Remote Observation over Time (Drone in a Box) - Phase I

by

Jeremy Crowley
Director, Autonomous Aerial Systems Office

University of Montana

A proposal prepared for the

Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

July 19, 2024

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PROBLEM STATEMENT

One of the newest technologies in the Unmanned Aerial System (UAS) industry is a Drone in a Box (DiaB). This technology has been embraced by a few local and state law enforcement agencies and state Departments of Transportation (most notably in relation to this project is AKDOT). A DiaB solution, allows for the remote control of a UAS under beyond visual line of sight (BVLOS) operations. According to Federal Aviation Authority (FAA) 14 Code of Federal Regulations (CFR) Part 91, BVLOS is an advanced operation beyond the CFR Part 107 (FAA Certification of Remote UAS Pilot) and requires a waiver. The companies that manufacture DiaB solutions have been successful in FAA BVLOS waiver applications by incorporating an on-site weather station and a camera inside the box in order for the remote pilot in command (PIC) to be able to visually check the aircraft before BVLOS operations. As far as we know, there has not been a project to create a mobile solution (i.e. trailer) for DiaB that will function in nearly all weather conditions encountered in Montana and cellular "dead zones".

We envision this project to take shape in three phases, **Phase I** (which this proposal addresses) will identify appropriate deployment locations, initiate the process of obtaining BVLOS wavers, and explore scenarios that would enable the DiaB solution will interface with MDT maintenance operations and the traffic Transportation Management Center (TMC) response to natural hazards.

Phase II will develop the DiaB mobile trailer system with all the required components (power generation, communication, weather station, cameras, DiaB system). **Phase III** will address the use of environmental sensors to notify a PIC and automatically trigger the DiaB to fly to a location of a natural hazard to a roadway (i.e. rockslides, landslides, debris flows, avalanches, floods). Finally, this Phase III seeks to evaluate DiaB security and communication system interaction between MDT Maintenance, UAS Program, and the TMC.

BACKGROUND SUMMARY

Previous and Current UAS research at DOT

UAS technologies are already being utilized in a number of state departments of transportation around the nation. In 2023, the Federal Highway Administration (FHA) and partners in the United Kingdom and Germany published a report on the use of UAS utilization in design, construction, inspection, and maintenance of transportation infrastructure. The key findings of this report suggested that UAS methodologies, data, and products would benefit from data standardization and the development of best practices. They also found that UAS can enhance safety, efficiency, mapping, and management of transportation infrastructure (FHWA, 2023a).

A University Transportation Centers Program (UTCP) Phase 3 project is investigating the use of UAS for freeway incident detection and management in Florida and Puerto Rico. Researchers developed a performance algorithm to set parameters in RGB and thermal sensors to automatically detect incidents and abnormal traffic characteristics. The phase 3 seeks to validate the incident detection algorithm and explore the integration with the traffic management center (UTCP, 2023). In 2021, a MassDOT study investigated how to utilize UAS for highway incidents and natural disasters (fire and HAZMAT spills), and how to integrate UAS with their emergency management team (FHWA, 2021). A 2020 project sought to identify how UAS information in hard-to-reach areas before, during, and after natural disasters in the South-Central US. The particular focus is the state of flood control structures, power lines, water levels, and the number of damaged homes (UTCP, 2020).

A 2023 FHWA sponsored AKDOT project entitled “Integrated avalanche detection warning and snow distribution map” is planning to utilize infrasound sensors (and their ideal specification and placement) to detect avalanche activity. This work includes analysis of UAS Lidar and photogrammetry to conduct snow depth, avalanche size, and distribution surveys, and to develop an avalanche detection and early warning system (FHWA, 2023b). A FHWA Tech Brief details the use of UAS for detecting and monitoring earth movements. This report includes descriptions and methodologies that use Structure from Motion (SfM) photogrammetry and light detection and ranging (Lidar) to analyze rockfall activity and stability of rock slopes and change detection in rock slopes (FHWA, 2023c).

Of the awarded 2023 DOT Smart Planning grants, there were 3 out of 34 that proposed the use of UAS. A 2023 MD award proposed the use of medical package deliveries in coastal areas and another MD project proposed the use of UAS to support real-time speed management in work zones (Sarbanes, 2024). A 2023 Southern Alleghenies Planning and Development Commission (PA) grant proposed the use of UAS to provide emergency response supplies in rural areas (Government Technology, 2024).

A 2022 DOT Smart Grant issued to AKDOT is aimed towards providing UAS and geographical information systems (GIS) to respond to natural and man-made disasters in rural communities through the Alaska Rural Remote Operations Work Plan (ARROW, AKDOT, 2023). Another Smart Grant in 2022 to the Mandan, Hidatsa, and Arikara Nations and the University of North Dakota (UND) involves the use of UAS for medical delivery (UND, 2023). A MassDOT project in 2022 utilized UAS to monitor railroad infrastructure, and in 2023 they received an FAA waiver to fly BVLOS over their entire railway system (RT&S, 2023).

FAA UAS BVLOS and DiaB Operational Framework

The FAA has instituted an expedited approval for UAS advanced operation during natural disasters or emergency operations through its Special Governmental Interest process (FAA, 2023). First responders and other agencies responding for firefighting, search and rescue, law enforcement, utility or critical infrastructure restoration, damage assessments, and media coverage for critical public information can apply for a waiver through the SGI process. Although the FAA SGI process is available for UAS operations, it is unlikely that they would approve BVLOS except in critical conditions and in restricted cases under this process (Aloft, 2024).

There are a few organizations that have received FAA waivers for BVLOS (14 CFR Part 107.31), typically under very specific geographical location requirements, with altitude and airspace restrictions, pilot restrictions, daylight restrictions, and with specific UAS that have an airworthiness certificate (FAA, 2024). The FAA also does not allow stacking of waivers, for example, an organization that has a waiver for Flight Over People and a waiver for BVLOS, cannot operate in both BVLOS and Flight Over People simultaneously (Rupprecht, 2024).

