

# UNMANNED AERIAL SYSTEMS FOR AVALANCHE MONITORING AND MITIGATION: A COLLABORATIVE APPROACH BY ALASKA DOT&PF AND ALASKA RAILROAD

Patrick Dryer<sup>1</sup>, Timothy Glassett<sup>2\*</sup>, Ryan Marlow<sup>2</sup>, and Matt McKee<sup>3</sup>

<sup>1</sup> Alaska Department of Transportation and Public Facilities, Juneau Alaska, USA

<sup>2</sup> Alaska Department of Transportation and Public Facilities, Anchorage Alaska, USA

<sup>3</sup> Alaska Railroad Corporation, Anchorage Alaska, USA

**ABSTRACT:** The Alaska Department of Transportation and Public Facilities (DOT&PF) and the Alaska Railroad Corporation (ARRC) have been utilizing Unmanned Aerial Systems (UAS) technologies to transform avalanche monitoring and mitigation efforts in the region. Following the nation's first Federal Aviation Administration (FAA) approval to carry explosives onboard a UAS, these organizations have applied advanced techniques for avalanche monitoring, mitigation, and safety. This paper will discuss the innovative applications of UAS technologies in avalanche-prone areas, the collaborative efforts between DOT&PF and ARRC, and the future of automated data capture.

**KEYWORDS:** Unmanned Aerial Systems (UAS), Mitigation, Monitoring, Federal Aviation Administration (FAA)

## 1. INTRODUCTION

The Alaska Department of Transportation and Public Facilities (DOT&PF) recently completed a statewide Avalanche Hazard Index (AHI) and Mitigation Options Assessment. This report was commissioned to complete a baseline risk assessment and provide options for a future without the main avalanche mitigation tool that both Alaska DOT&PF and ARRC use, the M101A1 105mm Howitzer. In conjunction with the key findings of the AHI report the Alaska DOT&PF have also been pursuing efforts to modernize our avalanche programs using Unmanned Aerial Systems (UAS). Unmanned Aerial Systems have seen a rapid growth and development in the last decade as seen by increase in patents, platform development, and usage (Global Trends of Unmanned Aerial Systems DTI 2019).

For this paper the two main technologies discussed are a UAS based avalanche mitigation system and UAS docking stations for avalanche monitoring and repeated mapping missions. Avalanche monitoring and mitigation constitute pivotal areas of concern in regions vulnerable to these natural hazards, such as Alaska. Historically, these tasks have been manual, perilous, and characterized by unpredictability due to their dependence on human judgement and physical intervention. The advent of UAS technology provides an opportunity to significantly alter these traditional methodologies, greatly enhancing the efficiency, safety, and precision of avalanche mitigation processes.

The Alaska Department of Transportation and Public Facilities (DOT&PF) and the Alaska Railroad Corporation (ARRC) have initiated a pioneering endeavor to assimilate UAS technology into their avalanche monitoring and mitigation operations. A significant landmark in this venture has been obtaining the first-ever approval from the Federal Aviation Administration (FAA) to carry explosives onboard UAS for avalanche mitigation.

This technical paper elucidates the cooperative endeavors of Alaska DOT&PF and ARRC in harnessing UAS technology to revolutionize avalanche mitigation. It outlines the novel applications of UAS in avalanche prone regions, the amalgamation of advanced techniques into current mitigation protocols, and the ground-breaking utilization of explosives onboard a UAS to facilitate controlled avalanche initiation.

Additionally, the paper explores the merits of automated data capture, encompassing aspects like streamlining of Geographic Information Systems (GIS) workflows, improvement of data precision, and considerable risk reduction associated with manual data collection in hazardous terrains.

Through this alliance, Alaska DOT&PF and ARRC aim to devise a forward-thinking strategy that leverages innovative technology to boost safety, augment operational efficiency, and construct a resilient foundation for an advanced avalanche monitoring and mitigation system.

## 2. AVALANCHE MITIGATION USING UAS

The potential for expanding the use of a UAS extends beyond mere data collection. The technol-

ogy has expanded into areas considered hazardous for humans, such as avalanche mitigation operations. The next section of this paper delves into the innovative usage of drones to carry and deploy explosives for avalanche mitigation, the approval process under Section 336 of the FAA regulations, and the plans for integrating this technology into avalanche mitigation operations.

Active avalanche mitigation programs aim to reduce the avalanche risk by using explosives or other methods to trigger controlled avalanches, reducing potential hazards before they become large enough to cause significant damage to transportation corridors, utility infrastructure and ski areas. Operating active avalanche control programs along transportation networks are becoming increasingly expensive and therefore using innovative ways to reduce costs while improving safety and efficiency become integral for future program management.

