

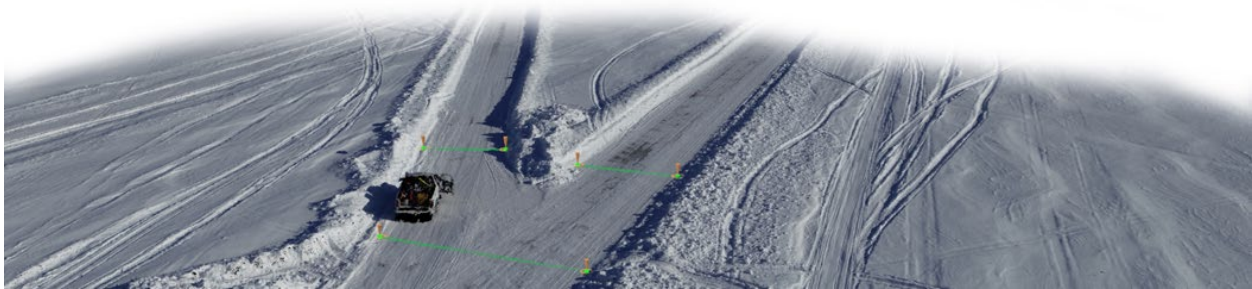
# ARROW FINAL IMPLEMENTATION PLAN

## STRENGTHENING MOBILITY AND REVOLUTIONIZING TRANSPORTATION (SMART) GRANT PROGRAM



U.S. Department of Transportation

# SMART



### Project Details

**Grant Number:** 69A3552341009

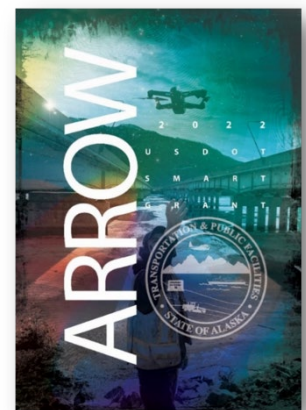
**Project Title:** Alaska Rural Remote Operations Workplan (ARROW)

**Recipient Name:** Alaska Department of Transportation & Public Facilities (DOT&PF)

**Fiscal Year of Award:** FY22

**Period of Performance:** July 15, 2023 - August 15, 2025

**Organization(s) Preparing the Implementation Report:** Alaska Department of Transportation & Public Facilities (DOT&PF)



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### Introduction and Project Overview

#### 1.1 ARROW Project Executive Summary

The Alaska Rural Remote Operations Workplan (ARROW), led by the Alaska Department of Transportation & Public Facilities (DOT&PF), is a Stage 1 SMART Grant initiative designed to evaluate the use of uncrewed aircraft systems (UAS), satellite communications, and cloud-based geospatial technologies to improve transportation safety, resiliency, and expand access to advanced technologies for remote communities. The project's primary goals are to enhance transportation safety and emergency response through rapid deployment of UAS and real-time data sharing; improve infrastructure monitoring and reliability for seasonal trails, ice roads, and remote facilities; expand access to advanced technologies for remote communities; increase system resiliency in response to natural disasters and infrastructure disruptions; support workforce development through local training and job creation; and reduce operational costs and improve operational efficiency by replacing traditional data collection methods with scalable, digital solutions. ARROW is deployed across multiple regions in Alaska, including Bethel, Quinhagak, the Yukon-Kuskokwim Delta, Anchorage, Fairbanks, Juneau, the Mat-Su Borough, and Valdez, representing a range of rural, remote, and urban environments with a focus on communities that are not connected to the road system and are accessible only by air or water.

The project is implemented through a broad coalition of partners spanning federal, state, tribal, academic, and private sectors. Key partners include the Federal Aviation Administration (FAA), the Department of Public Safety (DPS), local municipalities, tribal organizations such as the Association of Village Council Presidents (AVCP) and Nalaquq, the University of Alaska Fairbanks through the Alaska Center for UAS Integration (ACUASI), and industry partners including Skydio, Esri, Armada, Starlink, AT&T FirstNet, and Collins Aerospace, as well as workforce development organizations such as AFL-CIO, IBEW, and Yuut Elitnaurviat. During Stage 1, ARROW focused on establishing operational feasibility and building foundational capacity by training and certifying local UAS pilots, including FAA Part 107 certification and hands-on flight operations; deploying UAS platforms such as the Skydio X10 and X2 dock systems in real-world conditions, including beyond visual line of sight operations in controlled environments; implementing satellite-based connectivity through Starlink with LTE backup systems to enable real-time data transmission in areas without traditional infrastructure; developing cloud-based data workflows using Esri SiteScan and ArcGIS for processing, analysis, and sharing of geospatial data; integrating UAS into emergency response scenarios including flooding, wildfires, and infrastructure inspections; and engaging communities through outreach, training, and collaborative deployment planning.

The results of the Stage 1 proof-of-concept demonstrate strong performance across all major goal areas. Operational deployment times averaged approximately 30 minutes, with full system setup completed in approximately two hours. Data collected by UAS platforms achieved less than plus or minus three percent deviation from ground control measurements, validating accuracy and reliability across diverse environmental conditions. Starlink-enabled connectivity provided download speeds ranging from 50 to 150 megabits per second with latency between 20 and 40 milliseconds, enabling real-time video streaming and data transfer in remote regions. UAS deployments significantly improved emergency response capabilities by reducing response times and enhancing situational awareness, including enabling near real-time data sharing that supported state-level disaster declarations. Infrastructure monitoring improved through increased frequency,

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consistency, and quality of inspections, allowing for repeatable high-resolution documentation of critical assets and environmental changes. Workforce development efforts resulted in the certification and hiring of local UAS operators, creating new technical career pathways in rural communities, while community engagement efforts led to strong participation and adoption through targeted outreach and partnerships.

Based on these results, ARROW has demonstrated that at-scale implementation is both feasible and highly beneficial. The project successfully met its core objectives and validated the integration of UAS, connectivity, and cloud-based data systems in remote and challenging environments. It is recommended that ARROW proceed to Stage 2 at-scale deployment, expanding operations statewide and further integrating these technologies into routine transportation, emergency response, and infrastructure management workflows. A projected investment of approximately \$13.9 million over three years is expected to generate substantial returns, including improved life safety outcomes, reduced operational and emergency response costs, enhanced infrastructure resiliency, and expanded workforce and economic opportunities. The ARROW model represents a scalable and repeatable framework that can be applied not only across Alaska but also in other regions facing similar geographic, environmental, and infrastructure challenges.

### 1.2 Real-World Issues and Challenges

a. **Infrastructure Monitoring:** Continuous monitoring and inspection of transportation infrastructure in remote communities, including ice roads, seasonal trails, and multimodal infrastructure and support facilities, which often lack the resources for regular maintenance or in-person documentation.

b. **Airspace Integration:** Integrating UAS into the NAS faces significant scalability roadblocks for civil operations. This project, while currently under Public Aircraft Operations, aims to develop pathways to Part 107 and Part 108 Operations for nationwide implementation. It evaluates the airworthiness and deployment of airspace monitoring and surveillance technologies, focusing on equipment hardening, command and control link reliability, and overall scalability of remotely operated systems. Leveraging remote operations where workforce and response times are limited creates economic opportunities and future integration into civil operations.



c. **Natural and Manmade Disasters:** The project focuses on implementing rapid response and assessment strategies for natural disasters such as earthquakes, floods, permafrost subsidence, and wildfires, as well as manmade incidents. These efforts aim to ensure critical infrastructure access and effective community management of vital food resources.

Additionally, the project increases data collection and live video feeds of events to state emergency operations centers and FEMA, enhancing overall disaster resilience and recovery capabilities.

d. **Public Safety:** The project enhances search and rescue operations, public safety, and access to community assistance through 911 emergency

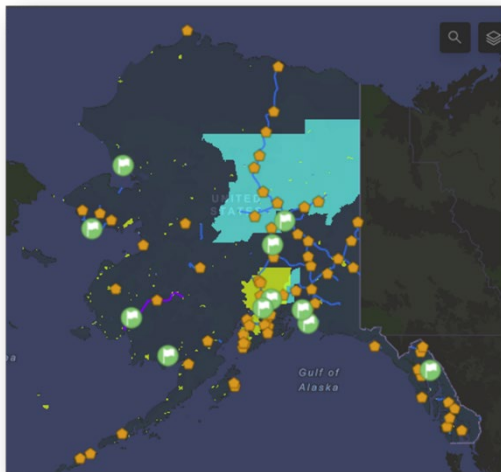


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- response, including the documentation of rural road and seasonal trail fatalities and live streaming support for Village Public Safety Officers.
- e. **Infrastructure and Environmental Monitoring:** Increasing data collection for monitoring and managing wildlife and subsistence hunting grounds, and addressing future infrastructure projects. This includes documenting infrastructure condition, erosion, surface changes, and other factors affecting transportation assets.
  - f. **Rural Workforce Development:** Augmenting rural communities with access to higher-paying jobs through union and labor training programs. The focus is on ensuring that community members remain local, are trained locally, and are employed locally. This initiative emphasizes the importance of integrating the workforce with tribal partners while combining efforts with the subsistence economy. It supports the sustainability and long-term success of technology and workforce communities.

### 1.3 Geographic Area & Jurisdiction



The ARROW project focuses on multiple regions and communities across Alaska, prioritizing remote communities based on criteria such as existing critical infrastructure, community leadership, engagement, and public safety facilities. As the largest U.S. state, Alaska spans 663,300 square miles, with 82% of its communities off the road system and accessible only by aviation or chartered vessels. This vast, challenging geography necessitates innovative transportation and communication solutions. Key Alaska DOT&PF initiatives like LEO broadband and the Statewide GNSS Network with NTRIP aim to enhance connectivity and precision guidance for autonomous systems in these remote areas, driving economic development and improving access to essential services.

### 1.4 Technologies Being Deployed

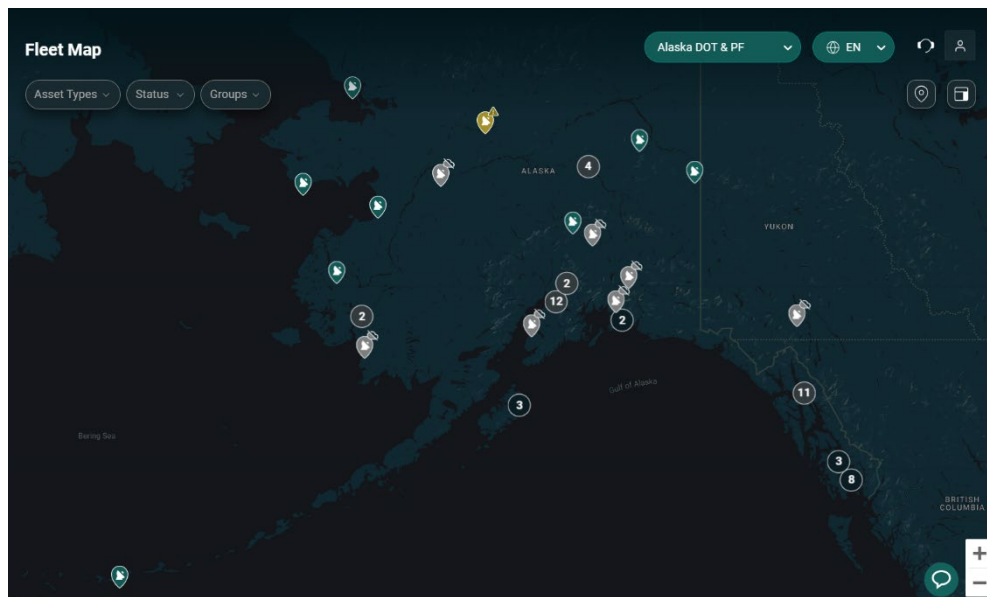
- a. **Innovative Aviation:**
  - **Skydio X10 Aircraft:** Deployment of Skydio X10 aircraft for rapid deployable uncrewed operations, including initial response, data collection, and visualization. The X10 platform provides advanced autonomous capabilities and high-resolution imaging, making it ideal for quick deployment in various scenarios such as traffic monitoring, infrastructure inspection, and emergency response.
  - **Skydio X2 Drone Dock:** Installation of Skydio X2 drone docks for long-term management of data, response, and live monitoring of deployment areas. The X2 platform supports continuous operations with automated charging and secure data transmission, enabling persistent surveillance and data collection over extended periods.



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- b. **Remote Sensing Technologies:** Implementation of Starlink communications technology across three categories to ensure connectivity in remote areas
  - **Mobile:** Hand-carried panels with battery backup for flexible and portable connectivity solutions.
  - **DOT SEF Vehicle-Mounted Panels:** Panels mounted on Department of Transportation Special Equipment Fleet (SEF) vehicles to provide robust and mobile internet access during operations.
  - **Emergency FirstNet Panels:** Enabling LTE rebroadcast for Band 14 to ensure reliable communication for emergency responders.
  - **Armada Connect:** Utilizing Armada Connect for management and reporting of panel analytics, monitoring outages, data rates, and service performance. Armada also manages VPN tunneling from IoT and UAS devices to ensure data remains secure.

