts needed: (Does the flight crew need to be escorted by cleared individuals or citizens of the host location?)
Power: (Is there shore power to support operations or will generators be required? Generator fuel?)
Hangar Space: (Is there a space available for storing the aircraft and working on them away from the elements?)
Storage Space: (Is there an area for storing elements other than the aircraft?) (Shipping containers, GSE?)
Fuel and Oil Source: (Where will fuel be obtained? Are there constraints on how often and how much can be obtained? Transportation?)

Spares and Consumable: (How will they be transported to or obtained while on deployment?)
Office Space: (Will there be a space available for office tasks to include flight planning, briefing, and meetings?)
Connectivity: (Does the proposed site have data coverage, Wifi, telephones, fax, printers, and other assorted connective elements?)
Vehicle Parking: (Does the proposed site have parking space available for vehicles and trailers?)
Vehicle Driving Privileges: (Are there any special licenses or approvals for the flight crew to drive vehicles at the site?)
Lodging for flight crew: (Are there convenient lodging options for the flight crew?)
Food for flight crew: (Are there restaurants and grocery stores for the crew? On site food (catering) for mission?)
Travel times: (How long to get from lodging location to flight operations location?)
Access to civilization: (How close is a city where unforeseen requirements could be met?)
Medical Requirements: (How far is closest medical facility in case of emergency?)

Original document is the site survey used for the Sea Hunter UAS flown by Andrew Wentworth at UAF ACUASI.

Google Drive Link: https://docs.google.com/document/d/1bJYyMw9uDizf_JyIEcYvylZvjI9zofD3qKglwT2dFUg/edit#



c2. Go Bag

Created 11/2021

Following is a list of Items to pack when flying a mission away from home. A copy of it should be printed and kept in the UAS notebook and also in your own Go Bag.

Non-UAS Items

- | | |
|---|----------------------------------|
| ■ Small pack (fanny pack, fancy S&R satchel) | ■ Benadryl |
| ■ Headlamp | ■ Aspirin or other pain reliever |
| ■ Compass | ■ Fire starter |
| ■ Extra batteries in waterproof case | ■ Lighter/safety matches |
| ■ Gloves (fingerless gloves, gloves that can be used with iPad) | ■ Toe warmers |
| ■ Carabiner | ■ Snow pants/Rain pants |
| ■ Ankle Gators | ■ Heavier gloves/mittens |
| ■ Double-sided tarp (silver heat side/solid color side) | ■ Wool hat |
| ■ First Aid Kit | ■ Toilet Paper |
| ■ Leatherman | ■ Webbing |
| ■ Parachute cord | ■ Flare |
| ■ Snacks - non-perishable (Nuts, crackers, trail mix, etc.) | ■ Waterproof boots |
| | ■ Water bottle |

UAS Materials

- UAS
- Anemometer
- Pens and pencils
- Rite in the Rain Notebook
- Ground-to-air radio
- Walkie talkies
- Small generator (no fuel or oil)

Try to have compatible batteries across devices, like headlamps and radios.

c3. Preflight Checklist

Updated 10/14/2021

The below Preflight Checklists, copies of which should be kept in the UAS Notebook, are designed to ensure that basic health and safety measures are being followed during each UAS mission. Checklists may need to be modified based upon mission location and requirements in conjunction with equipment logs and/or mission logs, but are designed to be applicable to all missions using the specific UAS identified. Prior to completing the checklists, conduct an assessment of the operating environment for situational awareness as well as potential hazard identification (ground and air). The preflight assessment should be performed at least once per day and should be repeated when component significantly change and must include at least the following:

Operational Space

- Flight Locations
- Purpose of Flight/Objectives
- Weather conditions and forecast
- Success Criteria
- Site Space and Flight Restrictions
- Waiver (Necessary? In place?)
- Airspace and Controlling Authority (contacting requirements)
- Local and Regional ATC Frequencies (see circular for area)
- NOTAMs (filed?)
- Land Ownership
- Crew Assignments
- PIC Part 107 certification card in-hand
- Safety (PPE, procedural logistics e.g. where first aid kit is)
- Emergency Procedure of the Day (nearest EMT, emergency call numbers in-hand?)
- Contingency Procedures (Lost Link, GPS Fail, Ditch)
- Crew Communications---test the tech
- Potential Radio Interferences
- Situational awareness of surroundings
- Handoff Procedures and Positive Transfer of Controls
- Sterile Cockpit and non-Mission Essential Personnel

Aircraft Status and Preparation - Skydio S2⁷

These items need to be completed prior to EACH flight:

- Confirm System Maintenance Status (review maintenance logbooks).
- Confirm Micro SD cards installed in aircraft.²
- Check aircraft body for damage.
- **Clean all camera lenses** using a microfiber cloth.
- **Inspect batteries**
 - Do not fly with any batteries with enclosures that are cracked, gouged, dented or otherwise substantially physically deformed.
 - Contact the Skydio support team if you suspect an issue with battery use or with the batteries themselves.
- Ensure any Battery Saver or Low Power modes are disabled on controller (phone or tablet).
- Remove the gimbal retaining clip.
- Ensure all propellers are firmly attached and free of nicks, cracks, or other visible damage. **Never fly with damaged propellers.**
- Inspect the chassis for damage and debris prior to flight.
- Do not fly in precipitation, fog, or snow.

Google Drive Link: https://docs.google.com/document/d/1dy39iaw3tuXxcfNjHjLLtWv_QlHvf4qRoQyIEbWDGJk/edit#

⁷ Skydio Operator Manual - Skydio 2 <https://drive.google.com/file/d/1Hlh8EZJ8uTov2tEOH6f0u9a-FTYdkGUX/view?usp=sharing>

² Ideally SD card is empty so that all flight data is recorded.



c4. Debrief Checklist

After each day's flight activities, the PIC will lead a mission debrief laying out the results of the flight. The PIC shall solicit input from every member of the crew during this debrief. The following list of suggested topics should be used by the PIC as a guide. A copy of it should be kept in the UAS Notebook.

- Weather
- Takeoff Time, Flight Duration, Landing Time, Delays
- Flight Profile Locations
- Purpose of Flight/Objectives
- Were Flight/Objectives met?
- What went well?
- Communications success/failures
- Safety issues or abnormalities encountered
- Risk reduction plan
- Maintenance required before next flight
- Next steps for data (downloading, processing, archiving, delivery)
- What (if any) external follow-up will be required and by whom?
- Plan for next operation

Google Drive Link: https://docs.google.com/document/d/1zQkM3RJIEnxG4kzv_qe8-qUW_zle2ny-Oq0qXL3PYw/edit#heading=h.lnik34kq1q3f



C5a. Aircraft Flight Log

This form is intended to be printed and kept in the UAS notebook.

Google Drive Link: <https://docs.google.com/document/d/1w8RXxfBzNOqohLUha04li0cfbrOBmqdm/edit#>

NVU Aircraft Flight Log

Sheet Number: 1

Aircraft Model:

Aircraft name:

N:

s/n:

Previous Sheet Total Ldgs:

Flight hours:

Date	Location	Pilot	Observer	Payload	Batt	Launch Time	Land Time	Ldgs	Comments	Flight Time	Total Aircraft Hours
Page Totals											

- Use one line per flight.
- Fill in header information for a/c registration and s/n.
- PIC: First Initial and Last Name

Version 1: 11/22/2021



c5b. NVU UAS Flight Activities

This form is intended to be printed out for each mission and a copy kept in the UAS notebook.

Google Drive Link: https://docs.google.com/spreadsheets/d/1zTDy3FarnoEUMIIHK_P5tOi8plhgVvr/edit#gid=1332639950

	UAS #/ Name: _____ Date: _____ Location: _____ Flight #: _____									
Crew Mission Leader: _____ PIC: _____ VO: _____ SIC: _____	Objectives Free fly 2D 3D									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%; text-align: center;">Totals</td> </tr> <tr> <td>Flight Time</td> <td>_____</td> </tr> <tr> <td>Batteries Used</td> <td>_____</td> </tr> </table>		Totals	Flight Time	_____	Batteries Used	_____				
	Totals									
Flight Time	_____									
Batteries Used	_____									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%; text-align: center;">Times 1</td> </tr> <tr> <td>Takeoff Time</td> <td>_____</td> </tr> <tr> <td>Landing Time</td> <td>_____</td> </tr> <tr> <td>Total Flight Time</td> <td>_____</td> </tr> <tr> <td>Battery #</td> <td>_____</td> </tr> </table>		Times 1	Takeoff Time	_____	Landing Time	_____		Total Flight Time	_____	Battery #
	Times 1									
Takeoff Time	_____									
Landing Time	_____									
Total Flight Time	_____									
Battery #	_____									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%; text-align: center;">Times 2</td> </tr> <tr> <td>Takeoff Time</td> <td>_____</td> </tr> <tr> <td>Landing Time</td> <td>_____</td> </tr> <tr> <td>Total Flight Time</td> <td>_____</td> </tr> <tr> <td>Battery #</td> <td>_____</td> </tr> </table>		Times 2	Takeoff Time	_____	Landing Time	_____	Total Flight Time	_____	Battery #	_____
	Times 2									
Takeoff Time	_____									
Landing Time	_____									
Total Flight Time	_____									
Battery #	_____									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%; text-align: center;">Times 3</td> </tr> <tr> <td>Takeoff Time</td> <td>_____</td> </tr> <tr> <td>Landing Time</td> <td>_____</td> </tr> <tr> <td>Total Flight Time</td> <td>_____</td> </tr> <tr> <td>Battery #</td> <td>_____</td> </tr> </table>		Times 3	Takeoff Time	_____	Landing Time	_____	Total Flight Time	_____	Battery #	_____
	Times 3									
Takeoff Time	_____									
Landing Time	_____									
Total Flight Time	_____									
Battery #	_____									
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%; text-align: center;">Times 4</td> </tr> <tr> <td>Takeoff Time</td> <td>_____</td> </tr> <tr> <td>Landing Time</td> <td>_____</td> </tr> <tr> <td>Total Flight Time</td> <td>_____</td> </tr> <tr> <td>Battery #</td> <td>_____</td> </tr> </table>		Times 4	Takeoff Time	_____	Landing Time	_____	Total Flight Time	_____	Battery #	_____
	Times 4									
Takeoff Time	_____									
Landing Time	_____									
Total Flight Time	_____									
Battery #	_____									

SIC = Second in command; copilot



c6. NVU UAS Aggregate Flight Log

This form is for online tracking of missions and file name of data collected.

The current Aggregate Flight Log is found at:

https://docs.google.com/spreadsheets/d/1d0XW0_3Gd0rRmMU4qW89C8DsiiQlltdPoVYJv_Fjs/edit#gid=0.

If file is moved to the NVU UAS Program Shared Drive, the link will need to be updated.

