Unmanned Aerial Vehicle Uses for Winter Maintenance

Synthesis Report

CLEAR ROADS

research for winter highway maintenance

CTC & Associates LLC

Project CR23-S3
May 2025

Pooled Fund #TPF-5(353)
www.clearroads.org

Disclaimer

This document is disseminated under the sponsorship of the Clear Roads pooled fund project, #TPF(5)-353 (lead state Minnesota Department of Transportation), in the interest of information exchange. The sponsoring agencies assume no liability for its contents or use thereof.

The purpose of this report is to serve as a synthesis of pertinent completed research and practitioner survey results to be used for further study and evaluation. This synthesis does not represent the conclusions of the authors or the Clear Roads member agencies. This document does not constitute a standard, specification or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor or consultant. Trade names of commercial products appearing in this publication are included for clarity only.

Acknowledgments

CTC & Associates LLC would like to extend our appreciation to the members of the Technical Advisory Committee of the Clear Roads pooled fund for their assistance with this project. We also extend our thanks to the state DOT employees and others who participated in the project's survey.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CR 23-S3		

4. Title and Subtitle	4. Report Date
Unmanned Aerial Vehicle Uses for Winter Maintenance	May 2025
	5. Performing Organization Code N/A

7. Author(s)	8. Performing Organization Report #
CTC & Associates LLC	N/A

9. Performing Organization Name & Address	10. Purchase Order No.
CTC & Associates LLC 2323 Woodscrest Ave. Lincoln, NE 68502	N/A
	11. Contract or Grant No. N/A

12. Sponsoring Agency Name & Address	13. Type of Report & Period Covered
Clear Roads Pooled Fund Minnesota Department of Transportation 395 John Ireland Blvd. St. Paul, MN 55155-1899	Final Report
	14. Sponsoring Agency Code N/A

15. Supplementary Notes
Project completed for the Clear Roads pooled fund, TPF-5(353). See clearroads.org.

16. Abstract

In recent years, state departments of transportation (DOTs) have adopted unmanned aerial systems (UASs) for use in many agency operations. These emerging technologies have the potential to streamline workflows in multiple disciplines within highway transportation, including construction, engineering, intermodal transportation and operations permitting. Unmanned aerial vehicles (UAVs) can provide a safe and cost-effective alternative to traditional asset inspection, data collection, emergency response and other DOT practices. However, information about their application in winter maintenance operations is limited.

This synthesis report explores transportation agency use of UAVs to identify ways in which the technology has been implemented specifically in winter maintenance operations and more broadly throughout a transportation agency, as well as opportunities that could benefit from UAV implementation. A survey of winter maintenance professionals and a review of relevant literature gathered information about current UAV applications within an agency and specific UAV models and product features, including drone software, flight speed and duration, operational and maintenance requirements, and costs. UAV program information describes responsibility for program oversight, staffing levels, training and licensing requirements of pilots, program funding and effective program management practices.

17. Key Words	18. Distribution Statement
Winter road maintenance; unmanned aerial vehicle; UAV; unmanned aerial system; UAS	No restriction. This document is available to the public through the Clear Roads pooled fund project and the Minnesota Department of Transportation.

19. Security Classification (this report)	20. Security Classification (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	98	

Table of Contents

List of Tables

Abbreviations and Acronyms

AI	artificial intelligence
Alaska DOT&PF	Alaska Department of Transportation and Public Facilities
AVL	automatic vehicle location
BVLOS	beyond visual line of sight
COA	Certificate of Waiver or Authorization (FAA)
DiaB	Drone in a Box
DOT	department of transportation
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	geographic information system
I-80	Interstate 80
LAANC	Low Altitude Authorization and Notification Capability (FAA)
NOTAM	Notice to Airmen
Part 107	Section of FAA regulations governing pilot licensing to operate unmanned aerial vehicle
PPK	post-processing kinetics (connectivity)
ROW	right of way
RPIC	remote pilot in command
RTK	real-time kinematic (connectivity)
RWIS	road weather information system
SLAM	simultaneous localization and mapping (technology)
SMART (grant)	Strengthening Mobility and Revolutionizing Transportation (Grant Program) (Montana DOT)
SPOT	snowplow operator training
SPR	State Planning and Research (funding)
STIC	State Transportation Innovation Councils incentive program (FHWA)
sUAS	small unmanned aerial system
TFR	Temporary Flight Restrictions
TMC	Transportation Management Center
UAS	unmanned aerial system
UAV	unmanned aerial vehicle

Executive Summary

Unmanned aerial systems (UASs) are increasingly used by state departments of transportation (DOTs) for many agency operations, streamlining workflows in construction, engineering, intermodal transportation, operations permitting and other aspects of highway transportation. A UAS commonly comprises an unmanned aerial vehicle (UAV) or drone; a pilot; and the equipment, technologies and communication systems required to facilitate UAV use. UAVs can provide a safe and cost-effective alternative to traditional asset inspection, data collection, emergency response and other DOT practices.

This synthesis report explores UAV use in winter maintenance operations and opportunities that could benefit from UAV implementation. A survey of winter maintenance professionals and a review of relevant literature gathered information about UAV use for winter maintenance activities and across disciplines within transportation agencies. In addition to describing winter operations applications, survey respondents addressed questions related to specific UAV models; regulatory, operations and safety requirements; UAV program development; and assessment of UAVs in use. Supplementing these findings was a literature search that examined completed and in-progress research.

The survey received 35 responses from 30 agencies: 26 state DOTs, three local governments and one consultant. Units or divisions within agencies that provided multiple responses are identified in the discussion.

Twenty-four respondents from 20 agencies—18 DOTs and two local governments—indicated that their agencies use UAVs for winter maintenance activities or other agency operations.

Note: Both Utah DOT respondents provided partial responses; these responses have been combined as one response in the presentation of survey findings.

Unmanned Aerial Vehicle Applications

Winter Maintenance Activities

Nearly all of the respondents using UAVs for some type of agency operation (20 of 23 respondents) indicated that their agencies use UAVs for winter maintenance activities such as stockpile measurement (12 respondents), avalanche hazard reduction (seven respondents) and identification of areas prone to ice formation (four respondents). Other winter maintenance activities that frequently employ UAVs include search and rescue operations; emergency response; monitoring geological hazards, ice dams, flooding, road conditions and traffic flow; measuring and documenting snow storage of vertical post snow fences; and snowplow operator training.

Interdepartmental Applications

Other agency applications where UAVs are typically used include bridge inspections, construction projects, landslide and steep terrain investigations, engineering projects, emergency response, data collection, and project design and planning.

Adapting Interdepartmental Uses to Winter Maintenance

Survey respondents noted that many of the interdepartmental applications could be leveraged toward winter maintenance. Practices related to emergency management and response, landslide and avalanche monitoring, road condition monitoring and traffic monitoring could most easily be adapted.

Respondents also noted challenges with adapting these applications to winter operations, including Federal Aviation Administration (FAA) restrictions, geographic location, and extreme or inclement weather.

Product Information

The number of UAVs owned by agencies responding to the survey varied considerably. Nine respondents reported owning from one to 15 UAVs. Alaska Department of Transportation & Public Facilities (Alaska DOT&PF) reported owning 130 drones, and Illinois DOT has 27 UAVs in its recently launched program.

Systems in Use

Note: Below is a summary of information provided by survey respondents about the UAV models their agencies use. The U.S. Department of Commerce along with some state governments are considering or have imposed new rules and restrictions for using foreign-manufactured drones and technology, some of which are referred to below.

Survey respondents describe a range of features for UAVs manufactured by six companies:

Manufacturer	Number of Models	Description
DJI (SZ Technology Company)	13	**Mavic models:** Mavic 2 Pro, Mavic 3 Enterprise, Mavic 3 and Mavic 2 Zoom, Mavic 2, Mavic 3 Pro, Phantom 4 Pro V2.0, Phantom 4 RTK and Air 2S **Matrice models:** Matrice 350, Matrice 30T, M30T Dock and Matrice 300 RTK
Skydio, Inc.	5	X10, S2+, 2+, S2 and X2
Autel Intelligent Technology Corporation	3	EVO II Enterprise, EVO II Pro V3 and EVO II RTK
Parrot ANAFI USA	2	Parrot Anafi Ai and Parrot Anafi Work
Acecore Technologies	1	Zoe
Prism (Watts Innovations)	1	Prism Ranger with Reigl miniVUX-3

Below is information provided by survey respondents for the most commonly used models from three manufacturers: DJI, Skydio and Autel. Included in this discussion is information about software, UAV specifications, flight speed and duration, maintenance and operational requirements, benefits and challenges, and cost.

Complete details for all of the models described by survey respondents are presented in Appendices A through D.

DJI

Mavic 2 Pro

Users of the Mavic 2 Pro noted the UAV's compact size, ease of use, quality of photography and "better final product." Weighing approximately 2 pounds, this untethered drone travels at 25 to 35 mph for approximately 30 minutes. Survey respondents reported using Pix4D and DJI Fly software.

According to users, these drones must meet FAA Part 107 regulatory requirements governing pilot licensing (Part 107) and are operational to 14 degrees Fahrenheit (F), wind gusts of less than 20 mph and no precipitation. Only line of sight flying is allowed; Visual Flight Rules (daytime only) must be followed, and no night flying is allowed. Minimal, routine maintenance is required, mainly with batteries; propeller and software updates are common; and the drone is limited to approximately 200 cycles. Challenges of this UAV include the need for training; inability to fly beyond visual line of sight (BVLOS), at night or in the rain; no lookup capability; China-based data storage; and operating near airports, traffic and pedestrians. Costs reported by respondents ranged from approximately $2,000 to $5,000.

Mavic 3 Enterprise

According to survey respondents, the Mavic 3 Enterprise allows for a quick deployment time, enhances operator safety, offers efficiency benefits and provides a record of change in conditions over time. Measuring 347.5 x 283 x 107.7 mm (unfolded, without propellers) with a maximum takeoff weight of 1,050 grams, this untethered drone travels at 35 to 47 mph for 40 to 45 minutes. One respondent reported using the DJI Pilot 2 app. The UAV's simple mapping and videography platform has zoom capabilities and is limited by Part 107 regulations. The drone can operate at temperatures ranging from 14 to 104 degrees F with a maximum wind speed of 28 mph. Routine maintenance according to manufacturer's recommendations is required.

Some state governments have recently mandated that purchase and use of this and other DJI products, which are manufactured in China, be discontinued. According to a survey respondent, U.S.-manufactured UAS equipment is "three to four times as expensive with very limited functionality and capabilities compared to DJI models." Another respondent noted the model's fixed gimbal cannot be changed or swapped. Costs reported by respondents ranged from $3,680 to approximately $5,000.

Matrice 350 Series

A Matrice 350 drone offers multiple payloads, according to one survey respondent. However, the larger size of this untethered UAV (8.3 pounds, according to one survey respondent) makes it difficult to transport and fly. Flight speed ranges from 35 to 50 mph for 45 to 50 minutes. Ideal operating conditions include no precipitation and a wind speed of less than 25 mph. Minimal maintenance is required. Trimble Stratus software is used by one respondent. Costs reported by respondents ranged from $50,000 (including an L2 lidar sensor, P1 camera and cases) to $75,000.

Skydio

X10

The X10 UAV is portable and operates without GPS, according to survey respondents. Software programs used are ESRI Site Scan, Skydio Cloud, Aren and Skydio VT300-L. The model measures 31.1 x 25.6 x 5.7 inches. Most units used by respondents were untethered, however, one respondent reported using tethered and untethered models. Flight speed is 30 mph for 30 to 35 minutes. (One respondent reported 15 to 20 minutes.) One respondent reported that the model is water-resistant and can operate in light rain. Another respondent noted that environmental conditions (e.g., wind, snow and rain) should be considered before operation. Challenges with this model are consistent with any new product.

Proprietary software and a skilled pilot are required. Costs reported by respondents ranged from $15,000 to $40,000.

S2+

The Skydio S2+ is capable of advanced obstacle avoidance, allowing agencies to operate the unit in GPS-denied environments such as under bridge decks. The unit measures 229 x 274 x 126 mm (with battery and antennas up) and weighs 790 grams (with battery). Flight speed ranges from 30 to 36 mph for approximately 30 minutes. The unit requires only routine maintenance and can fly at temperatures ranging from 23 to 104 degrees F and a wind resistance of up to 25 mph. It is not waterproof, however, and cannot operate in rain. Costs reported by respondents ranged from $800 to $8,500.

Autel

EVO II Series

Respondents described product features of two Autel Intelligent Technology UAVs: EVO II Enterprise and EVO II RTK. Both units are untethered and can fly at 45 mph for approximately 40 minutes.

The EVO II Enterprise has a 6K camera and optional real-time kinematic (RTK) connectivity with post-processing files. Autel Explorer flight application is used with the unit, which operates at temperatures ranging from 14 to 104 degrees F and a maximum wind speed of 39 mph. Maintenance requirements include general cleaning, firmware updates and sensor calibrations. The respondent noted that the controls are not as responsive as other DJI models, and the unit has had some minor flight application glitches. Cost reported by the respondent was $4,000.

The EVO II Pro V.3 offers improved employee safety, has better imagery and photo positioning, and can create 3D models. RTK allows for better positioning and a more accurate survey (to 1 cm). Unfolded, the unit measures 457 x 558 x 108 mm. Moonlight algorithm 2.0 and Skylink 2.0 with dynamic track 2.1 are used with the model, which flies at 45 mph for 40 minutes. Propellers must be replaced as needed or once each year. Battery health should also be monitored to keep it from freezing or overheating. Challenges related to UAV use include obtaining approval from the executive team, ensuring pilots obtain an FAA Part 107 certification, developing a training program for UAV pilots, and developing procedures and guidelines for using UAS technologies. Cost reported by the respondent was $3,650.

Regulatory, Operations and Safety Requirements

Regulatory Needs and Use Restrictions

UAS use among survey respondents is primarily regulated by the FAA and state governments. Survey respondents most frequently noted that their agencies follow all FAA UAS regulations and Part 107 licensing requirements. Airspace restrictions impact UAV use for some agencies. Alaska DOT&PF is required to obtain waivers for BVLOS operations, and Temporary Flight Restrictions are required for remote operations. Montana DOT's UAS Program is currently working with the University of Montana to develop safety cases specific to BVLOS operations. Washington State DOT/Olympic Region operates drones in many locations within military-restricted airspace and near general aviation airports with no Low Altitude Authorization and Notification Capability (LAANC) available. The agency typically needs to fly less than 100 feet above ground level, which should never conflict with other air traffic. But gaining authorization in some areas makes it very difficult at times.

Among state restrictions reported by survey respondents are environmental considerations for operating drones in national forests and areas managed by state wildlife and parks departments. In

some cases, agencies must coordinate with Native American reservations, local governments, and railroad and private property owners before conducting operations.

Operational Requirements and Restrictions

Manufacturer guidelines and FAA regulations were the focus of operational requirements and restrictions cited by survey respondents. Alaska DOT&PF and Nebraska DOT noted that operational and environmental restrictions are often dependent on the platform used. North Dakota DOT noted that waivers and certain equipment are required for operations conducted over people and during night navigation.

Safety Requirements and Restrictions

Again, FAA and state requirements factor heavily in safe UAV operations. Power lines, trees, environmental conditions and man-made obstacles must be considered before flight. Pilot-specific requirements factor into operations at Nebraska and New Jersey DOTs, where visual observers are required to assist pilots in identifying potential hazards. Other safety considerations include avoiding flying over people or people in moving vehicles and in inclement weather.

Program Information

To assist agencies that are beginning a UAV program within their organizations, survey respondents described four elements of their programs:

- UAV program oversight.
- Participation by other divisions.
- Staffing.
- Program funding.

UAV Program Oversight

In seven agencies, the aviation or aeronautics division typically oversees the UAV program. But responsibility may fall with a host of other divisions, such as engineering, geographic information systems, planning and technical services.

Some agency divisions share oversight. For example, a joint committee at Illinois DOT is developing the agency's new program; committee members include the chief operating officer and representatives from the Aeronautics, Design and Environment, and Operations divisions. Other agency units operate independently. The respondent from Washington State DOT/Environmental reported that units within the agency receive some guidance from the Aviation office, but for the most part, each UAV program is independently operated. With supervisor approval, staff may purchase a drone and necessary software.

Participation by Other Divisions

Multiple divisions within transportation agencies, and districts in some cases, participate in the UAV program, according to 14 survey respondents. Construction, bridges, highways and right of way, and maintenance units most frequently use UAVs, as do communications, public information and media relations departments. The Road Commission of Oakland County (Michigan) works with any division that has a valid use case. In the past five years, the commission has collaborated with its construction, design, inventory, legal, maintenance, public relations, right of way, subdivision improvements and traffic safety divisions.

Staffing

Staffing levels varied widely among the eight survey respondents who reported the number of full- and part-time employees in their programs and the number of administrative staff and pilots. Programs in four agencies have two to three full-time employees. The respondents from Iowa and South Dakota DOTs reported no full-time employees.

Four agencies have one to five part-time employees. Minnesota DOT employs 160 part-time visual observers. The North Dakota DOT respondent noted that no one is totally dedicated to its UAS program; instead UAS activity is an add-on responsibility.

Pilot Training and Certification Requirements

Most agencies participating in the survey reported one to 50 pilots in their programs, with Alaska DOT&PF reporting 115 pilots. All agencies providing information about their pilot licensing and certification requirements require completion of FAA Part 107 certification. Training for this certification includes classroom and hands-on exercises. Some also require agency-specific training and flight reviews. The Nebraska DOT respondent added that before each flight operation, pilots are required to submit a request to the UAS program that includes a mission plan and site survey. Once these documents are reviewed and approved by the UAS program, the mission can be scheduled.

Effective Management Practices

Best practices for managing UAV programs and staff can increase program efficiency and reduce issues with staffing. Survey respondents shared program management practices in five topic areas, listed below along with an example practice:

- **Management**: Require the program manager to delegate flight operations to pilots depending on their other work schedule (*Washington/Environmental*).
- **Operations**: Ensure business lines contribute time and money to have buy-in (*Oregon*).
- **Leadership Partners**: Maintain a UAS committee that includes staff leaders from Bridge, Survey and Communication divisions (*South Dakota*).
- **Pilot- and Aircraft-Specific Practices**: Maintain a one-to-one ratio of pilots to aircraft to provide pilots with hands-on training and encourage innovation (*Alaska*).
- **Recordkeeping**: Maintain a drone log book to record and manage all flights, personnel, equipment and related information (*North Dakota*).

Staffing Challenges

Nine survey respondents reported challenges that they encounter with staffing, particularly related to dedicating time and staff to UAS operations given employees' other work commitments. Keeping pilots engaged can also be challenging, especially once they become familiar with FAA and agency program requirements. Other challenges include communicating with staff during emergency-related flights, ensuring staff has the right equipment and prioritizes safety, managing flight logs and locating instructor pilots.

Program Funding

UAV programs in agencies responding to the survey are nearly always funded by state resources. None of the respondents reported receiving local funding. Two agencies receive program funding from multiple sources:

- *Alaska*: Federal (40 percent), state (40 percent) and grants (20 percent).

- *Kentucky*: Federal (State Planning and Research (SPR)), state (maintenance- or project-specific funds) and grants (State Transportation Innovation Councils (STIC) incentive program).

In addition to receiving Washington State DOT Rapid Research Grant funding, Washington State DOT/Olympic Region has received some maintenance and research funding from agency headquarters. Montana DOT/UAS Program has submitted another SMART (Strengthening Mobility and Revolutionizing Transportation) grant request to fund the second and third phases of its Drone in a Box (DiaB) research project.

Program Assessment

Using UAVs in agency operations offers many benefits, according to survey respondents, including improved data acquisition and accuracy; enhanced operational efficiency, resulting in reduced time and costs; and increased safety. Other elements of agency operations that benefit from UAV use include improved inventory management, streamlined project documentation and more effective communication.