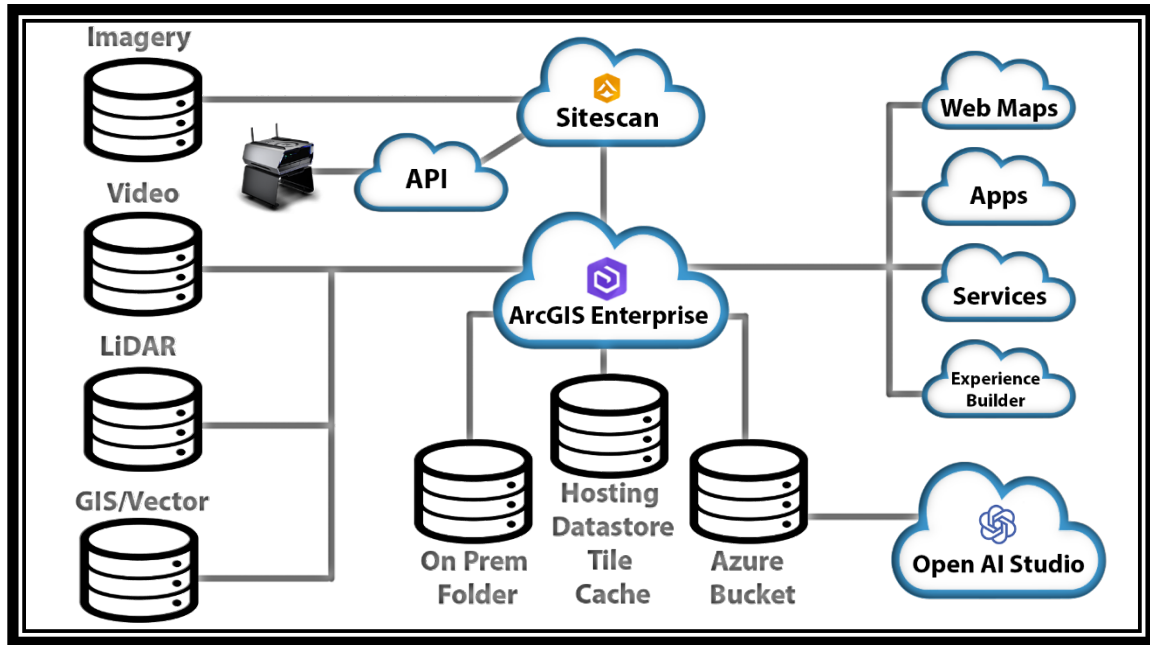


(Figure 1. Armada Connect Dashboard for management of Starlink Panels)

- c. **Systems Integration:** Developing a cohesive system that integrates various technologies for data collection, processing, and analysis, including:
  - **ArcGIS Online and Webmap Creation:** Utilizing ArcGIS Online for creating and sharing webmaps, facilitating real-time data visualization and collaboration.
  - **Esri SiteScan:** Deploying SiteScan for cloud processing and imagery management, enabling efficient offsite data processing and analysis.
  - **Image Dedicated:** Using dedicated image storage for the creation of dynamic imagery services, allowing for seamless sharing and access to data by field users.

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(Figure 2. Automated Data workflows for cloud processing and storage)

### 1.5 Goals and Desired Outcomes

The ARROW project has several key goals aligned with the SMART grant program's benefit areas:

**a. Safety and Reliability:**

- Improve the safety of rural transportation systems for seasonal trails and ice road travel for communities and the broader traveling public.
- Enhance emergency response capabilities through rapid deployment of UAS and real-time data collection.

**b. Resiliency:**

- Increase the reliability and resiliency of transportation infrastructure against natural disasters, infrastructure failures, and operational disruptions.
- Ensure cybersecurity measures are in place to protect data and systems.

**c. Access and Opportunity:**

- Expand access to advanced transportation technologies in rural communities.
- Improve access to jobs, education, and essential services by enhancing transportation infrastructure.

**d. Partnerships and Integration:**

- Foster partnerships with local governments, tribal entities, and private organizations to enhance project implementation.
- Promote integration of various transportation systems and technologies to create a seamless user experience.

### 1.6 Alignment with IJJA SMART Statutory Goals

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The ARROW project directly aligns with the statutory goals outlined in the Infrastructure Investment and Jobs Act (IIJA) SMART program by leveraging advanced data, uncrewed aircraft systems (UAS), and communications technologies to deliver measurable transportation benefits across Alaska.

- a. **Reduce Congestion and Delays (IIJA I):**  
ARROW improves situational awareness and route monitoring for seasonal trails, ice roads, and rural transportation corridors, enabling more efficient travel and reducing delays caused by unreported hazards and infrastructure issues.
- b. **Improve Safety (IIJA II):**  
The deployment of UAS enables high-frequency infrastructure inspections and real-time monitoring, improving detection of hazardous conditions and enhancing safety for the traveling public, including snowmachine, ATV, and aviation users.
- c. **Improve Access to Jobs, Education, and Services (IIJA III):**  
ARROW expands access to emergency response, infrastructure monitoring, and workforce training in remote communities that are not connected to the road system, improving access to essential services and economic opportunities.
- d. **Expand Access for Remote Communities (IIJA IV):**  
The project prioritizes rural and tribal communities, providing access to advanced technologies, training programs, and employment pathways in areas with limited access to such resources.
- e. **Support Economic Competitiveness (IIJA V):**  
By reducing infrastructure maintenance costs, enabling faster disaster response, and creating high-paying technical jobs, ARROW contributes to both regional and statewide economic growth.
- f. **Improve System Reliability (IIJA VI):**  
Continuous monitoring and repeatable data collection improve the reliability of transportation infrastructure by enabling early detection of failures and proactive maintenance planning.
- g. **Promote Connectivity Across Systems (IIJA VII):**  
ARROW integrates UAS, satellite communications (Starlink), LTE (FirstNet), and cloud-based GIS platforms to create a connected ecosystem that supports real-time data sharing between agencies and communities.
- h. **Incentivize Partnerships (IIJA VIII):**  
The project fosters strong partnerships with tribal governments, federal agencies, and private industry, including telecommunications providers and UAS manufacturers, to support scalable deployment.
- i. **Improve Energy Efficiency and Reduce Pollution (IIJA IX):**  
The use of UAS platforms reduces the need for time-intensive field deployments and improves operational efficiency during inspections, monitoring, and emergency response activities.
- j. **Increase Resiliency (IIJA X):**  
ARROW enhances transportation system resiliency by enabling rapid assessment and response to natural disasters and infrastructure failures in extreme environments.
- k. **Improve Emergency Response (IIJA XI):**  
Real-time data collection and transmission through UAS and satellite connectivity significantly improve emergency response times and coordination, particularly in remote areas where traditional response capabilities are limited.

### 1.7 Additional Information

- a. **Community Engagement:** ARROW emphasizes community involvement, providing training and resources to local residents, and ensuring the ensuring training and educational opportunities

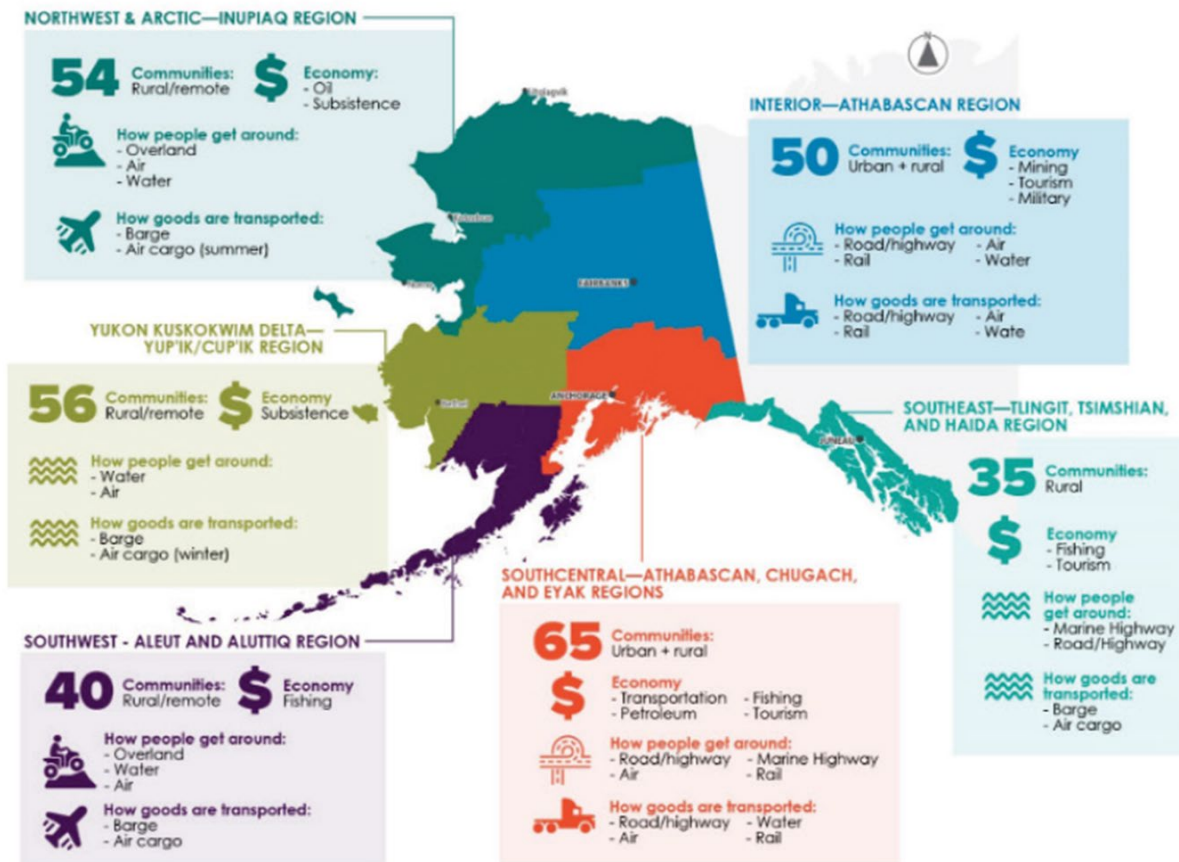
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are broadly available to participating communities in technical education and employment opportunities.

- b. Data Management:** A comprehensive data management plan has been created to ensure that all collected data is properly handled, stored, and made accessible for public use while protecting sensitive information.
- c. Evaluation and Reporting:** Regular evaluation and reporting will be conducted to assess the project's impact and effectiveness, ensuring continuous improvement and accountability.

### 1.8 Communities Impacted by At-Scale Implementation



(Figure 3. Alaska tribal and multimodal transportation planning jurisdictions)

Selected test and deployment sites include Bethel (Primary Deployment Area), Quinhagak, the Yukon-Kuskokwim Delta, Fairbanks, Mat-Su Borough, Valdez, Juneau, and Anchorage. These efforts support transportation solutions that improve safety, resiliency, infrastructure management, and community access across Alaska. These communities were chosen based on criteria such as existing critical infrastructure, strong community leadership and engagement, and the presence of public safety facilities.

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### a. Selected Test and Deployment Sites:

#### ➤ Bethel (Primary Deployment Area):

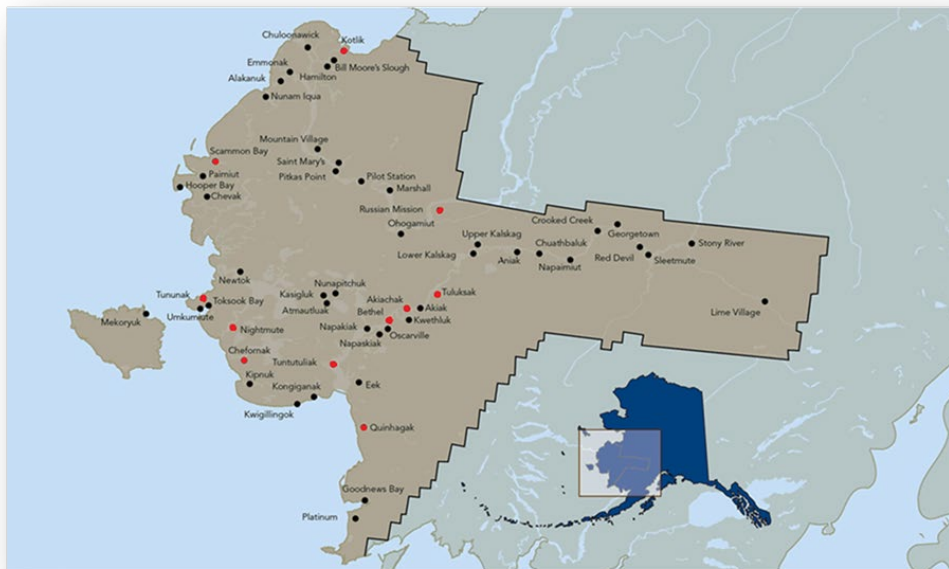
- **Population:** Approximately 6,500
- **Description:** As a major hub in western Alaska, Bethel is a key center for transportation, health care, and education for the Yukon-Kuskokwim Delta region. The community's role as a regional hub makes it an ideal primary deployment area for testing and development of new technologies and solutions.

