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EDC-5 UAS Peer-to-Peer Exchange

Salt Lake City, Utah

June 22-23, 2022

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16. Abstract: This peer exchange brought together representatives from the Wyoming and Utah Departments of Transportation. The peer exchange facilitated discussion and collaboration around Unmanned Aircraft Systems (UAS) practices and UAS use cases across construction, material quantity calculations, earth movement, emergency response, asset management, and structural inspections. Both transportation agencies reported increased safety, time savings, and cost savings as a direct result of UAS utilization. The information contained within this report was up-to-date at the time of the peer exchange on June 22-23, 2022.

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ACRONYMS AND ABBREVIATIONS

3D	Three-dimensional
AI	Artificial Intelligence
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
SMS	Safety Management System
SOPs	Standard Operating Procedures
UAS	Unmanned Aircraft Systems
UDOT	Utah Department of Transportation
U.S.C.	United States Code
WYDOT	Wyoming Department of Transportation

INTRODUCTION

As part of the Federal Highway Administration (FHWA) Every Day Counts Unmanned Aircraft Systems (UAS) Initiative, the Utah Department of Transportation (UDOT) and the Wyoming Department of Transportation (WYDOT) held a peer exchange in Salt Lake City on June 22-23, 2022. The goal of the peer exchange was to share how these two DOTs use UAS across their operations, foster collaboration and discussion around solutions to UAS concerns, and describe best practices. This report provides an overview of the UAS programs at WYDOT and UDOT 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/

WYOMING DOT UAS PROGRAM

This section provides an overview of WYDOT's UAS program at the time of the peer exchange and describes WYDOT's immediate plans for UAS program growth. Current UAS WYDOT use cases are described later in this section.

OVERVIEW

In 2017, the Wyoming State legislature passed legislation that called upon the WYDOT Division of Aeronautics to create a UAS program. The following year, WYDOT started a task force that was charged with creating UAS program goals, policies, and procedures. At the time, WYDOT staff had little UAS experience and temporarily hired a consultant to assist with the creation of the program.

In 2019, the Wyoming Highway Patrol and University of Wyoming, through WYDOT, used a FHWA State Transportation Innovation Council grant to purchase nine different UAS. These initial UAS were used primarily for accident reconstruction and emergency response; many UAS from this original fleet are currently being replaced after software-inflicted accidents.

In the last few years, WYDOT's UAS program has grown to 19 UAS and 21 trained remote pilots. At the time of the peer exchange, WYDOT reported plans to add more UAS to its fleet and to double the number of trained pilots in the coming months. Many of the use cases that WYDOT is exploring or implementing are for use on construction projects.

CURRENT USE CASES

At the time of the peer exchange, WYDOT reported using UAS mainly for material calculations, structural inspections, and emergency response. Staff members are working to expand UAS utilization in Wyoming and are exploring the following use cases:

- Construction Inspections.
- Surveying and Mapping.
- Earthwork Quantities.
- Asset Management and Maintenance.
- Bridge Inspections.
- Additional Emergency Response Uses.

Tower Inspections

The remainder of this section describes WYDOT's current UAS use cases. The WYDOT field operation teams have been assisting staff members from WYOLINK, the statewide public safety interoperable radio communications system. UAS are being used to inspect these communications towers across the State. These structural inspections check for missing hardware, cracks, and other defects. WYDOT is currently assisting WYOLINK with processing the UAS-collected data and creating three-dimensional (3D) models from the raw photography. WYDOT staff are exploring various software to improve this process.

Figure 1. UAS-Collected Data Creates 3D Model of WYOLINK Communications Tower (Source: WYDOT)

Material Inventories

WYDOT also is exploring UAS use in performing material inventory calculations in its more than 150 roadside salt and sand sheds. Traditionally, these material estimations were educated guesses or based on calculations using a Robotic Total Station. Figure 2 depicts a UAS flight within one of these indoor material sheds. WYDOT is in the initial stages and is testing autonomous indoor flights and the use of fiducial markers and exploring solutions for the unique lighting situation. These shed structures are covered with a heavy tarp material that causes the indoor lighting to appear yellow.

