UAS in Transportation Expo
Final Report

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Introduction

Unmanned aircraft systems (UAS), also called drones, are becoming an increasingly valuable tool for transportation agencies. A number of state DOTs are considering implementing UAS programs, while others are already using UAS for a wide range of applications. It has been estimated that over half of all state DOTs have had some level of involvement with UAS, to date. Despite recent progress, however, a number of challenges remain, both technical and procedural. In implementing UAS programs, agencies are facing issues related to maintenance and reporting, personnel training (e.g., FAA Part 107 and operational training requirements), regulations (federal, state and local), data storage, data collection and analysis, and overall management of a UAS program.

A *UAS in Transportation Expo*, sponsored by PacTrans, was held on July 30-31, 2018 to explore these topics. The specific goals of the workshop were to:

1. Review and document lessons learned from over three years of PacTrans and Oregon Department of Transportation (ODOT) sponsored research into UAS for transportation applications, including bridge inspection, communication tower inspection, and traffic network monitoring
2. Discuss ongoing challenges
3. Brainstorm solutions and chart a path forward to increase the effective, safe, and cost-efficient use of UAS in transportation

Forty participants, representing state and local government agencies, industry, and academia, attended the workshop (see full participant list in Appendix B). Most of the participants had a strong background in UAS, and nearly a third were FAA Part 107 certified remote pilots, based on show of hands. This report summarizes the workshop and presents key points from the brainstorming sessions. Based on the overarching themes from the workshop and group consensus during the brainstorming sessions, the report concludes with recommendations for ongoing work in extending and improving the use of UAS in transportation.

Workshop Summary

The workshop was organized with most of the presentations (Fig. 1) scheduled on Day 1, such that the majority of Day 2 could be devoted to group discussion and brainstorming. The Day 1 presentations covered UAS technologies and findings from a range of transportation-related projects, including bridge inspection, communication tower inspection, and rockfall site monitoring projects. Lessons learned from operationalizing UAS in Los Angeles' major transportation hubs were also presented. On the afternoon of Day 1, UAS demonstration flights were conducted in a project site located at the southwest concourse of OSU's Reser Stadium. The flights were conducted under FAA Part 107 and with approval from the OSU Athletic Department. Two flights were conducted (Fig. 2), demonstrating typical procedures used in: 1) structural-inspection flight, and 2) mapping flight to produce georeferenced orthomosaics and point clouds.

Day 2 began with a presentation on Structure from Motion (SfM) photogrammetry, followed by a hands-on SfM demonstration (Fig. 3), in which participants processed imagery collected with a senseFly albris over an ODOT communications tower using Pix4D software. Following the SfM demo, participants from the participating state DOTs, ODOT and Washington DOT (WSDOT), shared their experiences in UAS, which facilitated the subsequent group brainstorming sessions.

Figure 1: Presentations by (clockwise from upper left): Michael Olsen (OSU), Adrienne Lindgren (WSP USA), Chris Parrish and Chase Simpson (OSU), and Chris Glantz (ODOT).

Figure 2: UAS demo flights conducted as part of workshop. Two flights were conducted, illustrating different types of operations: structural inspection, and mapping.

Figure 3: Structure from Motion (SfM) hands-on demo on Day 2 of workshop.

Summary of Lessons Learned

The workshop attendees' experiences attest to the growing use of UAS in transportation and related disciplines. There was general consensus among attendees that the applications listed in Table 1 constitute the current top uses of UAS in transportation. There was, however, some discussion of the exact ordering of these uses, and it was acknowledged that the priority or prevalence of these different applications are likely to be region- and agency-specific.

Table 1: Top uses of UAS in transportation.

Rank	Application
1	Bridge inspection
2	Rockfall site monitoring
3	Communication tower inspection
4	Construction site monitoring/inspection
5	Transportation network monitoring
6	Geotechnical engineering analysis
7	Effective messaging/outreach/storytelling

Based on their UAS experiences and discussion in the brainstorming sessions, the attendees provided recommendations in four broad categories: organizational, procedural, training-related, and contracting-related.