Common challenges reported by survey respondents were program management issues and environmental limitations. Other issues reported included obtaining executive buy-in to the program, staying up-to-date with quickly changing technology and regulations, and finding pilots. Operational concerns were also reported, such as mapping missions that require the UAV to fly close to the road, gaining authorization to fly in locations where an LAANC is unavailable, sharing collected data in a format that is easily accessible to everyone and addressing restrictions placed by equipment manufacturers.

Best Management Practices

Best practices for developing and managing a UAV program can support agencies as they create their own programs. Survey respondents shared best management practices and lessons learned in five topic areas, listed below along with a sampling of practices:

- **Program startup**:
    - Keep the program simple and use UAVs as tools to support the program (*Iowa*).
    - Develop policies and procedures early (*Nebraska*, *South Dakota*).
    - Create a department UAS Teams channel for information, software use and other important policies and procedures (*North Dakota*).
- **Program operations and management**:
    - Document all flights and follow FAA Part 107 rules (*Oakland County (Michigan)*).
    - Use fleet management software to track flights (*Kentucky*).
    - Share lessons learned and experiences from various flight operations with other agencies (*Montana/UAS Program*).
- **Flight planning**:
    - Preplan flights (*Oakland County (Michigan)*).
    - Position at least one visual observer at larger sites or sites with many obstacles or safety risks (e.g., trees, power lines, buildings, areas near fast-moving traffic or with unstable footing) (*Washington/Environmental*).
    - Be familiar with the flight paths and all flight restrictions, including temporary restrictions such as forest fires (*Montana/Maintenance*).

- **Training**:
    - Ensure staff is properly trained (*Montana/Maintenance*, *Washington/Olympic Region*).
    - Develop or enlist a trusted training program for Part 107 certification and flight operations (*Nebraska*).
- **Staffing**:
    - Determine a flight schedule for pilots (*Oregon*).
    - Determine pilot reporting requirements (*Nebraska*).

Examining the Literature

An examination of the literature aimed to identify current uses of UAVs in highway transportation and opportunities where UAV use may be transferable to winter maintenance and operations. The search identified a limited number of in-progress and published research citations and other resources, including an update to the 1999 *AASHTO Guide for Snow and Ice Control Operations* that has a brief section about UAS. The guide was submitted to the AASHTO Committee on Maintenance in 2022 for consideration and adoption.

Additional resources are presented in four categories:

Avalanche mitigation and monitoring. A number of projects are underway to determine how emerging technologies can assist in avalanche hazard forecasting and decision-making. Among these projects is the DiaB effort by the Maintenance and Unmanned Aircraft Systems programs at Montana DOT, which is exploring a fully automated UAV to monitor and/or map hazardous areas remotely for avalanches and other risks. Washington State DOT is developing a low-cost, durable sensor that can be deployed by a UAV in inaccessible areas above roads to collect data and monitor avalanche risk. Alaska DOT&PF may use UAS with lidar and photogrammetry to determine snow depth and avalanche size and to conduct distribution mapping capturing. In a separate project, Alaska DOT&PF will create two forecasting tools to help agencies keep roads free from snow.

Identifying areas prone to ice formation. Another project in Alaska is evaluating UAV technology to identify cracks, thin ice and other hazards unique to ice roads. (Ice roads are corridors that run across the surface of a frozen body of water and are commonly used in the state and other northern regions to transport passenger and freight vehicles.) If UAS performance is successful, it would eliminate the risk to field workers at a site.

In a 2022 study, Montana DOT used road weather information system observations and UAV-based ice detection technology to refine the state's IcyRoad Detection and Alert system. Researchers developed a system that used remote sensing technology and a UAV to launch a hyperspectral camera for data collection.

Stockpile measurement. A 2022 Clear Roads pooled fund study evaluated the ability of automated technologies, including a UAS with an onboard camera system, to reliably report the amount of salt stored in an indoor facility. A 2022 AASHTO Innovation Initiative addresses digital stockpile management and features case studies of Montana and Oregon DOTs, which use UAVs to inventory salt and sanding materials for winter operations.

Developing a UAV program. This segment of the literature search identified policies, protocols and other measures to assist transportation agencies in launching a UAV program. An NCHRP research

project currently underway aims to develop a guidebook to help state DOTs and local agencies implement UAS operational capabilities. Two other in-progress projects are dedicated to UAV program development in state DOTs. A pooled fund study is developing the standards, protocols and testing requirements that a UAS must meet and demonstrate for a particular application. An NCHRP project is developing a practical flight skills component for state DOT UAV pilots to demonstrate their UAV operating skills and verify pilot proficiency.

National resources include the U.S. Department of Defense Blue UAS website, which provides a listing of approved products and frequently asked questions about UAS policy, and the FAADroneZone website, which provides information for registering a drone, obtaining authorizations and waivers, becoming an FAA-certified remote pilot, meeting operational and airspace requirements, and starting a drone program. Numerous state resources address program development, including a 2023 New Hampshire DOT report outlining program implementation; a 2021 interview with New Jersey DOT's Aeronautics and UAS Program manager that includes a discussion of UAV applications, STIC incentive funding, staffing and training; and a 2021 Pennsylvania DOT guidance document that presents roles and responsibilities, equipment purchase and registration, and other operational requirements.

1 Introduction

1.1 Background

In recent years, state departments of transportation (DOTs) have adopted unmanned aerial systems (UASs) for use in many agency operations. These emerging technologies have the potential to streamline workflows in multiple disciplines within highway transportation, including construction, engineering, intermodal transportation and operations permitting. A UAS commonly comprises an unmanned aerial vehicle (UAV) or drone; a pilot; and the equipment, technologies and communication systems required to facilitate UAV use. UAVs can provide a safe and cost-effective alternative to traditional asset inspection, data collection, emergency response and other DOT practices. However, information about their application in winter maintenance operations is limited.

Clear Roads members were interested in exploring transportation agency use of UAVs to identify ways in which this technology has been implemented specifically in winter maintenance operations and more broadly throughout a transportation agency, as well as opportunities that could benefit from UAV implementation.

1.2 Project Description

To gather information for this synthesis, CTC & Associates conducted the following:

- *Survey of winter maintenance professionals*. A survey of Clear Roads member states and members of the Snow and Ice List-Serv queried transportation agencies about their experience with UAVs in winter maintenance and across disciplines within their agencies. The survey sought information about a range of issues, including:
    - Applications of UAV use.
    - UAV product information. (Respondents could describe up to three UAVs in use at their agencies.)
    - Regulatory, operations and safety requirements.
    - UAV program information.
    - Assessment of UAVs in use.
- *Literature search*. An examination of publicly available domestic and in-progress research supplemented survey findings.

1.3 Survey Response

The survey received 35 responses from 30 agencies:

State Departments of Transportation

- Alaska
- Colorado[1]
- Idaho
- Illinois[1]
- Indiana
- Iowa
- Kansas[2]
- Kentucky
- Maryland
- Massachusetts[3]
- Michigan[1]
- Minnesota
- Montana[2]
- Nebraska
- New Hampshire[1]
- New Jersey
- North Dakota
- Oregon
- Pennsylvania
- South Dakota
- Utah[1,2]
- Vermont[1]
- Virginia
- Washington[1,4]
- West Virginia
- Wyoming[1]

1 Partial response.
2 Two responses.
3 Email communication only. Did not participate in the survey.
4 Three responses.

Local Governments

- City of Columbus (Ohio)
- City of Farmington Hills (Michigan) (partial response)
- Road Commission for Oakland County (Michigan)

Consultant

- Kiewit Meridiam Partners LLC

Survey questions are provided in Appendix E. The full text of survey responses, including respondent contact information, is presented in a supplement to this report.

Six agencies (seven respondents) participating in the survey do not use UAVs and have no immediate interest in or plans to use them: Idaho Transportation Department and Indiana, Kansas (two responses) and Virginia DOTs; City of Columbus (Ohio); and Kiewit Meridiam Partners LLC. The respondent from Kiewit Meridiam Partners noted that given the presence of automatic vehicle location (AVL) and cameras in many snowplows along with sensors to determine air and surface temperatures, and friction sensors in some trucks, there may not be "solid value" in flying a drone in inclement weather and cold temperatures that would affect battery life.

Three other agencies responding to the survey also do not currently use UAVs but are considering using them:

- **Maryland State Highway Administration** currently has two drones but needs more units to expand the program and make it a success. A lack of funding is preventing this expansion. The agency anticipates using drones for winter operations and for storm, facility and pipe/culvert damage.
- **Pennsylvania Department of Transportation** currently uses UAVs for bridge inspections and various summer-related work activities, but not for winter activities typically. The agency anticipates using drones in the future for incident management.
- **West Virginia Department of Highways** has an extensive UAS program that uses drones for surveying and mapping, pre-engineering, bridge inspection, stockpile measurement and contract administration on construction projects. The agency is not engaged in UAS projects for winter maintenance but is interested in learning more about potential applications.

A fourth agency, Massachusetts DOT, did not complete the online survey but in email correspondence noted that while the agency does not use UAVs for winter operations, there are some winter operations activities for which it may consider UAV use.

A summary of survey responses from agencies that use UAVs for winter maintenance activities or other agency operations begins in Chapter 2.

1.4 Organization of This Synthesis Report

Chapter 2 of this synthesis report provides a general description of UAV use for winter maintenance activities and for tasks in other agency departments. Chapter 3 continues the presentation of survey findings with respondents' descriptions of their UAS programs, including the total number of UAVs owned and details of up to three UAV systems. In Chapter 4, respondents explain the regulatory, operational and safety requirements that agencies address. Chapter 5 focuses on the UAS program, in which respondents describe the divisions within the agency that have oversight or involvement in the program, staffing levels and funding sources. In Chapter 6, respondents summarize the benefits and challenges of using UAVs in agency operations and also share best practices for other agencies using UAVs. Chapter 7 supplements the survey findings with a summary of relevant literature. The report appendices provide the survey questions, survey responses describing agency UAVs and guidance from participating agencies.

While the survey conducted for this synthesis received responses from many Clear Roads members and a small number of municipalities conducting winter maintenance, the survey findings do not serve as a representative sampling of all public transportation agencies. These results will, however, inform the practices of winter maintenance managers interested in refining or expanding their use of UAVs in agency operations.

2 UAV Applications

2.1 Introduction

This chapter presents survey responses describing agency use of UAVs for winter maintenance operations and across departments within the agency. Units or divisions within agencies that provided multiple responses are identified in the discussion. Because both Utah DOT respondents provided partial responses, the responses have been combined as one response in the survey findings. Also, the UAV program at Illinois DOT only recently started. The respondent noted that the agency will have more information to share about the overall program as it develops.

2.2 Using UAVs for Winter Maintenance Activities

Nearly all of the respondents using UAVs for some type of agency operation (20 of 23 respondents) indicated that their agencies use UAVs for winter maintenance activities. Common activities where these devices are used include measuring stockpiles (12 respondents), reducing avalanche hazard (seven respondents) and identifying areas that are prone to ice formation (four respondents). Several agencies reported using UAVs occasionally for these activities or exploring their use as an established practice. Illinois DOT plans to use UAVs for more winter maintenance activities once more pilots become certified.

Table 1 summarizes agency use in selected winter maintenance activities. Following the table are additional details about agency practices for each activity.

Table 1. UAV Use for Winter Maintenance Activities

Agency	Reducing Avalanche Hazard	Identifying Areas Prone to Ice Formation	Measuring Stockpiles	Other Winter Activities
Alaska	X	X	X	X
Colorado	X			
Illinois			X	
Iowa				X
Kentucky		X		
Michigan			X	
Farmington Hills (Michigan)				X
Oakland County (Michigan)			X	
Montana/Maintenance			X	
Montana/UAS Program	X		X	
Nebraska			X	X
New Hampshire				X
New Jersey			X[1]	
North Dakota		X	X	
Oregon	X		X	X
South Dakota			X	
Utah	X			X

Agency	Reducing Avalanche Hazard	Identifying Areas Prone to Ice Formation	Measuring Stockpiles	Other Winter Activities
Washington/Maintenance	X			
Washington/Olympic Region	X	X		X
Wyoming			X	
Total	**7**	**4**	**12**	**8**

1 The agency is exploring stockpile measurement via UAS but has not yet fully adopted it as a common practice.

Avalanche Hazard Reduction

Alaska Department of Transportation and Public Facilities (DOT&PF) uses UAS to inspect areas remotely; map and document avalanche terrain; and reduce avalanche hazards through the use of munitions. This practice significantly reduces hazards to staff. According to the survey respondent, the agency is the first in the nation to acquire Federal Aviation Administration (FAA) approval and conduct successful live training operations for munitions use.

Other agencies are conducting research related to UAV use and avalanche control:

- Montana DOT is currently using a Drone in a Box (DiaB) to detect rapid gravitational mass movement events, such as rockslide and avalanche events. Phase I of the project is focusing on proof of concept and assessing whether a DiaB system will tie into the agency's existing Transportation Management Center (TMC).
- Oregon DOT has used UAS to gather imagery at the agency's highest risk site. Currently there are no ongoing operations for this application.
- Washington State DOT/Maintenance is conducting several research projects relating to dropping remote sensors, mapping and deploying explosives to mitigate avalanches in highway environments.

Table 2 summarizes survey responses.

Table 2. UAV Use for Avalanche Hazard Reduction

Activity	Agency and Description
Avalanche Control	*Alaska*. Conducts avalanche hazard reduction using munitions, which significantly reduces hazards to agency staff. *Washington/Maintenance*: • Drops remote sensors (research project). • Deploys explosives to mitigate avalanches in highway environment (research project).

Activity	Agency and Description
Inspection and Surveying	*Alaska*. Views current or past avalanche occurrences remotely without placing agency staff in avalanche terrain and potentially dangerous situations. *Colorado*: • Inspects remote systems. • Surveys an avalanche zone after mitigation.
Mapping and Documentation	*Alaska*. Maps and documents avalanche terrain following large storm events, pre- and post-mitigation, and routine mapping. *Oregon*. Gathers imagery. *Utah*: • Maps avalanches. • Flies avalanche paths. *Washington/Maintenance*. Maps terrain (research project).
Mass Land Movement Events	*Montana/UAS Program*. Detects rapid gravitational mass movement events, such as rockslide and avalanche events, using a DiaB (research project).
Other	*Washington/Olympic Region.* Available for slope overflight but rarely used.

Identification of Areas Prone to Ice Formation

Alaska DOT&PF uses UAVs for avalanche control, inspection, and mapping and documentation to identify areas where ice typically forms. The agency installs a drone dock along the road near an avalanche zone, which could be used to identify road conditions within the range of the dock aircraft. Montana DOT's UAS Program has discussed using this application but has not currently adopted it. Michigan Road Commission for Oakland County is considering using UAVs for this application in an area that is frequently affected by ski area snow machines. Table 3 summarizes survey responses.

Table 3. UAV Use to Identify Areas Prone to Ice Formation

Activity	Agency and Description
Avalanche Control and Monitoring	*Alaska*. Installs a drone dock on the road near an avalanche zone to identify road conditions within the range of the dock aircraft. *Kentucky*. Uses photogrammetry to monitor project runoff and determine possible icy locations. *Washington/Olympic Region*. Monitors State Route 7 through the canyon to Mount Rainier.
Inspection	*Alaska*. *North Dakota*. Identifies ice jams near bridges.
Mapping and Documentation	*Alaska*.
Other	*Oakland County (Michigan)*. May use to monitor an area frequently affected by ski area snow machines.

Stockpile Measurements

Several agencies use UAVs to measure stockpile volumes, including Alaska, Illinois, Michigan, Montana/Maintenance, Nebraska, South Dakota and Wyoming DOTs and the Road Commission for Oakland County (Michigan). Oregon DOT uses UAVs at multiple locations to measure stockpiles using the Stockpile Reports application that leverages UAS and cellphones to make measurements and manage quantities. North Dakota uses various software programs: Stockpile Reports to measure salt and sand, and Pix4D photogrammetry software used in conjunction with MicroStation and Trimble Business Center software for construction.

Other agencies are exploring this application, including Kentucky Transportation Cabinet, which is using photogrammetry with a large indoor stockpile maintained at an underground storage location. Nebraska DOT is working with a Skydio representative on a proof of concept for salt measurement at an indoor salt shed.

In place of a UAV, Iowa DOT uses a handheld lidar unit to measure stockpiles. Table 4 summarizes survey responses.

Table 4. UAV Use for Stockpile Measurement

Practice	Agency and Description
Currently Using	*Alaska.* Sand and salt stockpile volumes. *Illinois.* Road salt volumes. *Michigan*, *Oakland County (Michigan)*, *Montana/Maintenance.* *Nebraska.* Granular stockpile sites as needed. *North Dakota:* Various software: • Stockpile Reports for salt and sand. • Pix4D to MicroStation/Trimble Business Center for construction. *Oregon*. Stockpile Reports application at multiple locations, leveraging UAS and cellphones to measure and manage quantities. *South Dakota*. Surveyors and technicians fly UASs to calculate stockpile volumes. *Wyoming*. UAVs fly at all salt sheds in September for end-of-year reconciliation of inventory. (New fiscal year begins October 1.)
Considering	*Kentucky*. Currently working on using this application with photogrammetry for a large indoor stockpile at an underground storage site. *Nebraska.* Conducting a proof of concept using Skydio to measure salt at an indoor facility. *New Jersey*. Exploring stockpile measurement with UAS but not yet common practice. *Washington/Maintenance*. Experimented with this application, but currently not operational.

Other Winter Maintenance Activities

UAVs are also used for other winter maintenance activities among these agencies, including to perform search and rescue; respond to emergencies; monitor geological hazards, ice dams and flooding, road

conditions and traffic flow; measure and document snow storage of vertical post snow fences; and train snowplow operators. Table 5 summarizes survey responses.

Table 5. UAV Use in Other Winter Maintenance Activities

Application	Agency and Description
Emergency Response	*Alaska*. Used in search and rescue and emergency response.
Geological Hazards	*Alaska*. Assesses scene safety following avalanches, rockfall, landslides and other geohazard events. *New Hampshire*. Examines rock faces near roads and washout from rainstorms. *Utah*. Monitors mudslide risk. *Washington/Olympic Region*. Responds to most slide events, floods and sinkholes, as needed.
Ice Dam/Flooding Monitoring	*Nebraska*.
Road Condition Monitoring	*Alaska*. Assists in sweeping the road after closure (using thermal-equipped UAV). *Iowa*: • Checks road conditions, especially roads that are blocked or impassable. • Monitors progress of snowplow operations.
Snow Storage of Vertical Post Snow Fences	*Wyoming.* Maps snow drifts to determine the quantity of snow that vertical post snow fences hold. When earlier research suggested the fences were not holding as much snow as anticipated, Wyoming DOT added a second bottom board to the structure to increase storage. Future mapping and documentation efforts will indicate if storage improved with the additional board.
Traffic Monitoring	*Oregon*. Monitors weather-related accidents and traffic impacts (when flying conditions allow).
Training	*Farmington Hills (Michigan)*. Police department uses its UAVs to film city staff during SPOT [snowplow operator training] in the fall for the Metro Detroit American Public Works Association Chapter.

2.3 Interdepartmental Uses of UAV

Agencies responding to the survey use UAS for tasks in other agency departments, including:

- Accident reconstruction.
- Bridge inspection.
- Construction (including construction and contractor oversight).
- Data collection.
- Emergency management and response.
- Engineering (including environmental and right of way (ROW) studies).
- Intermodal transportation.
- Landslide/steep terrain investigations.
- Maintenance.
- Monitoring remote and rural areas.
- Permitting and operations.
- Project design, planning and implementation.
- Roadside and roadway inspections.
- Traffic monitoring.
- Traffic operations.

Of these tasks, agencies responding to the survey most commonly use UAVs for bridge inspection, construction and landslide/steep terrain investigations. These devices are least likely to be used for accident reconstruction and permitting and operations.

Table 6 summarizes survey responses. Specific tasks performed by agencies in each of these categories are presented following the summary table.

