New Hampshire DOT Research

New Hampshire Department of Transportation Development of an Unmanned Aircraft Systems (UAS) Program

Final Report

Prepared by WSP USA, Inc., for the
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16. Abstract

Unmanned Aircraft Systems (UAS) are being used nationwide in an effort to improve safety, increase efficiency, increase quality, and reduce costs. A previous New Hampshire Department of Transportation (NHDOT) research project tested UAS technology to ascertain the ability to assist NHDOT with operations, development, and the execution of transportation-related projects. The study also assessed UAS uses for other NH state agencies such as the Department of Safety. To facilitate deployment of UAS in the day-to-day activities of NHDOT, a UAS program plan was needed to outline the organizational structure and program requirements to support implementation of this valuable technology. This report outlines the phased implementation of UAS by NHDOT over the course of three years. The roadmap outlines a short-term, medium-term, and long-term approach that focuses on scaling up and accelerating a UAS program. The proposed timeline reflects the current position of the UAS program and the progress NHDOT has made to date as the starting point. The outlined timeline also accounts for the experiences of other public sector agencies and reflects the estimated amount of time that it will take to acquire the appropriate technology, develop consensus regarding the priorities for implementation of the UAS program, and develop in-house capabilities to the appropriate level. This roadmap recommends steps for (1) maintaining leadership support; (2) identifying methods for obtaining stakeholder feedback; (3) suggesting roles and responsibilities for various functions within the UAS program; (4) defining specific missions for UAS operations; (5) identifying the appropriate UAS platforms and sensors to accomplish the defined missions; (6) formally adopting UAS Program Policies and Procedures; (7) establish a training and maintenance program; and (8) procuring the necessary data management and analysis tools and expertise required for the defined missions. The roadmap also discusses the importance of tracking costs against conventional techniques for conducting the same job to validate the appropriate uses of UAS within NHDOT.

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DISCLAIMER

NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION

DEVELOPMENT OF AN UNMANNED AIRCRAFT SYSTEMS (UAS) PROGRAM 43272B

TASK 3 STRATEGIC PLANNING AND IMPLEMENTATION PLAN

AUGUST 21, 2023

Prepared By:
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ACRONYMS AND ABBREVIATIONS

3D	Three-dimensional
AAM	Advanced Air Mobility
ATC	Air Traffic Control
CFR	Code of Federal Regulations
CMOS	Complementary Metal-Oxide Semiconductor
DOT	Department of Transportation
FAA	Federal Aviation Administration
FOV	Field of View
FTE	Full-time Equivalent
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
LiDAR	Light Detection and Ranging
MPO	Mission Payload Operator
NHDOT	New Hampshire Department of Transportation
NOTAM	Notice to Air Missions
PIC	Pilot in Command
PPK	Post-processing Kinematic
RGB	Red, Green, Blue
ROI	Return on Investment
RPIC	Remote Pilot in Command
RTK	Real-time Kinematic
SME	Subject Matter Expert
SRPIC	Secondary Pilot in Command
TSMO	Traffic Systems Management and Operations
UAS	Unmanned Aircraft Systems
UA	Unmanned Aircraft

1.0 EXECUTIVE SUMMARY

The New Hampshire Department of Transportation (NHDOT) is actively working on maturing its Unmanned Aircraft Systems (UAS) program to leverage UAS technology to meet the goals of the Department. NHDOT purchased its first UAS in 2019 and has grown its fleet to five by 2023. In 2021, NHDOT formalized the UAS Planner position, housed within the Bureau of Aeronautics, which enabled the secure establishment of the UAS program. Over the last two years, the UAS Planner has worked across various bureaus within NHDOT to test and implement UAS use cases. While this ad hoc structure has enabled rapid growth of the UAS enterprise within NHDOT, the need for a more structured and permanent organizational posture and vision for capability integration within the department became clear.

To this end, the development of the UAS Implementation Program (NHDOT project #43242B) project was designed to build on these efforts and assist in formalizing NHDOT's UAS program. In Task 1 of this project, the research team worked closely with the Bureau of Aeronautics to identify six use cases that are ripe for UAS implementation into traditional workflows. In Task 2, the NHDOT UAS program was formally evaluated using a Capability Maturity Model and a suggested business plan was developed. As part of Task 3, this implementation roadmap builds on the previous project tasks and outlines implementation guidance and suggestions for the next three years.

As UAS technology has matured, State Departments of Transportation (DOTs) have increased their UAS adoption, recognizing that UAS can serve as an efficient, highly valuable, increasingly affordable tool for acquiring large, high-resolution photo/video and geospatial datasets. This technology has the potential to improve safety, increase productivity, reduce negative impacts, and improve the accuracy and reliability of data gathering across all DOT business units. UAS have the advantage of acquiring data remotely. A camera or remote sensors housed, or carried, by the UAS aircraft can operate without direct human intervention from within the aircraft. The sensors use a specific method of detection or measurement, e.g., thermal imaging, light detection and ranging (LiDAR), or ground-penetrating radar, and the associated software converts the data input into digital data and measurements through automated processes.

Like any cutting-edge technology, the adoption of new or novel technology comes with certain risks; therefore, the large-scale implementation of UAS by NHDOT should be managed and should adhere to a well-coordinated, phased implementation plan (i.e., a roadmap) that is implemented in tandem with an agency wide UAS policy. An agreed-upon policy statement and roadmap will support the establishment of organizational capacity and a UAS program that can mitigate risk, as well as foster collaboration and knowledge sharing across NHDOT's business units and comply with all federal, state, and local regulations.

This report outlines the phased implementation of UAS by NHDOT over the course of three years. The roadmap outlines a short-term, medium-term, and long-term approach that focuses on scaling up and accelerating a UAS program. The proposed timeline reflects the current position of the UAS program and the progress NHDOT has made to date as the starting point. The outlined timeline also accounts for the experiences of other public sector agencies and reflects the estimated amount of time that it will take to acquire the appropriate technology, develop consensus regarding the priorities for implementation of the UAS program, and develop in-house capabilities to the appropriate level. Specifically, this roadmap recommends steps for (1) maintaining leadership support; (2) identifying methods for obtaining stakeholder feedback for improving the UAS program; (3) suggesting roles and responsibilities for various functions within the UAS program, including, for instance, converting the current UAS Planner role to a UAS Program Manager position to facilitate the operational duties in the Bureau of Aeronautics with a focus on the UAS program; (4) defining specific missions for UAS operations; (5) identifying the appropriate UAS platforms and sensors to accomplish the defined missions; (6) formally adopting UAS Program Policies and Procedures; (7) establish a training and maintenance program; and (8) procuring the necessary data management and analysis tools and expertise required for the defined missions. The roadmap also discusses the importance of tracking costs against conventional techniques for conducting the same job to validate the appropriate uses of UAS within NHDOT. The high-level recommendations, including prioritized key tasks across the implementation phases, are outlined in Table 1.

While this roadmap is not intended to be prescriptive, the process of adhering to a coordinated, implementation plan will help NHDOT, at the organizational level, to leverage cost savings, ensure proper support, and mitigate risk associated with uncoordinated expenditures and reduce/eliminate risk at hazardous work sites for NHDOT personnel. UAS technology, if implemented and managed properly, can offer significant benefits, and enhance the overall efficiency of NHDOT's data collection methods by supplementing new tools into traditional workflows.

Table 1. Implementation Phases.

SHORT TERM	MEDIUM TERM	LONG TERM
Key Tasks	**Key Tasks**	**Key Tasks**
☐ Establish UAS Program milestones at which NHDOT stakeholder feedback is desired. ☐ Finalize and achieve approval for an agency-wide policy on the applicable uses of UAS. ☐ Maintain support of NHDOT leadership and state executive leadership by communicating the continual progress and development of the UAS program. ☐ Build upon test and demonstration flights and begin integration of UAS into the defined UAS missions. ☐ Develop the UAS Program Manager position job description for review and approval by NHDAS/Division of Personnel ☐ Formalize the job duties of the UAS positions including roles and duties. ☐ Establish a maintenance schedule for hardware and provide dedicated physical space for the storage and maintenance needs of the expanding UAS fleet as well as physical office/training	☐ Document and monitor UAS mission outcomes especially with regard to cost differences. Reevaluate the cost differences at the one-year point to calculate cost savings. ☐ Establish pilot and fleet tracking software to monitor UAS operations across NHDOT. ☐ Continue discussions as the UAS program matures regarding staff and equipment to be embedded in the willing bureaus. Solicit bureaus interested in having an embedded UAS pilot. ☐ Hire a UAS Data Processing Technician/Training Specialist or assign training as a shared duty of the new position to support the UAS Program Manager. ☐ Formalize an internal UAS training program and supplement with third-party services and/or software (flight simulator) as needed to enable NHDOT personnel to integrate UAS confidently and safely into the daily work tasks at NHDOT.	☐ Fine tune the in-house UAS program capabilities across the use cases throughout NHDOT to meet near-term mission needs. ☐ Evaluate demand for UAS mission needs against available pilot and UAS platforms then pursue assets to address the gaps either on a temporary or permanent basis. ☐ Evaluate future technology, regulatory limitations, and necessary budget for the UAS fleet renewal. ☐ Maintain third-party contracts for complex UAS missions. ☐ Leverage an established Return on Investment (ROI) tracking model to routinely communicate the ongoing positive impacts of the UAS program to NHDOT leadership and other interested parties.

SHORT TERM	MEDIUM TERM	LONG TERM
space to meet the needs of the additional UAS program team. ☐ UAS Program Manager leads the development of a UAS Data Management Plan in coordination with the Information Technology Services division	☐ Acquire the necessary software tools to begin establishing internal robust UAS data processing capabilities.	
Mission Implementation	**Mission Implementation**	**Mission Implementation**
☐ Develop UAS mission management plans and processes. ☐ Follow a UAS program organizational structure of Centralized Control within the Bureau of Aeronautics and Decentralized Execution for routine some UAS missions. ☐ Engage NHDOT leadership as UAS-use milestones are reached. ☐ Approve, disseminate, and train NHDOT's UAS pilots on UAS Policy and Procedures. ☐ Develop pathways for UAS program growth based on projected UAS needs in the near term. ☐ Market UAS services across bureaus at NHDOT and conduct pilot projects to demonstrate how UAS can improve processes and jobsite safety for personnel.	☐ Prioritize the UAS missions and operate multiple and various UAS operations across the identified priorities. ☐ Perform an internal audit of UAS mission costs vs. benefits. ☐ Continue program organizational structure by starting to train current DOT employees as UAS Operating Crews to be embedded in some NHDOT non-Aeronautics bureaus where UAS demand is high. ☐ Implement and improve in-house UAS equipment maintenance and pilot training programs. ☐ Implement a robust data management plan to use UAS data across NHDOT and ensure adequate storage of the UAS-collected data.	☐ Conduct majority of UAS missions across the initially identified use cases with NHDOT staff or provide oversight for any UAS missions conducted by contractors. ☐ Expand beyond the initially identified six UAS use cases in this report and conduct additional UAS missions for multiple applications using specialized sensing systems. ☐ Identify process for letting NHDOT bureaus know what UAS data has been collected so they don't need to duplicate the effort themselves. ☐ Identify near-term and mid-term UAS mission needs and supporting resources, budget accordingly. ☐ Expand UAS program organizational structure by training additional current DOT employees as UAS Operating Crews to be embedded in more NHDOT non-Aeronautics bureaus as UAS demand increases.
Resource & Cost Estimates	**Resource & Cost Estimates**	**Resource & Cost Estimates**
UAS mission labor considerations • 2 UAS pilots in Bureau of Aeronautics • 1 visual observer, 1 safety personnel additional duties assigned to current	**UAS mission related labor considerations** • 2 UAS pilots in Bureau of Aeronautics • If the need arises the Bureau of Aeronautics will train 1-2 part-time UAS pilots as additional	**UAS labor considerations for in-house program** • 2 UAS pilots in Bureau of Aeronautics • Train an additional 2–3 part-time UAS pilots as additional duties from

SHORT TERM	MEDIUM TERM	LONG TERM
personnel in Bureau of *Aeronautics* *(approx. 2–3 full-time equivalents [FTE] combined)* **UAS mission technology/equipment estimates** • NHDOT should rely on its current fleet of 5 UAS but plan for approximately $5,000 for ongoing maintenance needs (e.g., batteries, propeller replacements, etc.)	duties from willing non-Aeronautics bureaus • Train an additional 1-2 visual observers, 1–2 safety personnel from current personnel in Bureau of Aeronautics or other willing bureaus *(approx. 4 FTE combined)* **UAS mission technology/equipment estimates** • UAS missions for priority UAS use cases, additional UAS platforms and payload, imaging systems, data processing software with on-going service contracts for in-house evaluations: approx. *$100,000 to $150,000*	willing non-Aeronautics bureaus • From current DOT staff train and additional 1-3 visual observers, 1–3 safety personnel, technical expert/inspector, technical support staff *(approx. 6–8 FTE combined)* **UAS technology equipment for in-house program** • Additional or replacement UAS platforms, advanced payload and sensing systems, post-processing software with on-going service contracts, additional peripheral equipment, field vehicles, data storage: *approx. $200,000 to $300,000*

Note: The cost estimates are presented for comparison. Estimates reflect initial startup costs for UAS implementation, which can vary depending on the number of missions, individual project requirements, use cases and specialization of sensing technology that is employed. FTE = full-time equivalent employees

The report found that the best organizational structure for the management of the UAS program within the New Hampshire DOT is to maintain centralized control within the Bureau of Aeronautics. The Bureau of Aeronautics is where UAS Program Manager and other full-time UAS positions should be housed. Centralized control of UAS policy, standards, training, evaluation, certification, expert execution, data processing, UAS acquisition, management and maintenance should remain with the Bureau of Aeronautics. A decentralized execution of UAS operations across the other bureaus using people within those bureaus to conduct UAS operations as additional duties was determined to be the most sustainable approach for UAS implementation. All UAS operations regardless of which bureau is conducting the operation will coordinate with the UAS Program Manager.

Figure 1 depicts this organizational model as described; the report provides the findings outlining why it was determined this is the best model for NHDOT.

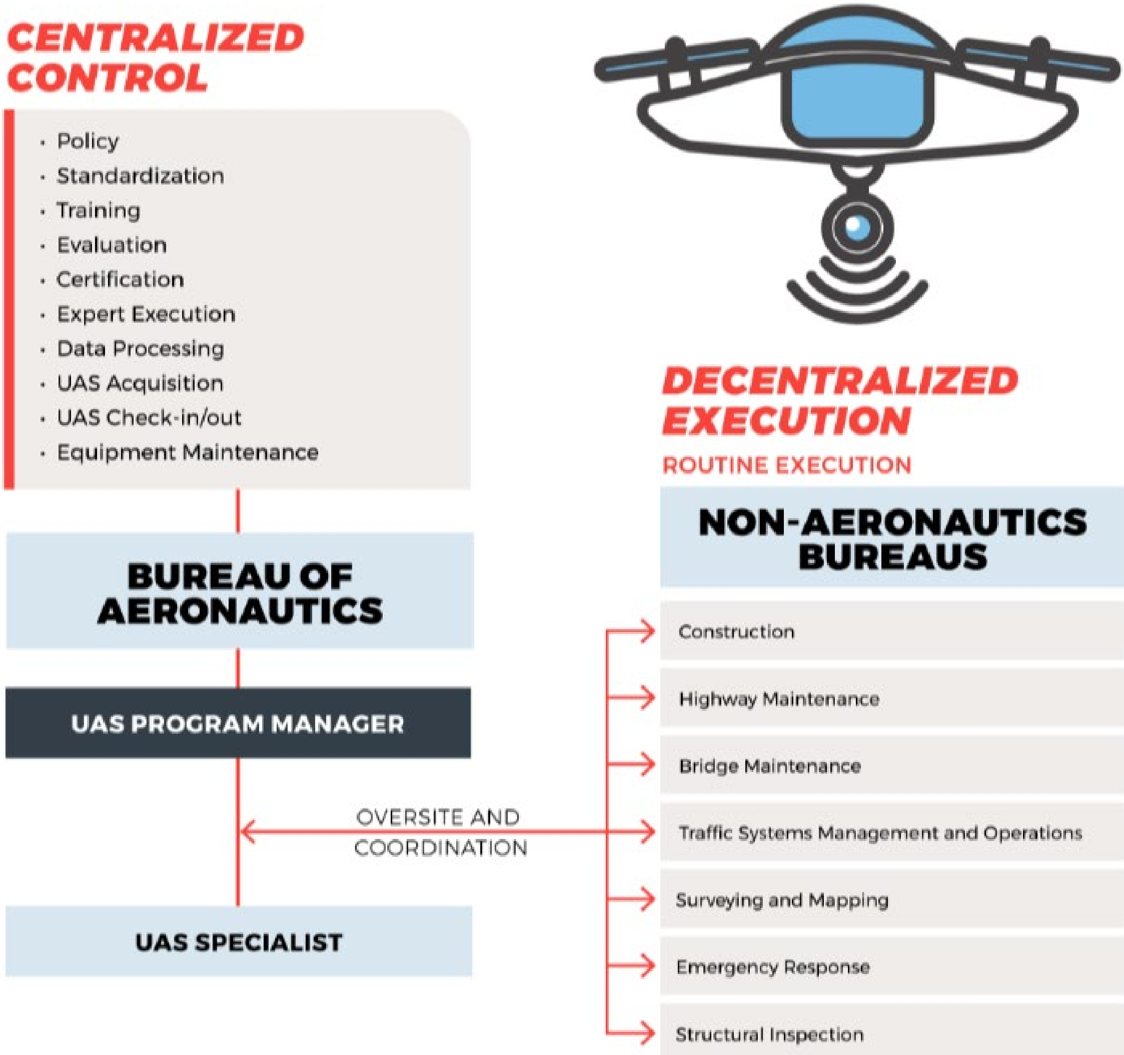


Figure 1. NHDOT UAS Program Organizational Structure

2.0 STRATEGIC ROADMAP

2.1 Leadership Support

Having executive support for the UAS program at NHDOT is of utmost importance for the overall success of the program. First and foremost, executive support allows the acquisition of necessary resources and ongoing funding to establish and sustain an enduring successful UAS program. A UAS program requires initial investment in equipment, training, and infrastructure, as well as continuous maintenance and operational costs. Without executive support, securing the necessary financial backing could be challenging, hindering the program's ability to effectively use UAS technology for surveying and mapping, bridge inspections, or other transportation-related tasks. With executive support, NHDOT can allocate adequate resources to procure advanced UAS platforms, develop training programs, and establish protocols for safe and efficient UAS operations.

To date, the executive leadership of NHDOT has been very supportive of UAS adoption. Leadership continues to enthusiastically support formalizing and growing the UAS program at NHDOT, specifically, they have expressed the desire to see how the current fleet of UAS are being used, the potential benefits, and the potential ROI. Communicating the increase in safety, cost efficiency, data quality/analysis, and other “wins” from the UAS program to leadership is key to a successful UAS integration program. This communication is built directly into each of the phases of the near-term, mid-term, and long-term phases in the implementation roadmap.

Furthermore, executive support sets the tone for the organization and fosters a culture of acceptance and adoption of UAS technology among employees and other stakeholders. When top-level executives see and understand the benefits of UAS, they will be able to communicate the value of UAS, which sends a clear message to staff members, legislators, and other parties that the UAS program is a priority that improves the safety and efficiency of its existing duties. This support helps overcome resistance to change and encourages staff to embrace the benefits and potential of UAS for improving operations. Executive endorsement also plays a crucial role in addressing staff concerns about job security, training, and the integration of UAS into existing workflows. By actively supporting and promoting the UAS program, executives can help alleviate anxieties and facilitate a smooth transition, ensuring that UAS becomes an integral part of NHDOT's operations and contributes to the overall success of the organization's transportation initiatives while providing new skillsets to existing employees and providing attractive jobs for new hires.

2.2 Organizational Structure and Oversight of UAS Program

The organizational structure of a UAS program is important because it identifies the reporting, communication, and operations structures to be used across all of the bureaus and divisions throughout NHDOT. An organizational structure, delineating oversight procedures and chain of command for agency-wide deployment of UAS, is outlined below.

2.2.1 Organizational Structure

It is important when starting a UAS program that a State DOT understand the various organizational structure models that are typically used to house the UAS program nationally. Three models were presented in the *Task 1a Report – UAS State of the Practice Review* including: Aeronautics, Department of Transportation, and Centralized. Over the last five plus years, NHDOT has organized its UAS program within the Bureau of Aeronautics where it continues to leverage existing aviation knowledge and established relationships with the Federal Aviation Administration (FAA) along with its partnerships with other bureaus within NHDOT. Because of these reasons, it is recommended that NHDOT keep this

Centralized Control and Decentralized Execution organization model. It is the best organizational location for the UAS program because it is where the program development taken place and there are dedicated, existing resources enabling UAS services to be provided to internal customers which the Bureau of Aeronautics has trusted relationships.

As the UAS program is being more formalized and maturing, it would be unwise to move the organization structure that has already been established. Additionally, UAS operations are Federally governed through Federal Aviation Regulations and policies, the Bureau of Aeronautics contains the aviation knowledge to continue to lead safe integration of UAS operations. The Aeronautics model can be reviewed in the future to see if modifying the UAS program organizational structure would be beneficial to meet NHDOT's needs as the UAS program matures. Appendix A reviews these three UAS program organizational models more fully and describes their associated advantages and disadvantages.

The most adopted model nationally is to organize the UAS program as Centralized Control under the Aeronautics group and Decentralized Execution with other Bureaus for some of the missions. Twenty-four states are currently using this model. Figure 1 above is a customized organizational chart for the NHDOT based on the traditional aeronautics organizational structure. The typical structure includes having a UAS program managed from within the Aeronautics group including oversight of a UAS training coordinator, full-time UAS pilots, embedded UAS pilots within other bureaus, and supplemental consultant UAS pilots on an as-needed basis.

One of the essential advantages to this model is the ability to leverage existing aviation knowledge and expertise that is critical to establishing a successful UAS program. Having a relationship with the FAA and understanding Federal Aviation Regulations are crucial components to the UAS program (Banks et al., 2018). The Division of Aeronautics will include people who understand FAA terminology; have a working relationship with the FAA; and may have a pilot background with knowledge of checklists, aircraft operations, airspace, emergency procedures, and other key functions of establishing the UAS program.

Currently, NHDOT has developed their UAS program using this Aeronautics model, and it continues to be a good model to move the program forward in the foreseeable future. Efforts should be made to add capacity to the UAS program when needed by utilizing embedded UAS pilots within other Bureaus of NHDOT. As further discussions regarding UAS use statewide continue, decisions can be made to adjust the program accordingly.

2.2.2 UAS Stakeholder Committee

To develop standards and guidelines for the safe use and operation of UAS technologies, NHDOT has already begun developing draft Standard Operating Procedures (SOPs) and could benefit from feedback from a UAS Stakeholder Committee. This committee would meet on an as-needed basis using affected stakeholders to help NHDOT address unmet needs of its UAS program. While advisory in nature, this committee might include different stakeholders from time to time depending on the issue(s) to be addressed. Oversight of the UAS program will come from the Aeronautics Administrator, Director of Aeronautics, Rail & Transit, Deputy Commissioner, and Commissioner. A UAS Stakeholder Committee serves as a central advisory body that can strategize, plan, and recommend policies and practices related to UAS operations within the NHDOT. The dynamic nature of UAS technology requires a cohesive and multi-disciplinary approach to effectively address safety, privacy, infrastructure, and integration concerns. A UAS Stakeholder Committee brings together key stakeholders from various stakeholder groups to collaboratively navigate these challenges.

The UAS Stakeholder Committee could comprise representatives from different entities to provide a comprehensive perspective. At a minimum when needed, the committee should include members from the different bureaus within NHDOT affected by the challenge at hand. This group will serve as a forum to understand the Department needs, including UAS data requirements, staffing capabilities, and facility space capabilities or needs. A member of executive leadership should be included to ensure consistency with NHDOT mission and directives. While it may be preferrable for these individuals to be interested in and supportive of the UAS implementation, having opposing views at the table can help make the UAS program stronger and more resilient. Having a member of the executive leadership team on the committee is a good way to build understanding regarding the ongoing status of the UAS program at the leadership level.

The frequency of meetings for the UAS Stakeholder Committee should be as needed to address emerging issues promptly. These interactions should facilitate open communication and foster a collaborative environment to tackle complex challenges effectively.

Initially, the UAS Stakeholder Committee should consider providing feedback on newly developed NHDOT UAS policies and procedures, integrating UAS into the department's workflow, and promoting safe integration of UAS into the daily operations of NHDOT. In the future, this committee may also be helpful in addressing public concerns about privacy and security and encouraging innovation in the UAS industry while promoting safety as a top priority. By working together, the UAS Stakeholder Committee can ensure that UAS technology contributes positively to NHDOT operations while minimizing potential risks and maximizing its benefits for the State's economy and infrastructure.

The UAS Stakeholder Committee would be responsible for providing feedback on initial and updated protocols and procedures, and with unique UAS program issues in the future to help ensure the timely guidance needed as the UAS program grows at NHDOT.

2.2.3 UAS Program Asset Needs

At the rate NHDOT's UAS program is currently growing, and is anticipated to grow, leadership should begin to plan for additional space to accommodate the need for personnel, secure equipment storage, a maintenance area equipment, fireproof environment for battery storage, and a UAS training and testing facility. The current Bureau of Aeronautics physical office space to house UAS operations may hinder the ability for the UAS program to grow to its full potential or meet the growing needs of its stakeholders. New or larger UAS facilities would make possible the ability for the NHDOT to smoothly transition to a central Statewide hub for UAS State agency operations when the need is triggered.

Additionally, transporting UAS equipment and personnel to UAS mission sites requires a specialized vehicle to support UAS battery charging, storage of UAS equipment and accessories, as well as accommodate UAS pilots, VOs, and safety crew. This vehicle also needs to be able to get through rugged terrain to get as close to the UAS mission job site as possible to minimize the manual relocation of the UAS equipment to a location where the UAS can be flown within FAA regulatory requirements. The existing Chevrolet Equinox AWD is sufficient for job sites only requiring use of one small UAS platform and no need to recharge UAS batteries. The existing vehicle is insufficient for carrying multiple UAS platforms, accessory items, battery chargers, and flight crew. Whereas the Bureau is already utilizing multiple UAS platforms, accessories, battery chargers and flight crew on numerous UAS mission job sites, a four-wheel drive truck with cap, and integrated battery charging hookups is a critical tool for the successful implementation and growth of NHDOT's UAS program.

Lastly, as NHDOT evaluates its UAS platform needs over time, new or replacement UAS platforms with improved or unique capabilities should be considered and measured against forecasted UAS mission needs for NHDOT. Supporting software and ancillary equipment may also be needed and should be considered.

2.3 UAS Implementation – Key Program Requirements

The purpose of UAS is not to fully automate or replace any existing inspection activity but rather to introduce a tool that increases task-level efficiency and safety. The ROI from UAS multiplies as its routine use increases across various tasks, quickly recouping the initial up-front costs for training and technology. Figure 2 outlines the several distinct UAS implementation activities that would be critical to the build-out of NHDOT's in-house capabilities.

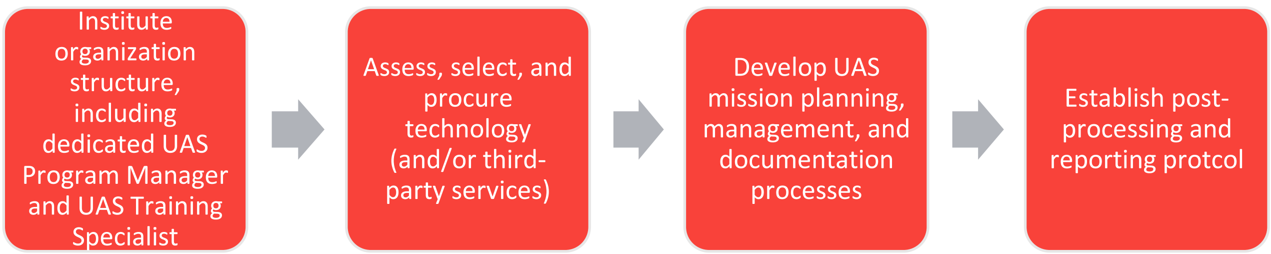


Figure 2. UAS Implementation Activities.

2.4 Designation of Roles and Responsibilities

As noted above, implementing the recommended Aeronautics-model organizational structure and a coordinated agency-wide approach to UAS implementation will maximize the value of the technology while mitigating risk and exposure for NHDOT's existing non-UAS activities. Activities focused on building capacity inside the NHDOT, starting with training and development of NHDOT staff in UAS operations and post-processing of data generated by UAS, will lead to a successful UAS program.

This report identifies the UAS position roles and responsibilities that may one day in the future be needed at NHDOT for its UAS program. It is understood that budgeting consideration of UAS team member additions will be tied to demand for UAS services at NHDOT while factoring in whether temporary or embedded UAS-trained staff are sufficient to meet that demand in the short term. Until the UAS demand exceeds available capacity, the UAS team members will continue to be cross-trained and will have responsibilities that covering more than one UAS team position.

The following describes the UAS team members proposed for NHDOT.

UAS Program Manager

The existing UAS Aviation Planner currently oversees the UAS operations for NHDOT as well as other bureau-assigned duties. It would be recommended that the position becomes the UAS Program Manager in the near future, effectively setting up a new UAS section within the Bureau of Aeronautics to oversee UAS operations and any embedded UAS Operating Crew within other Bureaus at NHDOT as well as other Aeronautics Operational duties.

The UAS Program Manager is responsible for oversight of the UAS program undertaken in support of NHDOT business or activities. Almost all successful agencies that have implemented a successful UAS program have a designated UAS Program Manager. The UAS Program Manager should be a member of the UAS Stakeholder Committee.

The UAS Program Manager will oversee the review and approval processes of UAS missions. The UAS Program Manager will ensure that staff and contractors adhere to FAA rules and regulations, and to any State and local regulations, policies, and procedures governing the use of UAS.

The UAS Program Manager will be responsible for (1) providing guidance on key UAS activities as described in this roadmap; (2) providing oversight of all UAS missions in support of NHDOT business and activities on property owned or managed by NHDOT; (3) providing guidance on procurement of UAS services through third-party contractors; (4) ensuring that the appropriate documentation and evaluations are being captured for all UAS missions; and (5) developing a workforce training program to support the development of in-house technical capabilities.

The UAS Program Manager will serve as the central liaison between federal and state regulators and NHDOT. The UAS Program Manager will also act as a steward of NHDOT's UAS Policy documents and will be responsible for updates on an as-needed basis. He or she will also provide supplemental guidance on UAS-deployment procedures, which may have a separate set of considerations for unique situations.

Specifically, for the UAS program, the UAS Program Manager will be responsible for:

- Centralizing UAS-deployment requests and monitoring project outcomes.
- Ensuring proper certification and permitting for every mission.
- Developing and implementing guidance around UAS-deployment procedures.
- Advising on the development of workforce training opportunities to support the development of in-house technical capabilities.
- Providing oversight so that all training, flight, and maintenance records for each operator are kept current.
- Providing oversight of documentation of registration and maintenance records for individual UAS platforms.
- Providing oversight so that UAS platforms are selected based on mission needs.
- Acting as steward of a NHDOT-wide UAS Policy document.
- Serving as the central liaison between NHDOT and FAA regulators and providing guidance on regulations as they change.
- Facilitating training as needed.
- Conducting UAS missions.
- Soliciting funding and approval for, then coordinating the purchase of UAS platforms and ancillary equipment and software.

The UAS Program Manager will oversee efforts to advise NHDOT business units that wish to procure UAS service on technology requirements, best practices, appropriate contract provisions, and qualifications of consultants/contractors. The UAS Program Manager would report directly to the Aeronautics Administrator, effectively creating a third line of business within the Bureau.

NHDOT has already taken the important step of identifying a key individual within the agency who has been serving in this role and has coordinated UAS activities, flown UAS missions, and liaised with the FAA along with other Aeronautics' duties that include. airfield safety inspections and traditional aircraft emergency response, aviation outreach efforts, and management of the Alton Bay Ice Runway each winter. His bandwidth to meet the demands of the growing UAS program and his other responsibilities is becoming increasingly thin. As outlined above, the UAS Program Manager has significant responsibility over the UAS program, equipment, personnel, policies and procedures, and oversight of every NHDOT UAS operation. It is recommended that the NHDOT Bureau of Aeronautics consider redefining this position as a UAS Program Manager to recognize the UAS program focus of this position while remaining active in other bureau assigned operation duties. To handle the additional UAS missions and program requirements the NHDOT has secured the approval to hire one new UAS specialist in the near term to assist with the UAS operations and other shared duties.

UAS Mission Coordinator

Any bureau, consultant, vendor, or third-party contractor wishing to deploy UAS technology in support of NHDOT's endeavors will coordinate through a UAS Mission Coordinator within the Bureau of Aeronautics. The UAS Mission Coordinator would typically be the UAS Program Manager, but can also be the UAS Specialist, or it can be another individual within the Bureau of Aeronautics who helps coordinate UAS operations to meet the data collection needs of that specific request. The UAS Mission Coordinator does not need to be an FAA-certified UAS operator, but at minimum, he or she must be familiar with any established NHDOT rules regarding accessing facilities, any policies regarding UAS deployment, and any safety regulations relevant to the mission. If not the UAS Program Manager, the UAS Mission Coordinator will report to the UAS Program Manager.

The UAS Mission Coordinator is responsible for evaluating all requests to deploy UAS for NHDOT endeavors and for developing proper documentation regarding the mission, including the pre-flight planning package and post-flight report. The UAS Mission Coordinator will have the ability to approve or deny the UAS mission requests based on NHDOT policy and FAA requirements.

UAS Operating Crew

Under most circumstances, the UAS flight crew should consist of at least a pilot and a visual observer, and it is recommended that safety personnel also participate. Additional personnel depend on the scale and complexity of UAS flight operations. The UAS Operating Crew reports to the UAS Mission Coordinator.

UAS Operating Crew: Pilot-in-Command (PIC)

The primary authority for any mission is the PIC. The PIC is responsible for meeting all regulatory requirements are met; adhering to the security plan and any existing safety standards; making sure crew members are aware of their individual responsibilities; and conducting pre-flight, pre-landing, and post-flight checks. Once flights are completed, the PIC conducts an on-site debrief with all members of crew to review flight operations and verify all information for the activity log has been documented.

- The PIC must be Part 107 Certified, with recertification within the past 24 months. At a minimum, the PIC is responsible for:
- Maintaining up-to-date certification.
- Demonstrate currency of training by providing proof of completion to the UAS Mission Coordinator of a related UAS mission within no more than 90 days prior to the proposed mission date.
- Ensuring the UAS is registered.
- Providing the necessary equipment, including for communication and safe battery storage.
- Executing a flight plan, including approvals from all bodies governing the flight.

- Overseeing all necessary crew members and support.
- Obtaining permission to access site.
- Ensuring they are familiar with all New Hampshire state rules and statutes governing use of UAS, FAA regulations, and all relevant NHDOT UAS policies and safety regulations.

For complex missions, pilots may be asked to demonstrate proficiency with certain UAS maneuvers to the UAS Mission Coordinator before flight operation.

UAS Operating Crew: Secondary Pilot-in-Command

Requirements for the Secondary Pilot-in-Command (SRPIC) are the same as for the PIC. The SRPIC may be helpful in complex or emergency response situations when the operation merits the need for a SRPIC who must be prepared to take over command of the flight if needed. It is possible that initially this is not a full-time position with the Bureau of Aeronautics but could be filled as needed by an embedded PIC within another NHDOT bureau.

UAS Operating Crew: Visual Observer

A Visual Observer's primary duty is communication with other UAS Operating Crew members and property owners, as well as identifying anything that may affect the PIC's primary duty (see and avoid obstacles while completing the UAS mission).

Visual Observers are not required to be Aeronautics staff, however, must be provided with sufficient training to assist the PIC in maintaining visual line of sight to help avoid obstacles or conflicting traffic. An observer need not be FAA Part 107 certified but must have received training on rules and responsibilities described in 14 Code of Federal Regulations (CFR) 91.111, Operating Near Other Aircraft; 14 CFR 91.13, Right-of-Way Rules, cloud clearance, in-flight visibility; and the pilot controller glossary including standard air traffic control (ATC) phraseology and communication. Additionally, 14 CFR 91.17, Alcohol or Drugs, applies to UAS observers.

The Visual Observer's duties include:

- Observes the airspace for other aircraft or hazards.
- Maintains effective communications with the PIC at all times.
- Communicates with non-UAS Operating Crew regarding the mission at hand.

UAS Operating Crew: Safety Personnel

The UAS Program Manager and operation PIC may assign safety personnel for complex missions. In most cases, safety personnel will be NHDOT staff who are present to enforce safety rules and regulations. Individuals should be familiar with the site or facility, and with the risk mitigation plan (including strategies for each identified risk and a detailed security plan for the specific UAS flight operations). These positions could be filled as needed by NHDOT staff from within the Bureau of Aeronautics or another NHDOT Bureau.

UAS Operating Crew: Technical Expert

Technical Experts have a demonstrated level of experience with remote sensing technology, such as surveying, photogrammetry, structure for motion, LiDAR, or geospatial principles related to in-flight data acquisition as well as knowledge related to the specific use case, including data processing platforms and software, and basic understanding of photography for aperture, shutter speed, and ISO. Additionally, Technical Experts understand video and two-dimensional software packages or image processing algorithms, software that addresses poor illumination, and/or knowledge of reading and interpreting data. If NHDOT proceeds with having UAS pilots embedded within the various bureaus, then the PIC and Technical Expert may be the same individual.

UAS Operating Crew: Training Specialist

Provide initial and recurrent training using study resources, online resources, simulator training, and hands-on training to all PICs within NHDOT. Provides initial and recurrent training using study resources, online resources, and hands-on training for UAS VOs and Safety Personnel. Responsible for ensuring continuous training on federal laws and regulations and NHDOT policies regarding the safe operation of UAS. Responsible for providing appropriate documentation on the UAS Operating Crew's training status in reports to the UAS Program Manager. This duty will be fulfilled by the UAS Specialist within the Bureau of Aeronautics or be a shared duty with UAS Program Manager until the need arises to have a standalone UAS Training Specialist.

2.5 UAS Services: In-house Versus Outsourcing

In-house UAS services tend to be more cost-effective than third-party service providers, especially if the UAS is deployed to support routine activities. The ROI for in-house UAS services increases as routine use increases, quickly recouping the initial up-front costs for training and technology.

For specialized inspections, the complexity of the operation may require procurement of third-party services (piloting experience or processing knowledge or technology) that are unavailable inside the agency. Additionally, when multiple UAS missions must be accomplished with tight timeframes or when in-house staffing resources cannot accommodate the added workload, having a third-party provide UAS services leads to success for the entire UAS program. When considering an in-house program vs. outsourcing to third-party contractors, it is important to note that both models have been effective at a range of transportation agencies, with many agencies opting for a blended model (in-house operations augmented by third-party support for high-complexity missions).

Regardless of the source of the UAS data, NHDOT projects would normally need to pay for these services from ground survey, aerial photogrammetry, or third-party UAS organizations. If procured internally at NHDOT, the project would pay for NHDOT employees' time to produce this data; if procured from a third-party, the project would pay for the firms' services to provide this data. The Bureau of Aeronautics has only recently begun charging NHDOT projects for the labor needed to provide the requested UAS data. No charges back to the project have been made for use of the UAS equipment, vehicle mileage, or other overhead costs (e.g., software costs, utilities, office supplies, computer storage drives). As the Bureau of Aeronautics begins to track these costs as compared to traditional data collection/processing methods, it can gain a better understanding of what is the actual cost for internally supplied UAS services so that its customers can make sound financial decisions regarding their projects' data. It is recommended that the Bureau of Aeronautics charge labor, expenses, and overhead for the UAS services it provides so that it can offset the need for other revenue sources needed to make the UAS program self-sustaining well into the future.

2.6 UAS Training Opportunities

Regardless of whether specialized UAS services are outsourced or not, it is important to build capacity and core competency inside the agency. At a minimum, building knowledge and workforce skills around UAS technology will support staff during their scoping for UAS services. To harness the full benefits of UAS technology and safely and efficiently integrate UAS into their workflows, offering a dedicated UAS training program at a State DOT is of paramount importance. These training programs can be internal, external, or a combination of both; both options are outlined within this section.

2.6.1 Internal UAS Training Program

An internal UAS training program is one that would be developed and conducted by NHDOT. This approach offers several advantages:

1. Tailored to Specific Needs: An internal program can be customized to suit the unique requirements and challenges faced by NHDOT. It can focus on specific applications like bridge inspections, traffic monitoring, or disaster response, and be directly aligned with NHDOT's goals.
2. Cost Management: Over time, investing in an in-house training program can be more cost-effective than relying on external trainers. Once the initial setup is done, NHDOT can conduct multiple training sessions without incurring additional expenses.
3. Institutional Knowledge: Internal training fosters a deeper understanding of UAS operations within the organization. The trainers have an intimate understanding of NHDOT's infrastructure, policies, and procedures, ensuring a seamless integration of UAS into existing processes.

Challenges to consider with an internal training program include:

1. Expertise and Resources: Developing an effective UAS training program requires subject matter experts (SMEs), resources, and time. NHDOT would need to provide the time and resources necessary to the UAS Program Manager and UAS Training Specialist to develop the program and to provide comprehensive training.
2. Regulatory Compliance: Keeping up with rapidly evolving UAS regulations and best practices is critical. NHDOT must invest in continuous education and updates for its internal trainers to remain current with new regulations and ensure safety.

If NHDOT does proceed with the development of an internal training program, then consideration should be given to the current language regarding training in the Draft UAS Policies and Procedures document in Section 4.0 of this report. The following three courses are currently included in the draft copy of this governance document:

> *Basic Operator Course:* This course teaches basic operator skills, mission planning, and emergency procedures. The Basic Operator Course for multi-rotor is very different than the fixed-wing. Completing one does not certify the operator for the other.
>
> *Advanced Operator Course:* This course is mission focused and requires that the Air Crew Member be qualified and proficient with the systems that will be used for the mission type. These qualifications will be determined by passing an oral and/or flight review evaluation. There are many types of Advanced Operator Courses. They may include land survey & road construction, bridge & sign inspections, disaster response and many others. The Advanced Operator Course will cover detailed mission planning, flight operations, and data processing if applicable.
>
> *Refresher Training*: This is required if the operator has not flown the system or similar system in the last six months. Refresher training can consist of:
>
> - Simple oral review covering the system operating procedures and emergency procedures.