Organizational recommendations:

An overarching recommendation is that transportation agencies (e.g., state DOTs) initiating a UAS program should implement a formal UAS structure. An example from ODOT is shown in Fig. 4. A designated UAS Program Manager has overall oversight responsibility for the program, while a Flight Operations Coordinator, reporting to the UAS Program Manager, oversees program operations. Chief Pilots are designated for specific disciplines. Individual pilots, reporting to the Chief Pilot, are responsible for maintaining FAA Part 107 Remote Pilot certification, as well as completing agency-approved training and maintaining currency. This structure—which could clearly differ from one agency to another—and all applicable policies, rules and regulations should be spelled out in a UAS Policy document, tied to the agency's Operations Manual.

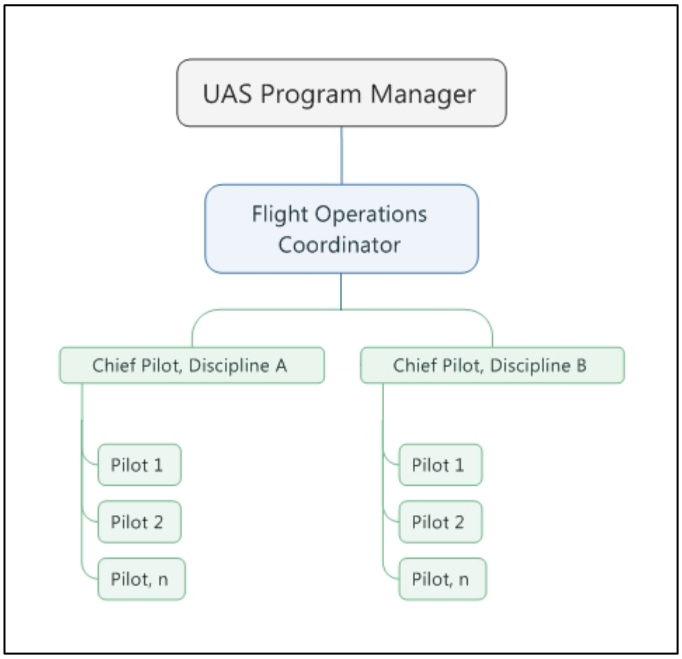

Figure 4: UAS organizational structure used at ODOT (from presentation of ODOT's Chris Glantz; used with permission).

<u>Procedural recommendations</u>:

It is recommended to codify the decision-making process for approving a UAS project. An example of a decision tree used by ODOT is shown in Fig. 5. This type of decision tree is useful when UAS will be used in multiple disciplines across an agency. Specifically, the decision tree aids in the ability to orient the work toward the experts, both in the field and in the office. Similarly, it is recommended that detailed standard operating procedures (SOPs) be developed for as many operational aspects of the program as possible. One beneficial aspect of SOPs is that they reduce the need for on-the-fly decision making in a potentially stressful field environment. An example is to codify go/no-go rules for flights with a particular aircraft as a function of wind speed (maximum sustained winds and gusts, as measured by a handheld anemometer, provided to all flight crews). Similarly, detailed checklists are extremely helpful in the field and can include checks to ensure that the rules prescribed in the SOPs are satisfied.

Another subset of procedural recommendations relates to defining the required flight crew members and other essential personnel and required equipment. ODOT requires a visual observer (VO) for all flights. One of the VO's duties is to help maintain a "sterile cockpit" environment, in which the takeoff/landing zone and pilot's control station are kept clear of personnel, unnecessary equipment, etc. Other essential personnel for a UAS project may include a subject matter expert (SME), such as a bridge inspector for bridge inspection flights. Required equipment may include: 1) closed-loop intercom headsets; 2) ATC radio; 3) handheld anemometer (noted above); and 4) spectrum analyzer for flights at communication towers to identify potential interference.