Table 6. Interdepartmental Uses of UAVs

Agency	Accident Reconstruction	Bridge Inspection	Construction	Data Collection	Emergency Response	Engineering
Alaska		X	X	X	X	X
Colorado	X	X		X		X
Illinois		X[1]	X		X	
Iowa		X	X		.	X
Kentucky		X	X	X	X	X
Michigan		X				
Farmington Hills (Michigan)			X	X		X
Oakland County (Michigan)			X			X
Minnesota		X	X	X	X	X
Montana/Maintenance		X	X	X		
Montana/UAS Program		X	X	X	X	X[1]
Nebraska		X	X	X	X	X
New Hampshire						
New Jersey		X	X	X	X	X
North Dakota		X	X	X	X	
Oregon		X[1]	X		X	X
South Dakota		X	X		X	X
Utah	X					
Vermont		X		X	X	
Washington/Environmental					X	
Washington/Maintenance		X		X		X
Washington/Olympic Region		X	X		X	
Wyoming		X	X			X
Total	**2**	**18**	**16**	**12**	**13**	**14**

1 Pilot projects.

Table 6. Interdepartmental Uses of UAVs, continued

Agency	Intermodal Transportation	Slide/Steep Terrain	Maintenance	Remote/Rural Area Monitoring	Permitting/ Operations
Alaska		X	X	X	
Colorado		X			
Illinois					
Iowa	X	X			

Agency	Intermodal Transportation	Slide/Steep Terrain	Maintenance	Remote/Rural Area Monitoring	Permitting/ Operations
Kentucky		X			
Michigan					
Farmington Hills (Michigan)					
Oakland County (Michigan)					
Minnesota			X		X
Montana/Maintenance		X	X		
Montana/UAS Program		X[1]	X	X[1]	
Nebraska		X	X		X
New Hampshire		X			
New Jersey	X	X			
North Dakota	X	X	X		
Oregon		X			
South Dakota		X			
Utah					
Vermont	X	X			
Washington/Environmental		X		X	
Washington/Maintenance		X	X		
Washington/Olympic Region			X	X	
Wyoming		X		X	
Total	**4**	**16**	**8**	**5**	**2**

1 Research project.

Table 6. Interdepartmental Uses of UAVs, continued

Agency	Project Design/ Planning	Roadside Inspections	Traffic Monitoring	Traffic Operations	Other
Alaska					
Colorado					
Illinois					
Iowa	X	X	X	X	
Kentucky				X	
Michigan					X
Farmington Hills (Michigan)					X
Oakland County (Michigan)		X	X	X	
Minnesota	X				
Montana/Maintenance		X			
Montana/UAS Program	X	X			
Nebraska	X	X	X	X	X
New Hampshire					X
New Jersey	X		X.	X	X
North Dakota	X	X		X	

Agency	Project Design/ Planning	Roadside Inspections	Traffic Monitoring	Traffic Operations	Other
Oregon	X				X
South Dakota	X				X
Utah					
Vermont					
Washington/Environmental	X				
Washington/Maintenance	X	X			
Washington/Olympic Region	X	X			X
Wyoming	X	X			
Total	**12**	**9**	**4**	**6**	**8**

Accident Reconstruction

Utah DOT's Incident Management Team uses UAVs to perform accident reconstruction. The agency also partners with the Utah Highway Patrol and flies the crash scenes for that agency.

Eleven other survey respondents reported that incident management responsibilities are largely with the State Police or Highway Patrol (*Alaska, Illinois, Iowa, Kentucky, Montana/Maintenance, Montana/UAS Program, Nebraska, North Dakota, Oregon, Washington/Maintenance* and *Wyoming*) or area police departments (*Farmington Hills (Michigan)*). Transportation agencies may assist or collaborate in these efforts through equipment purchases or training. For example:

- Alaska State Troopers use UAVs for 3D rendering of accident reconstruction and documentation.
- Illinois DOT has purchased UAVs for State Police use.
- Kentucky Transportation Cabinet also assists State Patrol with accident reconstruction.
- In Montana, the Highway Patrol spearheads accident scene reconstruction. Montana DOT's UAS Program has helped inform Montana Highway Patrol troopers about FAA Part 107 regulations governing pilot licensing (Part 107) and train them for the FAA's Part 107 pilot exam, which certifies pilots to operate small commercial UAS. Montana Highway Patrol leaders coordinate live flight training.

Bridge Inspection

Eleven survey respondents reported using UAVs for bridge inspections. In addition, Alaska and Iowa DOTs use UAVs to supplement bridge inspections, and Montana DOT/Maintenance uses drones for bridge construction. Pilot inspection programs are underway at Illinois (in the Chicago area) and Oregon DOTs. Montana DOT/UAS Program uses Skydio for most bridge inspection work, unless simple videography is required. In these cases, the agency uses one of its DJI Mavic 3 Enterprise aircraft. In Wyoming, where consultants perform most of the bridge inspections, UAVs are primarily used to take photos during those inspections. The respondent from Washington/Maintenance noted that UAV use for bridge inspections is increasing year over year. Table 7 summarizes inspection activities and agency programs.

Table 7. UAV Use in Bridge Inspections

Topic	Agency and Description
Bridge Inspections	*Colorado, Michigan, Minnesota, Montana/Maintenance, Montana/UAS Program, New Jersey, North Dakota, South Dakota, Vermont, Washington/Maintenance, Washington/Olympic Region.* *Alaska, Iowa.* Supplemental inspection tool. *Illinois, Oregon.* Pilot program. *Kentucky.* Modeling the structure. *Nebraska.* Annual bridge condition inspections via video/photo above and below deck; livestream inspections to subject matter experts; as-needed digital twin creation for documentation of existing conditions and/or damage/repair assessment; and historic preservation documentation. *Wyoming.* Consultants use UAVs to take photos during inspections.
Cracking and Delamination	*Kentucky.* Crack detection. *Nebraska*. Proof of concept thermal deck delamination detection. *North Dakota*. Three Skydio X10s (thermal) purchased for delamination and crack identification.
Mapping and Photography	*Minnesota.* Photogrammetry and photography.
Program Information	*Montana/UAS Program.* Skydio used for most bridge inspection work unless simple videography is required. In those instances, DJI Mavic 3 Enterprise aircraft is used. *Nebraska.* UAS program performs inspection under direction of the Bridge division. *New Jersey*. Four trained pilots use UAS to inspect bridges, allowing access to hard-to-reach bridges and reducing reliance on snooper trucks. *Vermont*. Highway division uses UAVs from Aviation program. *Washington/Olympic Region*. Dedicated aircraft used for structural and nonstructural inspections on the Tacoma Narrows Bridge. The region is also equipped to visually inspect for scour and fracture-critical bridges in the area.
Other	*Montana/Maintenance.* Bridge construction.

Construction

Agencies participating in the survey commonly use UAVs for construction activities, including construction and contractor oversight. Illinois DOT is beginning to use UAVs for construction activities in a small number of districts and is creating a program manual and best practices for using UAS for construction and surveying.

Construction activities are performed by various departments within an agency and by outside groups:

- Construction (*Montana*).
- Construction and Materials (*Iowa*).
- Engineering (*Washington/Olympic Region*).
- Surveys (Wyoming).
- UAS program (*Nebraska*).

- Multiple units (*New Jersey*).
- Districts (*Illinois, Iowa, Nebraska*).
- Contractors (*Washington/Olympic Region*).

Table 8 summarizes construction activities.

Table 8. UAV Use in Construction

Application	Agency and Description
Mapping	*Nebraska.* Mapping for stockpile and borrow pit measurements, seeding and erosion control measurements, pavement cross slope checks, grade/earthwork volumes, concrete paving grade checks, final wetland survey and as-built earthwork computation dispute resolution.
Modeling	*Kentucky*. Collecting thousands of project photographs to use cloud-based photogrammetry to 3D model construction sites on a periodic and as-needed basis. Cloud-based processing allows the agency to quickly and efficiently: • Share 3D models with inspectors and project managers to perform field slope measurements; volume calculations; new guardrail installation checks; and seeding. Also used to identify rock cut benches and gather information about bridges, poles and underground pipes (during installation). • Compare the collected data to the design files so inspectors and project managers can make informed and timely decisions. *Montana/UAS Program*. Construction uses DJI M350 with the Yellowscan lidar scanner to create highly accurate digital elevation and terrain models.
Project Documentation	*Alaska.* Site conditions.
Project Monitoring	*Minnesota, Nebraska, New Jersey, Wyoming.* Capturing preconstruction, during construction and post-construction photos/videos. *North Dakota, Oakland County (Michigan), Oregon, Washington/Olympic Region, Wyoming.* Monitoring progress at job sites. *Oakland County (Michigan).* Documenting project conditions. *South Dakota*. Monitoring project quality control.
Public Communications	*Nebraska, South Dakota, Wyoming*.
Stockpile Measurement	*Alaska, Nebraska*. *Wyoming*. Flying gravel pits for quantities.
Winter Activities	*Farmington Hills (Michigan)*. Police department has flown some of the engineering projects for winter training and changes to plow routes.
Other	*Alaska*. Measuring pay items. *Illinois*. Currently preparing a program manual and best practices for using UAS in construction and surveying. *Oregon.* Quantity calculations (2D and 3D) and location verification of design features (horizontal and vertical). *Washington/Olympic Region.* Using for landscape design, wetland design and many other aspects of construction. *Wyoming*. Collecting data in the field for field designs and earthwork computations (performed by Survey).

Data Collection

Agencies participating in the survey use UAVs to collect data for construction, geohazard, maintenance, and surveying and modeling applications. The respondent from Kentucky Transportation Cabinet shared the agency's process for collecting data for a construction project (see Table 9). Montana DOT's UAS Program management is involved with a pooled fund study to help develop UAS data collection standards for DOTs. (See **Related Resource** below.) Respondents from Alaska DOT&PF and New Jersey DOT reported collecting data across various departments and units. Table 9 summarizes survey responses.

Table 9. UAV Use in Data Collection

Application	Agency and Description
Construction	*Kentucky*: Data collection process: • Before flying a drone, establishes ground control points. Preferably sets up permanent monuments for repeatability and efficiency. • Adds in smart targets that will collect GPS data every 10 seconds during the flight to allow the software to perform a post-processing kinetics (PPK) technique for high-accuracy results. • For a typical construction project, flies a survey-grade drone approximately 250 feet above the project with a preprogrammed forward and side overlap of the photographs. *Minnesota*. Collects lidar data for Construction. *North Dakota*.
Geohazards	*Vermont.* Examines rock slope issues, damages from natural disasters and related issues/events.
Maintenance	*Montana/Maintenance*. Inspects roads for cracks. *North Dakota.*
Surveying and Modeling	*Colorado*. Conducts surveys. *Farmington Hills (Michigan)*. Used by police department. *Minnesota*. Collects lidar data for airport obstacles and geographic information systems (GIS). *Montana/UAS Program*. Uses UAS with real-time kinematic (RTK) technology to create very accurate orthomosaics (performed by Survey). *Nebraska*. Gathers photo, video, photogrammetry and thermal imagery data (performed by the agency's UAS program and various district pilots). *New Jersey.* Collects photos, videos and thermal images. *Vermont*: Collects data for GIS. *Washington/Maintenance.* Routinely collects remote sensing data.
Other	*Alaska, New Jersey*. Collects variety of data across departments. *Montana/UAS Program*. Participates in pooled fund study to help develop UAS data collection standards for DOTs. (See **Related Resource** below.)

Related Resource

Project Solicitation: Uncrewed Aircraft Systems (UAS) Standardization, Transportation Pooled Fund, solicitation expires: June 2025, expected completion date: 2030.
https://www.pooledfund.org/Details/Solicitation/1620
From the project description: This project will create a comprehensive UAS [s]tandards and [s]pecifications guidebook that provides [s]tate DOTs with the needed UAS data collection standards and best practices. A stand-alone standards guidebook will be developed and validated for the following use cases: survey, construction, bridge inspections, as-builts, incident management, earth movement [and] asset life cycle and maintenance.

Emergency Management and Response

Among participating agencies, UAVs are commonly used in emergency management and for flooding, extreme weather and geohazard assessment. Although currently not using drones for this application, Colorado DOT is considering tethered drones with cameras for incident management and occasionally uses UAVs to survey burn scars after wildfires. Several agencies noted that other state agencies use UAVs for emergency management and response, including search and rescue teams, primarily related to infrared sensing (*Washington/Maintenance*); State Patrol (*Iowa, Wyoming*); and local law enforcement (*Iowa*). Montana DOT's UAS Program manager noted that the agency hasn't had a natural disaster event that affects the traveling public since the program's inception two years ago, but the agency "recognize[s] that it's only a matter of time before an event occurs." Table 10 summarizes survey responses.

Table 10. UAV Use in Emergency Management and Response

Application	Agency and Description
Avalanche Response	*Alaska.*
Damage Assessment	*Kentucky.* *Nebraska*. Photo, video and mapping of accident and environmental disaster damage assessment to infrastructure (performed by Nebraska DOT's UAS program). *Vermont*. Damages from natural disasters or flooded areas. *Washington/Olympic Region*. Third-party damage inspection when bridges are damaged by vehicles.
Emergency Management	*Kentucky*. Live feed from the field to the Emergency Operations center. *Minnesota*. Photos and videos for emergency management.
Flooding and Extreme Weather	*Alaska*, *South Dakota*, *Washington/Olympic Region.* *Illinois*. Can deploy UAS for any flood response. Have used for video feed of flooding. *Montana/UAS Program*. Flooding response and assessment. *North Dakota*. Flood and extreme weather events. Post to public media to inform traveling public. *Oregon*. Wildfire response for mapping sites, evaluating access and quantifying materials.

Application	Agency and Description
Geohazards	*Alaska*. Landslides, rockfalls and other geohazards. *Illinois*. Monitored a sinkhole (size and continuous growth) from a mine operation near a state road until remediation from the mining company. *New Jersey*. Sinkholes and landslides. *Washington/Environmental*: • Get footage of slides. • Sometimes work with geotechnical staff using the zoom function on drones to identify the safest areas to climb and belay on unstable slopes. • Can use DroneDeploy to take slope measurements and identify the amount of material that must be removed from the roadway. *Washington/Olympic Region*. Responding to most slide events and sinkholes, as needed.
Modeling and Mapping	*Kentucky*. Modeling for debris estimation.
Road Closures	*Alaska.*
Search and Rescue	*Kentucky.*
Other	*Montana/UAS Program*. Participated in UAS-specific Federal Emergency Management Agency (FEMA) response training. *New Jersey*. Seven active UAS pilots in Emergency Management that use UAS to respond to a variety of emergent situations, including sinkholes and landslides.

Engineering

UAVs are also commonly used among participating agencies in engineering projects, including environmental and ROW studies. The respondent from Kentucky Transportation Cabinet shared the agency's process for collecting data for an engineering project (see Table 11). Table 11 summarizes survey responses.

Table 11. UAV Use in Engineering

Application	Agency and Description
Design	*Iowa.* Used by Design Bureau and Location and Environment Bureau.
Environment	*Minnesota*. Environmental surveying. *Montana/UAS Program*. Current research project using UAS to determine wetland boundaries. *Nebraska*: • Photos/videos for monthly stormwater pollution prevention plan inspections and potential wetland mitigation site investigation. • Mapping for orthomosaic imagery of existing wetland mitigation sites for annual reporting. (These tasks are performed by the agency's UAS program with direction from the Project Development/Environmental Division.) *Oregon*. Identifying specific foliage on cliff faces, monitoring health of mitigation sites and other environmental applications. *Washington/Maintenance Operations*. Initial mapping of wetlands.
Planning	*Alaska*. Updates to aerial images of projects for planning (performed by Right of Way).
Pre-Construction	*Minnesota.* Pre-construction surveying.
Public Outreach	*Oregon*. Aerial imagery for ROW exhibits during public outreach and legal disputes.
Surveying and Modeling	*Colorado*. Area surveys. *Kentucky*. Information-gathering process: • Before design, drone photogrammetry and PPK workflow to 3D model projects are used. The agency will convert drone data to a traditional survey using virtual survey techniques and supplement a traditional survey, as needed, to capture data from items that aren't visible from the sky (such as pipe inverts and vegetated areas in ditch lines). 3D models are generated through cloud-based processing for simple hydrology analysis, including watershed, flood limits, runoff and simulated storm events. • For ROW, preliminary studies are performed with current high-resolution maps and models with resolutions as low as 0.5 to 1 inch. Preliminary design models are placed over high-resolution maps to make informed decisions about the impact of roads to an area. • GPS is used on tablets to view the model in the field, walk the site and roughly identify the location in the model at any point. *Oakland County (Michigan)*. Partnering with Orthomosaics to experiment with generating contour lines using lidar data collected with a UAV. *South Dakota*. Drainage surveys. *Wyoming*. Up-to-date mapping.
Other	*Farmington Hills (Michigan).* Police department has flown some of the engineering projects, including flooded areas. *New Jersey.* Eight engineers trained as UAS pilots across many different units.

Intermodal Transportation

Respondents from four agencies reported using UAVs for intermodal transportation. Iowa and New Jersey DOTs and Vermont Agency of Transportation typically use drones in aviation applications. The New Jersey DOT respondent noted that its Bureau of Aeronautics gathers images of many of the state's 40 public-use airports to supplement airport inspections. Iowa DOT also uses UAVs in rail applications, and North Dakota DOT frequently uses drones for public events and future outcomes.

Landslide and Steep Terrain Investigations

Sixteen agencies use UAS to investigate geohazard events, such as rockfalls and landslides, and steep terrain. Research projects related to this application are underway at Montana and Oregon DOTs. Montana DOT's DiaB research project is tailored to avalanche and landslide/rockslide events. The goal is to develop an early warning system that will allow the agency to alert the traveling public when a rapid gravitational mass movement event has obstructed the roadway.

Oregon DOT is currently starting a rockfall hazard research project that will allow the agency to use data to determine existing risk. The Kentucky Transportation Cabinet respondent noted that using drones and cloud-based data processing for these investigations is "significantly improving" communication between its Maintenance and Geotechnical branches. Finally, Washington State DOT's Olympic Region aims to "put an aircraft on scene" to provide information to its geotechnical staff. Table 12 summarizes survey results.

Table 12. UAV Use in Geohazard Events

Application	Agency and Description
Damage Assessment and Mitigation	*Kentucky*: • Maintenance creates a 3D model of a landslide, rock face, rockslide, etc., quickly during the event and shares data with Geotech, eliminating the need for Geotech to physically walk the site. Drone data can be used to cut cross sections through the area and estimate volumes removed. • Geotech can assist Maintenance in assessing rock cuts using open-face logging methods from the drone data, which includes vertical face imagery options to allow for high-resolution images of the rock face with overlaid contours to allow geotechnical engineers to log rock types, discontinuities, bench elevations and slopes with their respective elevations at specific station intervals. *Montana/Maintenance*. Mitigates rockfall events. *New Jersey*. Plans mitigation for rockfalls and landslides (performed by two UAS pilots in Engineering Geology).
Early Warning System	*Alaska*. Detects changes using repeated data collection. *Montana/UAS Program*. With DiaB research project, intends to develop an early warning system about avalanche and landslide/rockslide events that will allow the agency to alert the traveling public when a rapid gravitational mass movement obstructs the roadway.

Application	Agency and Description
Inspection and Monitoring	*Colorado*. Inspects potential rockfall areas. *New Hampshire*. Inspects rock faces near roads to find cracks that would cause rocks to fall onto road surfaces. *New Jersey*. Inspects rock slopes (performed by two UAS pilots in Engineering Geology). *North Dakota*. Inspects landslide areas. *Oregon*. Currently starting a rockfall hazard research project that will use data to determine existing risk.
Mapping and Documentation	*Alaska*. Maps using repeated data collection. *Nebraska*. Maps for landslide and foreslope slough monitoring (performed by the agency's UAS program). *Oregon*. Frequently uses UAS lidar to map sites after landslides and rockfalls. Starting a rockfall hazard research project that will use data to determine existing risk. *South Dakota*. Documents slide areas. *Washington/Environmental*: • Captures footage of slides. • Sometimes works with geotechnical staff to identify the safest areas to climb and belay on unstable slopes. (Uses the drone's zoom function.) • Uses DroneDeploy to take slope measurements and identify the amount of material that must be removed from the roadway.
Surface Hydrology	*Alaska*. Uses thermal payloads to investigate surface water seeps and changes in surface hydrology.
Other	*Iowa*. Used by districts. *Vermont*. Used by: • Highway and Construction and Materials divisions. • Geotechnical Engineering Division for ledge investigations and slope issues. *Washington/Maintenance*. Routinely uses drones for this application. *Wyoming*. Gathers information for Public Affairs to provide media updates.