A recent revolution in the ability to conduct avalanche mitigation is the use of drones to carry and deploy explosives to intentionally trigger avalanches. Large rotor wing drones, specifically the Freefly Systems Alta X, have been retrofitted to safely handle explosive payloads (Image 1). With its impressive payload capacity and precise navigational capabilities, the Alta X drone can accurately deliver these explosives to targeted areas, mitigating the need for humans to venture into hazardous, avalanche prone terrains. The Alta X is a certified Blue 2.0 UAS, as defined by the United States Department of Defense (DOD). The Blue UAS classification, as defined by the DOD, includes UAS platforms that have critical components which are compliant with the National Defense Authorization Act. Blue 2.0 is evaluating current commercial UAS platforms and vetting them for DOD use so that they are compliant and secure (Blue UAS 2023). Many Federal and State agencies are concerned with potential foreign government interference and have banned foreign made drones ('banned drones'). For this reason, it was prudent to adopt Blue 2.0 certified UAS for the integration into our avalanche mitigation efforts.

Implementing this pioneering technique required regulatory approvals, primarily through a Section 363 Waiver from the FAA allowing for the equipping of a dangerous weapons onboard UAS.

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\* Corresponding author address:

Timothy Glassett, Alaska Department of Transportation and Public Facilities,  
Anchorage, AK 98523-1234;  
tel: +1 907-269-0763;  
email: timothy.glassett@alaska.gov

Given that the usage of explosives on drones represents a significant shift from conventional applications, a rigorous approval process was necessary to ensure safety and compliance with existing aviation laws and Federal regulations.



*Image 1 – Drone Amplified modified Alta X dropping inert payload out of Maple Leaf Products modified Sentinel 6000 Prototype during testing February 2023.*

*“Operating a drone that has a dangerous weapon attached to it is a violation of Section 363 of the 2018 FAA Reauthorization Act (congress.gov) enacted Oct. 5, 2018. Operators are subject to civil penalties up to \$25,000 for each violation unless the operator has received specific authorization from the Administrator of the FAA to conduct the operation. “Dangerous Weapon” means any item that is used for, or is readily capable of, causing death or serious bodily injury.” – FAA, August 22, 2019 (Govinfo 2023).*

The Section 363 Waiver approval process entailed demonstrating how safety concerns associated with carrying and deploying explosives would be mitigated. This included showcasing the design and testing of the drone systems, safe handling and transportation of the explosives, contingency plans for failures, and the training requirements of the drone pilots.

The FAA granted approval to Alaska DOT&PF and ARRC through a Certificate of Authorization (COA) after a thorough examination of the safety measures, risk assessments, and operational protocols, thereby authorizing them to carry explosives onboard a UAS for avalanche mitigation.

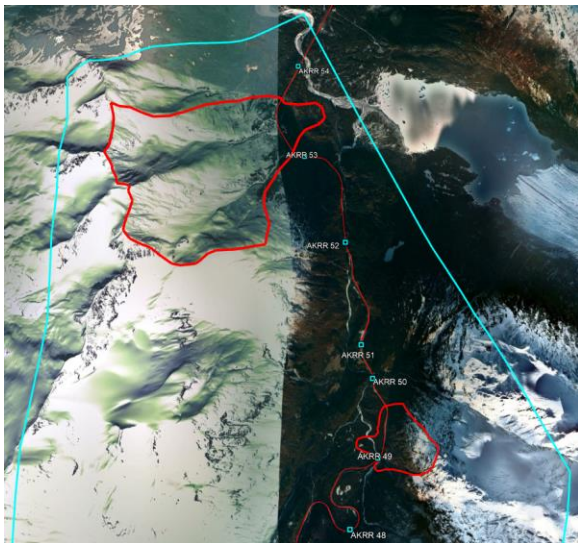
#### *Integration and Deployment Testing: The Road Ahead*

With regulatory approval in hand, the focus now shifts to the implementation of this innovative approach. Continuing in Fall 2023, Alaska DOT&PF

plans to continue rigorous testing to develop and integrate the explosive carrying Alta X drones into their avalanche mitigation operations.

This phase will test the accuracy and reliability of the drone's delivery of explosives, the effectiveness of the explosives in triggering controlled avalanches, and the overall safety and efficiency of the operations. Real-world data gathered from these tests will be used to refine operational protocols, safety measures, and the training provided to drone pilots.

For a testing area we chose two avalanche paths located along the ARRC railroad corridor that are miles away from the nearest highways and inhabited buildings (Image 2). These paths will test the UAS out to ranges between 1 km and 3 km, with targets between 200 m and 1200 m above takeoff elevation. Real-Time Kinematic (RTK) GPS receivers and base stations are utilized to provide accurate positioning and distance to terrain during flight. Additionally laser rangefinders onboard the UAS are utilized to provide additional information to the pilot with the distance to target and distance to terrain.



*Image 2 – UAS Testing area; Alaska Railroad Corporation 49 Mile and 53 Mile avalanche paths.*

In response to Alaska DOT&PF's Section 363 waiver for testing UAS for avalanche mitigation, the United States Forest Service amended ARRC's Special Use Permit to allow for UAS mitigation testing in two avalanche paths. The ARRC is obtaining written permission from their explosives supplier to use their product for the upcoming testing.

The integration of explosive carrying UAS into avalanche mitigation operations represents a significant milestone in leveraging technology for pub-

lic safety. By moving ahead with deployment testing, Alaska DOT&PF and ARRC underscore their commitment to innovation and their dedication to ensuring the safety of Alaska's transportation networks and communities.