Figure 2. UAS Data Collection Mission within a WYDOT Materials Shed (Source: WYDOT)

WYDOT is finding that the combination of shed's tight quarters (packed full), suboptimal lighting conditions, and the smooth texture of the housed materials (e.g., sand) are making these UAS flights difficult. Potential solutions that were discussed included adding supplemental lighting inside the structure prior to the UAS data collection mission or equipping the UAS with additional lighting. UDOT staff shared in the discussion that to add texture for better photogrammetry, it may be helpful to spread some gravel on top of the sand or salt. It may also be useful to increase the overlap of the flight lines and strategically place the control points.

WYDOT staff has also started to investigate using UAS to inspect the material shed structure itself. Figure 3 shows a large crack in a shed that was being further inspected via UAS.

Figure 3. UAS Inspection of Damaged Beam within Wyoming Material Shed (Source: WYDOT)

Surveying and Earth Movement

The WYDOT field operations team is also assisting the Wyoming Geology Department in monitoring or responding to various rockslides throughout the State. The Wyoming Geology Department report finding benefits from having an initial aerial view which provides an understanding of the size and scope of the event, while also inspecting the area to make decisions about initial response of ground crews. Figure 4 shows the aerial view of the Little Tongue River Rockslide.

Figure 4. UAS Photo of the Little Tongue River Rockslide(Source: WYDOT)

Another rockslide in Wyoming, known as the Red Bed Rockslide, served as a case study for WYDOT to compare traditional aerial digital mapping equipment to the use of UAS. The picture on the left in Figure 5 is the roadside view of this rockslide, while the picture on the right is the aerial view of the designated mapping area.

Figure 5. Roadside View and Aerial Mapping View of the Red Bed Rockslide(Source: WYDOT)

For this mapping mission, WYDOT used an airplane equipped with an aging digital mapping camera as seen in Figure 6. The aircraft flew at 1,800 feet to collect the data that were subsequently used to create a 3D model for the Geology Department to use in measurements and other analysis.

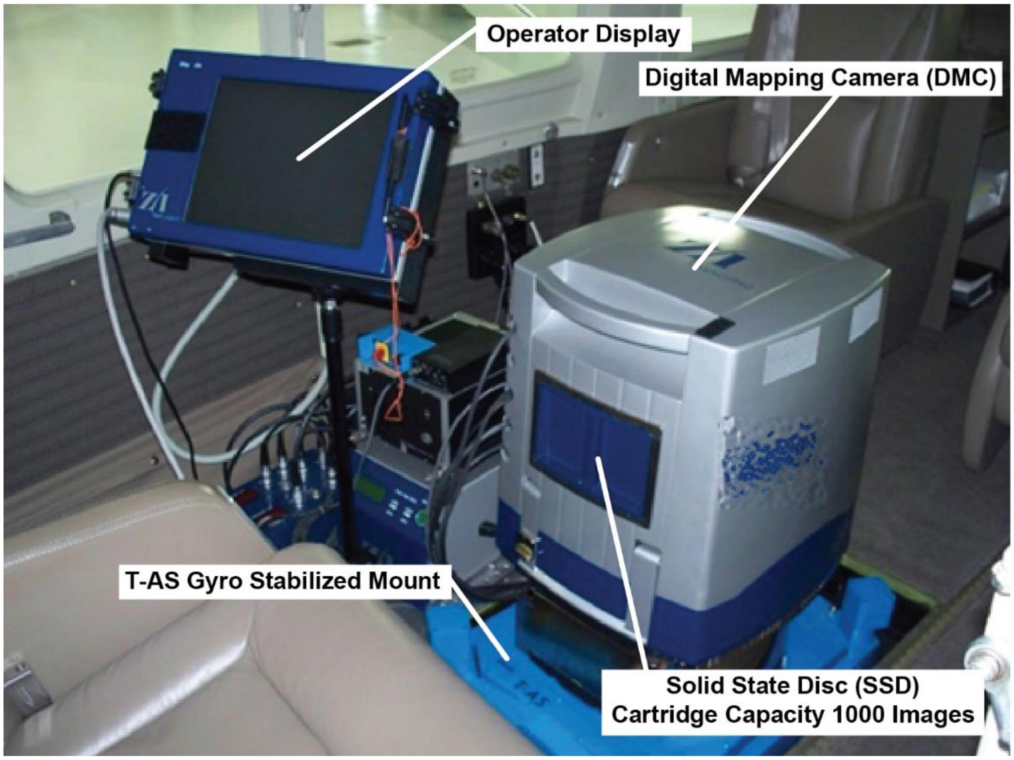

Figure 6. Digital Mapping Camera Installed in Aircraft (Source: WYDOT)