Maintenance

Several agencies provided more detail about their agencies' use of UAVs in maintenance operations. Other agencies shared practices that they are considering. For example, Montana DOT is exploring the use of UAVs for asset management opportunities. The respondent from the Washington/Environmental noted that the agency's Maintenance Operations Division is planning to use a drone to spray pesticides for nuisance and noxious weeds in areas along the agency's ROW that are potentially unsafe or hard to reach on foot. If that project is successful, the Environmental Services Office would be interested in adopting this practice to help maintain wetland sites. Table 13 summarizes survey results.

Table 13. UAV Use in Maintenance

Application	Agency and Description
Damage Assessment	*Montana/Maintenance*. Planning for road clearing. *Nebraska*. Performed by the UAS program.
Geohazard Events	*Alaska*. Avalanche hazard reduction. *Montana/Maintenance*. Rockfalls and flooding.
Inspections and Project Documentation	*Montana/Maintenance.* Project documentation. *Washington/Maintenance.* Photography, slope inspections. *Wyoming*. Monitor snow fence performance by documenting snow drifting on parts of Interstate 80 (I-80).
Mapping	*Nebraska*. Mapping for subgrade compaction/roadway settlement measurements (performed by the UAS program).
Planning	*Washington/Olympic Region.* Assistance with intersection layout for striping, thermal plastics and raised pavement marking crews.
Stockpile Measurement	*Alaska*, *Montana/UAS Program*, *Nebraska*. *North Dakota*. Salt and sand quantities.
Vegetation Management	*Michigan.* Pesticide application. *Minnesota*. Weed control. *Washington/Maintenance.* Currently piloting a spray drone on the ROW.
Other	*Washington/Maintenance.* Currently in a pilot phase using a tethered drone for graffiti removal. *Washington/Olympic Region.* Videos made of various maintenance operations to help educate the public.

Monitoring Remote and Rural Areas

Survey respondents also use drones to monitor remote areas:

- Alaska DOT&PF collects imagery in remote areas for monitoring geohazards.
- Washington/Environmental collects data on remote ROW segments to allow the agency to monitor wetland areas and identify suitable locations for building wildlife crossings.
- Washington/Olympic Region uses an aircraft with thermal imaging to locate populated homeless camps before scheduling outreach and cleanup in the areas.
- Wyoming DOT Telecommunications Program uses drones near radio towers for inspections.

The Montana DOT/UAS Program respondent noted that its DiaB research project will help get the agency to "an operational point where monitoring remote and rural areas will become routine." According to the respondent, current regulatory constraints restrict operational distance. The program is working on FAA waivers to allow it to "take full advantage of beyond visual line of sight [BVLOS] flight operations." In Iowa, remote and rural areas are monitored by local law enforcement and the State Patrol.

Permitting and Operations

Two survey respondents use drones for permitting:

- Minnesota DOT uses this application for airport licensing and inspections.
- Nebraska DOT's UAS program captures videos and photos of nonpermitted work.

In North Dakota, this function is conducted by Highway Patrol.

Project Design, Planning and Implementation

Twelve survey respondents indicated that their agencies use UAVs for project design, planning and implementation. Activities varied, ranging from airport planning to pavement surveying and public outreach. Multiple units across the agencies may use drones for these activities, including the Maritime unit at New Jersey DOT, which employs UAVs in dredging projects. Table 14 summarizes survey results.

Table 14. UAV Use in Project Design, Planning and Implementation

Application	Agency and Description
Construction	*Minnesota*. Pre-construction planning/GIS data. *Washington/Environmental*. Most phases of environmental projects for initial scoping (planning) and follow-up (periodic flights throughout the construction process and the result). *Wyoming*: • Pre-design flights for all reconstruction projects to keep mapping up to date (performed by Photogrammetry and Surveys). • Flights scheduled as necessary throughout the construction process. Earthwork quantities are sometimes computed for payment using UAV data collection, in particular, borrow areas and stockpiles.
Pavement	*Nebraska*. Photogrammetry to supplement preliminary survey on pavement surface (performed by agency's UAS program).
Project Documentation and Planning	*Minnesota*. Airport planning. *Montana/UAS Program*. UAS lidar data for project design and planning. *New Jersey*: • Documentation of project progress. • Pre- and post-project images. • Multiple units support this use, including the Maritime unit, which conducts dredging projects. *Washington/Maintenance*. Lidar and imaging.
Public Outreach	*North Dakota*. Communication Division to assist with public meetings, local events and videos.
Surveying	*Oregon*: • UAS photogrammetry and lidar regularly used during survey operations for project delivery. • Orthomosiacs and reality meshes for 2D/3D project visualizations. *South Dakota*. Assistance in survey data collection.

Application	Agency and Description
Other	Units supporting this application: • *Iowa*. Design Bureau, Traffic and Safety Bureau, and districts. • *Washington/Olympic Region*. Contractors and engineering offices.

Roadside and Roadway Inspections

UAV uses in roadside and roadway inspections varied among survey respondents:

- *Oakland County (Michigan)*. Orthomosaics, oblique imagery and video.
- *Montana/Maintenance*. Crack counting.
- *Montana/UAS Program*. The agency recently used UAS with thermal capabilities to locate an explosive shape charge used in pipeline blasting that had fallen off a transport truck.
- *Nebraska*. Mapping for subgrade compaction/roadway settlement measurements (performed by the UAS program).
- *North Dakota*. Washout assessment.
- *Washington/Maintenance*. Spraying.
- *Washington/Olympic Region*. Overhead inspection of scour and landscape design.

The Iowa DOT respondent noted districts use UAVs for these inspections.

Traffic Monitoring

Survey respondents from four agencies described practices for using drones to monitor traffic:

- Iowa DOT's Construction and Materials Bureau and districts use UAVs for traffic monitoring.
- The Road Commission for Oakland County (Michigan) specifically uses video of traffic flow through roundabouts.
- In Nebraska, photos and videos support intersection analysis related to average daily traffic, speed, turning radius and patterns (performed by UAS program at the direction of the Traffic Division).
- New Jersey DOT uses UAS to monitor traffic before, during and after road construction projects.

Several agencies are purchasing or considering the purchase of drones for this practice. Kentucky Transportation Cabinet and North Dakota DOT are pursuing the purchase of a tethered drone for use in traffic monitoring. South Dakota DOT is also considering a tethered drone for future traffic monitoring. Colorado DOT is considering the use of drones in areas where cameras are unavailable during incident and traffic management. Montana DOT/UAS Program submitted a SMART (Strengthening Mobility and Revolutionizing Transportation) grant to use a tethered UAS system for traffic monitoring, however, the proposal was not selected for funding. The agency plans to continue looking at this opportunity.

Traffic Operations

Six agencies participating in the survey use UAVs for traffic operations, primarily to monitor traffic flow but also related to other activities, including construction and planning. Drones are not typically used for

this application by Washington State DOT/Maintenance, but it has been discussed. Table 15 summarizes survey responses.

Table 15. UAV Use in Traffic Operations

Application	Agency and Description
Construction	*New Jersey*. Monitors traffic before, during and after road construction projects. *North Dakota*. Used by Communication Division to help with construction.
Modeling	*Kentucky.* Models intersections to help in the design process.
Traffic Flow	*Kentucky.* Conducts traffic turn movement studies. *Oakland County (Michigan).*Captures video for traffic flow. *Nebraska*. Gathers photos and videos to monitor impacts to traffic and parking from traffic control, road closures, realignments and roundabouts (performed by UAS program under the direction of the Traffic Division). *North Dakota*. Used by Communication Division to help with traffic flow and temporary lane closures.
Other	*Iowa*. Used by Iowa State Patrol and Traffic Operations Bureau.

Other Uses Throughout Agencies

Survey respondents from eight agencies described other activities within their agencies where drones are used. Oregon DOT is testing the use of caged UAS with SLAM (simultaneous localization and mapping) technology to map the inside of large culverts. Several respondents noted the use of UAVs to create agency communication materials for social media and to educate the public. In addition, Washington State DOT/Olympic Region uses an aircraft designed to spray paint for graffiti mitigation. Montana DOT/UAS Program is considering this application using a tethered UAS with a spray nozzle attachment to paint over graffiti in urban areas.

In Illinois, where the agency only began implementing UAVs in the last year, the transportation agency has started training pilots for FAA Part 107 licensing. Implementation will continue to grow and the uses will expand as employees are trained and the agency acquires more UAS statewide. Table 16 summarizes survey responses.

Table 16. Additional Uses of UAVs Across Agency Departments

Application	Agency and Description
Communication and Public Outreach	*Michigan*. Project documentation for presentations and social media. *Nebraska*. Promotional videos and photos for agency events, roadway openings, general imagery of the state (performed by the agency's UAS program under the direction of the Communications Division). *Oregon*. News stories to share on social media and other media outlets (performed by Communications office). *South Dakota*. Projects for public engagement (performed by Communications staff).

Application	Agency and Description
Damage Assessment	*Farmington Hills (Michigan)*. Fire department using with neighboring communities for damage assessment. *New Hampshire*. Photos of damage to roads and bridges after rainstorms.
Other	*New Jersey*. Pollinator habitat inspection of areas planted on roadsides and medians (performed by Landscape Architecture unit, which has one trained UAS pilot). *Oregon*. Testing caged UAS with SLAM technology to map inside of large culverts. *Washington/Olympic Region*. Graffiti mitigation with an aircraft that sprays paint.

2.4 Adapting Interdepartment Uses to Winter Maintenance

According to survey respondents, many of the interagency applications described in Section 2.3 could be leveraged toward winter maintenance. Based on respondent suggestions, practices related to emergency management and response, landslide and avalanche monitoring, road condition monitoring and traffic monitoring could most easily be adapted.

Respondents also noted challenges with adapting these applications, including FAA restrictions, geographic location, and extreme or inclement weather. The Colorado DOT respondent, who was among the respondents citing extreme weather as challenging, added that an infrared camera might be used to monitor road conditions to make the application adaptable. The South Dakota DOT respondent suggested that none of the applications could be implemented at this time due to FAA restrictions concerning flying BVLOS, and the Road Commission for Oakland County (Michigan) respondent noted the current lack of adaptability because of the area's geographic location. Table 17 summarizes survey responses.

Table 17. Leveraging Applications Toward Winter Maintenance

Application	Agency and Description
Bridge Inspection	*Nebraska*. Deicing operations.
Emergency Management and Response	*Nebraska*. Accident and environmental disaster assessment. *Vermont*. Winter flooding to investigate area(s) where the extent of the frozen roadway is unknown.
Landslide/Avalanche Monitoring and Mitigation	*Montana DOT/UAS Program*. Multiple DiaB systems could be deployed year-round to known "hotspot" locations prone to avalanche and/or rockslides. *New Jersey*. Landslide and rockfall response leveraged toward monitoring avalanche and falling ice. *Washington/Maintenance*. Avalanche mitigation. *Wyoming*. Landslide and avalanche monitoring.
Monitoring Remote Areas	*Washington/Maintenance*. Remote sensing of problem areas using real-time lidar.
Road Condition Monitoring	*Colorado, Iowa*. Monitoring road conditions. *Iowa*. Monitoring snowplow operations. *Montana/Maintenance*. Blocked and drifted roads after storms subside to expedite road recovery.

Application	Agency and Description
Stockpile Measurements	*Nebraska*, *Oregon, Wyoming*.
Traffic Monitoring and Operations	*Kentucky*. Livestream data, specifically tethered drones used for traffic monitoring. *New Jersey*. Traffic monitoring and operations could be leveraged to monitor traffic on roads affected by ice and snow. *Oregon*. Traffic impacts (when weather allows).
Other	*Alaska*. All applications. *Kentucky*. Hydrology. *North Dakota*. Continuous daily monitoring. (Currently using a DJI product but leaning toward a fixed wing (BVLOS) or DiaB.) *Farmington Hills (Michigan)*. Training tool. Agencies should budget and train someone in public works. (Farmington Hills has used GoPro cameras to produce training videos.) *Wyoming*. Monitoring the performance of snow fences by documenting snow drifting on parts of I-80.

3 Product Information

3.1 UAV Inventory

The number of UAVs owned by responding agencies varied considerably. Nine respondents reported owning from one to 15 UAVs. Alaska DOTP&F reported owning 130 drones, and Illinois DOT has 27 UAVs in its recently launched program. Table 18 summarizes survey responses.

Table 18. Number of UAVs Owned by Agencies

Number of UAVs	Number of Respondents
1 to 15	9
16 to 30	4
31 to 70	3
More Than 70	1
Unknown	2

3.2 UAV Systems in Use

Note: This section summarizes information provided by survey respondents about the UAV models they use. The U.S. Department of Commerce along with some state governments are considering or have imposed new rules and restrictions for using foreign-manufactured drones and technology, some of which are referred to in this section.

Agencies responding to the survey reported using drones from six manufacturers:

- DJI (SZ DJI Technology Company, Ltd.) (13 models).
- Skydio, Inc. (five models).
- Autel Intelligent Technology Corporation (three models).
- Parrot ANAFI USA (two models).
- Acecore Technologies (one model).
- Prism (Watts Innovations) (one model).

Nineteen agencies provided details about their agencies' UAVs, including software, specifications, flight speed and duration, maintenance and operational requirements, benefits and challenges, and cost. Summaries of these details are presented in Appendices A through D. Table 19 presents the specific models used by each agency. Following the table is information about each manufacturer.

Four agencies provided general information about their agencies' UAVs. Illinois DOT has three UAVs: Matrice 350, Mavic 2 Pro (DJI) and Skydio S2+. The Colorado DOT and Vermont Agency of Transportation respondents reported that their agencies each have two UAV systems, but product names and features were not provided. The Farmington Hills (Michigan) respondent noted that its police department owns two UAVs (product name unknown) and has three licensed pilots.

Table 19. UAVs Employed by Agencies

Agency	Number of UAVs	Manufacturer and Product
Alaska	130	• DJI Matrice 30T • Skydio X10 • DJI M30T Dock
Colorado	Unknown	Unknown
Illinois	27	• DJI Matrice 350 • DJI Mavic 2 Pro • Skydio S2+
Iowa	12	DJI Mavic 2 Pro
Kentucky	52	• DJI Mavic 3 • Skydio X10 • DJI Matrice 350
Farmington Hills (Michigan)	Police department owns 2	Unknown
Oakland County (Michigan)	2	• DJI Mavic 2 Pro • DJI Matrice 350
Minnesota	69	• DJI Mavic 2 Pro • DJI Mavic 3 Pro • DJI Mavic Zoom • DJI Mavic Enterprise
Montana/Maintenance	10+	DJI
Montana/UAS Program	25	• DJI Mavic 3 Enterprise • Skydio X2
Nebraska	15	• DJI Phantom 4 RTK • Autel EVO II Enterprise • Skydio 2+
New Jersey	12	• DJI Mavic 3 Enterprise • Skydio S2+ • Parrot Anafi Ai
North Dakota	32	• DJI Mavic 2 • DJI Mavic 3 • Skydio X10 • Prism Ranger with Reigl miniVUX-3
Oregon	25	• DJI Matrice 300 RTK • Autel EVO II RTK • DJI Air2S
South Dakota	9	• Skydio S2 • Autel EVO II Pro V3
Vermont	3 or 4	Unknown (differing sizes and complexity)
Washington/ Environmental	Unknown	• DJI Phantom 4 Pro V2.0 • DJI Mavic 2 Zoom

Agency	Number of UAVs	Manufacturer and Product
Washington/Olympic Region	8	• Skydio S2+, X2, X10 • DJI Mavic 2 Pro
Wyoming	17	• Skydio • Acecore Technologies Zoe • Parrot Anafi Work

DJI (SZ DJI Technology Company, Ltd.)

https://www.dji.com/
Mavic drones are the most commonly used DJI models among survey respondents:

- Mavic 2 Pro (five agencies).
- Mavic 3 Enterprise (three agencies).
- Mavic 3 and Mavic 2 Zoom (two agencies each).
- Mavic 2, Mavic 3 Pro, Phantom 4 Pro V2.0, Phantom 4 RTK and Air2S (one agency each).

Matrice models are also used:

- Matrice 350 (three agencies).
- Matrice 30T, M30T Dock and Matrice 300 RTK (one agency each).

Agency Use

- Alaska
- Illinois
- Iowa
- Kentucky
- Road Commission of Oakland County (Michigan)
- Minnesota
- Montana/Maintenance
- Montana/UAS Program
- Nebraska
- New Jersey
- North Dakota
- Oregon
- Washington/Environmental
- Washington/Olympic Region

Appendix A provides specific details about each agency's UAV.

Skydio, Inc.

https://www.skydio.com/
Skydio drones used by survey respondents are:

- X10 (four agencies).
- S2+ (three agencies).
- X2 (two agencies).
- 2+ and S2 (one agency each).

Agency Use

- Alaska
- Illinois
- Kentucky

- Montana/UAS Program
- Nebraska
- New Jersey
- North Dakota
- South Dakota
- Washington/Olympic Region
- Wyoming

Appendix B provides specific details about each agency's UAV.

Autel Intelligent Technology Corporation

www.autelrobotics.com
Autel drones used by survey respondents are:

- EVO II Enterprise.
- EVO II Pro V3.
- EVO II RTK.

Agency Use

- Nebraska
- Oregon
- South Dakota

Appendix C provides specific details about each agency's UAV.

Parrot ANAFI USA

https://www.parrot.com/
Parrot ANAFI drones used by survey respondents are:

- Parrot Anafi Ai.
- Parrot Anafi Work.

Agency Use

- New Jersey
- Wyoming

Appendix D provides specific details about each agency's UAV.

Acecore Technologies

https://www.acecoretechnologies.com/
The Acecore Technologies drone used by survey respondents is:

- Zoe.

Agency Use

- Wyoming

Appendix D provides specific details about the agency's UAV.

Watts Innovations (Prism)

www.prismdrones.com

Note: Watts Innovations ended drone manufacturing in 2024.

The Prism drone used by survey respondents is:

- Prism Ranger with Reigl miniVUX-3.

Agency Use

- North Dakota

Appendix D provides specific details about the agency's UAV.

4 Regulatory, Operations and Safety Requirements

4.1 Introduction

In this chapter, survey respondents explain the regulatory, operational and safety requirements and restrictions related to UAV use that agencies must address.

4.2 Regulatory Needs and Use Restrictions

Respondents generally reported UAV regulatory requirements issued by the FAA or the state, which are presented below.

Federal Aviation Administration Restrictions and Regulations

Survey respondents most frequently noted that their agencies follow all FAA UAS regulations and Part 107 licensing requirements. Airspace restrictions impact UAV use for some agencies. Table 20 summarizes agency responses.

Table 20. FAA Restrictions and Regulations

Regulatory Need	Agency and Description
Airspace Requirements	*Alaska*: • BVLOS operations: Certificate of Waiver or Authorization (COA) and waivers required. • Remote operations: Temporary Flight Restrictions (TFR) required. *Montana/UAV Program*: Working with the University of Montana to develop safety cases specific to BVLOS operations. To take full advantage of the DiaB system's autonomous capabilities, the agency would like to stairstep operations using the DiaB from localized flight operations to BVLOS operations to get better fidelity across a larger geographic footprint. *Nebraska:* • Airspace authorizations (Low Altitude Authorization and Notification Capability (LAANC), COA). • Maintaining visual line of sight. *Washington/Olympic Region*. Many locations within military-restricted airspace and near general aviation airports with no LAANC available. Agency typically needs to fly less than 100 feet above ground level, which should never conflict with other air traffic. But gaining authorization in some areas makes it very difficult at times.
General Regulations and Requirements	*New Jersey*. Agency follows all requirements for all airspace classifications. *South Dakota*. Pilots must follow all FAA UAS regulations. *Vermont.* Agency follows FAA regulations. *Washington/Environmental*. Agency registers drone and sets up remote identification in FAADroneZone (see Chapter 7 for additional information).