According to the FAA, there are 303 entities that have current BVLOS waivers (FAA, 2024). Some of the milestones (The Drone Girl, 2023) in BVLOS waiver issuance include:

- Statefarm was the first in the US to be authorized for BVLOS and operations over people (OOP) in January 2019 for catastrophic damage assessments.
- Phoenix Air Unmanned was authorized on in Aug 2023 to conduct aerial photography and inspections below 400’ over sparsely populated areas in pre-planned flight paths operating SwissDrones SVO 50 V2 UAS
- Zipline was authorized in September 2023 to operate their Sparrow UAS (with preflight safety checks, detect and avoid system, Automatic Dependent Surveillance- Broadcast (ADS-B), acoustic avoidance system, etc.) for package delivery.
- Percepto was authorized in May 2023 to enable their employees to conduct remote BVLOS with their DiaB solution at critical infrastructure sites in the US below 200’ without detect and avoid systems.

Some studies have investigated detect and avoid requirements for BVLOS flights (FAA, 2018). There are UAS interference, security, and communication considerations including radio frequency signal jammers can lead to loss of link, increased power consumption, packet delays and bit errors (FAA, 2016). Requirements and procedures for sUAS BVLOS operations vary by country, and many BVLOS waivers issued have a small detect and avoid system incorporated into the UAS system (Fang et al., 2018). There have been rapid advances in persistent navigation systems and communications systems that are starting to enable highly reliable and autonomous BVLOS operations (Politi et al., 2024).

In June 2023, NASA studied the safety of flying BVLOS at Langley Research Center as part of the Advanced Air Mobility High Density Vertiplex (AAM HDV) project in support of Urban Air Mobility UAM (UAM) to conduct BVLOS at an acceptable level of risk. NASA planned a tiered approach resulting in 5 UAS being flown simultaneously (no more than 3 in BVLOS) in Class D airspace lower than 400’ above ground level (AGL). This report and interviews with NASA personnel will be the basis for the planning of the MDT BVLOS waiver and the development of MDT standard operating procedures (SOPs) for BVLOS (NASA, 2023).

BENEFITS AND BUSINESS CASE

Globally the expected annual damages to road and railway infrastructure due to natural hazards is estimated to be from \$3.1 to \$22B (Koks et al., 2019). In 2015, MDT implemented a Rockfall Assessment Management Program (RAMP) (Landslide Technology, 2015) and the analysis determined that rock slope management costs would be approximately \$35M per year. In 2022 the US Department of Transportation (DOT) provided over \$513M in emergency relief to make repairs to roads and bridges damaged by natural disasters (Stone, 2022). The DOT also announced a \$7.9B program Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) to help states and communities prepare and respond to extreme weather events from 2022-2026 (USDOT, 2022). In 2024 the Federal Transit Administration awarded \$110M to state DOTs to recover from recent natural disasters (Druga, 2024). In 2022, a single historic flood event on the Yellowstone River cost \$1B in federal recovery costs and infrastructure repairs (Tester, 2023).

A DiaB solution applied to natural disaster risk has a number of benefits, including cost savings, efficiency gains, increased safety, to both MDT and the traveling public. Analogous to how improving traffic light efficiency reduces emissions and time spent at intersections, a DiaB can potentially reduce the amount of traffic congestions at rock falls in MT. It could also act as an early hazard detection system that could reduce traffic injuries and fatalities, facilitate rapid response to natural disasters and highway incidents, speed efficiency through a rapid data collection to determine the level of response, and trigger warnings for the traveling public. A DiaB mobile trailer system could be deployed at remote work zones, speeding up incident response time, freeing up staff to attend to other incidents, and providing verification of incidents that are uncertain or outside of traditional cell communication.

OBJECTIVES

Phase I will identify appropriate deployment locations, initiate the process of obtaining BVLOS wavers, and explore scenarios that would enable the DiaB solution will interface with MDT maintenance operations and the traffic Transportation Management Center (TMC) response to natural hazards.

Task 1: GIS Analysis of Natural Hazards. The goal of this task is to centralize all of the current data on known or potential natural hazards and cellular “dead zones” that may impact transportation infrastructure. This analysis will assist in determining the placement for the DiaB system.

Task 2: Analysis on the current state of the industry/technology and costs for DiaB. This task involves interviewing vendors and researchers currently utilizing DiaB systems. Specifically, we will interview AKDOT to determine their DiaB solution status, assess the lessons learned, technology utilized, and determine pitfalls and potential solutions.

Task 3: Preparation and submission of FAA waiver for BVLOS operations. The research group, in consultation with MDT will review successful BVLOS waivers, consult with the FAA, and determine the best path forward to submit a BVLOS waiver to the FAA.

Task 4: Staged testing of DiaB operations. The FAA encourages applicants to determine the risk involved in operations and work to minimize the risk involved in those operations. The research group will set up a tiered series of proof-of-concept flight operations of increasing complexity and document these to provide to the MDT and the FAA in support of this research.

Task 5: Analysis of potential applied use-case scenarios incorporating MDT Maintenance, UAS Program, and the TMC. This task involves developing scenarios or use-cases in which the DiaB capabilities can provide efficiencies or benefits to both the Maintenance and TMC groups at MDT.

RESEARCH PLAN

Task 1: GIS Analysis of Natural Hazards.

Natural hazards that can affect transportation infrastructure in Montana include floods, rockfall, landslides, earthquakes and active faults, and avalanches. The Montana Bureau of Mines and Geology (MBMG) has a Geohazards group that has mapped active faults (Figure 1 left top), earthquakes, and landslides throughout MT (MBMG, 2024) and the USGS has a US landslide inventory that includes MT (Figure 1, right top). According to the National Ocean and Atmospheric Administration (NOAA) storm event database, from 2010 to 2024 there were 198 days of flooding and 490 flood events in MT and these events have affected all 56 counties in MT (NOAA, 2024, Fig. 1 left bottom). MDT implemented a Rockfall Assessment Management Program (RAMP) (Landslide Technology, Figure 1 right bottom) to determine the slope stability in proximity to roads in MT. We will also evaluate the cell phone “dead zones” in MT. This geographical information system (GIS) data will be compiled, categorized, and prioritized to determine target locations for DiaB deployment.