### 3. UAS DOCK

The addition of UAS docks into our avalanche program is a critical component of our avalanche monitoring and mitigation strategy. Currently, we are evaluating UAS docks for dispatching drones in remote locations to conduct avalanche monitoring, emergency response, and inspection of areas (Image 3). To monitor avalanche occurrences in remote areas we are utilizing photogrammetry image capture techniques and Starlink data terminals to transmit the data to a cloud processing portal. This innovative approach using UAS docks allows for the scheduling of flights, enabling repeatable mission planning and providing situational awareness for pre- and post-storm events as well as documentation following avalanche mitigation efforts.



*Image 3 – UAS Dock Testing area; Thane Road, Juneau Alaska.*

The Alaska DOT&PF operates under a public Certificate of Waiver or Authorization (COA) which allows for operations beyond visual line of sight (BVLOS) for the inspection of critical infrastructure. Avalanche paths and associated transportation networks fall under this category of critical infrastructure, and hence, are authorized un-

der this COA. This authorization enables repeatable operations using UAS docks in remote areas.

Our approach to implementing the UAS Dock began with utilizing existing resources, specifically Temporary Flight Restrictions (TFRs). These allowed us to safely operate UAS systems in areas where avalanche mitigation was already occurring. Pending FAA approval, autonomous flights are planned within a TFR following avalanche mitigation to document and map artificially triggered avalanche size and distribution.

To conduct avalanche and snowpack distribution monitoring during winter months, first a Digital Terrain Model (DTM), topographic model of the bare Earth surface, was captured using LiDAR instrumentation. During the avalanche season repeated preprogrammed mapping missions are conducted to allow for differencing of photogrammetrically derived DTM models to analyze snowpack distribution in starting zones. The same process can be utilized to map and document the extent and size of avalanche activity following natural or artificially triggered avalanches.

For specific avalanche paths, or areas of concern to monitor, intensive mission planning occurred to validate flight routes and emergency procedures. Complex mountainous terrain presents unique challenges for conducting flights that are compliant with Part 107 regulations. To ensure compliance with these regulations, mapping mission flights were pioneered using terrain following techniques to stay at or below 120 meters AGL for the duration of the mission.

One of the challenges we've faced involves the return-to-home protocol for unmanned aircraft. In the event of a lost signal between the UAS dock and aircraft, the aircraft will maintain its current altitude as it returns to the dock. For example, if the aircraft is at an altitude of 1200 meters MSL and the dock is at 30 meters above ground level (AGL), the aircraft will remain at 1170 meters AGL as it begins its descent to the dock. This is unacceptable with airspace restrictions and requires an alternative method, which we are currently developing.

Proper site selection was important to accomplish the objectives of our avalanche program (monitoring and documentation). The site of the UAS docking station must be located closely adjacent to avalanche paths to allow for the ability to dispatch the UAS following natural avalanches or during periods of increased avalanche activity, day or night. The UAS is equipped with a zoom camera for close inspections, wide camera for mapping, and infrared camera for identifying wildlife or Search and Rescue operations. A laser

range finder can also be utilized to determine the distance of the UAS to the area of interest.

The UAS dock is managed via a cloud portal and allows for the live streaming of video during flight operations. The video stream can be viewed by numerous personnel, and we have found this to be extremely beneficial during emergency response and incident briefing activities.

A key aspect of this UAS monitoring strategy is the data workflow following completed mapping flights. After the data collection process is complete, the data is uploaded to a cloud portal or data bucket. This can then be scripted to automatically start an API draw, allowing for data to transfer to a processing engine. The processing engine then creates a geo-rectified orthomosaic and 3D point cloud, enabling real-time 3D analysis as well as cut-fill volume calculations. The imagery is then processed into tiles and delivered as a dynamic imagery service back into field tablets allowing for the latest imagery to be visible to anyone working in the field with internet connectivity.

This streamlined data workflow is essential for the remote deployment of UAS docks and allows for rapid, data-driven decision making. The near real-time ability to model avalanche size/distribution allows for avalanche professionals to make informed decisions on avalanche hazards and mitigation strategies. The georeferenced imagery collected by the UAS docks also allows for the integration into other GIS platforms to catalog and document avalanche occurrence.

One of the most significant benefits of the UAS dock is the shift in focus it allows. Instead of dedicating resources to flight specific training, operators can concentrate on data analysis, streamlining operations in areas where resources are limited. This shift is particularly beneficial in the context of avalanche monitoring and mitigation, where the ability to rapidly analyze and respond to data can be critical.

In conclusion, the UAS Dock is a significant step forward in our efforts to improve avalanche monitoring and mitigation. By enabling more efficient operations and data analysis, it allows us to better protect our infrastructure and the people who rely on it.

#### 4. CONCLUSION

The current and future development of alternative means to both mitigate avalanches and map snowpack distribution and avalanches via a UAS will improve safety, increase efficiencies, and provide an agile asset to avalanche programs across the State of Alaska.

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