Regulatory Need	Agency and Description
FAA Part 107 Regulations and Licensing	*Illinois, Iowa, Oakland County (Michigan).* Agency follows Part 107 requirements. *Minnesota*: • Operations mainly under Part 107 with no waivers and no COA. • NOTAMs (Notice to Airmen) created as required. • Use of LAANC. • Weed control operations under Part 107 with waiver and Part 137 with waiver. *Montana/Maintenance*. Commercial FAA drone pilot license. *New Jersey*. Remote pilots are Part 107 certified. *Washington/Environmental*. Commercial FAA drone pilot license.
Other	*Nebraska*: • Flight restricted over people and moving vehicles. • Remote Identification. *North Dakota*. Working with FAA and Northern Plains UAS Test Site (beyond Phase II) (see **Related Resource** below).

Related Resource

Northern Plains UAS Test Site, undated.
https://www.npuasts.com/
From the website: The Northern Plains UAS Test Site is one of seven Federal Aviation Administration (FAA) unmanned aircraft system (UAS) test sites in the nation. The mission of the NPUASTS is to collaborate with FAA and industry partners to develop systems, rules and procedures to safely integrate unmanned aircraft into the National Airspace System without negatively impacting existing general or commercial aviation.

State Restrictions and Regulations

In addition to FAA restrictions, survey respondents cited environmental considerations for operating drones in national forest, coordinating with Native American reservations and following regulations established by state wildlife and parks departments. Table 21 summarizes agency responses.

Table 21. State Restrictions and Regulations

Regulatory Need	Agency and Description
FAA Restrictions (Including Part 107)	*Alaska*. Operates under both Part 107 and Part 91 as a public aircraft for numerous COA and waivers. *Oakland County (Michigan)*. Follows FAA Part 107. *Montana/Maintenance*. Requires commercial drone license.
Other Federal Restrictions	*Nebraska*. Follow federal game and parks restrictions. *Washington/Environmental*. Banned from takeoff/landing in national forest.

Regulatory Need	Agency and Description
State Policy, Guidance and Restrictions	*Illinois*. Developing an agency program manual. *Minnesota*. Follows agency's Office of Aeronautics operations manual (see **Related Resources** below). *Montana/UAV Program, North Dakota, Vermont.* Follows state requirements and restrictions. *Nebraska*. Follows state game and parks restrictions. *New Jersey*: • Follows primary state UAS regulation: New Jersey Rev Stat § 2C:40-27-30 (2023) (see **Related Resources** below). • Follows New Jersey Department of Environmental Protection policy, which prohibits UAS operations in all New Jersey state parks. *South Dakota*. Require pilots to follow: • South Dakota DOT UAS procedures and guidelines. • South Dakota Codified Laws, Chapter 50 (see **Related Resources** below).
Other	*Minnesota.* Operates according to: • Weather requirements. • Maintenance requirements. • Pilot training/currency/recency. *Nebraska.* Coordinates with Native American reservations. *Washington/Environmental*: • Prohibited from flying with city limits of City of Seattle unless on a private driveway or over waterways. Exception: filming, which requires a special permit. • Adheres to restrictions of other parks and cities. • For state parks, files a Remote Controlled Aircraft Permit 60 days before intended flight date.

Related Resources

Minnesota

"Unmanned Aircraft Systems Procedures." Unmanned Aircraft Systems Policy #OE006. Minnesota Department of Transportation. July 1, 2020.
https://www.dot.state.mn.us/policy/operations/oe006-procedures.html
The companion document to Minnesota DOT's UAS policy (see citation below), this resource includes the procedures for UAS contracting and purchasing, and requirements for UAS operations by Minnesota DOT staff.

"Unmanned Aircraft Systems (UAS)." MnDOT Policy #OE006. Minnesota Department of Transportation. July 1, 2020.
https://www.dot.state.mn.us/policy/operations/oe006.html
Requirements for Minnesota DOT staff and third parties who operate UASs are presented.

New Jersey

"Definitions Relative to Operation of Unmanned Aircraft Systems." New Jersey Revised Statutes 2C:40-27. 2023.
https://law.justia.com/codes/new-jersey/title-2c/section-2c-40-27/
Guidance and definitions related to UAS operation are presented.

South Dakota

South Dakota Codified Laws. Title 50, Aviation, 2025.
https://sdlegislature.gov/Statutes/50
Chapter 50-15 describes requirements and restrictions related to UAV operation.

Other Restrictions and Regulations

Respondents from two agencies—Nebraska DOT and Washington State DOT/Environmental—described additional restrictions governing the use of UAS. In Nebraska, UAS use requires coordination with railroads and private property owners, and operating on state ROWs. The Washington State DOT/Environmental respondent noted that UASs cannot be flown over people or moving vehicles.

4.3 Operational Requirements and Restrictions

Manufacturer guidelines and FAA regulations were the focus of operational requirements and restrictions cited by survey respondents. Alaska DOT&PF noted that operational restrictions are often dependent on the platform used. Table 22 summarizes survey responses.

Table 22. Operational Requirements and Restrictions

Regulatory Need	Agency and Description
FAA Restrictions	*Illinois*. Follows Part 107 requirements. *Minnesota*. Follows federal regulations. *South Dakota*. Requires airspace authorization from FAA for controlled airspace. *Washington/Environmental*: • Can fly only within FAA-designated unrestricted areas. (DJI may lock certain areas.) • Must plan for project areas that may require a permit waiver or LAANC.
State/Agency Guidelines	*Iowa*. Follows internal guidelines and flight review process. *Minnesota*. Follows state regulations.
Manufacturer Guidelines	*Alaska*. Follows manufacturer guidance (platform-specific). *Minnesota* *Nebraska*. Follows manufacturer-recommended environmental restrictions for each platform.
Other	*Montana/UAV Program*. Would like to begin conducting BVLOS flight operations within a "shielded" environment; UAS operation would take place at altitudes that shouldn't contain manned air traffic activities. *North Dakota*. Requires waivers and certain equipment for operations over people and during night navigation.

4.4 Safety Requirements and Restrictions

In terms of safety, survey respondents again noted FAA and state requirements. Environmental conditions and man-made obstacles such as power lines and trees were also described. Three agencies—Nebraska, New Jersey and South Dakota DOTs—provided pilot-specific requirements, in particular the need to operate UAVs only when a visual observer is present to assist in identifying hazards. Table 23 summarizes survey responses.

Table 23. Safety Requirements and Restrictions

Regulatory Need	Agency and Description
FAA Restrictions	*Illinois*. Follows Part 107 requirements. *Minnesota*. Follows federal regulations.
State/Agency Guidelines	*Iowa*. Follows internal guidelines and flight review process. *Minnesota*. Follows state regulations.
Pilot-Specific Restrictions	*Nebraska*. Remote pilots must: • Operate with a visual observer for all operations unless specific requirements are met. • Maintain a 62-day currency for assigned platform. • Complete a biennial review in addition to Part 107 requirements, consisting of but not limited to FAA regulations, Nebraska DOT policy and standard operating procedures, and flight maneuvers. *New Jersey*. Requires all remote pilots to operate only with the presence of a visual observer, who assists in identifying hazards. *South Dakota*. Per agency procedures and guidelines, each UAS pilot must: • Renew Part 107 certificate. • Receive a flight review with a flight examiner every two years.
Manufacturer Guidelines	*Alaska*. Is platform-specific. *Minnesota.* Follows manufacturer guidance. *Nebraska*. Follows manufacturer-recommended environmental restrictions for each platform.
Other	*Montana/Maintenance*. Cannot fly over people. *North Dakota*: • Uses safety gear. • Identifies where to fly. *Washington/Environmental*: • Must be aware of power lines and other man-made obstacles, trees, birds, sun in the camera. • Cannot fly over people or people in moving vehicles. • Cannot fly in inclement weather.

5 Program Information

Details about the UAV programs within the agencies participating in the survey are presented in this chapter in the following topic areas:

- UAV program oversight.
- Participation by other divisions.
- Staffing.
- Program funding.

5.1 UAV Program Oversight

Among participating agencies, the Aviation or Aeronautics division typically oversees the UAV program (seven agencies). Some agency divisions share oversight; for example, at Illinois DOT, a joint committee that includes the chief operating officer, Aeronautics, Design and Environment, and Operations divisions is developing the program. The respondent from Washington State DOT/Environmental reported that units within the agency receive some guidance from the Aviation office, but for the most part, each UAV program is independently operated. With supervisor approval, staff may purchase a drone and necessary software. Table 24 summarizes survey responses.

Table 24. Primary Oversight of UAS Program

Agency	Aviation/ Aeronautics	Design/ Environment	Engineering	Maintenance	Other	Description
Alaska	X					
Illinois	X	X			X	Secretary's rep (chief operating officer), Aeronautics, Design and Environment, and Operations
Iowa					X	Model Transportation Bureau
Kentucky		X		X		
Farmington Hills (Michigan)					X	Police department
Oakland County (Michigan)					X	Geographic Information Systems
Minnesota	X					
Montana/ Maintenance				X	X	Construction: construction projects. Maintenance: maintenance projects.
Montana/ UAS Program				X		
Nebraska					X	Business Technology Support Division
New Jersey	X					
North Dakota					X	Strategy and Innovation Division
Oregon			X		X	Engineering and Technical Services
South Dakota			X		X	Planning and Engineering

Agency	Aviation/ Aeronautics	Design/ Environment	Engineering	Maintenance	Other	Description
Washington/ Environmental	X				X	• Each UAV program operates independently. Drones/software purchased with supervisor approval. • Some guidance from Aviation.
Washington/ Olympic Region	X					
Wyoming	X					
Total	**7**	**2**	**2**	**3**	**10**	

5.2 Participation by Other Divisions

Fourteen survey respondents reported that multiple divisions within their agencies, and districts in some cases, participate in the UAV program. Divisions most frequently mentioned were construction, bridges, highways and ROW, and maintenance. The Road Commission of Oakland County (Michigan) noted that it works with any division that has a valid use case. Table 25 summarizes survey responses.

Table 25. Other Divisions Using UAS

Agency	Other Participating Divisions
Alaska	Bridge Section, Construction, Environmental, Maintenance and Operations, Marine, Materials, Right of Way, Survey, Statewide Aviation
Illinois	Currently Aeronautics, Bridge, Construction, Local Roads, Operations and Surveys have certified pilots.
Iowa	Bridge, Design, Field Operations (districts), Location and Environment, Traffic and Safety
Kentucky	Design, Environmental Analysis, Equipment, Facilities, GeoTech, Highway Safety, Maintenance, Public Information, Right of Way, Traffic, Utilities
Oakland County (Michigan)	Any division that has a valid use case. In the past five years: Construction, Design, Inventory, Legal, Maintenance, Public Relations, Right of Way, Subdivision Improvements, Traffic Safety
Minnesota	Aeronautics, Bike/Pedestrians, Bridge, Highway, Land Management, Maintenance, Media/Relations
Montana/Maintenance	Construction
Montana/UAS Program	Bridge, Construction/Engineering, Survey
Nebraska	Bridge, Communications, District Construction, Environmental Materials and Research
New Jersey	Aeronautics, Communications, Emergency Management, Engineering Geology, Fixed Guideway, Landscape Architecture, Local Aid, Maritime Resources, Structural Evaluation
North Dakota	Communication, Construction, districts (eight), Maintenance, Planning

Agency	Other Participating Divisions
Oregon	Communications, Maintenance, Region Tech Centers (Survey)
South Dakota	Communications, Operations
Washington/Environmental	Aviation, Construction, Maintenance Operations (Each of these divisions has its own UAV program.)

5.3 Staffing

Survey respondents provided significant detail about UAV program staffing, including pilot training and certification requirements, and staffing management practices.

Program Staffing

Staffing levels varied widely among the eight survey respondents who reported the number of full- and part-time employees in their programs, with four agencies reporting two to three full-time employees, and four agencies reporting one to five part-time employees. Minnesota DOT employs 160 part-time visual observers. The respondents from Iowa, South Dakota and Washington State DOT/Environmental reported no full-time employees. The North Dakota respondent noted that no one is totally dedicated to its UAS program; it is an add-on responsibility. Table 26 summarizes survey responses.

Table 26. UAS Program Staffing Levels

Agency	Full-Time Employees	Part-Time Employees	Administrative Staff	Pilots	Description
Alaska				115	
Illinois				Approx. 50 (waiting for a few to test)	• No formal UAS section; staffing will grow with program. • Currently a retired State Police UAS program manager administers tasks under personal services contract.
Iowa	0	0	0	12	
Kentucky				50	
Oakland County (Michigan)	Approx. 500	Unknown	Approx. 150	1	More than 99% of employees are full time.
Minnesota	2	48 pilots, 160 visual observers	1 program administrator	48	
Montana/ Maintenance	30		2	30	The respondent estimated both the number of full-time employees and the number of pilots.
Montana/ UAS Program	2	0	2 program managers*	60	*A UAS program manager in Maintenance and another in Construction/Engineering.
Nebraska	2	1	1	15	

Agency	Full-Time Employees	Part-Time Employees	Administrative Staff	Pilots	Description
New Jersey	3	1	2	1	
North Dakota	See Description		1 (additional responsibility to current position)	52	No one is totally dedicated to UAS; it's an add-on responsibility.
Oregon		3		20	
South Dakota	0	0	0	17	No dedicated full-time employees in the UAS program.
Washington/ Environmental	0	5	1 UAV program manager*	5	*The UAV program manager is one of the five part-time employees.
Washington/ Olympic Region	10		1	10	

Pilot Training and Certification Requirements

Like program staffing levels, the number of pilots employed by participating agencies also varies, ranging from one (two agencies) to 115 (one agency), with most programs supporting one to 50 pilots (12 agencies). All agencies providing information about their pilot licensing and certification requirements require completion of FAA Part 107 certification. Training for this certification includes classroom and hands-on exercises. Some also require agency-specific training and flight reviews. Table 27 summarizes survey responses.

The Nebraska DOT respondent added that before each flight operation, pilots are required to make a request to the UAS program. As part of the request, the pilot writes a mission plan and site survey. Once these documents are reviewed and approved by the UAS program, the mission can be scheduled.

Table 27. Pilot Training and Certification Requirements

Agency	Number of Pilots	Training	Licensing/ Certification	Additional Requirements
Alaska	115	• FAA Part 107 • National Institute of Standards and Technology bucket exam • UAS General Operations Manual review	FAA Part 107	Skills test I required
Illinois	Approx. 50	• FAA Part 107 • Developing additional training	FAA Part 107	Waiting to test some pilots.
Iowa	12	• FAA Part 107 • Iowa DOT guidelines • Flight review	FAA Part 107	
Kentucky	50	Kentucky Technology Center training		

Agency	Number of Pilots	Training	Licensing/ Certification	Additional Requirements
Oakland County (Michigan)	1	FAA Part 107	FAA Part 107	Ability to use image reconstruction program, Drone2map, Pix4D, DJI Terra and other programs.
Minnesota	48	• FAA Part 107 • Before acting as remote pilot in command (RPIC), new pilots of small UAS (sUAS) will also: ○ Complete an initial Minnesota DOT-specific training course at the discretion of Aeronautics. ○ Complete a Minnesota DOT-administered oral proficiency exam. ○ Complete a flight review. ○ Receive a letter of completion from Minnesota DOT UAS Aeronautics. • Trainees may operate sUAS before certification and qualification if RPIC for flight is: ○ Designated an instructor pilot by Minnesota DOT UAS Aeronautics sUAS Program Administration. ○ Currently enrolled in training for the remote pilot certificate. ○ Has an approved flight plan on file. • Pilots: ○ Offered refresher courses as necessary. ○ Must maintain currency in accordance with FAA and Minnesota DOT regulations and requirements. ○ Operating under operational waivers, will complete required training. Person or office responsible for each waiver must document and administer any additional required training or documentation.	FAA Part 107 sUAS	• Currency/recency requirements • Visual observer required below a certain number of hours
Montana/ Maintenance	30 (est.)	2-day training before taking FAA Part 107	• FAA Part 107 • Commercial pilot license	

Agency	Number of Pilots	Training	Licensing/ Certification	Additional Requirements
Montana/ UAS Program	60	• Internal UAS training program offers 3-day FAA Part 107 training. Trainees take exam at the end of that week. • 3 days of live flight training covering basic, intermediate and advanced flight maneuvers; emergency procedures; and autonomous flight planning. Participants evaluated at end of 3 days and must pass a "check ride" (evaluated by a Montana DOT flight instructor). • If they meet proficiency levels, cleared to operate UAS for Montana DOT business.	FAA Part 107: 3-day in person instruction, 3-day in person live flight training with evaluation	Annual flight review to evaluate pilot proficiency
Nebraska	15	• FAA Part 107 prep course (Nebraska DOT/Kansas State University) • Nebraska DOT ground school (agency policy, standard operating procedures, applications, planning) • Flight training	FAA Part 107	• Pass Nebraska DOT tests: ○ Ground School Test (Passing Score: 70%) ○ Mission Plan Scenario Test (Passing Score: 70%) ○ Flight Maneuvers Test (Passing Score: 70%) • Maintain: ○ 62-day platform currency. ○ Biennial agency's ground school/flight review.
New Jersey	1	Training program that includes: • Introductory phase • Operational phase • Competency check	FAA Part 107 Remote Pilot Certificate	
North Dakota	52	• FAA Part 107 certification • Yearly proficiency training	FAA Part 107	Working on BVLOS
Oregon	20	• FAA Part 107 • Oregon DOT training (4-hour classroom, 8-hour hands on)	• FAA Part 107 • Oregon DOT training	
South Dakota	17	• FAA Part 107 exam preparation (outside trainer) • Minimum flight time: 2 hours before flying projects.	• FAA Part 107 • Flight review every 2 years	
Washington/ Environmental	5	• FAA Part 107 training • Flight time for practice	FAA Part 107	
Washington/ Olympic Region	10	• FAA Part 107 • In-house training	FAA Part 107	

Staffing Practices

Best practices for managing UAV programs and staff can ensure the program operates efficiently and that challenges related to staffing are limited. Below are recommended strategies from survey respondents.

Effective Management Practices

Program management, operations and recordkeeping practices were among the most recommended by survey participants. The Washington State DOT/Olympic Region respondent also suggested that stationing pilots and aircraft across a large region can enable agencies to respond quickly if an incident occurs. Table 28 summarizes effective program management practices.

Table 28. Effective Management Practices

Topic	Agency and Description
Management	*Iowa*. Provide decentralized management. *Washington/Environmental.* Require program manager to delegate flight operations to pilots depending on their other work schedule.
Operations	*Illinois*. Is similar to operating any new equipment "with a few extra steps. … [C]an be likened to a flying camera with a few more strings attached." *Oregon*. Ensure business lines contribute time and money to have buy-in.
Partners	*South Dakota*. Maintain a UAS committee that includes Bridge, Survey and Communication staff leadership.
Pilot- and Aircraft-Specific Practices	*Alaska*. Maintain a one-to-one ratio of pilots to aircraft to provide pilots with hands-on training and encourage innovation. *Oregon*: • Have currency requirements so that pilots fly frequently. • Hold pilots accountable to program expectations. *Washington/Olympic Region.* Provide expansive geographic coverage. The Olympic Region stations aircraft and pilots across a large region. If an incident occurs, the agency can call on resources from any direction to accommodate the need.
Recordkeeping	*Nebraska*: • Maintain monthly flight log roll-up and audit to rectify any reporting discrepancies. • Report pilot flight totals and currencies to UAS program manager. • Coordinate with individual pilots as needed to maintain currencies. *North Dakota*. Maintain a drone log book to record and manage all flights, personnel, equipment and related information. *Washington/Environmental:* • Use a shared inbox to track drone flight requests, hold flight operations on a calendar, etc. • Use ESRI Survey123 to receive flight requests.

