September 2023 | FHWA-HIF-23-060

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EDC-5 UAS Peer-to-Peer Exchange

Lakewood, Colorado

August 10-11, 2022

U.S. Department of Transportation
Federal Highway Administration

TECHNICAL DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
FHWA-HIF-23-060</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
EDC-5 Unmanned Aerial Systems (UAS) for Peer Exchange in Lakewood, Colorado</td><td colspan="2">5. Report Date
October 2023</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Jagannath Mallela PhD, Paul Wheeler, Aaron Organ</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
WSP USA Inc.
1250 23rd Street NW, Suite 300
Washington, DC 20037</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
HIF190085PR</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Federal Highway Administration
Office of Infrastructure
1200 New Jersey Ave, SE
Washington, DC 20590</td><td colspan="2">13. Type of Report and Period Covered</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes</td></tr>
<tr><td colspan="4">16. Abstract: This peer exchange brought together representatives from the Colorado, New Mexico, and Utah Departments of Transportation. The peer exchange facilitated discussion and collaboration around Unmanned Aircraft Systems (UAS) practices and UAS use cases across infrastructure inspections, emergency response, water quality, surveying, mapping, construction, and risk management. While the three transportation agencies are at various stages of implementing UAS across operations, each agency reported benefits from utilizing UAS. The information contained within this report was up-to-date at the time of the peer exchange on August 10-11, 2022.

Cover Page Image Credits: The top five images in the banner were provided by Getty Images. The larger, lower photo was provided by Adobe Stock Images.</td></tr>
<tr><td colspan="2">17. Key Words
UAS, Unmanned Aircraft Systems, Uncrewed Aircraft Systems</td><td colspan="2">18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service Alexandria, Virginia 22312</td></tr>
<tr><td>19. Security Classif.(of this report)
Unclassified</td><td>20. Security Classif.(of this page)
Unclassified</td><td>21. No. of Pages
26</td><td>22. Price</td></tr>
</table>

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ACRONYMS AND ABBREVIATIONS

3D	Three-dimensional
AI	Artificial Intelligence
CDOT	Colorado Department of Transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GCP	Ground Control Point
HWM	High Water Marks
LiDAR	Light Detection and Ranging
MS4	Municipal Separate Storm Sewer System
NMDOT	New Mexico Department of Transportation
SMS	Safety Management System
SOPs	Standard Operating Procedures
STIC	State Transportation Innovation Council
UAS	Unmanned Aircraft Systems
UDOT	Utah Department of Transportation
U.S.C.	United States Code
USGS	United State Geological Survey

INTRODUCTION

As part of the Federal Highway Administration (FHWA) Every Day Counts Unmanned Aircraft Systems (UAS) Initiative, the Colorado Department of Transportation (CDOT) hosted a peer exchange in Lakewood, Colorado, on August 10-11, 2022. Personnel from the Utah Department of Transportation (UDOT), and New Mexico Department of Transportation (NMDOT) were among those in attendance. The goal was to share how the three DOTs use UAS across its operations, discuss practices, and foster collaboration. This report provides an overview of the UAS programs at CDOT, UDOT, and NMDOT as presented and outlines the information presented at the peer exchange along with the findings from the various round table discussions. The information was up-to-date at the time of the peer exchange.

FAA REGULATIONS

UAS operators in both the public and private sectors must also adhere to statutory and regulatory requirements. Public aircraft operations (including UAS operations) are governed under the statutory requirements for public aircraft established in 49 USC § 40102 and § 40125. Additionally, both public and civil UAS operators may operate under the regulations promulgated by the Federal Aviation Administration. The provisions of 14 CFR part 107 apply to most operations of UAS weighing less than 55 lbs. Operators of UAS weighing greater than 55 lbs may request exemptions to the airworthiness requirements of 14 CFR part 91 pursuant to 49 USC §44807. UAS operators should also be aware of the requirements of the airspace in which they wish to fly as well as the requirements for the remote identification of unmanned aircraft. The FAA provides extensive resources and information to help guide UAS operators in determining which laws, rules, and regulations apply to a particular UAS operation. For more information, please see https://www.faa.gov/uas/.

CDOT UAS PROGRAM

OVERVIEW

At the time of the peer exchange, CDOT reported having 15 certified remote pilots with 5 additional individuals preparing to take the Federal Aviation Administration (FAA) remote pilot written exam. One of CDOT's ongoing concerns is keeping certified remote pilots current and proficient in using UAS. Only half of CDOT's current remote pilots are actively using UAS. CDOT has goals of securing funding that will assist with ongoing training for all remote pilots within the organization. CDOT currently owns and operates 6 UAS aircraft and uses software to document each operation and is working to optimize its UAS program.

CURRENT USE CASES

CDOT reported that staff from the Survey, Geohazards, Water Quality, and Bridge Inspections departments were all using UAS, working to expand UAS use, and exploring other potential use cases.