S2 - Grogu Flight Log

v10/18/2021

Total Flight Time (Column I)						Total Flight Time		148	
Date	Drone	PIC	1st Officer (UFN)	Observer	Flight Locations	Take-off Time (local)	Landing Time (local)	Total Flight Time (Mins.)	Purpose of Flight/Objectives
11/01/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Echo Acres Dr./FAI	1440 AKT	1447 AKT	7	Harry's 1st Flight!
11/01/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Echo Acres Dr./FAI	1449 AKT	1458 AKT	9	Harry's Flight cont.
11/01/2021	Grogu	Sam Jeffries	John Henry	Jessica Garron	Echo Acres Dr./FAI	1502 AKT	1509 AKT	7	John's 2D Scan
11/01/2021	Grogu	Sam Jeffries	Margaret Hall	Jessica Garron	Echo Acres Dr./FAI	1509 AKT	1515 AKT	6	Margy's 1st Flight.
11/01/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Echo Acres Dr./FAI	1517 AKT	1521 AKT	4	Harry's 2D Scan
11/01/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Echo Acres Dr./FAI	1524 AKT	1531 AKT	7	Harry's 2D Scan #2
11/02/2021	Grogu	Sam Jeffries	Margaret Hall	Jessica Garron	Poker Flats/FAI	1355 AKT	1414 AKT	19	Test 1 (@PF) (MWH)
11/02/2021	Grogu	Sam Jeffries	Margaret Hall	Jessica Garron	Poker Flats/FAI	1355 AKT	1414 AKT	19	Test 2 (@PF) (MWH)
11/02/2021	Grogu	Sam Jeffries	N/A	Jessica Garron	Poker Flats/FAI	1439 AKT	1457 AKT	18	Dueling Drones
11/02/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Poker Flats/FAI	1503 AKT	1515 AKT	12	Harry's 3D Scan
11/02/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Poker Flats/FAI	1526 AKT	1534 AKT	8	Harry's Dueling Ortho
11/02/2021	Grogu	Sam Jeffries	Harry Ivanoff	Jessica Garron	Poker Flats/FAI	1537 AKT	1541 AKT	4	Harry's Dueling Ortho cont.
11/02/2021	Grogu	Sam Jeffries	John Henry	Jessica Garron	Poker Flats/FAI	1548 AKT	1604 AKT	16	John's 3D Scan
11/02/2021	Grogu	Sam Jeffries	John Henry	Jessica Garron	Poker Flats/FAI	1607 AKT	1612 AKT	5	John's 3D Scan cont.
11/03/2021	Grogu	Harry Ivanoff	N/A	Katie Daniels	Test Basin/Poker Flats/FA	1545 AKT	1559 AKT	14	2D Mapping of Test Basin

First half of spreadsheet.

Second half of spreadsheet.

Temperature (include F or C)	Wind Speed	Wind Direction	Local Airspace Restrictions	UAS Waivers in-place	Local/regional ATC frequencies	Filenames	Notes
37F	0-1	N/A	None	N/A	118.3	Harry's 1st Flight	Landed; battery change; continued scan.
37F	0-1	N/A	None	N/A	118.3	Harry's 1st Flight cont.	
37F	3.1	N/A	None	N/A	118.3	Test_1_2021-11-01T22-58-32.704244+00-00	
37F	3.1	N/A	None	N/A	118.3	Test_2_2021-11-01T23-06-19.780556+00-00	
37F	3.1	N/A	None	N/A	118.3	Test_3_2021-11-01T23-12-42.141491+00-00	
37F	3.1	N/A	None	N/A	118.3	Test4_2021-11-01T23-20-22.817027+00-00	
26F	Light/Variable	Variable	None	N/A	125.35	Test 1 (@PF)	MWH 2D Scan
26F	Light/Variable	Variable	None	N/A	125.35	Test_2_11022021_2021-11-02T22-13-09.389487+00-00	
26F	Light/Variable	Variable	None	N/A	125.35	Dueling Drones	Testing interference between 2 drones. Some chance of collision.
26F	Light/Variable	Variable	None	N/A	125.35	3D Test 1	Harry's 3D Scan.
26F	Light/Variable	Variable	None	N/A	125.35	Harry's Dueling Ortho	Harry flew at 250'; 25 images.
26F	Light/Variable	Variable	None	N/A	125.35	Harry's Dueling Ortho cont.	Harry flew at 250'; 25 images.
26F	Light/Variable	Variable	None	N/A	125.35	John's 3D Scan	Switched out battery.
26F	Light/Variable	Variable	None	N/A	125.35	John's 3D Scan cont.	Remainder of 3D after battery switch. Total images: 284.
32F	Hollow/No Wind	N/A	None	N/A	125.35	Grogu_test_1_11321_2021-11-03T23-39-36.034396+00-00	Battery #1. Posts set at 280'; flown @ 200+/-; 56 images.

The Example spreadsheet is found at the following Google Drive link: https://docs.google.com/spreadsheets/d/1cYDI5otPeFobBnEA2Q-H_zkcrNb-APLPf-X2fxN74k/edit#gid=0

c7. Flight Test Program Card

A copy of this form should be printed out and kept in the UAS notebook.

Google Drive Link: <https://docs.google.com/document/d/1KZRwALCAfTszmludaCJCTvQnuujxo5IA/edit#>.

Purpose:		Date:
Location:		Time
Crew Assignments		Begin:
		End:
Weather:		
Limitations:		
Objective(s):		
Success Criteria:		

Aircraft Configuration:	
Takeoff Weight:	
GS Software:	
Payload:	

Event	Action	Notes	Pass
1.			
2.			
3.			
4.			
5.			



c8. Maintenance Operations Log

A copy of this form should be printed out and kept in the UAS notebook.

Google Drive Link: <https://docs.google.com/document/d/1KZRwALCAfTszmludaCJCTvQnuujxo5IA/edit#>.

Tail #:		System/Serial:			Page #:	
Status:	Date:	Discovered By:	Date:	Hours: /		
Fault:			Correction:			
			Corrected By:	Inspected By:		
Status:	Date:	Discovered By:	Date:	Hours: /		
Fault:			Correction:			
			Corrected By:	Inspected By:		
Status:	Date:	Discovered By:	Date:	Hours: /		
Fault:			Correction:			
			Corrected By:	Inspected By:		
Status:	Date:	Discovered By:	Date:	Hours: /		
Fault:			Correction:			
			Corrected By:	Inspected By:		

A copy of this form should be printed out and kept in the UAS notebook to track maintenance on equipment.

NVU DRONE TEAM

Native Village of
Unalakleet

[illegible]

NVU UAS Contact Information: Phone: (907) 624-3622 or sUAS@unkira.org.

Google Drive Link: <https://docs.google.com/spreadsheets/d/1Zq-boTRqfy2ApwkTuMiOjZ32zjoaeFWV/edit#gid=1465983853>.

[illegible]

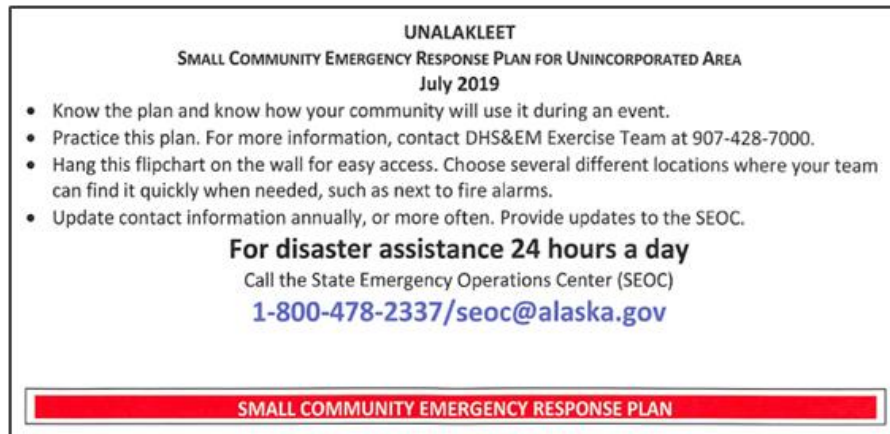
NVU UAS SOPs / April 2022



c12. Emergency Response Plan

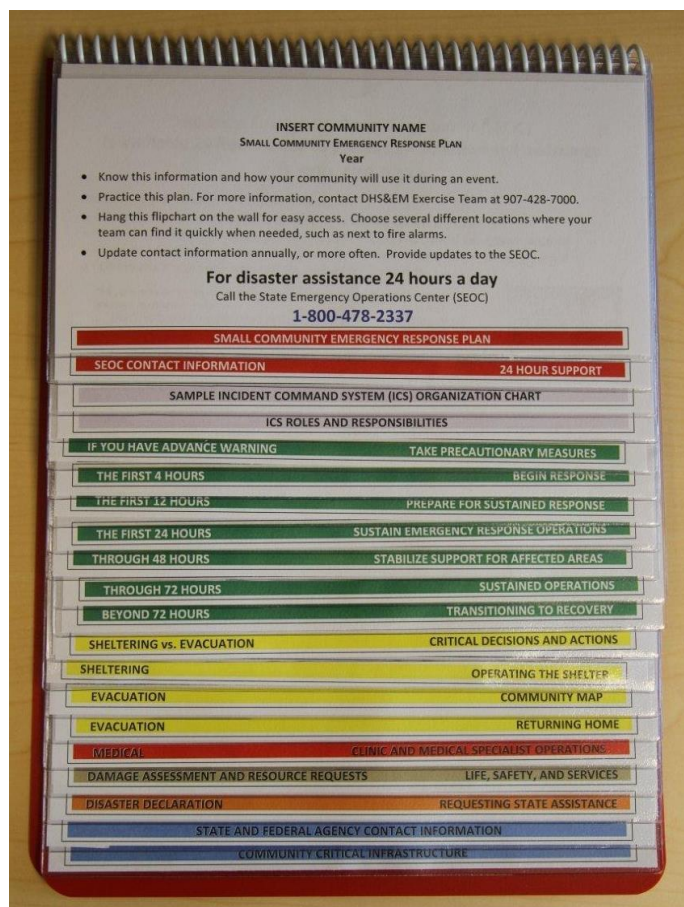
A copy of the most current *Unalakleet Small Community Emergency Response Plan for Unincorporated Area* should be kept in the NVU Drone Team Office. Another copy should be available to take in the field on missions. If need be, a copy may be printed out by downloading the document from the following link:

<https://drive.google.com/file/d/1fregUtsYnER8p6AREODFTHXvrMLYRSLI/view?usp=sharing>.



A *Small Community Emergency Response Plan* template is available online at:

<https://drive.google.com/file/d/1vVMF8uNKNgfWMrLFa-rnvzon97zI87AC/view?usp=sharing>. More information about SCERPs is available on the Alaska Division of Homeland Security and Emergency Management - Planning Section website at: <https://www.ready.alaska.gov/Plans/SCERP>.



Appendix D: FAA Airspace Authorization and Waiver Resources

What is a Waiver?⁸

A waiver is an official document issued by the FAA which approves certain operations of aircraft outside the limitations of a regulation.

You may request to fly specific drone operations not allowed under part 107 by requesting an operational waiver. These waivers allow drone pilots to deviate from certain rules under part 107 by demonstrating they can still fly safely using alternative methods.

To determine if your operational flights will require an Airspace Authorization or Flight Waiver to be conducted, visit B4UFLY, either at, <https://b4ufly.aloft.ai/>, or through the B4UFLY app on your phone, to determine if any additional authorizations will be required before your UAS flight.

Airspace Authorizations

Flights that need to take place near a Low Altitude Authorization and Notification Capability (LAANC) enabled airport will require an Airspace Authorization request submitted through the LAANC system via one of the approved third-party LAANC portals. A detailed list of LAANC enabled airports is available from the FAA at, https://www.faa.gov/uas/programs_partnerships/data_exchange/laanc_facilities/#all. The Alaskan airports included in this list that are in the Bering Strait and Norton Sound region include:

- Unalakleet
- St. Mary's
- Nome
- Kotzebue

To see the different UAS flight altitude restrictions for any of the LAANC enabled airports, visit the online UAS Facilities Maps, <https://faa.maps.arcgis.com/apps/webappviewer/index.html>. The UAS Facilities Maps can be used to identify unrestricted airspace nearby or to help build your LAANC Airspace Authorization request if operations within the restricted airspace around a LAANC enabled airport is required.