#### ➤ Quinhagak:

- **Population:** Approximately 700
- **Description:** A small village located near the mouth of the Kuskokwim River, Quinhagak has a rich cultural heritage and strong community ties. Its remote location and transportation challenges make it a significant site for evaluating the impacts of new infrastructure and technology on isolated communities.

#### ➤ Yukon-Kuskokwim Delta:

- **Population:** Approximately 25,000 (spread across numerous small communities)
- **Description:** This expansive region, characterized by its vast wetlands and diverse wildlife, is home to many Indigenous communities. The Delta's challenging environment and scattered population centers provide a unique setting for developing sustainable solutions that can be scaled to other remote areas.



(Figure 4. Alaska Village Council Presidents (AVCP) supported communities)

#### ➤ Fairbanks:

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- **Population:** Approximately 31,500
  - **Description:** Known as the "Golden Heart City," Fairbanks is the largest city in the Interior region of Alaska. It serves as an important center for education and research, with the University of Alaska Fairbanks located here. The city's infrastructure and resources make it an ideal test site for various technological advancements.
- **Mat-Su Borough:**
- **Population:** Approximately 107,000
  - **Description:** The Matanuska-Susitna Borough, often referred to as the Mat-Su, is one of the fastest-growing regions in Alaska. Its diverse geography, ranging from the Matanuska Glacier to the Susitna River, presents a variety of deployment opportunities for enhancing connectivity and public safety.
- **Valdez:**
- **Population:** Approximately 3,900
  - **Description:** Situated on the northeastern shore of Prince William Sound, Valdez is an important port and the southern terminus of the Trans-Alaska Pipeline System. Its strategic location and critical infrastructure make it an essential site for testing and deploying new technologies.



(Figure 5. Valdez Skydio training on the X10 Platform during rainy conditions)

- **Juneau:**
- **Population:** Approximately 32,000

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- **Description:** The capital city of Alaska, Juneau is known for its stunning natural beauty and vibrant cultural scene. As the administrative center of the state, it offers a unique environment for implementing projects that require close coordination with government agencies.

➤ **Anchorage:**

- **Population:** Approximately 291,000
- **Description:** Anchorage is the largest city in Alaska and a key economic and transportation hub. Its diverse population and well-developed infrastructure make it a crucial site for testing large-scale deployments and ensuring the scalability of new solutions.

**b. Direct Benefits to Rural Communities**

The ARROW project is designed to benefit rural communities by:

- **Providing Access to Advanced Technologies:** Deploying UAS and remote sensing technologies, enhancing infrastructure monitoring and emergency response capabilities where traditional aerial means are cost prohibitive or not available.



- **Job Creation and Training:** Offering training programs and job opportunities in emerging fields with UAS including operator, remote technicians and GIS analyst utilizing existing labor and access to apprenticeship programs

- **Improved Safety and Infrastructure Management:** Reducing the risks and costs associated with infrastructure inspection and routine maintenance, thus enhancing overall safety and reliability and repair downtimes.

## 1.9 Community Stakeholder Involvement

a. Community stakeholders were meaningfully involved in the project through:

- **Engagement and Outreach:** Conducting outreach programs through training and development of multimedia videos distributed via conferences and social media proved to be the most successful distribution method for ARROW's reach. These initial concept videos brought numerous partners to light, including our tribal partner Nulaquq of Quinhagak, who was already utilizing UAS to augment their SAR teams. From the beginning, these technologies were placed in communities that had stories to tell with data. This facilitated increased adoption and integration, making the process smoother. Additionally, presentations at conferences and increased awareness through local news were beneficial for sharing information and announcing upcoming events and training opportunities. The NIITC presentation on ARROW and its connection with tribal communities garnered interest across numerous communities. Site visits involved local residents and leaders identifying areas where the technology could be utilized.

The importance of telling stories via multimedia, interviewing stakeholders and partners, and documenting how this technology is being utilized, adapted, and deployed for emergencies allows communities to thrive.

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- **Partnerships:** Collaborating with local organizations, tribal governments, and public safety offices to ensure the project meets community needs and priorities. A focus on tribal communities and deploying the capabilities for immediate response to their critical issues has opened the door for more partners wanting to deploy this technology. Training included members of the public, numerous state and federal agencies, and tribal partners, allowing for a hands-on approach to training and understanding what this technology is capable of.

None of this would be possible without the 24/7 support and dedication of industry partners, enabling beta features, and being open to trying new things. These partnerships have made ARROW possible and scalable.



(Figure 6. Bethel SMART – AVCP, Nalaquq, DOT&PF during a visit from USDOT)

### 1.10 Scale of Deployment

#### a. Stage 1 Deployment

- In Stage 1 of the ARROW project deployment, the focus was on three primary areas to ensure the project's foundation was robust and well-structured. Here's an elaboration on each focus area:
- **UAS Pilot Training and Certification**
  - **Objective:** The primary goal was to build local capacity by training and certifying pilots to operate Uncrewed Aircraft Systems (UAS).
  - **Activities:**
    - **Training Programs:** Conducted comprehensive training sessions for local pilots, covering essential aspects of UAS operation, safety protocols, and FAA regulations.
    - **Certification:** Ensured pilots obtained necessary certifications, such as the FAA Part 107 certification, which is crucial for legal and safe UAS operations.
    - **On-site Flight Training:** Practical training sessions were held to provide hands-on experience, preparing pilots for real-world applications.
- **Data Processing and Emergency Response Protocols**
  - **Objective:** To establish robust protocols for infrastructure inspections and emergency response scenarios.
  - **Activities:**
    - **Protocol Development:** Created and tested protocols for using UAS in various scenarios, including routine infrastructure inspections and emergency response situations.

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- **Data Management and Cloud Processing Framework:** Developed a comprehensive framework for managing the data collected by UAS, ensuring it is processed via Cloud services, stored, and utilized effectively.
- **Emergency Response:** Focused on integrating UAS technology into existing emergency response frameworks to enhance rapid response capabilities in critical situations.

### ➤ 3. Initial Deployments

- **Objective:** To test and validate UAS and support technologies in real-world conditions within selected communities.
- **Activities:**
  - **Community Selection:** Key communities such as Bethel were selected based on criteria like existing infrastructure, community leadership, and the presence of public safety facilities.
  - **Deployment and Testing:** UAS and related technologies were deployed in these communities for initial testing and data collection. This phase involved evaluating the operational effectiveness of UAS in real-world conditions.
  - **Community Engagement:** Engaged with local communities to ensure the deployment was aligned with their needs and to gather feedback for further refinement of the technologies and protocols. Activities in Stage 1 were crucial for laying the groundwork for more extensive deployments and implementations planned for subsequent stages of the ARROW project. By focusing on training, data management, and initial real-world testing, the project aimed to ensure a smooth and effective scale-up in future phases.



### b. Anticipated Scale of At-Scale Implementation

- At-scale implementation will expand the deployment to all targeted communities, including:
  - **Increased Number of UAS and remote Docks:** Expanding the fleet of UAS to cover more areas and conduct more frequent inspections with larger areas of interest and longer flight times

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*(Figure 7. Skydio X2 dock launching in Juneau)*

- **Broader Geographic Coverage:** Covering more remote regions, enhancing statewide infrastructure monitoring and emergency response capabilities. Scalability to other states with larger infrastructure demands will allow for nationwide adoption of findings.
- **Enhanced Integration and Surveillance:** Integrating more technologies such as connected vehicles and intelligent sensor-based infrastructure to improve data collection and system efficiency. The importance of ground based surveillance technologies is crucial for integration into the NAS, and mixing with general aviation not equipped with ADSB or transponder.

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### 1.11 Stage 1 Project Activities



(Figure 8. Bethel SMART team training on Skydio X10 platform using 3D scan)

#### a. Key Milestones Accomplished

- **Completion of Pilot Training:** Training local pilots and obtaining FAA certification for UAS operations.
  - **Objective:** Equip local pilots with the necessary skills and certifications to operate UAS.
  - **Activities:**
    - **Training Programs:** Conducted extensive training sessions focused on UAS operations, safety protocols, and emergency procedures.
    - **Certification:** Facilitated the process for pilots to obtain FAA Part 107 certification, a critical requirement for legal UAS operations.
    - **On-Site Training:** Delivered hands-on flight training to ensure pilots were proficient in real-world operations.
    - **Outcome:** Successful certification of local pilots, enhancing community capacity for UAS operations.
- **Deployment and Testing:** Initial deployment of UAS in Bethel and other communities, testing their capabilities in real-world scenarios including BVLOS Operations in TFRs.
  - **Objective:** Test the capabilities of UAS in real-world scenarios within selected communities.
  - **Activities:**
    - **Initial Deployments:** Deployed UAS in Bethel and other selected communities, focusing on infrastructure inspections and emergency response applications.

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- **Testing Scenarios:** Conducted tests in various real-world scenarios, including BVLOS (Beyond Visual Line of Sight) operations within Temporary Flight Restrictions (TFRs) and remote operations, inclement weather and connectivity reliability.
  - **Collaborations:** Worked with local authorities and community leaders to ensure deployments were effective and met community needs.
  - **Outcome:** Gathered valuable data on UAS performance in diverse conditions, providing insights for further improvements and scalability.
- **Data Management Setup:** Establishing a comprehensive data management framework to handle and utilize collected data effectively.
- **Objective:** Establish a robust framework for managing the data collected by UAS.
  - **Activities:**
    - **Framework Development:** Developed a comprehensive data management plan, detailing how data would be collected, processed, stored, and utilized.
    - **System Integration:** Integrated advanced GIS and data processing software (such as ESRI) to handle and analyze the data effectively.
    - **Standardization:** Implemented data standards and protocols to ensure consistency and accuracy in data handling.
    - **Outcome:** A fully operational data management system that enhances the project's efficiency and effectiveness in utilizing UAS-collected data.

### b. Partners Engaged



- **Alaska Department of Transportation & Public Facilities (DOT&PF)**
- **Alaska Municipal League (AML)**
- **University of Alaska Fairbanks/Alaska Center for Unmanned Systems Integration (UAF/ACUASI)**
- **Federal Aviation Administration (FAA)**
- **Association of Village Council Presidents (AVCP) Local tribal governments and public safety offices**

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- **National Oceanic and Atmospheric Administration (NOAA)**
- **Nalaquq and the community of Quinhagak**
- **Yuut Elitnaurviat the community of Bethel**
- **Department of Public Safety (DPS)**
- **Division of Natural Resources (DNR)**
- **Anchorage Police Department (APD)**
- **Department of Labor**
- **Starlink**
- **Armada**
- **Skydio**
- **AT&T FirstNet**
- **Collins Aerospace**
- **Valdez Police Department**
- **Alaska American Federation of Labor and Congress of Industrial Organizations (AFL-CIO)**
- **ESRI**
- **International Brotherhood of Electrical Workers (IBEW) Local 1547**
- **Alcan Electric**

### c. Outcomes Described

- The ARROW project has significantly advanced community engagement and infrastructure monitoring through the strategic deployment of Unmanned Aerial Systems (UAS) technology. Community engagement was enhanced by organizing fairs, training programs, and outreach activities that fostered local participation and trust. These activities included community fairs to showcase UAS technology, extensive training sessions on UAS operations, and safety protocols, which equipped participants with essential skills. Collaborations with local authorities, tribal governments, and public safety offices ensured that outreach activities were well-received and aligned with community needs.
- The project also facilitated FAA Part 107 certification for local pilots through rigorous training and examinations, preparing them for legal and practical UAS operations. On-site hands-on flight training ensured proficiency, building local pilots' confidence and competence. These efforts led to increased community capacity to operate UAS, fostering greater local ownership and enthusiasm for the ARROW project. Strong relationships between the project team and local populations were established, essential for the project's ongoing success and sustainability.
- The ARROW project demonstrated the value of UAS in infrastructure inspections and emergency responses, particularly in remote and rural areas. Initial deployments in Bethel and other communities focused on infrastructure inspections and emergency

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response applications, including Beyond Visual Line of Sight (BVLOS) operations within Temporary Flight Restrictions (TFRs). A robust data management framework incorporating advanced GIS and data processing software ensured efficient data handling and utilization, supporting better decision-making for infrastructure maintenance and emergency response. Collaborations with local and state authorities, such as the Alaska Department of Transportation & Public Facilities (DOT&PF) and the University of Alaska Fairbanks/Alaska Center for Unmanned Systems Integration (UAF/ACUASI), were pivotal for successful UAS deployment.