Surveying

CDOT has started using UAS for survey applications (Figure 1). Some of the UAS platforms are used to acquire photos and capture the aerial perspective, while other projects have started to use photogrammetry to create models. CDOT has one Light Detection and Ranging (LiDAR) sensor mounted on a larger UAS platform that has been deployed on survey projects. Because of the higher cost of the LiDAR sensor, personnel have been using smaller UAS to conduct reconnaissance and search for obstacles in the Area of Interest prior to using the larger UAS LiDAR sensor. CDOT reported finding success in using UAS as a supplemental tool to conventional survey tools and plans to expand UAS use for this use case.

Figure 1. CDOT Using UAS for Reconnaissance Prior to LiDAR Surveying Operation. (Source: CDOT)

Geohazards

Site documentation and geohazard modeling (Figure 2) using UAS have been explored by CDOT. UAS are being used to assist in ongoing monitoring of earth movements at various locations in Colorado. UAS-collected data, including photos, videos, and LiDAR data are being used to create change maps and three-dimensional (3D) models. CDOT reported these rich data sets are assisting in making more data-driven decisions. Recently CDOT began outsourcing some of the geohazard UAS work to access better equipment and expertise. This recent move has enabled CDOT to focus more on the data processing and management piece while receiving high-quality UAS data from the consultants and their equipment.

Figure 2. Example of UAS Data in Geohazards Work. (Source: CDOT)

Water Quality

One of CDOT's primary goals for UAS is to use it as a supplemental tool to improve permanent water quality inspections and wetland delineations. The agency is looking to augment Municipal Separate Storm Sewer System (MS4) construction site inspections for storm drainage systems and is exploring the use of artificial intelligence (AI) software to detect settlements.

Information was shared about research on CDOT's Permanent Water Quality Project. A primary goal of this project was to determine if UAS could be used to calculate water quality capture volume of the CDOT-managed detention basin. Another goal was to accomplish these volume calculations more efficiently and for less cost than traditional methods. The project team found that UAS LiDAR and photogrammetry data can be used to perform these calculations.

As part of the same project, UAS have been used to analyze the vegetation of extended detention basin areas as seen in Figure 3 and to perform remote wetlands detection where UAS detect wetlands and collect data for analysis regarding the health of wetland environments. Research team members reported that they discovered the flight altitude of the UAS affected data collection—flights flown at the maximum height of 400 feet above the ground provided better data about the vegetation and saved a lot of time. Figure 4 depicts one of these wetland analyses.

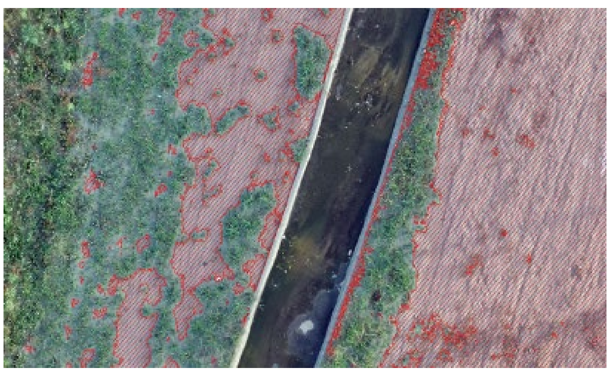

Figure 3. Vegetation Analysis. (Source: CDOT)

Figure 4. Wetlands Analysis. (Source: CDOT)

Bridge Inspections

Figure 5. CDOT UAS on Bridge Inspection. (Source: CDOT)

CDOT recently acquired a new UAS platform for bridge inspections as seen in Figure 5 but had issues finding a tablet that was compatible with both the UAS and the documentation software. CDOT is currently using UAS to supplement traditional bridge inspection methods and analyzing additional ways UAS can be leveraged for bridge inspections.

Research also is underway on data-driven bridge management using descriptive and predictive machine learning models. The project is focused on designing, developing, and testing a bridge deterioration forecasting machine learning model. Factors considered that affect bridge deterioration are the materials, design, daily traffic, and climate. Bridge reporting data include sufficiency rating, condition rating, structure identification, year built, average daily traffic, and average daily truck traffic. To help inform the machine learning model, data from various sources are being used, including the National Bridge Inventory from 1992 to current day, the National Oceanic and Atmospheric Administration climate data set, and the Colorado Online Transportation Information System dataset. At the time of the peer exchange, the research team was testing and evaluating the system for results.

Emergency Management

United States Geological Survey (USGS) Colorado Water Science Center staff presented on UAS use in flood management and avalanche risk mitigation efforts.

The USGS team reported that UAS has provided the following benefits:

- Remote access to inaccessible locations.
- High resolution data.
- Ability to cover large areas.
- Ability to deploy rapidly.
- Improved personnel safety.

USGS reported that collecting topography data with UAS and using photogrammetry methods has both advantages and disadvantages. The advantages are that data collection is relatively fast, produces high resolution data, and is the relatively cheaper option. Disadvantages include not being able to penetrate dense vegetation or water and the possible need for ground control points (GCPs).

According to USGS, collecting topography data with LiDAR sensors also has advantages and disadvantages. UAS with LiDAR sensors can quickly capture an area and produce high-resolution data; these sensors can also penetrate the vegetation to collect data beneath the vegetation. However, LiDAR sensors are expensive, especially water-penetrating LiDAR, which is highly specialized and therefore may be cost prohibitive. In addition, LiDAR sensors cannot penetrate turbid water.