- Receive a near real-time authorization for operations under 400 feet in controlled airspace around 731 airports.
- Commercial operators can apply for further coordination (requests above pre-approved ceilings) within 24 hours of the start time.
- Apply up to 90 days in advance of a flight and the approval is coordinated manually through the applicable airspace owners.
- LAANC authorization areas can span up to 10 miles.

⁸ Federal Aviation Administration, Part 107 Waiver:
https://www.faa.gov/uas/commercial_operators/part_107_waivers/#:~:text=A%20waiver%20is%20an%20official,by%20requesting%20an%20operational%20waiver.

- Apply for a LAANC authorization for someone else in your organization. A UAS program manager can apply for a LAANC authorization on behalf of the UAS operator in the field who will be flying the mission, even if those people are scattered across the country. This saves time for the operator, gives a program manager a lot more flexibility to assign missions, and makes it much easier to track LAANC authorizations across an organization.
- A user can have up to five LAANC authorizations occurring during the same time period. Operations using these overlapping LAANC authorizations must be located within 100 nautical miles of one another.
- As of August 2021, commercial operators can apply for access to controlled airspace at night via LAANC.

Drone Operations that Require Waivers...from the FAA Website⁹

You do NOT need a waiver to fly a drone following part 107 rules. You DO need a waiver when you want to operate a drone contrary to the rules in part 107 under the waivable operations listed below:

You want to...	Part 107 regulation you need a waiver from...
Fly a small UAS from a moving aircraft or a vehicle in populated areas	§ 107.25 – Operation from a Moving Vehicle or Aircraft
Fly a small UAS at night without anti-collision lighting	§ 107.29(a)(2) – Operation at night
Fly a small UAS during periods of civil twilight without anti-collision lighting	§ 107.29(b) – Operation at Night
Fly a small UAS beyond your ability to clearly determine its orientation with unaided vision	§ 107.31 – Visual Line of Sight Aircraft Operation
Use a visual observer without following all visual observer requirements	§ 107.33 – Visual Observer
Fly multiple small UAS with only one remote pilot	§ 107.35 – Operation of Multiple Small UAS
Fly over a person with a small UAS which does not meet operational categories 1, 2, 3, or 4	§ 107.39 – Operation over human beings.
Fly a small UAS: ● Over 100 miles per hour groundspeed ● Over 400 feet above ground level (AGL) ● With less than 3 statute miles of visibility	§ 107.51 – Operating limitations for Small Unmanned Aircraft

⁹ Ibid, prior footnote.

● Within 500 feet vertically or 2000 feet horizontally from clouds	
Fly over moving vehicles with a small UAS which does not meet operational categories 1, 2, 3, or 4 or other conditions	§ 107.145 – Operations Over Moving Vehicles

Part 107 Waiver applications and Airspace Authorization requests for non-LAANC airports can be submitted for review and approval by the FAA through DroneZone, <https://faadronezone.faa.gov/#/>.

The DroneZone portal, operated by the FAA, requires the UAS pilot to be registered to access the waiver application system. To apply for a flight waiver through DroneZone, create an account, or log into your existing account. Select "Fly a sUAS under Part 107." Users of this service do not need to register a drone to request a waiver, but without a registered drone, a user must register with LAANC prior to any operation. In these cases, when prompted to input make/model information for the drone, users can move through the screen and keep selecting "next" to bypass the payment forms. Submit your application, including all supporting documents and attachments, through your FAA DroneZone account. Select the "Operational Waiver" option. Review and approval or disapproval of waiver requests will be completed within 90 days of submission. Processing times will vary based on the complexity of the request and the completeness of their initial application.

When is it appropriate to apply for a waiver through DroneZone vs. Aloft?

FAADroneZone waiver requests are for operations where restrictions exist and LAANC is insufficient or unavailable. LAANC requests through Aloft are the easier and preferred approach when practical. FAADroneZone requests are appropriate if exceptions to the Part 107 restrictions are required for operation (as listed in the table on page 36) or when one wishes to fly in controlled airspace that does not offer LAANC - for example in a 0' grid square near over a LAANC airport, or in class B, C, D, or appropriate class E airspace which doesn't offer LAANC.

Requesting a Part 107 Airspace Authorization and/or a Part 107 Waiver, is described in additional detail with additional links to FAA resources here, https://www.faa.gov/uas/commercial_operators/part_107_airspace_authorizations/.

APPENDIX D: NVU UAS Flight Protocols

D1: NVU UAS Infrastructure Inspection Protocol

D2: NVU UAS Oil Spill Detection and Monitoring Protocol

D3: NVU UAS Flood Delineation Protocol

D4: NVU UAS Search & Rescue Protocol

NVU UAS Infrastructure Inspection Protocol

Version April 30, 2022

Aim

The aim of this protocol is to provide preliminary guidance to pilots flying in support of infrastructure inspections in rural Alaskan communities. These flights can be used for area-based, linear, and 3D data collections, to help interrogate infrastructure and cultural resources in support of decision-making. The automated obstacle avoidance of the Skydio UAS is key to the safe semi-automated scanning capacity of the below missions but is not required nor used for all the missions described below. The below missions can be flown as part of a one-time effort or be conducted regularly and systematically to perform change detection analyses.

Assumptions

This protocol makes several Assumptions about the UAS team, standard operating procedures (SOPs), and access to airspace during infrastructure inspection missions. It is the responsibility of the pilot-in-command (PIC) to ensure these Assumptions are met, and if not, to identify and employ additional measures to ensure safety and FAA compliance.

- *Assumption 1:* All pilots flying missions are Part 107 certified by the FAA and are fully aware of and are following all FAA regulations and guidance during flights.
- *Assumption 2:* All members of the UAS team are following the SOPs for UAS flight operations that include: preflight safety checklist, flight logs, maintenance logs, and data logs (filenames and chain-of-custody).
- *Assumption 3:* All FAA flight requirements are being met by the UAS team. If FAA waivers are required for the mission, it is assumed that they will be acquired using defined FAA procedures for routine flight or through the Special Government Interest (SGI) process¹.
- *Assumption 4:* Flight protocol will be used with a UAS manufactured by Skydio, Inc., specifically either the S2 or the X2E licensed with Skydio 3D Scan software.

¹ FAA SGI resources can be found at,
https://www.faa.gov/uas/advanced_operations/emergency_situations/

Flight Scenarios

Flight scenarios are designed as templates for missions associated with a specific flight objective. Scenarios include mission intention, flight patterns, UAS mission settings, data products, and data product applications for the specific scenario.

Scenario 1: 3D Capture – Structure Model

Aim of Flight Pattern

The 3D capture flight mode is used to create detailed 3D models of a structure or groups of structures. The flight plan is automatically calculated by the aircraft's internal software when the UAS pilot defines the "pillars" that represent the extent of the area to be scanned, or by using a mission planning software that is compatible with the UAS; at this time only DroneDeploy is compatible in this way and only with the S2 aircraft. The 3D scan consists of: 1) a preliminary flight to identify the extent of the 3D scan and set the boundaries (pillars) of the scan, 2) a preliminary 3D scan during the "Exploratory Phase" of the scan, and after both processes the 3) data gathering scan will commence. Most 3D scans will require multiple batteries, and care needs to be taken to follow the proper data saving and UAS shut down procedure for the battery exchange to ensure no data loss.

3D captured data and the resulting 3D models that are created in DroneDeploy can be used for detailed documentation and interrogation of targets of interest. This capacity is best applied to 3D targets such as cultural resources, fuel tanks, tank farms, water tanks, damaged buildings, bridges, and to determine volumes, such as at a gravel pit or dump site.

Infrared 3D scan image capture is not an option using the Skydio UAS with DroneDeploy at this time.

Detailed Settings and Parameters

Sensor: EO

Altitude: When setting the pillar boundaries of the scan, also set the flight ceiling height above the highest point of the scan and the flight floor at the ground level of the structure being scanned, which may be below where the pilot is standing. Plan around wires and twigs smaller than thumb's width as these narrow objects, and those smaller, may not be detected by the aircraft when flying under obstacle avoidance features of 3D capture. Flight altitude over and around the target structure will be determined by the UAS once the Exploratory Phase of the scan is complete.

Data Capture Mode(s): 3D Capture within the 3D Capture settings on the Skydio controllers.

Data products (post-processing)

Data captured by the UAS in 3D capture mode will be used by DroneDeploy to automatically produce a 2D orthomosaic and a 3D model of the mission area uploaded. Both the 2D and 3D models can be explored within DroneDeploy or exported to an alternative software for model analysis. It should be noted that 2D change detection of a structural target can be analyzed with

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the 2D orthomosaic products. However, 3D models are not designed to be critiqued in the same way and need to be analyzed as discrete models of the target.

Product Applications

The 3D structural models created from infrastructure targets allow for the localized, informed, prioritization of asset management. Analysis of these models can be used to identify weaknesses in structural integrity and other potential risks to that infrastructure function due to acute or chronic wear. Using 3D models, consistent observations of fuel bearing infrastructure located can support the identification of areas of concern resulting from subsidence of permafrost before there is an oil or diesel release into the environment. Regular 3D inspection of bridges is also possible using 3D capture; a partnership delivering annual bridge inspection models to the Department of Transportation could be a new model for community-driven infrastructure inspections, and resource prioritization.

Scenario 2: Real-time Site Interrogation – Ad Hoc

Aim of Flight Pattern

The real-time site interrogation/ad hoc flight pattern is used when determining preliminary situational awareness or when programming a scanned flight would prove challenging. There is no predetermined flight plan, and the pilot is often working directly with a stakeholder of the data and being directed to fly in specific locations to gain general and point specific situational awareness. The resulting information gathered can be used to design a 2D or 3D scan of the infrastructure target, or to provide real-time information to decision-makers.

Prioritizing infrared video collection during these ad hoc flights may support the identification of oil or other hazardous substances being released from infrastructure, as well as any distinct heat signatures from an anomalous location or poorly insulated structure.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Altitude: Variable based upon specific mission targets; when interrogating a large area, start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered during flight if sensor resolution remains acceptable.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *Manual still image capture*: Still images can be captured prior to video collection activation or as isolated snapshots of the collected video.

Data products (post-processing)

Ad hoc flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video or orthomosaics from still imagery due to the lack of systematic collection standards. These non-standardized videos and still images can serve as key before and after timestamps when improvements are made to a targeted piece of

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infrastructure, but their collection is intended for real-time awareness and possible real-time iteration.

Product Applications

Videos of real-time site interrogation/ad hoc missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

Scenario 3: Real-Time Site Interrogation – Lawnmower

Aim of Flight Pattern

The real-time site interrogation/lawnmower flight pattern² is used when the need is to cover a defined area in a systematic way for real-time and subsequent analyses. Lawnmower patterns can be used for real-time site interrogation when an infrastructure manager is available to observe the video output, or can be flown to collect video footage or imagery for review by infrastructure managers or inspectors after the flight.