- An oral and basic flight review.
- A complete Annual Proficiency and Readiness Test evaluation.
- Additional training.
- All flight training and evaluations will be conducted by the UAS Training Specialist.
- All training will be documented in the operator's flight and training file.

2.6.2 External UAS Training Program

NHDOT can also choose to contract with a third-party organization that specializes in UAS training or with a university that offers UAS courses and training. This approach offers distinct advantages:

1. Industry Expertise: External providers are likely to have extensive experience and knowledge in UAS operations. They keep abreast of the latest developments, regulations, and best practices, ensuring that NHDOT staff receive the most up-to-date training.
2. Time Efficiency: Relying on a third-party for training can expedite the process. NHDOT could quickly get its personnel trained and operational without dedicating substantial time and resources to development of an internal training program.
3. Objective Perspective: External trainers can bring fresh perspectives and innovative ideas, broadening NHDOT's understanding of UAS applications and potential benefits.

Potential drawbacks to an external UAS training program include:

4. Cost Considerations: Contracting with a third-party may involve higher initial costs, depending on the scale and duration of the training. This might become less cost-effective in the long run compared to developing an internal program.
5. Tailoring Challenges: External trainers might not fully understand the specific needs and requirements for NHDOT personnel. Some customizations may be necessary to align the training with NHDOT's goals and operations.

A dedicated UAS training program is indispensable for a State DOT to harness the potential of UAS technology, safely and effectively. Both internal or external training approaches have their merits and drawbacks, but with either option, there should be a dedicated UAS Training Manager. Training can be a shared duty with the UAS Program Manager initially but eventually is likely to need to be its own position. The new UAS Data Processing Technician/Training Specialist position for which NHDOT has approved funding could be a good fit as part of the duties and job requirements for this position, including UAS Training Specialist responsibilities.

If NHDOT chooses to do an internal training program, the UAS Program Manager and UAS Training Specialist can work closely together to design, develop, and deliver the UAS training to NHDOT personnel. If NHDOT elects to use an external training program, the UAS Training Specialist will still be responsible for tracking training records, certification status, and currency for all NHDOT UAS pilots. This individual can also assist the UAS Program Manager in maintaining a program and associated training that is up-to-date with regulations and industry best practices.

In addition to baseline Part 107 trainings, additional course modules focused on specific knowledge areas and specialized skills for specific, high-complexity use cases is recommended. Knowledge areas would include specific areas of aviation competencies, including applicable regulations, airspace, weather information sources and related effects on UAS operations, UAS loading, emergency procedures, flight crew resource management, radio communications procedures, UAS performance, physiological/human factors, aeronautical decision-making and judgment, airport operations, and aircraft maintenance and inspections. Beyond these minimum competencies, subject matter expertise in relevant transportation operations is important so that the collected data are contextually accurate for decision-making.

These additional training courses should also include practical skill training by providing hands-on flying opportunities. While Part 107 courses covers the essential knowledge for individuals to pass the FAA knowledge exam, it does not provide actual flying experience. Hands-on UAS training bridges this gap by providing personnel with supervised flight practice, allowing them to master flight maneuvers, emergency procedures, and obstacle avoidance. This experiential learning enhances a pilot's ability to handle unforeseen situations, thereby increasing safety and reducing the risk of accidents. Additionally, hands-on training fosters a deeper understanding of the capabilities and limitations of different UAS platforms and enables operators to optimize their flight missions effectively. Overall, incorporating hands-on UAS training into the learning process is fundamental in producing proficient and responsible UAS pilots to meet NHDOT's data collection needs. Alternatively, it may be appropriate in some circumstances to augment the hand-on training with UAS simulator training as a way to stay proficient operating a UAS.

A final recommendation related to training is regarding the payment for the FAA UAS knowledge exam and other associated trainings. During the workshop held in conjunction with this project, NHDOT leadership expressed concerns about paying for the $175 Part 107 exam fee. Integrating UAS technology into NHDOT operations will require an initial cost associated with training, and it is recommended that NHDOT covers these costs rather than requiring it of their staff as these costs will assist in maturing the internal UAS capabilities of NHDOT. To avoid large groups of people signing up for free training and certification, the UAS Program Manager can work with leadership throughout NHDOT to identify individuals who would be required to use UAS or who show a genuine interest in implementing the technology in their workflows. These costs are an investment in the program and in demonstrate the value each trainee has within NHDOT. These costs will be recouped through the repeated use of UAS rather than conventional workflows to increase cost savings, efficiencies, and safety.

2.7 UAS Technology Selection and Procurement

Acquisition of UAS technology should be driven by the data products and outputs required by the mission for which the UAS is being used. This is in part because UAS technology ranges significantly in operability and pricing depending on the performance specifications required (e.g., length of flight or types of additional cameras and sensors needed for data collection). Once the data products are identified, it becomes relatively easy to choose an appropriate sensor and platform that can deliver the data at the required accuracy.

As an example, UAS equipped with certain Laser Imaging, Detection, and Ranging (LiDAR) sensors are potentially cost prohibitive if purchased outright by the agency and used only a single time. While LiDAR is not necessarily required for a basic application like community engagement, it may be relevant for additional, more complex use cases like surveying and mapping. The more expensive and specialized the equipment, the more appropriate it is to consider the frequency of use along with (1) leasing the technology, or (2) procuring third-party contracted services to complete these specialized missions.

For the purposes of NHDOT's in-house UAS program, robust professional-grade UAS systems that provide utility across multiple use cases have been procured since 2019, and NHDOT now owns five different UAS platforms with ranging capabilities. These initial systems will allow for downstream purchase of additional, specialized sensor technologies and cameras as needed, once NHDOT has increased its in-house UAS operator capabilities. A consideration for the existing fleet and as the fleet grows is to have adequate storage capacity for the UAS platforms and their associated batteries. A safe, secure, and fire conscious location should be dedicated to the storage of UAS equipment and charging of batteries.

Software plays a crucial role in managing various stages of a UAS mission including flight planning and control, data collection, and post-flight data processing. The widespread adoption of UAS across several industrial sectors has led to the creation of different types of software solutions to meet the needs of customers and the specific requirements of applications.

2.8 Data Processing, Data Storage, and Data Management

To allow for the most efficient use of resources, UAS data should be centralized, indexed, and made available across the agency. Any protocols or procedures related to backend storage or processing of data should be overseen by NHDOT or the State's Information Technology Services division's data governance and data management protocols.

Currently UAS data reside on NHDOT's central server, which all NHDOT bureaus can access. The total UAS data storage need currently is about 1.4 terabytes but will quickly continue to grow as more bureaus request UAS services from the Bureau of Aeronautics. The dominant limitations of software or computers are processing power and data storage. UAS data (imagery, video, and point data) are resource-intensive given the size of the dataset(s). A single UAS flight can generate several gigabytes of data, so sustainable solutions for data processing and storage are critical to the success of NHDOT's UAS program. There are many reliable and secure solutions available for managing UAS data using cloud computing or on-premises servers. UAS data management should align with agency data governance policies and practices, but there are significant benefits of using a combination of storage solutions. On-premises data storage improves data accessibility and exchange behind the firewall. However, sharing data/products that require limited resources (e.g., processors, bandwidth) is best done through cloud-based platforms. The UAS Program Manager should work closely with NHDOT's Information Technology Services division to define current capacities and outline a robust data management plan to use as the amount of data increases.

Processing the UAS-collected data was identified as a key concern throughout the research efforts of this project. The UAS Planner is currently the only certified UAS pilot in the Bureau of Aeronautics, and he has been fulfilling a growing number of UAS flight requests across various bureaus and has not had sufficient time to process the data being collected. Ideally, the bureaus requesting the UAS data would have the necessary expertise and equipment to process the data in the way that they can best use it. Currently, this expertise and these resources appear to be lacking in the individual bureaus—many of the interviewees in Task 1b of this project expressed the desire to rely on the Bureau of Aeronautics and UAS program to collect and process the data. It is recommended that the Bureau of Aeronautics properly leverage the newly approved and funded UAS Specialist position to attract participants who have strong data processing experience and the skills needed to process the UAS-collected data on behalf of the requesting bureaus.

2.9 UAS Mission Planning and Deployment

Table 3 depicts the three phases of UAS deployment: pre-flight planning, flight operations, and post-processing. The following sections detail some of the key activities that occur during these three primary phases of UAS operations.

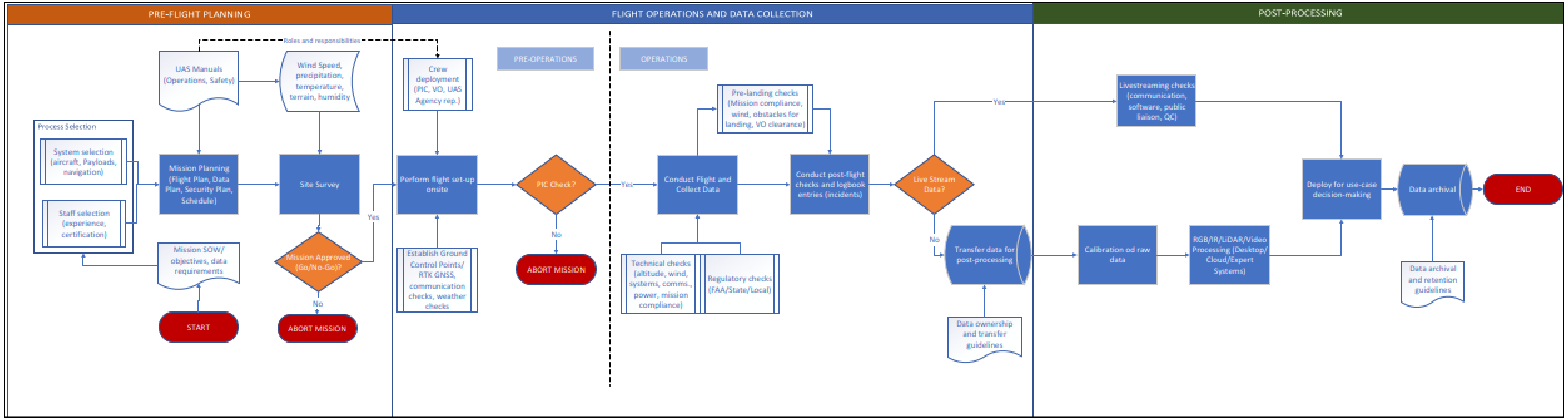


Figure 3. UAS Mission and Flight Planning Phases

2.10 UAS Applications – Project Prioritization

As part of the short-term phase of the roadmap, NHDOT should build on its various test flights and initial current uses of UAS and begin integrating UAS more fully into the previously identified use cases. This integration should be a phased approach, starting with the higher priority use cases. NHDOT should focus on the top two or three use cases during the short and medium-term phases of the roadmap in conjunction with the other items to mature the UAS program will still providing good customer service. This approach will enable a natural evolution of UAS adoption into the remaining use cases during the latter half of the medium-term phase and throughout the long-term phase. Table 2 lists the identified use cases in order of priority and identifies high-level capabilities and anticipated benefits.

Table 2. UAS Capabilities and Benefits for the Prioritized Use Cases.

Use Case	Capabilities	Anticipated Benefits
Surveying and Mapping	High-resolution imagery and video of project sites/corridors enable immersive conceptual renderings that improve project awareness and oversight. UAS can provide survey-grade data in the form of three-dimensional (3D) point clouds to supplement or verify existing surveying.	Produces quality and accurate data in a more time efficient and safe manner. Reduction in rework and increase in cost savings.
Construction Monitoring	Calculating volumes from UAS imagery, documenting pre-project conditions to make data-driven decisions regarding the project bid, automating and improving progress reports, construction traffic control and thermal applications for paving projects.	High-resolution imagery is processed into surface models that can quickly produce accurate volumes and locations of material. Provides real-time information, enabling data-driven decisions that result in on-time delivery and costs savings over traditional construction monitoring.
Structures Inspection	Inspectors may use UAS as part of their toolbox to remain clear of dangerous situations, identify defects, identify delamination's, avoid lane closures, and collect data more efficiently. UAS can also assist with rapid bridge damage assessment in the cases of a bridge strike or other emergency damage assessment.	High-resolution imagery and video can provide accurate condition awareness and increase efficiency, safety, and cost savings.
Traffic Operations and Incident Management	Snapshot traffic counts for peak and trough hours can be collected, as well as post-construction traffic flows. Traffic camera infrastructure inspections and camera sight-line analysis. Traffic accidents can be mapped and photographed quickly to produce event simulations.	Increased use of internal UAS capabilities rather than historical use of consultants. Decrease in delay time and cost after effective integration of UAS in incident response.
Emergency Response	Initial emergency evaluation and situational awareness data can be collected in real time. Search and rescue can be accomplished more effectively and more efficiently than conventional aircraft. Quick comparisons of before and after photos of transportation assets can be rendered via UAS data.	Better offering of internal NHDOT resources to support multi-agency response to emergencies. Increased situational awareness and efficiency in meeting the needs of emergencies.

Use Case	Capabilities	Anticipated Benefits
Asset Maintenance and Operations	UAS can provide higher resolution imagery of 1-inch ground sampling distance or less of transportation assets. UAS can also be used to scan RFID tags on assets and perform condition assessments.	Better data that can be collected in a cost-effective manner more frequently than the current rate of every five years.

2.10.1 Surveying and Mapping

Using UAS for surveying and mapping, specifically to gather existing topographic information for design purposes, is an optimal initial use case to build NHDOT's in-house UAS capabilities. It is ranked as the first use case to focus on for UAS adoption because the NHDOT Chief of Survey and Mapping is open and receptive to adding UAS as a tool. The UAS Planner has worked closely with surveying and mapping personnel on test survey projects using UAS. By focusing on surveying projects, the UAS Planner has helped to solidify UAS workflow integration, which will create synergies as the repeated success grows and pave the way for expanding into additional use cases for UAS such as construction progress, site monitoring, airport inspections, quantities measurement, and work zone planning. Moreover, NHDOT has a robust, long-term pipeline of projects at different stages of project delivery and procurement, which indicates potential for high ROI to the agency over time.

UAS Technology Recommendations for Surveying and Mapping

Outlined below are some options for UAS platforms and sensors that can meet the needs of surveying and mapping projects. Please note that UAS technology, including platforms and sensors, is continually evolving, and the considerations below are only a sampling of what is available at the time of this report. State DOTs can work with UAS manufacturers to secure a trial period of these platforms and sensors to ensure the technology will meet the agency's needs. These trial periods are highly recommended.

Aircraft: DJI M300, Skyfish M4, Freefly Astro Map, Freefly Alta X, WingtraOne

Sensors:

DJI M300

L1 LiDAR sensor (LiDAR workflow)

- Detection Range: 450 m at 80 percent reflectivity, 190 m at 10 percent reflectivity.
- Point Rate: Single return: 240,000 points per second; multiple return: 480,000 points per second.
- Accuracy Horizontal 10 cm, vertical 5 cm at 50 m.

P1 Sensor (Photogrammetry/Structure for Motion Workflow)

- 45 megapixel full-frame sensor with three lens options (24/35/50 mm) for optimal mapping solutions.
- Adjustable gimbal to capture data at multiple angles to accommodate detailed collection of 3D features.

Skyfish M4

Sensor agnostic with real-time kinematic (RTK) capability, which can use multiple sensors including LiDAR, high-resolution red, green, blue (RGB) camera. The Skyfish M4 can accommodate a sensor up to 6 lbs to accommodate a maximum gross weight of 24 lbs, which will allow for an array of light weight LiDAR, RGB, thermal, or multispectral sensors.

Freefly Astro Map

RTK Global Positioning System ground station to support RTK and post-processing kinematic (PPK) collection to improve accuracy and reduce ground control points.

Sony Alpha 7R IVA.

Freefly Alta X

The Alta X can carry up to 17 lbs to accommodate multiple sensors with a typical flight time of 41 minutes, which varies depended on weight carried.

Truview 655 with Riegl Mini-Vux (LiDAR Workflow).

Sony IMX-183 (Photogrammetry/Structure for Motion Workflow).

Wingtra One GenII

Sensor agnostic: The Wingtra One GenII is designed to be compatible with various sensors, including the Sony RX1 RGB camera, which is ideal for aerial imagery and mapping collection.

Sony RX1 RGB Camera.

- Camera Resolution: The Sony RX1R II RGB camera has a full-frame sensor with a resolution of 42 megapixels.
- RTK Capability: The Wingtra One GenII sensor has RTK capability that provides precise positioning and accurate data collection.
- Weight Capacity: The Wingtra One GenII can accommodate a sensor weighing up to 6 lbs, allowing for the integration of the Sony RX1 RGB camera.
- Maximum Gross Weight: The Wingtra One GenII has a maximum gross weight limit of 24 lbs, ensuring it can handle the weight of the Sony RX1 RGB camera along with other lightweight sensors if desired.
- Versatile Sensor Support: In addition to the Sony RX1 RGB camera, the Wingtra One GenII can also support other sensor options, such as LiDAR, thermal, or multispectral sensors.
- High-Resolution Imaging: With the Sony RX1 RGB camera, the Wingtra One GenII can capture high-resolution imagery for detailed aerial mapping and inspection applications.
- Integration: The Wingtra One GenII seamlessly integrates with the Sony RX1 RGB camera, enabling efficient data acquisition and post-processing for various industries and applications.

PPK or RTK Onboard

These models are specifically designed for mapping and surveying applications. They offer high-precision RGB and/or LiDAR sensors and advanced flight planning software, ensuring accurate data collection for detailed land surveys and topographic mapping.

Anticipated Challenges and Solutions

Two main concerns for UAS integration into this use case emerged during the data collection period of this project. One was a concern about whether UAS-collected data can achieve the accuracy needed to meet NHDOT requirements. The second concern was if the current lack of time, resources, and expertise needed for data analysis prohibit its use in a meaningful way.

The first concern was largely addressed in discussions regarding UAS technology and their capabilities with the Chief of Survey and Mapping. UAS sensors can provide the necessary accuracy to provide survey-grade data. The second concern was addressed above in the Data Processing, Data Storage, and Data Management section and the discussion about the responsibilities for the new UAS Data Processing Technician/Training Specialist position. If the Bureau of Aeronautics can hire an individual with the data processing knowledge and skills required to meet this need, then the UAS program would be better prepared to meet the requests of the various bureaus for data collection, data processing, and delivery.

Anticipated Benefits

The use of UAS at a State DOT for surveying and mapping purposes is expected to bring numerous benefits. UAS can significantly enhance the efficiency and accuracy of surveying and mapping operations. Equipped with high-resolution cameras and LiDAR sensors, UAS can capture detailed aerial imagery and topographic data of large areas in a fraction of the time it would take traditional surveying methods. This allows the State DOT to quickly gather comprehensive data for infrastructure planning, maintenance, and construction projects. The precise and up-to-date information obtained through UAS can aid in detecting potential issues, optimizing designs, and making informed decisions, leading to improved project outcomes, reduced rework, and cost savings.

In addition, using UAS for surveying and mapping can enhance worker safety and reduce risks associated with traditional surveying methods. Surveying often involves working in hazardous environments such as busy roadways, steep slopes, or remote areas. By deploying UAS, the State DOT can eliminate or minimize the need for personnel to physically access these dangerous locations, mitigating potential accidents and injuries. UAS also offer the advantage of being able to access hard-to-reach or inaccessible areas, such as bridges, tunnels, or rugged terrains without the need for extensive manual labor or specialized equipment. This not only improves safety but also reduces project timelines and costs by streamlining field operations and minimizing the impact on traffic flow or public disruptions.

2.10.2 Construction Monitoring

Construction monitoring is listed as the second use case on which to focus because, similar to the surveying team, the NHDOT Bureau of Construction is familiar with UAS and is open to using UAS more frequently. NHDOT construction projects began using UAS about six years ago when consultants and contractors started integrating them into projects. UAS have primarily been used for photogrammetry to create detailed maps, generate point clouds, and obtain accurate measurements of construction sites. Internal use of UAS with the Bureau of Aeronautics has been more limited. A few projects have been flown, but the Bureau of Construction would like to increase internal use of UAS rather than relying on consultants. This is a prime opportunity for the UAS program to grow its internal capabilities and serve the needs within this use case. The younger personnel within the Bureau of Construction are open and eager to adopting innovative technologies, which could provide an opportunity for UAS pilots to be embedded within a bureau that is not the Bureau of Aeronautics.

UAS Technology Recommendations for Construction Monitoring

Outlined below are some UAS platform and sensor options that can meet the needs of construction monitoring use cases.

Aircraft: Matrice 300 with H20T, or L1 LiDAR, Freefly Astro Map, Wingtra One GenII, Autel Evo II

Sensors:

Matrice 300

- H20T
    - RGB Camera: The 20-megapixel camera captures high-resolution images for detailed visual inspection and documentation purposes.
    - Thermal Camera: The thermal camera, using radiometric technology, detects temperature differences and provides thermal imagery. This enables the identification of potential issues such as heat leaks, insulation problems, or water infiltration.
    - Laser Rangefinder: The integrated laser rangefinder measures distances accurately to facilitate precise measurements for construction quantities, land surveying, and other applications.
    - Zoom Camera: The H20T payload includes a 23x hybrid optical zoom camera that allows inspectors to capture detailed images from a distance, providing a closer look at specific areas of interest.
    - Spotlight: The spotlight function enhances visibility in low-light conditions by focusing a high-intensity light beam on the targeted area to aid inspections during nighttime or in poorly lit environments.
- L1 LiDAR
    - Detailed 3D Mapping: The DJI L1 LiDAR can create highly accurate and detailed 3D maps of construction sites. These maps help inspectors identify potential issues, monitor progress, and analyze the as-built conditions against digital models. By capturing precise measurements and identifying deformations or deviations, inspectors can assess the safety and quality of construction projects.
    - Accurate Point Cloud Generation: The LiDAR sensor in the DJI L1 captures millions of points per second, creating a highly dense and accurate point cloud representation of the surveyed area. This point cloud can be used to measure distances, volumes, and surface areas, assisting in quantity estimations and earthwork calculations.
    - Height and Elevation Measurements: The L1 LiDAR can provide precise measurements of heights and elevations, helping construction professionals determine clearance requirements, assess slopes, and ensure proper grading.

Freefly Astro Map

- Sony Alpha 7R IVA
    - Sony Alpha 7R IVA Camera: The Sony Alpha 7R IVA is a full-frame mirrorless camera known for its high-resolution capabilities. With its 61-megapixel resolution, it captures incredibly detailed still images, ensuring precise inspection and documentation of construction sites.
    - Oblique and Overhead Imagery: The versatile camera allows for oblique and overhead imaging, providing comprehensive coverage of construction sites from different angles. This enables inspectors to view and analyze structures and areas that may be inaccessible on foot.
    - Photogrammetry Capabilities: The high-resolution imagery captured by the Sony Alpha 7R IVA can be processed using photogrammetry software. By leveraging the camera's images, the Astro Map system can generate accurate 3D models, point clouds, and orthomosaic maps. These outputs can be used for measuring distances, volumes, and areas, facilitating quantity estimations and earthwork calculations.

Wingtra One GenII (suited for larger construction sites)

- The Wingtra One GenII, equipped with a Sony RX1 camera, is an advanced hybrid eVTOL fixed-wing UAS solution designed for larger sites and can be used for construction inspections, quantities, and measurements. The platform requires a larger vehicle to carry the UAS due to its larger case.
- Sony RX1 Camera: The Sony RX1 is a professional-grade camera known for its high-resolution imaging capabilities. It captures detailed images with its 42.4-megapixel full-frame sensor, ensuring precise inspection and documentation of construction sites.
- Global Navigation Satellite System (GNSS): The Wingtra One GenII integrates GNSS receivers for accurate positioning and geolocation. This allows for precise alignment of the captured imagery and enables seamless integration with existing mapping and surveying workflows.

Autel Evo II

- The Autel Evo II has the capability of using multiple interchangeable sensors (e.g., thermal, RGB).
- The RGB sensor consists of a 0.5-inch Complementary Metal-Oxide Semiconductor (CMOS) sensor capable of 48 megapixels to obtain high-resolution imaging.
- The thermal sensor options include an InfiRay 640 x 512 radiometric thermal or FLIR Boson 640 x 512 radiometric thermal.

For roadway construction inspections and quantities, the Matrice 300 with H20T payload offers a comprehensive solution. It combines a versatile and rugged UAS platform with a high-resolution camera, thermal imaging, zoom capabilities, and a laser rangefinder. This combination allows for visual inspections, thermal analysis, precise measurements, and volumetric calculations. Alternatively, the L1 LiDAR system provides accurate 3D mapping, point cloud generation, and distance/volume measurements, making it ideal for detailed analysis of construction sites. The Freefly Astro Map with Sony RX1 excels in capturing high-resolution imagery and generating detailed maps through photogrammetry. Finally, the Wingtra One GenII offers a large coverage area, high-resolution imaging, and photogrammetry capabilities, making it suitable for extensive roadway inspections and accurate measurements. The choice depends on factors such as budget, specific requirements, and integration with existing workflows. These models are designed for efficient and accurate aerial surveys that can be used for construction inspections and quantities. They can also serve to monitor and document progress throughout the project. Furthermore, UAS may also be used as a supplemental tool for material quantity monitoring and inventory management. A smaller platform (e.g., an Autel Evo II) may be used if there are space limitations.

Current UAS Opportunities

During the interviews conducted as part of Task 1b of this project, interviewees noted that the State of New Hampshire as a whole is entering a savings and preservation mode, rather than a spending and building mode. Currently many of the construction projects are focused on restriping, and interviewees discussed how internal use of UAS on these projects during the prestriping planning phase could be beneficial. UAS could assist in providing high-resolution imagery to document current conditions and assess necessary changes before putting projects out for bids.

Other potential opportunities for using UAS in construction were discussed such as assisting in the production of project weekly or quarterly reports, progress photos, quantity calculations, thermal sensor applications, construction traffic control, and providing completed project data for as-builts that can be used throughout the asset management life cycle. However, interviewees noted the need to overcome challenges related to project size, workforce experience, data management, workflow integration, and public perception to fully leverage the advantages of UAS technology in construction projects.

A UAS Program Manager and the new UAS Specialist position, if hired with data processing capabilities, could support the Bureau of Construction, and overcome these identified challenges.

Anticipated Benefits

Interviewees mentioned numerous anticipated benefits of using UAS for construction monitoring at NHDOT. UAS may enhance the efficiency and accuracy of construction monitoring activities. UAS are equipped with high-resolution cameras and sensors, allowing them to capture detailed images, videos, and data of construction sites from various angles and altitudes. These comprehensive visual data can be used for monitoring the progress of construction projects, identifying potential issues or delays, and assessing compliance with safety and environmental regulations. UAS can be used in quantity estimations of materials on construction project sites; the UAS-collected data can then be used to check contractor invoicing and other documentation. By providing real-time and up-to-date information, UAS enable project managers to make informed decisions promptly, leading to improved project management and cost control.

In addition, UAS may offer significant cost and time savings compared to traditional monitoring methods. In the past, construction monitoring relied on manual inspections by personnel on the ground or expensive aerial surveys using helicopters or planes. These methods often require significant time and resources, as well as increased safety risks. UAS, on the other hand, can rapidly collect data over large areas in a fraction of the time and at a fraction of the cost. They can quickly survey extensive stretches of highways, bridges, or other infrastructure projects, providing a holistic view of the construction progress. For materials testing, UAS may be used to monitor and evaluate materials in real time. For example, UAS equipped with multispectral or hyperspectral cameras can capture high-resolution imagery to assess the condition and quality of road surfaces and identify cracks, potholes, or areas requiring maintenance. UAS can also monitor erosion, vegetation encroachment, or soil stability in geotechnical applications, providing valuable data for infrastructure planning and maintenance. Additionally, UAS may offer the advantage of accessing hard-to-reach or hazardous areas that may be difficult or dangerous for inspectors or technicians to reach. By using UAS, personnel can inspect materials in remote locations, at great heights, or over water bodies without putting themselves at risk. This accessibility improves the efficiency of inspections, reduces costs, and minimizes disruptions to traffic or operations. Third-party software providers are available that allow construction crews to make notes in UAS-created progress reports, which allows pins to be placed directly on photos or 3D models of the project that then open to detailed notes regarding areas of concern or progress in general. This accelerated data collection process not only reduces labor costs but also minimizes the disruption caused to ongoing construction activities. Overall, the utilization of UAS for construction monitoring leads to improved efficiency, cost-effectiveness, and safety in infrastructure development.

2.10.3 Structural Inspection

Although UAS can be used on a variety of structures (bridges, culverts, guard rail, retaining walls, overhead signage), for the purposes of this use case, this section is focused on bridge inspections. Bridge inspection plays a key role in ensuring public safety and confidence in bridge structural capacity and integrity to effectively perform maintenance and rehabilitation operations. Legislatively, bridge inspection needs to comply with federal standards to receive federal funding for bridge rehabilitation and replacement. Some agencies have established more detailed guidelines for short-term, periodic inspections, including hands-on bridge inspection processes, close-up reviews, and collecting quantitative bridge data.

Currently, the NHDOT bridge inspection approach involves sending inspectors close to the bridges to measure cracks and other damage. However, there are bridges that are difficult to reach, making UAS potentially helpful in such cases. Ninety percent of the inspection schedule for NHDOT bridges follows a 24-month cycle, with more frequent inspections for bridges in poor condition or those on the red list (NH's red-list bridges are in poor condition and in need of immediate improvements). The team focuses solely on bridges that interface with the highway system and reports challenges when inspecting bridges over railroads because of the need to coordinate with the railroad and schedule railroad flaggers.

The NHDOT bridge inspection team currently employs a snooper truck for under-bridge inspections and consults climbers for specific bridges that require detailed inspections. In the case of a bridge strike, the bridge maintenance team and bridge inspection team work together and determine who should assess the situation based on various factors. Unfortunately, bridge hits occur more frequently than desired, particularly on covered bridges.

Visual inspections are primarily conducted to assess bridge deck lamination, with additional sounding as needed. The bridge team consists of a central engineering team and four inspection teams spread throughout the state; team members live in the areas they inspect. The data collected by the inspection teams are stored locally on laptops for a few days to a couple of weeks before being transferred to the central office.

Staff managing the bridge inspectors are interested in UAS for data clarity and reliable access. Seasoned inspectors are not always enthusiastic about learning new technology; however, the inspection teams recently transitioned from point-and-shoot cameras to iPhones for capturing inspection photos. These photos are stored in folders and processed using specialized software to create reports. Inspectors make notes in the photo captions, associating them with specific bridge inspections.

Although the current NHDOT bridge inspectors have been historically hesitant to adopt technology, bridge inspections using UAS has been identified as the third priority because of the tremendous success of other State DOTs and high adoption rates of UAS in this use case. Seventy-five percent of all State DOTs have adopted UAS for structural inspections. Michigan DOT has reported up to a 74 percent increase in savings on single bridge inspections, while Minnesota DOT reported a 40 percent savings across its entire bridge inspection program with UAS adoption. There is significant potential for the UAS Program Manager to begin working with the NHDOT bridge inspection team—initially UAS technology is likely an enhancement to the inspection process (i.e., identifying areas for more focused inspection) and not a replacement for visual inspection. UAS can also be effectively deployed to collect data through a variety of sensors especially during routine inspections and in areas where there are severe accessibility constraints.

UAS Technology Recommendations for Structural Inspection

Outlined below are some UAS platform and sensor options that can meet the needs for UAS structural inspections.

Aircraft: Skydio 2+, Matrice 300 RTK

Sensors:

Skydio 2+ Sensor Specifications

- Camera: The Skydio 2+ is equipped with a 12.3-megapixel Sony IMX577 1/2.3inch CMOS sensor. It captures still photos with a resolution of 4056 x 3040 pixels.
- Video Resolution: The UAS can record video at a maximum resolution of 4K (3840 x 2160 pixels) at 60 frames per second. It also supports various other video recording modes and frame rates.
- Image Stabilization: The Skydio 2+ features a three-axis gimbal stabilization system, providing steady and smooth footage even during fast-paced flights.
- Field of View (FOV): The camera has a fixed FOV of 78.8 degrees, providing a wide perspective for capturing expansive scenes.

Matrice 300 H20T

- The H20T sensor integrates multiple sensors into a single unit, providing a wide range of capabilities. The specifications include a high-resolution RGB camera with zoom capabilities, high-resolution thermal sensor, and built-in image stabilization to capture clear images of signs from various distances and angles.
- RGB Camera: The H20T features a 20-megapixel RGB camera with a 23 mm focal length. It captures high-resolution still photos with excellent detail and color accuracy.
- Thermal Camera: It is equipped with a 640 x 512-pixel thermal camera, allowing for thermal imaging and temperature measurements. The thermal camera provides valuable insights for detecting heat signatures and identifying potential issues.
- Laser Range Finder: The H20T incorporates a laser range finder that measures distances with high accuracy. This feature is particularly useful for gauging the size and dimensions of objects or structures during inspections.
- Three-axis Stabilized Gimbal: The camera system is mounted on a three-axis gimbal, providing stable and smooth footage even during turbulent flights. This ensures sharp and clear imagery for inspections.
- Zoom Capabilities: The H20T offers a 23x hybrid optical zoom, allowing users to zoom in and capture detailed visuals from a distance. This feature is advantageous for inspections that require close examination without the need to fly the UAS too close.

- Real-time Data Transmission: The H20T supports real-time data transmission, enabling live streaming of video and thermal imagery to the ground station during flights. This facilitates real-time monitoring and analysis of inspection data.
- Compatibility: The DJI H20T is designed specifically for the DJI Matrice 300 RTK. It seamlessly integrates with the aircraft's flight control system, enabling precise control and seamless data integration.

Both the Skydio 2+ and the Matrice 300 are platforms that excel in performing bridge inspections. The Skydio 2+ is a highly maneuverable and intelligent system equipped with an array of cameras and sensors, including a 4K60 High Dynamic Range camera and a 3D imaging system. Its autonomous flight capabilities and obstacle avoidance technology allow it to navigate complex bridge structures with ease, capturing high-resolution images and videos for detailed inspections. The sensor size is limited; however, because it can fly in close proximity, it can still capture accurate data. The Matrice 300 features a versatile payload capacity and robust flight endurance. With the advanced imaging capabilities of H20T sensors that include thermal and zoom cameras, the Matrice 300 can capture precise and detailed visual data, making it ideal for detecting structural issues and performing thermal inspections. Both UAS offer powerful tools for bridge inspections, providing engineers and inspectors with valuable data to assess the condition and integrity of bridges safely and efficiently. Both models are versatile and reliable, offering advanced flight capabilities, long flight times, and a stable platform for aerial inspections. The Matrice 300 is not capable of operating in smaller spaces and relies on assessing the bridge from a distance and using its high-resolution zoom and RGB sensors to capture accurate data from a distance. Flying from a distance may work in many situations but may prove difficult at times to see every angle of the structure.

Anticipated Benefits and Challenges

Data gathering for this project identified two main scenarios where UAS could prove advantageous to the NHDOT bridge inspection team: (1) reducing inspection time while providing high-quality data when inspecting larger structures that require detailed examination; and (2) mitigating risks associated with inspections over railroads or in situations where a bridge has been struck by a vehicle or affected by a natural disaster. By deploying UAS to evaluate the safety of a bridge, inspectors can avoid unnecessary risks before sending personnel onto or under the structure.

Each bridge inspection team consists of two people, inspecting two to four bridges per day. Larger structures may require coordination and involve four to six inspectors. Fortunately, the team has not encountered any traffic control incidents or collisions, and the inspectors prioritize safety. Using UAS to assess safety before sending personnel onto or under bridges could help increase or completely avoid risks associated with inspections over railroads and in dangerous situations.

Overall, the bridge inspection team displays mixed perceptions toward UAS adoption. While managerial staff is interested in UAS for its data clarity and reliable access, the inspectors themselves, who are primarily experienced in traditional bridge inspection methods, are hesitant. The research team recommends that the UAS Program Manager initiate collaboration with the bridge inspection team to begin testing UAS use on inspection of NHDOT bridges.

2.10.4 Traffic Systems Management and Operations

The NHDOT Traffic Systems Management and Operations (TSMO) team has used UAS sparsely over the last six years and identified several uses where the Bureau of Aeronautics could support them or, as the program matures, train TSMO UAS pilots. The TSMO team is responsible for a variety of structures, although not all of these structures are included in the inspection schedule. However, using UAS for inspections may enhance asset management capabilities or at the very least, be used as a screening tool to allow the TSMO team to focus more intensive inspection or management of their structures with traditional methods while screening out those not needing immediate attention. UAS can also be used for inspection if existing equipment, such as traffic cameras, stop working or malfunction. By deploying UAS, the TSMO team can efficiently assess the condition and functionality of these cameras, ensuring optimal performance and identifying any maintenance or repair needs. This can be helpful in identifying what the true needs are before sending a bucket truck and operator to make repairs.

Another potential use of UAS for the NHDOT TSMO team is sight-line analysis for new camera placement. By employing UAS, the team can gather aerial data and imagery to evaluate the line-of-sight from prospective camera locations. This analysis can help identify optimal positions for the placement of new cameras and maximize their coverage and effectiveness in monitoring traffic conditions. As the UAS program grows and as bandwidth will allow, these use cases should be explored because they appear to be fairly straightforward uses of UAS that can yield immediate value to the TSMO team.

UAS Technology Recommendations for TSMO

Outlined below are some UAS platform and sensor options that could be used for TSMO applications.

Aircraft: DJI Matrice 300, Mavic Pro 3, Autel Evo II Pro

Sensors:

DJI Matrice 300 – H20T (details noted in previous section).

DJI Mavic Pro 3.

- RGB Camera: The Mavic 3 Pro features two cameras, a 20-megapixel RGB camera with a 24 mm equivalent focal length. It captures high-resolution still photos with excellent detail and color accuracy. It also includes a secondary camera that provides a 7x optical and up to a 28x hybrid zoom.
- Zoom Capability: The UAS includes a secondary camera that provides a 7x optical and up to a 28x hybrid zoom.
- Transmission Range: The Mavic uses the 03+ OccSync, which can provide 1080p HD video at a distance of up to 9.32 miles.
- Real-time Data Transmission: The Mavic 3, similar to the Matrice 300, supports real-time data transmission, enabling live streaming of video imagery to the ground station during flights to facilitate real-time monitoring and analysis of inspection data.

Autel Evo II Pro (details noted in previous section).

All three UAS models offer extended flight times and high-resolution imagery capabilities. However, the DJI Mavic 3 Pro and Autel Evo II Pro have the added advantage of being smaller and more portable. These compact UAS are easier to transport and may be less noticeable to the traveling public during monitoring operations. On the other hand, the DJI Matrice 300 is ideal for professional-grade applications and provides dual-operator control, but it is a larger platform that may require more logistic planning for transportation and may be more noticeable in public settings. Furthermore, the additional capabilities and sensor selections on the M300 can be useful when zoom or thermal sensors are required.

Mature UAS Integration and Anticipated Benefits

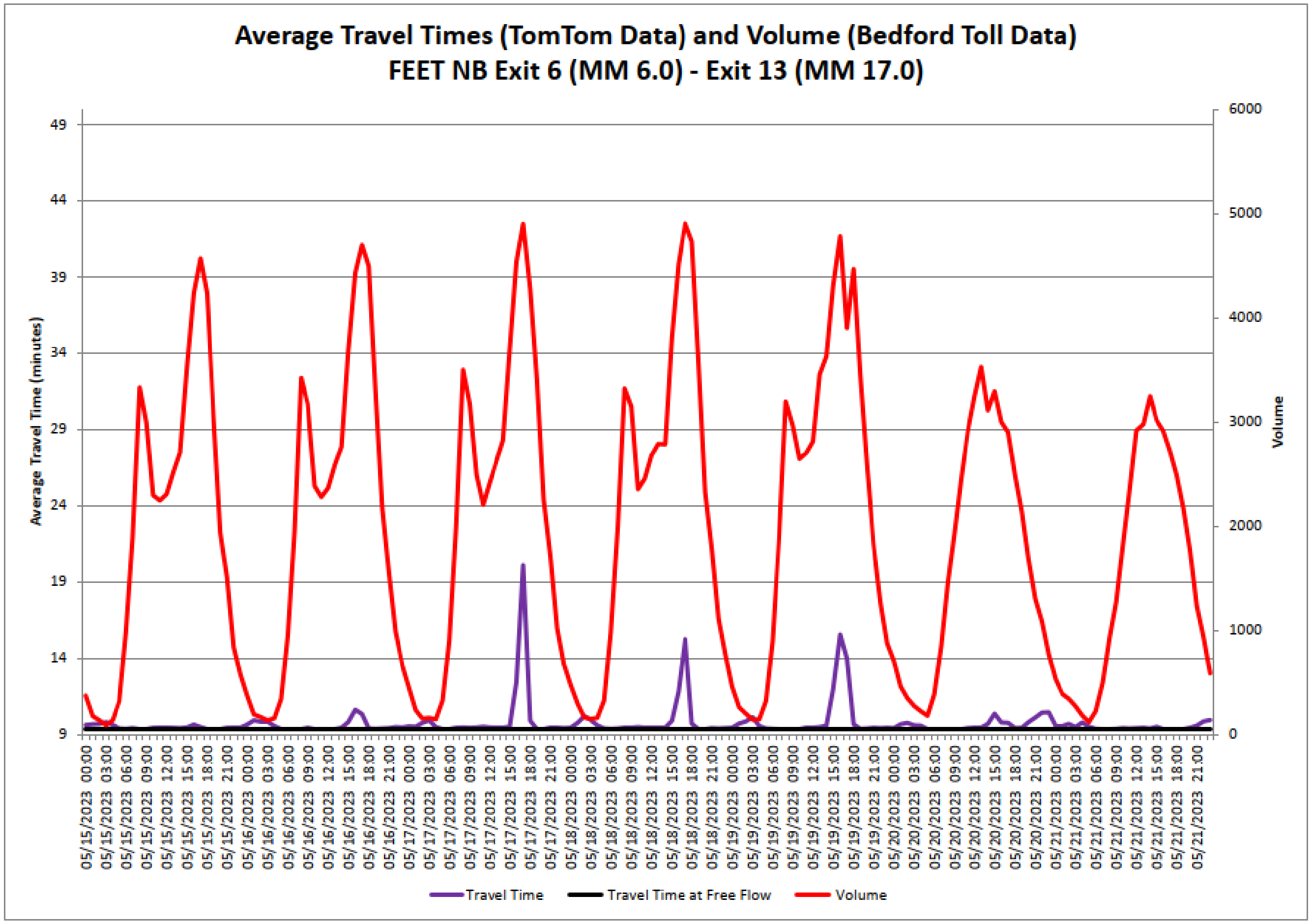
As the NHDOT UAS program matures, opportunities for more mature integrations across various applications will be available. One of these applications is outlined below. The TSMO team works closely with the NHDOT Bureau of Turnpikes, which has a turnpike-specific Motor Safety Patrol; there is also a non-turnpike safety patrol. One path for integration of UAS would be to equip these safety patrol units with tethered or non-tethered UAS to support TSMO and State Police with incident response. Another avenue for integration would be to equip only a select number of safety patrol units with UAS based on geography or roadway traffic use and to establish protocols for when UAS should be a part of the response.