Figure 7. UAS-Collected Data Point Cloud (Source: WYDOT)

A small UAS was also used to map this same rockslide; the UAS-collected data created a 3D point cloud for analysis. WYDOT reported that when it compared the results of the UAS-collected data to traditional aircraft aerial data, the UAS data were more accurate, thus proving internally that UAS may be a viable option.

WYDOT has found that using UAS for surveying and mapping is also less expensive than its traditional aerial methods, which is one of the reasons the agency is exploring ways to increase UAS use on small to medium projects.

WYDOT staff also used UAS on the Big Piney Cutoff erosion control project. Figure 8 depicts the survey area and a close-up view of the erosion along the riverbank. UAS-collected data were used to create the topographic map of the area as seen in Figure 9.

Figure 8. Survey Area of the Big Piney Cutoff and Riverside View of Erosion (Source: WYDOT)

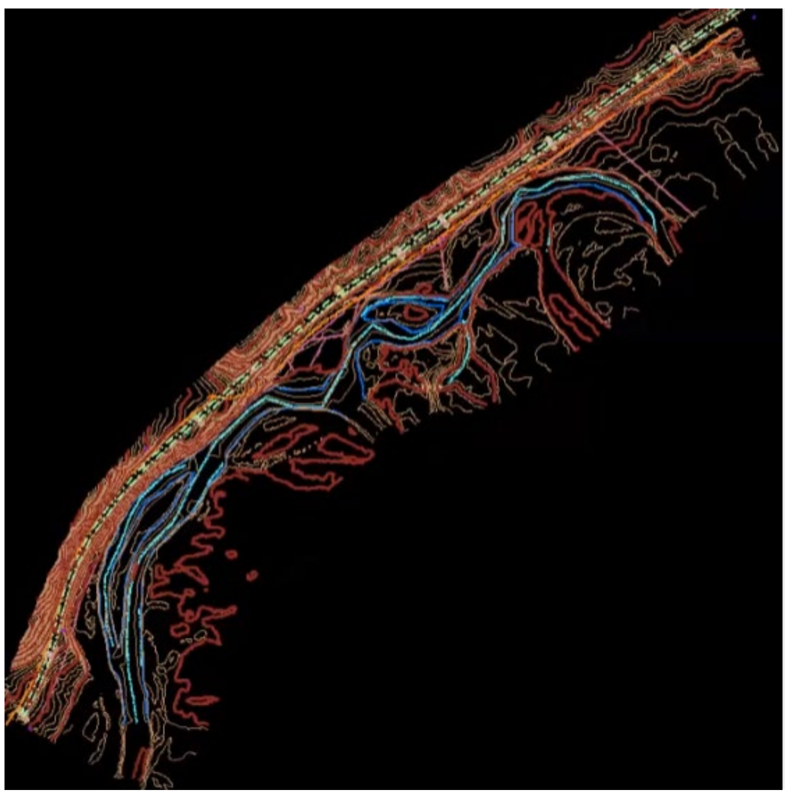

Figure 9. UAS-Collected Data Creates Topographic Map of Big Piney Cutoff Area (Source: WYDOT)

WYDOT shared that it is finding UAS to be a viable tool across the operations in which they have been implemented. WYDOT performed a cost analysis on the same project using various means to conduct the survey. The traditional field surveys cost was $10,000-$12,000, aerial photography using a traditional aircraft was $15,000-$18,000 and using Unmanned Aircraft Systems cost $6,000-$8,000 on the test project which was equally compared across these data collection methods. WYDOT reports that UAS are consistently proving to be an affordable option that often improve the quality of the data collected.