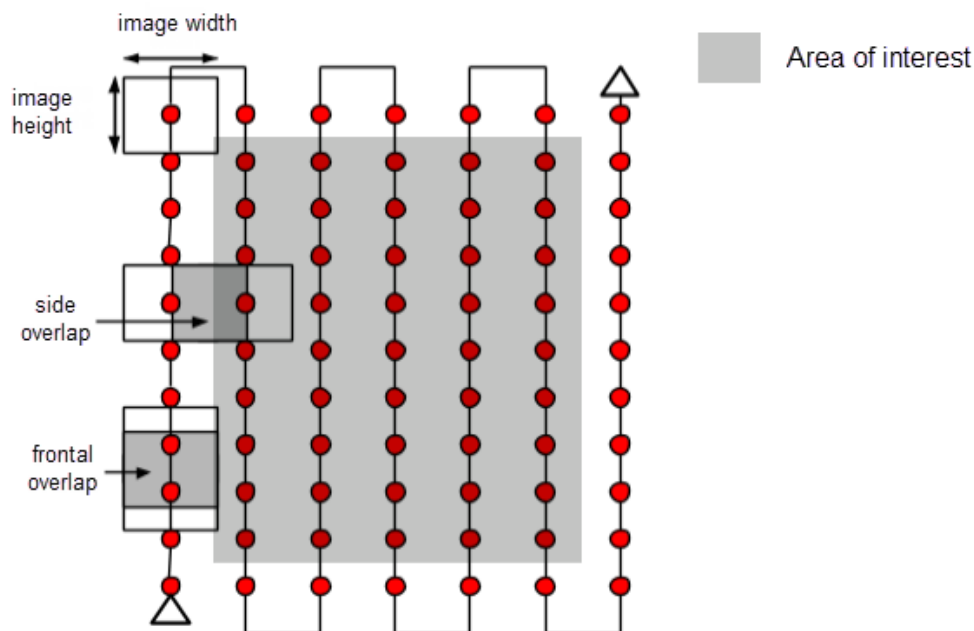


Figure 1. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

² Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

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Detailed Settings and Parameters

Sensor:

- For real-time interrogation, simultaneous EO/IR video collection, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).
- For orthomosaic creation, EO sensor in 2D scan mode with 75% overlap in all directions.

Angle:

- For real-time interrogation utilizing simultaneous EO/IR video collection, both nadir and oblique angles can be used during video collection.
- For orthomosaic creation, nadir image collection is required.

Altitude:

- For EO/IR real-time interrogation, start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.
- For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific infrastructure inspection needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *2D scan*: Only available in EO channel. To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side. Infrastructure inspections collected in 2D scan mode can provide rich information over most 3D features but does not collect as many images as a 3D scan, thus any 3D models created from a 2D scan are not as robust. Please see flight Scenario 1:3D capture for guidance on detailed 3D capture over a set of structures or a given area.

Data products (post-processing)

Lawnmower pattern flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video as the aim is for detailed and overlapping area coverage provided in one flight that ideally not repeated. Video recordings of lawnmower missions may be valuable if infrastructure management personnel are unable to accompany the UAS team into the field to observe the UAS flights in real-time.

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Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the spirals is maintained. The value of these orthomosaics would be for archival and detailed review if real-time observations prove difficult or if a member of the infrastructure management team is not available to observe the flight in real-time.

Still images of specific targets can also be isolated from either the EO or IR video footage if valuable to the response operation.

Product Applications

Videos and orthomosaics of real-time site interrogation/lawnmower missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

Scenario 4: Change Detection – Lawnmower

Aim of Flight Pattern

The change detection/lawnmower flight pattern³ is used when the requirement is to cover a defined area in a systematic way for short- and long-term change detection analyses of a given set of infrastructure. Lawnmower patterns can be used for real-time site interrogation when a member of the infrastructure management team is available to observe the video output or can be flown to imagery for review by decision-makers after the flight.

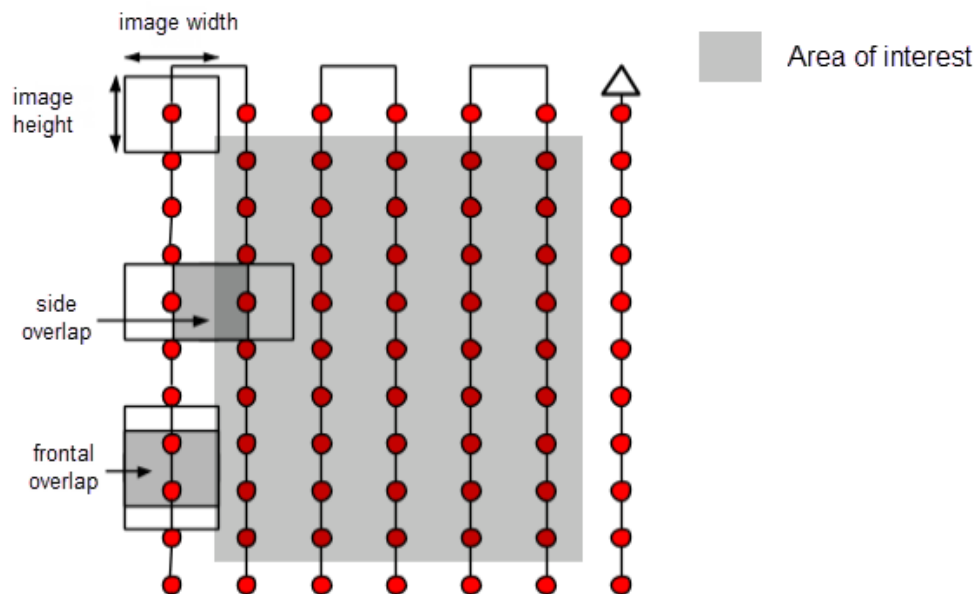


Figure 2. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

³ Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

Detailed Settings and Parameters

Sensor: For orthomosaic creation, use the EO sensor in 2D scan with 75% overlap in all directions. A 3D capture could be used instead of a 2D scan for collecting images for orthomosaicing, which would employ the 360° obstacle avoidance capacity of the UAS and allow for greater interrogation capacity of the infrastructure within orthomosaic. However, the length of time to collect the 3D data may not be worth the additional detail afforded.

Angle: For orthomosaic creation, nadir image collection is required.

Altitude: For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s): *2D scan*: 2D and 3D scan are only available in EO channel. To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side.

Data products (post-processing)

Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the pattern are maintained. The value of these orthomosaics would be for change detection analyses and archival of infrastructure changes and the resulting impacts over time.

Product Applications

Change detection orthomosaics are most valuable when viewed in series. These geospatially referenced maps of an area or target infrastructure can document impacts over time and can be used for time series analyses of those targets. Orthomosaics of change detection/lawnmower missions should be archived in case subsequent review is required.

Scenario 5: Change Detection – Linear

Aim of Flight Pattern

The change detection/linear flight pattern is used when the requirement is to cover a defined linear feature such as a section of coastline, runway, road, or trail, in a systematic way for short- and long-term change detection analyses. Linear patterns can be used for real-time site interrogation when a stakeholder is available to observe the video output but is primarily flown to collect imagery for review by decision-makers after the flight.



Figure 4. Sample of linear flight pattern over road segment. 75% frontal overlap and 75% side overlap is recommended change detection/linear orthomosaic operations. Segment stitching requires an additional 100' of overlap between segment ends.

Detailed Settings and Parameters

Sensor: EO sensor

Angle: Nadir image collection is required for orthomosaic creation.

Altitude: Set-up 2D or 3D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s): *2D scan and 3D scan*: For orthomosaic creation of linear features, use the EO sensor in 2D scan or 3D scan mode with 75% overlap in all directions. 2D and 3D scan are only available in EO channel. The benefit of using 3D scan over 2D scan for collecting images for orthomosaicing is to employ the 360° obstacle avoidance capacity of the UAS and for greater interrogation capacity of features within the orthomosaic. This may be particularly valuable in permafrost rich coastal zones or when imaging line-based, above-ground, electrical infrastructure such as power lines, poles, and transformers, and their dynamic angles on permafrost rich ground.

To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side. Overlap should be set to 75% front and 75% side lap. This recommendation is the same for all photogrammetry projects. Try and fly at least 3 parallel lines per segment to create a robust orthomosaic.

If segments for imaging are longer than line-of-sight (between 1500'-3000'), break segments into line-of-sight missions, and stitch them together during post-processing. Having 100' of overlap between the segments allows for features to be matched in both segments and will give the model enough overlap to stitch the segments together. Ideally, there should be at least 1 ground control point in the area of overlap to additionally ensure that both segments are true to the model from a shared point.

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Data products (post-processing)

Orthomosaics from still imagery can be created when collecting data in a linear pattern if 75% overlap between parallel lines of the pattern are maintained. The value of these orthomosaics would be for change detection analyses and archival of the flood event and the resulting impacts over time. If data is captured in 3D capture mode 3D models of these linear features can also be developed for detailed analyses, which may be required in cases of erosion documentation or electrical line infrastructure integrity. However, from a data management and applications perspective, 2D scan should be the default setting for conducting and processing these linear missions.

Product Applications

Change detection orthomosaics are most valuable when viewed in series. These geospatially referenced maps of an area can document baseline conditions, long-term, and acute impacts to a wide variety of infrastructure targets. Regular infrastructure inspection throughout time can be used for time series analyses and in support of decision-making, especially risk prioritization for resource allocations. Using these linear orthomosaics to measure change detection along riverbanks and ocean coastlines can help prioritize risk to infrastructure in a community. Orthomosaics of change detection/linear missions should be archived in case subsequent review is required.

In Unalakleet,

The characteristics of Unalakleet that should be considered when applying this protocol locally are airspace regulations, collections over water, and impacts of operations occurring in highly congested areas; most community-supporting infrastructure is located in highly congested areas. All airspace over the city of Unalakleet is Class E airspace with no LAANC exceptions until the airport closes and reverts to Class G airspace. Monitoring of infrastructure outside of the city during or after regular airport operational hours may still require LAANC authorization, which should be applied for prior to deployment to the field based upon internet connectivity challenges outside of the city. Though the airspace challenges are not insignificant for conducting regular infrastructure flights, the value of the information provided for planning and decision-making is worth identifying the solutions to safely operate in airspace over the city. All efforts should be made to respect and protect people's privacy when flying in more congested areas and/or over people's home and/or seasonal camps.

Flights over Sensitive Areas

If not an emergency response mission, when conducting a mission over subsistence harvest location and/or cultural/historical resource, the tribal historic preservation officers (THPOs), elder and/or other person(s) knowledgeable about the sensitivity of the site or resource should be contacted prior to flight. If an emergency response UAS mission, then the THPO or person(s) knowledgeable about a site's sensitivity should be contacted as soon as possible if this has not already been done by the entity in command of the emergency response.

NVU UAS Oil Spill Detection and Monitoring Protocol

Version April 30, 2022

Aim

The aim of this protocol is to provide preliminary guidance to pilots flying in support of the detection of unplanned releases of oil and diesel products (collectively referred to as “oil spills” throughout the rest of this protocol), and the monitoring of their clean up. This protocol only addresses missions flown within line-of-sight and focuses on the spills of greatest probability for western Alaska communities. This protocol does not address off-shore oil spills that occur beyond line-of-sight of the Alaskan coast.

When flying UAS as part of a coordinated oil spill response, the UAS team will likely be working under the direction of the Operations Branch of the Incident Command Post (ICP), ideally directly under the Air Boss. UAS support of oil spill response activities is still unique, as such UAS pilots operating in these environments need to plan on developing and executing UAS missions plans according to the capacity of the equipment and team, and not rely on the Air Boss to design the UAS missions. It is possible that the UAS team may be the first group on-site in rural Alaskan communities that have the capacity to collect preliminary observations over the oil spill. If this is the case, stay calm and stay away from the oil or diesel product as these substances are toxic and will off gas volatile toxic compounds. If the UAS team does not feel safe in the oil spill environment, for any reason, they should leave and not fly the mission; human health and safety is always the top priority during an oil spill response. **Report all oil spills to the National Response Center at 1-800-424-8802.** All calls fielded on this 24-hour hotline will be dispatched locally in Alaska.