### d. Attention and Publications

The ARROW project has gained attention through:

- **Media Stories:** Various local news outlets have covered the project's progress and its impact on the communities.
- **Multi-Media And Social Media:**
  - [ARROW Program Overview \(arcgis.com\)](#)
  - [ARROW Program Outreach Video \(dropbox\)](#)
  - [ARROW Bethel Team Spotlight \(youtube\)](#)
  - [ARROW Nalaquq Team Spotlight \(youtube\)](#)



(Figure 9. DOT&PF showcasing remotely operated Drone Docks and Aircraft via laptop)

- **Press Releases:**
  - [May 1<sup>st</sup> 2023 - Alaska DOT&PF launches ARROW drone program to assist communities during emergencies- State Of Alaska](#)

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- **June 28<sup>th</sup> 2023** - [The ARROW Program: Drones Add New Tool to State Emergency Response Quiver - Alaska Business Magazine \(akbizmag.com\)](#)
- **July 7<sup>th</sup> 2023** - [Alaska DOT&PF Deploys Drones for Rural Emergency Use - AASHTO](#)
- **April 29<sup>th</sup> 2024** [Drone program takes off in Bethel with first round of federal funding \(kyuk.org\)](#)
- **July 11<sup>th</sup> 2024** [Alaska leads the nation in drone innovation, wants to use it to save more lives - Juneau Empire](#)
- **Conference Presentations:** The ARROW project and its data has been presented at numerous conference and numerous Peer Exchanges, and industry gathers highlighting its innovations and not just community, but nationwide impacts.
  - **NTICC – National Tribal in Indian Country Conference - Anchorage**
  - **ESRI UC 2023 - SanDiego**
  - **Global Autonomous Conference 2023 – Anchorage**
  - **IHEEP 2023 (with Caltrans) - Salt Lake City**
  - **AUVSI 2024 – SanDiego**
  - **FHWA Advance UAS Operations Peer Exchange – Juneau**
  - **ESRI UC 2024 - SanDiego**
  - **Global Autonomous Conference 2024 – Anchorage**
- **Publications:** Information about the project, including data and best practices, has been published in technical reports and shared during webinars.
  - **Skydio Webinar – Infrastructure inspection**
  - **SMART GRANT PP Slide deck**

### e. Major Deviations or Changes

There have been no significant deviations from the original proposal. The project remains on track, with all key milestones being achieved as planned. Any minor adjustments have been made to enhance project efficiency and effectiveness based on feedback from initial deployments and community engagement activities.

### f. Emphasis on Learning from Multiple Communities

Numerous communities were selected to ensure a comprehensive understanding of both the successes and challenges associated with each deployment. This approach allows the project team to gather valuable insights from a diverse range of environments, including road system, rural, and ultra-rural communities. By analyzing the outcomes in these varied settings, the project aims to develop scalable solutions that can be successfully implemented across different types of communities. This methodical approach ensures that the technologies and protocols developed are robust, adaptable, and capable of meeting the unique needs of each community type, thereby achieving successful scalability.

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## Proof-of-Concept or Prototype Evaluation Findings

### 2.1 Overview

The Alaska Rural Remote Operator Workplan (ARROW) project aimed to deploy uncrewed aircraft systems (UAS) and remote sensing technologies across various communities in Alaska. The proof-of-concept for Stage 1 focused on establishing the feasibility and operational effectiveness of these technologies in real-world scenarios. This report section evaluates the findings from the proof-of-concept deployment based on the performance metrics established in the Evaluation Plan.



*(Figure 10. Imagery documentation and monitoring of coastal erosion)*

### 2.2 Performance Metrics

In the Evaluation Plan, the following performance metrics were identified to assess the proof-of-concept:

- a. **Operational Readiness and Deployment Time:** The time required to deploy UAS and set up remote sensing operations.
- b. **Data Accuracy and Reliability:** The precision and consistency of data collected by UAS and remote sensing technologies.
- c. **Community Engagement and Training Success:** The extent of local community participation and successful completion of training programs.
- d. **Infrastructure Monitoring Effectiveness:** The ability of UAS to monitor and inspect critical infrastructure effectively.
- e. **Emergency Response Enhancement:** Improvement in response times and effectiveness in natural and manmade disaster scenarios.

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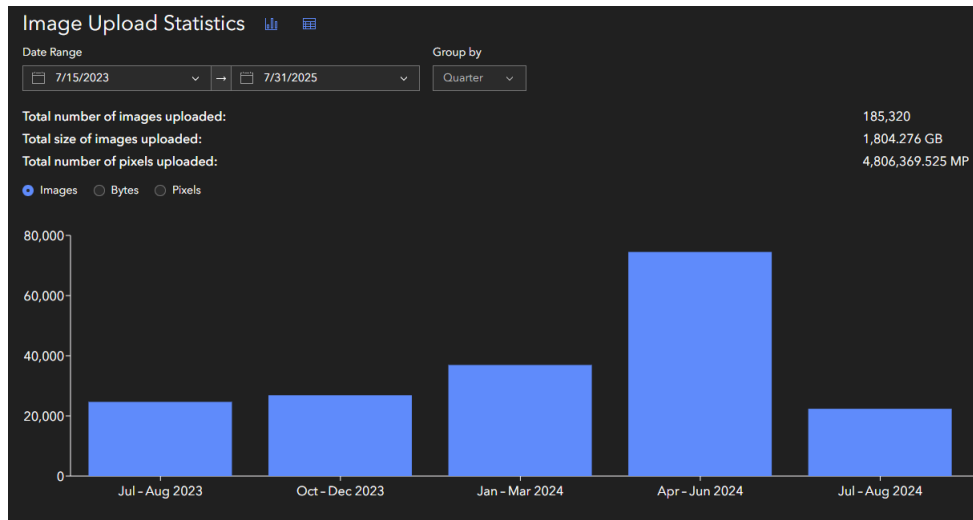
## STRENGTHENING MOBILITY AND REVOLUTIONIZING TRANSPORTATION (SMART) GRANT PROGRAM

- f. **Connectivity through Starlink:** Evaluation of Starlink satellite internet for providing connectivity in rural locations not served by other means of communication.
- g. **Cloud Processing with ESRI SiteScan:** Utilization of ESRI SiteScan for off-site data processing to increase access to external agency assistance and enhance situational awareness.
- h. **Rural Workforce Development and Job Creation:** Development of a rural workforce and creation of new high-paying jobs in partnership with AFL-CIO and IBEW.

### 2.3 Data Collected

During the Stage 1 deployment, data was collected from various sources including:

- Aircraft Deployment logs and flight telemetry
- Accuracy and reliability assessment reports of collected data
- Training completion records and feedback from community participants
- Inspection reports and monitoring data from infrastructure assessments
- Response logs from emergency scenarios where UAS were utilized
- Connectivity performance metrics from Starlink satellite internet deployments
- Cloud processing performance metrics and external agency feedback on ESRI SiteScan usage
- Pilot and Employment records and workforce development metrics



(Figure 11. ARROW cloud processing and storage utilization)

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### 2.4 Findings

#### 1. Operational Readiness and Deployment Time

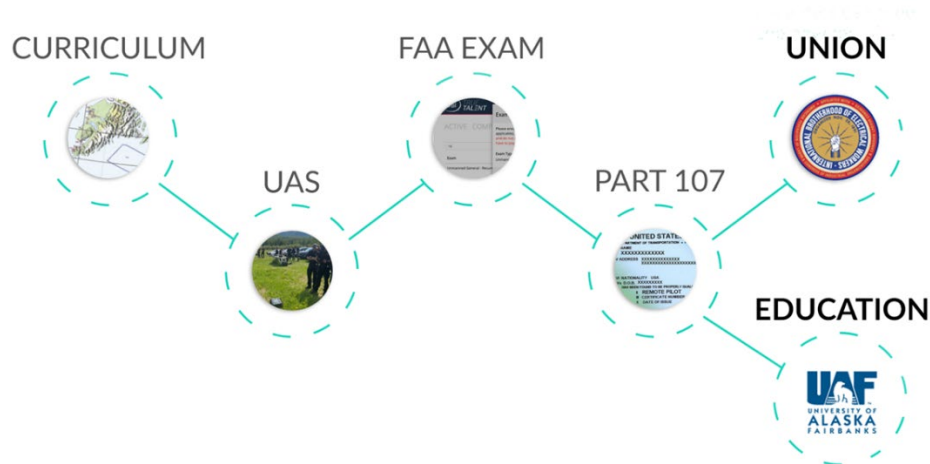
- Average deployment time for UAS was recorded at 30 minutes, with an initial setup phase taking approximately 2 hours. This includes the setup of Skydio aircraft mapping parameters and Starlink mobile packs, as well as Esri Sitedscan mission setup with ESRI tools for Cloud processing.
- Feedback from BETA users highlighted the efficiency of the deployment process, indicating that the setup procedures were well-documented and easy to follow.

#### 2. Data Accuracy and Reliability

- Data collected by the UAS demonstrated high accuracy, with less than a +/- 3% deviation from scale constraints and ground truth measurements. The reliability of CORS data and the large variance in weather conditions was also validated, ensuring robustness of the technology throughout Alaska.
- The comprehensive data management framework established aligns with the Data Management and Evaluation Plan, ensuring that data workflows are efficient and effectively managed.

#### 3. Community Engagement and Training Success

- Local community members completed Part 107 training and received FAA certification. On-site flight training further empowered participants with practical skills to operate UAS independently.



(Figure 12. ARROW workforce development training pathway)

- Engagement initiatives, including media content and tutorials, and support, training received positive feedback, enhancing the educational resources available to community members.

#### 4. Infrastructure Monitoring Effectiveness

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- UAS successfully conducted inspections of critical infrastructure, including bridges and transportation routes and most recently responding to wildfires. The ability to capture high-resolution imagery and real-time data found numerous maintenance items.
- Digital Documentation indicate a significant improvement in the frequency, quality and repeatability of infrastructure monitoring, directly contributing to the safety and reliability of transportation networks.

### 5. **Emergency Response Enhancement**

- UAS deployment in response to natural disasters, such as flooding, landslide and wildfires demonstrated a reduced response timelines from hours or days required for traditional reporting in remote locations to near real-time data availability (minutes to hours), and in some places offering a response that up until now hasn't been available. The real-time data provided by UAS enabled more efficient coordination of rescue and relief efforts.
- The collaboration with the Alaska Village Council Presidents (AVCP) leveraged their network to enhance UAS technology deployment, proving critical in emergency response to Bethel flooding. AVCP was able to share Realtime information with state of Alaska prompting a state disaster declaration. This otherwise would have taken days for the information to get to authorities.

### 6. **Connectivity through Starlink**

- Starlink satellite internet has been the backbone of making this program successful. Starlink mobile Backpacks and Vehicle mounted panels have been deployed in rural locations where traditional means of communication are unavailable. The setup involves a Starlink mobile pack with battery backup allowing for 6-8 hours of connectivity.
- Performance metrics indicated an average latency of 20-40 milliseconds and download speeds ranging from 50-150 Mbps. These speeds were sufficient to support UAS operations, real-time data transmission, and communication needs throughout Alaska.
- The reliability of Starlink was tested under various weather conditions, and it maintained stable connections with minimal downtime, ensuring continuous operational capabilities. The only limitation discovered was torrential downpour limiting connectivity speeds by an average of 30%.
- Feedback from local communities and operators indicated that Starlink significantly improved their ability to communicate and coordinate, especially during emergency response situations where traditional communication networks were non-existent or unreliable.

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(Figure 13. Skydio X10 live streaming via Starlink)

### 7. Cloud Processing with ESRI SiteScan

- The use of ESRI SiteScan for cloud processing enabled off-site data processing, which was crucial for enhancing access to external agency assistance and improving situational awareness, while minimizing significant implementation costs of local machines, software and 1 to 1 deployment of UA and processing technology license management.
- SiteScan allowed for the seamless integration and automation of collected UAS scan data into cloud-based GIS systems, facilitating real-time, repeatable data analysis and sharing with relevant stakeholders.
- External agencies, including the Alaska Department of Transportation and Public Facilities (DOT&PF) and State Emergency Operations Center (SEOC) other local government bodies, reported improved decision-making capabilities due to the increased availability and accessibility of processed and live stream data.
- The cloud processing capabilities of SiteScan significantly reduced processing loads and data transfer on state network and the time required for data analysis, enabling quicker responses to infrastructure issues and emergency situations.
- Cloud-based processing reduced data turnaround times from days to hours, enabling faster decision-making and response coordination.