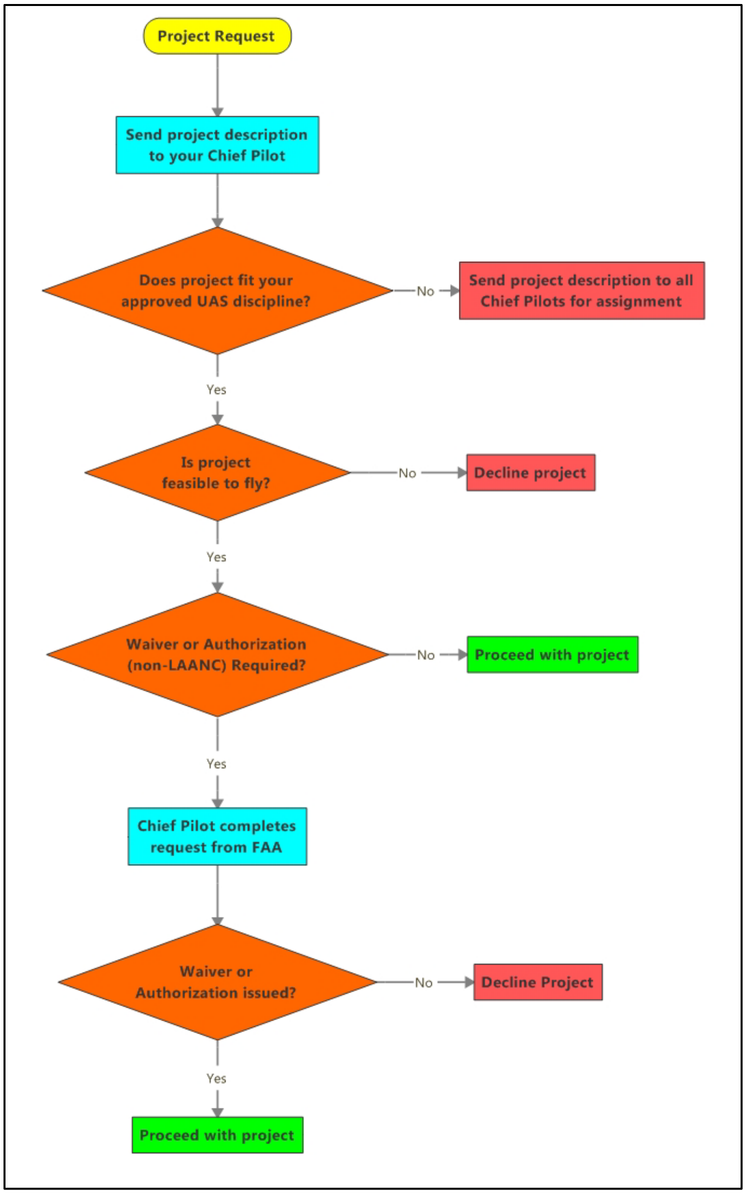

Figure 5: Decision tree (flowchart) for approval of a proposed UAS project (from presentation of ODOT's Chris Glantz; used with permission).

Requirements for the aircraft and payloads/sensors are project-specific. However, some general recommendations made by workshop participants were: 1) for structural inspection projects (e.g., bridge inspection), having a camera with optical zoom is important, as it allows the required level of detail to be captured in the imagery (i.e., sufficient image resolution), while maintaining a safe standoff distance from the structure; and 2) anti-collision lighting, which is required for operating during twilight, is recommended for operating during daylight, as well. The latter recommendation is based on the fact that the lights on many UAS are not bright enough to allow the aircraft to be easily seen by the pilot and VO, when viewing the aircraft against a dark background, such as tree canopy or a canyon wall.

Other recommendations relate to the UAS flight planning and operations. For operations in controlled airspace, conversations with Air Traffic Control (ATC) should happen as early as possible in the project planning. (The FAA UAS facility maps (https://www.faa.gov/uas/request_waiver/uas_facility_maps/) and Low Altitude Authorization and Notification Capability (LAANC), were also noted as being extremely useful, although the latter was not yet complete for many areas in the Pacific Northwest, as of the date of the workshop.) Similarly, landowners should be contacted as early as possible when planning a project.