UAS can provide a TSMO team with real-time situational awareness and enhanced data collection capabilities. By deploying UAS, the TSMO team can gather aerial imagery and video footage of traffic conditions, accidents, and congestion, allowing for quicker response times and more accurate decision-making. The real-time data can be used to identify traffic bottlenecks, optimize signal timing, and improve incident management, ultimately leading to reduced congestion and improved traffic flow.

As noted for other use cases, UAS can enhance safety and efficiency during incident management. UAS equipped with thermal imaging cameras and other sensors can quickly assess the severity of accidents and identify potential hazards, such as spills or damaged infrastructure. This information can be shared with incident responders on the ground, enabling them to take appropriate actions and allocate resources more effectively. UAS can also be used to quickly map accident scenes and collect data that can be used in accident reconstruction, which allows the scene to be cleared faster, restoring traffic flow to normal as soon as possible.

The NHDOT TSMO team tracks weekly travel times and analyzes the associated cost of delay related to the length of time the delay occurred. They provided the research team with an example of these reports, Figure 4 shows the longest delay for the week of May 22, 2023, and its associated delay costs.

As the UAS program matures, NHDOT will be in a better position to begin testing the implementation of UAS for this identified use case and can work closely with the TSMO team to measure the impact of UAS integration. Other State DOTs have reported great success with using UAS to clear accident scenes more efficiently. Utah DOT reports a 33 percent increase of efficiency on clearing fatal accidents, and up to four times faster clearing on other accidents (UDOT, 2023). The North Carolina DOT credited a 300 percent-time savings over traditional 3D laser mapping when using UAS (Jodoin et al., 2021).



Delay Cost:
$71,878.88
Total Volume Delayed:
319,462
Total Volume:
327,550
Total Delay (HH:MM):
0:57

Figure 4. NHDOT Total Delay Data.

2.10.5 Emergency Response

Although emergency response is ranked fifth in the order of priority, this use case could be a relatively easy one to more fully integrate UAS. As the NHDOT UAS program matures and the number of experienced and certified UAS pilots throughout the agency grows, then there will be a higher level of internal capabilities to support the response to emergencies. Currently during active emergencies, the Bureau of Aeronautics maintains a team of four individuals who are on call and ready to support the needs of the Emergency Operations Center. These services may include issuing Temporary Flight Restrictions to ensure airspace safety or coordinating UAS operations as needed. This on-call support helps streamline communication and coordination efforts between the Bureau of Aeronautics and the Emergency Operations Center during critical situations.

Efficient coordination of UAS and other aviation assets is essential for effective emergency response. The Bureau of Aeronautics maintains an aviation asset list for NHDOT-owned aircraft that tracks UAS and other relevant resources, which enables efficient coordination with other agencies such as the State Police, National Guard, and Civil Air Patrol. This comprehensive tracking system helps the bureau deploy resources efficiently and leverage UAS capabilities when required.

Anticipated Benefits

As the NHDOT fleet of UAS and team of certified UAS pilots grows, additional internal resources can be offered in conjunction with other agencies to meet the needs of emergencies.

UAS can provide invaluable situational awareness during emergency situations. Equipped with high-resolution cameras and sensors, these aerial vehicles can swiftly gather real-time data and imagery of affected areas, allowing emergency responders to assess the extent of the damage, identify potential hazards, and formulate effective response strategies. This enhanced situational awareness leads to a more efficient allocation of resources and a coordinated and effective emergency response.

UAS can also play a crucial role in conducting rapid damage assessments following natural disasters or other emergencies. These aerial platforms can cover large areas in a short period, capturing detailed images and footage of affected infrastructure such as roads, bridges, and buildings. By analyzing this data, State DOT personnel can swiftly identify critical damage and prioritize repair and recovery efforts to expedite the restoration of essential transportation infrastructure; enable emergency services to reach affected areas faster; and facilitate the safe and timely movement of goods, services, and personnel. Many of the UAS platforms and sensors used for structural inspections, surveying, mapping, and construction monitoring can also serve the needs of emergency response situations.

2.10.6 Asset Maintenance and Operations

Besides meeting the regular structural inspection requirements, the popularity of the UAS is also on the rise for collecting asset inventory data. Asset management teams stand to benefit by deploying UAS for tracking locations and conditions of various assets including traffic signs, signal heads, retaining walls, and guardrails. Reconciling the asset data along with characteristics of an asset management system helps produce a more accurate asset inventory, enables compliance checks with various operational requirements, and helps define appropriate maintenance schedules.

To date, there has only been one NHDOT Geographic Information System (GIS)-specific UAS operation. A GIS use case that could be integrated initially is to use UAS to supplement the NHDOT aerial imagery. Every five years, the NHDOT GIS team uses a fixed-wing aircraft to fly over the state to collect aerial data that are then used in asset management. UAS could supplement this traditional fixed-wing aerial data collection. The traditional aerial data is collected at 6-inch ground sampling distance, whereas UAS can provide higher resolution of 1-inch ground sampling distance or less. Furthermore, during the interviews conducted for the project, interviewees touched on the need for improved asset data collection. Currently many of these data collection efforts are being carried out by one individual with a tablet. The team expressed a desire for better data collection methods and delivery mechanisms and agrees that UAS can play a big role in improving these data collection efforts.

The best UAS platform or sensor to be used for asset maintenance and operations largely depends on the asset to be analyzed. Many of the UAS discussed in previous use case sections (e.g., DJI M300, Mavic 3, and Autel Evo II) can also be used to meet the needs of asset maintenance and operations.

Anticipated Benefits

The anticipated benefits of using UAS across the operations and maintenance of NHDOT's transportation infrastructure are largely similar to the benefits outlined in the other use cases. The biggest anticipated benefit of UAS and GIS working together is enabling a powerful, up-to-date, and detailed statewide infrastructure database. By combining the aerial capabilities of UAS with the spatial analysis capabilities of GIS, NHDOT can capture high-resolution imagery and data of infrastructure systems such as roads, bridges, utilities, and buildings. This powerful combination supports the creation of an up-to-date and detailed repository of geospatial information, providing a wealth of knowledge for planning, maintenance, and emergency response. The UAS-GIS partnership ensures that infrastructure databases are regularly updated, enabling decision-makers to make informed choices based on accurate and timely information. This synergy brings unprecedented efficiency, cost savings, and improved infrastructure management across the state, ultimately leading to enhanced public safety and a more resilient and sustainable future.

2.11 Software Solutions for UAS Mission

Software plays a crucial role in managing various stages of a UAS mission ranging from flight planning and control, data collection, and post-flight data processing. Three models are available for processing UAS data: (1) off-the-shelf cloud-based automated processing; (2) off-the-shelf desktop processing; and (3) expert processing (by NHDOT or consultant). Table 3 shows some general characteristics of these categories and their respective ratings.

Table 3. General UAS Software Examples and Characteristics.

Characteristic	Cloud-based Automated Processing (DroneDeploy®, Pix4d Cloud, Skycatch®, or Propeller®)	Desktop Processing (Pix4D® or Agisoft® Photoscan®, or Correlator3D®)	Expert Processing (NHDOT or consultant)
Accuracy	Medium to High	High	High
Reliability	High	Dependent on local hardware	High
Simplicity	Simple	Complex	Simple
Flexibility	Rigid	Flexible	Flexible
Turnaround Time	Fast	Dependent on local hardware	Slow
Cost	Options ranging from $600-$7,200/year	Each of these options are about $3,600/year	Variable based on project size and data needs

Characteristic	Cloud-based Automated Processing (DroneDeploy®, Pix4d Cloud, Skycatch®, or Propeller®)	Desktop Processing (Pix4D® or Agisoft® Photoscan®, or Correlator3D®)	Expert Processing (NHDOT or consultant)
Suitability	General monitoring, measurements, quantities, interactive notes, sharing data across the organization via the cloud.	Poor internet connectivity; sensitive data; unusual projects	High-accuracy land surveying and mapping

The widespread adoption of UAS across several industrial sectors has led to the creation of software solutions of different types to meet the needs of customers and the specific requirements of applications. The following tables describe the various software solutions used for (1) multiple phases of UAS operations, (2) UAS flight planning, (3) UAS flight operations and control, and (4) UAS data processing. The computing model for each application is provided for reference.

Table 4. Commercial Off-the-Shelf Software Applications for Multiple Phases of UAS Operations.

Application	Description	Phase	Computing Model
Pix4D	Suite of photogrammetry software widely used by many industries such as surveying, incident management, and construction for UAS mapping.	Flight operations/ post-flight data processing	Desktop client/ cloud
B4Ufly	Mobile application developed by the FAA for airspace awareness and authorization. Its primary purpose is to provide UAS operators (UAS pilots) with information about whether it is safe and legal to fly UAS in a particular location or to receive Low Altitude Authorization and Notification Capability authorizations.	Flight planning and operations	Desktop, cloud, mobile application
Aloft	Aloft mobile applications help prepare for a safe and successful mission by checking airspace and weather, running a safety assessment, and getting necessary authorizations. Flight logging happens automatically. Media is securely transmitted to business applications. Operators experience maximum situational awareness. Sometimes there is no time to wait and see what a UAS saw after the fact. The application can create a live video stream of what the UAS is seeing and share it with anyone on the team, complete with conference-call audio. A powerful tool for incident response, training, flight planning, fleet management, and safety.	Flight planning, flight operations, fleet management, and live streaming	Cloud, mobile application

Table 5. Commercial Off-the-Shelf Software Applications for UAS Flight Planning.

Application	Description	Computing Model
Esri ArcGIS	GIS used for generally mapping out areas of interest and understanding site conditions that may impact flights such as elevations, vegetation, structures, and airport locations.	Desktop client
iFlightPlanner	Online and mobile-enabled flight planning application for planning flight routes using Instrument Flight Rules/Visual Flight Rules aviation charts and Google Maps; viewing enroute aviation weather, translated Meteorological Aerodrome Reports and Terminal Area Forecasts, Temporary Flight Restrictions, and graphical Airman Meteorological Information or Significant Meteorological Information charts; receiving certified weather briefs, performing weight and balance calculations, filing and closing FAA flight plans, viewing airport information, and logging flight information in online logbooks.	Cloud
UgCS	Software for planning and flying UAS survey missions that supports almost any UAS platform, providing convenient tools for ariel and linear surveys and enabling direct UAS control.	Desktop client
SkyVector	Web-based aeronautical sectional flight planning and filing system.	Cloud

Table 6. Commercial Off-the-Shelf Software Applications for UAS Flight Operations/Control.

Application	Description	Computing Model
DJI Go	Software to control various aspects of flight operations in DJI Enterprise UAS, including full control of sensors, take-off and landing, and automatic flight logs.	Cloud
DJI Pilot	Software to assist DJI Enterprise UAS in real-time picture transmission, flight control, and customized control of sensors.	Cloud
DJI GS Pro	An iPad application for DJI Enterprise UAS for automated flight missions to manage flight data on the cloud and collaborate across projects to efficiently run the UAS program.	Cloud
Litchi	An autonomous flight application for DJI UAS for mission planning, gimbal and sensor control, and automated tracking of objects.	Cloud
DroneHarmony	A 3D flight planning software for automated mission planning targeting challenging vertical inspection tasks.	Cloud
PX4 AutoPilot	Open-source flight control software for UAS operations that includes mission planning and flight control.	Desktop client
MapPilot	Software for DJI UAS to create optimal flight path and rapidly create high-resolution aerial maps.	Cloud

Table 7. Commercial Off-the-Shelf Software Applications For Post-UAS Flight Data Processing.

Application	Description	Computing Model
Agisoft Metashape	A stand-alone software that uses photogrammetric techniques and computer vision methods to generate 3D spatial data for GIS applications.	Desktop Client
DroneDeploy	A collaborative, cloud-based platform that can be deployed in a mobile application; commonly used for UAS mapping to create various photogrammetric outputs and perform aerial site intelligence in real time.	Cloud
Skycatch	An enterprise-grade aerial intelligence platform with powerful data analysis tools for data from UAS.	Cloud
Propeller	An end-to-end solution that has a suite of products to assist ground control and UAS mapping and data analysis of the worksite. Allows CADD design data to be integrated with UAS and project data. Workflows suited toward construction and project team collaboration.	Cloud
Trimble Inpho	An Office solution that processes aerial images from UAS using photogrammetry and remote sensing to produce orthomosaics, 3D surface models, and 3D point clouds.	Desktop client
Bentley Context Capture	A reality modeling software that uses UAS imagery to produce a 3D mesh model of real-world conditions that can be used for design, construction, and operation decisions.	Desktop client
Autodesk Recap Pro	Used for processing, classifying, and analysis of point clouds and 3D models.	Cloud
Certainty3D TopoDOT	CAD system for extracting features, topography, and 3D models form point cloud data.	Desktop client
PhotoModeler	Software tool for converting photographs into accurate and useful 3D data and models.	Desktop client
SimActive Correlator3D	Photogrammetry software with aerial triangulation, Digital Surface Model and point cloud generation, Digital Terrain Model extraction, orthorectification, mosaic creation, and 3D model generation. Works with any UAS platform and camera/sensor. Additional tools include Digital Elevation Model contour extraction, point cloud colorization, ground control point extraction, volume calculation, 3D change detection, and scripting.	Desktop Client
Modri Planet 3D Survey	Photogrammetry software. Ground control point processing. Point classification tools.	Desktop client
Virtual Surveyor	Used for creating hybrid model from orthomosaics and raster digital elevation models. Also, used for analyzing, cleaning, editing, and exporting data.	Both

Application	Description	Computing Model
Esri Site Scan	Process UAS imagery into high-resolution orthomosaics, elevation models, point clouds, 3D meshes, and more with both Pix4D and Autodesk ReCap. Export data into native Autodesk file formats—including RCS and RCM—along with common formats such as OBJ, LAS, and TIFF. Generate detailed processing reports from Pix4D with checkpoints to measure accuracy. Allows tracking of flights and pilots.	Cloud
Cardinal Systems Vr Mapping VrUAS	Perform aerial triangulation, automatic point tie and bundle adjustment and to create Digital Surface Models and orthophotos. Also allows for true 3D viewing, vector collection and editing from stereo images and point clouds.	Desktop client

2.12 Importance of Return-on-Investment (ROI) Tracking

The NHDOT UAS Program Manager plays a crucial role in the successful implementation and development of the UAS program. One key aspect of their responsibility is to track the ROI for the UAS program. Tracking ROI is essential for demonstrating the program's value, securing ongoing support from NHDOT leadership and state executives, and making informed decisions regarding the allocation of resources. Implementing the outlined steps in the phased approach to ROI tracking will enable a gradual and comprehensive assessment of the program's benefits and cost-effectiveness.

2.12.1 Short term

During the initial stage, the UAS Program Manager should focus on maintaining the support that has been offered from NHDOT leadership and state executive leadership. They should regularly communicate the progress and development of the UAS program, highlighting the positive impact it has had on various projects and transportation initiatives. Even when the positive impact may seem small or trivial, it should be documented. Over time, these small impacts add up to make a big difference. Documentation during this phase involves providing updates on successful UAS missions; showcasing how UAS technology has improved data collection, planning, and maintenance processes; and demonstrating compliance with relevant regulations and safety standards. By maintaining and building a strong foundation of support, the UAS Program Manager can build a stable foundation for the program's increased operations.

2.12.2 Medium term

As the program matures, the UAS Program Manager should shift focus to document and monitor project outcomes, with particular attention to cost differences. This process involves analyzing data on expenses related to traditional methods of transportation inspection or monitoring and comparing them to the costs associated with UAS operations. By tracking expenses, the manager can determine whether the UAS program is achieving cost savings or if adjustments are needed to further optimize efficiency.

At the one-year mark, the UAS Program Manager should conduct a comprehensive evaluation to calculate the actual cost savings achieved through the UAS program. Again, the focus should be on tracking all of the costs savings, small and large, to create a comprehensive picture. This assessment will provide tangible evidence of the program's benefits and identify any potential areas for improvement. It will also serve as a basis for presenting the program's successes to internal and external stakeholders.

2.12.3 Long term

In the long-term phase, the UAS Program Manager should develop and leverage an established ROI tracking model to routinely communicate the positive impacts of the UAS program to NHDOT leadership. This model should encompass all relevant data points, such as cost savings, time efficiencies, improved safety measures, and enhanced data accuracy. Routine reports and updates should be shared with decision-makers to demonstrate the program's ongoing value and inform future strategic planning.

Moreover, the UAS Program Manager should expand the scope of ROI tracking beyond cost savings. By highlighting the broader benefits that UAS technology brings (e.g., faster response times, safety improvements, reduced environmental impact, and improved asset management), the UAS Program Manager can strengthen the case for continued support and investment in the program.

Tracking the ROI of the UAS program is paramount for its long-term success. A short-, medium-, and long-term phased approach allows the UAS Program Manager to gradually build support, thoroughly evaluate outcomes, and effectively communicate the program's value to key stakeholders. By doing so, NHDOT can realize the anticipated benefits outlined for each use case and maximize the primary and secondary benefits of UAS technology.

3.0 PILOT PROJECT PLANNING AND CRITERIA

The UAS Program Manager has been reporting on the progress of the UAS program to date throughout the various bureaus and divisions of NHDOT. As a result, some pilot projects have occurred to use the NHDOT UAS fleet and evaluate their capabilities. These pilot projects will increase in number as NHDOT formalizes its UAS program with an implementation plan and approved governance documents. As the UAS Program Manager continues these efforts and integrates UAS across the identified use cases and beyond, the pilot project process can become more structured. The process can be organized in three distinct areas: project information request, project planning, and project feedback.

3.1 Pilot Project Information Request

The purpose of this process is to gather all the necessary information in as much detail as possible regarding the pilot project including the deliverable usage expectations so that the right personnel, UAS platforms, and resultant digital files can produce the requested deliverables the first time. The following list describes the information that should be collected.

- Which bureau is requesting the pilot?
- Is the UAS request or interest for a specific project or an overall general need?
- What is the project title and description (general project description/scope)?
- What are the project objectives (specific objectives and goals for pilot project)?
- Where is the project located?
- What is the proposed timeline?
- What specific stakeholders will be involved in the project?
- Will traffic control be needed?
- Is there a staging area on the project site?
- Are there any specific project or site protocols?
- Are there any environmental, legal, or ethical considerations for using UAS on this project?
- Will this be a one-time use or an ongoing UAS request?
- If ongoing, does the requesting bureau want to train their own individual(s) or rely solely on Bureau of Aeronautics for UAS services?
- What is the budget to support the UAS services? Is there a project code?
- What are the specific data needs (e.g., accuracy standards, specifications, format)?
- What reporting structure is needed for the UAS data?
- Are there any anticipated concerns regarding the use of UAS?
- What are the anticipated benefits for this project (e.g., increased efficiency, increased safety, cost savings, increased data quality)?
- What are the criteria to measure and evaluate the success of this pilot project?

3.2 Pilot Project Planning

Once the UAS Program Manager has worked with the requesting or exploring bureau to accumulate the details for the pilot project, he or she can proceed with creating a pilot project plan. The following list can serve as a guide for creating the project plan.

- Perform a thorough site analysis.
- Evaluate the level of risk.
- Is there an authorization or permit needed?
- Is UAS the appropriate tool for this project?
- Which UAS platform/sensor is best suited for this project?
- Will the requesting bureau process the data, or will the Bureau of Aeronautics process the data? Is there any propriety software needed?
- What personnel are needed to fulfill the request?
- What stakeholders will be involved in the project? What is the communication plan for these stakeholders?
- What milestones should be accomplished? What are the timelines?
- What key performance indicators should be tracked throughout the project for UAS use?
- Can the request be accomplished within the proposed budget?
- Complete a thorough project plan including the above information and outlining other phases of UAS operations (pre-flight, in-flight, post-flight).

3.3 Pilot Project Feedback

After the pilot project has been completed, it is critical to gather feedback on the overall process to gauge satisfaction with the deliverable, describe lessons learned, and indicate if the objectives were achieved. The UAS Program Manager should work closely with the stakeholders of the project and formally gather feedback. This feedback will be key to informing the development and maturity of the UAS program as NHDOT works through the implementation plan. This feedback can also help with tracking ROI for reporting to executive leadership. The following questions should be considered as part of the feedback criteria.

- Was the UAS and UAS Operations Team able to provide the requested data?
- Did the provided data meet the project needs, goals, objectives, and expectations?
- Was the UAS data provided in the correct format and was usable?
- Was the UAS-collected data better quality than traditional means? If so, in what ways?
- Did using UAS make this data collection process more efficient? How much time was saved?
- Did using UAS increase safety?
- Did using UAS decrease the cost over traditional methods on this single use? Would the continual use of UAS decrease costs overtime? What are the estimated cost savings?

The criteria across the areas of information request, planning, and feedback can be incorporated into one or perhaps three separate electronic forms to track these key data points across multiple pilot projects.

These forms could be hosted online for easy access of requesting bureaus, or the UAS Program Manager can provide the forms to the appropriate individuals as he or she continues to promote the NHDOT UAS program and its capabilities.

4.0 UAS PROGRAM GOVERNANCE DOCUMENTS

The NHDOT UAS program needs several governing documents to guide the development and formalization of the program. The governance documents guide day-to-day operations and enable the safe adoption of UAS across numerous operations throughout NHDOT. These documents should be reviewed, adjusted as needed, and agreed upon by the UAS Steering Committee prior to final approval and adoption. The documents include:

- Program Charter
- Policies and Procedures
    - Privacy Policy
    - Operations Manual
    - Safety Management Plan
    - Operating Procedures

4.1 Program Charter

NHDOT recognizes the potential of UAS in enhancing its operations, improving safety, and increasing efficiency. The purpose of the formal establishment of the NHDOT UAS program is to effectively integrate UAS technology into the department's daily activities, ensuring compliance with regulatory requirements while maximizing the benefits of UAS utilization. This charter outlines the objectives, scope, governance, and key considerations of the NHDOT UAS program.

4.1.1 Objectives

The following objectives serve as overarching goals for the UAS program.

- Improve Safety: As an organization committed to safety, NHDOT will strive to use UAS to enhance and maximize safety in all uses.
- Enhance Efficiency: UAS capabilities will be leveraged to streamline data collection, resulting in improved project planning, design, construction, and maintenance.
- Optimize Resource Allocation: UAS should be used to gather accurate and timely data, reducing the need for manual inspections, minimizing costs, and optimizing resource allocation across NHDOT.
- Foster Collaboration: To enable greater UAS program success, the UAS Program Manager will collaborate with internal and external stakeholders, including federal, state, and local agencies, industry partners, and the public, to promote the responsible use of UAS technology in transportation operations.
- Develop Expertise: Cultivate internal expertise and knowledge to effectively manage and operate UAS, ensuring compliance with regulations, privacy considerations, and safety standards.

4.1.2 Scope

The NHDOT UAS program exists to serve the needs of all NHDOT bureaus, divisions, and teams. The UAS Program Manager will work with any NHDOT personnel interested in exploring the integration of UAS. The following use cases are the initial primary focus in order of priority:

- Surveying and Mapping

- Construction Monitoring
- Structures Inspection
- Traffic Operations and Incident Management
- Emergency Response
- Asset Maintenance and Operations

4.1.3 Governance

The NHDOT UAS program will be controlled and operated using a centralized control though the Bureau of Aeronautics for policy, training, standardization, certification, and control functions. It is recommended that NHDOT utilizes decentralized execution for some routine UAS missions using current NHDOT employees in non-Aeronautics bureaus. Recommended governance structure for NHDOT's UAS program is as follows:

> **UAS Program Sponsor:** The UAS Program Sponsor will provide the support and resources necessary to promote the success of the UAS program. The sponsor should be an identified individual who serves as a senior executive within the leadership of NHDOT. This individual is expected to be a champion of the UAS program to the other members of executive leadership.
>
> **UAS Program Manager:** The UAS Program Manager will be responsible for the day-to-day management, coordination, and execution of the UAS program. They will oversee the various projects, ensure compliance, and foster collaboration with stakeholders. Additionally, the UAS Program Manager will actively participate in the UAS Steering Committee and report successes and challenges of the program to the UAS Program Sponsor and other members of leadership.
>
> **UAS Stakeholder Committee:** The UAS Stakeholder Committee will consist of key internal stakeholders, including representatives from different departments within NHDOT. The UAS Steering Committee may also benefit from the participation of external stakeholders and partners. This committee will provide strategic guidance, review the program guidance documents, and make decisions on program direction and resource allocation.
>
> **UAS Operations Crew:** The UAS Operations Crew will be responsible for operating and maintaining UAS equipment, complying with regulations, managing flight operations, and collecting and analyzing data. The members of the UAS Operations Crew is currently within the Bureau of Aeronautics and as the program grows, current NHDOT employees will be trained as UAS Operating Crews and embedded in their NHDOT non-Aeronautics bureaus where UAS demand is high. Each member of the UAS Operations Crew will work directly with the UAS Program Manager on fulfilling UAS operations requests.

4.2 UAS Policy and Procedure Considerations

Appendix B: NHDOT UAS Policy and Procedures provides the governance document(s) to be reviewed. The draft governance documents were provided by the Bureau of Aeronautics as part of this project. The research team has augmented these documents and made recommended changes. Additionally, to provide thorough information and key considerations, the following sections on the Privacy Policy and Safety Management Plan have been provided.

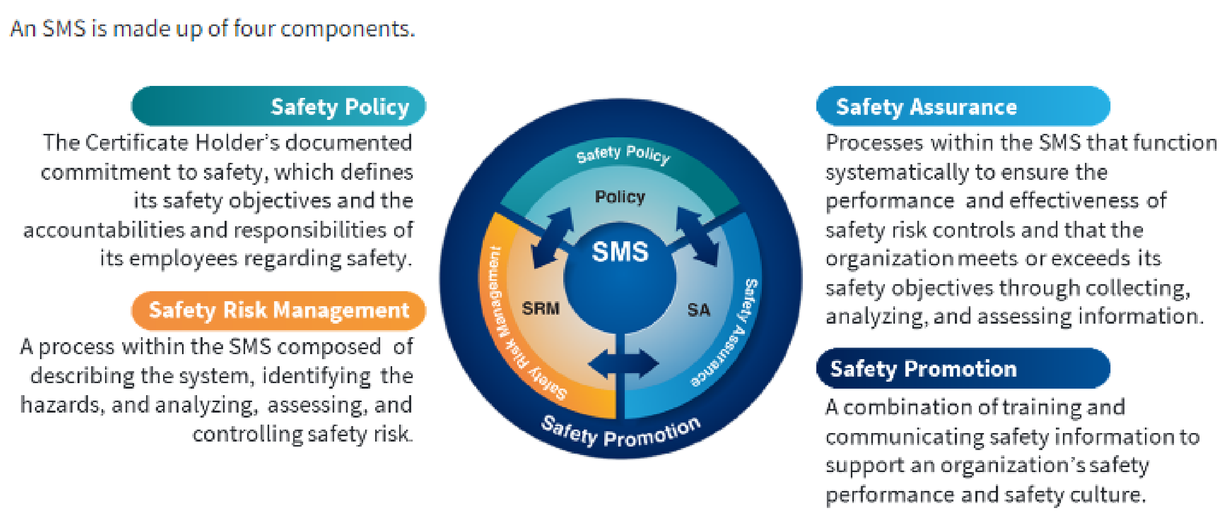
4.2.1 Privacy Policy

Additional considerations for the currently proposed UAS privacy policy may include strategies for communication with property owners or the public when needed. In the context of potentially high-sensitive projects, proactive communication may be needed to address privacy concerns and provide transparency. One effective strategy is the use of letters to inform the public prior to flying UAS for a project. By sending letters to affected communities and stakeholders, NHDOT can outline the purpose of the UAS flights, define the areas that will be covered, and describe the measures taken to protect individual privacy. This approach not only provides relevant information to those potentially impacted but also demonstrates a commitment to protecting privacy.

Conducting public hearings can serve as another valuable strategy on select projects. Public hearings provide an opportunity for concerned citizens, community members, and relevant organizations to voice their opinions, ask questions, and express any privacy concerns they might have. NHDOT can use these hearings to present detailed information about the UAS operations; data collection practices; and how the collected data will be used, stored, and safeguarded. These public forums can help address privacy-related misconceptions, build trust with the community, and enable the NHDOT to make any necessary adjustments to its UAS protocols based on public feedback as needed.

4.2.2 Safety Management Plan

Safety should be at the foundation of the UAS program. The FAA's Safety Management System Voluntary Program defines a Safety Management System as "a formal, top-down organization wide approach to managing safety risk and ensuring the effectiveness of safety risk controls" (FAA, n.d.). There are four key pillars to a Safety Management System, outlined in Figure 5. These core components of a safety management plan should be considered as NHDOT finalizes its safety policy.



Source: FAA (n.d.)

Figure 5. FAA Safety Management System.

The FAA risk matrix is a valuable tool used in UAS operations to assess and manage potential risks. The risk matrix is a graphical representation that helps UAS operators identify and quantify the likelihood and severity of various hazards (Figure 6). By evaluating different operational scenarios against predefined criteria, the risk matrix can assist in assigning levels of risk that enable operators to make informed decisions to mitigate potential hazards effectively.

In UAS operations, the risk matrix categorizes risks into specific levels, such as low, moderate, high, or severe, based on the likelihood of an event occurring and the potential consequences. Each level is associated with a set of corresponding risk mitigation measures. By using the risk matrix, UAS operators can prioritize their safety efforts and allocate resources accordingly. For instance, low-risk scenarios may require minimal intervention, while high-risk situations demand thorough risk reduction strategies or even the avoidance of the operation altogether. More information on the use of the risk matrix can be found in the FAA Order 8040.4B *Safety Risk Management Policy* (FAA, 2017).

Severity / Likelihood	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A	[Green]	[Yellow]	[Red]	[Red]	[Red]
Probable B	[Green]	[Yellow]	[Yellow]	[Red]	[Red]
Remote C	[Green]	[Green]	[Yellow]	[Yellow]	[Red]
Extremely Remote D	[Green]	[Green]	[Green]	[Yellow]	[Red] * / [Yellow]
Extremely Improbable E	[Green]	[Green]	[Green]	[Green]	[Yellow]

High Risk [Red]
Medium Risk [Yellow]
Low Risk [Green]

* High Risk with Single Point and/or Common Cause Failures

Source: FAA (2017)

Figure 6. Risk Matrix.

Furthermore, the FAA risk matrix can be used as part of a systematic and standardized approach to risk assessment. UAS operators should consider various factors such as weather conditions, airspace restrictions, operational complexity, and potential hazards in the vicinity. This comprehensive evaluation process can help NHDOT foster a safety-oriented culture within the UAS program, reducing the likelihood of accidents and incidents.

The following sections outline operational considerations for pre-flight planning, site analysis, in-flight procedures, including emergency procedures, and post-flight tasks. The UAS Program Manager with feedback from the UAS Stakeholder Committee can determine whether these considerations should be formally added to the policies and procedures governance documents.

Pre-Operation Procedures

The following tasks will be completed prior to all flight operations.

- Gather operation details from client.
- Perform site survey and review on-site planning with bureau or district.
- Finalize proposed operation dates and alternate dates.
- Verify FAA approval and rework as needed.
- Contact FAA and file for a Notice to Air Missions (NOTAM) where required.
- Review final operation plans with bureau or district.
- Inform authorities of commencement of operation, where necessary.
- Prepare equipment and aircraft for operation—full review and check of all gear and complete aircraft check.
- Ensure that all batteries are fully charged.
- Check weather leading up to and on the day of operation.
- Check-in with client before travel to site for any last-minute changes in operational plans.
- Arrive on-site and secure staging and take-off/landing areas.
- Setup and check field kit and flight gear.
- Perform aircraft inspection and ensure all systems are configured properly and fully operational.

Site Survey Procedures

As part of the pre-operational procedures, a site survey will be performed as part of the initial planning for all operations to confirm they can be conducted safely and meet the requirements of the client, FAA, and related operational documents.

The site survey will include a site visit and a visual inspection of the direct flight paths and surrounding areas by one or more personnel. Photographs will be taken of the site for reference as required, especially when all personnel are not on hand to assess the site directly.

In addition to direct on-site visits, an additional assessment will be made using aeronautical charts, Google Maps (or similar), and any additional reference material that may be of help to confirm that there are no elements of concern in the surrounding areas that may have been missed on a site visit alone.

The site survey will involve the following core elements:

- Address, latitude/longitude coordinates and radius of the site area.
- Define boundaries of the property and operational area and proposed flight paths.

- Determine the class of airspace of the area and note any nearby airports, helipads, or other aircraft operations in the area as determined by the FAA and Visual Flight Rules Navigation Charts.
- Establish the location and height of obstacles near proposed flight paths (e.g., power lines, towers, trees).
- Locate proposed take-off/landing zones and safe ditching areas.
- Identify hazards within the immediate or nearby area (e.g., oil tanks, gas stations, electrical power substations).
- Ascertain the distances the flight operation will be from outside structures, vehicles, roadways, or bystanders.
- Develop security provisions for limiting spectator access.
- Identify radio transmission devices/towers that could interfere with UAS control link.
- Ensure that direct radio and visual line-of-sight capability will be maintained at all times.
- Verify local bylaws that may impact operation.
- Identify local weather or related environmental issues that could be of concern (e.g., wind shear from buildings/hills, fog, salt spray).
- Obtain permissions from property owners or any associated authorities (e.g., National Park Service).

As part of the site assessment, a diagram can be created that outlines the boundaries, proposed take-off/landing zones, and all elements of concern. This diagram will become part of the operation-specific documentation.

Where operations involve multiple locations or locations with obvious physical boundaries, multiple site surveys will be performed and documented separately. The site survey details will be used for the request for NOTAM when required.

Pre-Flight Procedures

The following tasks will be completed prior to all flights within an operation:

- All crew members perform a self-assessment using the FAA IMSAFE checklist. IMSAFE=Illness, Medication, Stress, Alcohol, Fatigue, Emotion.
- Check that area is secure and free of animals, persons, and vehicles.
- Review NOTAMs for the area.
- Remove/dismantle or avoid any on-site items that may pose a potential hazard to operations.
- Check that weather conditions are within defined safe parameters.
- Notify bystanders and flight team of the flight plan details.
- Turn on the VHF airband radio and set to proper frequency of the local airspace, either ATC or common traffic advisory frequency. This aviation radio should be monitored, especially when within 10 miles of an airport.
- Visually inspect aircraft for any damage or structural issues.

- Verify that the control transmitter is fully charged, the correct aircraft is selected, and all switches and controls in the proper neutral position.
- Place aircraft in a defined area that is level, clear of obstacles or foreign objects, and safe for take-off (preferably a portable weighted landing pad). Verify that the flight batteries are fully charged and stable.
- Power aircraft and verify flight control connections and battery levels.
- Check radio signal strength within application to determine if it is at an appropriate level.
- Power camera and payload systems.
- Verify flight controls, fail-safes, and appropriate GPS locks (where equipped) are fully functional. Verify take-off and flight area are clear.
- Announce take-off to teams and bystanders.
- Engage motors on aircraft and perform take-off.
- Hover 6-ft to 8-ft AGL and perform movements in all directions to verify control and stability. If applicable move the sensor gimbal to verify freedom of movement.

In-Flight Procedures

The following tasks will be completed during all flights within an operation:

- Monitor battery levels during the duration of flight via telemetry or other visual/audible indicators.
- Monitor flight path for other aircraft, persons, animals, or other obstacles.
- Monitor weather conditions remain within defined safe parameters; land if conditions deteriorate beyond safe levels.
- Give way to all other aircraft and operate in accordance with the principles governing the flights of manned aircraft at all times.
- Announce landing procedure is to commence.
- Verify landing area is clear.
- Land aircraft in designated landing area.
- Crew members engaged in the operation of the UAS system must comply with the instructions of the PIC.

Operating Near Controlled Airspace

When operating near controlled airspace the following procedure will be followed:

- Determine and note boundaries of controlled airspace, including the maximum operational altitude, as part of the site survey process. Brief all crew personnel on this information prior to any flight operations.
- Monitor flight parameters in real time via telemetry from the UAS (altitude, distance, speed, and heading) by the RPIC and observer to ensure flight operations stay outside of boundary areas based on required altitude and distance from take-off location.
- Terminate flight operation immediately if the controlled airspace boundary is crossed and return the aircraft within the designated operational area outside controlled airspace.

Fly-away

In the event of a fly-away condition where UAS control cannot be immediately regained, the following procedure will be followed:

- For *vertical fly-aways* within controlled airspace or near an uncontrolled airport, broadcast the notice to the ATC of the nearest controlled airport and aircraft in the area via phone to warn them of the issue, location, and last known altitude. The ATC may also be informed by phone if they are unreachable by radio.
- For *horizontal fly-aways* within controlled airspace or near an uncontrolled airport, notify the ATC of the nearest controlled airport via phone to warn them of the issue, location, and last known altitude. This information can be found via the FAA.
- Notify local emergency agencies of the issue as appropriate for the location.
- Secure the take-off zone and associated equipment and start an immediate search for the aircraft.
- Upon retrieval of the aircraft or after the expiration of maximum flight time, notify the ATC via the phone to give an all clear to the incident.
- Inform appropriate emergency agencies of the recovery or failed recovery.
- Make a report to the FAA for occurrences where damage exceeds $500 not including the aircraft.

Command and Control Station/Link Failures

In the event of a loss of command and control or issues with associated radio link and ground station systems, the following procedures will be followed:

- In aircraft with failsafe systems, return to home will be initiated upon control loss. Follow procedures outlined in UAS manual to regain control and/or terminate flight on return safely.
- Give priority to flight control systems in the event of link-related issues or failures.
- Non-essential ground station and related system failures will initiate manual termination of the flight operation and immediate return to a safe landing zone.
- Reinitiate/cycle aircraft control systems to reestablish manual control.
- If control is regained, terminate operation and land immediately at the nearest safe landing zone.
- If control cannot be regained and no failsafe return to home is available or functional, initiate the fly-away and emergency procedures.

Communication Failures/Issues

In the event where verbal communication systems (e.g., radio, cell phone) between operation personnel or ATC/other critical stakeholders fail or become unreliable, the flight will be terminated immediately, and the aircraft returned in the quickest, safest manner to the take-off/landing zone. No further operations will be carried out until the issues are resolved.

Loss of Visual Contact

In the event of a visual loss of contact of both the pilot and observers with the aircraft, the following procedures will be followed:

- Neutralize control inputs to the aircraft to minimize further movement.
- All available personnel will scan the skyline for the aircraft.
- If not initially visible, slowly increase the altitude of the UAS while scanning the area.
- Once visual contact has been made, return the aircraft to the landing zone.
- In the event the aircraft is still not visible, trigger the failsafe return to home if the aircraft is equipped. Once the UAS is within sight, retake control and land the aircraft.
- If visual sight and control of the aircraft cannot immediately be restored (within approx. 30 seconds) the procedures outlined for fly-away and emergencies should be put into effect.

Aircraft Ditching

If unusual or abnormal aircraft operations are observed by either RPIC or observers, and normal control cannot be restored, the aircraft may need to be ditched in the nearest safe, clear area away from spectators and structures. This is largely dependent on the location of the operation and current level of risk. When normal control is lost, all reasonable efforts should be made to regain control. If control cannot be regained then emergency procedures should be put into effect, and proper accident/incident reporting procedures followed. Potential ditching zones should be noted during the site survey process and reviewed prior to all flight operations.

If the aircraft includes flight termination systems, they should be used as a last resort to terminate the flight of the aircraft in emergency situations where control cannot be regained immediately, or a manual ditching is performed. Emergency procedures should be followed in the event of a flight termination, and proper accident/incident reporting procedures should be followed. Consult the aircraft manufacturer user manuals for specifics on operation of the termination systems.

Post-Flight Procedures

The following checklist will be reviewed following all flights within an operation:

- Using flight controller, preview captured data to verify that data has been recorded and saved on the memory card.
- Power down aircraft.
- Power down onboard payloads and associated equipment.
- Power down control link transmitter.
- Return all equipment to a safe staging area.
- Notify team and bystanders that the flight is complete.
- Visually inspect aircraft and gear for any damage or wear from the flight.

Post-Operation Procedures

The following checklist will be reviewed following an operation:

- Remove any notifications, safety equipment, or other pertinent items from the area.
- Pack and store all aircraft and equipment for departure from the site.
- Return/replace any items moved/dismantled from the area to their prior state.
- Notify the team, and bystanders that the operation is complete.

- Where necessary, inform the authorities of the completion of the operation.
- If appropriate complete post flight checklist and record flight times, batteries, and sensors used.
- Report any incidents to the proper authorities.

5.0 LEGISLATIVE CONSIDERATIONS

New Hampshire State Code does not include many mentions of UAS, drones, or unmanned vehicles. However, UAS use is becoming more commonplace among State DOT's and their contractors. The discussion in this section refers to general state law and is not policy-specific to the UAS program.