Staffing Challenges

Nine agencies reported challenges that they encounter with staffing, particularly dedicating time and staff to UAS operations given employees' other work commitments. Keeping pilots engaged can also be challenging, especially after they become familiar with FAA and agency program requirements. Table 29 summarizes typical staffing challenges in UAS programs.

Table 29. Staffing Challenges

Topic	Agency and Description
Availability of Instructor Pilots	*Montana/UAS Program.* Very limited access to UAS instructor pilots. Currently, only two are qualified to serve as flight instructors. Need to reevaluate how to make instructor pilot availability more sustainable.
Communications	*Nebraska*. Communication during emergency-related flights.
Dedicated Time and Staff	*Alaska*. Dedicating time for UAS operations often limited by other work demands. *Washington/Environmental*. Working around staff's normal work schedules as flight operations is not a full-time job. *Washington/Olympic Region*. Understanding that pilots have other job duties and report to other managers, which may take precedence over UAS program needs.
Operations	*North Dakota*. Ensuring staff has the right equipment and prioritizes safety.
Pilot Retention	*Oregon*. Maintaining pilot interest. Frequently pilots are excited at first but get discouraged when they learn about FAA and agency program requirements. *South Dakota*. Continued engagement with some UAS pilots.
Program Launch	*Illinois*. With a new program, challenged to get: • Program manual developed and agreement with additional rules placed. • Staffing in place.
Recordkeeping	*Oregon*. Flight log management can be challenging.

5.4 Program Funding

Among the agencies responding to the survey, UAV programs are nearly always funded by state resources. None of the respondents reported receiving local funding.

The UAV programs in Alaska and Kentucky receive funding from multiple sources:

- *Alaska*: Federal (40 percent), state (40 percent) and grants (20 percent).
- *Kentucky*: Federal (State Planning and Research (SPR)), state (maintenance- or project-specific funds) and grants (State Transportation Innovation Councils (STIC) incentive program).

In addition to receiving Washington State DOT Rapid Research Grant funding, Washington State DOT/Olympic Region has received some maintenance and research funding from agency headquarters. Montana DOT/UAS Program has submitted another SMART grant request for its DiaB research project to fund phases II and III. Table 30 summarizes program funding sources.

Table 30. Primary Sources of Program Funding

Funding Source	Agency and Description
Federal Funding	*Alaska*. 40% federal funds. *Kentucky*. SPR.
State Funding	*Alaska*. 40% *Illinois*. Mostly using state funding for DJI Matrice, DJI Mavic 3 Enterprise and Skydio models. Received DJI Mavic 2 Pro models from Illinois State Police (equipment transfer). *Iowa*. 100% operational funds. *Kentucky*. Maintenance- or project-specific funds. *Oakland County (Michigan)*. Gas tax and vehicle registrations. *Minnesota, Montana/Maintenance, Oregon.* State funded. *Montana/UAS Program, North Dakota*. Primarily state funded. *Nebraska*. All agency-allocated funds to date. *South Dakota*. Operations capital asset. *Washington/Environmental*. Funding from Environmental Services. *Washington/Olympic Region*. Agency headquarters has provided some maintenance and research funding.
Grant Funding	*Alaska*. 20% *Kentucky, North Dakota*. STIC funding. *Montana/UAS Program*. Agency has submitted another SMART grant request for the DiaB research project to fund phases II and III. *Washington/Olympic Region*. Washington State DOT Rapid Research Grant funding.

5.5 State Resources

Survey respondents from two agencies, Iowa DOT and Oregon DOT, provided guidance related to UAV use and program development. *Small Unmanned Aircraft Systems (sUAS): Guidelines* for UAS use in Iowa describe operational and training requirements, procurement, contracting services and accident reporting. In addition, Iowa DOT's sUAS flight review ensures that a pilot has the basic knowledge, skills and proficiency to operate a UAS safely and effectively. Oregon DOT's *Unmanned Aircraft Systems Operations Manual* presents guidance related to the operation and management of the agency's UASs. An episode of the Clemson Drone Project podcast describes the evolution of drone technology at Oregon DOT.

References

Clemson Drone Project. "Start Small But Think Big." February 28, 2024.

Iowa Department of Transportation. Small Unmanned Aircraft Systems (sUAS): Guidelines. January 1, 2019. See Appendix F.

Iowa Department of Transportation. sUAS Flight Review. undated. See Appendix F.

Oregon Department of Transportation. Unmanned Aircraft Systems Operations Manual. September 2024.

6 Program Assessment

UAV programs provide transportation agencies with operational, economic and other benefits. Establishing a UAV program can also be challenging. In this chapter, survey respondents share their experiences along with lessons learned and best management practices.

6.1 Benefits

The key benefits of using UAVs in agency operations reported by survey respondents are improved data acquisition and accuracy, operational efficiency and safety. The Alaska DOT&PF respondent noted the value of data-driven decision-making. Other agencies cited efficiencies gained over traditional data acquisition methods and improved data accuracy. Four agencies noted the reduction in both time and costs. Six agencies reported on the improvements to safety. Although Illinois DOT's program is new, the agency anticipates improvements in efficiency and safety. Table 31 summarizes survey responses.

Table 31. Benefits of Using UAVs in Agency Operations

Benefit	Agency and Description
Data Acquisition and Accuracy	*Alaska*. Data-driven decision-making. *Montana/UAS Program, Nebraska, North Dakota, Oregon, Washington/Environmental*. Efficiencies gained over traditional data collection methods. *Nebraska, North Dakota, Oregon*. Improved data accuracy. *Oregon*. Full data coverage.
Efficiency	*Alaska, New Jersey, Washington/Environmental*. Lower overall costs. *Illinois.** Anticipates: • Improved efficiency. • Minimized congestion. *Montana/Maintenance, New Jersey, Washington/Environmental*. Time reduction. *New Jersey*. Increased efficiency of transportation system.
Inventory Management	*Kentucky*. Maintaining a tighter inventory of salt in storage units and emergency stockpile.
Operations	*Alaska*. Operational awareness. *Iowa.* Situational awareness.
Project Documentation	*Alaska.* Project documentation. *Oakland County (Michigan)*: • Streamlining subdivision improvement projects before construction by documenting driveway conditions. • Collecting parking lot imagery for litigation.
Safety	*Illinois*.* Improved safety anticipated. *Montana/UAS Program*. Reduction in slips, trips and spills by removing the need for staff to scale terrain. *Nebraska, New Jersey, Oregon, South Dakota.* Improved employee safety. *Washington/Olympic Region*. Reduced risk to staff. Using UAV never requires fall protection or bucket trucks, and often little or no traffic control.

Benefit	Agency and Description
Other	*Alaska.* More effective communication. *Illinois.** Could minimize congestion that can be caused by traditional methods. *Kentucky.* Livestream capabilities deployed in remote, high-traffic locations (e.g., the interstate during storm events) when existing video feeds are lost or unavailable. *Oakland County (Michigan)*. Public relations and presentations. *South Dakota*. Manpower.

* Program only recently launched.

6.2 Challenges

Program management issues and environmental limitations are common challenges among survey respondents. Obtaining executive buy-in to the program, staying up-to-date with quickly changing technology and regulations, and finding pilots were issues reported along with cold weather and other weather limitations. Operational concerns were also reported, such as mapping missions that require the UAV to fly close to the road and gaining authorization to fly in locations where an LAANC is unavailable. The respondent from the Road Commission of Oakland County (Michigan) noted a challenge with sharing collected data in a format that is easily accessible to everyone. The Montana DOT/UAS Program respondent cited restrictions placed by equipment manufacturers. Table 32 summarizes survey responses.

Table 32. Challenges with UAV Programs

Challenge	Agency and Description
Data Sharing	*Oakland County (Michigan)*. Sharing collected data in a format that is easily accessible.
Environmental Conditions	*Iowa, North Dakota*. Cold weather. *Montana/Maintenance*. Weather limitations.
Equipment Manufacturers	*Montana/UAS Program.* Equipment manufacturer restrictions.
Operational Concerns	*Washington/Environmental*: Security concern when flying close to the road and people in vehicles, which is illegal with heavier drones. Potential solution: Create flight plans that don't require the UAV to cross the road when mapping or that close the road briefly when UAV needs to fly over the road. *Washington/Olympic Region*. Gaining authorization to fly in many locations where LAANC is unavailable.
Program Startup and Management	*Illinois*.* Getting the program underway. *Nebraska*. Proving the concept and convincing those who are skeptical. *Oregon*. Program management, including keeping up with quickly changing technology and regulations. *South Dakota*: • Obtaining executive approval. • Initiating UAS state legislation.

Challenge	Agency and Description
Staffing Issues	*Kentucky*: • Finding pilots. • Establishing a pilot in each district who is always available for emergency response. *New Jersey*. Ensuring all remote pilots use the technology consistently.
UAV Availability	*Alaska*. Meeting user demand for UAVs.

* Program only recently launched.

6.3 Best Practices

Survey respondents shared best practices for creating and operating a UAV program for other agencies to consider. These practices primarily relate to program creation and development, staffing issues, training, and regulations and restrictions. Table 33 summarizes these practices by topic.

Table 33. Best Management Practices for Using UAVs

Practice Area	Agency and Description
Program Startup	• **Keep the program simple** and use UAVs as tools supporting the programs (*Iowa*). • **Create a long-term vision** for the program. Consider how various components (e.g., UAS, software, sensors, flight management applications) will integrate to support that vision (*Oregon*). • **Don't try to re-invent the wheel**. A lot of information is available for agencies that are beginning a UAS program (*Montana/UAS Program*). • **Obtain leadership buy-in**. Show the benefits and demonstrate the capabilities (*Illinois, Iowa, South Dakota*). • **Identify champions and organizations** (*Iowa*). • **Develop policies and procedures early** (*Nebraska, South Dakota*). • **Create a department UAS Teams channel** for information, software use and other important policies and procedures (*North Dakota*).

Program Operations and Management	• **Document all flights** and follow FAA Part 107 rules (*Oakland County (Michigan)*).
	• **Use a fleet management software** to track flights (*Kentucky*).
	• **Maintain drones** (*Kentucky*).
	• **Don't be afraid to fail.** Some unsuccessful operations teach valuable lessons. Learn from those experiences (*Montana/UAS Program*).
	• **Decentralize drones**. Locate them in districts and divisions (*North Dakota*).
	• **Reach out to other agencies:**
	  ○ Share lessons learned and experiences from various flight operations with other agencies (*Montana/UAS Program*).
	  ○ Participate in other state DOT peer exchanges (*South Dakota*).

Practice Area	Agency and Description

Flight Planning	• **Preplan flight**:
	  ○ Even though most drones have collision sensors, always **visually survey an area** for obstacles (e.g., power lines, tall trees, tree branches) before flying, even if it is just driving through an area (*Oakland County (Michigan)*).
	  ○ **Plan as far out as possible**, especially for larger projects in populated areas. Determine if agency needs to submit a flight waiver (approval may take 90 days), request an LAANC or unlock a DJI drone (unlocking may take a week or more) (*Washington/Environmental*, *Washington/Olympic Region*).
	• **Position at least one visual observer** at larger sites or sites with many obstacles or safety risks (e.g., trees, power lines, buildings, areas near fast-moving traffic or with unstable footing). Pilots are constantly looking at the drone and controller, and may not be able to identify obstacles and avoid them.
	  ○ **Locate a visual observer away from the pilot** and relay information about the flight and any potential obstacles to the pilot. *Potential solution*: *Up to a quarter mile*: Use one-eared Eartec headsets, with one ear on traffic and the other on a radio. *More than a quarter mile*: Use cellphones (*Washington/Environmental*).
	• **Be familiar with the flight paths and all flight restrictions**, including temporary restrictions such as forest fires (*Montana/Maintenance*).
	• **Update all firmware and software before flight**, and calibrate devices (*Washington/Environmental*).
	• **Inform staff about the use cases and limitations of different UAS platforms**, which is key to conducting the work and collecting the correct information (*Alaska*).
	• **Say no to UAS applications that are unsafe** or inappropriate (*Oregon*).
	• **Avoid flying in rainy weather**, even mist or low clouds. Any amount of precipitation can potentially damage the drone and/or cut the video feed during flight (*Washington/Environmental*).

Training	• **Ensure staff is properly trained** (*Montana/Maintenance*). Regular skills training always makes better pilots (*Washington/Olympic Region*). • **Develop or enlist a trusted training program** for Part 107 and flight (*Nebraska*). • **Set goals for the amount of study time needed** before taking the Part 107 written exam. Without a predetermined goal, some people will study forever and never test (*Washington/Olympic Region*). • **Identify ongoing training program and flight reviews** (*Iowa*). • **Follow uniform procedures** during training (quality and time) (*Kentucky*).
Staffing	• **Determine a flight schedule for pilots** and hold them accountable to expectations (*Oregon*). • **Determine reporting requirements** for pilots (*Nebraska*).

7 Examining the Literature

An examination of the literature aimed to identify current uses of UAVs in highway transportation and opportunities where UAV use may be transferable to winter maintenance and operations. The search identified a limited number of in-progress and published research citations and other resources related to the use of UAVs in winter maintenance and operations, including an update to the 1999 Guide for Snow and Ice Control Operations, which was submitted to the AASHTO Committee on Maintenance in 2022 for consideration and adoption. A resource for winter maintenance equipment operators, supervisors and managers, the guide addresses the state of practice for effectively addressing snow and ice conditions in transportation. Although the guide is currently unavailable, the contractor's final report refers to a brief section about UAS that is included in the update (Habermann et al. April 2022).

Results of the literature search are presented below in four categories: avalanche mitigation and monitoring, identifying areas prone to ice formation, stockpile measurement and developing a UAV program.

7.1 Avalanche Mitigation and Monitoring

A number of projects are underway to determine how emerging technologies can assist in avalanche hazard forecasting and decision-making. Among these projects is an effort by the Maintenance and Unmanned Aircraft Systems programs at Montana DOT exploring a fully automated UAV (referred to as Drone in a Box (DiaB)) that would monitor and/or map hazardous areas remotely for avalanches and other risks. The state's terrain and climatic conditions are diverse, which places maintenance crews at risk. The DiaB could potentially reduce the risk to both the work crews and travelers. The research is expected to determine whether the tool is a cost-effective alternative to in-person physical inspections, can reliably collect data and map snowpack, and can assess potential flooding issues during spring runoff. Washington State DOT is developing a low-cost, durable sensor that can be deployed by a UAV in inaccessible areas above roads to collect data and monitor avalanche risk. The sensors will use GPS to gather remote temperature and snow movement information, communicate with a signal receiving tower via Wi-Fi or a cellular connection, and use battery power to operate for six months.

As part of a research project with multiple objectives related to avalanche detection, Alaska DOT&PF is looking at using UAS with lidar and photogrammetry to determine snow depth and avalanche size, and conduct distribution mapping capturing. The agency also aims to document avalanche occurrence spatially using UAS platforms to capture information during inclement weather. In a separate project, the agency will create two forecasting tools that will help keep roads free from snow in an area of the state that experiences road blockages resulting from blowing snow and more than 180 avalanches each year. One of the tools will use UAS and software developed in-house to determine snow surface height. The software will record hazardous snow features such as a hanging cornice.

In previous research, Alaska DOT&PF collaborated with Alaska Railroad to examine how UAS technology can enhance the efficiency, safety and accuracy of avalanche mitigation (Dryer et al. 2023). Two technologies are discussed: a UAS-based avalanche mitigation system in which drones carry and deploy explosives for avalanche mitigation and UAS docking stations for avalanche monitoring and mapping. Another study paired UAS technology with photogrammetric capabilities to develop a decision-making tool that would aid DOTs in responding to and mitigating avalanche hazards (Belz and McCormack 2022). Data collected at test sites in Alaska and Washington provided accurate information about snowpack depth and volume that could be used to assess avalanche risk.

7.2 Identifying Areas Prone to Ice Formation

Recently UAV technology has been used to forecast road ice formation. Research on the mechanisms that lead to ice formation on roads is limited, which has made predicting road ice difficult. To identify black ice forming on road surfaces, Montana DOT used road weather information system (RWIS) observations and UAV-based ice detection technology to refine the state's IcyRoad Detection and Alert system. Researchers developed a system that used remote sensing technology and a UAV to launch a hyperspectral camera for data collection (Fowler et al. 2022).

Related research underway in Alaska is evaluating UAV technology to identify cracks, thin ice and other hazards unique to ice roads. These corridors run across the surface of a frozen body of water and are commonly used in the state and other northern regions to transport passenger and freight vehicles. In the study, UAS and three types of remote sensing sensors are being used to identify cracks and thin ice. Currently ground penetrating radar is used to assess ice-road hazards, which requires agency staff involvement at a site. If UAS is successful, it would eliminate risk to field workers.

7.3 Stockpile Measurement

Automated stockpile measurement systems may provide transportation agencies with an efficient alternative for managing salt stockpile inventories. A 2022 Clear Roads pooled fund study evaluated the ability of automated technologies, including a UAS with an onboard camera system, to reliably report the amount of salt stored in an indoor facility (Hirt, 2022). While the UAS-based system worked well, it was not considered an automated system since it relied on data collected by a manually operated UAV.

In 2019, West Virginia DOT began using UAS and seven pilots in place of manual practices to inventory stockpile materials at 150 sites (FHWA 2020). By employing UAVs for this task, the Division of Highways estimated a savings of $340,000 in man-hours alone. A 2022 AASHTO Innovation Initiative presents a business case for implementing digital stockpile management (AASHTO, 2022). Case studies feature Montana DOT and Oregon DOT, which use UAVs to inventory salt and sanding materials for winter operations.

7.4 Developing a UAV Program

The resources below include policies, protocols and other measures to assist transportation agencies in launching a UAV program.

An NCHRP research project currently underway aims to develop a guidebook to assist state DOTs and local agencies with the implementation of UAS operational capabilities. Two other in-process projects are dedicated to UAV program development in state DOTs. A pooled fund study is developing the standards, protocols and testing requirements that a UAS must meet and demonstrate for a particular application. The study aims to produce performance metrics and validation criteria that agencies can use when making decisions about UAS deployment. To complement the knowledge exam that pilots are required to pass, an NCHRP project is developing a practical flight skills component for state DOT UAV pilots to demonstrate their UAV operating skills and verify pilot proficiency. Researchers are developing a computer simulation with different scenarios that pilots can navigate using a generic drone controller or game pad. The only hardware needed is a computer with minimal processing power, access to the internet and a simulator controller.

A range of published research and related resources also support program development. The Blue UAS website provides a "holistic and continuous approach to rapidly prototyping and scaling capable and secure commercial UAS technology for the Department of Defense." A listing of approved products and frequently asked questions about UAS policy are available at the site (U.S. Department of Defense, 2024). A 2024 National Transportation Library resource guide provides a comprehensive list of UAV and UAS projects and pilot programs (NTL, 2024).

Other national research and resources include the FAADroneZone website, which is the "official FAA website for managing drone service" (FAA, undated). The website provides information for registering a drone, obtaining authorizations and waivers, becoming an FAA certificated remote pilot, meeting operational and airspace requirements, and starting a drone program. Also included in this section is a 2019 FAA webinar on public safety and starting a UAV program (FAA, July 2019), and a 2018 domestic scan report that presents key findings related to organizational structure, policy and regulation, safety and risk management, training and crew qualifications, applications and operations (Banks et al., 2018).

Numerous resources from state transportation agencies address organizational structure, program requirements, education and training. A 2023 New Hampshire DOT report includes a roadmap that outlines key tasks in a short-, medium- and long-term approach to program implementation (WSP USA, Inc., 2023). Case studies in a 2021 Nebraska DOT report include the use of UAS to measure the volume of soil in a construction site stockpile (Woldt, Starr and Neale, 2021). Organizational procedures and flight operational information are presented on a 2024 Texas DOT webpage (Texas DOT, 2024).

