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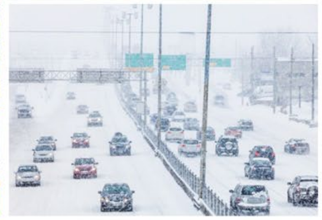
Every Day Counts
Innovation for a Nation on the Move




Mobility · Safety · Quality · Environment · Shortening Project Delivery

EDC-5 UAS Regional Workshops Report

U.S. Department of Transportation
Federal Highway Administration

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This report synthesizes the findings of four regional workshops held separately throughout 2022. These regional workshops brought together transportation agencies from around the Nation to discuss the state of practice and future use cases of UAS. It identified key areas for additional research concerning UAS regulations, funding, and technology. The information included was current and accurate at the time of each individual workshop.</td></tr>
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ACRONYMS AND ABBREVIATIONS

3D	Three-dimensional
AI	Artificial Intelligence
BVLOS	Beyond Visual Line of Sight
DOT	Department of Transportation
EDC	Every Day Counts
EOC	Emergency Operations Center
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
LiDAR	Light Detection and Ranging
RGB	Red, Green, Blue
ROI	Return on Investment
RPIC	Remote Pilot in Command
UAS	Unmanned Aircraft Systems
UA	Unmanned Aircraft

INTRODUCTION

The Federal Highway Administration (FHWA) developed the Every Day Counts (EDC) initiative[1] in 2011 to identify and deploy innovation aimed at reducing the time it takes to deliver highway projects, enhance safety, and protect the environment across the transportation sector. Unmanned Aircraft Systems (UAS) as an innovative technology was selected in 2018 for EDC-5. The purpose was to coordinate UAS adoption efforts and create a foundation of collaboration and peer networking. To accomplish this, FHWA developed peer exchanges, local UAS workshops, regional workshops, training programs, webinars, technical briefs, and reports. This report outlines the findings from four regional workshops held in 2022 as part of ongoing FHWA UAS activities.

The regional workshops brought State Departments of Transportation (DOTs) together to gain an understanding of how UAS are being used and the successes and challenges associated with UAS integration. A secondary goal was to foster networking opportunities by creating a venue for peers to gather, meet, and form relationships. Table 1 provides the details of these workshops.

Table 1. Details of the Regional Workshops.

Region	Dates	Location	Hosting Agency
Mid-America Region	April 11-12, 2022	Salina, Kansas	Kansas DOT
South Region	May 3-4, 2022	Durham, North Carolina	North Carolina DOT
West Region	May 15-16, 2022	Salt Lake City, Utah	Utah DOT
North Region	June 8-9, 2022	Boston, Massachusetts	Massachusetts DOT

WORKSHOP ATTENDEES

The regional workshops aligned with the FHWA field organization regions. The workshops targeted State DOTs within each region and invited additional guest agencies, listed below.

Mid-America Regional Workshop

The following State DOTs and local government or transportation agencies attended the Mid-America Regional Workshop.

- Indiana DOT
- Lincoln Transportation & Utilities
- Michigan DOT
- Mid-America Regional Council
- Minnehaha County, South Dakota
- Minnesota DOT
- Missouri DOT
- Nebraska DOT
- North Dakota DOT
- Oklahoma DOT
- South Dakota DOT
- Texas DOT

[1] Every Day Counts | FHWA (dot.gov)

South Regional Workshop

The following State DOTs and local government or transportation agencies attended the South Regional Workshop.

- Alabama DOT
- Arkansas DOT
- Florida DOT
- Georgia DOT
- Kentucky Transportation Cabinet
- Louisiana DOT
- Puerto Rico Highway and Transportation Authority
- South Carolina DOT
- Tennessee DOT
- Virginia DOT

West Regional Workshop

The following State DOTs and local government or transportation agencies attended the West Regional Workshop.

- Arizona DOT
- California DOT
- Colorado DOT
- Montana DOT
- New Mexico DOT
- Oregon DOT
- Washington DOT
- Wisconsin DOT
- Wyoming DOT
- Wyoming Highway Patrol

North Regional Workshop

The following State DOTs and local government or transportation agencies attended the North Regional Workshop.

- Connecticut DOT
- Delaware DOT
- Maine DOT
- Maryland DOT
- New Hampshire DOT
- New York State DOT
- Pennsylvania DOT
- Vermont DOT

WORKSHOP FORMAT

Each workshop provided an overview of EDC-5 and the UAS initiative; an opportunity for participants to discuss implementation and successes and challenges; breakout sessions on construction and structural inspections and emergency response; and field demonstrations.

REGIONAL WORKSHOP FINDINGS

A synthesis of the regional workshop findings follows. Recurring themes from break-out sessions and networking breaks included leadership buy-in, UAS training, and public involvement. Findings from the main break-out sessions are presented at the end of this section. These findings are centered around three main categories of UAS use: construction inspection, structural inspection, and emergency response.