Assumptions

This protocol makes several Assumptions about the UAS team, standard operating procedures (SOPs), and access to airspace during the oil spill detection and monitoring missions. It is the responsibility of the pilot-in-command (PIC) to ensure these Assumptions are met, and if not, to identify and employ additional measures to ensure safety and FAA compliance.

- *Assumption 1:* All pilots flying missions are Part 107 certified by the FAA and are fully aware of and are following all FAA regulations and guidance during flights.
- *Assumption 2:* All members of the UAS team are following the SOPs for UAS flight operations that include: preflight safety checklist, flight logs, maintenance logs, and data logs (filenames and chain-of-custody).

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- *Assumption 3:* All FAA flight requirements are being met by the UAS team. If FAA waivers are required for the mission, it is assumed that they will be acquired using defined FAA procedures for routine flight or through the Special Government Interest (SGI) process¹.
- *Assumption 4:* Flight protocol will be used with a UAS manufactured by Skydio, Inc., specifically either the S2 or the X2E licensed with Skydio 3D Scan software.
- ***Assumption 5:* Observations of oil and diesel spills will be thoroughly documented and archived as the data and imagery may become part of the Administrative Record of an oil spill liability action.**
- ***Assumption 6:* Any observed wildlife will be distinctly documented by animal type, geographic location and if possible, an accompanying image of the animal and the information will be shared with the Wildlife Branch of the response team, US Coast Guard at 1-866-396-1361, or US Fish and Wildlife Service (Lori Verbrugge) at 907-786-3483.**

Flight Scenarios

Flight scenarios are designed as templates for missions associated with a specific flight objective. Scenarios include mission intention, flight patterns, UAS mission settings, data products, and data product applications for the specific scenario.

Scenario 1: Real-time Site Interrogation – Synoptic View and Timestamp

Aim of Flight Pattern

The real-time site interrogation/synoptic view flight is used to collect a single, or small set, of images to show the full extent of the oil spill for situational awareness, daily or more frequently, for as long as the event persists. It is important to try and collect an image containing the greatest amount of the impacted area as possible from the same general location to document the extent of the impact. In addition to the synoptic view, collecting a consistent image of the oil extent can be used as an event timestamp.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing EO channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Angle: Nadir or oblique angle, as long as consistency is maintained across collected synoptic images.

Altitude: Start at 400' to obtain the largest field of view.

Data Capture Mode(s): *Manual still image capture*

¹ FAA SGI resources can be found at,
https://www.faa.gov/uas/advanced_operations/emergency_situations/

Data products (post-processing)

The resulting image products from these regularly collected synoptic images is a timeseries overview of the oil spill event and impacted area.

Product Applications

In cases of a terrestrial oil spill, these regularly collected summary images can serve as key timestamps in the oil spill cycle and important components of the event archive. In the case of oil released on water, the summary images can also be used as progressive time stamps. If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

Scenario 2: Real-time Site Interrogation – Ad Hoc

Aim of Flight Pattern

The real-time site interrogation/ad hoc flight pattern is used when determining preliminary situational awareness. There is no predetermined flight plan, and the pilot is often working directly with the emergency response team to fly in specific locations as requested by the response team UAS coordinator to gain general and point specific situational awareness. Ad hoc flights or sunburst pattern flights (Scenario 3) are the most common flight patterns when interrogating or searching for oil on water. Prioritizing infrared video collection during these ad hoc flights may support the identification of oil or other hazardous substances on the water, as well as the presence of wildlife, oiled or otherwise, in the area of interest.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Altitude: Variable; start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *Manual still image capture*: Still images can be captured prior to video collection activation or as isolated snapshots of the collected video.

Data products (post-processing)

Ad hoc flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video or orthomosaics from still imagery due to the lack of systematic collection standards. However, in case of an oil spill, these non-standardized videos can serve as key timestamps in the oil spill response cycle.

Product Applications

Videos of real-time site interrogation/ad hoc missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions. If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

Scenario 3: Real-time Site Interrogation – Sunburst

Aim of Flight Pattern

The real-time site interrogation/sunburst flight pattern is used when determining preliminary situational awareness. The sunburst flight pattern is designed for use when interrogating from a single point on a riverbank or coastline over water to try and locate oil on the water or impacted wildlife while maintaining a reference point of land for potential map applications. Prioritizing infrared video collection during these ad hoc flights may support the identification of oil or other hazardous substances on the water, as well as the presence wildlife, oiled or otherwise, in the area of interest.

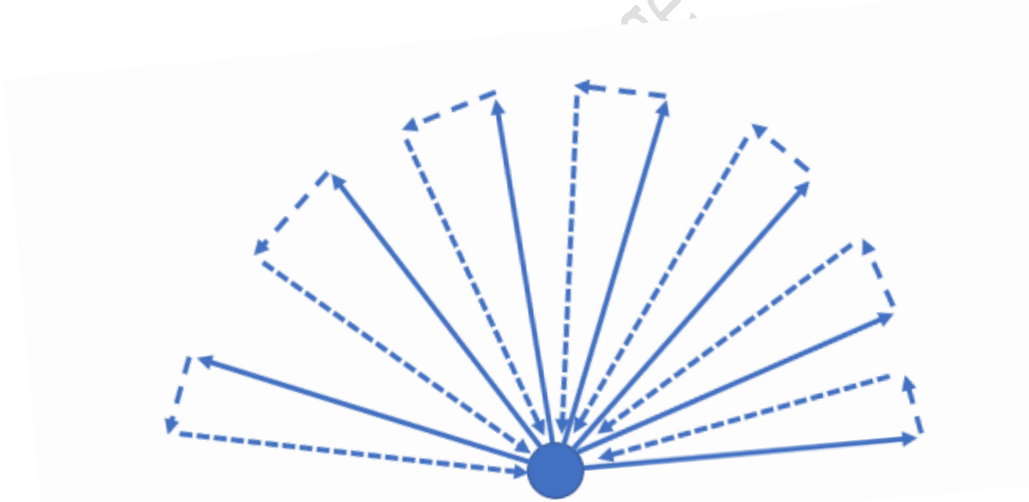


Figure 1. Sample of sunburst pattern flown from a single point, most typically from a shoreline over water. Maintain at least 50% overlap between flight lines if possible, so as not to neglect any of the targeted area for interrogation.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Altitude: Variable; start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.

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Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *Manual still image capture*: Still images can be captured prior to video collection activation or as isolated snapshots of the collected video.

Data products (post-processing)

Sunburst flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video or orthomosaics from still imagery due to the lack of systematic collection standards. In the case of an oil spill, these non-standardized videos can serve as key timestamps in the oil spill response cycle.

Product Applications

Videos of real-time site interrogation/sunburst missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions. If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

Scenario 4: Real-Time Site Interrogation – Lawnmower

Aim of Flight Pattern

The real-time site interrogation/lawnmower flight pattern² is used when the need is to cover a defined area in a systematic way for real-time and subsequent analyses. Lawnmower patterns can be used for real-time site interrogation when a member of the emergency response team is available to observe the video output or can be flown to collect video footage or imagery for review by response team members after the flight. The lawnmower pattern can be partially flown over a water body if there is some component of land, ideally a portion of land that has a ground control point on it, included in the scan, but orthomosaicing over water is not possible with most post-processing programs.

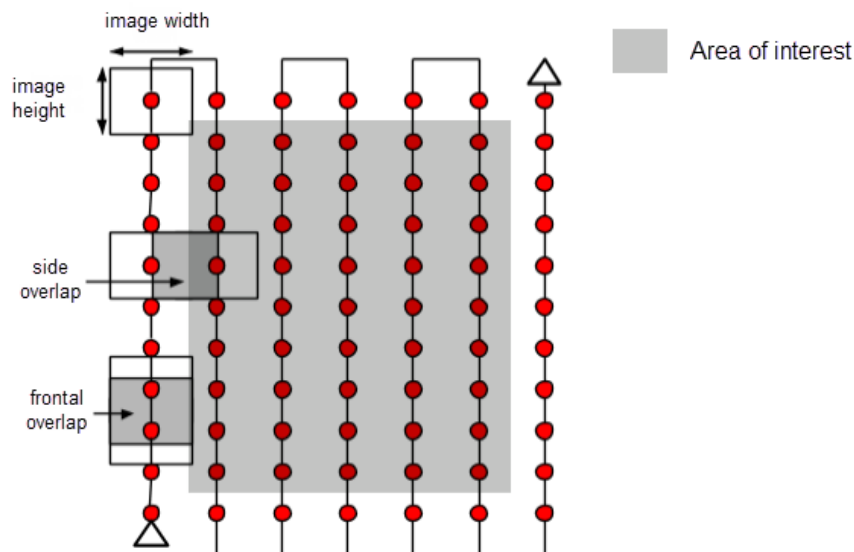


Figure 2. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

Detailed Settings and Parameters

Sensor:

- For real-time interrogation, simultaneous EO/IR video collection, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).
- For orthomosaic creation, EO sensor in 2D scan mode with 75% overlap in all directions.

Angle:

- For real-time interrogation utilizing simultaneous EO/IR video collection, both nadir and oblique angles can be used during video collection.

² Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

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- For orthomosaic creation, nadir image collection is required.

Altitude:

- For EO/IR real-time interrogation, start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.
- For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *2D scan*: Only available in EO channel. To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side.

Data products (post-processing)

Lawnmower pattern flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video as the aim is for detailed and overlapping area coverage provided in one flight that ideally not repeated. Video recordings of lawnmower missions may be valuable if response personnel are unable to accompany the UAS team into the field to observe the UAS flights in real-time.

Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the flight pattern is maintained. The value of these orthomosaics would be for archival and detailed review if real-time observations prove difficult or if a member of the response team is not available to observe the flight in real-time.

Still images of specific targets can also be isolated from either the EO or IR video footage if valuable to the response operation.

Product Applications

Videos and orthomosaics of real-time site interrogation/lawnmower missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions. If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

Scenario 5: Real-time Site Interrogation/Site Monitoring – Tactical Response Observation

Aim of Flight Pattern

The real-time site interrogation/tactical response observation flight is used to collect situational awareness and video footage of the tactical response strategies employed to control the oil spill by hovering over the tactical response. These tactical response observations show how effective the response tactics are at controlling the source of the oil spill, as well as the efficacy of tactics used to mitigate the impacts of the oil, e. g. containment boom placements. Using the IR sensor allows for the detection of oil not contained by the tactical measures, while the EO video can be reviewed for specific tactical components of the response. Flying these missions with a member of the oil spill tactical response team allows for real-time iteration to improve the tactical response in situ, and the videos of the tactical response can also be used in after action reports and for subsequent response training.

Flying UAS over people is a risk that should be avoided, even if the people being flown over are part of the UAS operation. If resources are available to mount an EO and/or an IR camera over the area of the tactical response instead of hovering over the tactical response with a UAS, the static mounted camera should be used instead of a UAS. Static cameras mounted to a high point are inherently less dangerous than having an unmanned aircraft flying over response workers. If UAS are employed to monitor response tactics, hover above and to the side of the response area, using oblique angles to record the operation.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing EO channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Angle: Nadir or oblique angle, maintaining consistency throughout the mission.

Altitude: Start at 200' to ensure high resolution imagery. Increase altitude with size of tactical response area.