Roles and responsibilities, equipment purchase and registration, and other operational requirements are presented in a 2021 Pennsylvania DOT guidance document (Pennsylvania DOT, 2021). The Montana DOT's Unmanned Aerial Systems Council webpage also summarizes the program's responsibilities, composition and organization (Montana DOT, undated). An interview with New Jersey DOT's Aeronautics and UAS Program manager includes a discussion of UAV applications, STIC incentive funding, staffing and training (New Jersey DOT, 2021).

A regional guide provides practices that New England states can use when incorporating UAS into daily operations, including data management policies for managing the information life cycle (Mallela et al., 2021). Effective data collection and management strategies are also discussed in an FHWA article (FHWA, May/June 2024).

A 2018 peer exchange hosted by FHWA included representatives from state transportation agencies and the private sector who discussed the state of the practice and potential uses of UAS in highway operations, construction and maintenance (Quinton and Regan, 2018). Among the key findings from the peer exchange was the need for a champion of the UAS program who pushed for program adoption by "leveraging available resources and knowledge and experience." A 2020 journal article features West Virginia DOT's efforts to develop an efficient, cost-effective UAV program (Huynh, 2020). (See Section 7.3, Stockpile Measurement, for more information about West Virginia DOT's UAV program.) Below are lessons learned after launching this program:

- **Start small.** The agency's first step was to develop standard operating procedures based on practices used by the West Virginia Department of Environmental Protection, which had a UAV program in place. In approximately three months, West Virginia DOT was able to plan its UAV program, obtain stakeholder buy-in and secure funding to launch the program.

- **Scale up and rely on a comprehensive UAV management platform.** The agency secured nine certified pilots and 12 UAVs for the program. A single, digital UAV management platform oversaw all flights, pilots and equipment.
- **Identify a use case.** To quickly demonstrate its return on investment, West Virginia DOT chose to use UAVs to survey stockpiled materials.

A 2022 journal article summarizes six key elements to consider when developing a UAV program: creating flight plans, workflows and processes; capturing accurate information; managing coordination between public agencies and private companies; managing regulations; acquiring personnel and providing training; and managing costs (Howe, 2022).

7.5 References

General Resources

AASHTO Committee on Maintenance. Research in Progress: *Guide for Snow and Ice Control Operations*. Start date: July 2019; completion date: February 2022.

Habermann, John, William Holik, William Hwang, Subasish Das, Emira Rista and Diana Clonch. *Guide for Snow and Ice Control Operations*. Texas A&M University. April 2022.

Winter Maintenance and Operations

Avalanche Mitigation and Monitoring

Alaska Department of Transportation and Public Facilities. Research in Progress: Integrated Avalanche Detection Warning and Snow Distribution Mapping. Start date: April 2023; expected completion date: February 2025.

Belz, Nathan, and Edward McCormack. Guidelines for Using Photogrammetric Tools on Unmanned Aircraft Systems to Support the Rapid Monitoring of Avalanche-Prone Roadside Environments. Pacific Northwest Transportation Consortium. 2022. (Dataset: Digital Elevation and Snow Depth Models for Atigun Pass, AK.)

Dryer, Patrick, Timothy Glassett, Ryan Marlow and Matt McKee. "Unmanned Aerial Systems for Avalanche Monitoring and Mitigation: A Collaborative Approach by Alaska DOT&PF and Alaska Railroad." *Proceedings of the International Snow Science Workshop*. 2023.

Montana Department of Transportation. Research in Progress: Remote Observation Over Time (Drone in a Box). Start date: June 2023; expected completion date: unknown.

Pacific Northwest Transportation Consortium. Research in Progress: Elucidating Snow Heights for Avalanche Assessment from Automated Data Processing from UAS and New Winter Hazards Station. Start date: June 2021; expected completion date: March 2023. (Project currently listed as active.)

Washington State Department of Transportation. Research in Progress: Smart Sensor for Snow Avalanche Monitoring. Start date: August 2023; expected completion date: May 2024. (Project currently listed as active.)

Identifying Areas Prone to Ice Formation

Center for Safety Equity in Transportation. Research in Progress: Evaluating Drone Technology at Identifying Ice Changes That Can Cause Ice-Road Hazards. Start date: December 2022; expected completion date: July 2023. (Project currently listed as active.)

Fowler, J. W., M. S. Jin, B. A. Bauer and J. R. Naylor. Icy Road Forecast and Alert (IcyRoad): Validation and Refinement Using MDT RWIS Data. Montana Department of Transportation. 2022.

Stockpile Measurement

American Association of State Highway and Transportation Officials (AASHTO). Digital Stockpile Management (DSM). AASHTO Innovation Initiative. 2022.

Federal Highway Administration (FHWA). "Using UAS Results in Huge Savings." *EDCNews*. July 23, 2020.

Hirt, Brian. Evaluation of Indoor Automated Stockpile Measurement Systems. CTC & Associates LLC, Clear Roads Pooled Fund, Minnesota Department of Transportation. December 2022.

Developing a UAV Program

Banks, Emanuel, Steven J. Cook, Gregg Fredrick, Shayne Gill, James S. Gray, Troy Larue, Jeff L. Milton, Amy Tootle, Paul Wheeler, Paul R. Snyder and Zach Waller. NCHRP Project 20-68A, Scan 17-01: Successful Approaches for the Use of Unmanned Aerial Systems by Surface Transportation Agencies. Transportation Research Board. July 2018.

Federal Aviation Administration (FAA). FAADroneZone. Undated.

Federal Aviation Administration (FAA). "Public Safety: Starting a Drone Program." Webinar. July 2019.

Federal Highway Administration (FHWA). "Unlocking UAS Data: Strategies for Effective Management and Collaboration." *Innovator*. May/June 2024.

Howe, Scott. "6 Barriers to Drone Adoption in Infrastructure and Transportation and How to Overcome Them." *Infrastructure & Transport*. December 7, 2022.

Huynh, Sally. "3 Lessons from the West Virginia DOT on Developing a Drone Program." *Construction Business Owner*. December 2020.

Joint Transportation Research Center Pooled Fund. Research in Progress: Development of an Integrated Unmanned Aerial Systems (UAS) Validation Center. Start date: September 2018; expected completion date: February 2025.

Mallela, Jagannath, Paul Wheeler, Bharathwaj Sankaran, Chan Choi, Elyssa Gensib, Richard Tetreault and Darren Hardy. Integration of UAS into Operations Conducted by New England Departments of Transportation — Develop Implementation Procedures for UAS Applications. Task 4 report. New England Transportation Consortium. March 2021.

Montana Department of Transportation. Montana Unmanned Aerial Systems (UAS) Council. undated.

National Cooperative Highway Research Program. Research in Progress: UAS Operations Practical Skills Pilot Program for State DOTs. Start date: April 2024; expected completion date: October 2025.

National Transportation Library (NTL). Unmanned Aerial Vehicles and Systems. Resource guide. Updated July 2024.

New Jersey Department of Transportation. Innovation Spotlight: NJDOT UAS Program. April 8, 2021.

Pennsylvania Department of Transportation. Unmanned Aircraft System (UAS) Policy, Version 2.0. September 2021.

Quinton, Drew, and Terrance Regan. Use of Unmanned Aerial Systems (UAS) by State DOTs February 27, 2018 Peer Exchange. Federal Highway Administration. November 2018.

Texas Department of Transportation. Unmanned Aircraft System (UAS) Services. 2024.

U.S. Department of Defense. Blue UAS Cleared List. Defense Innovation Unit. Updated May 2024.

U.S. Department of Defense. Blue UAS: Frequently Asked Questions. Defense Innovation Unit. Updated May 2024.

Woldt, Wayne, Jon Starr and Christopher Neale. Research and Education for Optimizing the Development and Implementation of an Unmanned Aircraft Program at the Nebraska Department of Transportation. Nebraska Department of Transportation. May 2021.

WSP USA, Inc. Research in Progress: Guidebook for Implementation of UAS Operational Capabilities. National Cooperative Highway Research Program, American Association of State Highway and Transportation Officials, Federal Highway Administration. Start date: October 2022; expected completion date: October 2024.

WSP USA, Inc. New Hampshire Department of Transportation — Development of an Unmanned Aircraft Systems (UAS) Program. August 2023.

Appendix A: DJI Technology Company UAVs

Presented below are the survey responses that provided product details about DJI UAVs used by 13 agencies:

- Alaska
- Iowa
- Kentucky
- Road Commission of Oakland County (Michigan)
- Minnesota
- Montana/Maintenance
- Montana/UAS Program
- Nebraska
- New Jersey
- North Dakota
- Oregon
- Washington/Environmental
- Washington/Olympic Region

Alaska Department of Transportation and Public Facilities

Alaska DOT&PF uses two DJI models: Matrice 30T and M30T Dock.

Matrice 30T

Topic	Description
Software/platform	• DJI Terra • Flight Hub 2
Specifications	• 470 x 585 x 215 mm • 4069 g
Tethered/untethered	Untethered
Flight speed and duration	• 30 mph • 35 minutes
Operational requirements	IP55 rated
Maintenance requirements	Routine maintenance to ensure airworthiness
Benefits of use	• All weather use • Portable • Adaptable to many program needs
Challenges of use	Skilled pilot required
Cost	$15,000

M30T Dock

Topic	Description
Software/platform	• DJI Flighthub2 • DJI Terra • ESRI Site Scan • UGCS Ground Control • Pix4D
Specifications	• 800 x 800 x 1065 mm • 200 lb
Tethered/untethered	Untethered
Flight speed and duration	• 30 mph • 35 minutes
Operational requirements	• IP55 rated • RTK and internet connection required
Maintenance requirements	Annual maintenance
Benefits of use	• Routing and remote monitoring of infrastructure (without having a pilot on scene) • Can be installed in remote areas and flown from the office • Routine monitoring can occur on scheduled intervals
Challenges of use	More effort for site selection and installation required
Cost	$40,000

Iowa Department of Transportation

Iowa DOT uses one DJI model: Mavic 2 Pro.

Mavic 2 Pro

Topic	Description
Software/platform	Pix4D
Specifications	2.5 lb
Tethered/untethered	Untethered
Flight speed and duration	• 25 mph • 30 minutes
Operational requirements	• Part 107 regulatory • Operational to 14 degrees Fahrenheit (F)
Maintenance requirements	Basic maintenance as directed by manufacturer

Topic	Description
Benefits of use	• Time • Safety • Better final product
Challenges of use	Training
Cost	$2,500

Kentucky Transportation Cabinet

Kentucky Transportation Cabinet uses two DJI models: Mavic 3 and Matrice 350.

DJI Mavic 3 (Vendor: Seiler)

Topic	Description
Software/platform	Trimble Stratus
Tethered/untethered	Untethered
Flight speed and duration	45 mph 40 minutes
Cost	$12,000

Matrice 350 (Vendor: Seiler)

Topic	Description
Software/platform	Trimble Stratus
Tethered/untethered	Untethered
Flight speed and duration	• 50 mph • 50 minutes
Cost	$75,000

Oakland County (Michigan) Road Commission

The Road Commission of Oakland County (Michigan) uses two DJI models: Mavic 2 Pro and Matrice M350.

Mavic 2 Pro

Topic	Description
Specifications	2.2 lb

Topic	Description
Tethered/untethered	Untethered
Flight speed and duration	• 33 mph maximum • 20 minutes maximum
Operational requirements	• Wind gust: Less than 20 mph • No precipitation
Maintenance requirements	Very minimal
Benefits of use	• Small, compact size • Low cost
Challenges of use	• Airports • Traffic • Pedestrians
Cost	Approximately $2,000 (in 2019)

Matrice M350 (Vendor: Fly Motion LLC)

Topic	Description
Specifications	8.3 lb
Tethered/untethered	Untethered
Flight speed and duration	• 35 mph maximum • 45 minutes maximum
Operational requirements	• Wind speed: Less than 25 mph • No precipitation ideal
Maintenance requirements	Minimal expected (Agency acquired UAV in June 2024.)
Benefits of use	Multiple payloads available
Challenges of use	Larger size makes it more difficult to transport and fly
Cost	$50,000 with an L2 lidar sensor, P1 camera and cases, etc.

Minnesota Department of Transportation

Minnesota DOT uses various DJI Mavic models: 2 Pro, 3 Pro, Zoom, Enterprise.

Mavic 2 Pro (Vendor: Frontier Precision)

Topic	Description
Software/platform	DJI Fly
Tethered/untethered	Untethered
Flight speed and duration	• Less than 35 mph • Approximately 30 minutes
Operational requirements	• LOS only • No night flying • Visual Flight Rules — day only
Maintenance requirements	• Mainly with the batteries • Limited to approximately 200 cycles • Propellors, software updates common items
Benefits of use	• Compact • Ease of use • Quality of photography
Challenges of use	• Chinese-based data storage • Unable BVLOS/night operations • No look-up capability
Cost	$4,000 to $5,000, including all accessories, batteries, cases

Montana Department of Transportation/Maintenance

Montana DOT/Maintenance did not specify the DJI models used.

DJI

Topic	Description
Software/platform	DJI
Tethered/untethered	Tethered
Flight speed and duration	• Speed: N/A • Duration: Depends on conditions
Operational requirements	Commercial drone license
Maintenance requirements	• Commercial drone license • Flight plans

Topic	Description
Benefits of use	• Accurate measurements • Reduction in cost and project time for some events
Challenges of use	Possibly discontinue DJI

Montana Department of Transportation/UAS Program

Montana DOT/UAS Program uses one DJI model: Mavic 3 Enterprise.

Mavic 3 Enterprise (Vendor: UVT/Luke Poore)

Topic	Description
Software/platform	DJI Pilot 2 app
Specifications	Small quad
Tethered/untethered	Untethered
Flight speed and duration	• Sport mode: 47 mph (75.6 km/h) • Normal mode: 35 mph (56 km/h) • 42 minutes
Operational requirements	• Simple mapping and videography platform with zoom capabilities • All operations limited by Part 107 regulations, including weather minimums
Maintenance requirements	Manufacturer's recommendations in operations manual
Benefits of use	• Reduced work-related injuries by removing staff from volatile environmental conditions • Efficiencies gained through use of new technologies and workflows • Records of change in conditions over time
Challenges of use	Recent mandate by the state governor to discontinue purchasing and using Chinese-made UAS equipment, specifically DJI. U.S.-made UAS equipment is three to four times as expensive with very limited functionality and capabilities compared to DJI models.
Cost	$3,680 per aircraft, including three batteries and hard pelican carry case

Nebraska Department of Transportation

Nebraska DOT uses one DJI model: Phantom 4 RTK.

DJI Phantom 4 RTK (Vendor: Rocky Mountain Unmanned Systems)

Topic	Description
Software/platform	DJI GS RTK flight application
Specifications	1,391 g
Tethered/untethered	Untethered
Flight speed and duration	• 31 mph • Approximately 30 minutes
Operational requirements	• Wind speed: 22 mph maximum • Operating temperature range: 32 to 104 degrees F
Maintenance requirements	• General cleaning • Firmware updates • Sensor calibrations
Benefits of use	Mapping capabilities with additional post-processing files provided.
Challenges of use	Spotty RTK connectivity. Most operations use PPK workflow.
Cost	$8,500

New Jersey Department of Transportation

New Jersey DOT uses one DJI model: Mavic 3 Enterprise.

Mavic 3 Enterprise

Topic	Description
Specifications	• Unfolded (without propellers): 347.5 x 283 x 107.7 mm • Maximum takeoff weight: 1,050 g
Tethered/untethered	Untethered
Flight speed and duration	• 47 mph (21 m/s) • 45 minutes
Operational requirements	• Wind speed: 28 mph (12 m/s) maximum • Operating temperature range: 14 to 104 degrees F
Benefits of use	• Quick deployment time • Small size (driver distraction)
Challenges of use	Fixed gimbal (cannot be changed or swapped)
Cost	Approximately $5,000

North Dakota Department of Transportation

North Dakota DOT uses two DJI models: Mavic 2 and Mavic 3.

Mavic 2 and Mavic 3 (Vendor: DJI)

Topic	Description
Specifications	Less than 55 lb
Tethered/untethered	Untethered
Flight speed and duration	• Speed: N/A • Duration: 15 to 20 minutes
Operational requirements	Environmental (wind, snow, rain)
Benefits of use	• Ease of use • "Great" cameras
Challenges of use	China product (December 2025)
Cost	"Cheapest drone in our fleet."

Oregon Department of Transportation

Oregon DOT uses two DJI models: Matrice 300 RTK and Air2S.

Matrice 300 RTK

Topic	Description
Tethered/untethered	Untethered
Flight speed and duration	• Speed: N/A • Duration: 20 minutes

Air2S

Topic	Description
Tethered/untethered	Untethered
Flight speed and duration	• Speed: N/A • Duration: 20 minutes

Washington State Department of Transportation/Environmental

Washington State DOT/Environmental uses two DJI models: Phantom 4 Pro V2.0 and Mavic 2 Zoom.
Note: DJI no longer sells the Phantom 4 Pro V2.0.

DJI Phantom 4 Pro V2.0 (Vendor: Frontier Precision)

Topic	Description
Software/platform	• DroneDeploy • Pix4D Mapper
Specifications	1,375 g (48.5 ounces)
Tethered/untethered	Untethered

Flight speed and duration	• Speed:
	  ○ Capable of up to 45 mph
	  ○ Automated flights for orthomosaics, photo and video usually flown at approximately 7 to 14 mph
	• Duration: Approximately 30 minutes

Operational requirements	Unable to fly in inclement weather and very tight spaces (such as small culverts and pipes)
Maintenance requirements	Routine maintenance (propellers, batteries)
Benefits of use	• Small and lightweight • White color makes it easy to see • Mechanical shutter that reduces blur at higher speeds, making it an ideal mapping drone that produces accurate, sharper 2D orthomosaics and 3D map models
Challenges of use	Difficult to transport. The model doesn't fold up, so it is usually hauled in a larger, hard Go Professional Case, which can be heavier and harder to bring on-site with unstable footing.
Cost	Approximately $2,000

DJI Mavic 2 Zoom (Vendor: Frontier Precision)

Topic	Description
Software/platform	• DroneDeploy • Pix4D Mapper
Specifications	905 g
Tethered/untethered	Untethered
Flight speed and duration	• Up to 45 mph (***Note***: Agency never flies drone that fast.) • Approximately 31 minutes
Operational requirements	Unable to fly in inclement weather

Topic	Description
Maintenance requirements	Routine maintenance (propellers, batteries) according to manufacturer guidance
Benefits of use	• Small and lightweight. Small size enables obstacle avoidance to fly under bridges and through small culverts. • Portable. Drone folds up and can be carried in a small shoulder bag. Good for hiking on large project sites. Is small enough with good enough obstacle avoidance to fly under bridges and through smaller culverts.
Challenges of use	Small and dark colored. Against a dark background, it can disappear easily from sight.
Cost	Approximately $1,800.

Washington State Department of Transportation/Olympic Region

Washington State DOT/Olympic Region uses one DJI model: Mavic 2 Pro.

Mavic 2 Pro (Vendor: Frontier Precision)

Topic	Description
Specifications	Less than 10 lb
Tethered/untethered	Untethered
Flight speed and duration	• 30 mph • 30 minutes
Operational requirements	Not waterproof
Maintenance requirements	As required by Part 107
Benefits of use	Multiple
Challenges of use	Not operational in rain
Cost	$4,000

Appendix B: Skydio, Inc. UAVs

Presented below are the survey responses that provided product details about Skydio UAVs used by nine agencies:

- Alaska
- Kentucky
- Montana/UAS Program
- Nebraska
- New Jersey
- North Dakota
- South Dakota
- Washington/Olympic Region
- Wyoming

Alaska Department of Transportation and Public Facilities

Alaska DOT&PF uses one Skydio model: Skydio X10.

Skydio X10

Topic	Description
Software/platform	• ESRI Site Scan • Skydio Cloud
Specifications	31.1 x 25.6 x 5.7 inches
Tethered/untethered	Untethered
Flight speed and duration	• 30 mph • 35 minutes
Operational requirements	IP55 rated
Maintenance requirements	Routine maintenance to ensure airworthiness
Benefits of use	• Portable • All weather use • Can operate without GPS
Challenges of use	Skilled pilot required
Cost	$40,000

Kentucky Transportation Cabinet

Kentucky Transportation Cabinet uses one Skydio model: Skydio X10.