LiDAR and photogrammetry and various software data processing products can be used to evaluate flood patterns, determine flood risk, and analyze High Water Marks (HWMs) as seen in Figure 6. Data can be collected quickly with UAS while HWMs are fresh, even when site access is poor. Locating HWM aerially rather than on the ground is easier, and remote measurements are safer to collect immediately post flood.

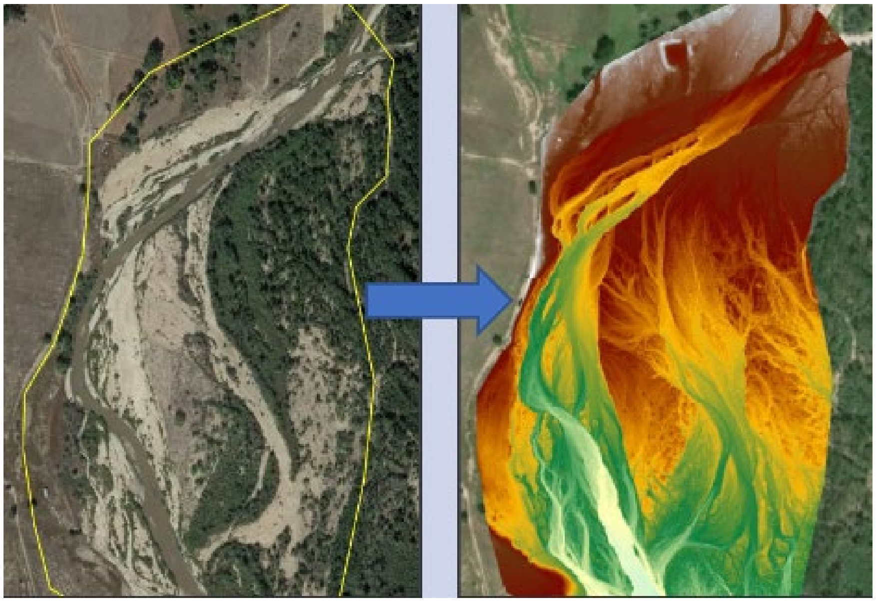

Figure 6. Flood Risk Analysis with UAS Collected Data. (Source: USGS)

The USGS team also uses UAS to evaluate avalanche risk near CDOT assets such as bridges and roadways. Traditional avalanche risk analysis methods typically employ back-country skiing in the Area of Interest and then digging snow pits or towing radar sleds as seen in Figure 7.

Ground-penetrating radar attached to UAS can measure snow depth and snow stratigraphy. The UAS-collected data assist in identifying avalanche-prone regions near CDOT assets and support with data-driven decisions regarding active avalanche mitigation.

Figure 7. Traditional Avalanche Risk Analysis. (Source: USGS)

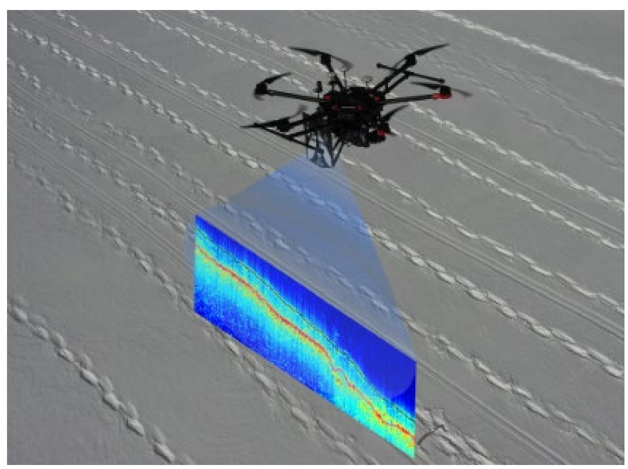

Figure 8. UAS Avalanche Risk Analysis. (Source: USGS)

NMDOT UAS PROGRAM

OVERVIEW

NMDOT is in the initial stages of organizing a formal UAS program and has assigned staff to integrate UAS into the agency's operations. Different offices within the NMDOT use UAS for surveying and report success in terms of efficiency and capturing quality data for design purposes. NMDOT is looking into UAS use for data processing and storage, automated data interpretation software, policy implementation, field implementation, and training. NMDOT presented how it plans to incorporate UAS into future use cases.

FUTURE USE CASES

Infrastructure Inspection

Figure 9. UAS Image of the Rio Grande Gorge Bridge. (Source: NMDOT)

NMDOT showed a UAS 3D scan of the State's largest bridge (Figure 9). As the agency grows its UAS program, it plans to integrate UAS as a supplemental tool for bridge inspections throughout the State.

New Mexico is home to significant railroad infrastructure, including rail yards where railroad bridges are often present. The agency plans to use UAS to assist in inspections of these railroad bridges. Extreme height, the presence of numerous sets of tracks, or crossing over water often make these bridges challenging to inspect (Figure 10). Traditional methods of inspection include using binoculars or accessing the bridge via a boat (when it is located over water). NMDOT reports these methods are less than ideal, and it anticipates that using UAS for these types of inspections will increase safety, produce cost savings, and reduce impacts on the public and train operators.