To help the state prepare for UAS issues that might arise in the future, Aeronautics is the natural statutory and divisional location for regulating and implementing UAS laws. Aeronautics and other New Hampshire entities are currently working towards proposing legislation to tie the State's Aeronautics Act Section 422 to the State's Criminal Code in Section 644. The Federal Government currently has jurisdiction over UAS operations, airspace, and airman. New Hampshire takes a prudent and incremental and targeted approach to adding new UAS legislation to align with Federal regulations.

It is the prerogative of the legislature to draft the proper policies that best fit the state. Potential basic regulatory topics are described below relative to UAS operations. The legislature might or might not consider any number of specific variations of these topics, and the following may or may not be appropriate for New Hampshire:

> **Registration:** Registration of aircraft can help inform state agencies on the number of aircraft and, by association, the number of UAS operators in the state. Registration can also help to track and identify operational use cases, which can assist with future Advanced Air Mobility (AAM) development. NH does not currently require UAS to be registered with the State. The states that currently have UAS registration legislation are noted in Appendix C.
>
> **Operations:** While the FAA dictates operational standards, the state might also consider regulating UAS be operated in a safe and responsible manner. This includes following all applicable FAA regulations, as well as any additional state or local laws. For example, states may prohibit UAS take-offs and landings in certain areas, such as near airports or prisons. This is known as regulating time, manner, and place.
>
> **Privacy:** Privacy laws are the purview of the state. The legislature might consider any number of privacy laws to prevent UAS from being used to violate the privacy of others. Some examples from various States are provided in Appendix C.
>
> **Safety:** This topic is always paramount for every level of regulations. UAS must be operated in a way that does not endanger the safety of others. This includes avoiding flying near manned aircraft, and it also includes flying at a safe altitude. While the prime directive of the FAA is ensuring aviation safety, the state legislature might consider establishing its own policies regarding the safety of aircraft operations.
>
> **Liability:** The FAA does not regulate or require aircraft insurance. As a result, aircraft insurance and liability have been contentious topics of discussion in many states. The legislature might consider liability regulations to ensure that UAS operators are liable for any damage or injury that their aircraft cause. This will help to ensure that people or property who are injured or damaged by unmanned aircraft may be compensated for any costs or losses.

In addition to these basic law topics, the State of New Hampshire may also want to consider enacting laws that address specific issues related to UAS, such as:

> **Commercial Operations:** The New Hampshire legislature may consider regulating commercial UAS operations, such as those used for delivery services or aerial taxis. Regulation at the state

level in these cases can be enabling rather than stifling by preventing a patchwork quilt of regulations from city to city with which operators have to learn and comply with depending on their location.

State Agency Appropriations: The New Hampshire legislature may consider encouraging the development of UAS use within state agencies such as the DOT and Division of Aeronautics. Using UAS to accomplish inspections, surveying, mapping, and other jobs that are dull, dirty, or dangerous saves the State time and more importantly, taxpayer money.

Disaster Response: New Hampshire may consider developing plans or a Memorandum of Understanding (MOU) with other State agencies for using UAS in disaster response situations. As part of the MOU training and coordination with all responding State agencies on how UAS would be leveraged during an emergency. UAS can be used for pre- and post-disaster photos for comparison and restoration planning. AAM vehicles such as delivery drones could also be used to deliver essential lifesaving items into isolated or cutoff communities after a natural disaster.

Other legislative considerations regarding UAS commercial package delivery and other emerging UAS technologies are included in Appendix C.

6.0 SUMMARY AND CONCLUSION

In conclusion, NHDOT has made significant progress in establishing a robust UAS program, and its commitment to this initiative is evident throughout its recent accomplishments and investments. Over the past several years, NHDOT has taken several crucial steps toward building a well-organized and fully operational UAS program.

NHDOT demonstrated its dedication to the UAS program by procuring five diverse UAS platforms. These platforms represent a strategic investment in modern technology that will enhance NHDOT's capabilities in various aspects of its operations. In addition, the official appointment of a UAS Planner in 2021was a pivotal milestone. The establishment of this position solidifies NHDOT's initial commitment to the UAS program and signifies the importance the organization places on the successful implementation of UAS technology. NHDOT furthered its commitment to the UAS program by authorizing a new UAS Specialist position to support the UAS Planner. It is highly recommended that NHDOT goes a step further and elevate the UAS Planner to a UAS Program Manager to facilitate the operational duties in the Bureau of Aeronautics with a focus on the increasing dynamics and demands of the UAS program. This will effectively set up a new Operations section within the Bureau of Aeronautics to address UAS mission demand at NHDOT. With a dedicated UAS Specialist assisting the UAS Program Manager, there will be a focused and well-coordinated effort to lead and guide the UAS program toward success. This provides the basic organizational structure that will provide the foundation for oversight of UAS operations and to allow the UAS program to meet future demand by training additional current NHDOT staff from other non-Aeronautic Bureaus as UAS pilots to perform some of the routine flight missions in high demand bureaus.

Furthermore, the strategic decision to house the UAS program within the Bureau of Aeronautics demonstrates NHDOT's forward-thinking and integrated approach to managing aerial technologies. By utilizing a centralized control within the Bureau of Aeronautics and targeted decentralized execution format, NHDOT can continue to leverage the expertise and resources already available within the Bureau of Aeronautics, fostering a smoother integration process of UAS implementation into NHDOT's workflow. As further discussion regarding UAS use statewide continues, decisions can be made to adjust the UAS program and these recommendations accordingly to meet demand for UAS services at NHDOT.

The recent approval of funding for an additional UAS Specialist position to assist with the UAS program is yet another strong signal of NHDOT leadership's commitment to the adoption and integration of UAS Technologies into NHDOT workflows. This funding allocation indicates that NHDOT is willing to invest in expanding the UAS program's resources to facilitate its continued development and that the benefits already being received are valuable and worth investing in. If possible, this UAS Specialist position should be filled by an individual with strong data processing and analytic skills to fill the gap that was identified for time associated with, and expertise in, processing UAS-collected data.

These investments in the UAS program and full leadership support have created a conducive environment for fostering innovation and operationalizing UAS technology across various use cases at NHDOT. By adopting a comprehensive UAS implementation plan and the necessary UAS program governance documents, NHDOT can create a well-structured and standardized framework for UAS operations. This framework will allow the seamless integration of UAS technology into the prioritized use cases: Surveying and Mapping, Construction Monitoring, Structural Inspection, TSMO, Emergency Response, and Asset Maintenance and Operations.

To assist with the preparation of the UAS program governance document including a program charter, privacy policy, operations manual, safety management plan, and operating procedures, the UAS Program

Manager should pursue establishing a UAS Stakeholder Committee. The UAS Stakeholder Committee, when developed and used correctly, can be an integral piece to a mature and successful UAS program.

While the UAS program is currently poised for continual and steady development across all phases of the UAS implementation plan, the UAS Program Manager will play a crucial role in expanding the scope of UAS adoption within NHDOT. Using the pilot project planning criteria, the UAS Program Manager can explore the integration of UAS technology in additional use cases. Moreover, tracking ROI will provide valuable insights into the cost-effectiveness of UAS implementation and support future decision-making processes. The NHDOT should consider recouping expenses associated with the UAS missions by charging labor, expenses, and overhead to the authorized project.

At the rate the UAS program is currently developing, and is anticipated to develop, NHDOT leadership should begin to plan for additional space to accommodate the UAS program team, secure equipment storage, a maintenance area for equipment, fireproof environment for battery storage, and a UAS training and testing facility. The current Bureau of Aeronautics physical office space to house UAS operations may reduce efficiency and hinder the ability for the UAS program to develop to its full potential. New UAS facilities, would make possible the ability for NHDOT's UAS program to become a central Statewide hub for UAS State agency operations. Also recommended is a four-wheel drive truck with cap and integrated battery charging hookups as a critical tool for the safe, successful implementation and development of NHDOT's UAS program.

As NHDOT evaluates its UAS platform needs over time, new or replacement UAS platforms with improved or unique capabilities should be considered and measured against forecasted UAS mission needs for NHDOT. Supporting software and ancillary equipment may also be needed and should be considered. NHDOT should take advantage of available grant programs for new UAS platforms and ancillary equipment while also being cognizant of changing federal and state requirements to be sure that future platforms can be utilized successfully in the future.

It is recommended that NHDOT re-evaluate the recommendations of this report annually using *Table 1: Implementation Phases* as a checklist. This table serves as triggering actions and demand thresholds to be sure that the appropriate next steps are taken at the appropriate time.

In conclusion, NHDOT has taken commendable strides toward establishing a strong and sustainable UAS program. The Department's initial progress in procuring UAS platforms, appointing a dedicated UAS Planner, and formalizing the program's organizational structure reflects its commitment to embracing cutting-edge technology. By adopting a well-structured UAS implementation plan and governance framework, NHDOT is poised to integrate UAS technology successfully into various operational areas. As the UAS program continues to grow, a UAS Program Manager will have the opportunity to explore additional applications, providing valuable data to support informed decisions. With full leadership support, NHDOT's UAS program is positioned for long-term success, contributing to enhanced efficiency, safety, cost saving, and innovation in transportation operations across the state of New Hampshire.

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APPENDIX A: ORGANIZATIONAL STRUCTURE MODELS

Below are the descriptions and overall discussion of the advantages and disadvantages to each Organizational Structure Model for Unmanned Aircraft Systems (UAS) programs.

Organizational Structure Models

When a State Department of Transportation (DOT) plans to integrate the use of UAS into its operations, it must consider various organizational structure models. This section provides an overview of three organizational structure models generally found throughout the nation. The positions within these various models are essentially the same, the role and responsibilities for each position role is defined and discussed.

UAS Organizational Structure – Division of Aeronautics

The most adopted model is to organize the UAS program under the Division of Aeronautics. Twenty-four states are currently using this model. Figure A-1 outlines the structure of having a UAS Program Manager within the Division of Aeronautics who oversees a UAS training coordinator, full-time UAS pilots, functional department pilots, and supplemental consultant pilots on an as-needed basis.

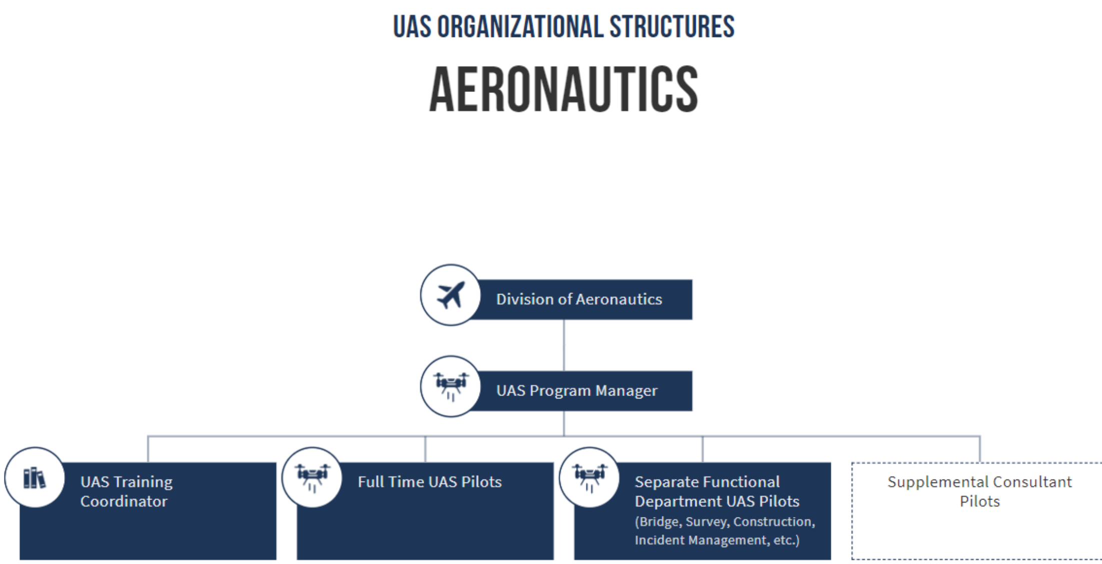

Figure A-1. UAS Organizational Structure – Aeronautics.

One of the essential advantages to this model is the ability to leverage existing aviation knowledge, expertise, and resources that are critical to establishing a successful UAS program with lower overhead since existing resource like office space and office equipment don't need to be procured. Having a relationship with the Federal Aviation Administration (FAA) and understanding Federal Aviation regulations are crucial components to the UAS program (Banks et al., 2018). The Aeronautics model already includes people who understand FAA terminology; have a working relationship with the FAA;

and may have a pilot background with knowledge of checklists, aircraft operations, airspace, emergency procedures, and other key functions of establishing the UAS program.

A potential disadvantage of this model is that the Aeronautics organization may be siloed and may not understand the various functions of the other divisions within the State DOT. The Aeronautics organization may lack the specialty knowledge for mission-specific needs and surface transportation use cases for UAS. A solution to this potential disadvantage is the creation of a UAS committee comprising key stakeholders from the different departments seeking to employ UAS in their operations. This committee can create an impactful platform for collaboration and communication between the UAS program personnel and the functional departments seeking UAS assets. Alternatively, use of embedded UAS operations crew members within other divisions of the State DOT can help ameliorate this disadvantage.

Other mitigations include using checklists for the requesting bureau and for the Bureau of Aeronautics to determine the expectations and use of the deliverables. The requesting bureau and Bureau of Aeronautics can also have a pre-UAS operation meeting for more complex operations. These checklists or meetings will also help the requestor to notify aeronautics about any changing regulations, for example if regs change on data requirements for the use case, e.g., surveying, bridge inspection, geotechnical, environmental.

It was determined in this study the Bureau of Aeronautics within NHDOT have strong relationships with other bureaus. These relationships will serve as a foundation to implementing these mitigations as needed.

A consideration for each of the UAS organizational models is that of funding sources. Under this Aeronautics organizational model, it must be determined how a dedicated budget can be added to the existing Aeronautics' budget. These dedicated funds should be secured for the UAS program with a focus on initial costs, ongoing maintenance, and program growth.

UAS Organizational Structure – Department of Transportation

The second most popular (21 states) organizational structure model observed nationally is to arrange the UAS program and personnel under another division(s) within the DOT that is(are) not the Division of Aeronautics. For example, Virginia houses its UAS program within the Office of Research and Innovation, while Colorado's UAS program is within the Survey, Mapping, and GIS Division of Project Support.

Figure A-2 outlines this structure, which offers a condensed organizational structure compared to the Division of Aeronautics model. Under this DOT model, each functional department using UAS has its own personnel with the added responsibility of conducting UAS operations specific to their needs. While each functional department has their own UAS pilots, it is still essential to have a clear line of command and the oversight of a UAS Program Manager which would be under the direction of whichever functional division or bureau the program is housed within. But this model can be very challenging especially if the functional departments are culturally siloed or don't support the need to coordinate with a UAS Program Manager or there isn't support for the internal UAS program from State DOT leadership. Depending on the size of the program, it may also require a dedicated UAS training coordinator to work across these functional departments with all UAS personnel. These positions may be shared duties with existing positions, or if the workload of the UAS program requires, these may need to be full-time UAS program specific positions.

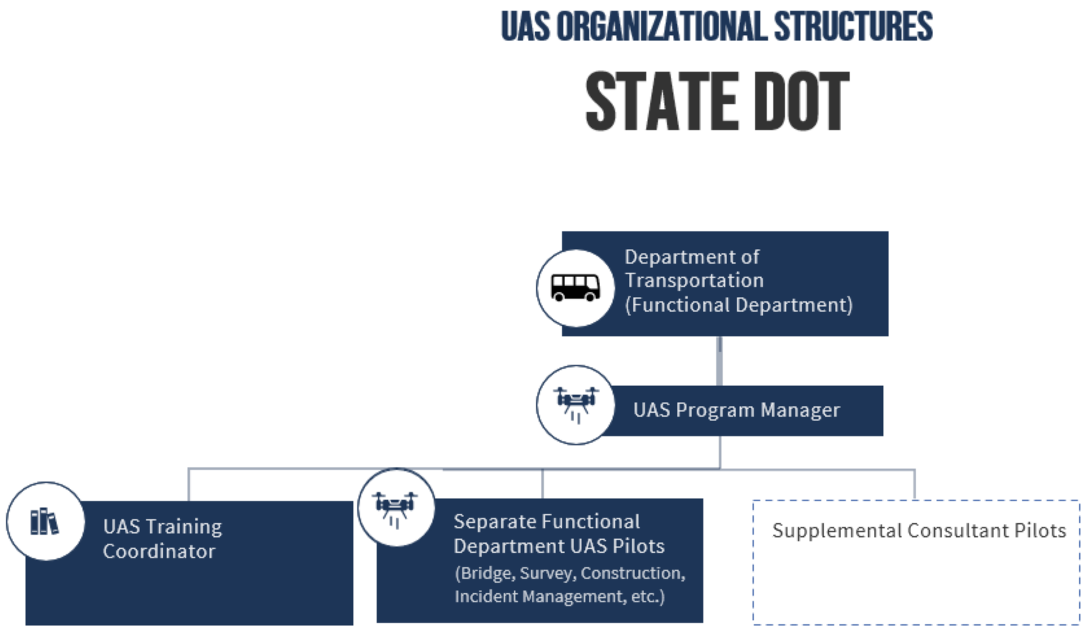

Figure A-2. UAS Organizational Structure – Department of Transportation.

This organizational structure model has similar advantages and potential disadvantages as the Division of Aeronautics model but in the reverse. The advantage of the DOT model is that the personnel within the various functional departments adopting UAS are subject matter experts (SMEs) on the focus point of the data collection. For example, in a bridge inspection, the engineers and construction specialists have the experience and knowledge to conduct a thorough inspection. These SMEs can acquire the knowledge necessary to employ UAS into their operations, and their historical expertise will likely be advantageous for these types of inspections.

The possible drawback of this model is the lack of aviation knowledge that is critical to the success of the UAS program. States often struggle to stand up a UAS program under this model unless there is a champion with aviation knowledge leading the program development. A possible solution to this problem is the same as previously mentioned: the need to establish a UAS committee as a core part of the program to leverage the strengths of each department. This model structures the overall design of the UAS program differently than the Aeronautics model; however, the leadership of a UAS Program Manager and a strong internal training program are still vital components of the program.

It was determined that because of the five plus years of steady development and progress that NHDOT has made establishing its UAS program through the Bureau of Aeronautics that this DOT organizational structure model is not a suitable option.

UAS Organizational Structure – Centralized UAS Department

The third organizational structure model is to have an independent, centralized agency that conducts all UAS operations across the State. This centralized UAS department is *independent* of the State DOT and maintains its own dedicated budget, full-time personnel, and equipment. In Figure A-3, this organizational structure is depicted as a central agency that has a UAS Program Manager, UAS training coordinator, full-time UAS pilots, and the potential use of consultant pilots when needed. These full-time UAS pilots would fly every operation needed across the different functional departments of a DOT and other state organizations.

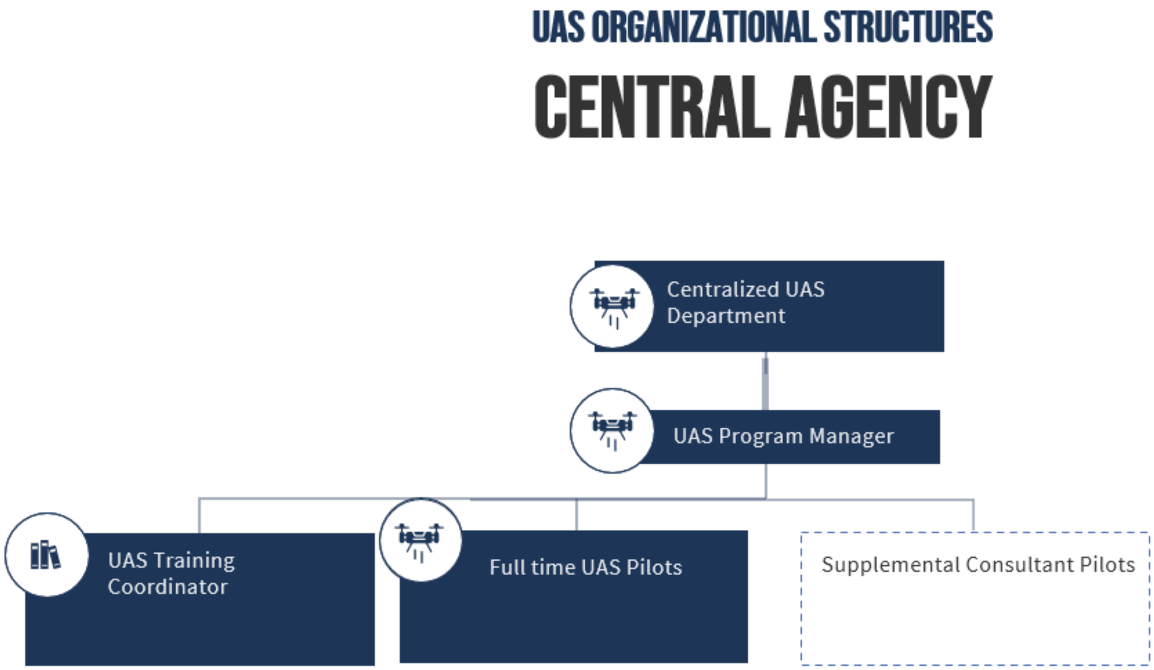

Figure A-3. UAS Organizational Structure – Centralized UAS Department.

A key strength of this organizational structure is the full control of the UAS program that is afforded by the nature of it being an independent, centralized agency supported and directed by the Governor. Another potential advantage is the scalability of this model that may not exist in the same way in the other two models. Depending on the volume of UAS operations throughout a particular state, this model can be expanded by creating additional positions in the form of regional or functional UAS program managers.

Ohio is the only current example of a truly separate and centralized UAS agency, known as the Ohio UAS Center and founded in 2013. The Ohio UAS Center deploys UAS pilots to meet the needs of the Ohio DOT and other local or state agencies (Ohio UAS Center, n.d.a). In addition to meeting the UAS operations for the state, this center has expanded into research initiatives, created key federal partnerships, and is planning for the integration of various Advanced Air Mobility (AAM) technologies (Ohio UAS Center, n.d.b).

A lesson learned from the Ohio UAS Center is that although the centralized UAS agency has highly proficient and experienced UAS pilots, there are occasions when these pilots lack the functional knowledge for specific operations. Returning to the bridge inspection example explored in the previous model, at times UAS pilots lack the expertise needed on how to best execute such an inspection so that expectations of the deliverables can be met the first time. This highlights the need for true collaboration and teamwork where the strengths of all involved SMEs can be leveraged.

While the centralized UAS department model has strengths, it is rare, with only one State using the model. It is budget intensive to establish this model and should only be pursued if the demand for UAS operations grows in such a way that the Bureau of Aeronautics model is no longer sustainable. Due to the size of the State of New Hampshire and anticipated UAS operations it was determined that this organizational model is not suitable for NHDOT.

Organizational Structure Models Summary

Figure A-4 offers a visual representation of which of the UAS organizational structure models have been adopted by the different states.

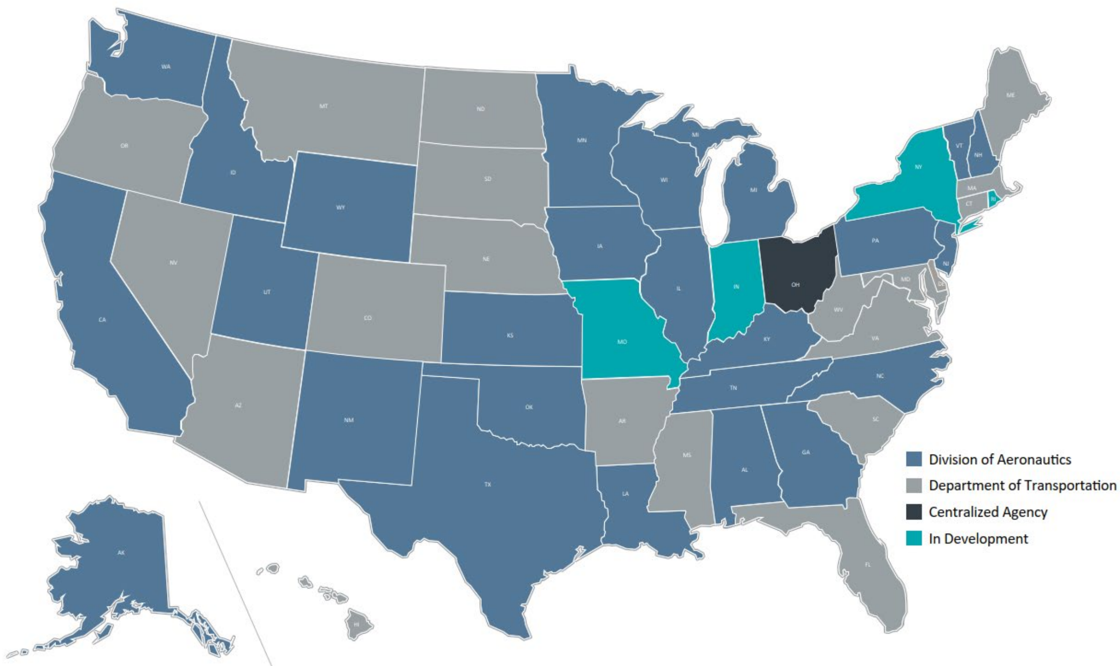

Figure A-4. UAS Organizational Structure Model Adoption by State.

Each of the various UAS organizational models has advantages and disadvantages to consider, but there are significant similarities between models. Regardless of the chosen organizational model, it is important to consider the following to ensure the success of the UAS program:

- Seek top-down support.
- Establish a clear chain of command.
- Collaborate with the existing aviation SMEs.
- Secure a dedicated and separate UAS program funding source.
- Create or nurture an established relationship with the FAA.
- Dedicate personnel to the management of the UAS program.
- Collaborate across departments by establishing a UAS stakeholder committee.
- Allow flexibility to modify the organizational structure as it matures or meets new challenges and requirements.

The above list was adapted from the NCHRP Project 20-68A, Scan 17-01: Successful Approaches for the Use of Unmanned Aerial Systems by Surface Transportation Agencies.

APPENDIX B: NHDOT UAS POLICY AND PROCEDURES

Prior to this project these draft Standard Operating Procedures were created and have been updated based on the recommendations provided within this report. Below is the updated draft copy of the NHDOT Standard Operating Procedures document.

New Hampshire Department of Transportation

Unmanned Aircraft System

Standard Operating Procedures

New Hampshire DOT

Bureau of Aeronautics

Revised 08/2023

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PREFACE

The following procedures are intended to promote safe, efficient, and lawful operation of the New Hampshire Department of Transportation (NHDOT) Unmanned Aircraft Systems (UAS) program. Above all else, safety is the primary concern in each operation, regardless of the nature of the mission. The purpose of this manual is to provide guidance for safe flight operations, operator training, safety measures, maintenance procedures, and the work order process for the NHDOT UAS program. The manual will be kept current using revisions. A copy of this manual, including all changes and revisions, will be available to all designated UAS team members.

NHDOT will keep a current and complete UAS flight operation manual available for each individual UAS. The UAS Program Manager is responsible for keeping this document current. UAS operators providing UAS support to NHDOT will be governed by this document.

The UAS Program Manager will make a concerted effort to ensure that this document is not contrary to any applicable law or FAA regulation. If a conflict occurs, the applicable law or Federal regulation will take precedence. It is the UAS Program Manager's responsibility to ensure that all FAA waivers or authorizations are current and in compliance. Any discrepancy within this document will be brought to the attention of the UAS Program Manager.

DISTRIBUTION

All UAS SOP Manual revisions will be prepared by the UAS Program Manager, and a copy of this manual will be available to all areas of responsibility within NHDOT, including butnot limited to:

- UAS Management Personnel
- UAS Maintenance Personnel
- UAS Flight Personnel

PHILOSOPHY & MISSION STATEMENT

All NHDOT UAS team members should develop and document operational procedures that will serve to guide flight operations, planning and execution. The Standard Operational Procedures (SOP) documents best practices and internal processes for safe and effective flight operations. This includes roles and responsibilities, mission phases, and emergency procedures. The aim is to document everything that needs to be done during a mission, from receipt of UAS support to mission complete, so it can act as a reference point for all team members. The information in this document is to provide a process for NHDOT to ensure that UAS operations are conducted under FAA 14 CFR Part 107, and any applicable State of New Hampshire rules, procedures, or guidance. When there is no applicable Federal, State or NHDOT guidance, use your best judgment and error on the side of safety.

PROTECTION OF RIGHTS AND PRIVACY

NHDOT UAS operators will respect and ensure that the protection of private individuals 'civil rights' and 'expectations of privacy' are respected before deploying the Unmanned Aircraft System (UAS). UAS operators will be held accountable for ensuring that the operations of the UAS will pose minimal interference as possible to private persons and businesses. To accomplish this primary goal, UAS operators will observe the following:

4.1. NHDOT will not conduct any type of non NHDOT related surveillance activities. The use of the UAS is to be tightly controlled and regulated.

4.2. All authorized UAS missions are only for:

4.2.1. Conducting information/data gathering on existing or proposed NHDOT projects.

4.2.2. Conducting detailed inspections of NHDOT signs, bridges, or other State of New Hampshire property.

4.2.3. Conducting damage assessment as a result of natural or man-made disasters.

4.2.4. Conducting training for new or current UAS operators.

4.3. NHDOT UAS operators will operate strictly within all Federal, State and NHDOT law, regulations, and policies. If in doubt, prior to conducting UAS operations the Pilot in Command (PIC) will contact the UAS Program Manager for guidance.

ADMINISTRATION

5.1. Operations Manual

5.1.1. The policies and procedures contained in this manual are issued by NHDOT. As such it is an official NHDOT document.

5.1.2. This manual does not supersede any FAA or any other federal or state regulation.

5.1.3. Definitions

5.1.4. Below are succinct definitions of key roles, additional responsibilities of these roles are outlined throughout the document.

5.1.4.1. UAS Program Manager is responsible for oversight of any UAS operations undertaken in support of NHDOT business or activities.

5.1.4.2. UAS Senior Operator (SO) supports and assists the UAS Program Manager and is responsible for the day-to-day operations and serves as the training coordinator for NHDOT UAS operators.

5.1.4.3. Pilot in Command (PIC) is the primary authority for any mission. The PIC is responsible for meeting all regulatory requirements are met; adhering to the operation plan and any existing safety standards; making sure crew members are aware of their individual responsibilities; and conducting pre-flight, pre-landing, and post-flight checks.

5.1.4.4. UAS Operator is one who supports the UAS Program Manager and SO in the daily NHDOT UAS operations.

5.1.4.5. UAS Technician is one who maintains UAS hardware and software, and other equipment used to execute UAS operations.

5.1.4.6. Visual Observer (VO) is one who observes the airspace for other aircraft or hazards and maintains effective communication with the PIC at all times.

5.1.4.7. Air Crew Member (ACM) refers to any member of the UAS operations team or crew performing NHDOT UAS operations.

5.1.5. The purpose of this document is to provide operational and training requirements, regulations, information, and policy guidance regarding how NHDOT will conduct all UAS flights, both training and operational.

5.1.6. All NHDOT personnel and contractors engaged in UAS activities in support of NHDOT must read and comply with all requirements of this documents unless receiving approval from the UAS Program Manager, who has reviewed and documented the deviation. Additionally, the PIC is always authorized to deviate from this or any other regulation to avoid an accident or incident.

5.1.7. This manual is applicable to all aspects of UAS training and operations. If events occur that are not addressed in this document, the PIC will contact the UAS Program Manager for guidance. In the absence of guidance from the UAS Program Manager, the PIC will contact the UAS Senior Operator. If the UAS Senior Operator is not available, the PIC will use their best judgment and common sense to resolve the issue. Any deviation from this document will require a written statement from the PIC to the UAS Program Manager stating the issues and what actions were taken.

5.1.8. A copy of the manual (electronic and/or paper) is issued to every person having UAS responsibilities and will be on-hand during all UAS flight activities.

5.2. Personnel

5.2.1. The UAS Program Manager is responsible for the overall direction and performance of the UAS team and exercises command and control over it.

5.2.2. The UAS Program Manager is responsible for day-to-day operations and manages all pilots within the group.

5.2.3. The UAS Program Manager is responsible for organizing and managing the UAS Steering Committee. The UAS Steering Committee assists with the oversight of the UAS program. The committee is to serve as a central governing body to strategize, plan, and implement policies and procedures to govern UAS operations within NHDOT.

5.2.4. The UAS Senior Operator (SO) supports and assists the UAS Program Manager and is responsible for the day-to-day operations and serves as the training coordinator for the group.

5.2.5. The UAS Operator supports the Senior Operator in day-to-day operations and serves as the Safety Coordinator.

5.2.6. The UAS Technician maintains all UAS equipment and software.

5.2.7. Pilot in Command (PIC): The PIC primary duty is the safe and effective operation of the UAS in accordance with the manufacturers' approved flight manual, FAA regulations and NHDOT policy and procedures.

5.2.7.1. A PIC must be designated for each flight and must be qualified and current in the UAS type and cannot be changed during the flight unless the PIC is unable to continue their duties. Current is defined as the ability to provide proof of completion of a related UAS mission or training within 60 days prior to the requested mission date.

5.2.7.2. A PIC must also meet any additional requirement under FAA or NHDOT guidance.

5.2.7.3. A PIC must possess a current FAA Part 107 Remote Pilot certificate and has ultimate authority over the flight and is responsible for all actions of other crew members involved in the flight.

5.2.7.4. A PIC must meet the requirements for and successfully pass the NHDOT UAS Basic Operating Course (BOC) to be certified as a PIC. The NHDOT UAS BOC is discussed in Section 7: Training.

5.2.7.5. Once a PIC has been authorized to conduct UAS operations independently, he or she can conduct the operation without direct supervision. Information on these approvals and mission risk analysis is in Section 5.3: Waivers and Authorization System.

5.2.7.6. A PIC meets and maintains both proficiency and currency on all systems authorized to operate.

5.2.7.7. A PIC must read and be familiar with this document and all other federal, state, and NHDOT regulations, policies, and procedures.

5.2.7.8. A PIC must understand and comply with FAA Regulations applicable to the airspace where the UAS operates and be able to Interact with Air Traffic Control (ATC).

5.2.7.9. A PIC shall have sufficient system and mission expertise to perform the tasks assigned.

5.2.7.10. A PIC must be able to determine whether the UAS is in a condition for safe flight.

5.2.7.11. A PIC must ensure that a site survey and risk assessment is completed prior to the first flight.

5.2.7.12. A PIC must conduct a pre-flight inspection and post-fight inspection for each mission ensure the UAS is in safe working order.

5.2.7.13. Note: The PIC may be temporarily removed from flight status at any time by either the UAS Program Manager or SO, for reasons including performance, proficiency, physical condition, etc. Should this become necessary, the operator will be notified verbally and in writing of the reason, further action to be taken and expected duration of such removal.

5.2.8. Remote Pilot in Training (RPIT): The RPIT is an individual who is still in training to become a PIC. The RPIT is able to operate the aircraft controls under the guidance of the PIC, who is in a position to take control of the aircraft if necessary. The RPIT has passed the FAA Part 107 certification test and is working towards completing NHDOT requirements to become PIC or is currently in the process of obtaining the FAA Part 107 certification.

5.2.9. Visual Observers (VO): The VO primary duty is to assist the PIC by maintaining visual observation of the UAS and surrounding airspace at all times to ensure the UAS does not interfere with ANY manned aircraft or other object either aloft or on the ground. The VO does not need to be FAA Part 107 certified but should have a basic working knowledge of the UAS capabilities and limitations. The VO duties are:

5.2.9.1. A VO observes the airspace for other aircraft or hazards.

5.2.9.2. A VO maintain effective communications with the PIC at all times.

5.2.9.3. The VO must be provided with sufficient training to communicate clearly to the operator and VO will give flight instructions required to stay clear of conflicting traffic and obstacles. The UAS Senior Operator maintains a file for each observer, which includes copies of training records, UAS incidents, etc.

5.3. Waivers and Authorization System

5.3.1. Waivers from FAA requirements must be submitted through the FAA waiver process. Waivers from other federal or state requirements will be submitted for review by the UAS Program Manager to the appropriate agency.

5.3.2. Waivers from the FAA, federal or state agencies will be maintained by the UAS Program Manager, and a copy will be provided for each UAS, or team as required.

5.3.3. Waivers from this document will be submitted via writing to the UAS Program Manager. The UAS Program Manager has the authority to waive requirements that do not conflict with any FAA, federal, state or NHDOT regulations policies or requirements. These waivers will be approved in writing and a copy maintained with the UAS or team.

5.3.4. When an NHDOT SOP waiver is issued, it should be in writing and shall be valid no more than the length of the applicable project. The waiver should be attached to the work order.

5.3.5. All UAS operators will conduct a risk analysis for each UAS operation and assign a level or risk associated with the mission. All High-Risk Safety Assessments should be submitted via writing to the UAS Program Manager for review.

5.3.6. Requests for support from third parties will be responded to by the UAS Program Manager. Should the request involve an immediate threat to life, or property, the PIC is authorized to accept or decline the request based on any aspect of the situation and platform being utilized. Proper policy and procedure, as well as FAA regulations, must be followed when accepting mutual aid support for the UAS.

5.3.7. Complaints or inquiries regarding UAS operations must be referred to the UAS Program Manager.

5.4. Miscellaneous

5.4.1. Any Inquiries from the news media or other must be forwarded to the NHDOT Public Information Officer. Operators / Observers shall follow currently established company policy regarding interactions and inquiries from the media.

5.4.2. Requests for support from entities outside of NHDOT will be responded to by the UAS Program Manager if available, if not the Senior UAS Operator will respond. Should the request involve an immediate threat to life, or property, the operator is authorized to accept or decline the request based on any aspect of the situation and platform being utilized. Proper policy and procedure, as well as FAA regulations, must be followed when accepting mutual aid support for the UAS.

SAFETY

6.1. Safety Policy: NHDOT is committed to a safe and healthy workplace including the following.

6.1.1. Accident-free workplace, including injury to persons, damage to private property, state property or UAS equipment.

6.1.2. A culture of open reporting of all safety hazards in which management will not initiate disciplinary action against any person who, in good faith, discloses a hazard or safety occurrence due to unintentional conduct.

6.1.3. Create strong safety training and awareness programs.

6.1.4. Conducting regular audits of safety policies, procedures, and practices.

6.1.5. Monitoring the UAS community to ensure best safety practices are incorporated into the organization.

6.2. Flight Team Duties: It is the duty of every member of the UAS flight team to contribute to the goal of continued safe operations. This contribution comes in many forms and includes always operating in the safest manner practicable and never taking unnecessary risks. Any safety hazard, whether procedural, operational, or maintenance related must be identified as soon as possible. Any suggestions in the interest of safety should be made to the UAS Program Manager.

6.2.1. While every member of the UAS flight team will contribute to safe operations, the final responsibility of the UAS operation lies with the PIC for the operation. The PIC will perform a thorough site analysis for each operation and determine the level of risk associated with the site and overall operation.

6.3. Safety Halt: If any member observes or has knowledge of an unsafe or dangerous act being committed and continuation of that action possesses a danger to NHDOT personnel, property, or other non-team persons, they are obligated to call a "safety halt" to that operation. The UAS Program Manager is to be notified immediately, if practical, so that corrective action may be taken. A post flight review of the incident will also be reviewed.

6.4. Safety Training

6.4.1. The UAS-SO will conduct a safety class for all NHDOT UAS team members, to include VOs, a minimum of once semi-annually.

6.4.2. Safety training will be inaugurated into each aspect of UAS training. At a minimum, all members of the UAS section team will receive training in the following subjects prior to operating the UAS:

6.4.2.1. NHDOT commitment to safety.

6.4.2.2. NHDOT UAS safety program.

6.4.2.3. NHDOT UAS mishap procedures.

6.4.2.4. NHDOT UAS team member's role in safety.

6.4.2.5. Emergency safety procedures.

6.4.3. All safety training received will be recorded in each Air Crew Member (ACM) Information and Training File, by the UAS-SO.

6.5. Mishap Reporting Procedures

6.5.1. The purpose of this procedure is to document the processes for handling mishaps that occur during UAS flight operations.

6.5.2. The scope of this section covers all NHDOT UAS operations, regardless of who owns the equipment. It applies to ALL flight operations, to include, but not limited to; commercial, training, currency, maintenance, and R&D. This mishap plan cannot address all incidents/mishaps. Consequently, when determining the appropriate action to take, common sense must be used. When in doubt, contact the UAS Program Manager, UAS Senior Operator, or Aeronautics Senior Aviation Planner for direction.

6.6. The understanding of the definitions of accident, incident, and occurrence are essential in interpreting mishap reporting procedures. They are as follows:

Aircraft Accident: NHDOT aligns its definition of aircraft accident with that of the FAA in Part 107.9. An accident is defined as an event associated with the operation of an aircraft which takes place between the time of takeoff to landing, in which any person suffers death or serious injury, or any loss of consciousness, or in which damage to property (other than the aircraft) occurs and is greater than $500 at fair market value.

Aircraft Incident: NHDOT UAS Incident is an unplanned event, i.e., Loss of GPS or failure of the sensor, which does not cause injury or damage (property or aircraft). Depending on the severity of the event there are several options for the PIC. They may decide to use a different aircraft, move to a different location, or retry the same mission. Any incident caused by failure of any part of the UAS system, even if issues appear temporary must be noted in the aircraft logbook.

An incident can also be an event other than an accident that affects or could affect the safety of operations. This could be a Near Midair Collision (NMAC) with a manned aircraft or damage to equipment when setting up or tearing down. A NMAC with manned aircraft is defined as an incident associated with the operation of an aircraft in which a possibility of collision occurs as a result of proximity of less than 500 feet to another aircraft, or a report is received from a pilot of a flight crewmember stating that a collision hazard existed between two or more aircraft.

Aircraft Occurrence: A source of irritation, annoyance, grievance, or nuisance. It is more appropriate to consider an occurrence a minor incident.

6.6.1. **Reporting Requirements:**

6.6.1.1. All aircraft accidents, incidents, and occurrences must be reported in writing to the UAS Program Manager.

6.6.1.2. In the event of an aircraft accident, it must also be reported by the PIC to the FAA within 10 calendar days as outlined in Part 107.9. The UAS Program Manager can assist the PIC with this mandatory reporting process as needed.