Data Capture Mode(s): *Video*: Video capture in IR channel (simultaneous capture in EO channel)

Data products (post-processing)

Video footage should be archived for tactical review in support of after-action reports and lessons learned about the oil spill response. If video footage is formally collected over an oil spill, it will become part of the administrative record, and should be provided to the coordinators of the response in accordance with data management plans.

Product Applications

The resulting EO/IR video products of the tactical response strategies can be used for immediate tactical iteration or in after-action reports and subsequent response training. Still images can be cut from videos to highlight specific components of the tactical response and can be used as timestamps throughout a response. Collecting video footage from UAS hovering over the

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tactical response from a consistent location could in some cases be replaced by a static camera, and this option should be considered for safety reasons above all others.

If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

Scenario 6: Site Monitoring – Lawnmower

Aim of Flight Pattern

The change detection/lawnmower flight pattern³ is used when the requirement is to cover a defined area in a systematic way for short- and long-term monitoring for change detection analyses of the oil spill event. Lawnmower patterns can be used for real-time site interrogation when a member of the emergency response team is available to observe the video output or can be flown to collect imagery for review by decision-makers after the flight. The lawnmower pattern can be partially flown over a water body if there is some component of land, ideally a portion of land that has a ground control point on it, included in the scan, but orthomosaicing over water is not possible with most post-processing programs.

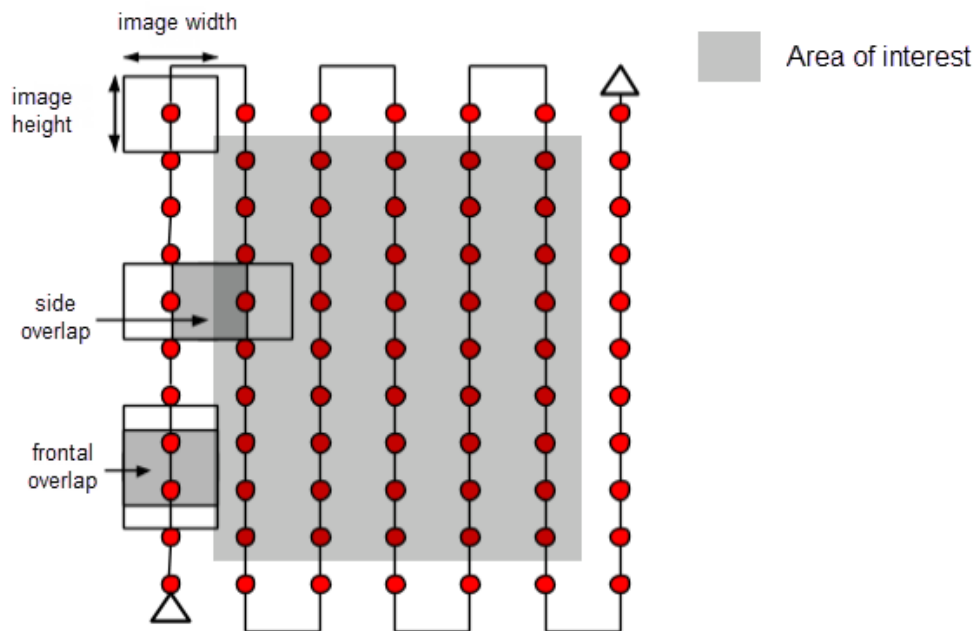


Figure 3. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

³ Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

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Detailed Settings and Parameters

Sensor: For orthomosaic creation, use the EO sensor in 2D scan mode with 75% overlap in all directions.

Angle: Nadir image collection is required for orthomosaic creation.

Altitude: For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s): *2D scan*: 2D and 3D scan are only available in EO channel. To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side.

Data products (post-processing)

Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the pattern are maintained. The value of these orthomosaics would be for change detection analyses and archival of the oil spill event and the resulting impacts over time.

Product Applications

Change detection orthomosaics are most valuable when viewed in series. These geospatially referenced maps of an area can document impacts over time and can be used for time series analyses of the event and resulting impacts. Orthomosaics of change detection/lawnmower missions should be archived in case subsequent review is required. If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

Scenario 7: Site Monitoring – Linear

Aim of Flight Pattern

The change detection/linear flight pattern is used when the requirement is to cover a defined linear feature such as a section of coastline, runway, road, or trail, in a systematic way for short- and long-term change detection analyses of the oil spill event. Linear patterns can be used for real-time site interrogation when a member of the emergency response team is available to observe the video output but is primarily flown to collect imagery for review by decision-makers after the flight.



Figure 4. Sample of linear flight pattern over road segment. 75% frontal overlap and 75% side overlap is recommended change detection/linear orthomosaic operations. Segment stitching requires an additional 100' of overlap between segment ends.

Detailed Settings and Parameters

Sensor: EO sensor

Angle: Nadir image collection is required for orthomosaic creation.

Altitude: Set-up 2D or 3D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s): *2D scan and 3D scan*: For orthomosaic creation of linear features, use the EO sensor in 2D scan or 3D scan mode with 75% overlap in all directions. 2D and 3D scan are only available in EO channel. The benefit of using 3D scan over 2D scan for collecting images for orthomosaicing is to employ the 360° obstacle avoidance capacity of the UAS and for greater interrogation capacity of features within the orthomosaic.

To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side. Overlap should be set to 75% front and 75% side lap. This recommendation is the same for all photogrammetry projects. Try and fly at least 3 parallel lines per segment to create a robust orthomosaic.

If segments for imaging are longer than line-of-sight (between 1500'-3000'), break segments into line-of-sight missions, and stitch them together during post-processing. Having 100' of overlap between the segments allows for features to be matched in both segments and will give the model plenty of overlap to stitch the segments together. Ideally, there should be at least 1

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ground control point in the area of overlap. This will further ensure that both segments are snapped true to the model from the same point.

Data products (post-processing)

Orthomosaics from still imagery can be created when collecting data in a linear pattern if 75% overlap between parallel lines of the pattern are maintained. The value of these orthomosaics would be for change detection analyses and archival of the oil spill event and the resulting impacts over time.

Product Applications

Change detection orthomosaics are most valuable when viewed in series. These geospatially referenced maps of an area can document immediate oil spill impacts and those observed throughout time and can be used for time series analyses of the event and resulting impacts.

Using these linear orthomosaics to measure change detection along riverbanks and ocean coastlines has broader applications than oil spill delineation or damage inspection.

Orthomosaics of change detection/linear missions should be archived in case subsequent review is required. If the response is locally managed, archive the data according to SOPs, and work with the response team to review or share data products as is most useful to the local response team decision-makers. If an ICP is established as part of the oil spill response, a copy of the data products resulting from the flights need to be provided to the designated data manager or to the Documentation Unit.

In Unalakleet,

The characteristics of Unalakleet that should be considered when applying this protocol locally are airspace regulations, searches over water, and response team coordination during and immediately after an oil spill event. All airspace over the city of Unalakleet is Class E airspace with no LAANC exceptions until the airport closes and reverts to Class G airspace. Oil spill delineation immediately after a release will depend on the emergency status of the community and if UAS operations over town during regular airport operation hours will require direct coordination with the airport, the implementation of a temporary flight restriction over the community, or an emergency waiver via the SGI process. Long-term monitoring of oil spill impacts outside of the city during or after regular airport operational hours may still require LAANC authorization, which should be applied for prior to deployment to the field based upon internet connectivity challenges outside of the city.

Response team coordination is key to collecting practical and useful information during and after an oil spill response. Working directly with response coordinators increases efficiencies as UAS teams can be directed to targeted areas to increase the depth of coverage over an impacted area. Documenting a synoptic view of the oil spill impacts and succinctly measuring change detection as a result of flood events can support informed community planning for the short- and long-term impacts of climate change.

Flights over Sensitive Areas

If not an emergency response mission, when conducting a mission over subsistence harvest location and/or cultural/historical resource, the tribal historic preservation officers (THPOs), elder and/or other

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person(s) knowledgeable about the sensitivity of the site or resource should be contacted prior to flight. If an emergency response UAS mission, then the THPO or person(s) knowledgeable about a site's sensitivity should be contacted as soon as possible if this has not already been done by the entity in command of the emergency response.

NVU UAS Flood Delineation Protocol

Version April 30, 2022

Aim

The aim of this protocol is to provide preliminary guidance to pilots flying post-storm flood delineation or active flood event missions. Understanding that the limitations of small UAS will prevent flight from taking place during high winds and precipitation, this protocol is designed for collecting information about the impacts after the given storm event has concluded, when flood water may or may not have receded. In the case of a sizable flood event, the UAS pilot will likely be working under the direction of a community-based response team or search and rescue team, and that is reflected in the below flight scenarios.

It is important that regardless of the flight scenarios flown that a synoptic view of the entire flood affected area be captured to the best of the abilities of the UAS and the pilot. If possible, the location from which that synoptic view is imaged should be the site of a time-series of individual still images showing the progression of the flood cycle. These synoptic images should be captured with both EO and IR sensors, with emphasis being on the EO sensor, due to its intuitive nature for non-specialist to interpret.

Assumptions

This protocol makes several Assumptions about the UAS team, standard operating procedures (SOPs), and access to airspace during the flood delineation mission. It is the responsibility of the pilot-in-command (PIC) to ensure these Assumptions are met, and if not, to identify and employ additional measures to ensure safety and FAA compliance.

- *Assumption 1:* All pilots flying missions are Part 107 certified by the FAA and are fully aware of and are following all FAA regulations and guidance during flights.
- *Assumption 2:* All members of the UAS team are following the SOPs for UAS flight operations that include: preflight safety checklist, flight logs, maintenance logs, and data logs (filenames and chain-of-custody).
- *Assumption 3:* All FAA flight requirements are being met by the UAS team. If FAA waivers are required for the mission, it is assumed that they will be acquired using defined FAA procedures for routine flight or through the Special Government Interest (SGI) process¹.
- *Assumption 4:* Flight protocol will be used with a UAS manufactured by Skydio, Inc., specifically either the S2 or the X2E licensed with Skydio 3D Scan software.

¹ FAA SGI resources can be found at,
https://www.faa.gov/uas/advanced_operations/emergency_situations/

Flight Scenarios

Flight scenarios are designed as templates for missions associated with a specific flight objective. Scenarios include mission intention, flight patterns, UAS mission settings, data products, and data product applications for the specific scenario.

Scenario 1: Real-time Site Interrogation – Synoptic View and Timestamp

Aim of Flight Pattern

The real-time site interrogation/synoptic view flight is used to collect a single, or small set, of images to show the full extent of the flooding event for situational awareness, daily or more frequently, for as long as the event persists. It is important to try and collect an image containing the greatest amount of the flood area as possible from the same general location to document the extent of the impact. In addition to the synoptic view, collecting a consistent image of the flood extent can be used as an event timestamp.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing EO channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Angle: Nadir or oblique angle, as long as consistency is maintained across collected synoptic images.

Altitude: Start at 400' to obtain the largest field of view.

Data Capture Mode(s): *Manual still image capture*

Data products (post-processing)

The resulting image products from these regularly collected synoptic images is a timeseries overview of the flooding event.

Product Applications

In cases of flooding, these regularly collected synoptic flood view images can serve as key timestamps in the flood cycle and important components of the event archive.

Scenario 2: Real-time Site Interrogation – Ad Hoc

Aim of Flight Pattern

The real-time site interrogation/ad hoc flight pattern is used when determining preliminary situational awareness. There is no predetermined flight plan, and the pilot is often working directly with the emergency response team to fly in specific locations as requested by the response team UAS coordinator to gain general and point specific situational awareness. Prioritizing infrared video collection during these ad hoc flights may support the identification of oil or other hazardous substances in the flood waters, as well as any distinct heat signatures from a person in distress, or some other anomalous component of the flood.