Figure 10. Difficult Access to Bridge Over Water in Need of Continual Monitoring. (Source: NMDOT)

NMDOT is also investigating UAS use for other infrastructure inspections, including confined spaces, tunnels, culverts, and in emergency assessments. It hopes that UAS can be a supplemental tool and help monitor problem areas without using traditional means such as hydro platforms or trucks that use articulated booms to lower a bucket down the bridge deck side and then underneath for inspections. The tunnel depicted in Figure 11 is key to access other parts of the State; the necessary detour adds about 100 miles to the trip. Although NMDOT provides a two-week notice on when the tunnel will be closed for inspection, issues still arise with the traveling public and especially emergency response vehicles. The anticipated benefit for this tunnel and other tunnel inspections is that they will remain open during UAS-assisted inspections.

NMDOT also plans to implement UAS in culvert inspections, especially in problem areas in need of regular monitoring (Figure 12). It is anticipated UAS can assist in accessing hard to reach areas and increase time and cost savings.

Figure 11. New Mexico Tunnel. (Source: NMDOT)

Figure 12. Deteriorating Culvert Infrastructure. (Source: NMDOT)

UDOT UAS PROGRAM

OVERVIEW

In 2010, UDOT began research to analyze potential uses with a fixed-wing UAS. In 2016, a formal committee was created to establish goals and guide the standup of a UAS program. At that time, UDOT had one certified remote pilot, and the agency purchased its first UAS. By 2018, UDOT had 10 certified remote pilots and was using six UAS to explore a variety of uses. As of 2021, UDOT owned and operated 48 UAS platforms and employed 50 certified remote pilots. UDOT's UAS operators and UAS committee members worked with the UDOT Division of Aeronautics to create an automated mission approval application. The way the system works is by conducting geospatial inquiries to check the location of the proposed mission against the airspace, Active Notices to Airman, and other potential hazards or risk factors. Operators are either given an automated approval or denial. If the request is denied by the system, the request is sent to the approval team for closer review. UDOT reported that its UAS approval system is increasing safety and assisting in tracking the use of the 50 UAS within the agency and helping prove utilization.

USE CASES

UDOT is using UAS in surveying, mapping, bridge inspections, pavement inspections, airport inspections, emergency response, and asset management. UDOT's UAS program has grown across these different use cases, and the agency is in the process of fine tuning its SOPs, workflows, training requirements, and other aspects to mature the program. This section provides examples of various UAS uses throughout Utah.

Surveying

According to UDOT, many Utah surveyors are using UAS in addition to traditional survey tools to produce data. UDOT reports success with hybrid models, using a combination of data from different tools such as UAS, terrestrial LiDAR, GPS rovers, and Total Stations. These hybrid models maximize benefits, reduce the weaknesses inherent in each tool, increase productivity and safety, and allow data from the best possible sources to be combined. Figure 13 depicts one of these hybrid models.

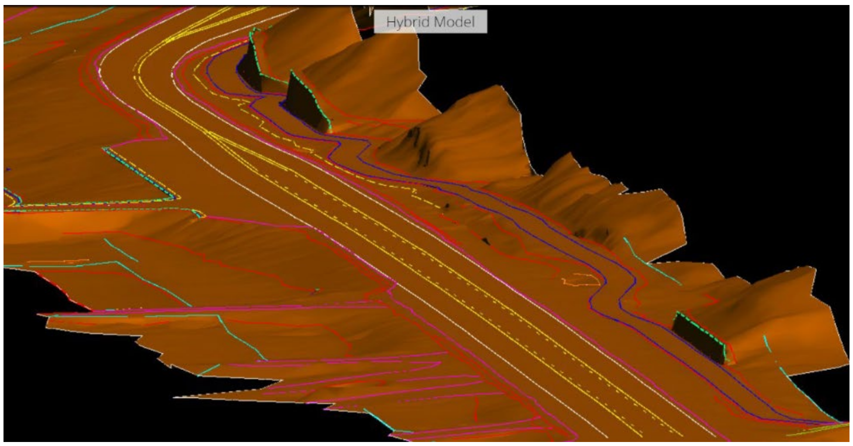

Figure 13. Hybrid Data Model. (Source: UDOT)

UDOT has found that GCPs can be very helpful when using UAS for surveying. Useful GCPs characteristics to consider include using a variety of targets, using existing objects, choosing GCPs that are highly visible from altitude and having high contrast. UDOT reports the following best practices when using GCPs:

- Keep GCPs no more than 1,000 feet from each other.
- Employ 5-Sided Die or the Ladder method. (Figure 14 demonstrates the 5-Sided Die method)
- Randomize GCPs throughout data collection area.
- Avoid placing GCPs on the edges of the flight data except when accounting for overlap on multiple days of data collection.
- Have targets large enough for ground sampling distance.
- Avoid obstructions and shadow areas.