UTAH DOT UAS PROGRAM

This section provides an overview of UDOT's UAS program at the time of the peer exchange and describes a sampling of current UDOT UAS use cases.

OVERVIEW

In 2010, UDOT began UAS research with Utah State University to analyze potential uses with a fixed-wing UAS. In 2016, a formal UAS 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, USDOT had ten 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. The UAS program organizational structure continues to be developed, and standard operating procedures (SOPs) are continually updated as needed. The UDOT UAS Steering Committee meets monthly to facilitate lessons learned, consider policy or workflow changes, and evaluate how the UAS program can increase in efficiency and safety.

USE CASES

UDOT is actively using UAS in surveying, mapping, bridge inspections, pavement inspections, airport inspections, emergency response, and asset management. The USDOT 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. The section provides examples of various UAS uses throughout Utah.

Surveying

UDOT reports that UAS are being used on many survey projects, including a recent survey for the Jensen Lane Project. Pre-construction planning teams were analyzing the multiple factors associated with adding an acceleration/deceleration lane to a stretch of highway. Traditionally, designers make educated guesses when it comes to earth removal estimates. Using UAS on this project, the surveyor was able to fly the 2-mile stretch of project road in about four hours. The UAS-collected data were used to create 3D models to provide quality measurement information that allowed the design team to make informed decisions. The data and products were delivered within 24 hours of the designer's initial request, and the State saved an estimated $25,000 on the project as a result. UDOT staff shared that employing UAS often saves time and money without compromising the data quality.

Figure 10. UAS-Collected Data used for Jensen Lane Project Analysis (Source: UDOT)

Bridge Inspections

Initially, UDOT UAS-trained pilots were assisting across divisions within the department, but UDOT changed its approach so that subject matter experts could be trained as UAS pilots to use UAS within their specialties. For example, in 2019, the first UDOT bridge inspection staff member became Federal Aviation Administration (FAA)-certified to fly UAS. In recent years, all bridge inspectors have become certified and are using UAS to assist in bridge inspections in Utah. UAS are a supplemental tool for bridge inspection and not a replacement for National Bridge Inspection Standards requirements.

The bridge inspection group has used a variety of UAS platforms and are still exploring different remote aircraft to determine which is best suited for inspecting bridges. Often inspectors are using UAS to get an initial look at a structure and note areas that may need a closer look. Rather than collecting hundreds or thousands of pictures to sort through later to conduct the inspection, UAS are being used to assist live throughout the inspection. Figure 11 shows a UAS being used in a routine inspection on one of Utah's 3,000 bridges.

Figure 11. Utah Bridge Inspectors using UAS on a Routine Bridge Inspection (Source: UDOT)

The Utah Bridge Inspection Team is also reporting benefits using UAS to map the bridge deck as part of routine inspections. Figure 12 shows how useful UAS-collected data and software can be in measuring, monitoring, and tracking deck deformities. Traditionally, crews would be on the bridge deck with measuring wheels noting information to be entered into software by hand. UDOT reports that by using UAS, this process is completed in a third of the time and increases safety by keeping personnel off the deck.

Figure 12. UAS Mapping Bridge Decks (Source: UDOT)

Not all bridges are suitable for UAS-assisted inspections because of location, vegetation, or other considerations. UDOT has determined which bridges can be inspected with the help of UAS which contributes to the first step of the established workflow. Figure 13 outlines the current workflow UDOT is using for UAS bridge inspections.