### 8. Rural Workforce Development and Job Creation

- The ARROW project, in partnership with AFL-CIO and IBEW, focused on developing a rural workforce and creating high-paying jobs. This effort has led to the creation of a new technician classification for remote pilots.
- Two remote pilots have been successfully hired for the communities of Bethel and Quinhagak, highlighting the project's commitment to local employment and skills development.
- Training programs and certifications have been instrumental in equipping local residents with the necessary skills to operate UAS, fostering career growth and enhancing local expertise.
- The creation of these jobs not only supports the local economy but also ensures that communities have the technical capabilities to leverage advanced UAS

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technologies for various applications, including infrastructure monitoring and emergency response.

### 2.5 Meeting Original Expectations

The ARROW project demonstrated measurable improvements across the IJA SMART statutory goal areas, including safety, resiliency, access, connectivity, and emergency response, as outlined below. The proof-of-concept deployment of ARROW has largely met the original expectations stated in the project proposal. The primary goals included enhancing transportation safety and efficiency through innovative aviation technologies, supporting infrastructure inspections, improving emergency response capabilities, providing connectivity in remote areas, utilizing advanced data processing techniques, and fostering rural workforce development. The findings from Stage 1 indicate substantial progress in these areas:

- a. **Safety and Reliability:** UAS deployments have enhanced the monitoring of critical infrastructure and improved emergency response times, directly contributing to transportation safety and reliability.
- b. **Resiliency:** The project's ability to operate effectively in various weather conditions underscores the resiliency of the deployed technologies.
- c. **Access and Opportunity:** Engaging rural communities and providing them with training opportunities has fostered greater access to advanced technologies.
- d. **Connectivity:** The deployment of Starlink satellite internet in remote locations has addressed a critical gap in communication infrastructure, enabling better coordination and operational efficiency.
- e. **Data Processing and Situational Awareness:** The integration of ESRI SiteScan for cloud processing has improved data accessibility and external agency collaboration, enhancing overall situational awareness and decision-making processes.
- f. **Workforce Development and Job Creation:** The partnership with AFL-CIO and IBEW has successfully created new high-paying jobs and developed a skilled rural workforce, supporting the local economy and technical capabilities.

### 2.6 Data Limitations

While the data collected provided valuable insights, certain limitations were noted:

- **Geographic and Climatic Variability:** The diverse and extreme weather conditions in different parts of Alaska sometimes posed challenges to UAS operations, potentially impacting data consistency.
- **Community Engagement:** While significant progress was made, ongoing efforts are needed to ensure sustained engagement and participation from all targeted communities.

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*(Figure 14. Traffic Monitoring out of Bethel on the Kuskokwim Ice Road)*

The proof-of-concept deployment of ARROW during Stage 1 has demonstrated promising results, meeting key project goals and setting a strong foundation for at-scale implementation. Continuous refinement based on the evaluation findings will further enhance the project's effectiveness and impact.

## At-Scale Implementation Expectations

### 3.1 Anticipated Impacts of At-Scale Implementation for Each Key Goal Area

#### 1. Safety and Reliability:

- **Qualitative Description:** The at-scale implementation of ARROW will enhance the safety and reliability of transportation systems in rural and remote communities. By deploying UAS for continuous infrastructure monitoring and emergency response, ARROW will augment the current routine inspection and maintenance processes. This improvement will enable timely and sometimes early detection of critical infrastructure anomalies from road damage, bridge deterioration, and environmental impacts like earthquakes, erosion and subsidence. Enhanced traffic monitoring capabilities for transportation networks and seasonal trails will lead to better traffic management, reducing the risk of accidents and improving overall safety for ice-road travelers, snowmobile and four-wheeler users, and the broader traveling public both land and air.
- **Expected Impacts:**
  - Reduced infrastructure maintenance issues by detecting anomalies or critical item before they become a hazard and improved safety metrics for rural transportation systems.

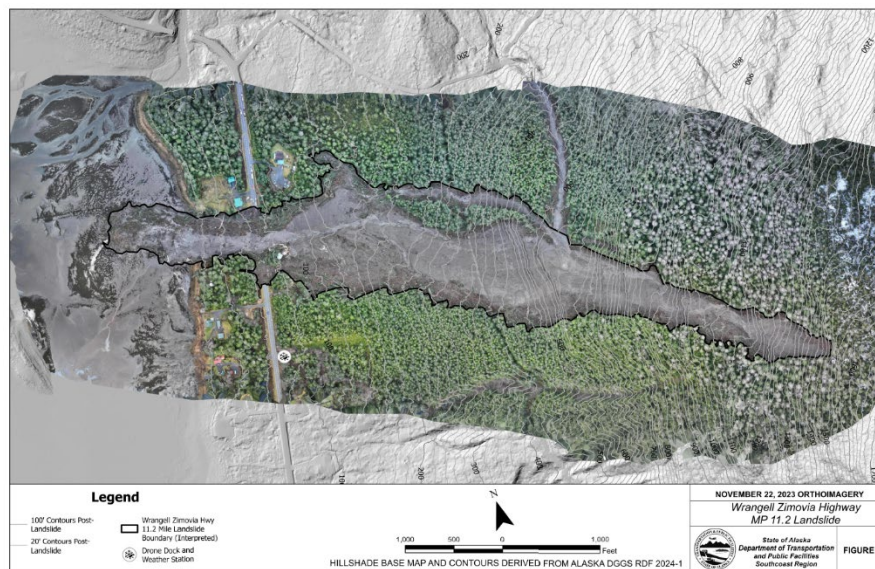
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- Documentation of rural fatality data on documented seasonal trails for updating national FARS data.
- Faster emergency response times and better situational awareness due to real-time data collection and rapid deployment with UAS.
- Enhanced monitoring and maintenance of critical infrastructure, leading to increased reliability and safety.

### 2. Resiliency:

- **Qualitative Description:** ARROW's deployment of UAS and remote sensing technologies will significantly increase the resiliency of Alaska's transportation infrastructure. These technologies will provide critical data for monitoring and responding to natural disasters such as earthquakes, floods, erosion, and severe weather events. The integration of robust data management and cybersecurity measures will further ensure the resilience of the system against cyber threats and environmental impacts.



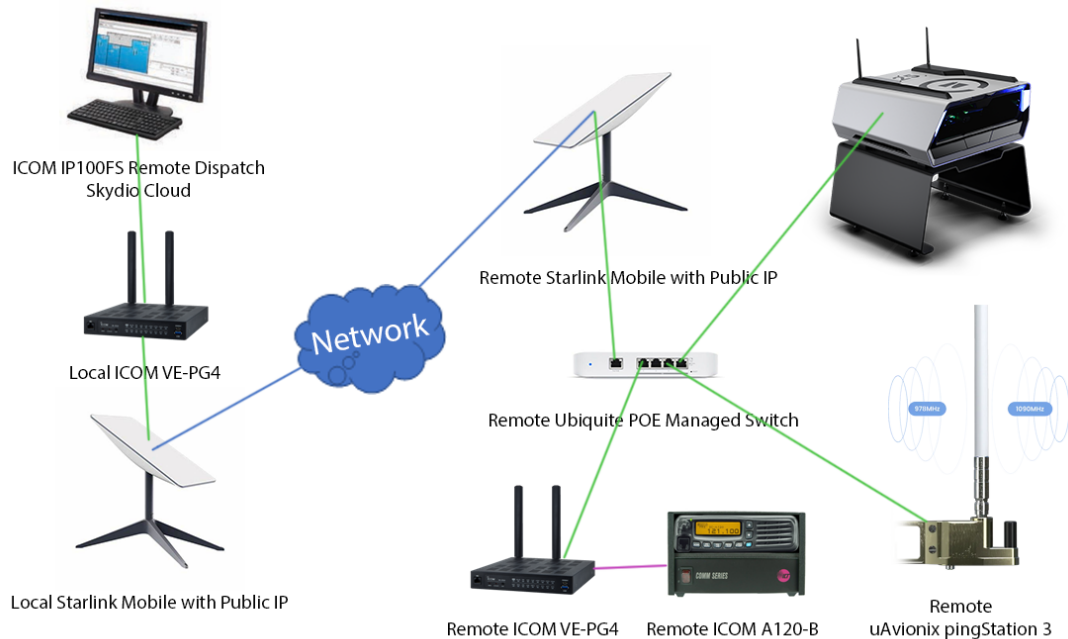
(Figure 15. Wrangell Landslide stability assessment created using ARROW Data workflows)

Additionally, this technology is designed to work in offline modes if communication to the cloud fails, allowing for multi-use based response scenarios. On top of using Starlink, the UAS are equipped with LTE FirstNet SIMs, enabling a secondary level of failure for command and control and data transfer. The aircraft are also equipped with onboard GPUs to allow for model processing onboard if cloud processing is not enabled. UAS remote operations will be managed via VPN tunneling to a secure edge facility, validating communications and data leaving out, thus securing IoT devices. The edge processing facility will enable immediate response to outages, security, or

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communications threats by eliminating single points of failure within the technology workflows. All data is protected within Esri's cloud enterprise and Azure's dedicated and secure environment. This comprehensive approach will enhance the ability to detect, assess, and mitigate risks, ultimately improving the overall safety and reliability of the transportation network.



(Figure 16. ROIP and data configuration for Skydio Dock installation)

- **Expected Impacts:**

- Improved infrastructure resilience to natural disasters and environmental impacts.
- Enhanced data security and protection measures within Esri's cloud enterprise and Azure's dedicated and secure environment.
- Increased reliability of transportation systems through the integration of UAS and remote sensing technologies, reducing downtime and enhancing service continuity.
- Immediate response capabilities to outages, security, or communications threats via the edge processing facility, eliminating single points of failure within technology workflows.
- Augmented inspection and maintenance processes, allowing for timely and early detection of infrastructure anomalies such as road damage, bridge deterioration, and erosion.

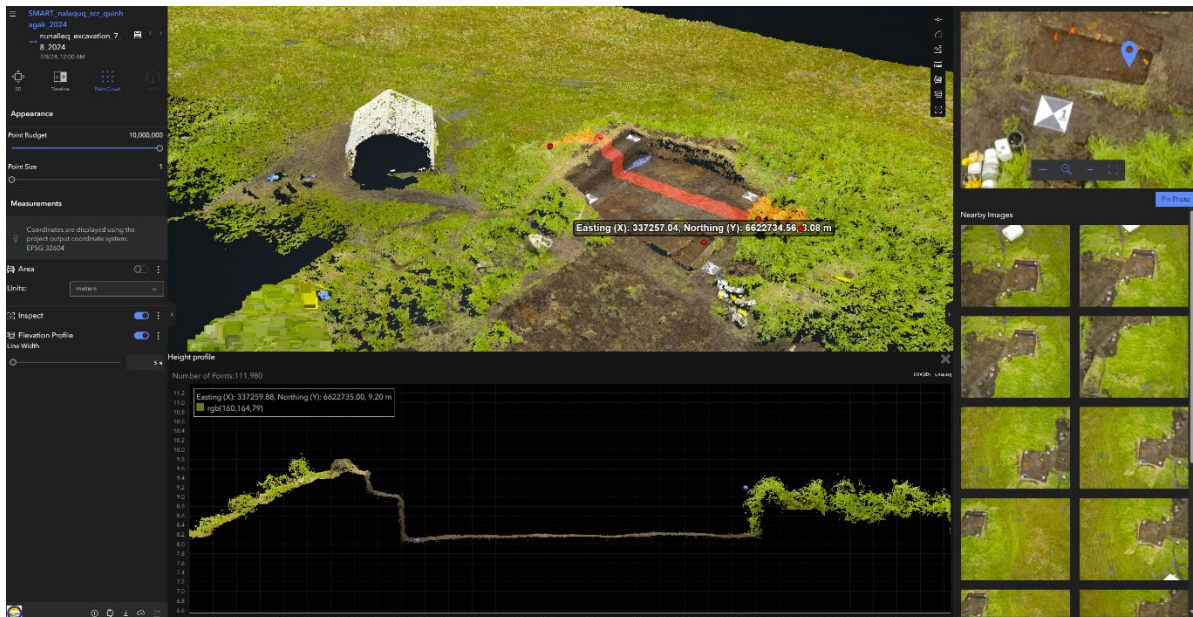
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- Improved traffic management and safety for travelers through enhanced monitoring capabilities.
- Secure management of UAS remote operations via VPN tunneling to a secure edge facility, ensuring the validation of communications and data security.
- Robust offline operational capabilities and redundancy with the use of Starlink, LTE FirstNet SIMs, and onboard GPUs for model processing, ensuring continuous operation even without cloud connectivity.
- Enhanced data security and protection measures.
- Increased reliability of transportation systems, reducing downtime and enhancing service continuity.

### 3. Access and Opportunity:

- **Qualitative Description:** The ARROW project aims to bridge the technology gap in rural communities by providing access to advanced UAS technologies and remote sensing data. This will improve infrastructure, enhance safety, and provide new opportunities for job creation and education in these regions. By focusing on access, ARROW ensures that these communities receive the benefits of modern transportation technologies and improved connectivity. Additionally, this technology brings the community to the table in transportation planning, ensuring their needs are adequately documented and visualized. Documentation of issues or highlighting successful projects is a crucial part of managing rural infrastructure.