6.6.1.3. In the event of a NMAC, it is the responsibility of the pilot and/or flight crew to determine whether a near midair collision did actually occur and, if so, to initiate a NMAC report. Be specific, as ATC will not interpret a casual remark to mean that a NMAC is being reported. The pilot should state "I wish to report a near midair collision." Pilots and/or flight crewmembers involved in NMAC occurrences are urged to report each incident immediately. Reports can be made by telephone to the nearest FAA Air Traffic Control facility or in writing, in lieu of the above, to the nearest Flight Standards District Office (FSDO).

6.6.2. Safety is the number one priority; the PIC will make every effort to avoid injury to personnel and damage to either private or public property. In the event of a mishap, the PIC will quickly evaluate the situation to determine if it is an accident or an incident.

6.7. Mishap Response Plan. NHDOT will establish and maintain a Mishap Response Plan, which includes a response to accidents and incidents. NOTE: NHDOT shall review and dry run the Mishap Response Plan on an annual basis. This plan will be initiated should any aircraft in the custody of NHDOT becomes involved in one of the below:

- Aircraft Accident
- Aircraft Incident with manned/unmanned aircraft during flight

6.8. Mishap Checklist - The checklist should be completed before leaving the accident site, this will ensure that all required information is obtained.

6.8.1. **Step 1.** If the mishap is a medical emergency, call 911 and request first responders. If there is a fire that involves more than the aircraft battery, inform the 911 operator, and request the fire department. If the fire can be put out with equipment on hand, extinguish the fire and evaluate if the fire department needs to be called.

6.8.2. **Step 2.** In the event of a medical emergency, after requesting first responders, the operating crew should render any necessary first aid.

6.8.3. **Step 3.** If accident scene will have an impact of the flow of traffic TSMO shall be notified. If first responders have been called do not move any equipment, aircraft, or Ground Control Systems (GCS), and do not shut down any equipment until the police arrive and release the system, unless necessary to do so for safety reasons. Attempt to notify the UAS Program Manager as soon as possible who will in turn notify the Bureau of Aeronautics Administrator, the Public Information Officer, and the FAA Regional Operation Center (ROC). Fully cooperate with authorities and obtain a business card of those individuals you talked with. Prior to moving anything take pictures from all angles and take pictures of the controller screen if necessary.

6.8.4. **Step 4.** If the damage is done to private property or public property, make sure that the property owners are advised of the damage. Obtain property owners information and provide them with the NHDOT UAS Program Manager's contact information.

6.8.5. **Step 5.** Do not discuss details of the operation or what you believed caused the accident to the property owner, the UAS Program Manager will contact them.

6.8.6. **Step 6.** Take detailed pictures and video of all the damage and any other system specific materials from the aircraft. Identify any witnesses. Determine the GPS location of the mishap. Secure the site as necessary.

6.8.7. **Step 7.** If a collision or NMAC occurs, all flight operations will immediately cease and any remaining aircraft airborne will return home and land. In the case of a NMAC, the PIC, observer, or another individual, may have observed the manned aircraft take evasive action. If a NMAC has occurred notify the UAS Program Manager immediately and provide all information available. The UAS Program Manager will notify the FAA and provide all available information.

6.8.8. **Step 8.** The UAS Program Manager will coordinate for the resumption of the operation.

6.8.9. Notification Process: The PIC will notify the UAS Program Manager, of any mishap as soon as possible. The PIC will notify the UAS Program Manager verbally and follow up with a written report within 24 hours. The UAS Program Manager will secure the UAS Maintenance records and the operator's flight records.

6.8.10. All NHDOT UAS operators will be trained on mishap reporting and will review the process annually.

6.9. Medical Factors.

6.9.1. Operator and Observers shall only deploy the UAS when rested and emotionally prepared for the tasks at hand.

6.9.2. Physical illness, exhaustion, emotional problems, etc., can seriously impair judgment, memory, and alertness. The safest rule is not to act as an operator or observer when suffering from any of the above. Members are prohibited from operations when these problems could reasonably be expected to affect their ability to perform flight duties.

6.9.3. A self-assessment of physical condition shall be made by all members during pre-flight activities using the FAA IMSAFE checklist. IMSAFE is an acronym that stands for: Illness, Medication, Stress, Alcohol, Fatigue, Emotion. All crew members should perform a self-assessment of their well-being using IMSAFE.

6.9.4. Performance can be seriously hampered by prescription and over-the-counter drugs. The UAS Program Manager must be advised anytime such drugs are being taken. If it is determined that the medication being taken could hamper an operator or observer, that member shall be prohibited from the deployment or exercise.

6.9.5. No member shall act as an operator or observer within eight hours after consumption of any alcoholic beverage, while under the influence of alcohol, or while having an alcohol concentration of 0.04 (FAR 91.17)

TRAINING

7.1. Objective: The objective of the NHDOT UAS Air Crew Member (ACM) Training Program is to ensure that all UAS operators are qualified, knowledgeable, competent, efficient, and safe in conducting UAS operations. These qualifications will be determined by passing an evaluation. There are three levels of flight training:

7.1.1. The Basic Operator Course (BOC). This course teaches basic operator skills, mission planning, and emergency procedures. The BOC for multi-rotor is very different than the fixed-wing. Completing one does not certify the operator for the other.

7.1.2. The Advanced Operator Course (AOC). This course is mission focused and requires that the ACM be qualified and proficient with the systems that will be used for the mission type. These qualifications will be determined by passing an oral and/or flight review evaluation. There are many types of AOCs. They may include land survey & road construction, bridge & sign inspections, disaster response and many others. The AOC will cover detailed mission planning, flight operations, and data processing if applicable.

7.1.3. Refresher Training (RT). This is required if the operator has not flown the system or similar system in the last six months. Refresher training can consist of:

7.1.3.1. A simple oral review covering the system operating procedures and emergency procedures.

7.1.3.2. An oral and basic flight review.

7.1.3.3. A complete Annual Proficiency and Readiness Test evaluation.

7.1.3.4. Additional Training.

7.1.3.5. All flight training and evaluations will be conducted by the SO.

7.1.3.6. All training will be documented in the ACM’s UAS flight and training file.

7.2. Instructors

7.2.1. The NHDOT UAS Program Manager will assign the SO to conduct all required instruction.

7.2.2. The SO is responsible for conducting the BOC, AOC, Refresher Training, and all evaluations.

7.2.3. The SO is responsible to ensure that each PIC is competent to operate the UAS(s) assigned.

7.3. Training Plans

7.3.1. Flight training consists of the BOC, AOC, and refresher training.

7.3.2. Evaluations are used to validate the ACM knowledge and proficiency.

7.3.3. ACM have a training plan on file that outlines training objectives for the upcoming year. This training plan will be held in conjunction with the member's normal training file per NHDOT policy.

7.3.4. It is ACM's responsibility to verify their training file contains all pertinent information.

7.4. Initial and Advanced Training

7.4.1. Initial Training. All NHDOT UAS team members will go through a formal BOC prior to conducting flight activity, other than acting as the VO. At a minimum, there will be a multi-rotor and/or fixed-wing BOC. Included in the BOC are classes on NHDOT policies, procedures, SOP, and FAA Part 107. Also included in the BOC is first aid training, fire extinguisher training, and mishap response and reporting training. When an ACM passes a BOC for one system, either multi-rotor or fixed-wing, when they attend the other BOC, they only need to take the classes based on the new system.

7.4.2. Advanced Training. Prior to acting as a PIC, the ACM must attendan Advanced Operator Course (AOC) for that system and mission to be flown. AOC will focus more on mission planning, advanced flight skills and proper payload operations.

7.5. Recurrent Training

7.5.1. The NHDOT uses both recurrent training and evaluations to ensure ACMs remain knowledgeable and proficient. Each ACM must pass an Annual Proficiency and Readiness Test which may include a written, oral, and practical evaluation every 12-months. It also requires each ACM to perform certain tasks multiple times within each 12-month period.

7.5.2. Each ACM will also be subject a no-notice evaluation throughout theyear.

7.5.3. An ACM is also required to maintain a level of currency and proficiency. If there is a question as to that proficiency, the UAS Program Manager or SO will conduct a Proficiency Flight Evaluation (PFE) to determine the ACM ability.

7.5.4. Failure to prove proficiency can result in removal from UAS flight responsibilities.

7.6. Miscellaneous

7.6.1. Safety is mission #1. If anyone in the NHDOT UAS program believes that an ACM is unsafe or is not proficient, it is their obligation to notify the UAS Program Manager.

7.6.1.1. Based on the stated level of concern, the UAS Program Manager will conduct an initial investigation. The ACM may or may not be relieved of flight duties until the investigation is complete.

7.6.1.2. If deficiencies are identified, they will be noted in the ACM's flight file. Ifno deficiencies are identified nothing will be placed in the flight file. (However, the individual conducting the investigation will maintain a copy of the investigation.)

7.6.1.3. Based on the investigation, the ACM may be given a PFE to determine the level of deficiency or need for recurrent training.

7.6.1.4. If an ACM feels that they need additional training, they should request it through the UAS Program Manager. No adverse action will be taken if an ACM requests additional support.

GENERAL OPERATING PROCEDURES

8.1. Operating Overview

8.1.1. All UAS operations and/or support for NHDOT will be conducted by the NHDOT UAS team. No department or individual may use any UAS or “drones” to conduct missions in support of NHDOT or contract for UAS support without going through the UAS Program Manager.

8.1.2. All UAS operations will comply with FAA, State of New Hampshire, and NHDOT policies and procedures. The exception to these policies will only be conducted with the approval of the UAS Program Manager and a written statement explaining why will be recorded. The PIC is authorized to take all means necessary to avoid a collision with manned aircraft or potential injury to individuals.

8.1.3. The UAS Program Manager is the only person authorized to submit waivers or airspace authorization request to the FAA.

8.2. Basic Operations

8.2.1. All UAS flights, regular planned missions, and training operations, will be flown under the FAA Part 107.

8.2.2. To fly under the FAA Part 107 the operator and system must comply with all Part 107 requirements.

8.2.3. All NHDOT operations with be conducted using “Sterile Cockpit Procedures”. This covers all aspects of the operation beginning with the pre-flight and ending after the aircraft has landed.

8.2.3.1. No crewmember will perform any duties that are not required for the safe operation of the aircraft.

8.2.3.2. No crewmember will engage in activities that either distract or interfere with standard crewmember’s duties.

8.2.3.3. All non-participating individuals will not interfere with any crewmembers during UAS operations.

8.2.3.4. See-and-Avoid: The PIC is responsible to ensure that the UAS does not interfere with and gives way to ANY manned flight activity.

8.3. Operational requirements. The following areas should be addressed in determining requirements. These requirements are based off the UAS work order that has been approved by the UAS Program Manager, or Sr. Pilot. Based on the work order, the assigned PIC should identify:

8.3.1. The area to be covered. It is important to remember that unless NHDOT has a BVLOS waiver, all flights must be conducted within LOS. Even with a BVLOS waiver most UASs have limited range and flight time making the area to be covered limited per flight.

8.3.2. Type of sensor. There are a large variety of sensors available that can provide singular data. If there are questions as to the right sensor, the PIC should work with the requestor to fully understand the desired data.

8.3.3. Operator qualifications. The UAS Program Manager should make sure that the PIC is qualified and current in the mission set required by the requester. If the PIC is not qualified and current, the UAS Program Manager should change PIC or provided mission training or currency training.

8.3.4. Support equipment required. Examples of these are generators, communications equipment, fuel, vehicle type, boats, computers, monitors, etc.

8.3.5. Support Staff. Will the UAS Team need additional VOs, will they need roads or lanes blocked off? Does the requester need to be at the flight site?

8.3.6. Airspace. Is the flight area within Class C, D, E (to the ground)? If yes, is there a current airspace waiver in place? If no, is the airport listed in LAANC? Can the flights be made under LAANC?

8.4. Work Order Request (M1_Form).

8.4.1. The UAS Program Manager will use the Work Order Request to task ACM to conduct UAS support. Upon completion of the operation, the PIC will update the Status Report on file for the project.

8.4.2. The PIC is responsible for contacting the customer to coordinate the final details. If there is a significant change to the mission work order, the PIC will notify the UAS Program Manager for approval.

8.5. Request for UAS Support During Disasters.

8.5.1. When providing disaster UAS operational support there are several areas that need to be addressed. All disasters are different and are event-driven and requirements can change quickly.

8.5.2. Prior to deployment teams should be provided as much information as possible. Operators should not depart without a basic understanding of the requirements, who and where to report to, and what the airspace procedures are. The following are focused on deployment:

8.5.2.1. Authority to activate: "Command and Control". The UAS Program Manager has the authority to tell the operators to

- 1- depart, and
- 2- begin flight operations.

8.5.2.2. Information: Prior to departure the operator should

- 1- have a good understanding of the requirements,
- 2- receive a final briefing,
- 3- ensure they have all required flight and life support equipment required.

8.5.2.3. Each operator needs to maintain a detailed log of all flights conducted including any issues or mishaps.

8.5.3. During times of emergency, natural or man-made, all NHDOT UAS assets will fall under the control of the UAS Program Manager. During those times Work Orders may be waived, and the UAS Program Manager can delegate control of assets to local managers.

8.5.4. If a request for NHDOT UAS assets is received from another state agency it must be approved by the NHDOT UAS Program Manager. If UAS assets, systems, and ACMs are assigned to support other agencies during emergencies the UAS Program Manager, or designee, will oversee the operations. During those periods, the UAS Program Manager will have the approval to waive policy and/or procedures if it does not cause a threat to manned aircraft or people on the ground. All operations should be documented and any deviation from policies and/or procedures should be noted.

8.6. Procedures

8.6.1. Upon receiving a Work Order Request, the PIC will review the requirements and ensure that the equipment and ACMs are available to accomplish the mission. If there are conflicts the PIC will attempt to resolve them, if not they will notify the UAS Program Manager.

8.6.2. The PIC will ensure all required equipment is clean and in working condition to include all batteries are charged, generators and other equipment are fueled, and will conduct a system logbook review.

8.6.3. Upon receipt of the Work Order Request, the PIC will contact the point of contact to confirm dates, locations, and requested data.

8.6.4. Upon arriving at the requested location, the PIC will contact the requestor if needed to check in and receive a final briefing on the mission requested. The PIC will confirm the information on initial site survey to make a final determination as to the ability of the UAS to perform the requested mission safely and within all regulations, policies, and procedures.

8.6.5. If the flight is likely to draw attention from the public or will have an impact on the flow of traffic TSMO shall be contacted and advised of the flight location and duration.

8.6.6. If the PIC determines that the use of the UAS would violate any regulation, policy or procedure, the PIC will inform the requestor of the potential conflict along with recommendations for modifying the requested mission to conform to regulations, policies, and procedures. If the change is significant, the PIC will contact the UAS Program Manager for approval.

8.6.7. The PIC will have final authority regarding whether or not to conduct the mission, based on safety or violations of regulations, policies, and procedures. If the PIC determines that a requested mission would violate FAA rules or endanger persons, property or NHDOT equipment then the PIC will respectfully inform the requestor of the reasons for refusing to operate the UAS and contact the UAS Program Manager immediately. The UAS will not be flown in this circumstance and the authority of the PIC is absolute.

8.6.8. The PIC will document all issues concerning the violation of regulations, policies, procedures and will send a report to the UAS Program Manager.

8.7. Minimum Personnel Requirements

8.7.1. Due to the nature and complexity of most missions, the minimum personnel required on ALL missions will be a PIC and VO.

8.7.2. The UAS Program Manager may approve:

8.7.2.1. Flight operations conducted only by a PIC if the operation conforms with FAA Part 107 regulations.

8.7.2.2. Flight operations using a non-trained observer. The PIC must give a detailed brief to the individual as to the duties of the VO. The VO must also have proper training as to what the duties are for the flights.

8.8. Personnel Responsibilities for Operations

8.8.1. PIC

8.8.1.1. Is directly responsible for and is the final authority over the actual operation of the UAS.

8.8.1.2. Has absolute authority to reject a flight based on safety or violation of FAA, State of New Hampshire, or NHDOT regulations. No member of NHDOT, regardless of position, shall order an operator to make a flight when, in the opinion of the PIC, it poses a safety risk to personnel or violation of FAA regulations or NHDOT SOP.

8.8.1.3. Is responsible for compliance with this manual, company policy and procedure and FAA regulations.

8.8.1.4. Main duty during the deployment of the UAS is to operate the UAS safely while accomplishing the goals of the deployment.

8.8.1.5. Shall see-and-avoid any obstacle that will lessen safety during the mission.

8.8.1.6. Shall be responsive to the requests of the observer to accomplish the mission.

8.8.1.7. Shall be responsible for documentation of mission training and updating of flight books.

8.8.2. Observer

8.8.2.1. Shall see-and-avoid any obstacle that will lessen safety during the mission.

8.8.2.2. Is responsible for the operational aspect of the deployment.

8.8.2.3. Shall remain alert for suspicious persons or activities on the ground and coordinate response by other UAS flight crew members.

8.8.2.4. Shall assist the operator in the main objective of safe operations of the UAS.

8.8.2.5. Shall be responsible for documentation for mission training and updating of flight books.

APPENDIX C: ADDITIONAL LEGISLATIVE CONSIDERATIONS

This appendix contains additional information as it relates to Section 5: Legislative Considerations.

Registration: Registration of aircraft can help inform state agencies on the number of aircraft and, by association, the number of UAS operators in the state. Registration can also help to track and identify operational use cases, which can assist with future Advanced Air Mobility (AAM) development. NH does not currently require UAS to be registered with the State. The states that currently have UAS registration legislation are noted below.

State	Statute	Requirements
MN	SF3148, HF3219	Requires state registration of UAS for $25 unless it is owned/operated for recreational purposes. Must report registration proof to the state. There are misdemeanor penalties for not registering or operating while unregistered.
MS	HB1383	An act to prohibit an individual from operating small, unmanned aircraft unless it has been registered with the Criminal Information Center of Department of Public Safety.
NY	S3602	Requires registration of general aviation aircraft; aircraft used for civil aviation; issuance of certificates of registration; proof of insurance.

Privacy: Privacy laws are the purview of the state. The legislature might consider any number of privacy laws to prevent UAS from being used to violate the privacy of others. Some examples from various States are provided in Appendix C.

State	Statute	Requirements
IN	HB1227	Legislation that notes using unmanned aerial vehicles is not a defense for avoiding prosecution for being "within 1,000 feet of a school."
KY	HB346	Prohibits federal, state, and local law enforcement agency from obtaining in-person or drone access to private lands for inspection, visit, surveillance, or installation of surveillance devices without probable cause, warrant, or consent.
MO	HB1619	Prohibits the use of a drone or unmanned aircraft to photograph, film, videotape, create an image, or livestream another person or personal property of another person, with exceptions.
MS	HB259	Prohibits any person from using an unmanned airborne device to capture unauthorized images without consent. Each image captured is a separate offense.
OH	2409	Ownership of the airspace above a parcel of property in this state is vested in the owner of that parcel. Allows for ownership above the legal limit.
OK	HB3171	New section of law to be codified in Oklahoma Statutes stating no person using UAS/drone can trespass with intent, install photographs, or videos without consent; intentionally use drone to surveillance; land drone on lands or waters of another resident without consent.

State	Statute	Requirements
SD	HB1065, SB74	Prohibits the use of UAS to photograph, record, or observe another person in a private place or to land on private property. Exceptions are government agencies or emergency management operations.
UT	SB68	Criminal penalties for trespassing. Includes section about UA that includes unlawful entry, flying over private property, reckless, fear of others' safety from "unmanned aircraft's presence," and unauthorized flying on any portion of private property.

The Mercatus Center at George Mason University lists additional considerations in its state-by-state UAS commerce scorecard. This scorecard report is related to UAS commercial operations and Advanced Air Mobility operations. New Hampshire ranked #33 in the overall UAS readiness scorecard (Skorup, 2023). That ranking should not be perceived as detrimental. The Federal government and the States are still determining each other's roles and responsibilities in this new system of transportation.

The first factor in the Mercatus Center's methodology is Airspace Lease Law. Airspace is a public good. New Hampshire is one of the states that allows political subdivisions to lease airspace over public rights-of-way (Skorup, 2023). However, it is important to remember that these laws were never intended for flight in those leased spaces. Only the FAA has authority over navigable airspace for flight purposes. Leasing airspace to private third parties to create aerial corridors may be considered in New Hampshire but may also carry unintentional consequences such as monopolization of a public good. The current New Hampshire law should be thoroughly analyzed before allowing the leasing of airspace to private parties for the creation of aerial corridors.

Avigation easements and "sandboxes" are other factors in the methodology. New Hampshire does not currently have laws on either of these factors.

Avigation easement laws allow flight over private property as long as that flight does not interfere with the best use of that property by the landowner. Sandbox laws designate state- and city-owned land as available for testing UAS package delivery and aerial taxis operations under very liberal rules for a predetermined duration. Together, these laws are excellent precursors that allow for the managed growth of new technologies and aviation operations.

In conclusion, the state may consider various options for legislation, but consider the potential consequences, especially the unintended ones. An easy place to start is the five basic concepts. Of those five, Operations, Safety, and Liability may be the lowest hanging fruit. New Hampshire may consider taking these first initial steps and then revisiting the other legislative options as UAS and AAM slowly become more prevalent with each legislative session. At a minimum, being aware of these legislative considerations allows the state to be more proactive than reactive in addressing the regulatory side of this emerging transportation technology.

APPENDIX D:

Task 1a Interim Report – UAS State of Practice Review and Workshop Findings

New Hampshire Department of Transportation

Development of an Unmanned Aircraft Systems (UAS) Program 43272B

Task 1a Interim Report – UAS State of Practice Review and Workshop Findings

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ACRONYMS AND ABBREVIATIONS

AAM	Advanced Air Mobility
BIL	Bipartisan Infrastructure Law
BVLOS	Beyond Visual Line of Sight
CFR	Code of Federal Regulations
DOT	Department of Transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRIA	FAA Recognized Identification Area
GIS	Geographic Information System
ID	Identification
NAS	National Airspace System
NETC	New England Transportation Consortium
NHDOT	New Hampshire Department of Transportation
RPIC	Remote Pilot in Command
SME	Subject Matter Expert
UAS	Uncrewed Aircraft Systems
UA	Uncrewed Aircraft

8.0 INTRODUCTION

The objective of Task 1a is to review and update the New England Transportation Consortium (NETC) Project 18-3 Task 1 Interim Report on the national state of the practice for using Uncrewed Aircraft Systems (UAS)[1] technology in support of core transportation applications. The emphasis of this report is on new literature, improved UAS capabilities, and the validation of NETC findings with current market conditions. Consistent with suitable New Hampshire Department of Transportation (NHDOT) mission areas, WSP has analyzed core use cases for effectiveness in achieving desired outcomes, efficiency in performing required tasks, and cost/labor savings for implementing UAS technology. Core use cases that were analyzed as part of the state of the practice are listed below.

6. Surveying and mapping.
7. Structure inspection.
8. Construction monitoring and quantities.
9. Emergency response and recovery.
10. Public engagement and outreach.

The remainder of this document follows the following outline:

Section 2 provides an overview of new revisions to 14 Code of Federal Regulations (CFR) Part 107, including UAS remote identification, operations over people or moving vehicles, and night operations. Each of these new regulatory amendments, associated deadlines, and the means of compliance are thoroughly explained.

Section 3 explains various considerations for UAS program components such as organizational structure models; program positions, roles, and responsibilities; and internal policies and procedures. Also provided within this section is an overview of recent state legislation concerning UAS. Traditional and new funding options are explored, including the impacts of the Bipartisan Infrastructure Law (BIL).

Section 4 gives numerous examples from various State Departments of Transportation (DOTs) of demonstrated effectiveness, efficiencies, cost savings, and other benefits of using UAS across the core use cases.

Section 5 presents the key findings from the UAS Implementation Planning Workshop held on February 15, 2023.

[1] UAS is more popularly defined as "unmanned aerial systems" today. However, the industry is showing sensitivity to gender-neutral terms and terms that can also be broadly applied to telerobotic-controlled or autonomous vehicles.

9.0 FEDERAL AVIATION ADMINISTRATION RULES AND REGULATIONS

As more aircraft platforms are developed in both the UAS and Advanced Air Mobility (AAM) industries, the Federal Aviation Administration (FAA) has made multiple revisions to 14 CFR Part 107 to assist with full integration of UAS into the National Airspace System (NAS). The latest rule modifications include remote identification (ID) of drones, operations over people or moving vehicles, and night operations. These changes to Part 107 went into effect on April 21, 2021.

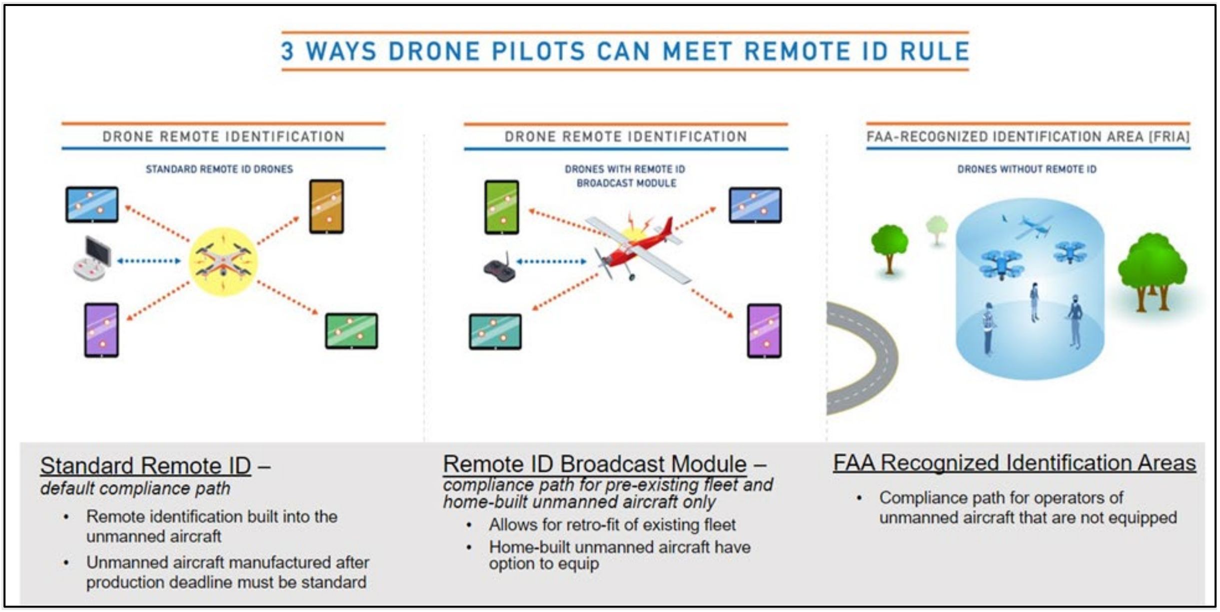
9.1 UAS Remote Identification

Remote ID allows Uncrewed Aircraft (UA) to transmit identification, location, and other real-time data throughout the operation from takeoff to shut down. The FAA and law enforcement can use this information to locate the operator in cases of misuse or operation within an unapproved area. Beyond these safety and security considerations, Remote ID is establishing a foundation for greater UAS integration into the NAS. The final rule requires every registered drone to meet the requirements of Remote ID by September 16, 2023.

There are three ways to comply with the Remote ID rule; Figure 1 depicts and outlines these methods of compliance. The first method is by using Standard Remote ID, whereby the drone has a built-in broadcast system to broadcast the drone ID, location, altitude, velocity, control station location, time mark, and emergency status. As of September 16, 2022, all drone manufacturers had to comply, by equipping all new production UAS with Standard Remote ID. Due to the adoption of the ASTM F3586-22, Standard Practice for Remote ID Means of Compliance, the FAA will use discretion on a case-by-case basis for manufacturers meeting Standard Remote ID compliance by December 16, 2022. It is important to note that Standard Remote ID aircraft can qualify for Beyond Visual Line of Sight (BVLOS) waivers and operations.

UA manufactured prior to this date or home built drones can be equipped with a Remote ID Broadcast Module. These modules broadcast the drone ID, location, altitude, velocity, takeoff location, and time mark. Drones that are retrofitted with a Remote ID Broadcast Module are limited to visual line of sight operations only.

The third means of compliance for drones that do not have either Standard Remote ID or the Remote ID Broadcast Module is to operate only within an FAA Recognized Identification Area (FRIA). Only community-based organizations and educational institutions can request and establish a FRIA. All operations within a FRIA must be within visual line of sight.



Source: FAA (2021b)

Figure 1. FAA Depiction of the Three Ways Drone Pilots Can Meet Remote ID Rule.

9.2 Flights Over People and Moving Vehicles

The Operation of Uncrewed Aircraft Systems Over People final rule is another amendment to 14 CFR Part 107 that enables more complex UA operations. This new final rule permits operations over people and moving vehicles, and night operations within established parameters. These conditions are set forth by category; the final rule refers to operations within Categories 1 through 4. It is important to note that if operations are to be conducted under the conditions outlined in any of these four categories, then compliance with the Remote ID rule is required, even if prior to the deadline of September 16, 2023.

Category 1 operations are permitted over people if the two following criteria are met. First, the small UA weighs 0.55 pounds or less; this weight includes the payload, and everything attached to the aircraft at the time of takeoff and throughout the operation. The second condition is that the aircraft does not have any exposed rotating parts that would "lacerate human skin on impact with a human being" (FAA, 2021a). The Remote Pilot in Command (RPIC) is responsible for ensuring the aircraft meets these two criteria prior to the operation.

Category 2 operations are for aircraft that weigh more than 0.55 pounds but do not hold an airworthiness certificate under Part 21. To conduct operations within this category, three criteria must be met. First, the UA must be manufactured or modified in a way that it would not cause injury to a human being "that is equivalent to or greater than the severity of injury caused by a transfer of 11 foot-pounds of kinetic energy upon impact from a rigid object" (FAA, 2021a). Anyone who designs, produces, or modifies a small UA would need to submit evidence via a declaration of compliance that the UA does not produce more than this established injury severity limit.

The second criteria repeat Category 1 requirements related to ensuring there are no exposed rotating parts that could cause lacerations. The third criteria states that the UA must be free of any safety defects. In addition to these three requirements, the UA must display a label noting its eligibility for Category 2 operations. This label would be applied after the operator confirms the UA is eligible and is listed on the

FAA-accepted declaration of compliance for Category 2 operations. The RPIC must also have updated operating instructions.

Category 3 operations employ the same injury severity limit as Category 2 operations but raise this limit to 25 foot-pounds of kinetic energy. Category 3 operations are subject to all the same requirements noted in for Category 2, but due to the higher injury severity limit, additional operational limitations apply. Category 3 operations are not permitted over open-air assemblies, and operations over people are only allowed if the flight is within or over a closed or restricted-access area. Within the closed or restricted-access area, everyone must be on notice regarding the UA operation. The UA should not sustain flight over nonoperational personnel or over people not located under a covered structure or within a nonmoving vehicle, both of which should provide reasonable protection if the UA were to fall from its position.

Category 4 is a category that is a result of public comments and therefore is an addition to the original Notice of Proposed Rule Making. This category will permit UA that have received an airworthiness certificate under the Part 21 certification process to operate over people. These UA must maintain their airworthiness certificates through established and FAA-approved maintenance programs.

To summarize, various UA operations over people are permitted under different circumstances and in compliance with the outlined requirements of Categories 1, 2, 3, or 4. Sustained flight operations over open-air assemblies are permitted within Category 1, 2, or 4. Sustained flight includes hovering above people, flying back and forth, or circling over people. Sustained flight does not include a one-time transition over people in an unrelated point-to-point operation. Category 3 operations do not permit flights over open-air assemblies, rather operations must comply with the forementioned requirements within a closed or restricted-access area.

Flight operations over moving vehicles are allowed if the UA meets the requirements of Category 1, 2, or 3 *and* meet one of the following two requirements. First, the UA must remain within a closed or restricted-access area, and all people within a moving vehicle in or moving through this area are notified that the UA may fly over them. Second, the UA does not maintain sustained flight over any moving vehicle.

9.3 Night Operations

The final rule now allows for night operations as long as two requirements are met. First, the RPIC must have completed an updated knowledge check or recurrent online training that includes training on night operations. Second, the UA is equipped with anti-collision lights that are visible from at least 3 statute miles away and has a sufficient flash rate to ensure other aircraft avoid a collision with the UA.

Table 1 outlines these recent updates to Part 107 and the status of additional changes that are currently in progress.

Table 1. Part 107 Updates and Additional Changes in Progress.

Name of Rule	Stage	Status
Operation and Certification of Small Unmanned Aircraft Systems (Part 107) https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-107	Final Rule	In effect August 29, 2016
External Marking Requirement for Small Unmanned Aircraft https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-48/subpart-C/section-48.205	Interim Final Rule	In effect February 25, 2019

Name of Rule	Stage	Status
Operations of sUAS Over People https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-107/subpart-D	Final Rule	In effect April 21, 2021
Safe and Secure Operations of Small UAS https://www.federalregister.gov/documents/2019/02/13/2019-00758/safe-and-secure-operations-of-small-unmanned-aircraft-systems	Advanced Notice of Proposed Rulemaking	1842 comments
Remote Identification https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-89	Final Rule	In effect April 21, 2021
Type Certification of Unmanned Aircraft Systems https://www.federalregister.gov/documents/2020/09/18/2020-17882/type-certification-of-certain-unmanned-aircraft-systems	Notice of Policy	In effect September 18, 2020
UAS Flight Restrictions Near Critical Infrastructure	Draft Notice of Proposed Rulemaking	Development is underway
Modernization of the Special Airworthiness Certification (MOSAIC)	Draft Notice of Proposed Rulemaking	Development is underway

Source: Department of Transportation (2022)

10.0 UAS PROGRAM COMPONENTS

10.1 Organizational Structure Models

When a State DOT plans to integrate the use of UAS into its operations, it must consider various organizational structure models. This section provides an overview of three organizational structure models. The positions within these various models are essentially the same, the role and responsibilities for each position role is defined and discussed.

10.1.1 UAS Organizational Structure – Division of Aeronautics

The most adopted model is to organize the UAS program under the Division of Aeronautics. Twenty-four states are currently using this model. Figure 2 outlines the structure of having a UAS program manager within the Division of Aeronautics who oversees a UAS training coordinator, full-time UAS pilots, functional department pilots, and supplemental consultant pilots on an as-needed basis.

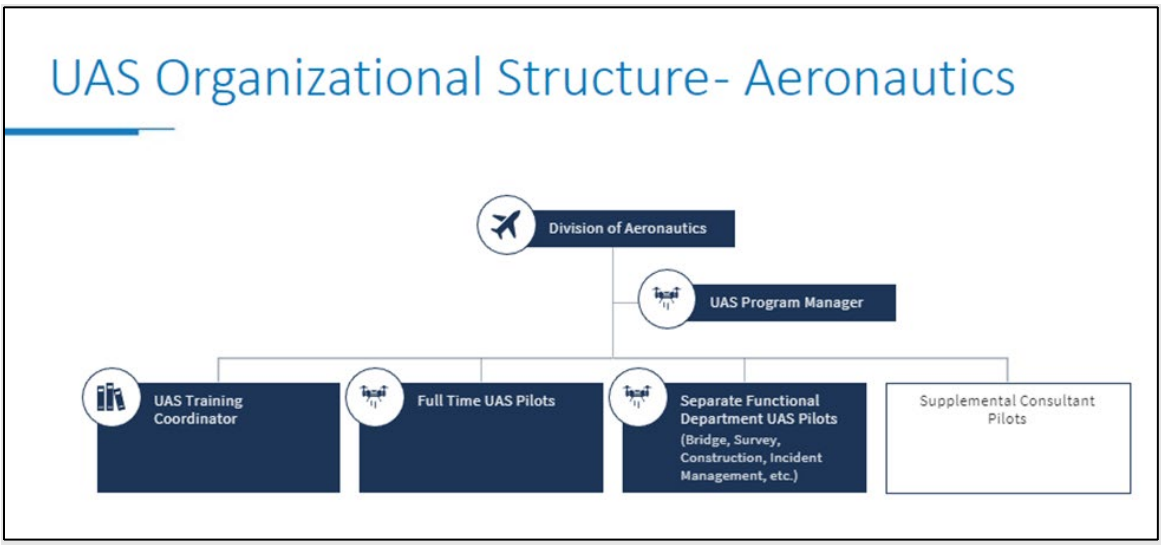


Figure 2. UAS Organizational Structure – Aeronautics.

One of the essential advantages to this model is the ability to leverage existing aviation knowledge and expertise that is critical to establishing a successful UAS program. Having a relationship with the FAA and understanding Federal Aviation Regulations are crucial components to the UAS program (Banks et al., 2018). The Division of Aeronautics will include people who understand FAA terminology; have a working relationship with the FAA; and may have a pilot background with knowledge of checklists, aircraft operations, airspace, emergency procedures, and other key functions of establishing the UAS program.

A potential disadvantage of this model is that the Division of Aeronautics may be siloed and may not understand the various functions of the other divisions within the State DOT. The division may lack the specialty knowledge for mission-specific needs and surface transportation use cases for UAS. A solution to this potential disadvantage is the creation of a UAS committee comprising key stakeholders from the different departments seeking to employ UAS in their operations. This committee can create an impactful platform for collaboration and communication between the UAS program personnel and the functional departments seeking UAS assets.

A consideration for each of the organizational models is that of funding sources. Under this Division of Aeronautics organizational model, it must be determined how a dedicated budget can be added to the existing division budget. These dedicated funds will be secured for the UAS program with a focus on initial costs, ongoing maintenance, and program growth. Additional information on funding is discussed in Section 3.3.2.

10.1.2 UAS Organizational Structure – Department of Transportation

Another organizational structure model is to arrange the UAS program and personnel as a centralized UAS division within the State DOT that serves the needs of the various functional departments. Alternatively, it can be organized under another division within the State DOT that is not the Division of Aeronautics. For example, Virginia houses its UAS program within the Office of Research and Innovation, while Colorado's program is within the Survey, Mapping, and Geographic Information Systems (GIS) Division of Project Support.

Figure 3 outlines this structure, which offers a condensed organizational structure compared to the Division of Aeronautics model. Under this State DOT model, each department using UAS has its own personnel with the added responsibility of conducting UAS operations specific to their needs. While each department has their own UAS pilots, it is still essential to have a clear line of command and the oversight of a UAS program manager. Depending on the size of the program, it may also require a dedicated UAS training coordinator to work across these departments with all UAS personnel. These positions may be shared duties with existing positions, or if the workload of the program requires, these may need to be full-time UAS program specific positions.

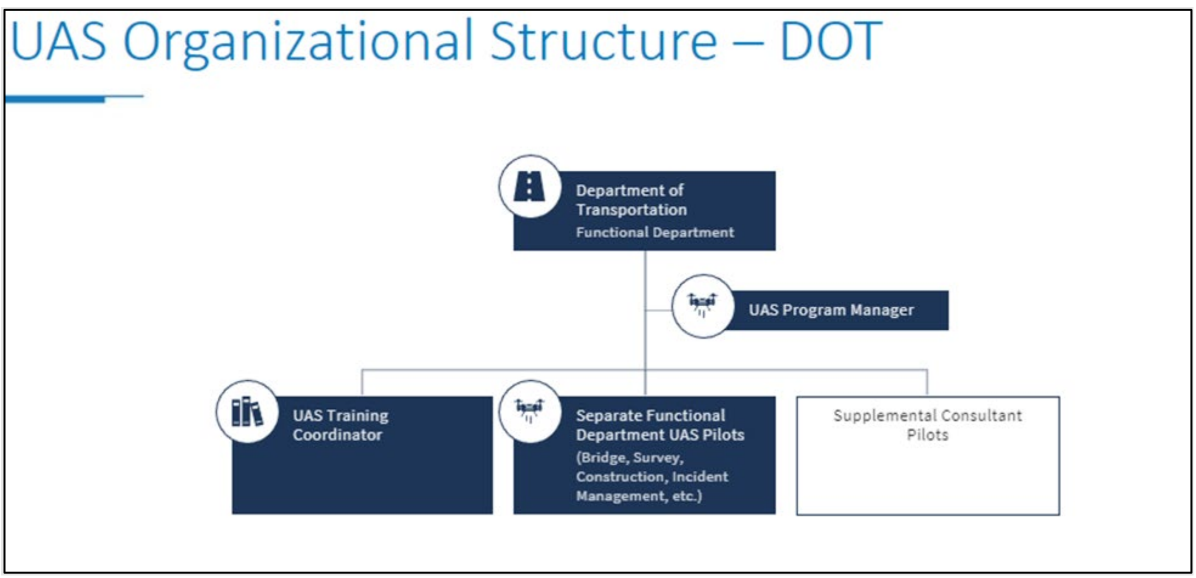


Figure 3. UAS Organizational Structure – Department of Transportation.

This organizational structure model has similar advantages and potential disadvantages as the Division of Aeronautics model but in the reverse. The advantage of the State DOT model is that the personnel within the various functional departments adopting UAS are subject matter experts (SMEs) on the focus point of the data collection. For example, in a bridge inspection, the engineers and construction specialists have the experience and knowledge to conduct a thorough inspection. These SMEs can acquire the knowledge necessary to employ UAS into their operations, and their historical expertise will likely be advantageous for these types of inspections.

The possible drawback of this model is the lack of aviation knowledge that is critical to the success of the UAS program. The solution to this problem is the same as previously mentioned: the need to establish a UAS committee as a core part of the program to leverage the strengths of each department. This model structures the overall design of the UAS program differently than the Division of Aeronautics model; however, the leadership of a UAS program manager and a strong internal training program are still vital components of the program.

10.1.3 UAS Organizational Structure – Centralized UAS Department

The third organizational structure model is to have an independent, centralized agency that conducts all UAS operations across the state. This centralized UAS department is independent of the State DOT and maintains its own dedicated budget, full-time personnel, and equipment. In Figure 4, this organizational structure is depicted as a central agency that has a UAS program manager, UAS training coordinator, full-time UAS pilots, and the potential use of consultant pilots when needed. These full-time UAS pilots would fly every operation needed across the different functional departments of a State DOT and other state organizations.