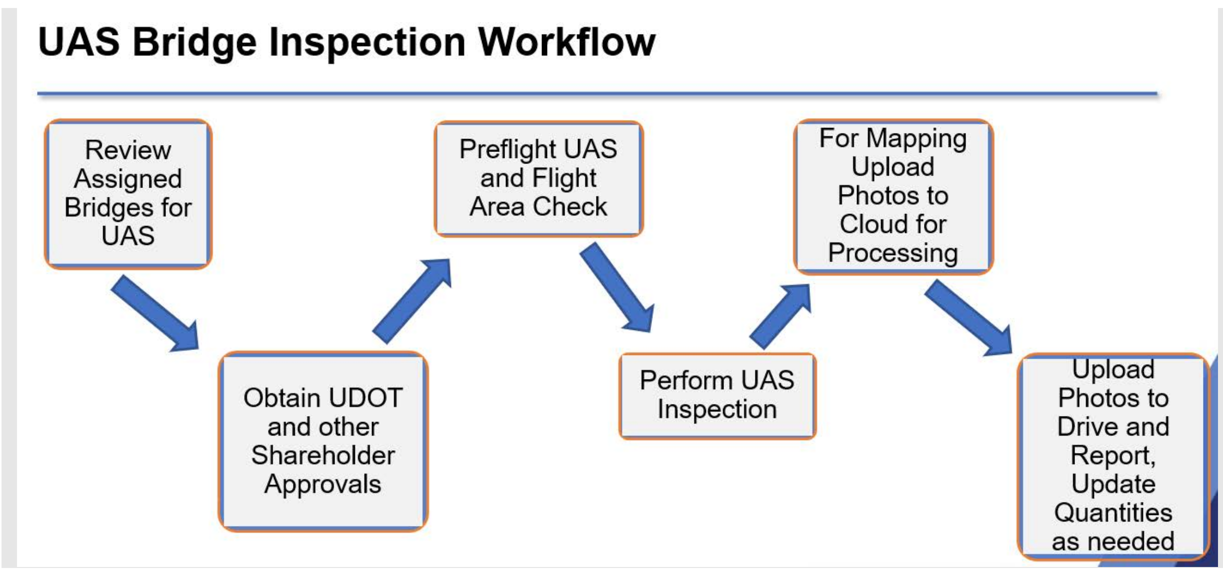

Figure 13. UDOT UAS Bridge Inspection Workflow (Source: UDOT)

The UDOT Bridge Inspection Team reports an increase in safety and data quality as a direct result of UAS use. Although the team is still exploring UAS platforms, they have concluded having multiple specialized UAS for bridge inspections is better than a general use platform. Near-term goals include, increasing the use of Artificial Intelligence (AI) to identify and quantify cracks and spalls, and testing UAS use on tunnels and cable inspections.

Incident Management and Emergency Response

The UDOT Incident Management Team has 25 specialists who respond to a variety of emergency situations throughout the State. Each specialist is an FAA-certified remote pilot, and each truck is equipped with a small UAS. This section describes how UAS may be helpful in emergency responses.

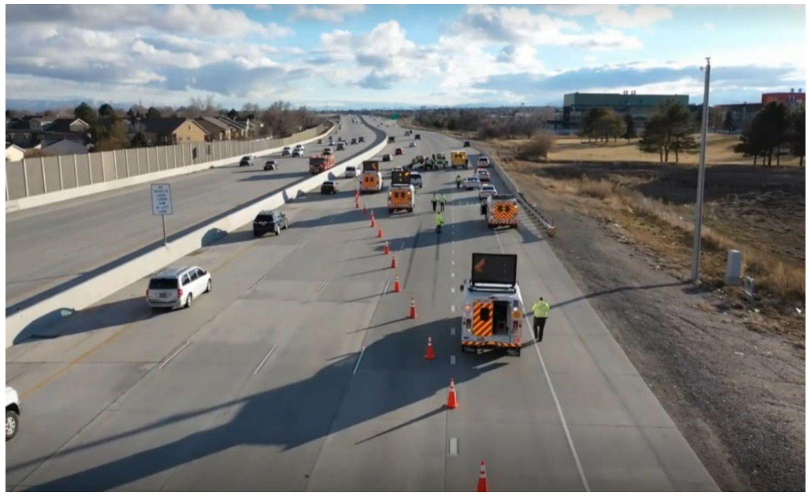

Figure 14. UAS Aerial Photo of Vehicle Accident Response (Source: UDOT)

UAS can help with training. Figure 14 is a still photo from a UAS video of an accident response. Upon review of the video, the UDOT Incident Management Team identified 15 items were identified that the on-site first responder agencies had done incorrectly. Information about the identified items was disseminated to the appropriate agencies to be used in training to improve safety.