(Figure 17. Nulaquq archaeological excavation documentation of cultural sensitive lands using ARROW processing workflows)

- **Expected Impacts:**

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- Expanded access to advanced transportation technologies for rural and remote populations.
- Improved access to essential services, jobs, and education through better infrastructure.
- Creation of job opportunities and technical training programs for local residents.
- Enhanced community involvement in transportation planning, ensuring their needs are adequately documented and visualized.
- Improved documentation of issues and successful projects, contributing to more effective management of rural infrastructure.

### 4. Operational Efficiency and Environmental Monitoring:

- **Qualitative Description:** ARROW improves transportation system efficiency through the use of uncrewed aircraft systems (UAS), remote sensing technologies, and advanced communications infrastructure. These capabilities enhance transportation monitoring, infrastructure inspections, and emergency response activities while reducing the need for time-intensive field deployments. Increased access to real-time information supports better decision-making, improved situational awareness, and more efficient use of personnel and equipment resources.

The project facilitates the collection and analysis of environmental and infrastructure data, supporting the monitoring of erosion, flooding, subsidence, landslides, severe weather events, and other conditions that may affect transportation assets and community access. Given the rapidly changing conditions across Alaska, consistent and repeatable documentation provides valuable information for infrastructure planning, maintenance, emergency preparedness, and long-term transportation system management.

The utilization of solar charging, battery backup systems, satellite communications, and redundant power solutions enhances operational reliability for remotely deployed systems. These technologies improve system availability, reduce maintenance requirements, and support continuous operations in areas with limited infrastructure, contributing to the overall resiliency and effectiveness of transportation monitoring and emergency response operations.

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(Figure 18. Skydio X2 Dock testing site battery backup configurations)

- **Expected Impacts:**

- Improved operational efficiency for transportation inspections, monitoring, and emergency response activities.
- Enhanced transportation system awareness through increased collection of infrastructure and environmental data.
- Improved documentation of erosion, flooding, subsidence, landslides, severe weather events, and other conditions affecting transportation assets.
- Increased reliability of remotely deployed systems through solar charging, battery backup, and redundant communications capabilities.
- Faster identification of infrastructure issues through repeatable monitoring and data collection.
- Improved transportation planning, maintenance prioritization, and emergency preparedness through access to current and historical data.
- Enhanced situational awareness for transportation agencies, emergency managers, and partner organizations.

### 5. Partnerships:

- **Qualitative Description:** ARROW will foster strong partnerships between local governments, tribal entities, and private organizations. These partnerships will be crucial for the successful implementation and sustainability of the project. By involving various stakeholders, ARROW will promote economic competitiveness and incentivize private sector investments, ensuring committed leadership and capacity from all partners.

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- **Expected Impacts:**

- Strengthened collaborations and partnerships with local, state, and private entities.
- Increased economic competitiveness and private sector investment in transportation technologies.
- Demonstrated leadership and commitment from all stakeholders.

### 6. Integration:

- **Qualitative Description:** ARROW has developed robust collaborations between local governments, tribal entities, private organizations, future workforce, and contractors. These partnerships are vital for the project's success and longevity. By engaging diverse stakeholders, including the communities and the future workforce, ARROW aims to enhance economic competitiveness and encourage private sector investments. This approach will ensure dedicated leadership and capacity from all involved parties.



*(Figure 19. Valdez police Department inspecting aircraft weather-resistance, after successful flight in rain)*

Empowering tribal communities by providing the institutional knowledge and support for long-term planning and implementation is central to ARROW's mission. This empowerment lays the digital foundation for the safe integration and normalization of operations currently considered advanced. By involving contractors who will deploy and manage these technologies as business and commercial endeavors, ARROW ensures sustainable and effective implementation, promoting economic growth and technological advancement.

The direct connection between federal, state, and tribal agencies and remote communities is crucial for addressing and updating federal regulations that have the potential to impact the way of life for all. By fostering these connections, ARROW will

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tackle regulatory challenges collaboratively, ensuring that the needs and perspectives of remote communities are represented and considered in the broader regulatory landscape.



(Figure 20. Skydio X10 hand-launch training with AVCP)

- **Expected Impacts:**

- **Enhanced Integration of Transportation Systems:** Improved efficiency and connectivity across transportation networks, facilitating seamless operations and services.
- **Better Coordination Between Stakeholders:** Strengthened collaboration among federal, state, tribal agencies, and remote communities, leading to more informed and effective decision-making.
- **Empowerment of Tribal Communities:** Providing institutional knowledge and support for long-term planning and implementation, establishing a digital foundation for advanced operations.
- **Economic Competitiveness and Private Sector Investment:** Encouragement of private sector involvement, ensuring sustained economic growth and technological advancement.
- **Sustainable Technology Deployment:** Involvement of future workforce and contractors in deploying and managing technologies as business and commercial endeavors.
- **Addressing and Updating Federal Regulations:** Direct connections with remote communities and agencies to collaboratively tackle regulatory challenges, ensuring that regulations support the well-being and way of life for all communities.

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- **Increased Utilization of Shared Data:** Enhanced data sharing for comprehensive transportation planning and management, leading to more effective and efficient use of resources.

#### 7. Workforce Development:

- **Qualitative Description:** ARROW will promote workforce development by providing technical training and education programs in UAS operations and data analysis. This initiative aims to create new career pathways and job opportunities for residents in remote communities, fostering local economic growth and enhancing technical expertise.

Partnering with the AFL-CIO and local labor organizations to increase access to apprenticeship programs is crucial for connecting individuals to high-paying jobs. This partnership will ensure that the training programs are aligned with industry standards and provide pathways to gainful employment.



*(Figure 21. Site Scan and Skydio X10 demonstration processing imagery in the field )*

Additionally, this effort requires a delicate focus and integration to adapt to a subsistence economy, which is not well documented. By understanding and incorporating the unique economic dynamics of remote communities, ARROW can better tailor its programs to meet the specific needs and circumstances of the residents, ensuring the sustainability and effectiveness of workforce development efforts. Through these targeted training programs and strategic partnerships, ARROW will equip individuals with the necessary skills to operate UAS and analyze data, opening up opportunities in various sectors such as infrastructure inspection, environmental monitoring, and disaster response. This focus on workforce

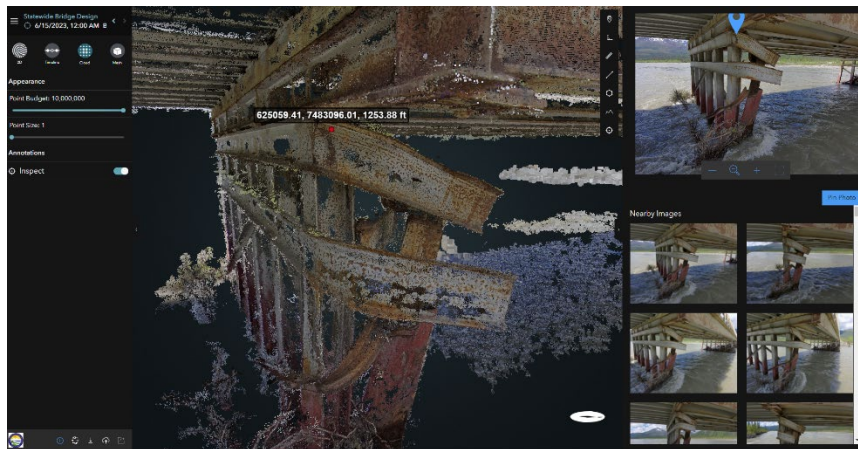
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development will not only support individual career advancement but also contribute to the overall economic resilience and sustainability of remote communities.

- **Expected Impacts:**

- Development of a skilled workforce in rural communities through targeted training and education programs in UAS operations and data analysis.
- Creation of high-paying jobs and career opportunities in emerging technology fields, facilitated by partnerships with AFL-CIO and local labor organizations to increase access to apprenticeship programs.
- Increased local expertise and technical capacity in UAS operations and data management, supported by programs that are carefully integrated to adapt to the unique dynamics of a subsistence economy.
- Enhanced local economic growth and sustainability, driven by new career pathways and job opportunities tailored to the specific needs of remote communities.



(Figure 22. Site Scan cloud tools visualizing damaged bridge scan from ice impact flown remotely)

- Strengthened economic resilience and sustainability of remote communities through the development of skills that support various sectors such as infrastructure inspection, environmental monitoring, and disaster response.

### 3.2 Estimated Costs and Benefits of At-Scale Implementation

#### 1. Estimated Costs:

##### **Proof-of-Concept or Prototype Costs:**

The total cost for the proof-of-concept stage was \$1,944,563. This covered several categories:

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- **Personnel:** \$496,125 for staff including remote pilots, planners, GIS specialists, IT staff, tribal liaisons, and infrastructure engineers, assuming a blended rate of \$135 per hour over 3,675 hours.
- **Fringe Benefits:** \$172,823, calculated at \$35 per hour for benefits such as health insurance and workers' compensation.
- **Travel:** \$159,000, allocated for community meetings, special events, and travel stipends for community pilots, which included airfare, hotel, and per diem costs.
- **Equipment:** \$822,892, covering costs for unmanned aircraft, laptops, tablets, internet connectivity, GIS & processing software.
- **Supplies:** \$21,000, including language translation services, paper survey mailing, and miscellaneous field and office supplies.
- **Contractual Services:** \$145,000, including partnerships and local community liaisons, as well as exam proctors for FAA certification.
- **Indirect Charges:** \$127,723 for covering indirect costs associated with sub-recipients and potential consultants.

### 2. Anticipated At-Scale Implementation Costs:

At-scale implementation is projected to cost approximately \$13.9 million over three years. This projection includes the following components:

- **Expanded Deployment:** Additional UAS units to cover multiple regions, requiring more unmanned aircraft systems and associated support technology.
  - Unmanned Aircraft: Expansion from the initial 22 to potentially 100 units to cover broader geographic areas.
  - Support Equipment: Increased number of laptops, tablets, and internet connectivity solutions.
- **Extended Training Programs:** Comprehensive training for new UAS operators and ongoing training for existing operators, including:
  - Initial and recurrent training sessions.
  - Specialized training for advanced operations and emergency response.
  - Online and in-person training modules.
- **Broader Data Management Infrastructure:** Enhanced systems for managing the influx of data from expanded UAS operations, including:
  - Upgraded servers and cloud storage solutions to handle large datasets.
  - Advanced GIS software licenses for more detailed spatial analysis and data integration.
  - Enhanced cybersecurity measures to protect sensitive data.

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*(Figure 23. Skydio X10 documentation corrosion changes during routine inspection )*

- **Cloud Storage Fees:** Increased capacity and usage fees for storing and managing data on cloud platforms.
- **Ongoing Maintenance and Operational Expenses:** Regular maintenance of UAS units, software updates, and operational costs such as:
  - Routine servicing and repairs for UAS units.
  - Software license renewals and upgrades.
  - Operational costs related to field deployments, including transportation and accommodation for personnel.

### **3. Scalability Considerations:**

- **Geographic Coverage:** Expansion to cover additional remote and rural areas, increasing the network's reach and impact.
- **Stakeholder Engagement:** Involvement of more local communities, tribal governments, and partner organizations to ensure comprehensive coverage and support.
- **Technology Integration:** Adoption of advanced UAS technologies and sensors to enhance data collection and analysis capabilities.
- **Economic Impact:** Creation of new job opportunities and training programs to support the local workforce, contributing to economic growth in remote areas.

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- **Infrastructure and Safety Benefits:** Improved disaster response, infrastructure monitoring, and environmental conservation through enhanced data and operational capabilities.

### 2. Cost-Benefit Comparison:

- The expected benefits of the ARROW project include enhanced safety, improved infrastructure resiliency, increased accessibility, and operational benefits. These benefits are anticipated to exceed the operational and deployment costs. The reduction in emergency response times, maintenance costs, and the creation of new job opportunities are significant factors that contribute to a positive cost-benefit ratio. Long-term savings from proactive infrastructure management and disaster response efficiency will further justify the investment.

ARROW is expected to deliver substantial benefits that outweigh the operational and deployment costs. Here is a detailed breakdown of the anticipated benefits, along with estimated costs and savings for each subject:

#### a. Enhanced Safety:

- **Reduction in Emergency Response Times:**
  - **Estimated Cost:** \$1.5 million annually for deploying and maintaining UAS units for emergency response.
  - **Estimated Savings:** \$3 million annually by reducing the severity and impact of emergencies through faster response times, potentially saving lives and reducing healthcare costs.
- **Increased Situational Awareness:**
  - **Estimated Cost:** \$500,000 annually for real-time aerial surveillance and data processing.
  - **Estimated Savings:** \$1 million annually by improving decision-making and coordination during emergencies, reducing resource wastage.
- **Search and Rescue Operations:**
  - **Estimated Cost:** \$700,000 annually for dedicated UAS units and training for search and rescue operations.
  - **Estimated Savings:** \$1.5 million annually by increasing the efficiency and success rates of search and rescue missions, reducing the time and resources required.