LEADERSHIP BUY-IN

For those involved in UAS program startups, obtaining initial and ongoing approval from internal and external stakeholders can be a challenge. Leadership's questions typically focus on the benefits of UAS and the return on investment (ROI). State DOTs which recently started UAS programs reported it has been helpful to work with FHWA and other State DOTs who have pioneered the way when seeking to understand ROI and the core benefits of increased safety, efficiency, costs savings, and data analysis quality. Peer States can often share evidence and case studies from their established experience. In addition, some leaders may find it helpful to offer a "hands-on" demonstration, perhaps from another State agency or university with UAS capabilities. Several transportation agencies reported success with using UAS as a key recruitment tool when engaging with the next generation of transportation, engineering, and construction professionals, which may be of interest to leadership.

Understanding funding opportunities for beginning or growing a UAS program is also helpful in these initial discussions with leadership. Startup or ongoing funding is often available from department year-end funds, multiple divisions pooled funds, or various grants.

Many State DOTs have found funding opportunities for UAS through Federal Emergency Management Agency (FEMA) grants and programs. The FHWA State Transportation Innovation Council program or the Strengthening Mobility and Revolutionizing Transportation grants program may also be sources for UAS funding. When using Federal funds, State DOTs noted that it is important to be familiar with the process and understand that only UAS on the U.S. Department of Defense's Defense Innovation Unit's Blue List may be purchased.

Several State DOTs also reported success in securing funding by working closely with their State legislature. State legislators may be familiar with the UAS industry and understand the value UAS can bring to various State agencies, such as the DOT. Other potential opportunities are to pursue research grants in partnership with local academic institutions. Various funding opportunities are available for starting or growing a UAS program, and collaborating with State DOTs who have mature programs to understand their funding choices may be helpful.

UAS TRAINING

State DOTs have reported that keeping staff current and up to date on regulations and operational skills can be a challenge. Some States have adopted minimal flight hour requirements for their personnel before they are allowed to perform structural inspections. Several State DOTs have implemented a 90-day currency rate for their UAS pilots—which means the remote pilot needs to fly UAS within 90 days to be considered current—but have found that at times it has been a struggle for everyone to meet the requirement. Several of the State DOTs reported one way this issue may be addressed is by hosting quarterly department wide UAS training days. These training days could serve as a time to share lessons learned and success stories and provide a hands-on component to assist with flight proficiency and currency. These more frequent training sessions may also boost operators' confidence in their abilities, which addresses a common concern about flying an expensive UAS near structures.

Several States noted as part of their “lessons learned” that it is more important to identify who should be a remote pilot rather than make a general push for anyone who wants to become a remote pilot to do so. A consensus of State DOTs found it is helpful to strategically identify which departments and who from those departments should be certified for UAS operations. State DOTs expressed concern about losing their training investment when personnel who have been trained for UAS operations no longer want to fly UAS or may leave for other UAS opportunities. Some States are exploring pay increases or other incentives to retain developed UAS operators within the organization.

PUBLIC INVOLVEMENT

Ohio DOT shared that public involvement and community outreach is an important component to building a UAS program. Staff indicated that it may be helpful to work closely with the organization’s Public Information Officer, who can disseminate information across a variety of platforms. The public information officer could assist with news releases, social media posts, and interviews. Creating short videos of UAS photos and video footage of projects could help shape public opinion about UAS.

North Carolina DOT reported that hosting public UAS workshops that are educational and include hands-on components has been a successful strategy in building public support. These workshops could provide a forum to explain how the State DOT uses UAS, the benefits being realized, and the difference between Federal Aviation Administration (FAA) Part 107 regulations versus recreational use of UAS. Utah DOT is working with middle school and high schools to educate students on UAS use. North Carolina DOT discussed the benefits of creating brief videos to help UAS recreational operators better understand the rules and regulations. These short videos were released on social media weekly as part of a mini-training series. The same idea could be used to highlight UAS utilization on key projects or inspections throughout the State.

CONSTRUCTION INSPECTION

State DOTs reported success using UAS across the construction lifecycle (i.e., pre-construction, construction, and post-construction) where they are used in a variety of ways. The States have found UAS applications during construction inspections increased safety, offered time savings, and provided higher quality data to create three-dimensional (3D) models and point clouds. Construction UAS teams reported that using 3D models created through aerial imagery can more quickly resolve disputes around data errors and more clearly communicate with stakeholders.

One of the discussion questions at the workshops was about the use of contractors or in-house remote pilots to conduct UAS operations on construction projects. State DOTs reported a mix between the two across the country—more mature UAS programs tend to have more in-house operations while newer UAS programs are using more contractors. Contractors may be used for larger jobs or for operations that require equipment that the State DOT does not have. State DOTs note that having a checklist or approval system in place when hiring contractors to perform UAS work has been helpful in managing expectations and safety.

State DOTs note some advantages and disadvantages to conducting UAS construction inspections with in-house resources versus using contractors. These State DOT reported advantages and disadvantages are outlined below in Table 2.