During the field operations, a basic level of quality assurance/quality control (QA/QC) should be performed in the field, at least sufficient to ensure that usable data has been acquired. All flights should be logged while in the field, just as aircraft maintenance should be logged at the time it occurs. Smartphone or tablet apps that provide weather forecasts, GPS visibility, and space weather forecasts (e.g., https://www.uavforecast.com/#/) are recommended for flight crews, as well as tools to facilitate automated logging of flights and battery usage. When possible, a geo-fence should be used to assist in keeping the aircraft within the defined project site. Additionally, it was noted that firmware updates should be avoided in the field, and only applied when there is sufficient time to test the updates before operational use. To acquire high-quality imagery for use in SfM software, it is strongly recommended that UAS flight crews have at least a basic level of expertise in photography, including understanding aperture, shutter speed, and ISO settings.

When the flight crew and flight operations are visible to nonparticipants (e.g., passing motorists), it is highly recommended that the flight crew be as conspicuous and official as possible, including wearing safety vests (as well as other personal protective equipment, such as hardhats, as required), and headsets. There was discussion among participants as to the usefulness of signs warning motorists of drone operations ahead. Participants generally felt that additional research is needed to make recommendations regarding signage. It was also noted that there may be cases when it is beneficial for the flight crew to remain out of sight, to the extent feasible, if they would create a potentially unsafe distraction for passersby or vice versa.

Training-related recommendations:

Structural inspection flights are among the most technically-challenging and nerve-wracking to perform, even for experienced UAS pilots. Particular challenges associated with these flights include:
1) requirement to operate close to the structure, increasing likelihood of crashing into the structure being inspected, 2) turbulent air around structures; 3) poor GPS, especially when operating close to or even under a portion of the structure; 4) loss of depth perception, when viewing a small aircraft against the backdrop of a large structure from a remote vantage point on the ground; and 5) risks associated with operating over water or deep canyons, in the case of bridge inspection. Multiple workshop speakers and participants voiced the requirement for flight crews to practice inspection type flights frequently. However, specific currency requirements need to be defined for UAS pilots (see challenges section below). Additionally, it must be recognized that different aircraft can behave very differently when operated near structures, so practice flights conducted with one aircraft may not suffice as training for operational flights with a different aircraft.

Contracting-related recommendations:

Participants noted that additional work is needed to develop contract specifications and contract language for UAS operations. A general recommendation is that the contract should specify that all flights must be conducted under FAA Part 107, but to leave other requirements as deliverable-based (e.g., file type requirements, spatial resolution and accuracy requirements), rather than specifying specific acquisition or flight parameters. It is recommended that, to the extent possible, contracts be written to support multi-use of the data.

Unsolved Challenges in UAS for Transportation

The unsolved challenges discussed during the workshop separated into four general categories: 1) operational, 2) technical, 3) contracting-related, and 4) IT-related.

Operational challenges

Beyond the UAS Policy document noted above, there is a need for transportation agencies to define "Rules of Engagement" for UAS operations, clearly stating what happens in an emergency (e.g., flyaway event, battery fire, emergency landing, crewmember medical emergency, etc.). Additionally, there is a need to develop SOPs for all equipment and to define procedures that are beyond those covered in the UAS Operations Manual. These additional procedures could become part of a Safety Management Plan. There may also be a need to revisit currency requirements for pilots (i.e., the number of flights per calendar month, quarter, or year to maintain currency), and to determine whether simulator flights can be used to maintain currency.

Technical challenges

UAS operations can result in vast data volumes (on the order of many terabytes per month). While the imagery and other sensor data collected by the UAS comprise a valuable resource, it is unrealistic to expect that transportation agencies would be able to hire teams of image analysts or lidar analysts to manually review huge volumes of data and extract information. Therefore, new machine learning approaches, such as deep learning, are needed to assist in turning data into information. A related need is for new image processing algorithms and software to deal with poor illumination (e.g., due to shadows or sub-optimal sun angles) and other challenges associated with imaging large structures. Another technical challenge relates to the need for extensive ground control for SfM photogrammetry and the desire to use direct georeferencing to alleviate ground control point (GCP) requirements.