#### b. Improved Infrastructure Resiliency:

- **Proactive Infrastructure Monitoring:**
  - **Estimated Cost:** \$2 million annually for regular UAS inspections of infrastructure.

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- **Estimated Savings:** \$5 million annually by identifying issues early, preventing costly repairs and infrastructure failures.
- **Infrastructure Risk Monitoring:**
  - **Estimated Cost:** \$800,000 annually for enhanced data collection and analysis related to erosion, flooding, subsidence, landslides, and infrastructure vulnerabilities.
  - **Estimated Savings:** \$2 million annually by supporting better planning and adaptation strategies, reducing disaster-related damages and infrastructure repair costs.
- **Disaster Response Efficiency:**
  - **Estimated Cost:** \$1 million annually for UAS deployment during and after disasters.
  - **Estimated Savings:** \$4 million annually by improving damage assessment and recovery efforts, reducing downtime and associated costs.
- c. **Increased Accessibility:**
  - **Remote Area Coverage:**
    - **Estimated Cost:** \$1.2 million annually for deploying UAS units in remote regions.
    - **Estimated Savings:** \$2.5 million annually by improving accessibility to essential services, reducing the need for expensive traditional transportation methods.
  - **Support for Rural Communities:**
    - **Estimated Cost:** \$600,000 annually for focused engagement and support initiatives.
    - **Estimated Savings:** \$1.2 million annually by ensuring access to UAS benefits, improving quality of life and economic opportunities in rural communities.
- d. **Operational Benefits:**
  - **Reduced Field Deployment Requirements:**
    - **Estimated Cost:** \$400,000 annually for UAS operations replacing traditional methods.
    - **Estimated Savings:** \$1 million annually by reducing travel requirements, personnel time, and operational costs.
  - **Enhanced Infrastructure and Environmental Monitoring:**

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- **Estimated Cost:** \$700,000 annually for comprehensive environmental monitoring using UAS.
- **Estimated Savings:** \$1.8 million annually by supporting conservation efforts and informed environmental management, supporting infrastructure planning and maintenance decisions.

#### e. Economic Benefits:

- **Creation of New Job Opportunities:**
  - **Estimated Cost:** \$1.5 million annually for job creation and training programs.
  - **Estimated Savings:** \$3 million annually by generating new jobs and contributing to local economies, reducing unemployment rates.
- **Training and Workforce Development:**
  - **Estimated Cost:** \$1 million annually for comprehensive training programs.
  - **Estimated Savings:** \$2 million annually by building local capacity and providing new career pathways, enhancing workforce skills.
- **Cost Savings in Maintenance:**
  - **Estimated Cost:** \$1.8 million annually for proactive monitoring and timely maintenance.
  - **Estimated Savings:** \$4.5 million annually by reducing long-term infrastructure costs and preventing major repairs.

#### f. Long-term Savings:

- **Proactive Infrastructure Management:**
  - **Estimated Cost:** \$2 million annually for early identification and resolution of infrastructure issues.
  - **Estimated Savings:** \$6 million annually by extending the lifespan of infrastructure assets and reducing emergency repair costs.
- **Disaster Response Efficiency:**
  - **Estimated Cost:** \$1.2 million annually for enhanced disaster response capabilities.
  - **Estimated Savings:** \$5 million annually by minimizing economic losses and reducing the financial burden on communities and governments.
- **Data-Driven Decision Making:**
  - **Estimated Cost:** \$800,000 annually for enhanced data collection and analysis.

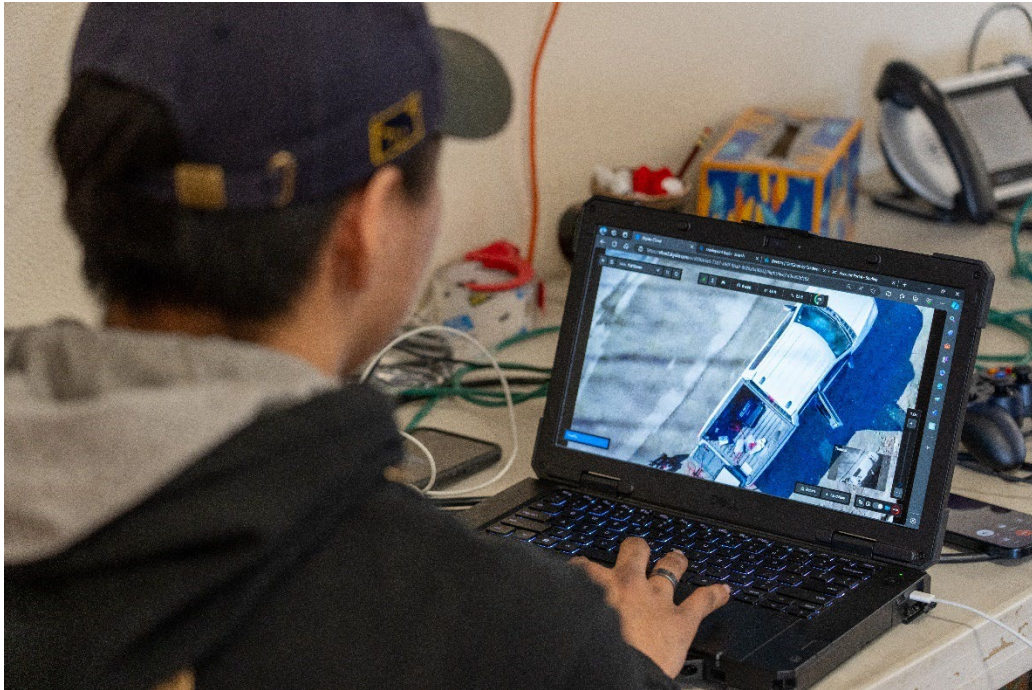
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- **Estimated Savings:** \$2.5 million annually by supporting informed decision-making, leading to more efficient resource allocation and policy implementation.

ARROW promises significant benefits across multiple domains, including safety, infrastructure resiliency, accessibility, long-term operational sustainability, and economic development. These benefits, with estimated annual savings significantly exceeding the costs, result in a positive cost-benefit ratio. The project's long-term savings from proactive infrastructure management and disaster response efficiency further justify the investment, making it a valuable and impactful initiative for Alaska's rural and remote communities.

A Stage 2 investment of \$13.9 million for at-scale implementation with ARROW is expected to generate substantial savings. Over three years, the total savings of \$138 million far exceed the implementation costs, leading to net savings of \$124.1 million. This results in an estimated investment-to-cost savings ratio of 1:10. This analysis highlights a highly positive return on investment, indicating that the ARROW project's benefits significantly outweigh its costs, providing strong justification for the investment.



*(Figure 24. Remote Operator in Bethel flying a Skydio X10 aircraft BVLOS in Anchorage)*

### 3. Preliminary Baseline Data:

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Baseline emergency response timelines in rural Alaska can range from several hours to multiple days depending on location, weather, and transportation access.

Traditional infrastructure inspections in remote areas are often conducted annually or less frequently due to logistical and cost constraints.

- **Safety Goals:** Current baseline data includes inconsistent fatality data for rural Alaska and longer response times for emergency services in remote areas. Historically, these regions have higher accident rates and longer response times due to their limited resources, isolation and challenging terrain.
- **Mobility Goals:** Baseline travel times and transportation reliability data are being quantified to measure improvements in documentation of traveling public, vehicle types, connectivity and efficiency. This data includes vehicle travel times, frequency of incidents, maintenance schedules and hazards.
- **Access and Opportunity:** Baseline data on access to essential services, employment, and education for remote communities is being gathered to assess the project's impact on improving these metrics.

By setting clear expectations and measuring the anticipated impacts across these key goal areas, the ARROW project aims to demonstrate significant benefits that justify the costs of at-scale implementation. The project's alignment with the SMART grant's objectives will ensure that it contributes meaningfully to the overall goals of enhancing transportation safety, resiliency, partnerships, integration, and workforce development in Alaska.

## Challenges & Lessons Learned

### 4.1 Project Challenges, Lessons Learned, and Recommendations

During Stage 1 of the ARROW project, several challenges were encountered across various areas. These challenges provided valuable lessons and led to important recommendations and adjustments for future implementation. Below is a detailed discussion of these challenges, the lessons learned, and the recommendations for each topic area.

#### 1. Legal, Policy, and Regulatory Requirements:

- **Challenges:** Compliance with the National Environmental Policy Act (NEPA) and Buy America, Build America (BABA) requirements posed significant delays. Navigating these regulatory frameworks required extensive documentation and coordination with multiple vendors.
- **Lessons Learned:** Early engagement with regulatory bodies and legal experts is crucial to ensure compliance and avoid delays. Comprehensive documentation and a clear understanding of regulatory requirements are essential.
- **Recommendations:**
  - Establish a dedicated legal and regulatory compliance team early in the project.

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- Develop detailed compliance checklists and timelines to manage regulatory requirements effectively.
- Engage in proactive communication with regulatory agencies to clarify requirements and expectations.

### 2. Procurement and Budget:

- **Challenges:** Delays in procurement processes and budget allocations impacted the timely acquisition of essential equipment and services. Budget constraints also limited the scope of some initial deployments.
- **Lessons Learned:** Streamlined procurement processes and realistic budget planning are vital for project success. Flexibility in budgeting to accommodate unexpected expenses can mitigate delays.
- **Recommendations:**
  - Simplify procurement procedures and establish clear procurement guidelines.
  - Allocate contingency funds to handle unexpected costs.
  - Maintain open communication with vendors to ensure timely delivery of goods and services.

### 3. Partnerships:

- **Challenges:** Coordinating with multiple stakeholders, including local governments, tribal entities, and private organizations, presented challenges in aligning goals and expectations. Variations in commitment levels and communication gaps also affected collaboration.
- **Lessons Learned:** Strong partnerships require clear communication, aligned objectives, and consistent engagement. Establishing formal agreements can help in maintaining commitment and accountability.
- **Recommendations:**
  - Develop formal Memorandums of Understanding (MOUs) with all partners outlining roles, responsibilities, and expectations.
  - Schedule regular meetings and updates to ensure continuous engagement and alignment.
  - Foster a collaborative environment by recognizing and addressing the unique needs and contributions of each partner.

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(Figure 25. Anchorage Police Department Skydio flight training)

#### 4. Technology Suitability:

- **Challenges:** Ensuring the suitability and reliability of UAS and remote sensing technologies in diverse and harsh Alaskan environments was challenging. Technical issues such as battery performance in cold weather and signal interference were encountered.
- **Lessons Learned:** Field testing and pilot programs are critical to identify and address technical issues before full-scale deployment. Technology should be adaptable to varying environmental conditions.
- **Recommendations:**
  - Conduct extensive field testing under different environmental conditions to assess technology performance.
  - Invest in technology that is specifically designed or adaptable for extreme weather conditions.
  - Develop maintenance and troubleshooting protocols to address technical issues promptly.

#### 5. Data Governance and Cyber Security:

- **Challenges:** Managing and securing large volumes of data collected by UAS posed significant challenges. Ensuring data privacy, integrity, and compliance with cybersecurity standards required robust data governance frameworks.
- **Lessons Learned:** A comprehensive data governance plan that includes cybersecurity measures is essential for protecting sensitive information. Regular audits and updates to data management practices help maintain data security.
- **Recommendations:**
  - Implement a robust data governance framework that includes policies for data collection, storage, access, and sharing.

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- Ensure compliance with cybersecurity standards and conduct regular security audits.
- Provide training for all project staff on data security best practices and protocols.
- **Highlight:** Hosting all data in a centralized hubsite powered by ESRI allowed for efficient documentation and monitoring of project success. This centralized approach facilitated real-time access to data, enhanced collaboration, and supported transparent reporting.

### 6. Workforce Capacity:

- **Challenges:** Building a skilled workforce capable of operating and maintaining UAS technology was challenging, especially in remote areas with limited access to training resources. A major problem was the availability of PSI exam centers in rural Alaska, which posed significant barriers to obtaining FAA Part 107 certification. Additionally, the FAA Part 107 exam presents challenges for many rural applicants due to technical terminology, testing availability, and limited access to preparation resources.
- **Lessons Learned:** Investing in local workforce development and providing comprehensive training programs are crucial for project sustainability. Collaboration with local educational institutions and organizations can enhance workforce capacity.
- **Recommendations:**
  - Develop partnerships with local educational institutions to create training programs tailored to the needs of the project.
  - Provide continuous professional development opportunities for project staff.
  - Offer competitive compensation and incentives to attract and retain skilled workers.
  - **Highlight:** Working with YUUT in Bethel, we were able to utilize a private testing center, which was crucial for overcoming the challenge of limited PSI exam centers. Additional training on how to take the FAA test and approval for the State of Alaska or a secondary entity to administer remote testing will be needed for future ARROW applicants.