UDOT Incident Management staff report that their primary use of UAS is in documenting vehicle accidents for accident reconstruction and investigation purposes. According to UDOT, UAS can efficiently document crash scenes to demonstrate the scale of the incident, the response, and to collect data for accident reconstruction. UDOT staff indicate that UAS are useful in tracking skid patterns and seeing points of impact and can save time, resulting in quicker accident clearance, which positively impacts safety by getting crews off active roads and minimizing the risk of secondary accidents.

Figure 15. UAS Aerial Photo of Multi-vehicle Incident (Source: UDOT)

As a specific example of the time savings that can be afforded by UAS, Figure 16 shows a vehicle accident in which a car had been pinned against the freeway barrier wall by a semi-trailer. Due to the severity of the accident and extraction requirements, the entire freeway was closed. UAS allowed the road to be reopened in 45 minutes compared to an estimated 3 hours if traditional methods had been used for documentation. In addition, this task was accomplished without negatively affecting the collection and quality of data needed.

Figure 16. UAS Aerial Photo of Severe Accident (Source: UDOT)

UDOT has used UAS to assist in hazardous materials (HAZMAT) response. Figure 17 shows a rolled butane gas tanker truck that was releasing gas on the road. Responders used UAS thermal imaging to see when the tanker had fully "off-gassed," to determine when it was safe to approach and secure the scene. Using UAS for incident investigation and data collection during HAZMAT events can keep responders out of harm's way.

Figure 17. UAS Thermal Sensor Used in HAZMAT Response (Source: UDOT)

Another emergency response use for UAS thermal imaging is with fire response. UAS may assist in seeing hot spots or providing an aerial view for firefighters to determine the best approach to fight a particular fire. UAS may also provide greater situational awareness at a fire scene in terms of understanding the location of personnel and direction of the fire path.

Figure 18. UDOT Incident Management and Fire Response to Tanker Fire(Source: UDOT)

UDOT has also been using UAS to assist in avalanche response. Again, the aerial vantage point can provide valuable information about flow paths, the extent of the damage, and the information to decide where it is safe for responders on the ground to proceed. UAS may also be used to estimate the amounts of snow to be removed or can assist with emergency infrastructure inspections. Figure 19 showcases UAS assistance in a Utah avalanche response.

Figure 19. Two UAS Aerial Photos of Utah Avalanche (Source: UDOT)

Similar to avalanches, UAS may provide great utility in responding to mudslides. Figure 20 is an aerial perspective of a Utah mudslide that was used to determine whether more debris would come down, study the slide path, and decide where mitigation efforts should first be deployed.

Figure 20. UAS Aerial Photo of Utah Mudslide (Source: UDOT)

The UDOT Incident Management Team is working with the Department of Natural Resources in using UAS to mitigate effects on wildlife. Because wildlife do not like the noise produced by small UAS, UAS may be used to nudge wildlife away from roadways. Figure 21 depicts one of these responses where the UAS was used to coax a bull moose away from an active road.

Figure 21. UAS Used in Wildlife Mitigation in Utah (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.

Simulator Training

Clemson University, through the South Carolina DOT, was awarded a FHWA State Transportation Innovation Council grant to develop a UAS simulation program with transportation agencies in mind. Ten free licenses to this simulator program are available to each State DOT. UDOT reported using this simulator and explained that it contains various levels of training for operators to gain proficiency across different courses and industry scenarios. The simulator can be used to evaluate and score people on a variety of missions across multiple UAS platforms.

Data Management Discussion

At the time of the peer exchange, both WYDOT and UDOT were using the agencies' unlimited storage via cloud accounts. Both agencies were still solidifying UAS data management plans and were researching how best practices around data management relate to their agency needs. However, UDOT shared some things to consider when creating a UAS data management plan:

- Is cloud storage or local server storage better for the agency?
- How long do we store the data?
- Are there State laws that prescribe how long the data should be stored?
- Do you keep a personal backup?
- How can the data be used?
- Who should be able to access the data?
- How should the data storage be organized?