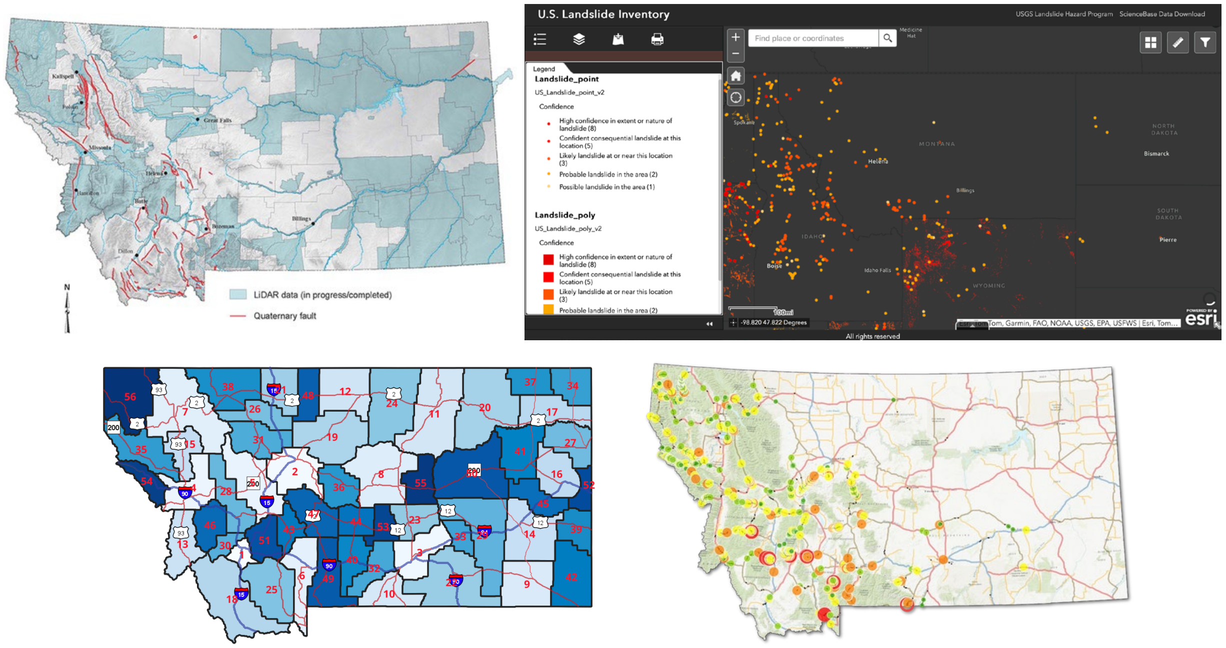

Figure 1: Potential Natural Disaster Locations in MT.

Top Left: Mapped active Quaternary faults in MT (MBMG, 2024). Top Right: Mapped landslides in MT (USGS, 2024). Bottom Left: Number of flood events by county in MT from 2010-2024 (NOAA, 2024). Bottom Right: Map of the condition of rock slopes in Montana. Green = good, yellow = fair, red = poor (Landslide Technology, 2017).

Task 2: Analysis on the current state of the industry/technology and costs in DiaB.

The UAS industry is rapidly changing and has new technological, regulatory changes, and research milestones on nearly a weekly to monthly basis. In order to provide a rolling snapshot of the state of the technology, the research group will interview DiaB manufacturers, vendors, AKDOT (and maybe other state DOTs), and NASA researchers to determine equipment (Figure 2) utilized, research status, communications concerns, lessons learned, pitfalls, and potential solutions. We will also closely follow the regulatory environment, the technological advances, and the market and applications for the UAS DiaB industry. We will develop a cost-benefit analysis of business-as-usual versus MDT incorporation of DiaB technology.

Figure 2: Three Common DiaB Systems

Left: Skydio Dock. Center: DJI Dock 2. Right: Percepto Sparrow Dock.

Task 3: Preparation and submission of FAA waiver for BVLOS operations.

The first step in evaluating the BVLOS waiver process will be a thorough analysis of current successfully authorized waivers. A synopsis of the operational characteristics, UAS utilized, technologies incorporated, and limitations applied by the FAA will be compiled. Also, as part of this task the research team will interview NASA participants in the BVLOS studies at Langley Research Center. This task will also include consultation with the FAA on the specific research we anticipate, and the potential pathways for the waiver application. In consultation with the MDT and the research priorities moving forward, we will design a schedule of testing and evaluation to help move the MDT towards fully remote BVLOS operations. The secondary goal of this task is to help MDT develop the knowledge and experience to submit their own waivers for advanced UAS operations.

Task 4: Staged testing of DiaB operations.

We anticipate that the FAA will require a tiered approach to fully remote (and potentially autonomous) BVLOS operations in cellular communication denied environments. This staged approach will most likely include simulated BVLOS operations with a PIC in visual line of sight (VLOS), simulated BVLOS with the PIC in close proximity but without visual line of sight, and BVLOS with the PIC off-site with fully remote control of the UAS, and finally with BVLOS ops with remote PIC in a cellular-denied environment.

These simulations will take place in the extremes of temperature encountered in Montana. There will be approximately 1 week of field testing in late summer, and 1 week in winter. The standard operating procedures, training materials, and knowledge transfer sessions will be developed, to the extent possible, in advance of the field testing scenarios, and will incorporate any lessons learned during the field testing. These field tests will have video logs to show verifiable proof that the operations were conducted in compliance with the FAA waiver, and also to aid in any troubleshooting, debriefing, analysis of unexpected behaviors or situations, etc.