Table 2. Advantages and Disadvantages of In-House Versus Contractor UAS Construction Inspections According to State DOTs.

	In-House	Contractors
Advantages	• Lower costs once established • On-demand use of asset • Can create high utilization of asset, stronger ROI potential • Can share the tool across departments	• May have greater UAS application expertise • May have better, more qualified sensors and equipment • May be able to process and store data more effectively
Disadvantages	• Must invest in DOT fleet • Funding or procurement may be challenging • Maintaining ample equipment and personnel may be challenging	• Potentially longer wait times, dependent on contractor schedule • Higher costs - weaker ROI potential overtime

During the workshops, staff from Alabama DOT noted that when establishing a UAS program to assist in construction inspection and other applications, it may be important to consider the various UAS platforms and sensors. A consensus of attendees reported that it was difficult to keep up with the latest UAS advancements because the technology is rapidly advancing. While this can be a challenge, having a foundational understanding of the broader UAS platforms and equipment is often helpful.

Participants were asked about the UAS platforms and sensors they employed. There are two main UAS platforms—fixed-wing and multirotor, many State DOTs reported using a mixed fleet of both fixed-wing and multirotor platforms. A third emerging type of remote aircraft, a hybrid aircraft capable of vertical takeoff and landing like a multirotor platform that can transition to forward flight like a fixed-wing aircraft, was discussed as a potential future platform. Table 3 outlines these pros and cons across the three main platforms, as discussed by the State DOTs.

Table 3. Advantages and Disadvantages Across UAS Platforms.

Platform	Advantages	Disadvantages
Fixed-Wing	• Long endurance, efficient • Cover large areas quickly	• Cannot hover • Need large takeoff/landing zone • Can be target for birds of prey
Multirotor	• Vertical Takeoff and Landing (VTOL) and ability to hover in place • Easy to fly and maneuverable • Ability to change camera angle • Lower cost	• Battery life (about 25-30 minutes) • Generally lower lift (max payload) capacity • Lower endurance than fixed-wing • Costly repairs

Each UAS platform can carry a payload, which is typically a type of remote sensor. Figure 1 depicts common UAS sensors.

RGB Camera	IR/Thermal	LiDAR	Multi-Spectral

Figure 1. Common Types of UAS Sensors. (Image sources left to right: UnSplash, UDOT, UDOT, Pixabay)

Each of these remote sensing technologies are useful in various applications. State DOTs reported primarily using red, green, blue (RGB) camera or light detection and ranging (LiDAR) sensors on construction projects. Factors such as project budget, material to be measured, the overall environment, and the ability to establish control points may determine if images or LiDAR is best for a certain operation. When using an RGB camera, users noted the importance of understanding the impacts of lighting and basic photography principles to capture quality images. High-quality images are beneficial to successfully use structure from motion software to produce a 3D model for measurements and quantity estimates. States are using a variety of software to process UAS-collected data to produce these 3D models and other deliverables. The type of software may be a consideration depending on data collection goals. State DOTs also noted that that some software is better when starting out versus other software that is best for more advanced operators.

State DOTs described a variety of current use cases with UAS across construction projects. UAS are being used in pre-construction surveying, slope analysis, quantity estimations, progress tracking, safety inspections, and as-built verifications. Prior to starting construction, gathering data regarding the topography, and calculating the amount of earth removal or movement has historically been a time-consuming and challenging task. State DOTs have found using UAS captured data and software results in accurate calculations, thus creating time and cost savings. Using UAS during construction allows for backchecking contractors' work and verifying change orders (e.g., being able to check calculations on large earthwork projects as seen in Figures 2 and 3).

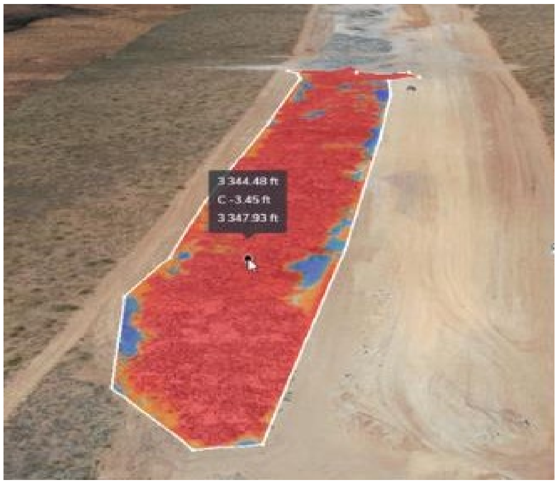

Figure 2. Construction Estimation. (Image DOT)