Contracting-related challenges

As many transportation agencies are currently in the process of developing and refining internal procedures for UAS operations, there is still work to be done in developing contracting specifications. Beyond requirements for deliverables (e.g., spatial accuracy and resolution, file formats, etc.) and adherence to FAA Part 107 and applicable federal, state, and local laws and regulations, participants expressed a need to further define contract requirements with respect to security, privacy, and operational practices.

IT-related challenges

Most of the identified IT-related challenges relate to effective data management. As noted above, an active UAS program will result in huge volumes of data. This creates issues related to data storage (e.g., server based vs. cloud based), discovery, archival and dissemination.

Potential Solutions

It is recognized that effective communications—both internal and external—are a large part of addressing the challenges noted above. As many transportation agencies are at similar stages of implementing UAS programs, information shared between agencies can be highly beneficial. Internal communications (i.e., within an agency) can facilitate multi-use of data and assist with educating and informing various parts of the agency about effective and safe uses of UAS. One example of an underexplored use of UAS data is for outreach and storytelling. Internal demonstrations by the UAS Program to other parts of the agency can be a highly-effective means of internal education and outreach. For external outreach, it may be possible to leverage existing state- and region-wide UAS and geospatial groups. These could include national groups, such as the Transportation Research Board (TRB) AFB80, and the American Society for Photogrammetry and Remote Sensing (ASPRS), as well as state groups, such as the Professional Land Surveyors of Oregon (PLSO), and Oregon UAS Users Group.

Ongoing improvement and adoption of automated UAS program tracking/reporting systems are anticipated to alleviate some of the current burdens associated with logging and reporting. New artificial intelligence (AI) and digital signal processing algorithms may be the keys to alleviating many of the IT-related challenges.

Conclusions

The use of UAS in transportation is accelerating, due to the efforts of a number of agencies. The *UAS in Transportation Expo*, held at OSU on July 30-31, 2018, documented recent successes and important lessons learned. Based on the participants' expertise, as well as the discussion during the brainstorming sessions, this report contains a number of key recommendations for transportation agencies initiating UAS programs. However, there are also lingering challenges that currently hinder effective use of UAS in transportation. These challenges, which can be categorized as operational, technical, contracting-related, and IT-related, were discussed during the workshop and are reported herein.

Some of the current challenges can be addressed through enhanced coordination and collaboration between agencies involved in using UAS in transportation. Many transportation agencies are at similar stages of implementing UAS and can assist one another by sharing information. Internal communications and outreach activities are also highly beneficial for educating users within an agency about safe, legal and cost-effective uses of UAS.

Other challenges will require further research and development to overcome. It is recommended that research be conducted to address: 1) direct georeferencing capabilities and procedures, using carrier-phased based relative positioning (e.g., PPK) and GNSS-aided inertial navigation systems (INS); 2) non-GNSS flight modes (e.g., for flights under bridge decks); 3) machine learning algorithms to assist transportation agencies in automated information extraction from extremely large imagery databases; 4) specifications for feature extraction in SfM-derived point clouds; and 5) development and testing of new tools and procedures for automated management, retrieval, visualization and dissemination of large imagery databases.

There is little doubt that the use of UAS in transportation will continue to grow in the foreseeable future and that new challenges and opportunities will arise. Therefore, a final recommendation is to continue the type of information exchange that this workshop enabled. It may be beneficial to hold a UAS in Transportation workshop annually and/or for transportation organizations to establish a working group that meets regularly.