MDT has identified two potential locations for this field testing: Hwy 12 east of Roundup in Verizon cellular dead zone and Hwy 200 east of Missoula in Verizon cellular dead zone. The final determination on the location/locations of the test zone will be determined based on the results of Task 1, logistical considerations based on the DiaB system availability, and the availability/schedule of the AASO, MDT, and Frontier Precision research participants.

Task 5: Analysis of potential applied use-case scenarios incorporating MDT Maintenance, UAS Program, and the TMC.

Through interviews with MDT staff in the Maintenance, UAS, and TMC groups, the research group will develop a list of scenarios with which to evaluate in the field in Phase II. This list could include such scenarios as a remote (outside of cellular communication) multivehicle crash within a work zone. Potential applications will be workshopped to see how the DiaB system could interface with the maintenance, UAS, and TMC groups to provide early detection, verification, and deployment of resources to address the incident.

INTELLECTUAL PROPERTY

During Phase I we do not anticipate any concerns with intellectual property. As we get into Phase II and Phase III, we will consult with MDT on any potential or actual concerns that involve intellectual property.

MDT AND TECHNICAL PANEL INVOLVEMENT

The research team will seek the MDT Technical Panel guidance in any major decisions that need to be undertaken to achieve the goals of the research. Some examples of potential topics to be addressed include any necessary changes to procedures, equipment, software, communications, DiaB testing locations, etc. We will do our best to respect the time of the Technical Panel members and to give a reasonable time to review and discuss and respond within about 2 weeks to any questions. We will request that the Technical Panel review final drafts of any deliverables, reports, publications, presentations, etc. within 2-3 weeks of their due date.

At this time, we are not requesting access to any MDT equipment, space, or field location access, but as the research progresses, we may ask to interview members of MDT IT support, TMC, etc. Depending on the site selection, we may also request access to a field location and/or work zone area.

One potential request (if feasible) we can anticipate is access to any database or GIS data MDT may have on natural disasters (i.e. past locations of rock falls, RAMP data, Avalanche location data, etc.). This request is flexible but is probably most useful if it is within 1 month of the contract initiation.

For Phases II and III, we request that MDT will provide access to a suitable trailer with a satellite communication system (Starlink) and any required components (i.e. computer, display, cameras, batteries, generator, and solar power

OTHER COLLABORATORS, PARTNERS, AND STAKEHOLDERS

Collin Kemmesat, Frontier Precision and Regional UAS Sales Manager. Collin will manage the subaward with which we will obtain access to the DiaB system for this project. We have already initiated discussion and have agreed on access to a DJI Drone in a Box, but we are exploring other options for the equipment (Skydio S2 DiaB, maybe Skydio X10 DiaB if it is released within the project timeline, maybe others).

For Phase II and III:

- Mary MacLaughlin, UAS Geotechnical Expert and Geological Engineering Professor, Montana Technological University
- Kevin Negus, Communications Expert and Electrical Engineering Professor, Montana Technological University

We have had some initial discussions about the project, and Mary and Kevin have indicated an interest in collaborating. Mary will research and determine the sensor system that would be the best fit for the early warning system for rockfalls, landslides, and avalanches and will conduct the rock fall experiments. Kevin will plan and manage the communication systems for the trailer sensor system and design the trigger mechanism to alert responsible parties of a natural disaster.

PRODUCTS

This research will result in quarterly Progress Reports, Task Reports for each of the 5 tasks detailed in the Research Plan, and a Final Report with recommendations, an Implementation Plan, a Performance Measures Report, and a Final Presentation, following MDT's Report Writing Requirements. In addition to the required reporting, there are some unique deliverables that will be included by the end of the project timeline.

The GIS analysis will result in a geodatabase (and any accompanying code or tools used to analyze the data) with which to access the level of susceptibility of transportation infrastructure to natural hazards (i.e. floods, rock falls, landslides, earthquakes, avalanches, etc.). MDT will be consulted to determine the preferred file formats, coordinate systems, and metadata requirements to provide data that is fully compatible with current MDT workflows, standard operating procedures, and reporting requirements.

The details of the FAA Waiver for BVLOS operations will be decided in consultation with the MDT to ensure MDT staff has the experience and ability to apply for more advance operations during Phase II and III. For example, as far as we are aware, there have been BVLOS waivers awarded for remote operations, but there have not been any BVLOS waivers that allow for "remote and autonomous operations simultaneously". A scenario that may encompass this "remote and autonomous" operation could be that a sensor system is triggered in response to a natural disaster and the MDT staff PIC is alerted via text and the PIC remotely plans and executes an automated flight plan to obtain photogrammetric survey photos to create a 3D model of the rockfall area to calculate the volume of the rockfall in the roadway.

Another unique deliverable of this research will be a video log of each of the test flights. The purpose of these video logs is to provide a digital record that each of the flights was conducted under the tiered terms of the BVLOS waiver for the MDT and the FAA. They will provide a record of any unexpected circumstances, unusual UAS flight behaviors encountered, or as a record that the flight operations were conducted as planned, the UAS equipment behaved as expected, and no unusual circumstances were encountered. The standard operating procedures for the operation of the DiaB system would also be developed based on the UAS equipment and results of the test flights.

The final deliverable that will unique (but included in the Implementation Plan) will be a thorough investigation of potential scenarios in which the MDT UAS Maintenance department and the TMC department could benefit from a DiaB trailer. This plan will be developed based on extensive interviews with staff in both departments, to determine where a DiaB could be most efficiently and adaptively applied to advance the priorities of both departments. This plan will include cybersecurity and safety concerns, telecommunication strategies, equipment compatibility, and logistical details.

RISKS

All UAS flights have a potential for some level of risk, and under 14 CFR Part 107, the responsibility for minimizing the risk falls on the pilot in command. There are tools that the PIC can utilize to help reduce the risk. In this case, a tiered approach, adopting progressively more complex operations in sparsely populated areas will keep the risk to an acceptable level (medium to low). Likewise, extensive flight planning, situational awareness, and the development of agile standard operating procedures are critical for minimizing risk. Under Task 3, we will develop a risk matrix showing that procedures will be undertaken to show that there is a low likelihood of an incident (i.e. failure, crash, etc.), and if there is an incident that it will result in minimal damage (potential damage to the UAS, but no accidents or injuries to the crew or public).