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Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Altitude: Variable; start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *Manual still image capture*: Still images can be captured prior to video collection activation or as isolated snapshots of the collected video.

Data products (post-processing)

Ad hoc flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video or orthomosaics from still imagery due to the lack of systematic collection standards. However, in case of flooding, these non-standardized videos can serve as key timestamps in the dynamic flood cycle.

Product Applications

Videos of real-time site interrogation/ad hoc missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

Scenario 3: Real-Time Site Interrogation – Lawnmower

Aim of Flight Pattern

The real-time site interrogation/lawnmower flight pattern² is used when the need is to cover a defined area in a systematic way for real-time and subsequent analyses. Lawnmower patterns can be used for real-time site interrogation when a member of the emergency response team is available to observe the video output or can be flown to collect video footage or imagery for review by response team members after the flight.

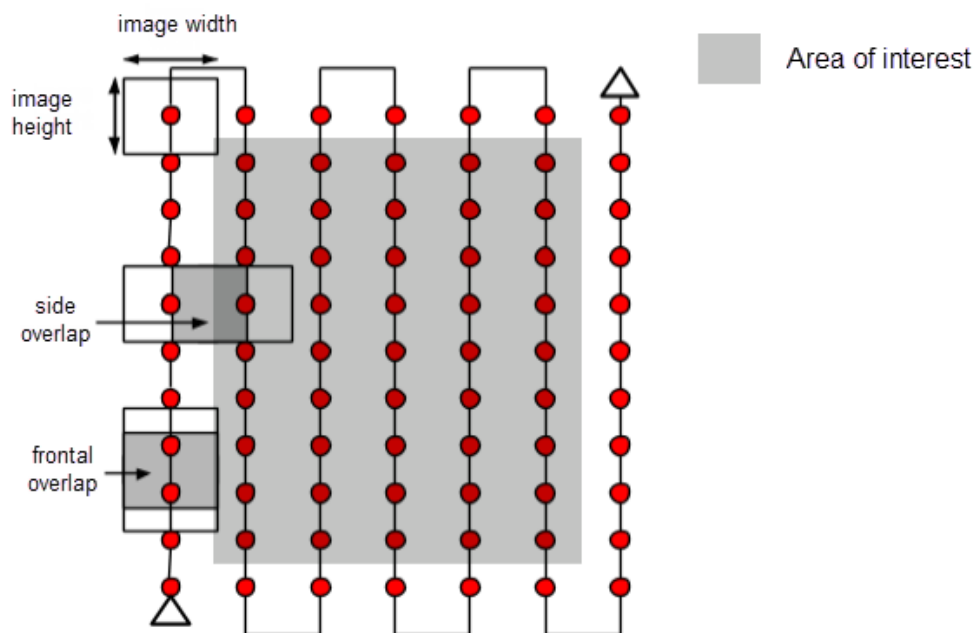


Figure 1. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

Detailed Settings and Parameters

Sensor:

- For real-time interrogation, simultaneous EO/IR video collection, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).
- For orthomosaic creation, EO sensor in 2D scan mode with 75% overlap in all directions.

² Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

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Angle:

- For real-time interrogation utilizing simultaneous EO/IR video collection, both nadir and oblique angles can be used during video collection.
- For orthomosaic creation, nadir image collection is required.

Altitude:

- For EO/IR real-time interrogation, start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.
- For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *2D scan*: Only available in EO channel. To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side.

Data products (post-processing)

Lawnmower pattern flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video as the aim is for detailed and overlapping area coverage provided in one flight that ideally not repeated. Video recordings of lawnmower missions may be valuable if response personnel are unable to accompany the UAS team into the field to observe the UAS flights in real-time.

Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the spirals is maintained. The value of these orthomosaics would be for archival and detailed review if real-time observations prove difficult or if a member of the response team is not available to observe the flight in real-time.

Still images of specific targets can also be isolated from either the EO or IR video footage if valuable to the response operation.

Product Applications

Videos and orthomosaics of real-time site interrogation/lawnmower missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

Scenario 4: Change Detection – Lawnmower

Aim of Flight Pattern

The change detection/lawnmower flight pattern³ is used when the requirement is to cover a defined area in a systematic way for short- and long-term change detection analyses of the flooding event. Lawnmower patterns can be used for real-time site interrogation when a member of the emergency response team is available to observe the video output or can be flown to imagery for review by decision-makers after the flight.

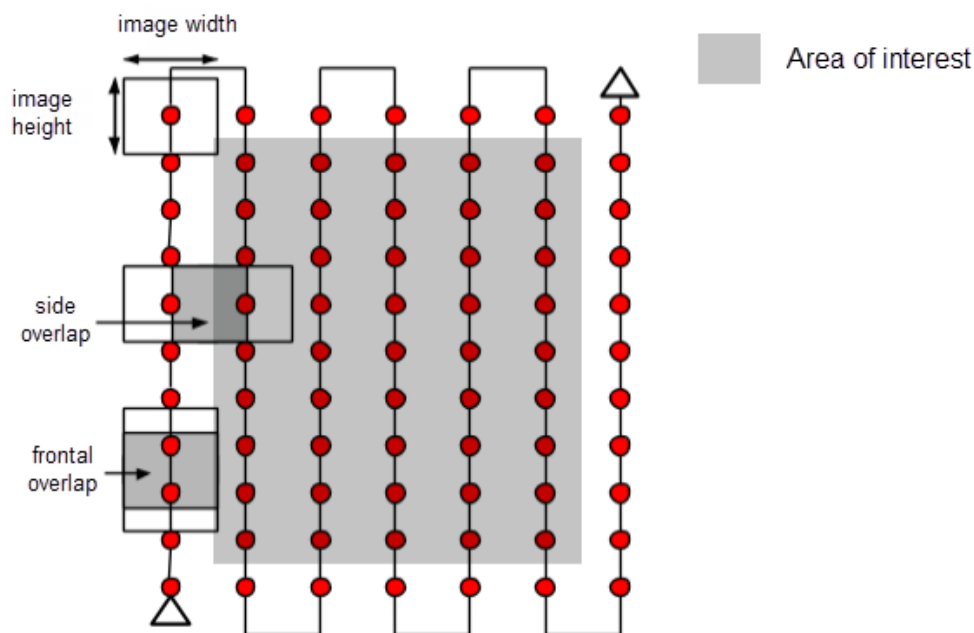


Figure 2. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

Detailed Settings and Parameters

Sensor: For orthomosaic creation, use the EO sensor in 2D scan mode with 75% overlap in all directions.

Angle: For orthomosaic creation, nadir image collection is required.

Altitude: For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to

³ Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

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cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s): 2D scan: 2D and 3D scan are only available in EO channel. To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side.

Data products (post-processing)

Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the pattern are maintained. The value of these orthomosaics would be for change detection analyses and archival of the flood event and the resulting impacts over time.

Product Applications

Change detection orthomosaics are most valuable when viewed in series. These geospatially referenced maps of an area can document impacts over time and can be used for time series analyses of the event and resulting impacts. Orthomosaics of change detection/lawnmower missions should be archived in case subsequent review is required.

Scenario 5: Change Detection – Linear

Aim of Flight Pattern

The change detection/linear flight pattern is used when the requirement is to cover a defined linear feature such as a section of coastline, runway, road, or trail, in a systematic way for short- and long-term change detection analyses of the flooding event. Linear patterns can be used for real-time site interrogation when a member of the emergency response team is available to observe the video output, but is primarily flown to collect imagery for review by decision-makers after the flight.



Figure 4. Sample of linear flight pattern over road segment. 75% frontal overlap and 75% side overlap is recommended change detection/linear orthomosaic operations. Segment stitching requires an additional 100' of overlap between segment ends.

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Detailed Settings and Parameters

Sensor: EO sensor

Angle: Nadir image collection is required for orthomosaic creation.

Altitude: Set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific response operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail and image overlap for response operation.

Data Capture Mode(s): *2D scan*: For orthomosaic creation of linear features, use the EO sensor in 2D scan mode with 75% overlap in all directions. 2D and 3D scan are only available in EO channel.

To reduce potential data loss for large search areas, define and conduct smaller sub scans that do not require battery change out in case there is a failure during the battery exchange, and repeat for adjacent areas. DroneDeploy is able to stitch separate scans together if flown close enough in time, at the same altitude, and have overlapping images along a side. Overlap should be set to 75% front and 75% side lap. This recommendation is the same for all photogrammetry projects. Try and fly at least 3 parallel lines per segment to create a robust orthomosaic.

If segments for imaging are longer than line-of-sight (between 1500'-3000'), break segments into line-of-sight missions, and stitch them together during post-processing. Having 100' of overlap between the segments allows for features to be matched in both segments and will give the model plenty of overlap to stitch the segments together. Ideally, there should be at least 1 ground control point in the area of overlap. This will further ensure that both segments are snapped true to the model from the same point.

Data products (post-processing)

Orthomosaics from still imagery can be created when collecting data in a linear pattern if 75% overlap between parallel lines of the pattern are maintained. The value of these orthomosaics would be for change detection analyses and archival of the flood event and the resulting impacts over time.

Product Applications

Change detection orthomosaics are most valuable when viewed in series. These geospatially referenced maps of an area can document immediate flood impacts and those observe throughout time and can be used for time series analyses of the event and resulting impacts.

Using these linear orthomosaics to measure change detection along riverbanks and ocean coastlines has broader applications beyond flood delineation or damage inspection.

Orthomosaics of change detection/linear missions should be archived in case subsequent review is required.

In Unalakleet,

The characteristics of Unalakleet that should be considered when applying this protocol locally are airspace regulations, searches over water, and response team coordination during and immediately

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after the flood event. All airspace over the city of Unalakleet is Class E airspace with no LAANC exceptions until the airport closes and reverts to Class G airspace. Flood delineation immediately after a storm will depend on the emergency status of the community and if UAS operations over town during regular airport operation hours will require direct coordination with the airport, the implementation of a temporary flight restriction over the community, or an emergency waiver via the SGI process. Long-term monitoring of flood impacts outside of the city during or after regular airport operational hours may still require LAANC authorization, which should be applied for prior to deployment to the field based upon internet connectivity challenges outside of the city.

Response team coordination is key to collecting practical and useful information during and after a flood event. Working directly with response and SAR coordinators increases efficiencies as UAS teams can be directed to targeted areas to increase the depth of coverage over an impacted area. Documenting a synoptic view of flood impacts and succinctly measuring change detection as a result of flood events can support informed community planning for the short- and long-term impacts of climate change.

Flights over Sensitive Areas

If not an emergency response mission, when conducting a mission over subsistence harvest location and/or cultural/historical resource, the tribal historic preservation officers (THPOs), elder and/or other person(s) knowledgeable about the sensitivity of the site or resource should be contacted prior to flight. If an emergency response UAS mission, then the THPO or person(s) knowledgeable about a site's sensitivity should be contacted as soon as possible if this has not already been done by the entity in command of the emergency response.

NVU UAS Search & Rescue Protocol

Version April 30, 2022

Protocol Aim

The aim of this protocol is to provide preliminary guidance to pilots flying in support of search and rescue (SAR) activities. Each pilot and mission should adopt this protocol as appropriate to the specific SAR scenario that is being supported. This protocol is designed for acute SAR applications, not routine data collections.