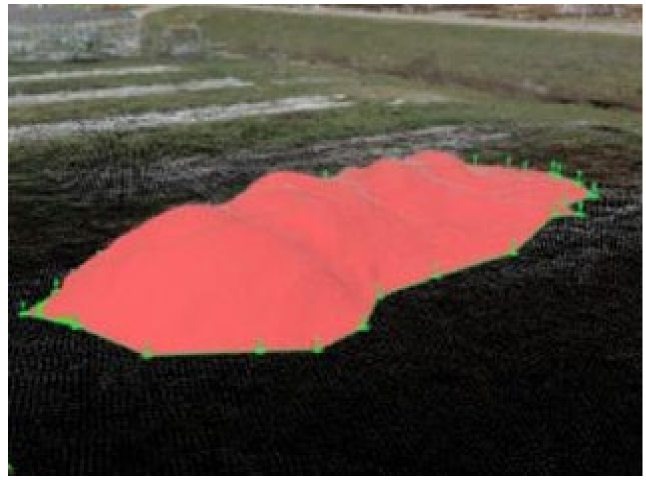

Figure 3. Stockpile Calculation. (Image Wang, 2018)

Transportation agencies shared that they often use UAS to capture progress pictures and videos from the start to completion of a project. These images can be used in progress reports for various stakeholders, including the public. Once projects are complete, transportation agencies have recently started to use UAS for as-built verifications. This means using UAS to confirm the project was built according to plan. Figure 4 shows UAS and terrestrial LiDAR as a hybrid model to verify a recently completed road project. UAS can also be used to verify linear measurements and deliverables such as curbs, fences, and pipe.

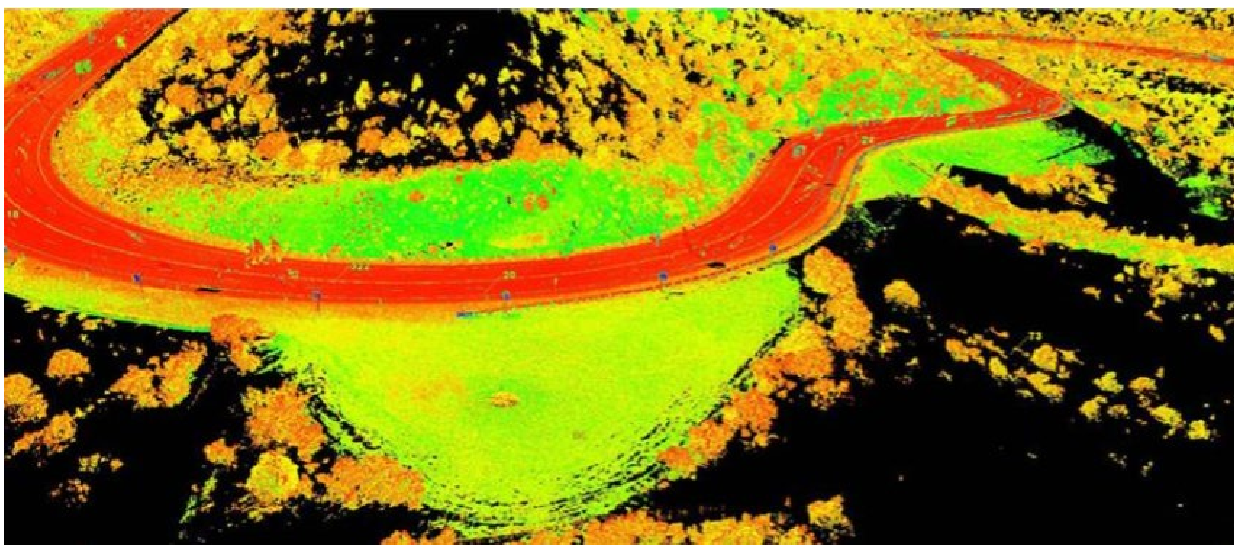

Figure 4. UAS and Terrestrial LiDAR Hybrid Model for As-built Verification. (Image UDOT)

STRUCTURAL INSPECTION

Most State DOTs at the regional workshops agreed that UAS is a supplemental tool to assist with structural inspections, but that it should not be a forced solution. UAS cannot fully remove the human factor from an inspection. Structures currently being inspected by UAS include bridges, culverts, high-mast light poles, signage, tunnels, portals, dams, spillways, retaining walls, and sound walls. UAS are a supplemental tool for bridge inspection and not a replacement for National Bridge Inspection Standards requirements.

Depending on the location of the infrastructure being inspected, there may be concerns about proper notification and communication with those in the immediate vicinity. Participants indicated that landowners have approached inspection crews with questions, and these questions are often about the UAS. It may be appropriate to notify neighbors, police, local field office, and other agencies prior to the inspection. In addition, communication with other airspace users and nearby airports should also be considered. These prior communications can help mitigate concerns and increase overall safety. If people do approach an active UAS operation, it may be helpful to have multiple visual observers, so that a visual observer can engage with the person(s) and help them understand what is taking place. Pre-data collection planning and understanding the overall operating environment for each inspection is helpful in determining communication efforts.

Another concern raised by State DOTs is that technology is changing rapidly, and it is difficult to stay current. Collaboration with other agencies and departments who have experience with UAS adoption may be helpful in meeting this challenge. In addition, selecting the best UAS and sensors for structural inspections can be challenging. For example, not all UAS are designed or suitable for bridge inspections, and it is important to consider the primary use cases when initially purchasing equipment. General platform considerations may include type of UAS (e.g., rotorcraft, fixed-wing), range, battery capacity, wind characteristics, and overall data collection goals.