Figure 14. UDOT GCP Layout on Construction Project. (Source: UDOT)

UDOT has found that UAS use can result in time savings, cost savings, and increased safety. A specific project where UDOT reaped these benefits is provided in Figure 15, which shows a 3D model created from UAS-collected data of a runaway truck ramp. UAS were used to map the area and gather data that was then used to compare two design options to understand which would be best for the project. Because of the UAS-collected data and the earthwork quantities comparison, UDOT saved an estimated $500,000 by making data-driven decisions regarding the best design. Utah surveyors report that UAS-collected data to create 3D models continues to help visualize and communicate project goals.

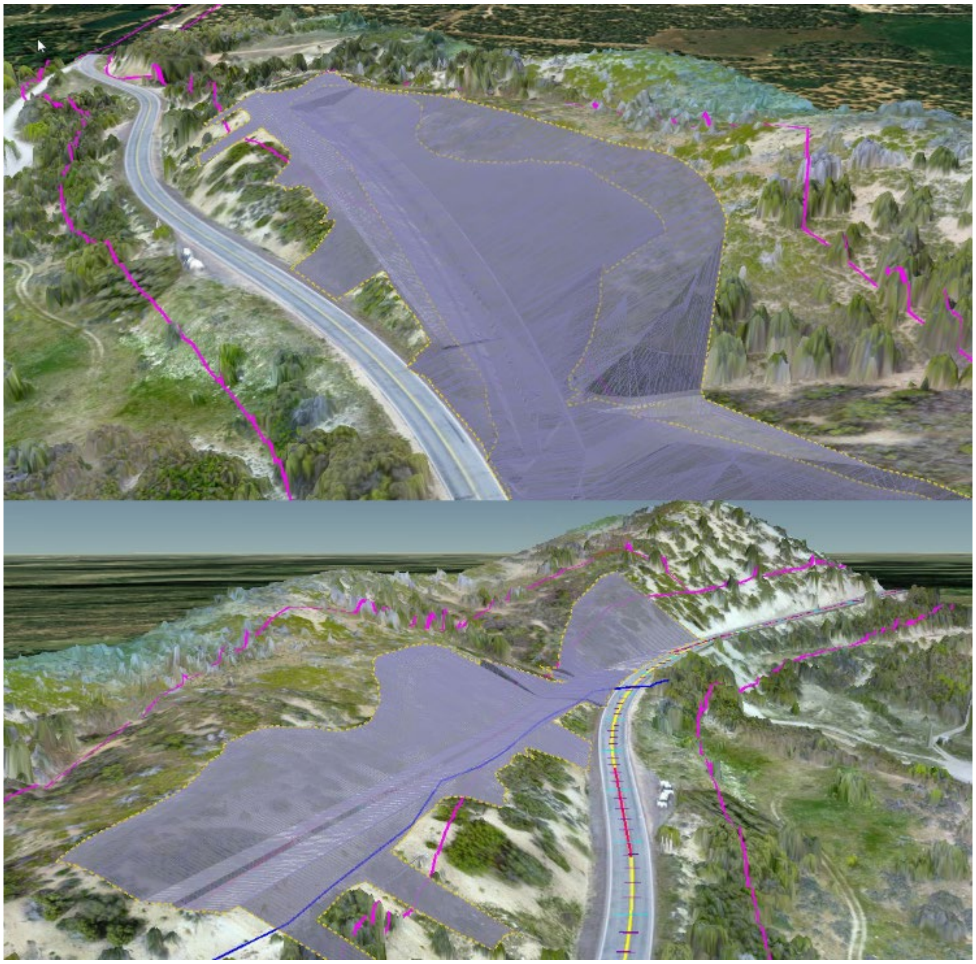

Figure 15. UAS Data Model Design Comparison. (Source: UDOT)

Utah surveyors have also been asked by other UDOT departments to assist in responding to rockslides or other earth movements. The image in Figure 16 is of a large landslide where the concern was that water may have been ponding on top of the fresh slide and could trigger a secondary landslide. UAS were used to provide situational awareness and gather critical data to help inform additional response decisions.

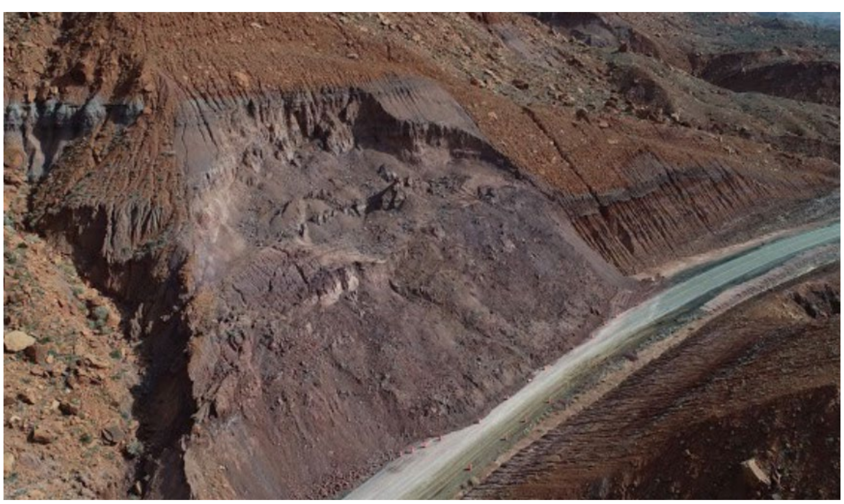

Figure 16. UAS Used to Gather Data on Utah Landslide. (Source: UDOT)