There is some risk that the FAA will not approve a waiver for BVLOS, and in fact the failure rate overall for BVLOS is high for those without a proven track record in requesting waivers (Ruppecht, 2024). The plan to ensure a successful waiver application is developed, is to interview multiple individuals and organizations that are currently conducting BVLOS operations. This includes DiaB manufacturers, AKDOT, NASA, and the FAA. It is advisable to gain a full understanding of the regulatory framework, any limitations of the equipment and technology, and to learn from the mistakes of others before testing new equipment and technologies.

IMPLEMENTATION

The primary methods in which the findings of this research will be reported will be geospatial data (geodatabases, maps, tools, code), interview and meeting summaries, a digital record of the FAA BVLOS waiver, the video log of all the test flights, standard operating procedures, and quarterly, task-oriented, and final reports. The geospatial analysis of the natural hazard risk to transportation, will be evaluated by UM experts in geostatistics, and will be available to MDT engineers and administrators to utilize for resource planning and allocation. It is expected that the application and implementation of the research results would be initiated and managed by the MDT UAS Maintenance Department.

The methodology to create a successful FAA BVLOS waiver could be broadly applicable to other state DOTs. The field testing of BVLOS operations in the extremes of temperature would be particularly informative to state DOTs in northern climates and/or the higher altitudes of the mountain west of the US. Although this is a rapidly changing technology, the background research and interviews with vendors and experts in BVLOS will provide a snapshot of the state-of-the-state of DiaB technologies, an evaluation of the specifications and costs of the currently-available-off-the-shelf (COTs) DiaB systems on the market, and guidance on the decision-making for the system utilized in the field testing. The field testing and SOPs developed during the research may speed adoption for the technology in the domain of disaster response, but also in the domains of inspection (bridges, roads, railways, etc.), monitoring (traffic speed, congestion, work zones, etc.), and safety (accident response, hazmat, digital message board management, etc.).

There are a few simple metrics that we will utilize to determine the measure of success for this research.

- For Task 1, we will monitor the ability of the natural hazard susceptibility model to predict natural hazards to transportation infrastructure (i.e. were the locations of natural hazards-floods, landslides, etc. predicted in the model overlapping with 2024-2025 documented actual locations of natural hazards, and if not why?).
- For Task 2, did we fully explore the current state of the DiaB technology, are there systems and/or experts in the technology that we overlooked?
- For Task 3, were we successful in obtaining a BVLOS waiver and what were the lessons learned in developing the application?
- For Task 4, did we properly prepare and have all the necessary equipment on hand to perform the field testing? Did we properly evaluate all the potential risks to the flight operations (magnetic interference, communications, GPS outages, weather concerns, etc.)? Did we document the flight testing in adequate detail to troubleshoot or modify methods in the case of unsuccessful operations?
- For Task 5, did we conduct interviews at an adequate depth to understand most of the potential scenarios/applications that the UAS Maintenance and TMC groups might encounter where DiaB might provide efficiencies, improvements to safety, or cost reductions, etc.?

There are a few potential barriers to the adoption of DiaB technology that fall into four broad classes: regulations, institutions, technology, and society. The National Airspace is managed and governed by the FAA and there are a few state regulations to consider when utilizing UAS technologies. Although the FAA is moving towards a more favorable regulatory environment for incorporating UAS into the National Airspace, they are reasonably cautious towards advanced

UAS operations, including BVOS. There have been waivers issued, but they have been trending from simple localized operations in time and space to more advanced but still broadly low-risk operations. In the state of Montana, UAS are prohibited from interfering with wildland firefighting operations, and no UAS data can be used as evidence in a trial without a prior warrant for that data.

Institutions are inherently risk-adverse, prone to adopt business-as-usual operations, and slow to adopt new technologies. Businesses are somewhat more agile in their ability to conduct low-risk operations, adopt new technologies, and maintain a competitive edge by incorporating new technologies quickly, especially when they have a large return on investment. Institutions, such as state agencies, are often limited by a lack of funding to provide for their current services, the threat of budget restrictions, and the capacity to engage in activities that may provide future time and cost savings. These institutional barriers can limit the adoption of new technologies that may provide significant returns on investment (cost savings, time savings, efficiencies, etc.).

DiaB technologies are relatively new and there are only a handful of companies that are manufacturing systems. Many of these companies specialize in surveillance, security, and infrastructure, so they are not optimized (as far as the payloads) for natural disaster response or environmental observation. This will likely change over time, because there are multiple (non-DiaB) UAS disaster response solutions currently on the market. One distinct limitation that we have in the largely rural, mountainous western US is the lack of widespread cellular connectivity. Many of these UAS systems depend on communications systems such as 4G/5G for data transfer, airspace situational awareness, and in the case of DiaB systems, remote connectivity. Satellite communications systems like Starlink have been utilized in different applications to provide connectivity in cellular “dead zones”, but as far as we are aware Starlink has not been utilized to provide remote connectivity for remote DiaB operations.

There is a societal tendency to be suspicious of UAS operations as being an arm of a surveillance state, regardless of the actual operations that the UAS are engaged in. This tendency can range from curiosity to animosity. Although UAS operations are becoming more common in agriculture, engineering, environmental monitoring, recreational use, and law enforcement, there is often a public perception (especially in rural areas) that they are being used for some sort of nefarious purpose. These negative connotations can sometimes be counteracted by including the public and/or adjacent landowners in the conversation about what the research is investigating and demonstrating the utility to the agency and the public. There are also valid concerns for the potential for vandalism, disruption, and theft for any operations of UAS in proximity to the traveling public.