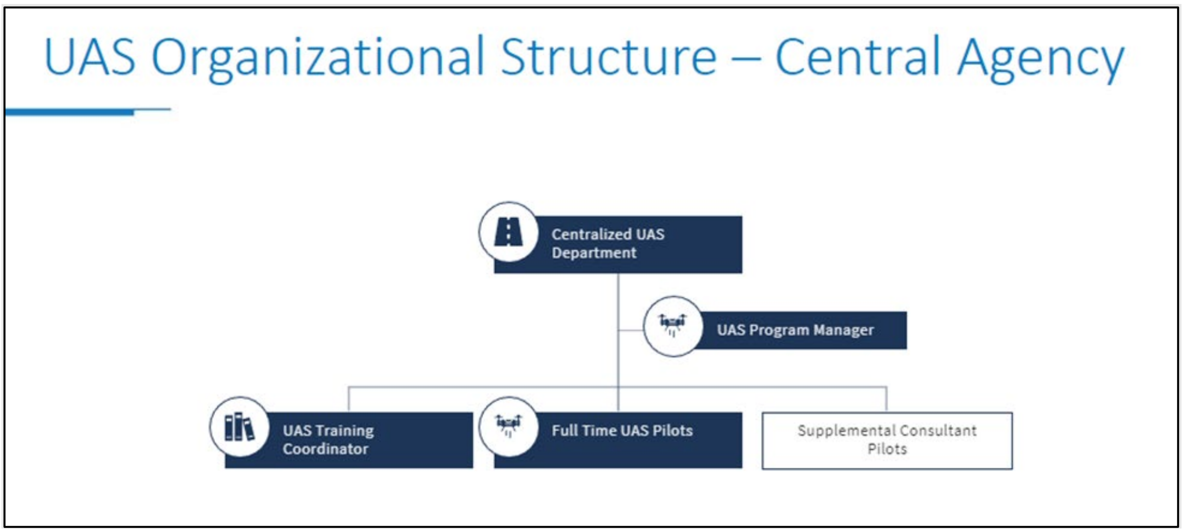


Figure 4. UAS Organizational Structure – Centralized UAS Department.

A key strength of this organizational structure is the full control of the UAS program that is afforded by the nature of it being an independent, centralized agency. Another potential advantage is the scalability of this model that may not exist in the same way in the other two models. Depending on the volume of UAS operations throughout a particular state, this model can be expanded by creating additional positions in the form of regional or functional UAS program managers.

Ohio is the only current example of a truly separate and centralized UAS agency, known as the Ohio UAS Center and founded in 2013. The Ohio UAS Center deploys UAS pilots to meet the needs of the Ohio DOT and other local or state agencies (Ohio UAS Center, n.d.a). In addition to meeting the UAS operations for the state, this center has expanded into research initiatives, created key federal partnerships, and is planning for the integration of various AAM technologies (Ohio UAS Center, n.d.b).

A lesson learned from the Ohio UAS Center is that although the center has highly proficient and experienced UAS pilots, there are occasions when these pilots lack the functional knowledge for specific operations. Returning to the bridge inspection example explored in the previous model, at times pilots lack the expertise needed on how to best execute such an inspection. This highlights the need for true collaboration and teamwork where the strengths of all involved SMEs can be leveraged.

10.1.4 Organizational Structure Models Summary

Figure 5 offers a visual representation of which of the UAS organizational structure models have been adopted by the different states.

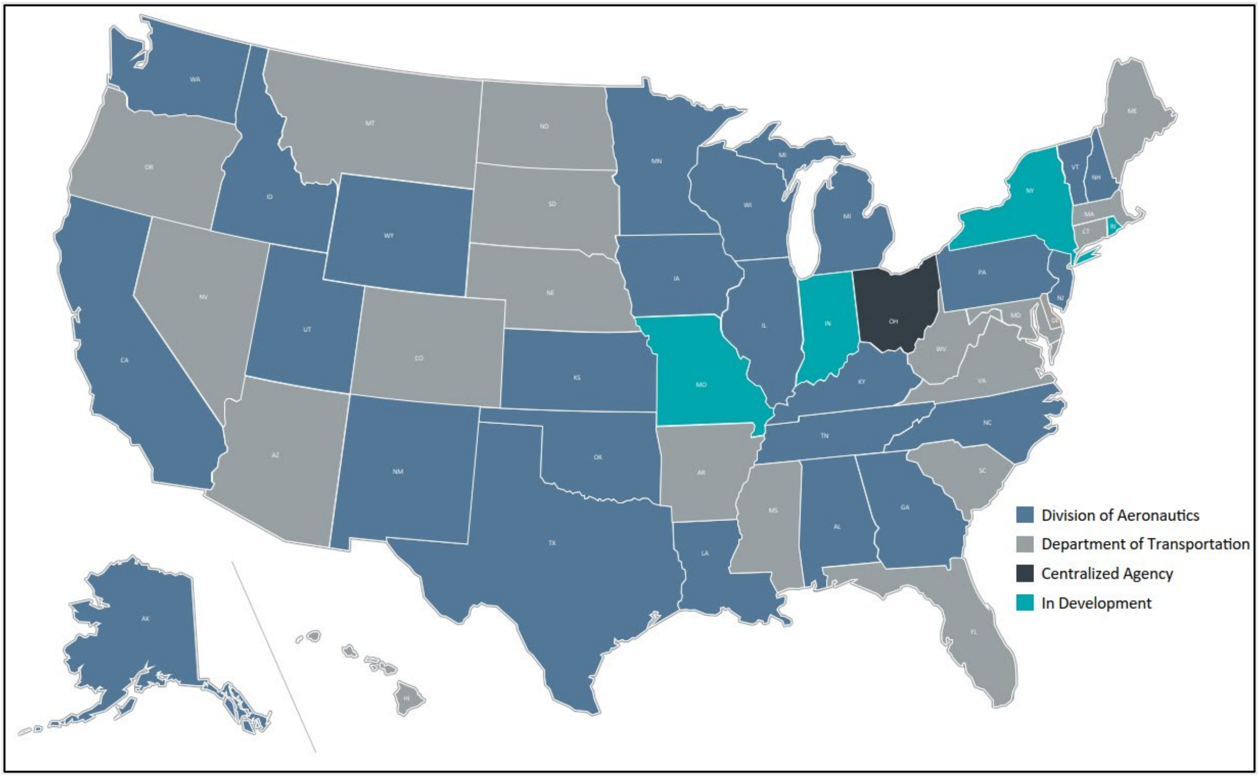


Figure 5. UAS Organizational Structure Model Adoption by State.

Each of the various models has advantages and potential disadvantages to consider, but there are significant similarities between models. Regardless of the chosen organizational model, it is important to consider the following to ensure the success of the UAS program:

11. Seek top-down support.
12. Establish a clear chain of command.
13. Collaborate with the existing aviation SMEs.
14. Secure a dedicated and separate funding source.
15. Create or nurture an established relationship with the FAA.
16. Dedicate personnel to the management.
17. Collaborate across departments by establishing a UAS committee.
18. Allow flexibility to modify the organizational structure as it matures or meets new challenges and requirements.

The above list was adapted from the NCHRP Project 20-68A, Scan 17-01: Successful Approaches for the Use of Unmanned Aerial Systems by Surface Transportation Agencies.

10.2 Organizational Structure Positions

Regardless of which organizational structure is selected, each structure has essentially the same necessary positions, although the roles and responsibilities of these positions may vary. This section outlines the things to consider for each UAS program position.

10.2.1 UAS Program Manager

The initial consideration for each position, but especially for the role of UAS program manager, is whether this role merits a full-time dedicated person or if the role will manage other functions in addition to the UAS program. The UAS program manager will oversee the program and may also coordinate with a UAS committee that is established from other divisions within the organization to best meet UAS needs organizationally.

The UAS program manager is the final authority on decisions within the program, is responsible for securing funding, understanding the procurement cycle, establishing policies and procedures, overseeing training and pilot requirements, and managing the fleet including maintenance. As a program grows, the UAS program manager should retain oversight and management, but many tasks can be delegated to other program positions.

10.2.2 UAS Training Coordinator

Establishing a formalized training program may help to mitigate issues and foster a safety culture across the UAS program. A dedicated UAS training coordinator role is helpful in managing the internal training program. This role should ensure new pilot training protocols are followed and currency requirements are being satisfied.

It is important to note that while an FAA Part 107 Certified Pilot with the sUAS rating is a great starting point, specific training beyond Part 107 will be helpful. Part 107 does not require a practical flight exam. Establishing internal practical flight training in addition to the remote pilot license can help pilots receive a core level of competency for flight. Without a practical training curriculum, it may be difficult to understand each pilot's strengths and weaknesses and the level of competency for UAS operations across an organization.

Some categories of training to consider when starting or growing a UAS training program:

19. Basic training for all pilots (to include aeronautical and practice knowledge)
20. Advanced Training (to cover areas like mapping, flying in complex environments, and advance maneuvers)
21. Recurring Training (to enable proficiency and keep current)

The UAS training program should be customized and adapted to meet the needs of the various mission profiles and UAS applications across the organization and learn from UAS incidents and accidents that occur within the program. In addition to the FAA and National Transportation Safety Board reporting requirements, the UAS training coordinator may evaluate the need for an internal, formal reporting system for incidents and accidents. Such a system could be used as a learning tool rather than as a means of discipline.

10.2.3 Full-Time UAS Pilots

Depending on the chosen UAS organizational structure model, the program may have full-time UAS pilots. The primary role of this core group of pilots is to plan and conduct advanced operations on a large scale to meet the needs of functional departments or across the geographic area.

Depending on the volume of flight operations and number of pilots, the program may consider adopting a traditional aviation flight department leadership model by designating a chief pilot. Someone in this role could assist the training coordinator in ensuring pilots meet current standards and are proficient. This role could manage the logistics and scheduling of pilots to meet the needs of the various UAS operations. This position could also serve as the sole point of contact for FAA authorizations and waivers and remain up to date on all regulatory changes.

Another role that could potentially be shared with that of a full-time pilot would be a fleet maintenance manager. The following are some considerations that may be helpful when planning for managing a UAS fleet:

22. Tracking
    - A centralized, easy to use software that can auto-upload all flight data and statistics
    - Risk management procedure for all flights to help mitigate issues
23. Health of Fleet
    - Ability to monitor the health of the fleet (aircraft, maintenance, batteries, compliance)
24. Compatibility
    - Ensure the solution can input data from all the aircraft

10.2.4 Separate Functional Department UAS Pilots

Within the Division of Aeronautics and State DOT organizational modules, there would be separate functional department pilots. These are decentralized staff who are already members of separate functional departments like bridge, survey, incident management, and others. These personnel may be cross trained as UAS pilots to conduct operations specific to their subject of expertise.

10.2.5 Supplemental Consultant Pilots

Pilots may be outsourced as needed from the consulting community to provide services when needs exceed the availability or ability of department pilots and equipment or when geographic convenience is a benefit. The UAS program manager would oversee the determination of need in contracting with consultant pilots. The program training coordinator can assist in validating these contracted pilots' training and experience.

10.3 State Legislative Priorities and Funding

As the use of UAS has increased over the past decade, state legislators throughout the United States continue to enact new local laws and regulations concerning UAS. This section outlines recent state laws on the subject of UAS and explores traditional and new avenues for funding UAS programs.

10.3.1 Legislative

As a State DOT proceeds with creating a formal UAS program to meet various needs across the state, a close working relationship with local law makers should be established. This relationship can be fostered using UAS working groups or committees. In many states, the state legislature has passed legislation calling for the formation of such committees that will often provide annual reports to state law makers.

For example, Louisiana passed House Bill 587, which established the Louisiana Drone Authority Committee to be housed under the State DOT. This committee brings together government, industry, and academic stakeholders to provide regulatory recommendations to the state legislator concerning the greater adoption of UAS in the state. Other examples include West Virginia's creation of the Unmanned Advisory Council or Oklahoma's organization of the Oklahoma Aeronautics Commission to serve as the group responsible for research, development, and supporting the adoption of UAS by various state agencies (State Unmanned Aircraft System Legislation, 2021).

Table 2 provides an overview of active or recent state legislation for UAS or closely related initiatives across the United States.

Table 2. Overview of Active State Legislation for UAS or Closely Related Initiatives.

State	Bill	Details
AK	HB281, SB162	University of Alaska Drone Program: $10M (Critical Minerals and Rare Earth Elements); $7.8M (Research and Development Heavy Oil Recovery Method); $5M Research and Development.
AL	HB21, SB17	Critical infrastructure, provides further for crime of unauthorized entry of a critical infrastructure, including UAS, provides additional penalties.
AR	SB173	Prohibits UAS operations over food processing, manufacturing, and correctional facilities.
CA	AB481	Requires law enforcement agencies to obtain approval from local legislative bodies to use military equipment, including UAS.
FL	HB659	Exempts certain government agencies that are non-law enforcement agencies from laws prohibiting the use of UAS related to managing invasive plants and animals.
FL	HB5001	Appropriates $14M for industry training and certification, including UAS. Provides $400,000 for UAS to be used locating intrusive snakes.
FL	SB44	Allows law enforcement agencies to use UAS for additional use cases. Requires a list of approved drone manufacturers to be published on the State Department of Management Services website.
ID	HB486	Allows law enforcement and other government agencies to use UAS to assist in accident investigations, crowd management, natural disaster assessments, training, and following the delivery of a search warrant.
IN	HB1227	Legislation that notes using unmanned aerial vehicles is not a defense for avoiding prosecution for being "within 1,000 feet of a school."

State	Bill	Details
KS	SB444	Bill that defines UAS as under the jurisdiction of "aviation only - no limit."
KY	HB346	Prohibits federal, state, and local law enforcement agency from obtaining in-person or drone access to private lands for inspection, visit, surveillance, or installation of surveillance devices without probable cause, warrant, or consent.
LA	HB587	Creates the Louisiana Drone Authority Committee under the State DOT to provide recommendations on policies and regulations related to adopting UAS. Notes state laws should align with federal control of airspace.
MA	HB4183	No person shall operate a small, UAS within a vertical distance of 400 feet in a school zone without authorization by the superintendent of schools.
MA	HB5164	Provides $25,000 to study wildlife using traditional aviation or the use of UAS.
MA	HB4002	Appropriates $100,000 for marsh restoration, including the use of UAS for mapping efforts.
MD	SB600, HB670	Prohibits law enforcement agencies from receiving specific UAS equipment from a federal surplus program.
MI	SB796	Restricts county, village, or township from enacting or adopting ordinance policies that relate to the ownership or operation of AAM aircraft Restricts their power in regulating as well.
MN	SF3258	Prohibits UAS operations over correctional facilities or land controlled by such a facility.
MN	SF3072	Allows law enforcement agencies to use UAS for emergency situations involving death or bodily harm, public events where there is a risk to safety or reasonable suspicion of a crime, counter-terrorism threat assessments, accident investigation, training, public relations, and to prevent loss of life or property in natural disasters.
MN	SF3148, HF3219	Requires state registration of UAS for $25 unless it is owned/operated for recreational purposes. Must report registration proof to the state. There are misdemeanor penalties for not registering or operating while unregistered.
MO	HB1619	Prohibits the use of a drone or unmanned aircraft to photograph, film, videotape, create an image, or livestream another person or personal property of another person, with exceptions.
MO	HB1963	Makes it a criminal offense to operate a UAS near a correctional facility, mental health facility, open-air stadiums with 5,000 or more seats, without written consent.
MS	HB259	Prohibits any person from using an unmanned airborne device to capture unauthorized images without consent. Each image captured is a separate offense.

State	Bill	Details
MS	HB1383	An act to prohibit an individual from operating small, unmanned aircraft unless it has been registered with the Criminal Information Center of Department of Public Safety.
MS	HB1517	Provides $16M dollars for horizon-thinking programs such as advanced manufacturing, drone, electric vehicle, fiber, data analytics, and management.
MS	HB974	Creates the Mississippi Unmanned Aircraft Systems Protection Act of 2021 that shall not prohibit UAS operations by law enforcement agencies for any lawful purpose in the state. Outlines penalties for the misuse of UAS.
NC	SB105	Requires an annual legislative report regarding UAS.
NJ	SB2022	Appropriates $500,000 for an aeronautics UAS program.
NJ	S451	Restricts the use of UAV to conduct surveillance, gather evidence, or any other law enforcement activity unless warrant, emergency, probable cause, written consent.
NJ	A3174, S2297	Requires certain drones to contain geo-fencing tech. Makes violation a fourth-degree crime. Every drone sold or operated in the state shall contain geo-fencing tech that prevents UAS from operating above 500 feet when within 2 miles of an airport, protected airspace.
NY	S3602	Requires registration of general aviation aircraft; aircraft used for civil aviation; issuance of certificates of registration; proof of insurance.
NY	S675	Imposes limitations on the use of drones for law enforcement and singles out drones.
NY	A417	Prohibits police from using unmanned aircraft to gather, store, or collect evidence of any type for criminal conduct unless a valid search warrant was first obtained.
OH	2409	Ownership of the airspace above a parcel of property in this state is vested in the owner of that parcel. Allows for ownership above the legal limit.
OK	HB3171	New section of law to be codified in Oklahoma Statutes stating no person using UAS/drone can trespass with intent, install photographs, videos, etc. without consent; intentionally use drone to surveillance; land drone on lands or waters of another resident without consent.
OK	SB659	Establishes the Oklahoma Aeronautics Commission to serve as the agency to research, develop, and support the adoption of UAS by various state agencies.
OR	SB315	Exempts information that would create competitive disadvantages for UAS owners or users.
OR	SB5506	Appropriates $15M to the Boardman Tactical UAV Facility.

State	Bill	Details
RI	H7787	Establishes regulations to reduce hazardous emissions.
SD	HB1059	Makes it a criminal offense to operate UAS that are not in full compliance with FAA regulations.
SD	HB1065, SB74	Prohibits the use of UAS to photograph, record, or observe another person in a private place or to land on private property. Exceptions are government agencies or emergency management operations.
TN	SB258, HB924	Outlines additional circumstances in which law enforcement agencies can use UAS without a search warrant. Increases the number of days from 3 to 30 regarding data storage of potential evidence.
TX	HB1758	Requires law enforcement agencies using UAS to adopt certain policies and file a report with the Texas Commission on Law Enforcement every two years.
TX	SB149	Prohibits a drone from flying over a public or private airport depicted in any current FAA aeronautical chart or any military installations.
UT	HB259	Amends provisions related to use of an UAS to apply to the use of an imaging surveillance device in conjunction with UAS. Prohibits police from obtaining data unless in good practices.
UT	SB68	Criminal penalties for trespassing. Includes section about UA that includes unlawful entry, flying over private property, reckless, fear of others' safety from "unmanned aircraft's presence," and unauthorized flying on any portion of private property.
UT	SB122	Provides the ability to be found guilty of a criminal offense that is committed with the aid of an UAS.
UT	SB166	Restricts a political subdivision or entity within the subdivision from enacting law, ordinance, or rule governing the private use of an unmanned or AAM unless authorized by this chapter or an airport operator has authority.
VA	SB1098	Provides UAS owners' exemptions regarding state aircraft registration.
VA	HB742	Empowers localities to regulate the takeoff or landing of UAS on property owned by said localities. Requires ordinances or regulations developed by the localities must be reported to the district attorney's office.
VA	HB1017	Requires an annual state assessment of current and future initiatives related to UAS.
VA	HB30	Appropriates $2M over two years to the Virginia Center for Unmanned Systems to serve as a catalyst for UAS growth in the state. Requires the center to begin industry and business collaboration.
VT	SB124	Prohibits law enforcement using facial recognition unless it is for operations related to search and rescue or assessment of natural disasters.

State	Bill	Details
WA	HB1470	Intends to extend certain aerospace industry tax preferences to commercial UAS manufacturing in order to encourage the migration of these businesses to Washington, in turn creating and retaining good wage jobs and new tax revenue for the state.
WA	HB1054	Prohibits law enforcement agencies from acquiring or using armed or armored drones. Any agency that currently owns such equipment must return it to the federal program from which it was acquired or destroy it.
WI	SB237	Permits a person to operate a drone over state facilities if prior written authorization is obtained.
WV	SB5, HB4667	Aims to create West Virginia Unmanned Advisory Council. Includes privacy and video legislation, restrictions on flying, harassment, property issues.
WV	HB2760	Expands tax credit availability to drone manufacturers.
WY	HB128	Except as otherwise permitted by law, a person is guilty of criminal trespass by drone if he causes a drone to fly 200 feet or lower over the private land or residence of another person without authorization.

Source: State UAS Legislation (2021)

10.3.2 Funding

One of the key elements to the success of a State DOT UAS program is the ability to secure initial and ongoing funding to support the program. Funding options to consider include academic partnerships to access research grants, end of the year department funding, state legislature appropriated funds, and federal funding. Historically many State DOTs have secured funding through different programs under the Federal Highway Administration (FHWA). Because of these historical federal funding programs, this section focuses on understanding the impact of the BIL that was signed into law in November 2021.

The BIL also known as the Infrastructure Investment and Jobs Act is known as the once-in-a-generation investment of over $550 billion into the infrastructure of the United States (The White House, 2021). These funds will be distributed across many federal agencies and programs to address a variety of infrastructure needs. The FHWA will receive $350.8 billion over the next five fiscal years (FHWA, n.d.) to fund more than a dozen new highway programs with a focus on safety, bridges, climate change, resilience, and acceleration of project delivery (Blanton, 2022). This type of funding for FHWA is unprecedented. Figure 6 summarizes new programs and stakeholders that may access funding under these programs.

Funding Available to a Range of Recipients

Program Examples	State	MPO	Local	Tribe	PA*	Territory	FLMA*
Apportioned programs (formula)	✓						
Bridge Program (formula)	✓			✓			
National Electric Vehicle Formula Program	✓		✓				
Safe Streets and Roads for All program		✓	✓	✓			
PROTECT Grants (discretionary)	✓	✓	✓	✓	✓		✓
Charging and Fueling Infrastructure Program	✓	✓	✓	✓	✓	✓	
Congestion Relief Program	✓	✓	✓				
Bridge Investment Program (discretionary)	✓	✓	✓	✓	✓		✓
Reconnecting Communities Pilot Program	✓	✓	✓	✓			
Rural Surface Transportation Grants	✓		✓	✓			
INFRA	✓	✓	✓	✓	✓		✓
Nat'l Infra. Project Assistance	✓	✓	✓	✓	✓		
Local and Regional Project Assistance	✓	✓	✓	✓	✓	✓	

Source: Blanton (2022)

Figure 6. FHWA New Funding under BIL.

UAS allows for projects to be completed more efficiently and safely in an environmentally conscious manner. These advantages of UAS align with the focus of the FHWA in desired impact of these new funds. UAS program managers should work collaboratively with state resources when applying for these various FHWA grants and funding opportunities.

Another potential form of funding would be from the Federal Drone Infrastructure Inspection Grant Act. This act, H.R.5315, was passed by the United States House of Representatives on September 13, 2022, and its companion bill S.4744 is under committee review in the Senate. This bill would invest $200 million into a grant program, half of which would be used to sponsor additional UAS inspection efforts and the other half would be spent on UAS training and workforce development (AUVSI Advocacy, 2022). If this bill passes the Senate and is signed into law by the Biden administration, it would likely be another viable form of funding for State DOTs and their UAS deployment efforts.

10.4 Policy and Procedures

UAS program policies and procedures should align with UAS-related policy at the federal, state, and local levels. The UAS program manager can create program policies and procedures but should work in collaboration with an established UAS committee. The committee can help create the policies or, at a minimum, it can review and approve the final draft.

Policy development should leverage other established UAS programs and rely on federal sites such as the FAA UAS website and FHWA UAS website that host many resources. A policy and procedures document for the UAS program should be as comprehensive as possible and should be a living document. The state of the industry regarding technology and regulations is constantly changing, and the UAS program manager should consider frequent periodic reviews of the document.

It may be helpful to consider the following elements when developing the policy and procedures document:

- Organizational structure
- Requirements for pilots, visual observers, other UAS crew members
- Training and proficiency requirements
- Acceptable uses
- Procurement
- Community coordination and dissemination
- Flight operations
    - Pre-flight planning
        - Site assessment
        - Waivers
        - Risk assessment
        - Some establish third party flight approvals
    - Flight operations
    - Data management
    - Emergency procedures
    - Accident reporting
- Contracting procedures
- Maintenance reporting and schedule requirements

10.5 Technology/Data Policy

Integrating UAS across different use cases will likely create large amounts of data. When starting or growing a UAS program, it may be helpful to plan for how these data will be managed across the organization. Efforts should be made to maximize the benefits of the data across the organization while also ensuring proper data management best practices. Figure 7 provides a visual representation of the data management lifecycle.

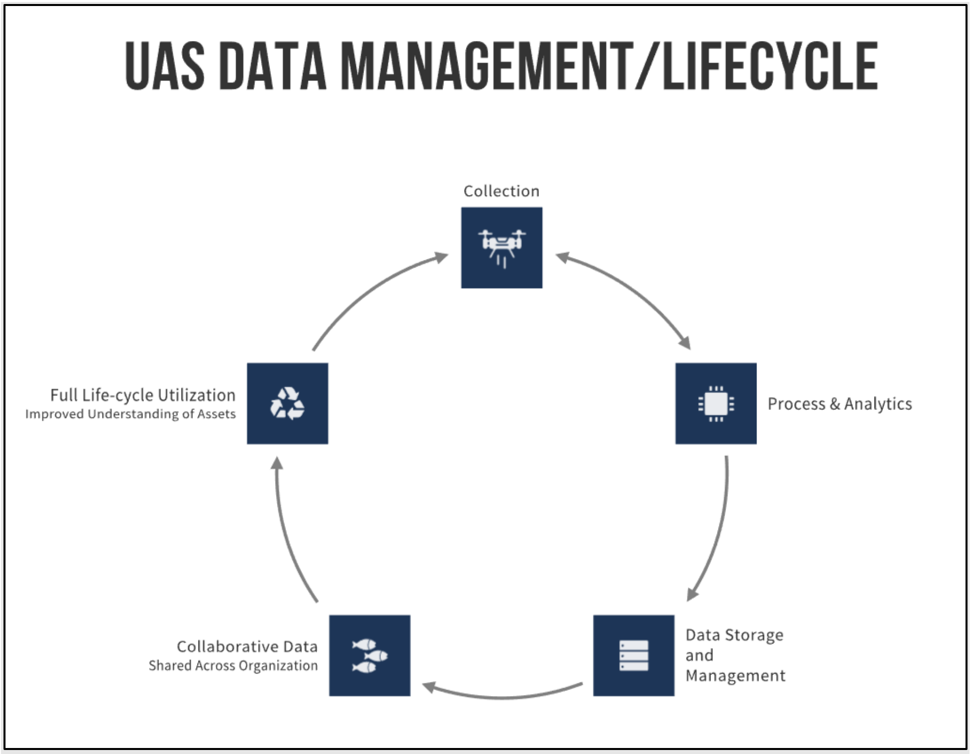


Figure 7. UAS Data Management/Lifecycle.

Some considerations when planning for data management include:

25. Establish goals for the data related to their use.
26. Determine what processing is required to accomplish those goals and what software may be required.
27. Determine how data will be transmitted to maintain security and suit the end user.
28. Determine privacy, storage, and retention methods to maintain data.
29. Find multiple uses for the data to share across an organization to increase the return on investment.

Having a well-conceived data management plan from the start of a program and including information technology departments and other repositories, such as GIS, may assist with data sharing across an organization. Fostering good data management practices may help organizations justify the costs of storing large data sets generated from UAS.

11.0 STATE OF THE PRACTICE

The State of the Practice for the UAS industry is still evolving because UAS applications are still being discovered and implemented. The last five years have witnessed tremendous growth regarding State DOT use of UAS in one form or another. In 2018, the American Association of State Highway and Transportation Officials reported that 45 percent of State DOTs were using UAS. By 2021 it was reported that all 50 states were in various stages of UAS integration (AASHTO, 2019). The positive impact of UAS on surface transportation projects is evident and likely the reason that 100 percent of State DOTs have adopted or are currently researching relevant use cases in which they can use UA resources. Figure 8 captures some of these positive impacts.

Source: Haynes (2022)

Figure 8. UAS Benefits in Surface Transportation Programs.

While these and other UAS benefits will be further discussed throughout this section, there are general challenges or downsides to using UAS which State DOTs should consider. One of the downsides of State DOTs using UAS which is often encountered is the high cost of procurement and maintenance. UAS platforms and remote sensing equipment can be expensive, and State DOTs often struggle to find the necessary budget to purchase and maintain a fleet of UAS. In addition, there may be additional costs associated with training personnel to operate and maintain the UAS, as well as potential legal and regulatory fees for obtaining necessary permits and certifications. These can be challenges especially when traditional equipment to complete inspections and other responsibilities is already owned and operators are familiar with the existing equipment.

Another potential challenge is public acceptance of UAS and overall concern for privacy. The use of UAS may raise concerns about data security and the protection of sensitive information collected by the UAS. In addition, the use of UAS may raise concerns about the safety of individuals and property in the airspace, particularly in densely populated areas. These issues should be considered by State DOTs because ultimately the development and implementation of regulations and policies surrounding the use of UAS and the State DOT's UAS program will be needed.

Many of these potential challenges have been addressed throughout the report, but ultimately each State DOT must carefully weigh the costs and the benefits of using UAS to ensure that it is making the most efficient use of resources. The remainder of this section will explore UAS use cases and the identified benefits that can come from UAS utilization.

While some responsibilities of State DOTs are the same, others are unique to different states. A sample of the various UAS use cases across the United States is provided below.

Agriculture	Planning
Archaeology	Preconstruction
Asset Management	Public Outreach
Avalanche Mitigation	Public Utilities
Bridge Inspection	Rail & Transit inspections
Commercial delivery	Slope Stability Assessment/Monitoring
Construction Inspection	Structural inspections
Data Management	Supplemental structure Inspections
Emergency Response	Supply Chain Management
Environmental Assessment	Surveying and Mapping
Incident Management	Traffic monitoring
Landslide Mitigation	Vegetation Health Analysis
Material Volume Quantities	Volcano Observation

While this list demonstrates the growing number of use cases across State DOTs, this section focuses on the core UAS use cases and topics listed below.

30. Surveying and mapping
31. Structure inspection
32. Construction monitoring and quantities
33. Emergency response and recovery
34. Public engagement and outreach

Examples from different states are provided concerning UAS effectiveness, efficiency, and cost savings across these core UAS use cases. Table 3 provides an overview of which states or U.S. territories are actively using UAS in these core use cases. There is a 78 percent participation in three or more use cases across the United States and territories.

Table 3. Core Use Cases Across the States.

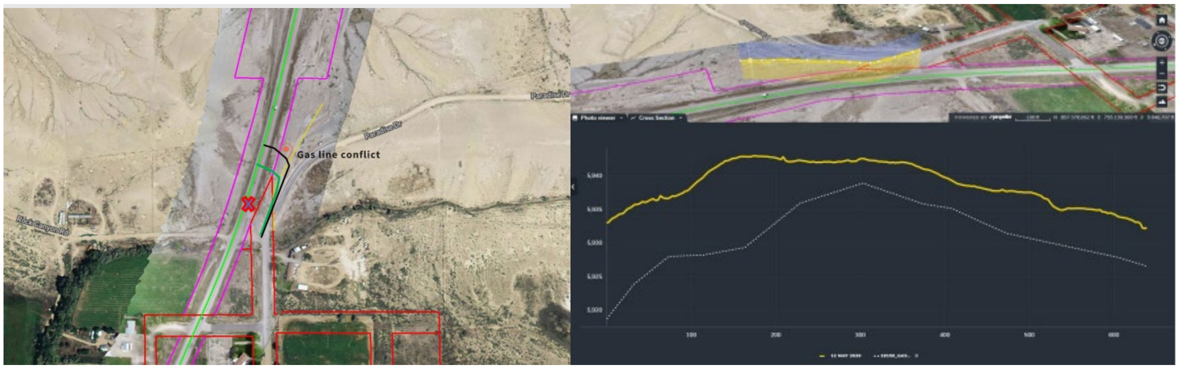
State or U.S. Territory	Surveying and Mapping	Structure Inspection	Construction Monitoring/Quantities	Emergency Response	Public Outreach
AK	✓	✓	✓	✓	✓
AL	✓	✓	✓	✓	✓
AR	✓			✓	✓
AZ	✓	✓	✓	✓	✓
CA	✓	✓	✓	✓	✓
CO	✓	✓		✓	
CT	✓	✓	✓		✓
DC					
DE	✓	✓		✓	
FL	✓	✓	✓	✓	
GA	✓	✓	✓	✓	
GU					
HI		✓	✓	✓	✓
IA	✓	✓	✓	✓	✓
ID	✓	✓			
IL	✓	✓	✓		
IN			✓		
KS	✓	✓	✓	✓	✓
KY	✓	✓	✓		
LA					
MA	✓	✓	✓	✓	
MD		✓		✓	✓
ME	✓	✓		✓	✓
MI	✓	✓			
MN	✓	✓	✓	✓	✓
MO		✓			
MS	✓		✓		

State or U.S. Territory	Surveying and Mapping	Structure Inspection	Construction Monitoring/Quantities	Emergency Response	Public Outreach
MT	✓	✓	✓		
NC	✓	✓	✓	✓	✓
ND	✓	✓	✓	✓	✓
NE	✓	✓	✓		
NH	✓	✓	✓	✓	✓
NJ	✓	✓	✓	✓	✓
NM	✓	✓	✓	✓	✓
NV	✓				
NY			✓		
OH	✓	✓	✓	✓	✓
OK	✓	✓	✓	✓	
OR	✓	✓	✓		
PA	✓	✓	✓	✓	✓
PR	✓	✓	✓	✓	✓
RI	✓			✓	✓
SC					✓
SD	✓	✓	✓		✓
TN	✓				
TX	✓	✓	✓		
UT	✓	✓	✓	✓	✓
VA		✓	✓	✓	✓
VI	✓		✓	✓	
VT	✓	✓	✓	✓	✓
WA	✓	✓	✓		
WI					
WV	✓	✓	✓	✓	
WY	✓	✓	✓		

11.1 Surveying and Mapping

Topographic surveys are often required for large transportation projects. Traditional surveys can be time consuming, and depending on the project, can have negative impacts such as lanes closures or safety concerns. The South Dakota Department of Transportation is currently using UAS for surveying and mapping on highway projects and plans to track different key indicators. South Dakota's program goals are to realize an increase of safety, time savings, and cost savings while increasing accuracy and precision (Dean et al., 2022).

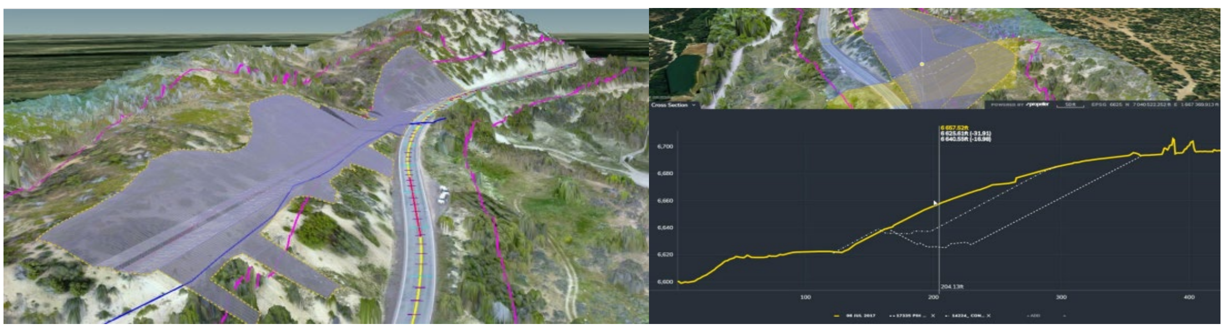
The Utah Department of Transportation (UDOT) has had great success using UAS for surveying on diverse projects. On a project evaluating the potential addition of a turning lane (Figure 9), the 1-mile, 30-minute UAS flight provided an in-depth report of the gas line depth and saved the project an estimated $250,000 (Lindsay, 2022).



Source: Lindsay (2022)

Figure 9. UDOT Turning Lane Surveying Project.

Another UDOT project focused on planning for a runaway truck ramp (Figure 10). Here again, a brief UAS flight provided a detailed comparison of earthwork quantities, which resulted in an estimated $500,000 savings (Lindsay, 2022).



Source: Lindsay (2022)

Figure 10. UDOT Runaway Truck Ramp Surveying Project.

11.2 Structure Inspection

Using UAS to inspect structures such as bridges, light poles, signage, towers, and other infrastructure has increased safety, improved quality and efficiency, and lowered costs. The New Jersey DOT used UAS in 96 percent of its High Mast Lighting Pole inspections. New Jersey DOT reports that by deploying UAS for these inspections, it reduced injury risk within work zones, eliminated injury risk to bucket operators, and removed the risk of vehicle crashes from lane closures (Stott, 2021). Using UAS to complete these inspections also resulted in increased efficiency and lower costs. Figure 11 outlines these benefits.

Criteria	Bucket Truck Approach (For all initial Inspections)	Traditional Approach (Bucket Truck for Secondary Inspection Only)	UAS Approach
Time (Labor-hours)*	3,312	1,264 – 1,552	1,476
Cost*	$477,022	$167,600 - $177,667	$186,025
Safety (cost)	$2,162 per pole requiring a lane closure (6)	$2,162 per pole requiring a lane closure (maximum 6)	$0
Efficiency (cost)	$1,736 per pole requiring a lane closure (6)	$1,736 per pole requiring a lane closure (maximum 6)	$0
Total Cost	$500,410	$190,988 - $201,055	$186,025

Note: * Assumes 10% of high mast light poles require a secondary inspection using the traditional approach. The range of values in the traditional approach accounts for the possible locations and access requirements of the poles requiring a secondary inspection.

Source: Stott (2021)

Figure 11. New Jersey DOT Benefits Report on UAS High Mast Lighting Pole Inspections.

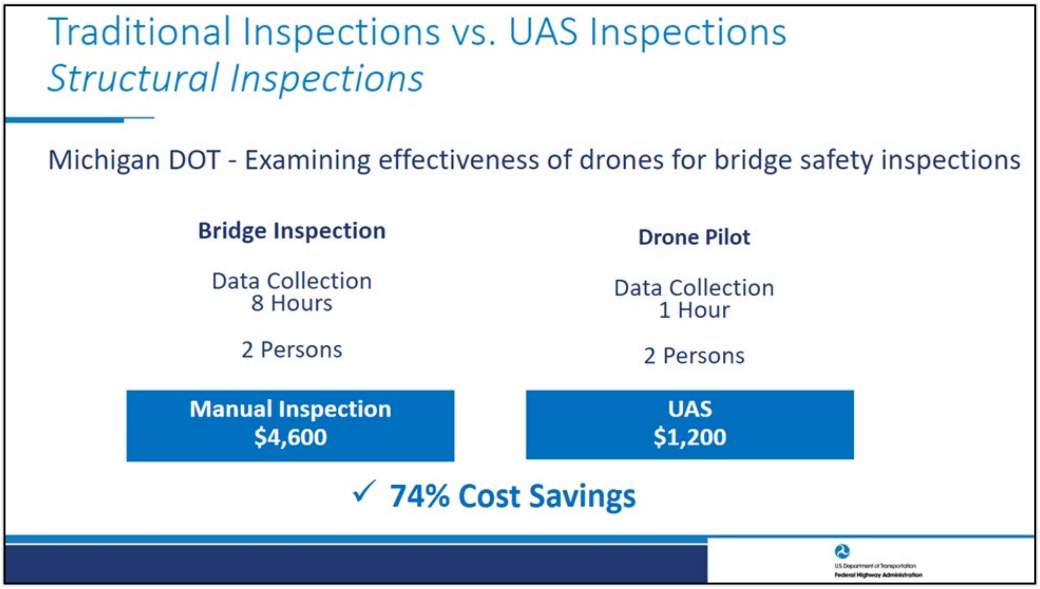
The Minnesota Department of Transportation takes advantage of UAS technologies for bridge inspections. The Minnesota DOT reports increased safety, mainly due to the ability to reduce lane closures, which reduces the risk of work zone accidents. Reduced lane closures yield lower costs because of the reduction or elimination of traffic control personnel and equipment (Wells, 2022). Figure 12 shows the average of 40 percent savings across various bridge and structural inspections.

Structure	Traditional Inspection Cost	UAS Assisted Inspection Cost	Savings +/-	Savings Percentage
19538	$1,080	$1,860	-780	-72%
4175	$15,980	$13,160	2,820	18%
27004	$6,080	$4,340	1740	29%
27201	$2,160	$1,620	540	25%
MDTA Bridges	$40,800	$19,800	21000	51%
2440	$2,160	$1,320	840	39%
27831	$2,580	$540	2040	79%
82045	$2,660	$1,920	740	28%
92080	$2,580	$1,350	1230	48%
92090	$2,410	$1,570	840	35%
62504	$3,660	$1,020	2640	72%
82502	$3,240	$2,400	840	26%
			Average Savings	**40%**

Source: Wells (2022)

Figure 12. Minnesota DOT Savings Report on Bridge Inspections.

Cost savings are often an important motivation for executive leadership buy-in for starting or expanding a UAS program. Although cost savings will vary from project to project or from structure to structure, it is a common theme seen across the states implementing UAS. Michigan DOT reporting savings when analyzing the use of drones for bridge inspections. The results are provided in Figure 13.



Source: Haynes (2022)

Figure 13. Michigan DOT Savings Report on Bridge Inspections.