Other considerations regarding structural inspections are that the operations may be in confined spaces, in GPS-denied environments, or present challenges with lighting and shadows. State DOTs have found that these challenges can be better met with a UAS designed for structural inspections. Figure 5 depicts the type of UAS and associated components that may be helpful depending on the structure being inspected. A front-mounted high-resolution camera that can rotate up and down is helpful in capturing still pictures and videos at various angles (e.g., underneath a bridge). A thermal sensor can be helpful in data collection and analysis. The navigation cameras (navcams) and ultrasonic sensors assist in maintaining control in GPS-denied environments.

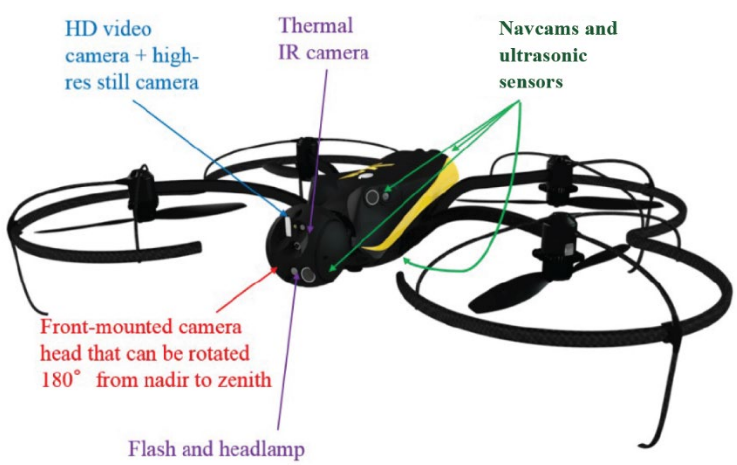

Figure 5. An example of a UAS Designed for Structural Inspections. (Image Oregon State University)

Thermal imaging can be helpful when looking for delamination on bridge decks or on other structures as seen in Figure 6. Kansas DOT reported that lower resolution thermal sensors are often inferior and do not perform as needed. When working with thermal sensors it may be helpful to consider environmental factors such as the sun position, clouds, shadows, and water. Inspectors have found that performing the inspection shortly after sunrise or shortly before sunset helps avoid false positives.

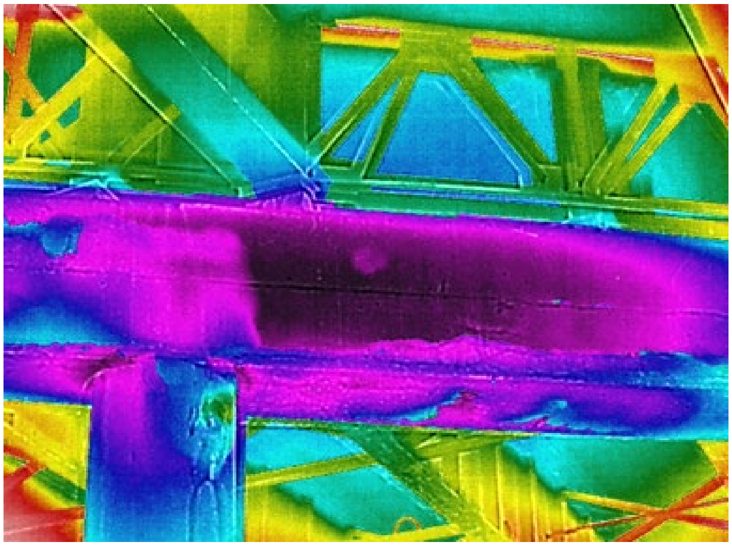

Figure 6. Ohio UAS Center using UAS Thermal Sensors on Bridge. (Image Ohio UAS Center)

Many DOTs express the need to fully integrate UAS into structural inspection workflow and checklists. Using a UAS for an inspection presents additional tasks related to pre-planning, the data collection mission, and post-inspection processing. Adjusting workflows and standard operating procedures may help mature the UAS program and ensures the benefits of using UAS can be fully realized. Additional pre-inspection planning that considers the airspace and operating environment may also be helpful.

Using UAS on infrastructure inspections may initially add time until experience and proficiency mature; at which time UAS typically decrease overall inspection time. The UAS Remote Pilot in Command (RPIC) cannot pilot the aircraft and perform a thorough inspection. Having another person serve as the principal inspector who works with the RPIC may be helpful. Having visual observers on-site and assisting with the operation, especially when flying close to structures is also often helpful. Minnesota DOT shared another method to consider is the use of goggles paired with the UAS. Several DOTs reported having one person operating the UAS while another person wears the goggles to assist in the inspection. These devices allow the inspector to take a closer look while the RPIC remains focused on the UAS. Some State DOTs that have been using UAS longer may have standardized workflows and checklists, and these States may be able to provide advice to other DOTs currently seeking to develop their own internal practices.