SCHEDULE

Table 1: Project Time Schedule

Activities	**Dates**	**2024**												**2025**											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Kick-off Meeting	7/1/24							x o z			z			z			z			z			z		
1- GIS Analysis of Natural Hazards								x																	
Task 1 Report	7/24/24							x o																	
2- DiaB Industry Research									x		x	x	x	x		x	x	x	x						
Task 2 Report	8/7/24								x o																
3- FAA Waiver Preparation									x		x	x	x	x		x	x	x	x						
Task 3 Report	8/21/24								x o																
Decision Point Meeting	9/6/24									x															
4- Staged Testing of DiaB Operations										x															
Field-Testing Late Summer	9/11/24									x															
Field-Testing Winter	2/19/25														x										
Task 4 Report	6/18/25																		x o	x					
Decision Point Meeting	7/2/25																								
5- Analysis of Use-case Scenarios with TMC																									
Task 5 Report	7/30/25																			x o					
Decision Point Meeting	8/13/24																				x				
5- Implementation Report	9/10/25																					x			
6- Final Reporting																									
6a- Draft Final Report	10/15/25																						xo		
6b- Project Summary Report	10/15/25																						xo	x	
6c- Final Report	12/3/25																								xo
6d- Final Presentation	12/17/25																								xo

x = research initiatives

o = deliverable due dates

z = quarterly progress reports

BUDGET

The project budget as a function of level of effort (hourly wages and benefits) is broken down by task in Table 2. In sum, the PI will work a total of 234 hours on all 5 Tasks, totaling $16,314. Both Jonathan and Anna will work for a total of 1280 hours each on all 5 Tasks, totaling $42,094. The total cost in wages and benefits for this Phase I research is $100,502. IDC's at the 25% state rate total $35,051, a subaward of $10,000 will be issued to Frontier Precision for access to a DiaB system. There is a total of $9,702 budgeted for in-state travel, and $20,000 (each item <$5000) for expendable supplies such as computing incidentals, software, batteries, etc.

Table 2: Detailed Project Budget

Labor Expenses													
Person	**Role**	**Kick-off Meeting**	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Total Hours**	**Hourly Wage Rate**	**Total Wages**	**Hourly Benefit Rate**	**Total Benefits**	**Total Cost**
Jeremy Crowley	PI	3	15	67	67	67	15	234	$48	$11,257	$16	$5,057	$16,314
Jonathan Cordova	Pilot /GIS	11	135	333	333	333	135	1280	$25	$32,011	$8	$10,083	$42,094
Anna Moser	GIS	11	135	333	333	333	135	1280	$25	$32,011	$8	$10,083	$42,094
Total:										**$75,279**	**$33**	**$25,223**	**$100,502**
Indirect Cost Assessed on Labor Expenses @ 25%:													$25,126
Total Labor Cost:													$125,628
Direct Expenses													
Subcontractor: Frontier Precision													$10,000
In State Travel													$9,702
Expendable Supplies													$20,000
Indirect Costs Assessed on Direct Expenses @ 25%													$9,926
Total Project Cost:													**$175,225**

Table 3: Travel Budget

Table 3 details the required travel for the Phase I research. We are estimating travel for 2 trips for 2 people totaling 20 nights including rental car and per diem. This estimate includes about 9 days (of which we will incorporate 2 weather days) for the field testing (7-days) in the late summer and winter, and travel to Helena for the Kickoff Meeting and Final Presentation. The total for this travel is $9,702. AASO verifies that travel will be in accordance with FHWA 48 CFR 31. And the per diem will be charged and the entire per diem amount will be paid to the traveler, and that alcohol is not an allowable charge.

Travel				
Assumption		**Number**	**Unit Cost**	**Total**
Airfare				$0
Hotel	2 trips for 2 persons	20	$122.80	$4,912
Rental Car	2 trips, 10 days per trip	20	$65.75	$2,630
Meals	2 trips for 2 persons	20	$54.00	$2,160
Total:				**$9,702**

Table 4: Task, Meeting, and Deliverable Budget

Table 4 breaks down the labor and travel costs for each meeting, task, and deliverable. Tasks 1 and 5 ($5,599 and $6,023) are determined to require a much lower level of effort than Tasks 2 and 3 ($56,051 each), and Task 4 ($23,143) will be a moderate level of effort. The costs for the meetings are relatively minor ($176-$188) and the level of effort to provide the deliverables is proportional to the level of effort to complete the research Tasks.

Task, Meeting, and Deliverable Cost Breakout			
Item	**Labor**	**Travel**	**Total**
Task 1	$5,599	$0	$5,599
Task 2	$56,151	$0	$56,151
Task 3	$56,151	$0	$56,151
Meeting 1: Interim Meeting	$176	$539	$715
Task 4	$15,058	$8,085	$23,143
Meeting 2: Interim Meeting	$176	$539	$715
Task 5	$6,023	$0	$6,023
Meeting 3: Interim Meeting	$188	$539	$727
Deliverable: GIS Analysis	$843	$0	$843
Deliverable: DiaB Market Survey and Analysis	$5,615	$0	$5,615
Deliverable: Project Summary Report	$5,615	$0	$5,615
Deliverable: Implementation Report	$2,808	$0	$2,808
Deliverable: Performance Measures Report	$560	$0	$560
Deliverable: Final Presentation	$560	$0	$560
Total:	**$155,523**	**$9,702**	**$165,225**

Table 5: State Fiscal Year (SFY) (7/1 – 6/30) Breakdown

Item	**State Fiscal Year (SFY)**		**Total Cost**
	2024	**2025**	
Salaries	$55,488	$19,791	$75,279
Benefits	$18,641	$6,572	$25,223
In State Travel	$4,851	$4,851	$9,702
Contract Services- Frontier Precision	$10,000	$0	$10,000
Expendable Supplies	$20,000	$0	$20,000
Total Direct Costs	$113,831	$26,373	$140,204
Indirect Cost – 25%	$28,458	$6,593	$35,051
Total Project Cost:	**$142,289**	**$32,966**	**$175,255**