Acknowledgements

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Appendix A: Workshop Agenda

UAS in Transportation

July 30-31, 2018 • Oregon State University • 102 Johnson Hall
http://blogs.oregonstate.edu/uasintransportation
Agenda

Day 1: Monday, July 30

8:30 - 9:00	Introductions	
9:00 - 9:45	UAS Basics for Transportation	Chris Parrish, OSU
9:45- 10:15	UAS for Rockfall Site Monitoring	Michael Olsen, OSU
10:15 - 10:30	Coffee break	
10:30 - 11:00	Lessons Learned from OSU PacTrans and ODOT UAS Projects	Chris Parrish and Chase Simpson, OSU
11:00 - 11:30	What's all the buzz about? Operationalizing UAS at LA's major transportation hubs	Adrienne Lindgren, WSP USA
11:30 - 12:00	Up and Under – On Using Drones for Bridge Inspection	Gary Licquia, senseFly
12:00 - 13:00	Lunch (catered)	
13:00 - 13:30	OSU's UAS research initiatives	Julie A. Adams, OSU
13:30 - 15:30	Drone flights (Reser SW concourse): mapping flight and inspection-type flight	Chase Simpson, Richie Slocum, Chris Parrish, OSU
15:30 - 15:45	Overview of goals for Day 2	
15:45	Adjourn	

Day 2: Tuesday, July 31

8:30 - 9:00	Structure from Motion (SfM) overview	Richie Slocum, OSU
9:00 - 10:30	SfM Processing: hands-on demo	Richie Slocum, Chase Simpson, Chris Parrish, OSU
10:30- 10:45	Coffee break	
10:45 - 11:15	ODOT's UAS Programs	Christopher Glantz, Oregon Department of Transportation

11:15 - 12:00	State DOTs/Transportation agencies: updates on current UAS programs/activities	
12:00 - 13:00	Lunch (catered)	
13:00 - 14:45	Discussion: challenges, solutions and opportunities in UAS for transportation	Open discussion
14:45 - 15:00	Break	
15:00 - 15:30	Next steps and collaboration opportunities	Open discussion
15:30	Adjourn	

Appendix B: Participants

First Name	Last Name	Organization/ Affiliation(s)
Julie A.	Adams	Oregon State University
Ciara	Annas	Oregon Department of Transportation
Jim	Ayres	Washington State County Road Administration Board
Matt	Balder	Thurston County Public Works
Darren	Blackwell	Marion County
Mike	Brinton	Oregon Department of Transportation
Jeremy	Gibboney	Marion County
Chris	Glantz	Oregon Department of Transportation
Christopher	Harris	Oregon Department of Transportation
Richard	Hill	The PPI Group, a Topcon Solutions Store
Spencer	Hohenshelt	Marion County
Heidi	Holmstrom	WA. State Department of Transportation
Jaehoon	Jung	Oregon State University College of Engineering
Mandar	Khanal	Boise State University
Cole	Kopca	PacTrans
Gary	Licquia	senseFly
Adrienne	Lindgren	WSP
Joseph	Louis	Oregon State University College of Engineering
John	MacArthur	Washington State Department of Transportation
Kevin	Maine	Oregon Department of Transportation
Jim	Moyer	THURSTON COUNTY PUBLIC WORKS
Brett	Murphy	Oregon Department of Transportation

Michael	Olsen	Oregon State University, College of Engineering
Aaron	Olson	Quantum Spatial, Inc.
Kent	Palmer	Washington State Department of Transportation
Paul	Panzica	Oregon Department of Transportation
Christopher	Parrish	Oregon State University, College of Engineering
Nisha	Puri	Oregon State University, College of Engineering
Khandakar	Rashid	Oregon State University, College of Engineering
Paul	Rydell	The PPI Group, a Topcon Solutions Store
Grace	Sethanant	Oregon State University
Chase	Simpson	Oregon State University
Richard	Slocum	Oregon State University
Michael	Smith	Washington State Department of Transportation
Kurt	Stiles	Washington State Department of Transportation
Chris	Tams	Washington State Department of Transportation
Joe	Thomas	Oregon Department of Transportation
Yelda	Turkan	Oregon State University, College of Engineering
Joshua	Wagner	Cal Engineering & Geology