Operating the UAS and completing the data collection is only one of the components of structural inspections; the other main task is post-processing and analysis. UAS-assisted inspections create large amounts of data that need to be processed, analyzed, and stored. Depending on computer and software equipment, this may add significant time to the overall workflow. Minnesota DOT has found that a first step in maximizing efficiency may be allocating resources or funding to acquire the quality equipment capable of processing large amounts of data, many other attendees agreed.

UAS may help provide access in difficult areas, supplement existing tools, reduce traffic control needs, and improve the frequency of inspection. UAS may also reduce the need for heavy inspection equipment and response times for emergency inspections. State DOTs have found that these and other benefits increase safety and savings over conventional inspection methods and report a strong trend of ROI.

EMERGENCY RESPONSE

UAS can serve as a tool to assist in emergency response and damage assessment, but coordination and communication are key. States will often work together to prepare and communicate prior to emergencies. Large-scale tabletop exercises across multiple states and agencies are helpful to identify operational shortcomings and opportunities for additional coordination. North Carolina and Georgia DOTs, which had recently responded to large-scale emergencies, reported that establishing informal agreements or formal agreements such as memoranda of understanding between agencies may be helpful in aligning efforts, resources, and establishing leadership.

Figure 7. UAS Assessment of Flood Damage in Texas. (Image Fort Bend County Office of Emergency Management)

When disaster strikes, UAS may be able to assist in the response in a variety of use cases. UAS can provide situational awareness, reconnaissance, search and rescue, damage assessment, communication, supply delivery, and emergency inspections. Historically satellite imagery and traditional aviation were used to assist in post-disaster evaluations to determine hot spots that needed to be prioritized. First responders from State DOTs reported at the workshops that satellite imagery does not have the best resolution and has been found unhelpful at times, especially in situations where cloud cover is in the area. Several State DOTs reported that with coordination, traditional aviation has been able to evaluate large areas, identify the hardest hit areas, and then communicate that information back to the Emergency Operations Center (EOC). The EOC can then coordinate with a UAS team to provide a more detailed analysis.

UAS may assist in data collection regarding hotspots, and they may be able to contribute to the response. State DOTs noted they have used UAS to locate survivors using thermal sensors. UAS equipped speakers have been used to communicate messages of evacuation prior to an event, or to communicate with stranded survivors post event. UAS may be used to deliver radios, first aid supplies, food, and water to inaccessible areas to provide relief to people until they can be rescued.

Figure 8. UAS Assessment of Flooding Across Road. (Image NCDOT)

UAS may also be used in fighting wildfires. Figure 9 shows how UAS infrared sensors can help identify fire hotspots and track movements of the fire. UAS have been used to drop self-igniting chemical balls that are used to start controlled burns in strategic locations.

Figure 9. UAS Utilization Against the Oregon Taylor Creek Fire. (Image U.S. Forest Service)

Many State DOTs report using UAS as part of their local response to vehicle accidents. UAS provide an aerial perspective during the event and are used to collect data for accident re-creation and modeling that may assist in accident investigations. UAS could also provide traffic monitoring as part of the vehicle accident management.

Figure 10. UAS Assisting in Vehicle Accident Response. (Image UDOT)

Other emergency response related use cases reported during the regional workshop sessions included the following:

- Aircraft accidents, assisting the National Transportation Safety Board in accident investigation and reconstruction using UAS-collected data.
- UAS inspections of train tracks post-wind or other weather incidents to look for debris.
- Mapping areas or key infrastructure prior to a disaster to understand existing conditions.
- Riot response where UAS monitor the situation and are used to communicate messages to the crowds.
- Emergency infrastructure inspections with UAS.
- UAS used to look for hazardous waste near water supplies.
- UAS tethered livestream and recording to document emergency response simulations.
- Wildlife mitigation with UAS to assist wildlife in evacuating dangerous areas.

One of the key findings was the importance of cross agency coordination and communication. When agencies are working together to meet the needs of an emergency, they may not all be using the same terminology. Some DOTs have found success in creating UAS-specific training courses related to emergency response and inviting various agencies to participate in the training.

State DOTs that have used UAS in emergency response shared that coordinating operations between manned aircraft and UAS while actively responding to an event should be a top priority. Having a UAS Chief Pilot who works directly with the air boss stationed in the Emergency Operations Center has been found to be helpful in coordinating the UAS efforts with traditional aviation operations. Many DOTs are concerned with properly deconflicting aircraft within the airspace and have found various tools to be helpful in meeting this concern. Using systems and software such as Automatic Dependent Surveillance –

Broadcast modules or the FAA "Drone Notice to Airman" may be helpful tools to coordinate UAS with manned aircraft. In addition, using very high frequency radio frequencies for radio communications may also assist in keeping everyone coordinated.