STAFFING

Table 6: Project Staffing

Name of Principal, Professional, Employee, or Support Classification	Role in Study	Task						Percent of Time vs. Total Project Hours (total hrs./person/total project hrs.)	Percent of Time - Annual Basis (total hours/ person/2080 hr.)
		1	2	3	4	5	Total		
Jeremy Crowley	Principal Investigator	18	67	67	67	15	234	8	11
Jonathan Cordova	Pilot/GIS	146	333	333	333	135	1280	45	62
Anna Moser	GIS Analysis	146	333	333	333	135	1280	45	62
Editor*	Report Preparation, Editing, and Review	10	20	20	20	10	50	2	2
TOTAL		320	753	753	753	295	2844	N/A	N/A
* No cost to MDT									

Jeremy Crowley, the PI and Director of the AASO, is a licensed GIS Professional (GISP), Professional Geologist (PG), and FAA Part 107 Remote UAS Pilot, and Unmanned Safety Institute (USI) Primary UAS Instructor for Part 107 Prep, Safety Level 1, Visual Line of Sight Operations (VSO) Ground and Fight Operations. Jeremy helped develop the Montana Bureau of Mines and Geology UAS program and is an instructor for Montana Technological University's UAS Certificate, and University of Montana's GIS Certificate. As an FAA Part 107 Remote UAS Pilot since 2017, Jeremy has trained hundreds of pilots in MT and AK to pass their Part 107 exam. Jeremy has published peer-reviewed papers on UAS thermal, multispectral, and RGB (Red, Green, Blue) photogrammetry, and artificial intelligence (AI) predictions using satellite data. Jeremy has currently funded projects with the USFS (5%), MT Fish Wildlife and Parks (5%), National Institute of Health (10%), and MT Established Program to Stimulate Competitive Research (EPSCoR- 10%) that total about 30% of his current workload, so he has 70% of his time available to directly supervise and participate in this Phase I research.

Jonathan Cordova is a UAS Pilot and GIS Analyst with AASO. He recently graduated with a BS in Geography from UM along with a GIS Certificate. Jonathan has worked as a UAS pilot and intern for AASO since 2022. Jonathan is working about 10% of his time on a USFS contract, so he has 90% of his time available to work on this project.

Anna Moser is a UAS Pilot and GIS Analyst with AASO. Anna recently graduated with her MS in Geography and GIS Certificate from UM. Anna has worked as UAS Pilot and GIS Analyst with AASO since 2023. Anna is working about 20% of her time on a USFS contract, so she has 80% of her time available to work on this project.

Collin Kemmesat is Frontier Precision's and Regional UAS Sales Manager. Collin will manage the subaward with which we will obtain access to the DiaB system for this project. Collin has been the head of Unmanned Technical Sales for about 4 years and has experience with DiaB systems and their associated communication/data link systems. Collin has agreed to be present as an advisor for the approximately 1-week DiaB field testing in late summer and 1-week in winter.

AASO has evaluated the level of effort required for this Phase I research and verifies that we have the capacity to complete this work within the timeframe detailed in the project schedule, if there are unforeseen circumstances that require any changes to the research team, we will obtain written consent from MDT approving any changes.

Table 6 details the project staffing by task and the percentage of time vs. total project hours and the percent of time on an annual basis by staff.

FACILITIES

The University of Montana Autonomous Aerial Systems Office (AASO) was one of the earliest groups in Montana to be awarded a series of Federal Aviation Authority (FAA) Certificate of Authorizations (COAs). These COAs (or waivers) include authorization to conduct UAS operations up to 10,000 ft AGL, nighttime flights (before they were incorporated into Part 107), and daisy-chain operations. Daisy-chain operations are when the pilot in command (PIC) can hand off UAS operations to another PIC to maintain visual line of sight for the UAS. Daisy-chain operations are a direct precursor for beyond visual line of sight (BVLOS) operations. During Stage 1 we will apply for COAs or waivers for the project areas of interest for BVLOS.

AASO operates under strict adherence to all FAA regulations regarding CFR Part 91 (general flight operations), Part 107 (commercial sUAS rule), Part 47 (aircraft registration), Part 48 (marking requirements), and Part 71 (Airspace designation). We also adhere to the newest regulations regarding flight over humans, flight at night, and remote identification (RID). All our current (and future) UAS are registered in DroneZone with the FAA. We have conducted hundreds of safe and legal flights using the low altitude authorization and notification capability (LAANC) using a variety of multirotor and fixed wing UAS. AASO is familiar with the Blue and Green UAS lists and will utilize US-made UAS for research and training when possible, for this project, in accordance with Executive Order 14005 “Ensuring the Future is Made in America by All of America’s Workers” and the requirements of § 70914(a) “Build America, Buy America” Act. In the event that US-made UAS are not available for the research and training, a secure third-party US-based application (i.e. FlyteBase) will be utilized to ensure that secure communications are enabled without the use of foreign servers.

MDT has a UAS program, a fleet of UAS, and an established training program for MDT employees. MDT employees who will be utilizing UAS attend a rigorous 2-week training program that focuses on FAA Part 107 UAS Remote Pilot test certification and hands on training utilizing UAS. MDT also has a Transport Management Center (TMC) that works to provide remote communications in work zones and remote offices.

REFERENCES

AKDOT, 2023. Alaska DOT&PF launches ARROW drone program to assist communities during emergencies. https://dot.alaska.gov/comm/pressbox/arch2023/PR23-0017.shtml Accessed June 10, 2024.

Aloft, 2024. Aloft introduces automated SGI waivers in Aloft Air Control, streamlining access to restricted airspaces. https://www.aloft.ai/blog/aloft-introduces-automated-sgi-waivers-in-aloft-air-control-streamlining-access-to-restricted-airspaces/ Accessed June 6, 2024.

Druga, M., 2024. FTA awards nearly $110M to help agencies recover from natural disasters. https://transportationtodaynews.com/featured/32270-fta-awards-nearly-110m-to-help-agencies-recover-from-natural-disasters/ Accessed June 12, 2024.