Skydio X10

Topic	Description
Software/platform	Aren
Tethered/untethered	Both
Flight speed and duration	• 30 mph • 30 minutes
Cost	$25,000

Montana Department of Transportation/UAS Program

Montana DOT/UAS Program uses one Skydio model: Skydio X2.

Skydio X2 (Vendor: Skydio/Collin Kemmesat)

Topic	Description
Software/platform	Skydio proprietary
Specifications	• 11.9 x 5.5 x 3.6 inches • 1,325 g
Tethered/untethered	Untethered
Flight speed and duration	• 36 mph • 35 minutes
Operational requirements	Specifically for close proximity bridge inspections
Maintenance requirements	Manufacturer's recommendations in user manual
Benefits of use	Fully autonomous flight and data collection of complex structures. Skydio uses artificial intelligence (AI) to map obstacles and hazards and will generate its own flight path to maintain separation from those obstacles, making Skydio one of the safest aircraft in our fleet.
Challenges of use	• Much more substantial learning curve than DJI aircraft since heavily rooted in AI • "Incredibly expensive" platform compared to DJI aircraft
Cost	$32,000 with recurrent annual subscription fees for AI and 3D scan software. Total: approximately $6,000/year.

Nebraska Department of Transportation

Nebraska DOT uses one Skydio model: Skydio 2+.

Skydio 2+ (Vendor: Rocky Mountain Unmanned Systems)

Topic	Description
Software/platform	Skydio flight application and 3D scan software
Specifications	800 g
Tethered/untethered	Untethered
Flight speed and duration	• 36 mph • 27 minutes
Operational requirements	• Wind speed: 25 mph maximum • Operating temperature range: 23 to 104 degrees F
Maintenance requirements	• General cleaning • Firmware updates • Sensor calibrations
Benefits of use	• Vision-based system for GPS-denied environments • 3D scan software for digital twin creation
Challenges of use	Low maximum wind resistance
Cost	$6,000

New Jersey Department of Transportation

New Jersey DOT uses one Skydio model: Skydio S2+.

Skydio S2+

Topic	Description
Specifications	• 229 x 274 x 126 mm (with battery, antennas up) • 790 g (with battery)
Tethered/untethered	Untethered
Flight speed and duration	• 36 mph • 27 minutes
Operational requirements	• Wind resistance: 25 mph maximum • Operating temperature range: 23 to 104 degrees F (-5 to 40 degrees Centigrade (C))
Benefits of use	Advanced obstacle avoidance, allowing agency to operate in GPS-denied environments, such as under bridge decks
Cost	Approximately $8,500

North Dakota Department of Transportation

North Dakota DOT uses one Skydio model: Skydio X10. The agency has three aircraft for its Bridge Division.

Skydio X10 (Vendor: Frontier Precision)

Topic	Description
Software/platform	Skydio VT300-L
Specifications	Less than 55 lb
Tethered/untethered	Untethered
Flight speed and duration	• Speed: N/A • Duration: 15 to 20 minutes
Operational requirements	Environmental (wind, snow, rain)
Maintenance requirements	General maintenance
Benefits of use	• Thermal camera and advanced sensors • Delamination, rack detection and monitoring
Challenges of use	• New product • Proprietary software required
Cost	$15,000 each (drone only) plus add-ons

South Dakota Department of Transportation

South Dakota DOT uses one Skydio model: Skydio S2.

Skydio S2

Topic	Description
Software/platform	Skydio Autonomy Enterprise license
Specifications	• 229 x 274 x 126 mm • 800 g
Tethered/untethered	Untethered
Flight speed and duration	• 25 to 36 mph • Up to 27 minutes
Operational requirements	23 to 104 degrees F (-5 to 40 degrees C)
Maintenance requirements	• Replacing propellers as needed or once each year. • Monitoring battery health: Keep the batteries from freezing and overheating.

Topic	Description
Benefits of use	• Improved employee and public safety • Reduced need for lane closures and use of Aspen inspection truck • Increased response time for oversized bridge collisions events • Ability to document flooding events
Challenges of use	• Difficulty obtaining approval from executive team • FAA Part 107 certificate required of pilots • Developing a training program for UAS pilots • Developing procedures and guidelines for using UAS technologies
Cost	• Skydio S2: Approximately $2,200 • Skydio Autonomy Enterprise license: Approximately $3,300

Washington State Department of Transportation/Olympic Region

Washington State DOT/Olympic Region uses three Skydio models: S2+, X2 and X10.

Skydio S2+

Topic	Description
Tethered/untethered	Untethered
Flight speed and duration	• 30 mph maximum • 30 minutes
Operational requirements	Not waterproof; not operational in rain.
Maintenance requirements	As required
Challenges of use	Not waterproof
Cost	$800

Skydio X2 and X10

Topic	Description
Specifications	Less than 10 lb
Tethered/untethered	Untethered
Flight speed and duration	• 30 mph • 30 minutes
Operational requirements	Water resistant; operational in light rain.

Topic	Description
Maintenance requirements	As required by Part 107
Benefits of use	Multiple
Cost	$18,000

Wyoming Department of Transportation

Wyoming DOT uses one Skydio model (product name not provided).

Skydio

Topic	Description
Software/platform	Used by nine units (Public Affairs, Aeronautics, five districts, Telecommunications, and Photos and Surveys), each with different software
Cost	$1,800 to $11,633, depending on software installed

Appendix C: Autel Intelligent Technology Corporation UAVs

Presented below are the survey responses that provided product details about Autel UAVs used by three agencies:

- Nebraska
- Oregon
- South Dakota

Nebraska Department of Transportation

Nebraska DOT uses one Autel model: EVO II Enterprise.

EVO II Enterprise (Vendor: Rocky Mountain Unmanned Systems)

Topic	Description
Software/platform	Autel Explorer flight application
Specifications	1,110 g
Tethered/untethered	Untethered
Flight speed and duration	• 45 mph • 42 minutes
Operational requirements	• Wind speed: 39 mph maximum • Operating temperature range: 14 to 104 degrees F
Maintenance requirements	• General cleaning • Firmware updates • Sensor calibrations
Benefits of use	• 6K camera • RTK optional with post-processing files
Challenges of use	• Controls not as responsive as DJI • Some minor flight application glitches
Cost	$4,000

Oregon Department of Transportation

Oregon DOT uses one Autel model: EVO 2 RTK.

EVO 2 RTK

Topic	Description
Tethered/untethered	Untethered
Flight speed and duration	• Speed: N/A • Duration: 20 minutes

South Dakota Department of Transportation

South Dakota DOT uses one Autel model: EVO II Pro V.3.

EVO II Pro V.3 (Vendor: Maverick Drone Systems)

Topic	Description
Software/platform	• Moonlight algorithm 2.0 • Skylink 2.0 with dynamic track 2.1
Specifications	• 457 x 558 x 108 mm (unfolded) • 1,191 g
Tethered/untethered	Untethered
Flight speed and duration	• 45 mph • 40 minutes
Operational requirements	23 to 104 degrees F (-5 to 40 degrees C)
Maintenance requirements	• Replacing propellers as needed or once each year. • Monitoring battery health: Keep the batteries from freezing and overheating.
Benefits of use	• Improved employee safety • Better imagery and photo positioning • RTK allows for better positioning and more accurate survey (to 1 cm) • Ability to create 3D models
Challenges of use	• Difficulty obtaining approval from executive team • FAA Part 107 certificate required of pilots • Developing a training program for UAS pilots • Developing procedures and guidelines for using UAS technologies
Cost	$3,650

Appendix D: Other UAVs

Three agencies–New Jersey, North Dakota and Wyoming–fly UAVs manufactured by:

- Parrot ANAFI USA
- Acecore Technologies
- Prism (Watts Innovations)

Presented below are the survey responses for these UAVs.

Parrot ANAFI USA

New Jersey Department of Transportation

New Jersey DOT uses one Parrot model: Parrot ANAFI Ai.

Parrot ANAFI Ai

Topic	Description
Specifications	• 320 x 440 x 118 mm (unfolded) • 898 g (1.98 lb)
Tethered/untethered	Untethered
Flight speed and duration	• 34 mph (16 m/s) • 32 minutes

Operational requirements	• Wind resistance:
	  ○ During takeoff and landing: 26.8 mph (12 m/s) maximum
	  ○ During flight: 31.3 mph (14 m/s) maximum
	• Operating temperature range: 14 to 104 degrees F (-10 to 40 degrees C)

Benefits of use	• Quick deployment time • 180-degree gimbal
Cost	Approximately $4,500

Wyoming Department of Transportation

Wyoming DOT uses two Parrot models: Parrot ANAFI USA and Parrot ANAFI Work. The agency has five Parrot ANAFI USA units and two Parrot ANAFI Work units.

Parrot ANAFI

Topic	Description
Software/platform	Patrol-5 USA and 2 Work
Cost	• USA: $7,000 each • Work: $999 each

Acecore Technologies

Wyoming Department of Transportation

Wyoming DOT uses one Acecore Technologies model: Zoe.

Zoe

Topic	Description
Software/platform	Patrol
Cost	$20,999

Prism (Watts Innovations)

North Dakota Department of Transportation

North Dakota DOT uses one Watts Innovations model: Prism with Ranger Reigl Mini-Vux 3. It is the largest aircraft in the agency's fleet and the most expensive.

Prism with Ranger Reigl Mini-Vux 3

Topic	Description
Software/platform	GeoCue
Specifications	Less than 55 lb
Tethered/untethered	Untethered
Flight speed and duration	• Speed: N/A • Duration: 15 to 25 minutes
Operational requirements	Environmental (wind, snow, rain)
Maintenance requirements	Routine maintenance
Benefits of use	Elimination of lidar plane at small or remote sites

Topic	Description
Challenges of use	• Well-trained pilots required, who know when they can and cannot fly • Damage to payload a major concern
Cost	• Drone only: $23,000 • With payload: $270,000

Appendix E: Survey

The survey below was provided in an online format to Clear Roads members and participants in the Snow and Ice List-Serv.

(Required) Does your agency use unmanned aerial vehicles (UAVs), or drones, for winter maintenance activities or other agency operations?

- Yes (Skipped the respondent to UAV Uses for Winter Maintenance and Other Agency Operations and the remaining survey questions.)
- No, but our agency is considering the use of UAVs. (Skipped the respondent to Considering Use of UAVs and Wrap-Up.)
- No, and our agency has no immediate interest in or plans for using UAVs. (Skipped the respondent to Wrap-Up.)

Considering Use of UAVs

1. Please briefly describe the activities your agency is considering in connection with UAV use.
2. What is needed for your agency to begin using UAVs?
3. When do you anticipate beginning this UAV use

UAV Uses for Winter Maintenance and Other Agency Operations

1. Please describe the winter maintenance activities in which your agency employs UAVs.
   - Avalanche hazard reduction:
   - Identification of areas prone to ice formation:
   - Stockpile measurement:
   - Other:
2. Please describe how UAVs are used across other departments in your agency. Include the task(s) and department administering the task.
   - Accident reconstruction:
   - Bridge inspection:
   - Construction (including construction and contractor oversight):
   - Data collection:
   - Emergency management and response:
   - Engineering (including environmental studies and right of way studies):
   - Intermodal transportation:
   - Landslide/steep terrain investigations:
   - Maintenance:
   - Monitoring remote and rural areas:
   - Permitting and operations:
   - Project design, planning and implementation:
   - Roadside and roadway inspections:
   - Traffic monitoring:
   - Traffic operations:
   - Other:
3. What applications of UAVs described in Question 2 could be leveraged toward winter maintenance?

Product Information

1. How many UAVs does your agency own?
2. Please provide details about the UAVs in use at your agency. You'll have the opportunity to describe up to three UAV systems.

UAV 1

Product name:

Vendor name (include contact information, if available):

Software/platform:

Specifications (size and weight):

Tethered or untethered:

Flight speed:

Flight duration:

Operational requirements (e.g., task limitations, environmental conditions):

Maintenance requirements:

Benefits of use:

Challenges of use:

Cost to purchase:

(Required) Does your agency currently use a third type of UAV?

Regulatory, Operations and Safety Requirements

1. Please describe regulatory needs and use restrictions.
    - Federal Aviation Administration:
    - State:
    - Other (e.g., right of way issues):
2. Please describe any operational requirements and restrictions.
3. Please describe any safety requirements and restrictions.

Program Information

1. What division within your agency has oversight of the UAV program?
2. Please list other divisions within your agency that participate in the UAV program.
3. Please describe the current staffing levels and responsibilities in your agency's program.
    - Number of full-time employees:
    - Number of part-time employees:
    - Administrative staff (e.g., program manager):
    - Pilots:
        Number:
        Training requirements:
        Licensing and certification requirements:
        Additional requirements:
    - Other:
4. Please describe any effective practices for managing staff.
5. Please describe any challenges that you have encountered with staffing.
6. Please describe the primary funding sources for the program.
    - Federal funding:
    - State funding:

- Local funding:
- Grant funding:

7. Has your agency developed specifications, policies and/or procedures related to UAV use?
    - No
    - Yes (Please provide a link to these documents or send an electronic copy to carol.rolland@ctcandassociates.com.)

Assessment

1. What are the benefits (e.g., operational, economical) of using UAVs in agency operations?
2. What has your agency found to be most challenging when using UAVs?
3. Please provide three lessons learned or best management practices for other agencies using UAVs.
    - Lesson or Practice 1:
    - Lesson or Practice 2:
    - Lesson or Practice 3:

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.

Small Unmanned Aircraft Systems (sUAS)

Guidelines

Effective: January 1, 2019

Purpose

To define the use of Small Unmanned Aircraft Systems (sUAS) for the purposes of conducting Iowa Department of Transportation (Department) business.

Guidelines

sUAS Use

• sUAS may be used to perform a wide range of Department functions.

• Employees are prohibited from using privately-owned UAS of any kind for Department business.

• Vendors are prohibited from using privately-owned UAS of any kind for Department business, unless under written agreement with the Department.

• All sUAS operations will comply with Federal Aviation Administration (FAA) Part 107 regulations involving operations, pilot certification and currency, aircraft registration, waivers/authorizations, and airworthiness standards.

• The sUAS Remote Pilot in Command (RPIC) has the final authority and responsibility for the operation, safety, and FAA Part 107 regulatory compliance of any sUAS operation. Employees or offices that require assistance complying with FAA regulations will consult with the Department's Office of Aviation.

Operational and Training Requirements

• Prior to conducting any sUAS flight on behalf of the Department, employees intending to operate as Remote Pilot in Command (RPIC) of Department-owned sUAS will notify the Office of Aviation with the following information:

Name:

Division and office:

Supervisor:

Scanned image of an FAA-issued Remote Pilot Certificate:

Information on what UAS they will fly and types of operations:

Confirmation the sUAS is registered in the Department's name with FAA:

• Prior to operating any sUAS on a Department project, FAA Part 107-certified employees must conduct a minimum of two hours of flight time in an uncongested area to develop UAS proficiency for each model of aircraft that will be flown. The employee must then satisfactorily complete a Flight Review with an Office of Aviation examiner, or other examiner designated by the Office of Aviation, to demonstrate operational knowledge and proficiency.

• Employees must subsequently complete a satisfactory Flight Review with the Office of Aviation, or other designated examiner, no less than every 24 calendar months

UAS Procurement

• Divisions and offices seeking to procure sUAS equipment will follow standard Department procurement requirements.

Contracting UAS Services

• Divisions and offices seeking to procure sUAS services will follow standard Department procurement requirements. Procurement notices and service contracts for services including sUAS operations will specify requirements to comply with all FAA Part 107 regulations. sUAS service providers contracting with the Iowa DOT will operate in strict compliance with FAA Part 107 regulations.

Protection of Individual Privacy and Personal Information

• sUAS operations will be limited to those necessary for the specific business purpose of the flight and will exercise reasonable precautions to avoid capturing images of people and private property, except for purposes provided for in Iowa Code 314.9 (entering property), and those that are incidental to the project.

Accident Reporting

• Accidents involving sUAS must be reported to the FAA and/or NTSB as required in FAA Part 107 regulations. Notification should be made to the RPIC's supervisor, and the Department's Office of Aviation, as soon as practical. In the case of sUAS service providers, notification should also be made in writing, as soon as practical to their specified contact at the Iowa DOT.

sUAS Flight Review

A satisfactory Small Unmanned Aircraft Systems (sUAS) Flight Review is required prior to operating any sUAS on a Department project. The flight review is intended to ensure basic knowledge, skills and proficiency are in place to support safe and effective sUAS operations, and to comply with FAA Part 107 regulations. The review includes both a demonstration of knowledge, and a demonstration of flight proficiency.

An FAA Part 107 Remote Pilot Certificate and a minimum of two hours of flight time are required prior to scheduling a flight review. Additional training and flight time may be needed to develop operational proficiency. A registered sUAS will need to be supplied by the applicant. Components of the flight review include:

Demonstration of Knowledge

- ☐ FAA Remote Pilot Certificate
  - *Able to produce a certificate*
- ☐ Aircraft registration and marking
  - *Understands non-hobby registration and marking requirements*
- ☐ Firmware and application updates
  - *Understands importance of updating firmware and applications*
- ☐ Charging/storing batteries
  - *Understands the importance of charged batteries and impact of wind in returning home*
  - *Batteries should be stored where they don't make contact with metal objects*
  - *Extreme temperatures impact battery performance.*
- ☐ Checking weather conditions
  - *How to check local weather using approved weather source*
    - *Foreflight, NOAA, other official sources*
  - *Knows weather minimum requirements*
    - *Min. 3 miles visibility, 500' below and 2,000' horizontal from clouds*
- ☐ Checking airspace and authorization requirements
  - *Understands how and where to check uncontrolled vs. controlled airspace*
  - *Identifies when authorizations/waivers are needed*
  - *Demonstrates ability to access and operate the LAANC system i.e. Airmap*
  - *Is aware of standing stadium flight restrictions in Iowa*
  - *Knows how to check for Temporary Flight Restrictions (TFR's)*
    - *Understands flight prohibited without specific FAA authorization*
- ☐ Site plan/flight plan
  - *Reviews site ahead of time and formulates plan for safe and effective flight*
- ☐ Part 107 regulations
  - *Review random selection of Part 107 regulations*
  - *Demonstrates understanding and applications to flying at the Iowa DOT*
    - *flights over people and vehicles*
    - *deviation from rules to extent necessary to address emergencies*
    - *Remote Pilot in Command (RPIC) is responsible for and has final authority*
    - *Can't act as RPIC if medical condition interferes with operation of sUAS*

☐ Commitment to maintaining a strong safety culture

Demonstrates intent for;

- *professionalism and making good judgements*
- *Complying with Part 107 requirements and DOT guidelines*
- *Maintaining recency requirements every 24 calendar months*

Reporting accidents immediately to supervisor

Reporting accidents within 10 days to FAA

- *if it meets criteria of serious injury or damage over $500*

☐ Respect for privacy

Keep flights limited to specific business purpose

Reasonable precautions with photos of people and property

Demonstration of Flight Proficiency

☐ Preflight inspection

☐ Satisfactory setup, launch point, and launch

☐ Confirmation of sUAS control links

☐ Proficiently operates the UAS in all phases of flight

☐ Maintains visual line of sight

☐ Manages distractions

☐ Monitors battery levels

☐ Division of attention between flying and scanning for traffic

☐ Able to operate camera during the flight

☐ Reacting to emergency situations i.e. lost link or visual contact

Name of applicant: _____ **Signature of applicant:** _____

Date of review: _____ **Model of aircraft flown:** _____

This applicant has satisfactorily completed the sUAS flight review.

Name of reviewer: _____ **Signature of reviewer:** _____

Date of review: _____

Comments:

_____

_____

_____

research for winter highway maintenance

Lead state:
Minnesota Department of Transportation
Research Services
395 John Ireland Blvd.
St. Paul, MN 55155