FIELD DEMONSTRATIONS

Three regional workshops included a field demonstration. A demonstration at the North Regional Workshop was canceled due to inclement weather.

Mid-America Regional Workshop

Various vendors and academic institutions demonstrated various sensor capabilities on different UAS, including zoom and thermal capabilities (Figures 11 and 12). The weather conditions at the time of the field demonstration included high winds, so each demonstrator was also showcasing how different UAS platforms performed in high-wind environments.

Figure 11. Mid-America Regional Workshop Group Gathered for Demonstration. (Image FHWA)

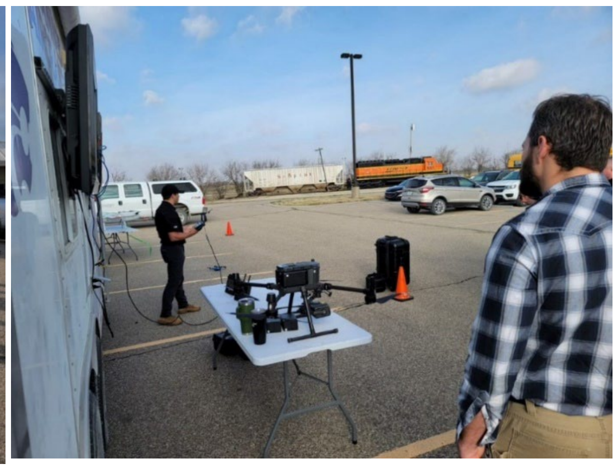

Figure 12. Mid-America Regional Demonstration of Various UAS Capabilities. (Image FHWA)

South Regional Workshop

Various vendors and the North Carolina DOT demonstrated UAS capabilities such as package delivery and tether technology. A robotic dog equipped with sensors was also displayed.

Figure 13. South Regional Workshop UAS Package Delivery Demonstration. (Image FHWA)

Figure 14. South Regional Workshop Demonstration of Package Delivery UAS Preparing for Liftoff. (Image FHWA)

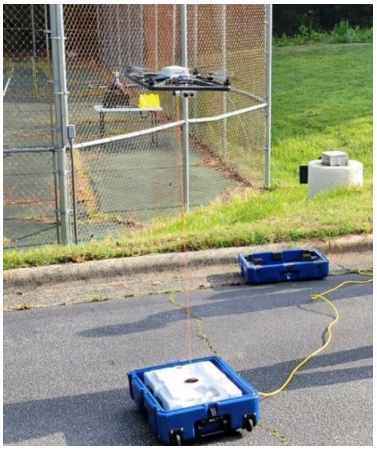

Figure 15. South Regional Workshop Demonstration of Tethered UAS Technologies. (Image FHWA)

Figure 16. South Regional Workshop Demonstration of Robotic Dog. (Image FHWA)

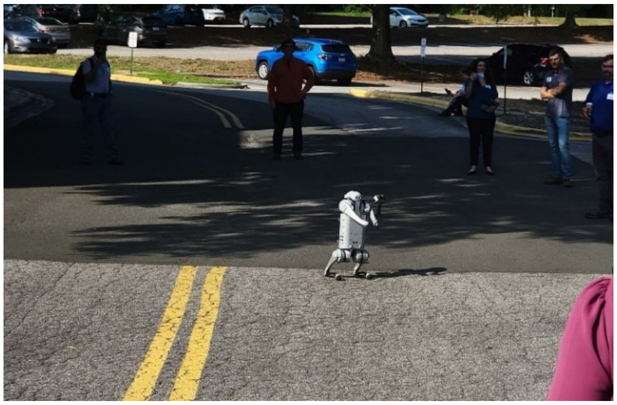

Figure 17. South Regional Workshop Demonstration of Standing Robotic Dog. (Image FHWA)

West Regional Workshop

Various vendors demonstrated autonomous UAS operations such as a point cloud scan of a vehicle and an autonomous mapping mission.

Figure 18. West Regional Workshop Group Gathered for Demonstration. (Image FHWA)

FUTURE RESEARCH

Participants identified several areas where future research is needed to continue to advance UAS technologies and mature State DOTs' UAS programs. This section outlines various topics for future and ongoing research. The FHWA is under no obligation to implement the suggestions.

DATA MANAGEMENT

Across all workshops, UAS practitioners raised concerns about data management. While some State DOTs are beginning to create internal procedures on how to best manage UAS data, many transportation agencies had the following questions:

- Should the data be stored in a cloud service or on servers?
- Who should be allowed access to UAS data?
- Should only final processed data be saved or all raw UAS data?
- How long should UAS data be saved?
- How should all the UAS saved data be organized?
- How can UAS-collected data be screened for privacy concerns?

Current UAS data storage practices were mixed across the Nation. Alabama DOT has found cloud services to be the more affordable option over purchasing a server large enough to be a long-term solution. While cloud storage may be an option, other State DOTs were hesitant to pursue it because of security and legal concerns. Several agencies have worked with the Information Technology department to dedicate servers to the processing and storage of UAS-collected data. One drawback noted about local server storage is it may be difficult to share larger data files, especially when sharing outside of the agency.