Bridge Inspections

UDOT also uses UAS as a supplemental tool to assist in the inspection of almost 3,000 bridges throughout the State. In 2019, the UDOT bridge inspection team began training personnel with UAS and now all UDOT bridge inspectors are certified UAS remote pilots. UDOT reported it has been working with the local FHWA office to identify bridges that were good candidates for UAS inspections. By using UAS on these identified bridges, UDOT is able to extend the frequency of snooper truck inspections by performing these supplemental inspections using UAS as an additional tool. This has resulted in cost and time savings and has minimized the impact on the traveling public.

UDOT has found that UAS platforms with a lower profile are often more useful in windy environments, especially when structural turbulence is an issue. UDOT also reported that UAS platforms that have cameras that can rotate up and have supplemental lighting are helpful for bridge inspections. UDOT uses two people on each inspection, one to pilot the UAS and a second person to conduct the inspection and be the visual observer. These two people work closely together throughout the entire inspection to gather the right data, perform the inspection, and ensure the safety of the operation.

Figures 17 and 18 are examples of UDOT using UAS to assist in the inspection of a large, curved bridge that overhangs a river with steep embankments. UAS are used to inspect the superstructure and substructure, where a large crack was discovered as seen in Figure 18.

Figure 17. UAS Use on Large Bridge Inspection. (Source: UDOT)

Figure 18. Cracked Substructure Support on Large Bridge. (Source: UDOT)

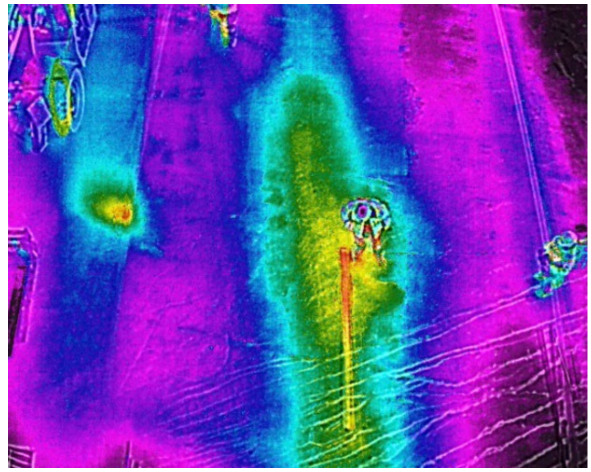

Figure 19. UAS Thermal Analysis of UDOT Bridge Deck. (Source: UDOT)

UDOT has also found benefits to using thermal sensors (Figure 19) on UAS to map bridge decks and detect delamination in the concrete. UDOT staff realized that not all thermal cameras are created equal, and that flying the mission at dusk or dawn with less-sensitive thermal sensors may be helpful.

Incident Management and Emergency Response

UDOT employs UAS across its incident and emergency response operations, with over 25 specialists operating 30 various UAS platforms. The Incident Management Team has developed a robust training program and standards to assist with initial and ongoing training for its certified remote pilots. The training program includes:

- Initial three-day UAS training course (two classroom days and one day flight training and mapping course).
- Additional hands-on training as the remote pilot becomes more proficient.
- Quarterly online training and testing.
- Annual flight and mapping training.
- Seminars and conference training.
- 50 UAS flight hours per year minimum.

UDOT uses UAS to increase oversight of hazards whether natural, human-made, hazardous materials, wildlife mitigation, or e-traffic queues. One of the most common UAS use cases for the incident management specialists are vehicle accidents. UAS provide accident scene situational awareness and can document the scene while collecting high-quality data for accident reconstruction. UDOT reports UAS use has reduced road closure times and saves an average of about two hours in fatal accident investigations.

UAS have also assisted in fire response by providing firefighters an aerial perspective of the fire; identifying hot spots, movement; or direction of the fire; and providing other data that can help in determining the best approach to fight the fire. On larger fires, the aerial situational awareness may also assist in determining where resources and personnel are most needed. Figure 20 depicts a recent grass fire near homes in Utah.

Figure 20. UAS Assisting in Response to Grass Fire. (Source: UDOT)

OTHER PEER PRESENTATIONS

Several other presentations and roundtable discussions occurred during the peer exchange. This section provides an overview of those presentations and the findings from the collaborative discussions.

SOPS, TRAINING, AND CERTIFICATION

A roundtable discussion was held regarding the development of SOPs, training, and certification of remote pilots. CDOT is developing its internal UAS operating procedures and finalizing the sections regarding risk management, traffic control when using UAS, and UAS night operations. CDOT is also still gathering information about software, tools, and best practices for UAS fleet management and maintenance.

UDOT reported that after initial training it has found use case-specific courses or workshops help build proficiency and UAS operator confidence before using UAS in the field. Each of the transportation agencies in attendance indicated the obstacle accomplishing these UAS best practices for training is usually the lack of resources and that current staff have too many shared responsibilities.