FAA, 2016. Secure Command and Control Link with Interference Mitigation. [Project]. Federal Aviation Administration. Start date: 8 Aug. 2016. https://rip.trb.org/view/1422582

FAA, 2018. Small UAS detect and avoid requirements necessary for limited BVLOS operations: separation requirements and training. [Project]. Federal Aviation Administration. Start date: 1 Jun. 2018. https://rip.trb.org/view/1562140

FAA, 2023. Unmanned aircraft systems, advanced operations, emergency situations. https://www.faa.gov/uas/advanced_operations/emergency_situations Accessed June 6, 2024.

FAA, 2024. Part 107 waivers issued. https://www.faa.gov/uas/commercial_operators/part_107_waivers/waivers_issued?saa_field_media_file=107.31 Accessed June 6, 2024.

Fang, S., O'Young, S., and Rolland, L., 2018. Development of small UAS beyond-visual-line-of-sight (BVLOS) flight operations: system requirements and procedures. Drones. 2, 13. http://doi:10.3390/drones20200013

FHWA, 2021. A UAS Network for Transportation Emergency Response. [Project]. Federal Highway Administration. Start date: 1 Mar. 2021. https://rip.trb.org/view/1851852

FHWA, 2023a. Use of unmanned aircraft systems (UAS) to enhance the design, construction, inspection, and maintenance of transportation infrastructure. FHWA Global Benchmarking Program Study Report, RPT NO FHWA-PL-23-007.

FHWA, 2023b. Integrated Avalanche Detection Warning & Snow Distribution Mapping. [Project]. Federal Highway Administration. Start date: 4 Apr. 2023. https://rip.trb.org/view/2190089

FHWA, 2023c. Tech Brief- Use of unmanned aircraft systems for earth movements. FHWA-HIF-23-069. https://www.fhwa.dot.gov/uas/resources/hif23069.pdf

Government Technology, 2024. Cambria, Count, PA., nets $2M grant for emergency drones. https://www.govtech.com/health/cambria-county-pa-nets-2m-grant-for-emergency-drones Accessed June 12, 2024.

Koks, E., Rozenberg, J., Zorn, C., Tariverdi, M., Vousdoukas, M., Fraser, S., Hall, J., and Hallegatte, S., 2019. A global multi-hazard risk analysis of road and railway infrastructure assets. Nature Communications. 10, 2677. https://doi.org/10.1038s41467-019-10442-3

Landslide Technology, 2015. Montana Rockfall Slope Asset Management Program (RAMP). Landslide Technology :: Projects : Montana RAMP - LANDSLIDE TECHNOLOGY Accessed June 12, 2024.

MBMG, 2024. Montana Geology, Geohazards. https://www.mbmg.mtech.edu/MontanaGeology/geohazards/main.asp#gsc.tab=0 Accessed June 6, 2024.

NASA, 2023. Safety case for small uncrewed aircraft systems (sUAS) beyond visual line of sight (BVLOS) operations at NASA Langley Research Center. NASA/TM-20230003007.

NOAA, 2024. Storm events database. https://www.ncdc.noaa.gov/stormevents/ Accessed June 6, 2024.

RT&S, 2023. MassDOT issued BVLOS waiver to fly drones over rail network. https://www.rtands.com/regulatory/massdot-issued-bvlos-waiver-to-fly-drones-over-rail-network/ Accessed June 6, 2024.

Politi, E. Purucker, P., Larsen, M., Dos Reis, R., Rajan, R., Penna, S., Boer, J., Rodosthenous, P, Dimitrakopoulos, G., Valamis, I., and Hob, A., 2024. Enabling technologies for the navigation and communication of UAS operating in the context of BVLOS. Electronics. 13, 340. https://doi.org/10.3390/electronics13020340

Rupprecht, J., 2024. Ultimate guide to drone in a box ops (laws, tips, lists, problems, companies)

https://jrupprechtlaw.com/drone-in-a-box/ Accessed June 12, 2024.

Sarbanes, 2024. Maryland delegation members announce over $6 Million to improve transportation and health technology, safety in Maryland. https://sarbanes.house.gov/media-center/press-releases/maryland-delegation-members-announce-over-6-million-improve Accessed June 12, 2024.

The Drone Girl, 2023. BVLOS approval: these four drone companies now hold the coveted FAA authorization. https://www.thedronegirl.com/2023/09/29/bvlos-approval-faa/ Accessed June 12, 2024.

Stone, T., 2022. Traffic Technology Today. USDOT to provide over $513m to repair natural disaster damage. https://www.traffictechnologytoday.com/news/funding/usdot-to-provide-over-513m-to-repair-natural-disaster-damage.html Accessed June 6, 2024.

Tester, 2023. Tester reflects on Yellowstone flood anniversary, celebrates nearly $1B in targeted federal aid. https://www.tester.senate.gov/newsroom/press-releases/tester-reflects-on-yellowstone-flood-anniversary-celebrates-nearly-1-billion-in-targeted-federal-aid/ Accessed June 6, 2024.

UND, 2023. Federal grant to support medicine deliveries by drone. https://blogs.und.edu/press-releases/2023/03/federal-grant-to-support-medicine-deliveries-by-drone/ Accessed June 6, 2024.

USDOT, 2022. USDOT announces promoting resilient operations for transformative, efficient, and cost-saving transportation (PROTECT) program. https://content.govdelivery.com/accounts/USDOTFTA/bulletins/325c736 Accessed June 6, 2024.

UTCP, 2020. Mining of Unmanned Aerial System Operations and Data to Improve Emergency Operations during Natural Disasters. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 1 Aug. 2020. https://rip.trb.org/view/1751140

UTCP, 2023. Corridor-wide Surveillance Using Unmanned Aircraft Systems Phase III: Exploration of the Implementation of Using Unmanned Aircraft Systems for Freeway Incident Detection and Management. [Project]. Office of the Assistant Secretary for Research and Technology. Start date: 1 Jun. 2022. https://rip.trb.org/view/2004402