### 7. Internal Project Coordination:

- **Challenges:** Coordinating activities across different project teams and ensuring alignment with project goals required effective internal communication and management.
- **Lessons Learned:** Clear communication channels, defined roles and responsibilities, and regular coordination meetings are essential for effective project management.
- **Recommendations:**
  - Establish a project management office (PMO) to oversee coordination and communication across teams.
  - Use project management tools and software to track progress and manage tasks.
  - Hold regular coordination meetings to review progress, address challenges, and align on objectives.

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### 8. Community Impact:

- **Challenges:** Ensuring that the project met the needs and expectations of the local communities was challenging. There were concerns about the impact of UAS operations on local wildlife and privacy.
- **Lessons Learned:** Engaging with the community early and often is crucial for gaining their support and addressing concerns. Transparent communication about the project's benefits and impacts helps build trust.



(Figure 26. Bethel SMART team meeting with USDOT)

- **Recommendations:**
  - Conduct community outreach and engagement activities to gather feedback and address concerns.
  - Provide clear and transparent information about the project's objectives, benefits, and potential impacts.
  - Develop community advisory boards to involve local residents in decision-making processes.
  - **Highlight:** Having a video and cinematography team to document and highlight community stories was crucial to the successful adoption and deployment of the project. This approach showcased the positive impacts of the project and built stronger relationships with tribal governments and local communities.

### 9. Public Acceptance:

- **Challenges:** Gaining public acceptance for the use of UAS technology, especially in remote and remote communities, was challenging. There were initial reservations about privacy and safety.
- **Lessons Learned:** Building public trust through education, transparency, and demonstrating the benefits of the technology is essential for gaining public acceptance.

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- **Recommendations:**

- Implement public education campaigns to inform residents about the benefits and safety of UAS technology.
- Address privacy and safety concerns through clear communication and transparent policies.
- Showcase success stories and positive impacts of the project to build public support.

By addressing these challenges and applying the lessons learned, the ARROW project can enhance its implementation strategy for future stages. These recommendations will help in overcoming potential obstacles, ensuring the successful deployment and sustainability of UAS and remote sensing technologies across Alaska.

## Deployment Readiness

### 5.1 Successful Implementation and Key Obstacles to Scaling

Deployment readiness for the ARROW project involves ensuring that all necessary components—legal, technical, financial, and community support—are in place to scale the project successfully.

During Stage 1, ARROW made significant strides in preparing for at-scale implementation by addressing key areas and uncovering previously unknown institutional barriers and technical limitations.

**a. To achieve successful implementation, the following requirements are critical:**

**1. Legal, Policy, and Regulatory Requirements:**

- **Requirements:**
  - Compliance with NEPA, BABA, and FAA regulations.
  - Legal frameworks for data privacy and cybersecurity.
- **Key Obstacles:**
  - Navigating complex regulatory requirements can delay project timelines.
  - Lack of streamlined processes for rural communities.
- **Strategies/Progress:**
  - Early engagement with regulatory bodies and legal experts.
  - Developing comprehensive compliance checklists and timelines.
  - **Uncertainties and Risk Mitigations:**
    - Continued monitoring of regulatory changes and proactive adaptation to new requirements.

**2. Procurement and Budget:**

- **Requirements:**
  - Efficient procurement processes and adequate budget allocation.

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- Contingency funds for unexpected expenses.
  - **Key Obstacles:**
    - Delays in procurement and budget constraints.
  - **Strategies/Progress:**
    - Streamlined procurement procedures.
    - Establishing clear procurement guidelines and maintaining open communication with vendors.
    - **Uncertainties and Risk Mitigations:**
      - Flexible budgeting and establishing contingency funds.
- 3. Partnerships:**
- **Requirements:**
    - Strong partnerships with local governments, tribal entities, and private organizations.
    - Clear communication and aligned objectives.
  - **Key Obstacles:**
    - Variations in commitment levels and communication gaps.
  - **Strategies/Progress:**
    - Formal MOUs with all partners.
    - Regular meetings and updates to ensure continuous engagement.
    - **Uncertainties and Risk Mitigations:**
      - Ongoing relationship management and addressing the unique needs of each partner.
- 4. Technology Suitability:**
- **Requirements:**
    - Reliable UAS and remote sensing technologies adaptable to Alaskan environments.
    - Robust maintenance and troubleshooting protocols.

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(Figure 27. Skydio X10 operated by DPS for fatality scene mapping)

- **Key Obstacles:**
  - Technical issues in harsh weather conditions.
- **Strategies/Progress:**
  - Extensive field testing and investment in suitable technology.
  - Developing maintenance protocols.
  - **Uncertainties and Risk Mitigations:**
    - Continuous technological updates and adaptation to new advancements.

### 5. Data Governance:

- **Requirements:**
  - Robust data management and cybersecurity frameworks.
  - Centralized data hosting and real-time access.
- **Key Obstacles:**
  - Managing and securing large volumes of data.
- **Strategies/Progress:**
  - Comprehensive data governance plan and cybersecurity measures.
  - **Highlight:** Hosting all data in a centralized hubsite powered by ESRI.
  - **Uncertainties and Risk Mitigations:**
    - Regular audits and updates to data management practices.

### 6. Workforce Capacity:

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- **Requirements:**
    - Skilled workforce for operating and maintaining UAS.
    - Training programs and partnerships with educational institutions.
  - **Key Obstacles:**
    - Limited access to training resources in remote areas.
    - **Highlight:** Availability of PSI exam centers in rural Alaska and difficulties with the FAA Part 107 exam.
  - **Strategies/Progress:**
    - Partnering with YUUT in Bethel for private testing centers.
    - Additional training on FAA test-taking and approval for remote testing administration.
    - **Uncertainties and Risk Mitigations:**
      - Continuous workforce development and professional training.
- 7. Internal Project Coordination:**
- **Requirements:**
    - Effective communication and management across project teams.
  - **Key Obstacles:**
    - Coordination challenges and alignment with project goals.
  - **Strategies/Progress:**
    - Establishing a PMO and using project management tools.
    - Regular coordination meetings.
    - **Uncertainties and Risk Mitigations:**
      - Continuous improvement of internal communication strategies.
- 8. Community Impact:**
- **Requirements:**
    - Ensuring the project meets community needs and expectations.
  - **Key Obstacles:**
    - Concerns about UAS operations' impact on wildlife and privacy.
  - **Strategies/Progress:**
    - Community outreach and engagement activities.
    - **Highlight:** A video and cinematography team documenting and highlighting community stories.
    - **Uncertainties and Risk Mitigations:**

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- Transparent communication and continuous community involvement.

### 9. Public Acceptance:

- **Requirements:**
  - Building public trust through education and transparency.
- **Key Obstacles:**
  - Initial reservations about privacy and safety.
- **Strategies/Progress:**
  - Public education campaigns and transparent policies.
  - Showcasing success stories and positive impacts.
  - **Uncertainties and Risk Mitigations:**
    - Ongoing public engagement and education efforts.

### b. Maintenance and Operating Requirements

Understanding Maintenance and Operating Requirements: To ensure the sustainability of ARROW post at-scale implementation, it is essential to understand and plan for the ongoing maintenance and operating requirements.

- **Learning Needs:**
  - Detailed knowledge of UAS maintenance schedules and protocols.
  - Understanding of software and hardware updates for remote sensing technologies.
  - Development of local expertise in data management and cybersecurity.
  - Capacity to train and retrain workforce as technology evolves.
- **Capacity for Improvements:**
  - ARROW has established a strong foundation with partnerships and training programs, but ongoing investment in technology and skills development is necessary.
  - Establishing a continuous improvement process to prevent technical debt and ensure the project remains up-to-date with technological advancements.
  - Collaboration with technology providers for timely updates and support.

### c. Harnessing Beneficial Impacts and Mitigating Negative Impacts on Jobs

**At-Scale Implementation Impacts:** At-scale implementation of ARROW will create significant opportunities for job creation and workforce development, particularly in remote and remote communities.

- **Beneficial Impacts:**
  - Creation of high-paying jobs in UAS operations, maintenance, and data analysis.
  - Development of new career pathways and technical training programs.
  - Increased local expertise and technical capacity.

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- **Highlight:** The partnership with AFL-CIO and IBEW has already demonstrated positive impacts on local employment.
- **Mitigating Negative Impacts:**
  - Ensuring that new technologies do not displace existing jobs but rather enhance and complement current roles.
  - Providing comprehensive training and upskilling opportunities to help workers transition to new roles.
  - Promoting fair labor practices and supporting unionization efforts to protect workers' rights.
- **Strategies:**
  - Engaging with local communities and workers to understand their needs and address concerns.
  - Developing policies that support inclusive growth and fair employment practices.
  - Regular assessment of job impacts and adjustments to training and support programs as needed.

ARROW is well-prepared for at-scale implementation. The project's comprehensive strategies and demonstrated progress in various areas highlight its readiness to overcome key obstacles and achieve successful deployment across Alaska. Continuous learning and adaptation will ensure the project's sustainability and positive impact on the communities it serves. Based on Stage 1 outcomes, ARROW is operationally and technically feasible for at-scale deployment, with identified risks considered manageable through established mitigation strategies.

## Wrap-Up

### 6.1 Reflections on the Proposed Solution and Future Recommendations

**Meeting Expectations:** Reflecting on the course of ARROW, the proposed solution has largely met our expectations. The deployment of UAS and remote sensing technologies has demonstrated significant improvements in infrastructure monitoring, emergency response, and community engagement in remote areas of Alaska. The project has successfully established a framework for continuous data collection and analysis, enhancing transportation safety and resilience.

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(Figure 27. Skydio X10 training with Alaska State troopers on 3D Scan)

**Notable Changes for At-Scale Implementation:** While the project has been successful, several areas have been identified for improvement to enhance at-scale implementation:

- **Regulatory Navigation:**
  - **Proposed Change:** Establish a dedicated regulatory compliance team earlier in the project to streamline navigation through complex regulatory frameworks with FAA.
  - **Reason:** Early engagement with regulatory bodies can prevent delays and ensure smoother project progress.
- **Procurement Processes:**
  - **Proposed Change:** Simplify procurement procedures and establish clearer guidelines for vendors.
  - **Reason:** Streamlined processes can prevent delays in acquiring necessary equipment and services.
- **Workforce Training:**
  - **Proposed Change:** Expand training programs to include test-taking strategies for the FAA Part 107 exam and advocate for the approval of state or secondary entity-administered remote testing.
  - **Reason:** Addressing the difficulties faced by tribal communities in accessing PSI exam centers and navigating confusing test language can enhance workforce capacity.
- **Community Engagement:**
  - **Proposed Change:** Continue leveraging video and cinematography teams to document and highlight community stories.
  - **Reason:** This approach has proven crucial for gaining community support and showcasing the project's positive impacts.
- **Technology Adaptation:**

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- **Proposed Change:** Invest in technology specifically designed for harsh environmental conditions and ensure continuous updates and maintenance protocols.
- **Reason:** Ensuring technology suitability in diverse Alaskan climates is essential for project success.

**Advice for Others:** For applicants embarking on similar projects, the following recommendations can enhance the likelihood of success:

1. **Early Regulatory Engagement:**
  - Engage with regulatory bodies early and establish a dedicated compliance team to navigate legal, policy, and regulatory requirements effectively.
2. **Streamlined Procurement and Budgeting:**
  - Simplify procurement processes and establish clear guidelines. Allocate contingency funds to handle unexpected costs.
3. **Strong Partnerships:**
  - Develop formal agreements with all partners and maintain regular communication to ensure alignment and continuous engagement.
4. **Robust Workforce Training:**
  - Provide comprehensive training programs, including test-taking strategies, and advocate for remote testing options where necessary.
5. **Community Involvement:**
  - Engage communities early and often. Use media and storytelling to build trust and support for the project.
6. **Adaptable Technology:**
  - Invest in technology that can withstand local environmental conditions and establish protocols for regular maintenance and updates.
7. **Data Governance and Cybersecurity:**
  - Implement robust data management frameworks and ensure compliance with cybersecurity standards to protect sensitive information.
8. **Public Education:**
  - Conduct public education campaigns to inform residents about the benefits and safety of new technologies. Address privacy and safety concerns transparently.

ARROW has demonstrated the potential of UAS and remote sensing technologies to transform transportation safety and resilience in remote communities. By reflecting on the challenges and successes of Stage 1, the project team has identified key areas for improvement and developed strategies to enhance at-scale implementation. These insights and recommendations will not only benefit ARROW but also serve as valuable guidance for other communities pursuing similar innovative transportation solutions.