UDOT shared how UAS simulators could be a helpful component of a training program. UDOT explained that each State DOT has access to 10 free licenses to a simulator program that contains various levels of training and use case-specific training scenarios. UDOT reported that utilizing this UAS simulator has been helpful to its internal training program. NMDOT plans to use its selected UAS manufacturer to provide training specific to the UAS platform and then build from there.

RISK MANAGEMENT

A roundtable discussion was also held to facilitate conversation about how the agencies mitigate risk across UAS operations. UDOT has had two incidents where UAS hit power lines mid-operation. UDOT is in the process of establishing checklists for each UAS operation to assist with risk mitigation and plans to use these checklists as the foundation of a formal risk assessment procedure. UDOT plans to integrate the checklists into the flight planning software so it can help UAS remote pilots slow down, double check themselves, and do formal checks of the area before putting the UAS into the air. The UDOT UAS steering committee plans to work together to develop these formal checklists and risk management procedures within the next year.

The conversation continued with each organization in attendance offering up best practices related to UAS risk management, which are outlined below:

- Prior to UAS operations, perform a visual scan of the area looking for obstacles, then put the UAS into the air to do another scan of the area from the aerial perspective prior to executing the data collection mission.
- Implement a process to keep staff proficient and their UAS skills sharp in the offseason, perhaps by utilizing classroom and simulation training.
- Do not allow external pressures to compromise safety. The Remote Pilot in Command of the UAS has the final authority for the go/no-go decision for each operation.
- Integrate SOPs, checklists, and risk assessments into the UAS software and ensure their use is seamless and efficient.
- Standardize documents across training operations and real field operations.
- Consider using a risk assessment matrix and scoring system for each operation.

- Consider emergency procedures and checklists to handle lost links or downed UAS aircraft.
- Increase safety and protect the agency by having formal risk assessments, permissions, and brief documentations of the operational procedures and risk mitigation efforts.

UAS FUNDING DISCUSSION

CDOT led a discussion about UAS funding options. In 2016, UDOT used year-end money to start its UAS program and has continued to use year-end funds to purchase additional UAS. UDOT is currently struggling to get funding for maintenance of its aging UAS fleet. For future UAS purchases, UDOT plans to set aside a maintenance budget upfront for the lifecycle of each UAS.

UDOT discussed the possibility of asking the State legislature to provide funding as ongoing support of the UAS program. However, such a request (even an internal request of executive leaderships) requires data regarding the positive impacts of UAS. CDOT emphasized the same point and explained the importance of coordinating the successes and collecting data across the entire organization to present a holistic case for UAS support rather than presenting a couple of examples.

UDOT staff talked about charging projects whenever possible for UAS use (e.g., on surveying projects, allocating a UAS budget line item as part of that project). NMDOT asks for funding upfront by including UAS into the existing budget like any other tool or equipment request would be filed within the agency. This ensures the UAS is a part of the annual equipment inventory, has an established lifecycle, and will receive maintenance funds or be replaced like any other asset.

Other points made as part of the funding discussion included:

- Securing dedicated year-over-year funds may be critical to the success of a UAS program as the price of UAS platform and sensors increases.
- Inviting executive leadership to UAS steering committee meetings to share the benefits of UAS utilization across the agency may be helpful in securing additional funding.
- Emphasizing the increase in safety UAS provide and demonstrating how UAS are increasing safety across operations may be a way to access the safety budget.
- Purchasing UAS using federal funds means adhering to the Blue List (the Department of Defense's approved list of UAS manufacturers and equipment).
- Seeking demonstrations or trial periods for new UAS and software prior to purchase may be helpful in determining if the equipment meets the needs of the organization.
- Purchasing sensors that are UAS platform-agnostic may help ensure the sensors are compatible with owned equipment.
- Using existing budget to hire a consultant to use UAS on projects where costs savings, safety, and overall efficiency can be demonstrated is one way of gathering evidence which can then be presented to executive leadership for initial support of an internal UAS program.

ARTIFICIAL INTELLIGENCE/MACHINE LEARNING

The use of AI or machine learning software may be helpful in increasing the efficiency of processing UAS-collected data and producing useful reports. UDOT has found success using machine learning software to process photos from overhead signage inspections. On a particular stretch of road, highlighted in Figure 21, all the overhead signs needed to be inspected after installation. Initially, traditional inspection methods using bucket trucks and traffic control were being used, which allowed for the inspection of two signs each night. Once UAS inspections were implemented, 16 signs could be inspected each day. The UAS was airborne over the side of the road and used a powerful zoom camera to zoom in on the overhead signage to check for missing rivets, bolts, and other hardware.