Assumptions

This protocol makes several Assumptions about the UAS team, standard operating procedures (SOPs), and access to airspace during the SAR operation. It is the responsibility of the pilot-in-command (PIC) to ensure these Assumptions are met, and if not, to identify and employ additional measures to ensure safety and FAA compliance.

- *Assumption 1:* All pilots flying the SAR mission are Part 107 certified by the FAA and are fully aware of and are following all FAA regulations and guidance for the SAR supporting flights.
- *Assumption 2:* All members of the UAS team are following the SOPs for UAS flight operations that include: preflight safety checklist, flight logs, maintenance logs, and data logs (filenames and chain-of-custody).
- *Assumption 3:* All FAA flight requirements are being met by the UAS team during the SAR operation. If FAA waivers are required for the SAR operation, it is assumed that they will be acquired using defined FAA procedures for routine flight or through the Special Government Interest (SGI) process¹.
- *Assumption 4:* Flight protocol will be used with a UAS manufactured by Skydio, Inc., specifically either the S2 or the X2E licensed with Skydio 3D Scan software.

Flight Scenarios

Flight scenarios are designed as templates for missions associated with a specific flight objective. Scenarios include mission intention, flight patterns, UAS mission settings, data products, and data product applications for the specific scenario.

¹ FAA SGI resources can be found at,
https://www.faa.gov/uas/advanced_operations/emergency_situations/

Scenario 1: Real-Time Site Interrogation – Ad Hoc

Aim of Flight Pattern

The real-time site interrogation/ad hoc flight pattern is used when determining preliminary situational awareness. There is no predetermined flight plan, and the pilot is working directly with the SAR team to fly in specific locations as requested by the SAR team UAS coordinator.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Angle: Ad hoc flights can be flown at nadir or oblique angles.

Altitude: Variable; start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *Manual still image capture*: Still images can be captured periodically on-demand or as isolated snapshots of the collected video.

Data products (post-processing)

Ad hoc flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video or orthomosaics from still imagery due to the lack of systematic collection standards.

Product Applications

Videos of real-time site interrogation/ad hoc missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

Scenario 2: Real-Time Site Interrogation – Spiral

Aim of Flight Pattern

The real-time site interrogation/spiral flight pattern² is used when the need is to start at a single point and to systematically move in all directions away from that point. Spiral patterns can be used for real-time site interrogation when a member of the SAR team is available to observe the video output or can be flown to collect video footage or imagery for review by SAR team members after the flight. This pattern is popular for SAR applications when the last known

² Spiral pattern adapted from: Kaushal, Hemani & Jain, V & Kar, Subrat. (2017). Acquisition, Tracking, and Pointing. 10.1007/978-81-322-3691-7_4.

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location of a person is known or when a specific article associated with the missing person is found with no leading indication of which direction the person may have traveled next.

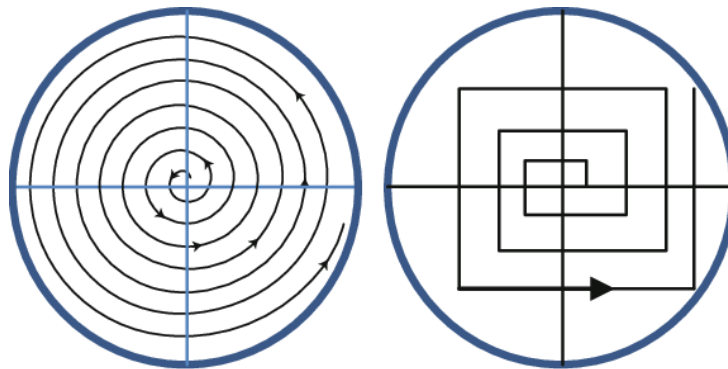


Figure 1. Two types of spiral patterns that can be flown by UAS in support of SAR missions.

Detailed Settings and Parameters

Sensor: Simultaneous EO/IR, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).

Angle: Spiral flight patterns can be flown at nadir or oblique angles when collecting video, but nadir only if individual still images are being collected for mosaicking at a later time.

Altitude: Variable; start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.

Data Capture Mode(s):

- *Video*: Video capture in IR channel (simultaneous capture in EO channel)
- *Manual still image capture*: Still images can be captured periodically on-demand or as isolated snapshots of the collected video.

Data products (post-processing)

Spiral flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video as the aim is for detailed and overlapping area coverage provided in one flight that ideally not repeated. Video recordings of spiral missions may be valuable if SAR personnel are unable to accompany the UAS team into the field to observe the UAS flights in real-time.

Orthomosaics from still imagery can be created when collecting data in a spiral pattern if 75% overlap between lines of the spirals is maintained. The value of these orthomosaics would be for archival and detailed review if real-time observations prove difficult or if a member of the SAR team is not available to observe the flight in real-time.

Still images of specific targets can also be isolated from either the EO or IR video footage if valuable to the SAR operation.

Product Applications

Videos of real-time site interrogation/spiral missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

Scenario 3: Real-Time Site Interrogation – Lawnmower

Aim of Flight Pattern

The real-time site interrogation/lawnmower flight pattern³ is used when the need is to cover a defined area in a systematic way for real-time and subsequent analyses. Lawnmower patterns can be used for real-time site interrogation when a member of the SAR team is available to observe the video output or can be flown to collect video footage or imagery for review by SAR team members after the flight.

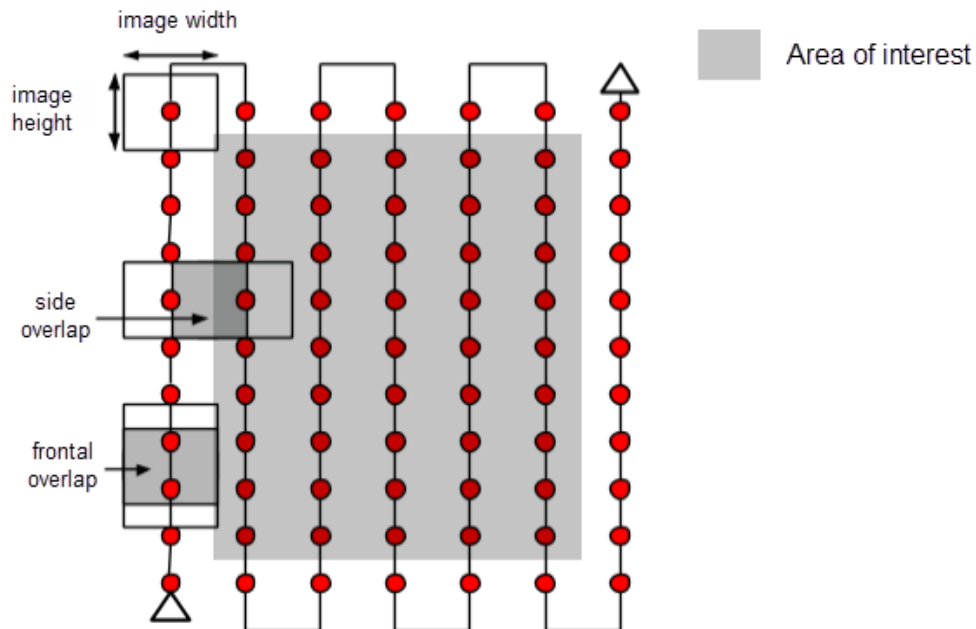


Figure 2. Sample of lawnmower pattern with 75% frontal overlap and 50% side overlap used for real-time and archivable SAR operations. Note: Overlap of less than 70% in any direction is not recommended if data collected is for orthomosaic creation.

Detailed Settings and Parameters

Sensor:

³ Lawnmower pattern adapted from: <https://www.aerotas.com/overlap-flight-pattern>.

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- For real-time interrogation, simultaneous EO/IR video collection, prioritizing IR channel settings (Note: choose rainbow, white hot, or black hot infrared settings based upon End User preferences).
- For orthomosaic creation, EO sensor in 2D scan mode with 75% overlap in all directions.

Angle: All flights flown in lawnmower pattern should be flown at nadir for the greatest processing options.

Altitude:

- For EO/IR real-time interrogation, start at 200' to maintain reasonable field of view for IR sensor and increase in altitude to increase area covered if sensor resolution remains acceptable.
- For EO orthomosaic creation, set-up 2D scan at 200' altitude to determine high resolution image detail, then increase to 400' to determine if resolution at max altitude will be sufficient for specific SAR operational needs. Perform scan at highest altitude possible to cover as much area as possible while maintaining required detail for SAR operation.

Data Capture Mode(s):

- *Video:* Video capture in IR channel (simultaneous capture in EO channel)
- *2D scan:* Only available in EO channel. For large search areas, define and conduct scans that do not require battery change out in case there is a failure during the battery exchange, as this will reduce potential data loss.

Data products (post-processing)

Lawnmower pattern flights can be used to create videos of the real-time interrogation but are rarely made into systematic products like full motion video as the aim is for detailed and overlapping area coverage provided in one flight that ideally not repeated. Video recordings of lawnmower missions may be valuable if SAR personnel are unable to accompany the UAS team into the field to observe the UAS flights in real-time.

Orthomosaics from still imagery can be created when collecting data in a lawnmower pattern if 75% overlap between lines of the spirals is maintained. The value of these orthomosaics would be for archival and detailed review if real-time observations prove difficult or if a member of the SAR team is not available to observe the flight in real-time.

Still images of specific targets can also be isolated from either the EO or IR video footage if valuable to the SAR operation.

Product Applications

Videos and orthomosaics of real-time site interrogation/lawnmower missions should be archived in case subsequent review is required, though it should be recognized that video and image products for review is not the primary aim of real-time interrogation missions.

In Unalakleet,

The characteristics of Unalakleet that should be considered when applying this protocol locally are airspace regulations, searches over water, and SAR team coordination. All airspace over the city of Unalakleet is Class E airspace with no LAANC exceptions until the airport closes and reverts to Class G airspace. SAR support operations in town during regular airport operation hours will require direct coordination with the airport, the implementation of a temporary flight restriction over the community, or an emergency waiver via the SGI process. SAR operation support outside of the city during or after regular airport operational hours may still require LAANC authorization, which should be applied for prior to deployment to the field based upon internet connectivity challenges outside of the city.

Searches over water should focus on the real-time observation of the UAS flight path by a member of the SAR operation as connecting open water video imagery to any location on earth without some type of ground point is not possible. Video over the ocean can still be recorded and viewed, but it cannot be reliably geospatially referenced without at least some anchor image to the land, ideally a formal ground control point. Imagery collected over rivers is less sensitive to this phenomenon as river can be narrow enough to allow for grounding of the image on one bank or the other. This phenomenon does not persist when sea ice is present, but again, without a proper ground control point, geospatial image referencing will be limited by the availability of nearby terrestrial ground control points.

SAR team coordination is key to all SAR supporting UAS missions. Working directly with SAR coordinators increases efficiencies as UAS teams can be directed to targeted areas and can work in tandem with foot-based operations to increase the depth of coverage over a given search area. If UAS teams are not embedded within the SAR operation, direct coordination with the SAR coordinators is necessary prior to UAS mission execution so that the most valuable UAS product can be collected for the SAR operation.

Flights over Sensitive Areas

If not an emergency response mission, when conducting a mission over subsistence harvest location and/or cultural/historical resource, the tribal historic preservation officers (THPOs), elder and/or other person(s) knowledgeable about the sensitivity of the site or resource should be contacted prior to flight. If an emergency response UAS mission, then the THPO or person(s) knowledgeable about a site's sensitivity should be contacted as soon as possible if this has not already been done by the entity in command of the emergency response.