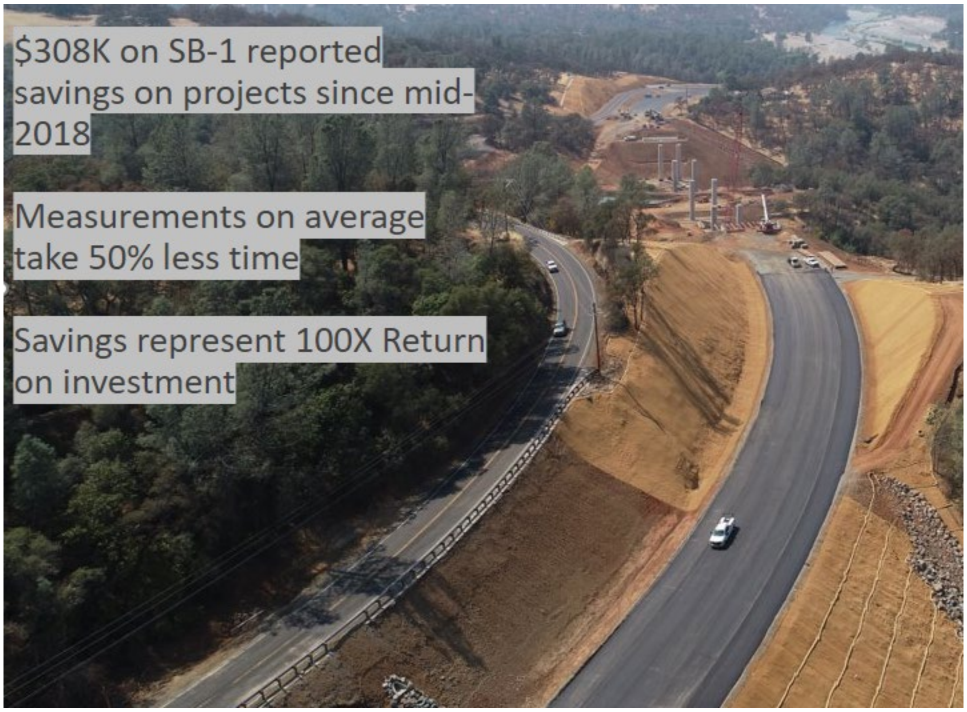
The above examples are focused on aboveground structural inspections, but UAS can be deployed to assist on inspections for belowground infrastructure such as train tunnels, subway routes, and culverts. In spring 2021, Maryland DOT tested the effectiveness of four different UAS in conducting concrete and metal culvert inspections. The flight testing found that UAS culvert inspections can be highly effective in producing quality data in a timelier manner than the ground robots that are traditionally used (Alexander et al., 2021).

Source: Alexander et al. (2021)

Figure 14. Flyability Elios 2 UAS Conducting Maryland DOT Culvert Inspection.

11.3 Construction Monitoring and Quantities

UAS equipped with the correct sensors and partnered with the correct software can be a powerful tool for construction monitoring and quantity measurements. The California Department of Transportation (Caltrans) uses UAS across many use cases, including construction monitoring. On a recent project in Smartsville, California, Caltrans reported that it rejected more than $60,000 in extra work bills because of UAS-collected data, and no claims of protest were filed from the contractor. Other benefits on this same project are captured in Figure 15 (Chamberlin, 2022).



Source: Chamberlin (2022)

Figure 15. Caltrans Report on UAS Savings on Smartsville Project.

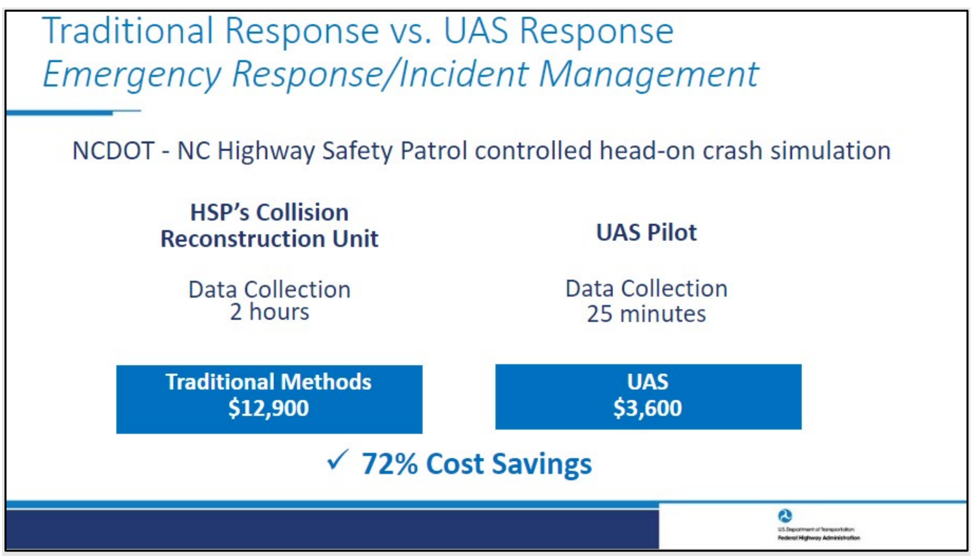
Alabama DOT notes several benefits related to construction monitoring using UAS. Deploying UAS on repeatable flight paths over large transportation projects has added a new and insightful perspective. The data collected and processed with various software allow for powerful weekly progress reports to be automatically generated and sent to key stakeholders (D’Arville, 2022).

Source: D'Arville (2022)

Figure 16. Alabama SR181 Progress Report Example.

11.4 Emergency Response and Recovery

UAS can be helpful in emergency response and recovery by collecting low-cost, high-quality data in a timely manner and by providing situational awareness in an ongoing recovery. North Carolina DOT and North Carolina Highway Safety Patrol simulated a head-on collision in a controlled testing environment. Traditional data collection for accident reconstruction took two hours, while the UAS method collected data in 25 minutes. Figure 17 displays the cost savings from the simulated test (Gray, 2022).



Source: Gray (2022)

Figure 17. NCDOT Cost Savings Report for Emergency Response.

The Washington State Patrol reported that within an 8-month period, UAS assisted in 91 accident investigations resulting in a 77 percent reduction in road closure time and an estimated savings of $3.4 million (Gray, 2022). Oklahoma DOT worked closely with Oklahoma Highway Patrol as both agencies embraced UAS. Oklahoma Highway Patrol has flown 164 missions to document traffic accidents with an average of 15 minutes and 35 seconds flight time per operation, allowing it to collect high-quality data on the accidents for future investigation. UAS use has increased time savings and allowed the accident to be cleared and the road reopened much faster than traditional methods (Schwennesen, 2021).

11.5 Public Engagement and Outreach

Like other new technologies, the public has concerns about UAS, and often these concerns are about noise, privacy, and safety. It is important to consider all stakeholder concerns, including the public, and to formulate a plan to address these concerns. Formal and informal outreach and education programs are common tools used by state agencies (Banks et al., 2018). In these outreach programs, State DOTs can share examples of how they use UAS to fulfill their responsibilities and by conveying the increased safety, time, and cost savings that directly benefit the public.

According to the Community Air Mobility Initiative, two keys to the foundation of public acceptance of aerial technology are earning the public's trust and demonstrating public benefits (Dietrich, 2020). State DOTs often have formal outreach programs tied into the many functions of the department and should include UAS in these traditional forms of messaging. Aerial imagery is a great asset when updating the public via websites or media outlets on the progress of construction projects. Educational messages about UAS and how they are used can seamlessly be tied into current and new outreach efforts.

12.0 WORKSHOP FINDINGS

NHDOT held a UAS Implementation Planning Workshop on February 15, 2023. This half-day workshop brought together representatives from various divisions across the NHDOT, including Aeronautics, Planning/GIS, Highway Design, Construction, Maintenance, Materials, Research, Bridge Inspection, and Transportation Systems Management and Operations. The purpose of this workshop was to present the key findings of the UAS State of the Practice and then to participate in breakout sessions to understand the status and growth plans for UAS implementation across the agency.

The workshop opened with a presentation and review of the Task 1a Report which provided an updated national perspective on the UAS State of the Practice. The remainder of the workshop was used to conduct two separate and concurrent breakout sessions, one with senior staff and one with junior staff. Interactive poll questions were used to guide the discussion in each breakout session; the results of these questions are included in Appendix A. The questions were designed to understand the current level of UAS integration, overall program organization, and plans for future UAS implementation and program growth. The questions were divided into the following key categories:

35. People, Organization, and Skills.
36. Data/Information Management, Governance, and Standards.
37. Tools, Systems, and Technologies.
38. Processes, Strategies, and Activities.

The poll question responses were recorded and analyzed post-workshop. The high-level findings from the workshop discussions and question analysis are outlined below by key category.

12.1 People, Organization, and Skills

The UAS program is currently housed within the Division of Aeronautics. The results of one of the poll questions demonstrated that most personnel throughout the agency are aware of this and know who the designated point of contact is for UAS. At the time of the workshop, only one certified UAS pilot was in attendance, and both junior and senior staff agreed that staff capacity, in terms of number of people and levels of expertise, is not completely sufficient, each group expressed goals to increase staff capacity. The strategy used by many State DOTs is to increase staff capacity by training people across functional departments how to use UAS as a tool to assist with their primary functional duties. The discussion in the senior staff breakout session revolved around this strategy and how the goal would be to initially develop a small group of pilots in Division of Aeronautics and then transition to embedding other UAS pilots across the agency.

Both junior and senior staff agreed that using UAS should be another expectation of required job functions is an acceptable approach. However, disagreement emerged around who should pay for the Part 107 UAS Remote Pilot exam. While 72 percent of junior staff think the Part 107 exam should be paid for by the agency, only 33 percent of senior staff answered the poll question in favor of paying for the exam fee.

As the UAS program grows, training needs will increase—100 percent of the senior staff in attendance foresee the need to hire an internal UAS training manager. This position likely will have other primary duties, but the individual will be charged with UAS training throughout the agency. Currently, 91 percent of junior staff reported they do not have adequate UAS training, and 81 percent noted the need for additional practical training and training on internal policies and procedures. NHDOT currently outsources UAS operations and can continue to do so until these training needs are met, and more internal individuals are qualified to use UAS.

The senior staff discussed an organizational model for growth that entails supporting the designated UAS program manager who oversees the UAS program within the Division of Aeronautics. Senior staff want the program to grow organically with the need for UAS to be used as tools. As the program grows, another position could be added below the UAS program manager to assist with training and support the development of internal UAS pilots. The UAS program could potentially become its own branch within Aeronautics or be housed within an emerging technologies division within NHDOT.

12.2 Data/Information Management, Governance, and Standards

The majority of those present in the workshop breakout sessions expressed the goal to share and use UAS data across the organization. However, most participants also reported they were either unaware of an existing structure or did not think one was currently in place that would enable the internal sharing of UAS data and deliverables. Sixty-six percent of senior staff and 82 percent of the junior staff reported they were unaware if any coordination had been initiated with NHDOT's chief data management officer regarding UAS data management.

The consensus across both groups was that cloud-based storage solutions could be best for future UAS data storage. NHDOT currently does not have a policy in place related to the length of time the UAS-collected data would be retained. In addition, current naming protocols for UAS data files are inconsistent, and the overall organization of UAS-collected data is lacking. Currently, there is a preliminary framework of a system where projects are organized by cities, and UAS data are saved in a folder as part of the project. Current UAS data is being processed using a combination of cloud-based solutions and internal hardware. When consultants collect UAS data, they go into the cloud and are not actively managed.

12.3 Tools, Systems, and Technologies

Each UAS program will have a variety of UAS platforms, tools, and equipment that will need to be actively managed as the program grows. NHDOT does not currently have a dedicated UAS fleet management software or process in place to manage the equipment; the agency uses a Work Order and Fleet Inventory tool that could be adapted. While 91 percent of junior staff were unsure if the agency plans to dictate which UAS platforms can be procured, 80 percent of senior staff reported that they did not want to restrict procurement of platforms. Senior staff envision that UAS platforms will be purchased to meet specific division needs.

There was overall agreement regarding the order of perceived benefits that would result from increased UAS utilization. Figure 18 depicts the results from the senior staff breakout session, and Figure 19 depicts the results from the junior staff breakout session.

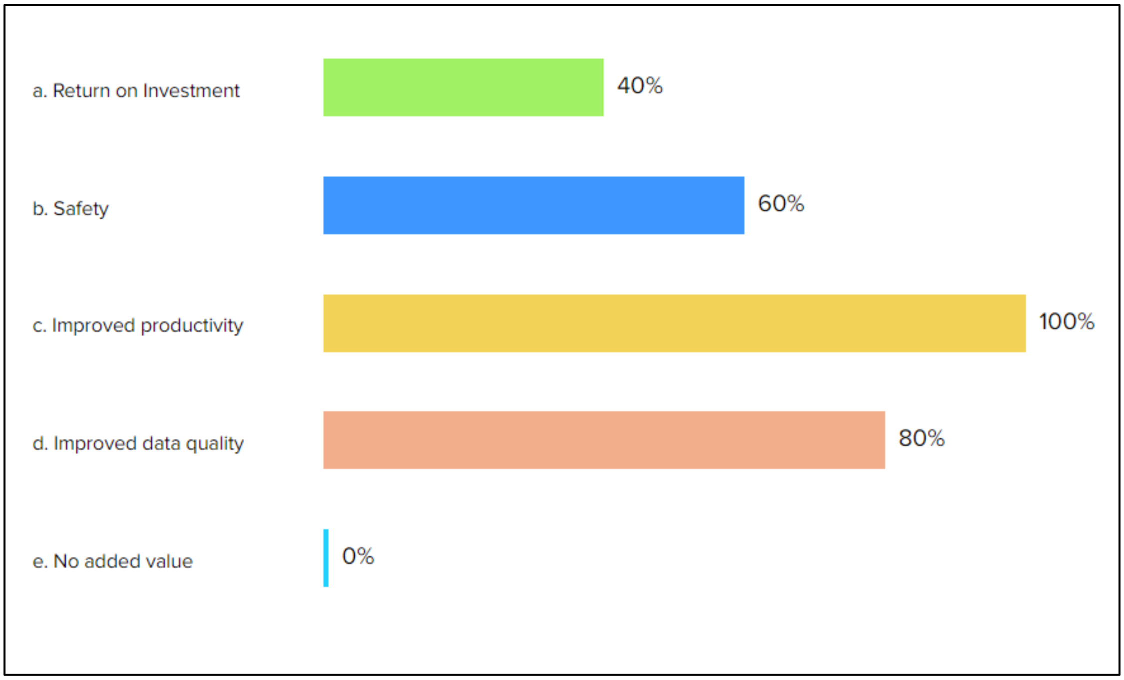


Figure 18. Senior Staff Results Regarding the Benefits UAS Utilization Will Contribute.

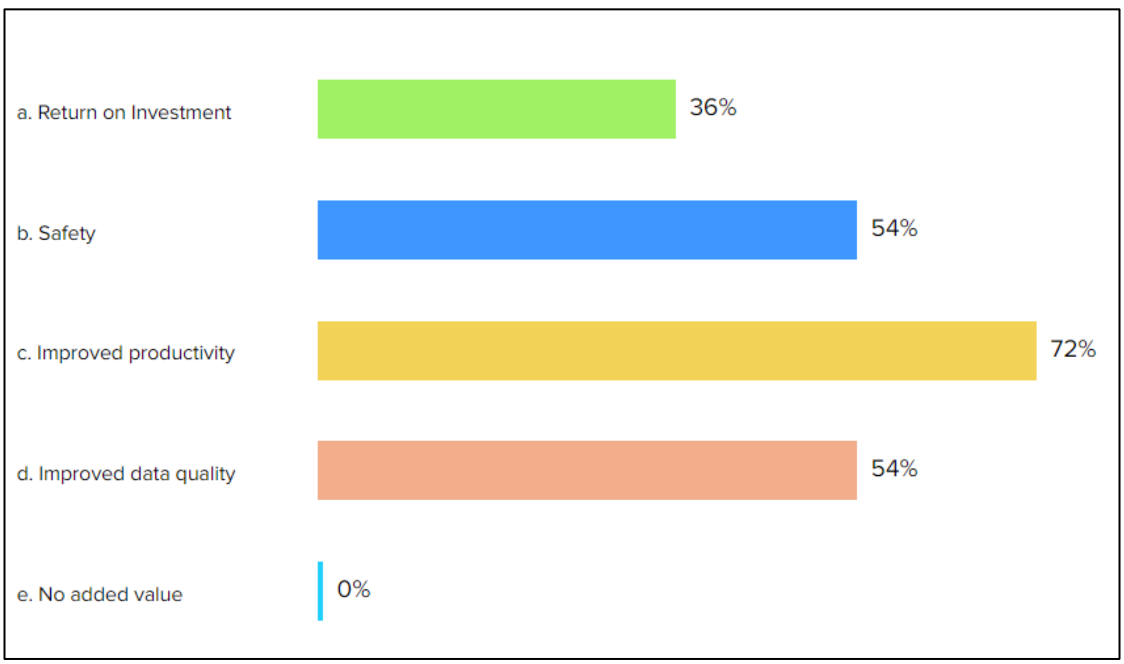


Figure 19. Junior Staff Results Regarding the Benefits UAS Utilization Will Contribute.

No one in attendance expressed the concern that UAS integration would result in no added value. The biggest anticipated benefit in both breakout sessions is improved productivity, followed by improved data quality, improved safety, and overall return on investment. In response to another question about greatest concerns, junior staff reported their greatest concern about UAS was the cost; senior staff's greatest concern was public perception (invasion of privacy being a main concern of citizens).

12.4 Processes, Strategies, and Activities

In the junior staff breakout session, 45 percent of participants reported that the agency has existing UAS workflows for several use cases, but the majority reported they were largely unaware of where to begin to establish UAS specific workflows. It was largely unknown if the agency has explored the use of Artificial Intelligence or Machine Learning software to assist with UAS data processing.

Junior staff were also largely unaware of relationships with academic institutions related to UAS integration or UAS-related research; however, 100 percent of senior staff reported initiating or having already established working relationships with academic institutions on UAS initiatives.

NHDOT has been funding the UAS program with appropriated state funds, and senior staff reported the plan is to continue to use state funding to meet most of the program needs, while potentially applying for federal funding for assistance. Participants in both breakout sessions agreed that UAS platforms should be used until the UAS is no longer functioning, rather than scheduling fleet renewal.

Overall, both groups were aligned when asked about the level of pre-flight approval that should be required prior to UAS operations. Only 18 percent of junior staff reported that pre-flight approval should be required only for high levels of risk. Figure 20 depicts the results from the senior staff breakout session, Figure 21 depicts the results from the junior staff breakout session.

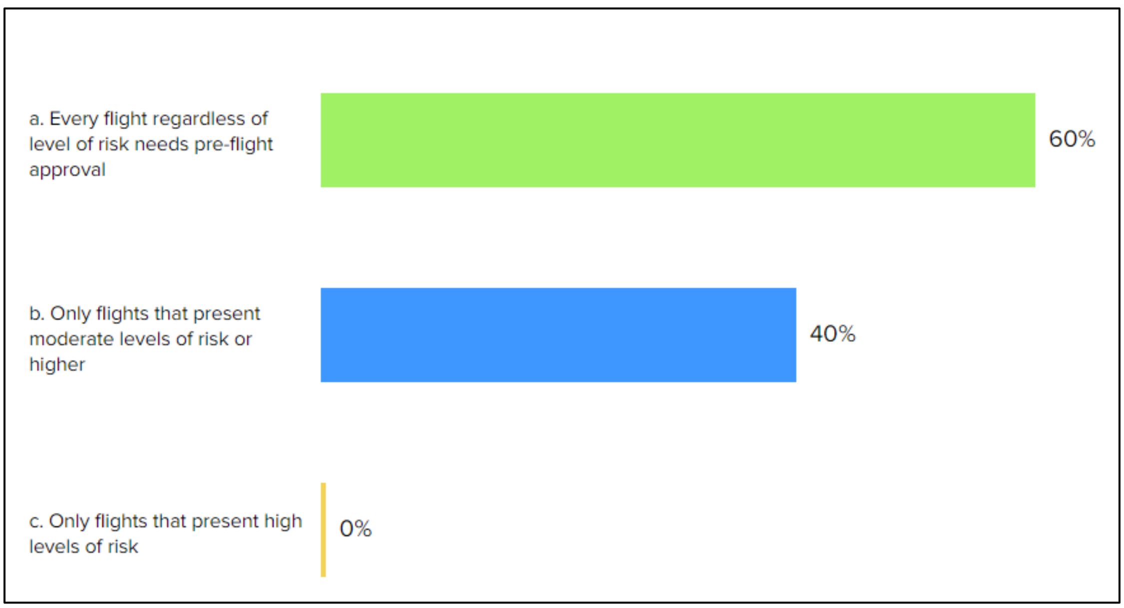


Figure 20. Senior Staff Results Regarding Pre-flight Approval Requirements.

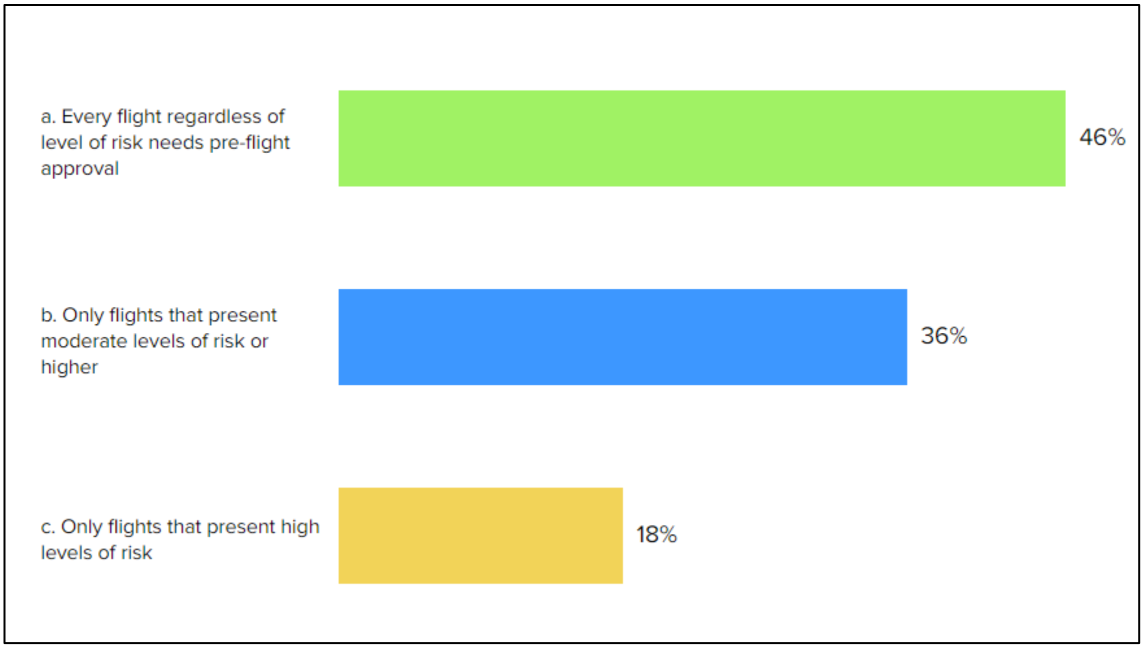


Figure 21. Junior Staff Results Regarding Pre-flight Approval Requirements.

Discussions during the breakout session yielded a long list of the various activities and potential use cases and how UAS can assist in each. This list is provided below:

39. Construction – during project design and layout to provide updated aerial imagery, throughout the project for monitoring, and for pavement marking layouts/pre-conditions/post-conditions/as-builts (for markings).
40. Asset management (asset inventories).
41. Bridge inspection – especially for where snoopers are not available or for areas where access is difficult and potentially dangerous.
42. Highway design – for updated aerial imagery and for conducting expanded surveys (quick turnaround).
43. Asset management (asset inventories).
44. Small site surveys.
45. Aerial photogrammetry and three-dimensional mapping.
46. Traffic movement – intersection turn movements for flow studies or for corridor studies.
47. Extreme weather applications—high water lines or to see how assets are performing under extreme weather.
48. Monitoring wildlife crossings.
49. Pavement inspections.

In addition to these potential use cases, attendees in both breakout sessions also discussed using UAS in recruitment activities. Attendees agreed that adopting UAS technologies will improve staff retention and help attract new staff to join NHDOT.

13.0 SUMMARY AND CONCLUSION

The use cases and benefits from the utilization of UAS by State DOTs continue to grow. All 50 State DOTs have adopted or are currently planning for adoption of UAS. State DOTs seeking to integrate UAS into their operations should have a working knowledge of FAA rules and regulations, especially Part 107, which governs the operations of small UAS. State DOTs in the process of formalizing a UAS program should consider the following:

50. The advantages and disadvantages of each organizational structure model.
51. The potential roles and responsibilities of each position within the UAS program.
52. Fostering collaborative relationships with state legislators and awareness of state legislative priorities concerning UAS.
53. Securing dedicated funding for startup and growth costs of the UAS program.
54. Creating program policies and procedures concerning flight operations and data management.

This report also analyzes core use cases including surveying, mapping, structural inspections, construction monitoring, quantity reporting, emergency response, and public outreach. Close to 80 percent of states are actively using UAS in three or more of these use cases. UA, when partnered with proper sensors and software, can be a powerful tool that increases safety, reduces impacts on the public, reduces emissions, lowers costs, and provides higher quality data.

As a result of the workshop discussions and poll questions, NHDOT identified six use cases for continued or initial UAS use:

55. Surveying/mapping.
56. Structural inspections.
57. Traffic operations and incident management.
58. Asset maintenance and operations.
59. Construction monitoring.
60. Emergency response.

Once NHDOT reviews and finalizes these, the research team will conduct up to six case studies using a 2-hour virtual interview and a 1-hour process mapping session for each use case. The intent of these case studies will be to evaluate traditional workflows (data and process) to identify areas that can be enabled through the use of UAS technology.

The case studies will showcase the UAS technology and support systems necessary for integration of UAS into the traditional workflows with a focus on specifications rather than specific systems. Additionally, the research team will evaluate the traditional methodology for mandatory and discretionary criteria to ensure compliance with policy/regulation and will develop a benefit/cost framework for each use case to showcase important considerations to support a business case for any investments.

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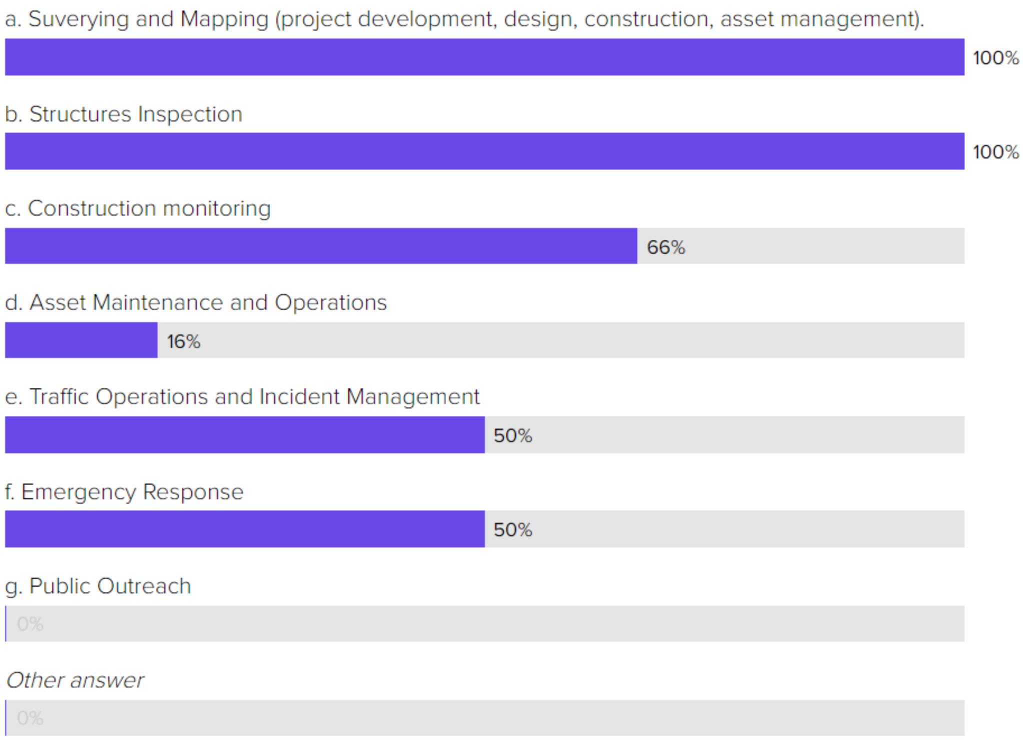
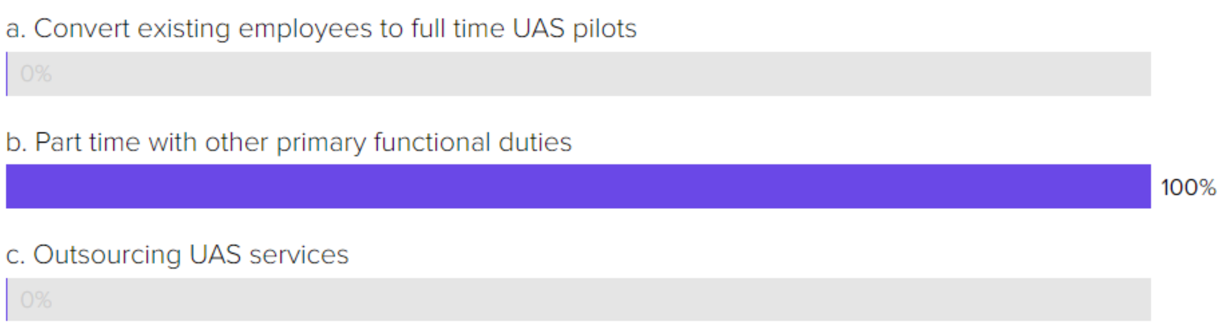
APPENDIX A

Senior Staff Breakout Session Poll Questions and Responses

0. What are the top UAS use cases NHDOT should consider?

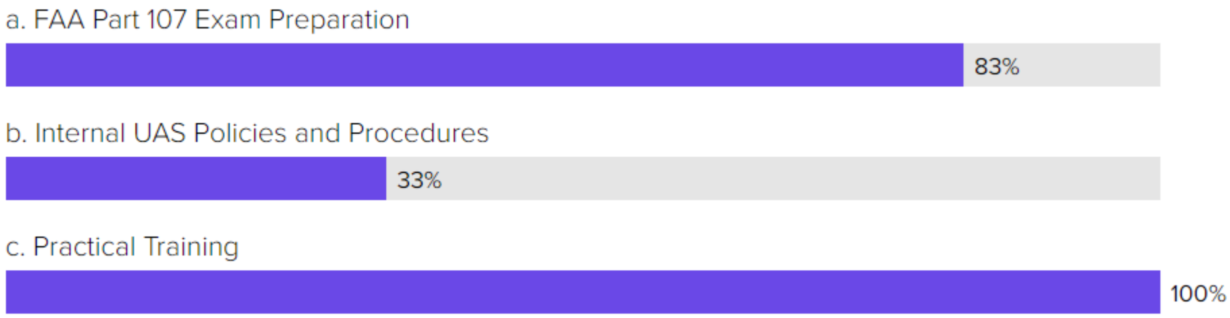


1. As the agency's UAS program grows, how would you plan to accommodate an increase in UAS operations?

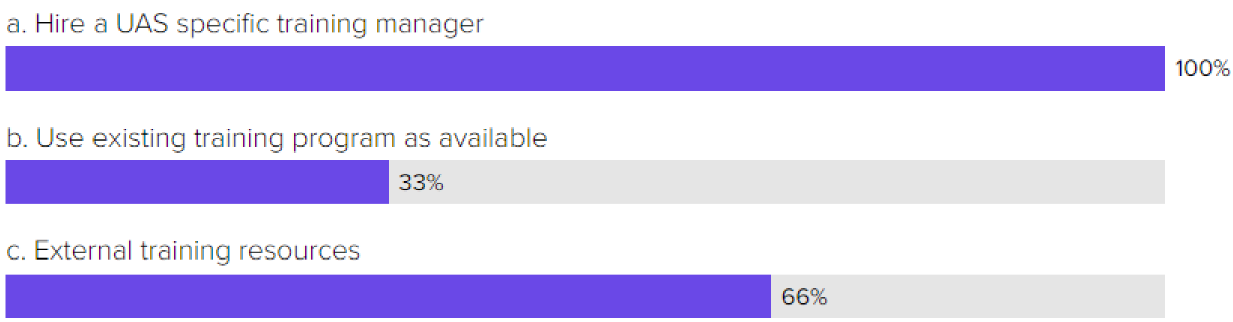


Votes: 2

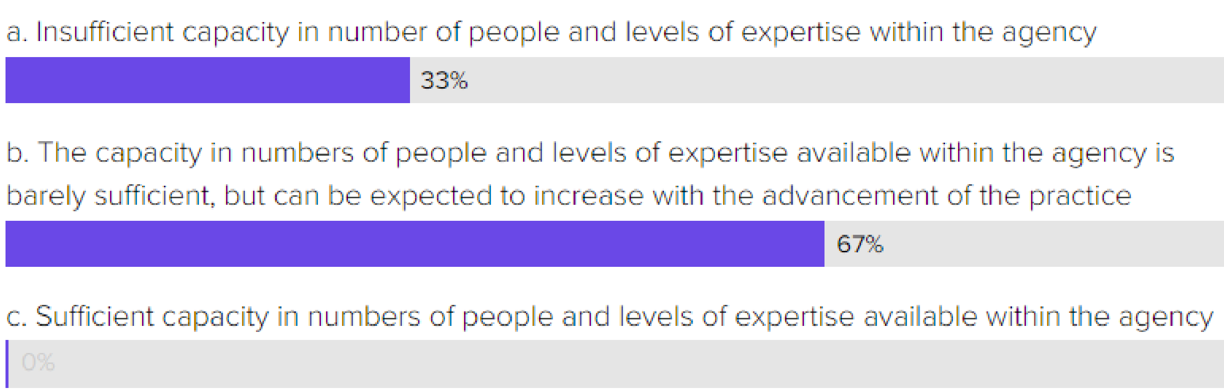
2. What type of UAS training would you anticipate providing internally for staff?



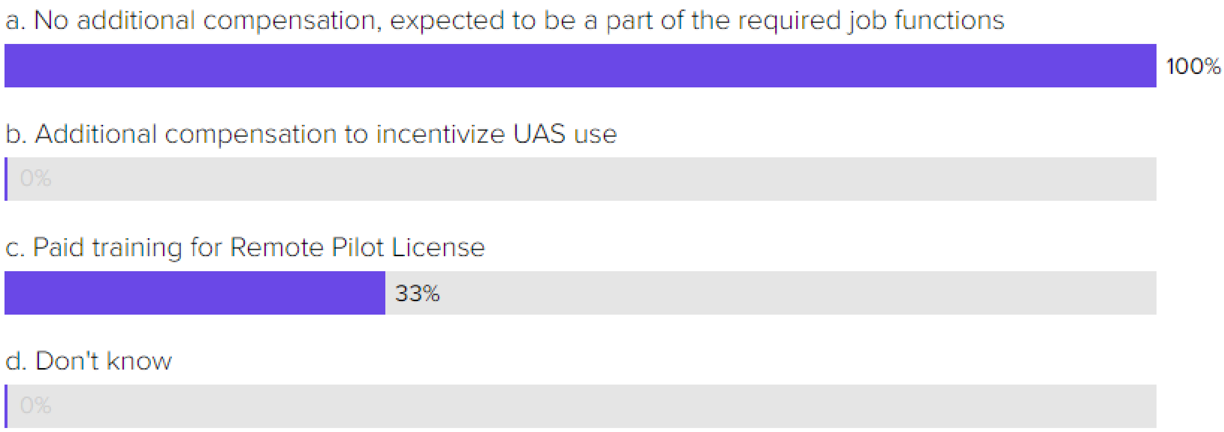
3. As the UAS program grows and UAS training needs increase, how should the agency plan to meet these needs?



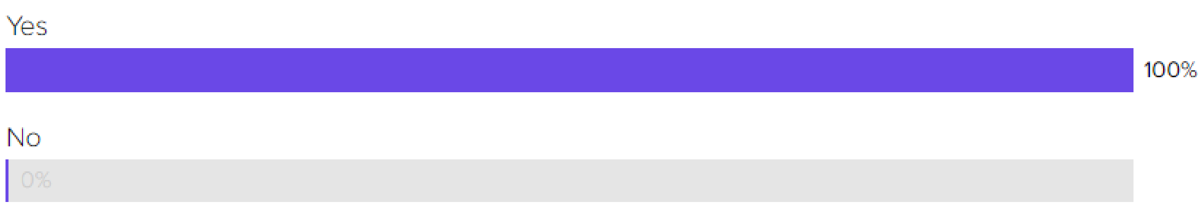
4. How would you rate the agency's staff capacity for UAS?



5. Does the agency have plans to incentivize employees to become UAS pilots?

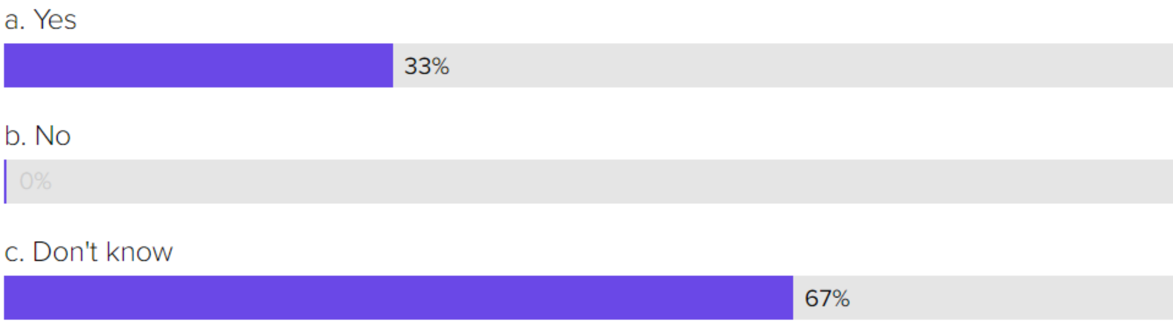


6. Is there a UAS point of contact within your agency?

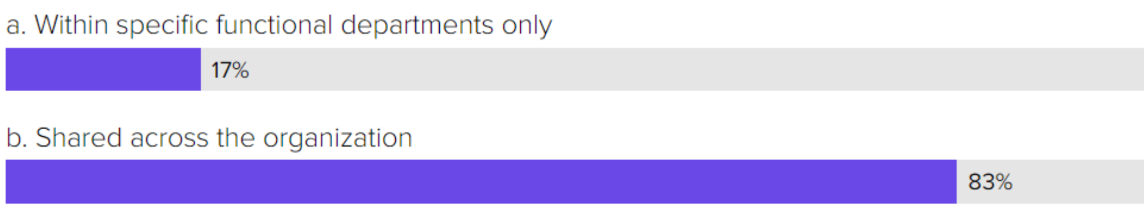


7. How should the agency plan to adapt the organizational model for program growth?

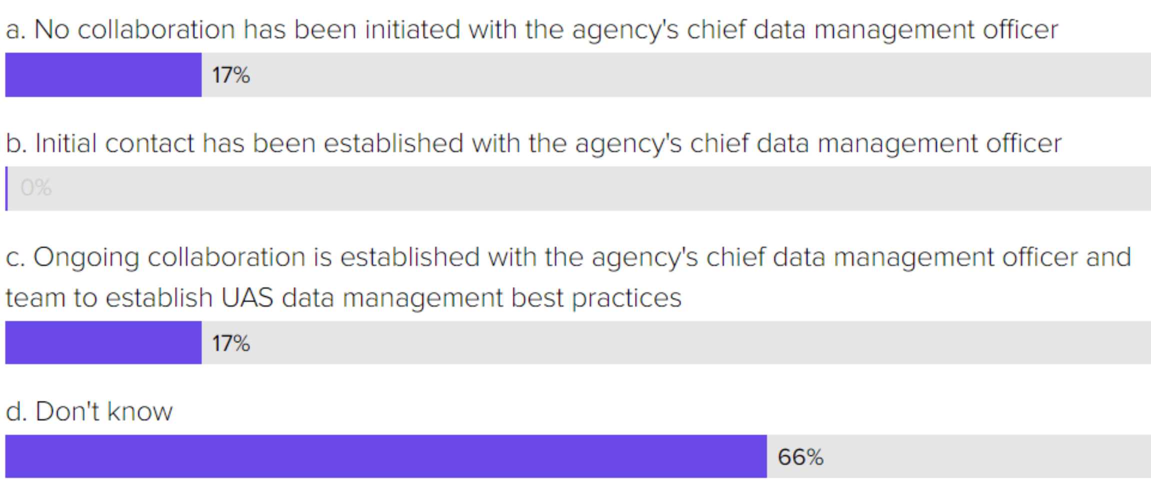
8. Is there a structure currently in place that allows for the internal sharing of UAS data and deliverables?



9. How do you plan to use UAS data internally?

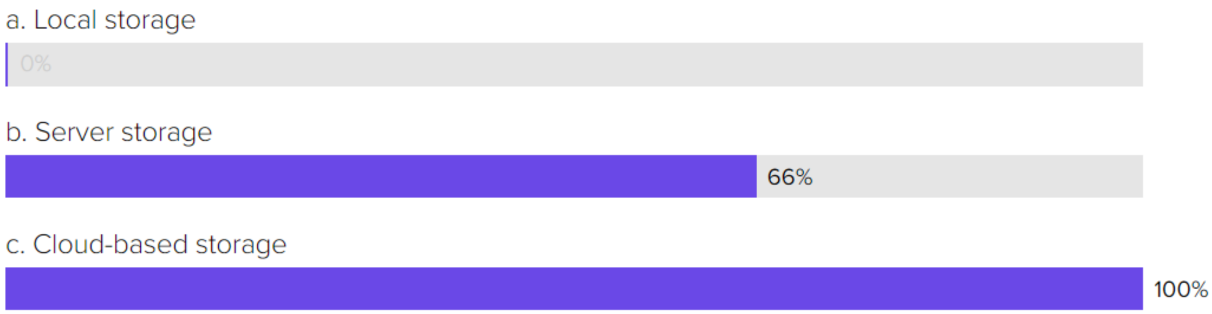


10. Is there coordination with the chief data management officer within the organization?



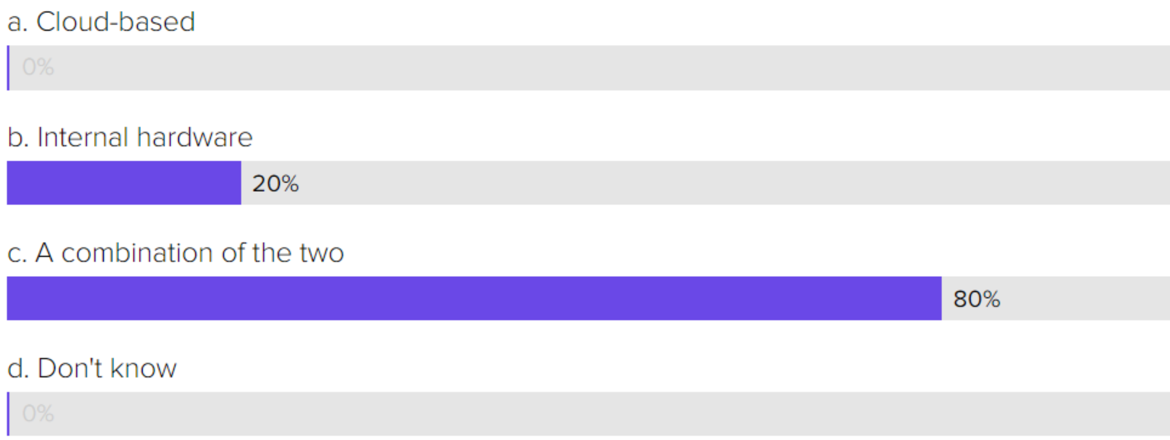
11. Is there a current policy related to the length of time for the retention of UAS data?