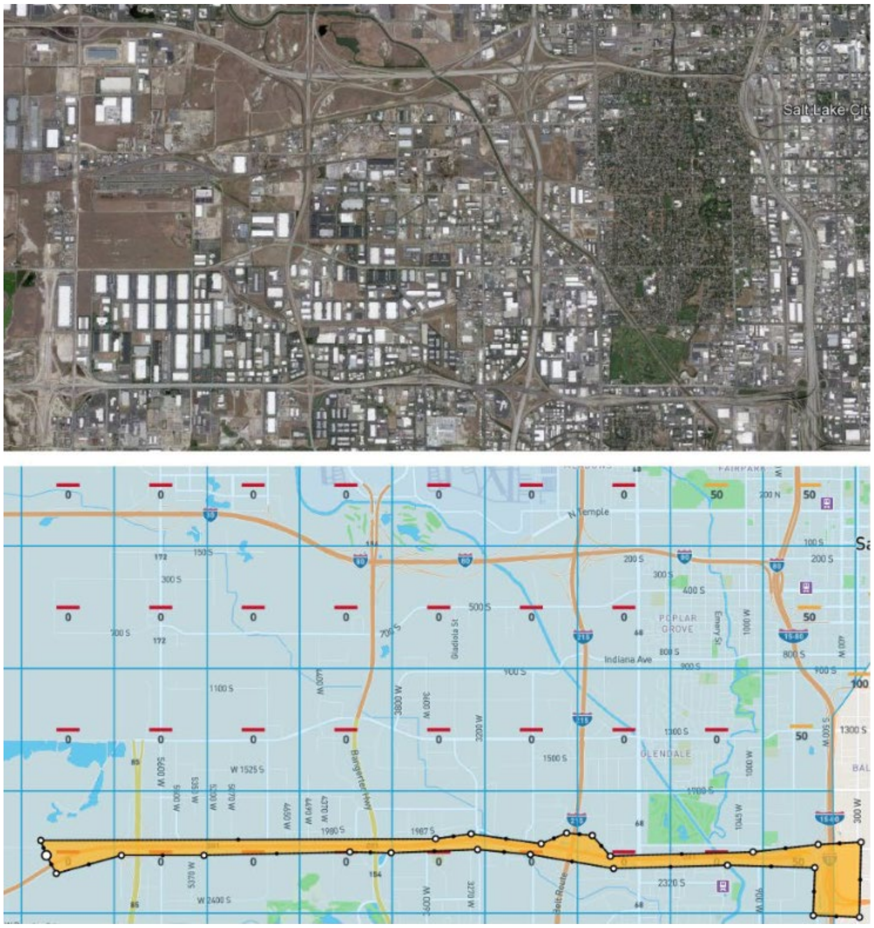

Figure 21. Map of Airspace Where UAS Performed Overhead Signage Inspections. (Source: UDOT)

The airspace overhead this stretch of highway is in is a no-fly zone because it is in the approach path of the runways at Salt Lake City International Airport. UDOT conducted a risk assessment for this operation and submitted a full plan to the FAA to receive approval to fly in this airspace to conduct the signage inspections. This approval process involved a significant amount of work, but UDOT reported that it was well worth the project savings, increased productivity, and safety.

UDOT was able to import the raw UAS-collected photos into a software program that allowed machine learning to inspect the photos. The operator trained the software about what to look for (e.g., missing rivets) using photos. Once the software has been trained for the inspection, it can run through the thousands of images and produce useful reports as seen in Figure 23. This example shows how the software identified missing rivets and then assigned a percentage to its confidence level, e.g., 98 percent sure it is a missing rivet, or in the darker area of the photo, 87 percent sure that was a missing rivet. UDOT reported that this system produced few false positives, thereby saving a lot of time over a manual review of each photo. All in all, UDOT estimates that UAS saved the agency more than $100,000 on this specific project.

Figure 22. Machine Learning Detecting Mission Rivets on UAS Collected Data. (Source: UDOT)

FLIGHT DEMONSTRATIONS

Figure 23. Hands-on UAS Training on Day Two of Peer Exchange. (Source: FHWA)

CDOT and UDOT organized hands-on beginning and advanced UAS flying courses for peer exchange attendees on Day Two. A UAS simulator was used for basic and advanced flight maneuvers for people to practice prior to flying the actual UAS platforms. The basic flight course was flying rectangular patterns (Figure 23), while the advanced course included circular courses to practice multiple, simultaneous control inputs.

CONCLUSION

Key takeaways from the peer exchange include:

- Smaller, less expensive UAS for reconnaissance used prior to a data collection mission with an expensive UAS platform or sensor (i.e., LiDAR) may help increase safety and mitigate risk.
- UAS can assist with ongoing monitoring needs on infrastructure areas of concern or in emergency inspections.

- UAS can assist inspecting infrastructure in difficult to reach areas (i.e., over water, in confined spaces, infrastructure of excessive height).
- UAS as a supplemental tool, along with other traditional tools, can help produce the best possible data set.
- An internal UAS training program may help increase safety, remote pilot proficiency, and help mitigate risks.
- UAS simulators can assist with training and maintaining proficiency, especially during the off-season.
- Formal UAS operations checklists and risk assessment procedures may help increase safety.
- A key to the overall success of an agency's UAS program may be its ability to secure annual funding.
- Data regarding the positive impacts of UAS across the organization may help secure leadership buy-in and additional funding.
- When requesting funds for UAS, it may be helpful to think about the complete lifecycle of the UAS platform and its maintenance needs.
- Machine learning software may be helpful in optimizing UAS data and increasing efficiency.