SOPs and Fleet Management Discussion

As part of the peer exchange, there was a round table discussion about SOPs and UAS fleet management. At the foundation of WYDOT's UAS program is a committee or task force that bring together various stakeholders from across WYDOT. For example, the committee consists of UAS operators, a representative from the Records Department, and someone from the Information Technology Department. The committee also includes members from outside WYDOT (e.g., academics from varying institutions). WYDOT has also created a Safety Management System (SMS) and has a safety board of six people who oversee safety and update the SMS document as needed. The SMS and safety board also assist in editing the SOPs.

Early on, the WYDOT UAS committee worked together to establish UAS program goals and general policies, which were used to inform their SOPs. WYDOT worked with other State DOTs who already had mature UAS programs. The document also includes pre-mission checklists, active mission checklists, post-mission checklists, UAS maintenance guidelines, and defines different program roles such as program manager, training manager, and fleet manager. WYDOT built its SOP document this way so as the program grows, many of these topics will already be addressed or defined; however, the document can be adjusted as needed.

At the time of the peer exchange, WYDOT's SOP document was not available outside the agency. The WYDOT UAS committee meets a few times a year to continually assist in guiding the growth of the UAS program. During the committee meetings, members discuss progress, explore new use cases, and listen to outside guest speakers who are brought in to facilitate learning opportunities. The committee talks in detail about new use cases and helps facilitate safety board review of proposed uses by identifying risk factors and providing additional information to facilitate decisions.

UDOT followed a similar committee process in creating its UAS policies and SOPs. At the peer exchange, UDOT staff described the UDOT UAS flight approval process. UDOT decided that it needed to have a UAS mission approval process, not to repeat FAA procedures, but to serve as another checklist item within the SOPs to double check airspace, regulatory, and safety considerations for each mission.

UDOT's UAS operators and UAS committee members worked with the Division of Aeronautics to create an automated mission approval application. This collaboration resulted in a user-friendly flight request that is accessed from the UDOT website. The system does geospatial inquiries to check the location of the proposed mission against the airspace, Active Notices to Airman, and other 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. Figure 22 depicts two different sections of the UDOT UAS approval form.

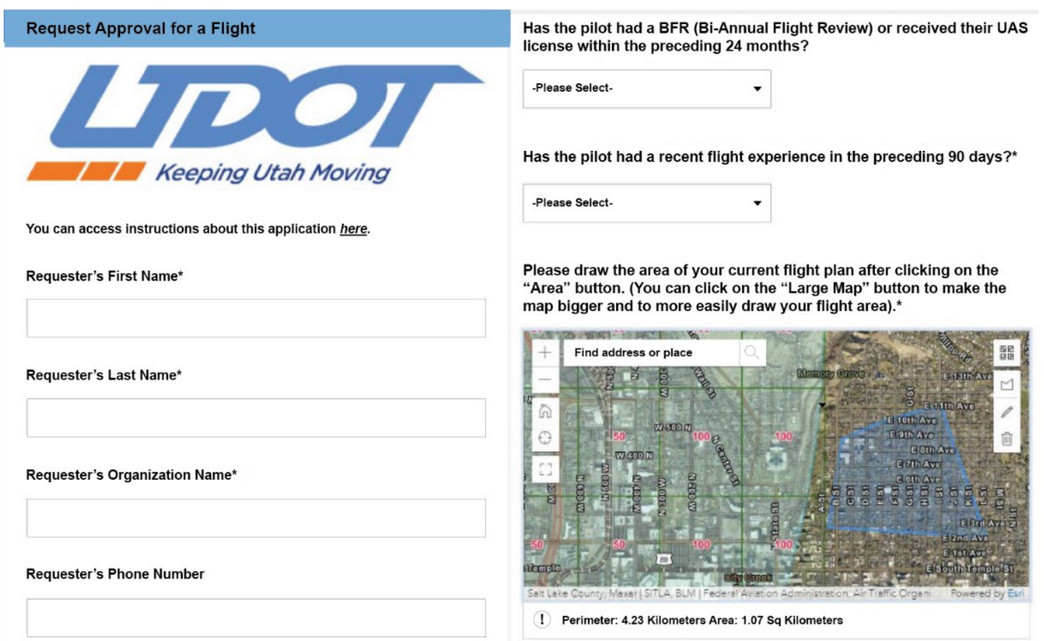

Figure 22. Depictions from the UDOT UAS Approval System(Source: UDOT)

Various UAS fleet management software is available to assist in tracking the maintenance and health of a transportation agency's UAS equipment. UDOT and WYDOT reported that properly maintaining UAS and their components (e.g., motors, batteries), tracking charging cycles, and properly storing all equipment has helped preserve their fleets. UDOT reported that properly communicating this information, along with success stories and increased safety components, to the right people has been helpful when requesting additional funding to grow or replace UAS in the fleet.