Regardless of whether an agency proceeds with cloud or local server storage, a consensus of attendees was that it is important to determine who has access to the data and who can actively manage the data. Utah DOT shared the importance of establishing procedures, policy, permissions, and access controls is helpful in properly securing and governing stored UAS data. Some agencies have created a process that only allows the public to see any UAS data by request. State laws and policies may affect how public can access data or on how data should be managed overall within the transportation agency.

Some State DOTs store the raw UAS data and the processed final data, while others save only the processed data and delete the raw data to allow more room for additional storage. Participants had mixed thoughts on what data are critical and therefore should be saved. Some agencies are exploring other ways UAS-collected data may be repurposed or analyzed to be beneficial to other divisions or useful on other projects.

While some agencies are deleting processed data after projects are considered complete and closed, most State DOTs are saving project data long term. Several participants indicated that their State has local statutes that require indefinite storage of data related to all transportation projects and asset management. Other agencies not bound by State law still consider it best practice to find a long-term solution for archiving all UAS data. When saving large amounts of UAS data, it may be helpful to develop a uniform file structure, perhaps by project or by year.

At times, houses or other private property may be captured as part of the UAS data collection mission. These data are referred to as incidental data and are likely not critical to the UAS mission focus and are not needed. At other times, it is necessary to collect data outside an area of interest to be able to properly gather data within the area of interest. While privacy policies vary from State to State, State DOTs consider it best practice to remove or blur incidental data of private property whenever it is possible. The use of Artificial Intelligence (AI) to search through collected UAS data for sensitive information is a current and ongoing field of research.

Data governance of collected UAS data is an ongoing effort for most States and is an area of focus to define best practices. Many States have UAS committees that are actively discussing the concerns and questions around UAS data management.

EMERGING UAS TECHNOLOGY

As technology and regulations continue to advance, other use cases for UAS may be explored across the construction lifecycle, including technology such as the "drone-in-a-box" system, which is a complete system that can autonomously launch a UAS from a temperature-controlled, weatherproof charging hangar to conduct an autonomous mission and then return to the hangar. This innovation may reach its full potential when Beyond Visual Line of Sight (BVLOS) operations are enabled by regulation. This type of solution may be beneficial in increasing construction monitoring, emergency response, and other use cases such as monitoring striping painted by autonomous vehicles.

Other technologies, including AI, are being developed and tested that may assist with the post-inspection analysis. For example, Utah DOT used AI for analysis of hardware on overhead signs, Minnesota used AI for structure crack detection on bridge decks, and Ohio used AI for traffic monitoring. Through experience, lessons learned, proper equipment, and overall success with UAS-assisted structural inspections, DOTs may develop a standard workflow and checklist.

Emerging technologies when coupled with UAS-collected data may significantly increase efficiency in post-processing and analysis. AI is currently being tested and validated to identify types, extent, growth, and location of various defects on different structures (Perry et al., 2020). Companies are working to mature these AI technologies and with time, AI may be something that State DOTs will want to consider.

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 U.S.C. § 40102 and § 40125. Additionally, both public and civil UAS operators may operate under the regulations promulgated by the FAA. The provisions of 14 CFR part 107 apply to most operations of UAS weighing less than 55 pounds. Operators of UAS weighing greater than 55 pounds may request exemptions to the airworthiness requirements of 14 CFR part 91 pursuant to 49 U.S.C. §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/.

CONCLUSION

The regional workshops as part of the FHWA EDC UAS Initiative brought transportation agencies from around the Nation together to understand the state of practice regarding UAS. Practitioners identified and discussed current UAS use cases across construction inspection, structural inspection, and emergency response. Best practices, current concerns, and ongoing research regarding UAS regulations, funding, and data management were also identified.

As part of the synthesis of findings from the general breakout sessions, the three core track sessions, and the networking breaks across all the regional workshops, State DOTs identified the following topics to consider as next steps for success:

- Continue Federal support from the top down through grants, training, and dissemination of information on UAS use cases and technology.
- Develop a Federal UAS loaner program to assist new or growing State UAS programs.
- Create a national scale platform for sharing UAS incident and accident information to learn from one another.
- Continue peer exchange workshops and foster other forms of collaboration for transportation agencies to share success stories, best practices, and seek assistance on challenges.
- Create a national transportation agency UAS convention to bring together Federal, State, and local agencies; academia; and commercial vendors.
- Continue to use UAS committees from State DOTs to assist in local efforts.
- Maintain a flexible approach while advancing policy and regulations on transportation agencies' utilization of UAS.

While concerns and ongoing research needs were identified, overall State DOTs reported progress and optimism in continuing to integrate UAS as an additional tool to fulfill their responsibilities. UAS use cases across construction, infrastructure inspections, and emergency response continue to grow. Transportation agencies have found that UAS assist in increasing safety, time savings, and the collection of quality data.

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