UAS for Airport Inspections

UDOT reports working closely with airport managers to use UAS to assist in airport pavement inspections for crack detection and identification. The Division of Aeronautics also plan to use aerial images to update airport's FAA 5010-1 Airport Master Record Form. UDOT is also using UAS for mapping obstacles at the airport and checking them against safety area minimums outlined in 14 United States Code (U.S.C.) § 77.

Figure 23. UAS Pavement Inspection of Airport Taxiway(Source: UDOT)

Artificial Intelligence/Machine Learning

UDOT uses UAS to assist in overhead sign inspections. The UAS is airborne over the side of the road and using a powerful zoom camera can zoom in on the overhead signage to check for missing rivets, bolts, and other hardware. More than $100,000 was saved by using UAS to inspect 16 signs over one of Salt Lake City's freeways.

Using the raw photos that the UAS had collected, UDOT was able to import all those photos into a software that allowed machine learning to inspect the photos. The operator initially trains the software about what to look for (e.g., missing rivets) using photos. This can be done with any of the hardware or issues the operator wants the software to learn to look for during the inspection. 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 24. 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 reports this system worked well in producing few false positives, thereby saving a lot of time over a manual review of each photo.

Figure 24. Example of Machine Learning Report for Overhead Sign Inspections (Source: UDOT)

In the winter, UDOT often deals with issues around traffic and parking availability in the parking lots at the top of Cottonwood Canyons. UDOT employed the use of UAS and AI to track, monitor, and count cars as seen in Figure 25.

Figure 25. UAS and AI Monitoring Parking Availability(Source: UDOT)

Cold Weather and High-Wind Operations

Operating UAS in extreme cold or high-wind environments may be challenging for the operator and the equipment. UDOT found that keeping the UAS batteries warm improved their operating capacity and helped extend battery life. Protecting the equipment and keeping things in a dry environment may also prolong the life of the equipment. It may also be helpful to keep the UAS outside once the mission has begun rather than flying a section of the mission and returning to a warm environment because this can cause condensation that can ruin the sensor lenses.

Both UDOT and WYDOT reported that understanding wind patterns and time of day can be advantageous since early mornings tend to be calmer. When operating near buildings, towers, bridges, or other structures, UDOT and WYDOT suggested accounting for the wind turbulence off these structures.

CONCLUSION

Through presentations and discussions, participants were able to share their agency's history of establishing and growing a UAS program, outline the various established UAS use cases in their States, and offer a framework for creating UAS policy and procedures. Other State DOTs that are in various stages of UAS program development may find this information helpful in maturing their program. Key takeaways from the peer exchange include:

- State DOTs may find the use of a UAS steering committee to be helpful in establishing program goals, policies, and procedures
- WYDOT has found UAS to be an effective and cost savings supplemental tool in materials calculations, infrastructure inspection, earth movement analysis, surveying, and emergency response

- UDOT has found UAS to be a time and cost savings supplemental tool across a variety of use cases including incident response, wildlife mitigation, avalanche control and inspection, surveying, asset management, airport and bridge inspections
- State DOTs may find it helpful to have an internal UAS operations approval system
- Established UAS Standard Operating Procedures and UAS workflows may assist in the safe and efficient operation of UAS
- Considering advanced flight maneuvers, the use of visual observers, supplemental lighting and thorough pre-flight assessments may be helpful when conducting UAS data collection in confined spaces
- Artificial Intelligence and Machine Learning software may assist State DOTs with asset management or in streamlining inspection processes
- Properly planning for UAS cold weather operations by keeping UAS, batteries, and other equipment warm may preserve their operating capacity