12. How should the agency plan for future UAS data storage?

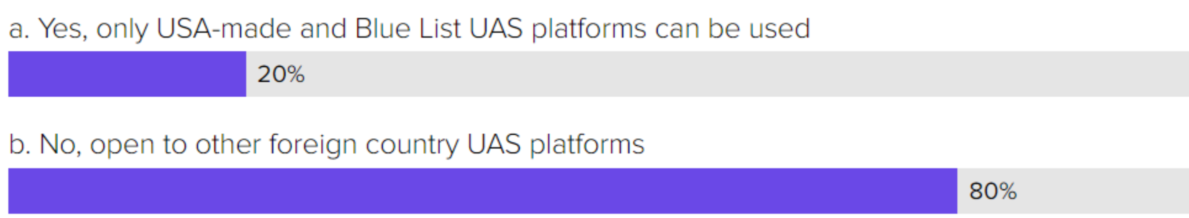


13. Do you have a process in place for naming UAS data files?

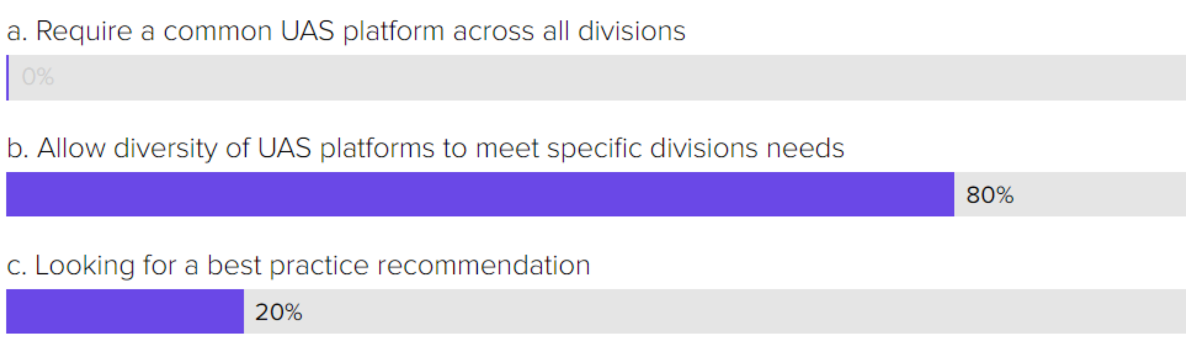
14. Is UAS data processed using cloud-based solutions or internal hardware solutions?



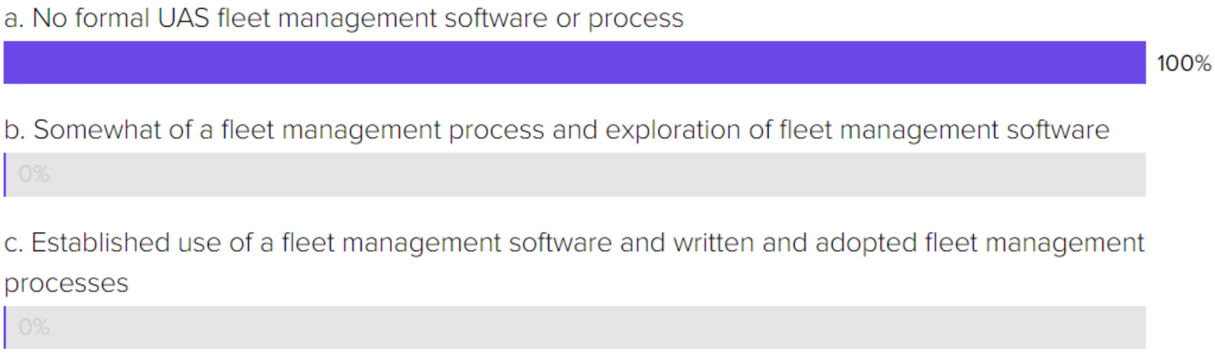
15. Does the agency plan to dictate which UAS platforms can be procured?



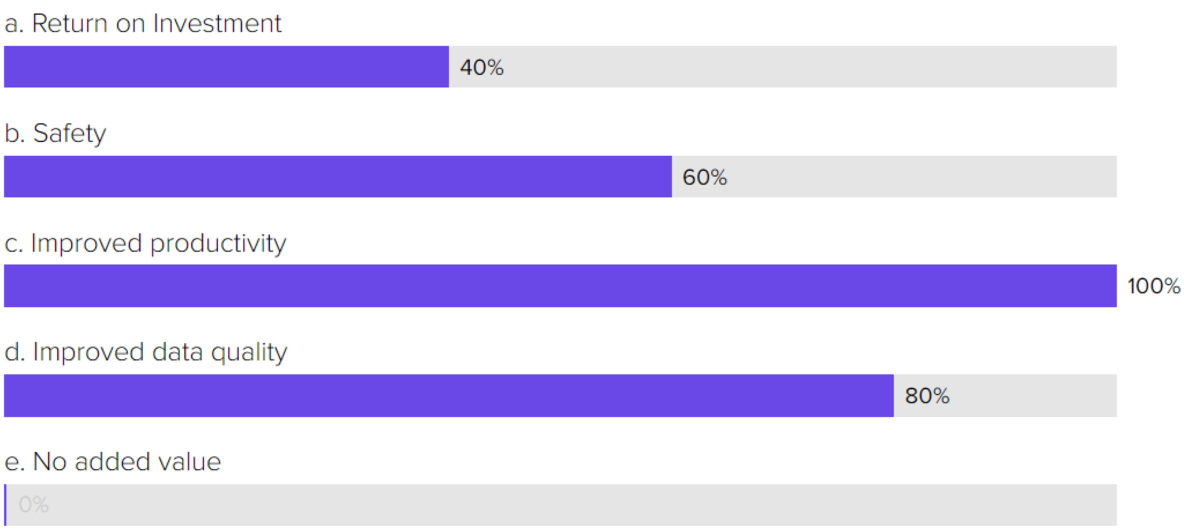
16. For future UAS platform procurement does the agency plan to



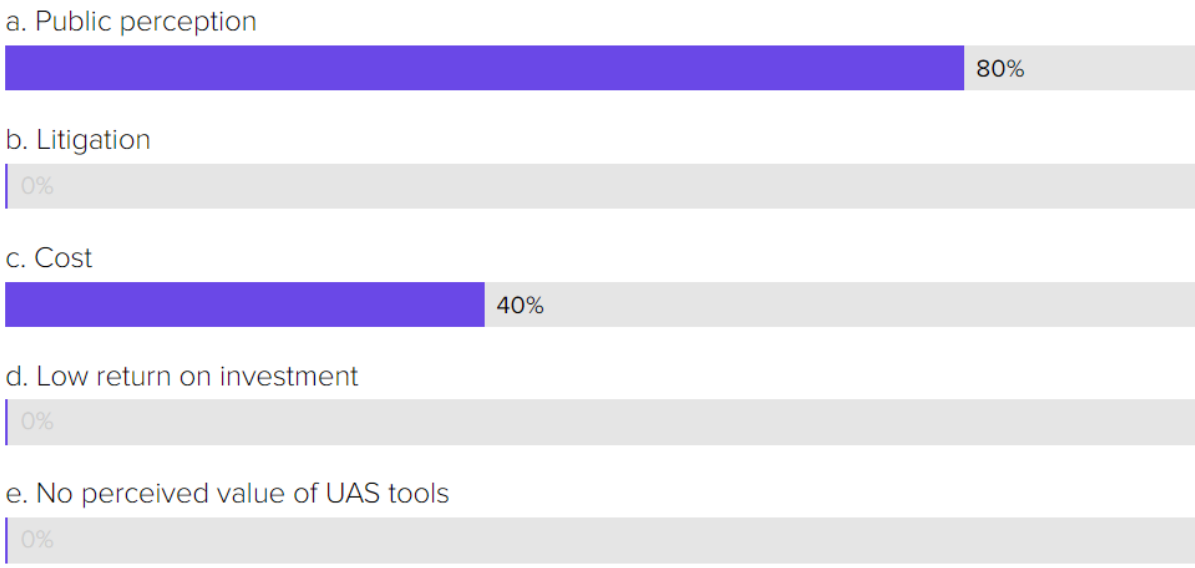
17. Does the agency have a dedicated UAS fleet management software or process in place?



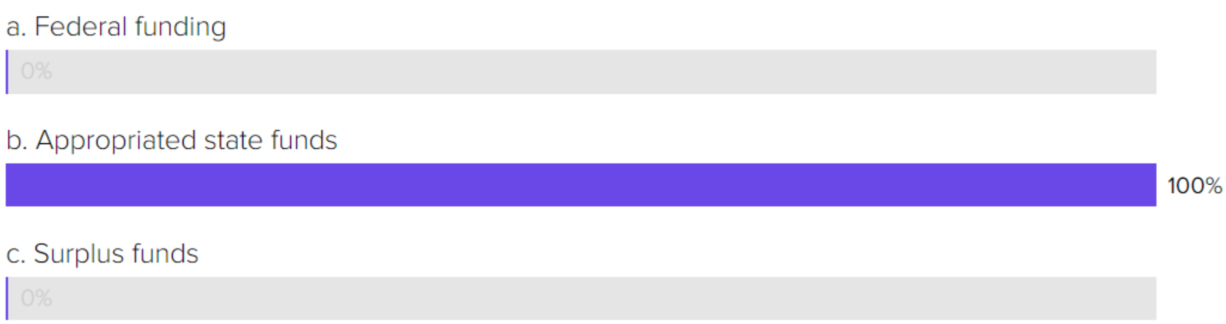
18. What benefits do you think UAS utilization will contribute to the most?



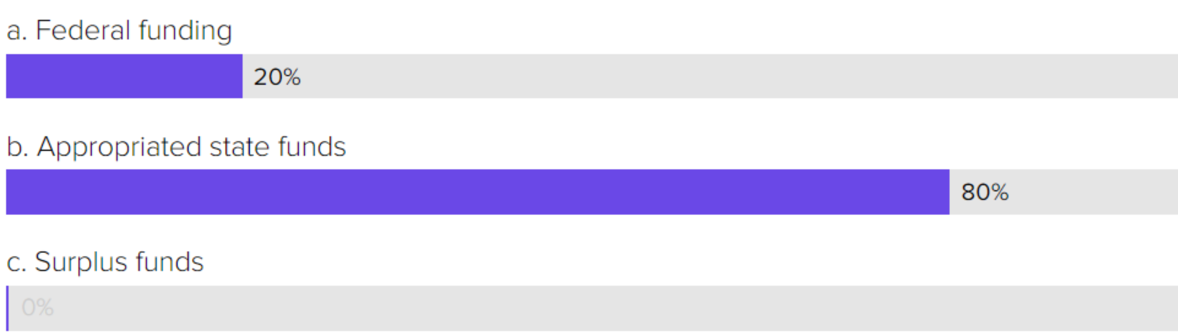
19. What is the greatest concern about UAS use?



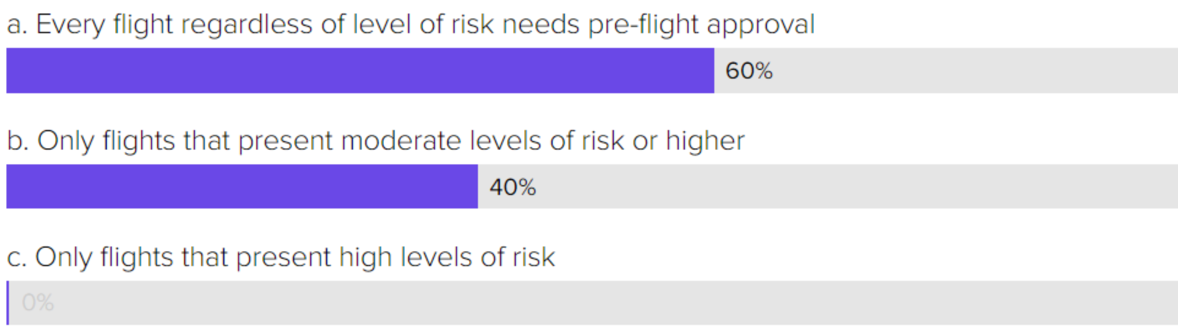
20. How is the UAS program currently funded?



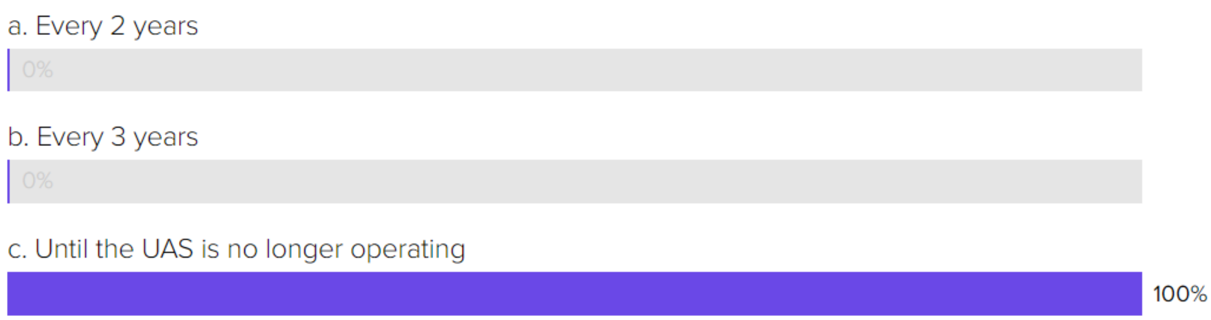
21. How does the agency plan to support the future funding needs of the UAS program?



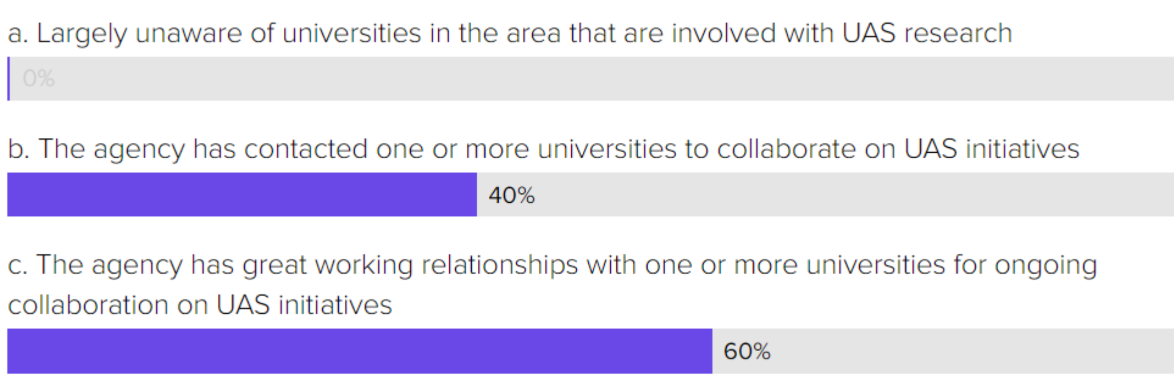
22. What level of pre-flight approval should be required?



23. In your opinion how often should the UAS fleet be replaced?

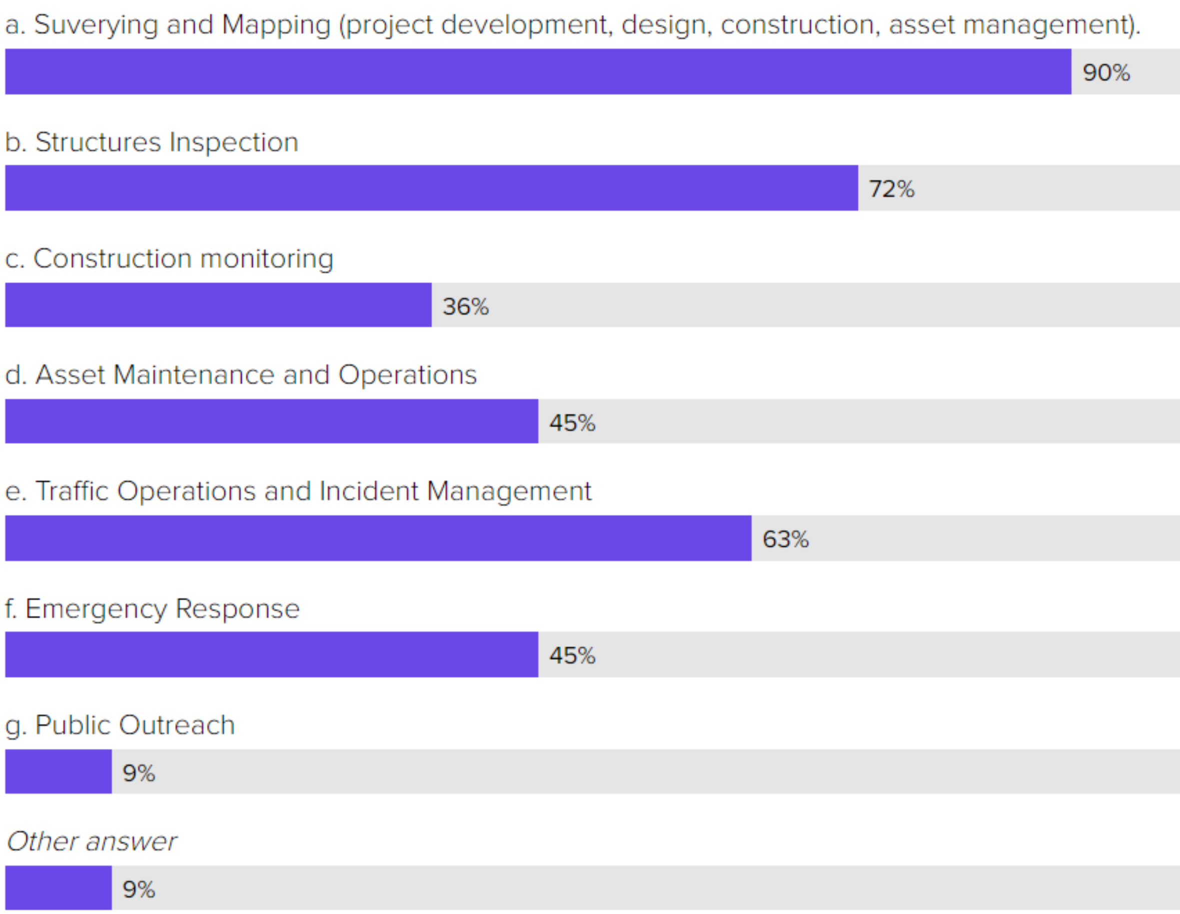


24. Does the agency have relationships or partnerships with academic institutions related to UAS integration or research?

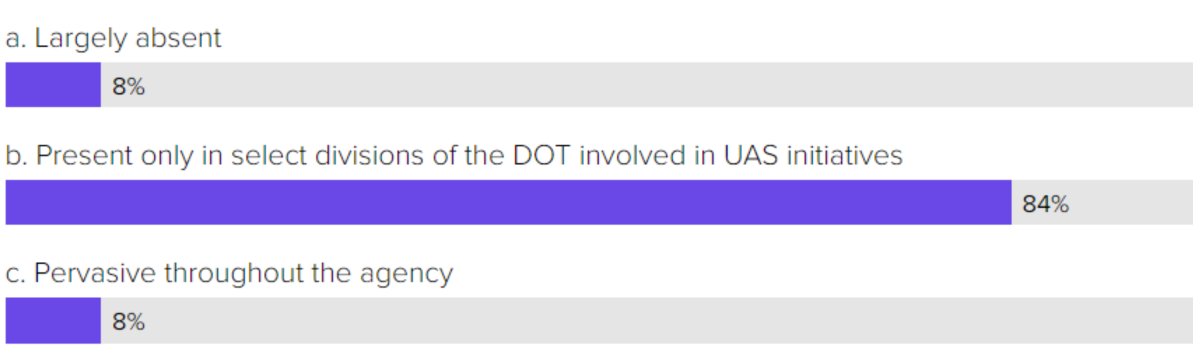


Junior Staff Breakout Session Poll Questions and Responses

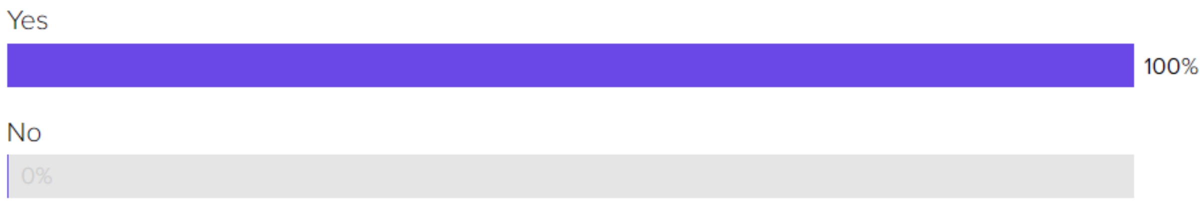
0. What are the top UAS use cases NHDOT should consider?



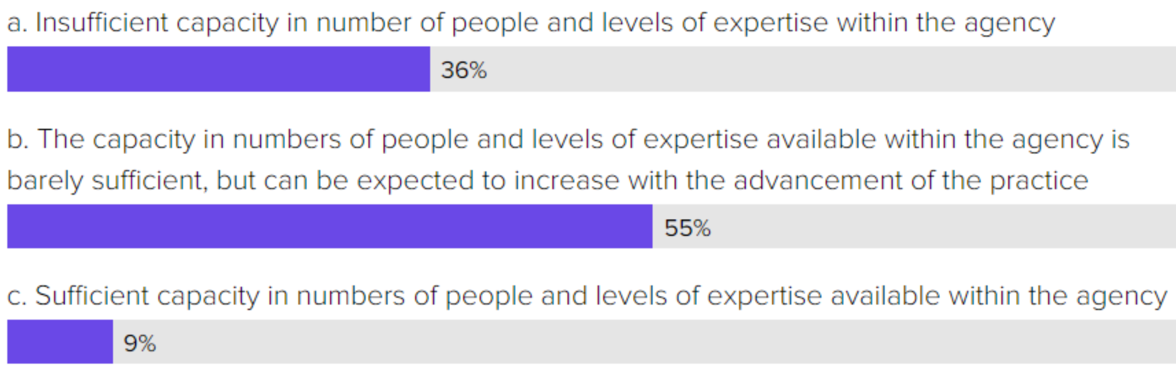
1. What level of Leadership Support do you have for UAS initiatives?



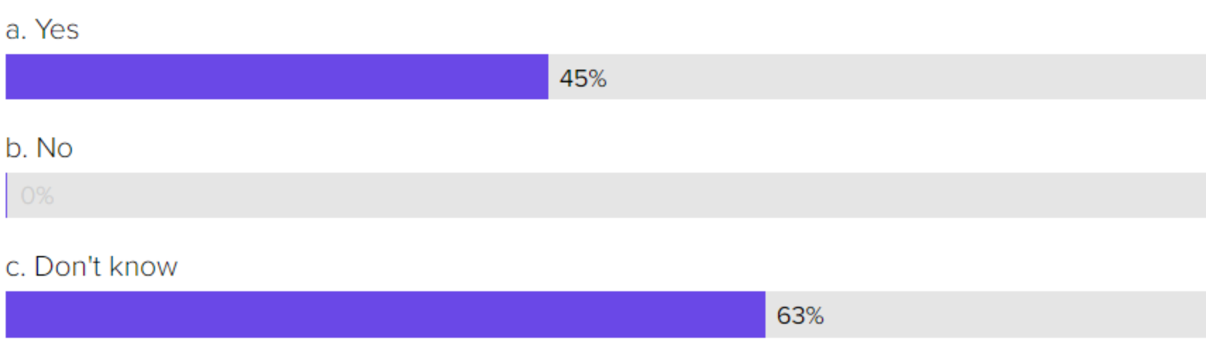
2. Do you know the UAS point of contact within your agency?



3. How would you rate the agency's staff capacity for UAS?

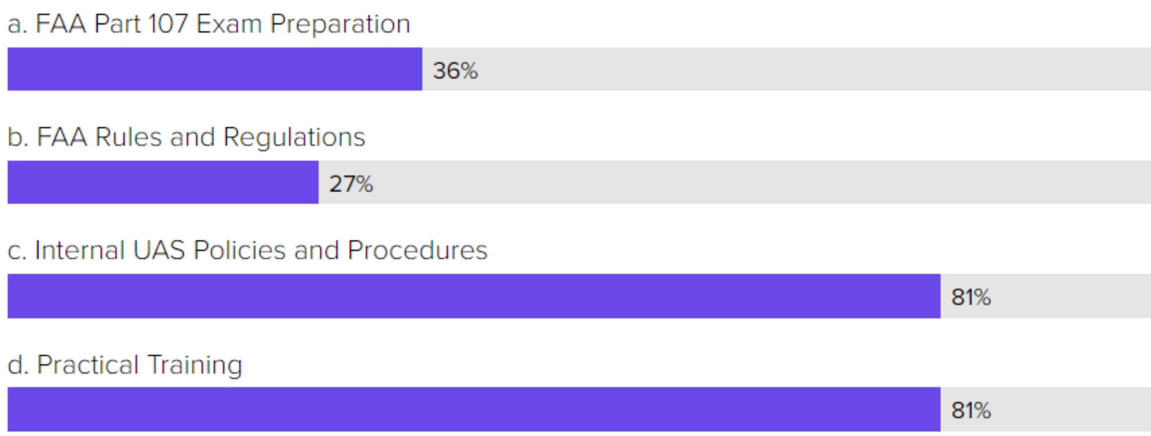


4. Is the agency currently outsourcing any UAS operations?

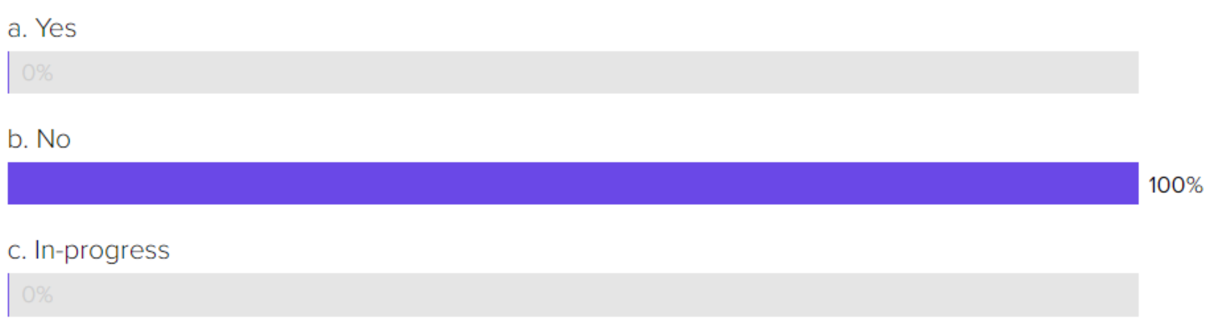


5. Do you have adequate training for UAS operations?

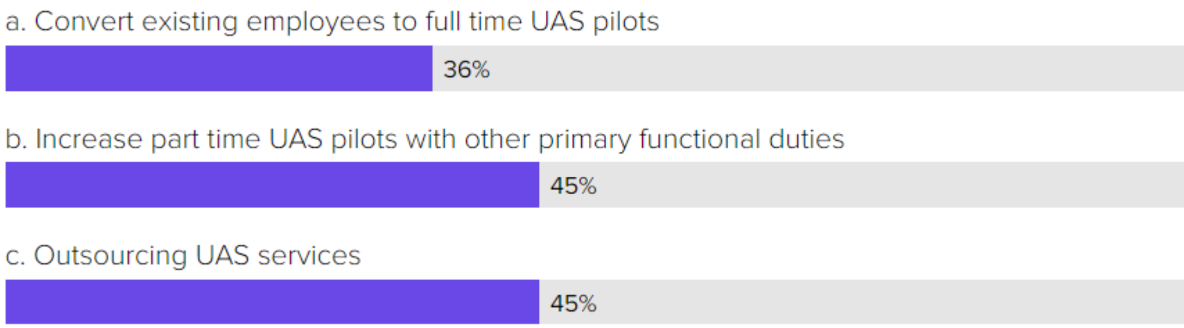
6. Where could you use additional UAS training?



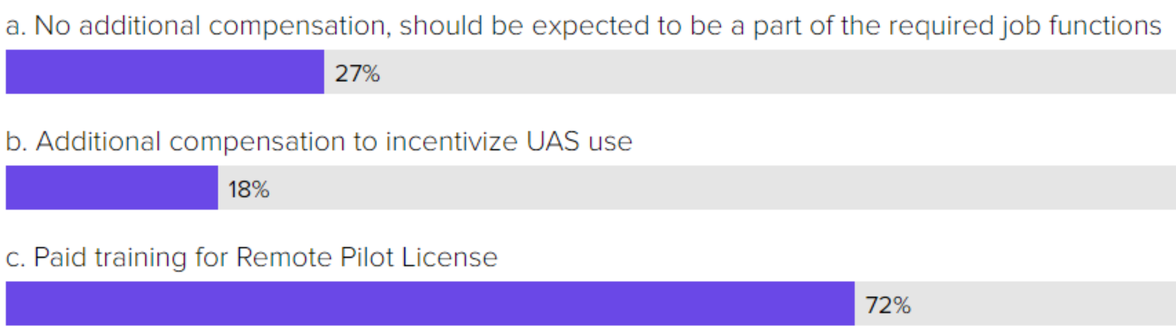
7. Are you currently a certified remote UAS pilot?



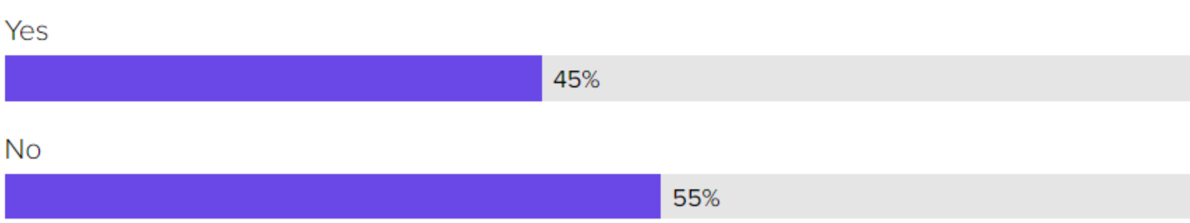
8. As the agency's UAS program grows, how should the increase in UAS operations be accommodated?



9. Should the agency incentivize employees to become UAS pilots?



10. Is there a structure currently in place that allows for the internal sharing of UAS data and deliverables?



11. How do you plan to use UAS data internally?

a. Within specific functional departments only

9%

b. Shared across the organization

73%

c. Don't know

18%

12. Is there coordination with the chief data management officer within the organization?

a. No collaboration has been initiated with the agency's chief data management officer

0%

b. Initial contact has been established with the agency's chief data management officer

9%

c. Ongoing collaboration is established with the agency's chief data management officer and team to establish UAS data management best practices

9%

d. Don't know

82%

13. Does the agency have a UAS data management plan?

a. Largely unaware of how to best manage the large amounts of data that can come from UAS

27%

b. The agency has begun coordinating with internal resources (IT department) and/or has a UAS data management plan in development

18%

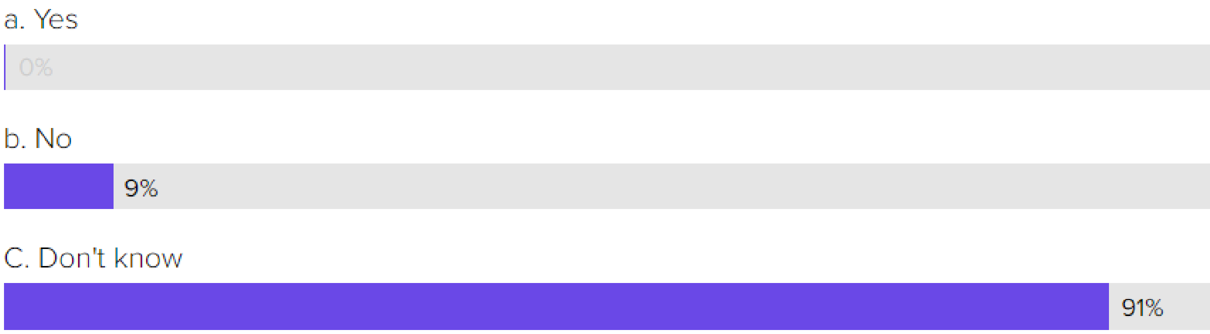
c. The agency has coordinated with internal and/or external resources to establish a thorough data management plan for all UAS collected data

0%

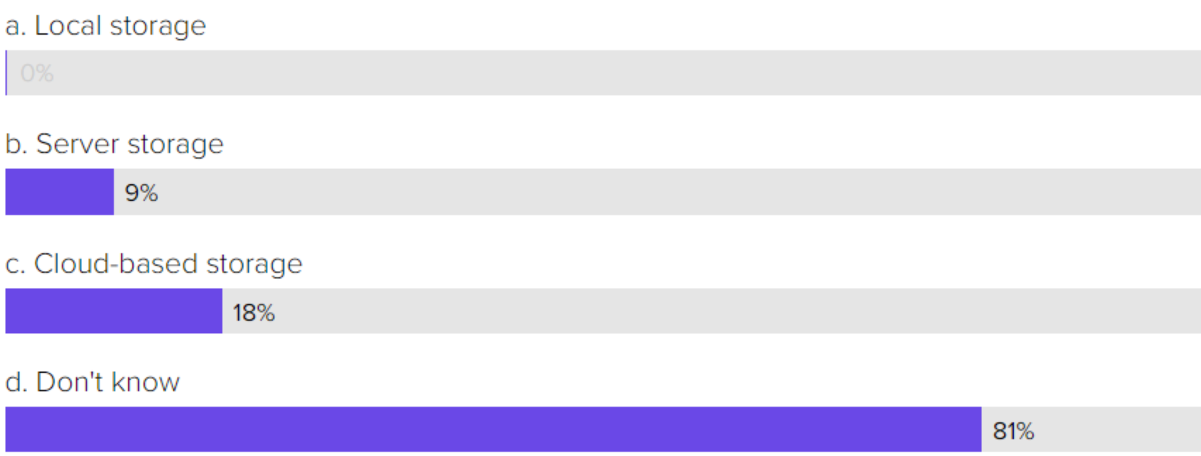
d. Don't know

55%

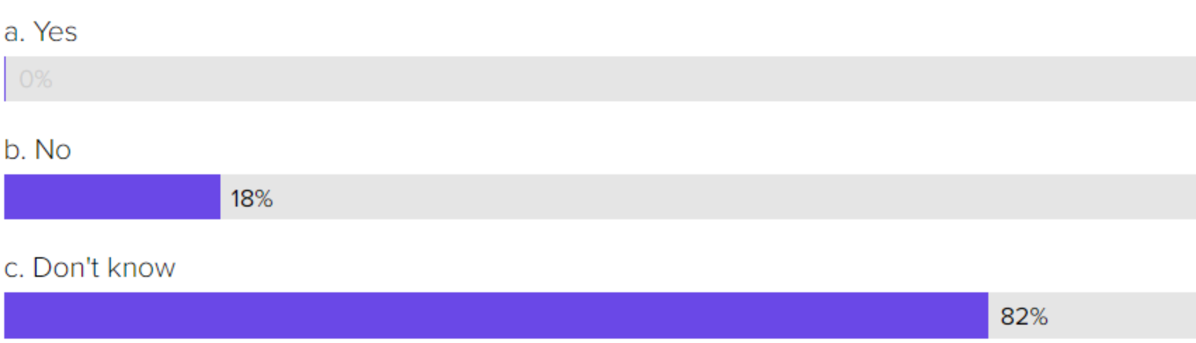
14. Is there a current policy related to the length of time for the retention of UAS data?



15. For future UAS data storage, does the agency plan to use



16. Do you have a process in place for naming UAS data files?



17. Is UAS data processed using cloud-based solutions or internal hardware solutions?

a. Cloud-based

0%

b. Internal hardware

0%

c. A combination of the two

55%

d. Don't know

45%

18. Does the agency plan to dictate which UAS platforms can be procured?

a. Yes, only USA-made and Blue List UAS platforms can be used

0%

b. No, open to other foreign country UAS platforms

9%

c. Don't know

91%

19. For future UAS platform procurement does the agency plan to

a. Require a common UAS platform across all divisions

0%

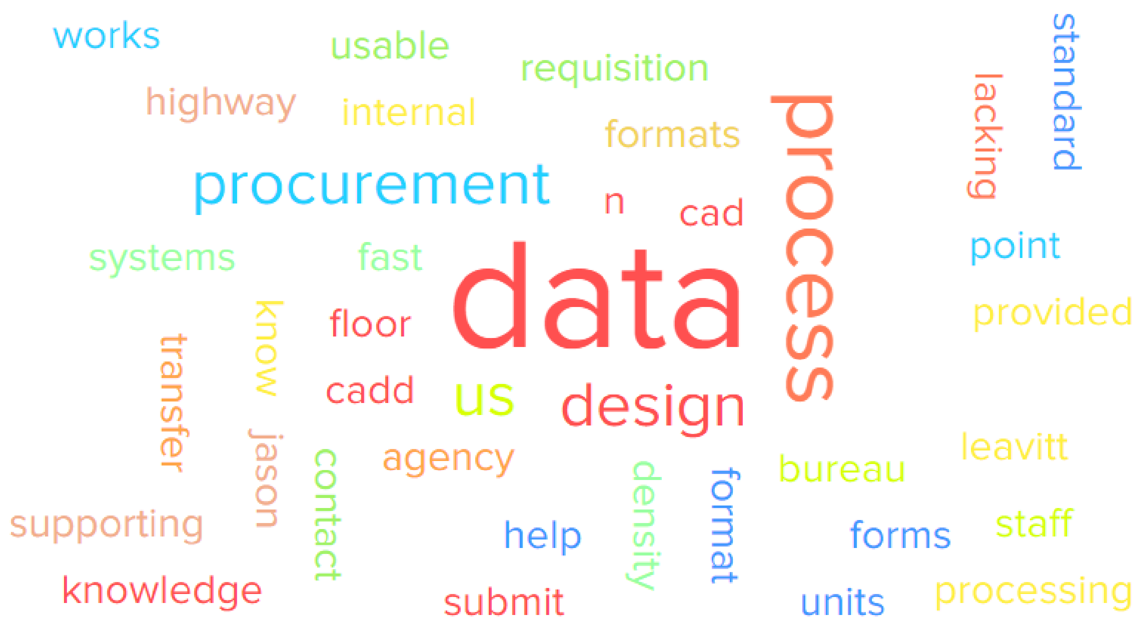
b. Allow diversity of UAS platforms to meet specific divisions needs

0%

c. Don't know

100%

20. What level of assistance from Support Functions: Information Technology, human resources, and procurement units and supporting systems is typically received as related to UAS?



21. Does the agency have a dedicated UAS fleet management software or process in place?

a. No formal UAS fleet management software or process

18%

b. Somewhat of a fleet management process and exploration of fleet management software

0%

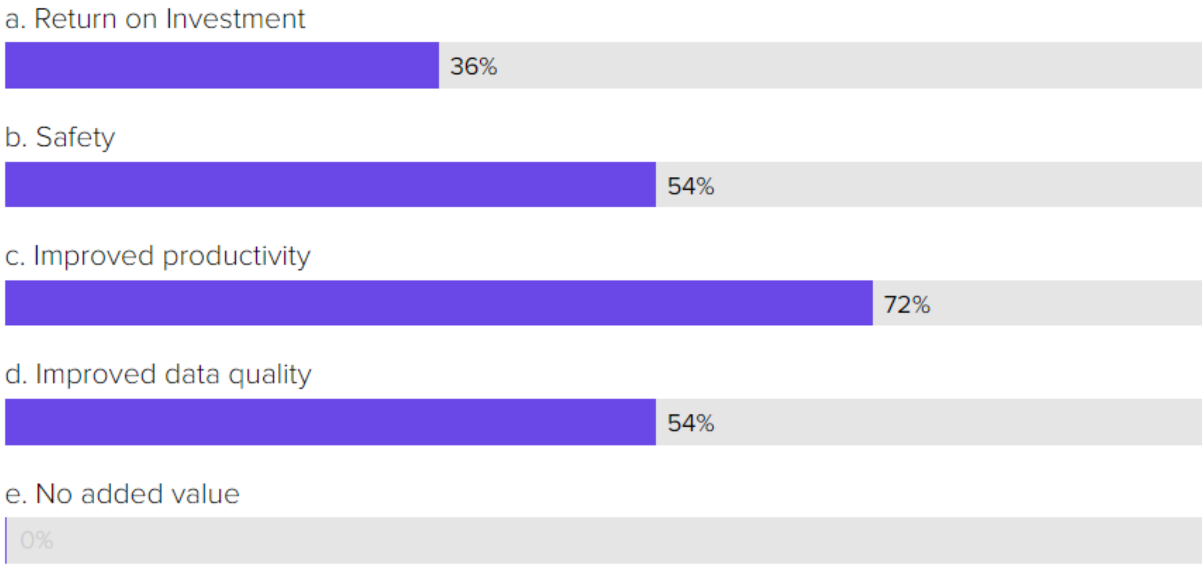
c. Established use of a fleet management software and written and adopted fleet management processes

0%

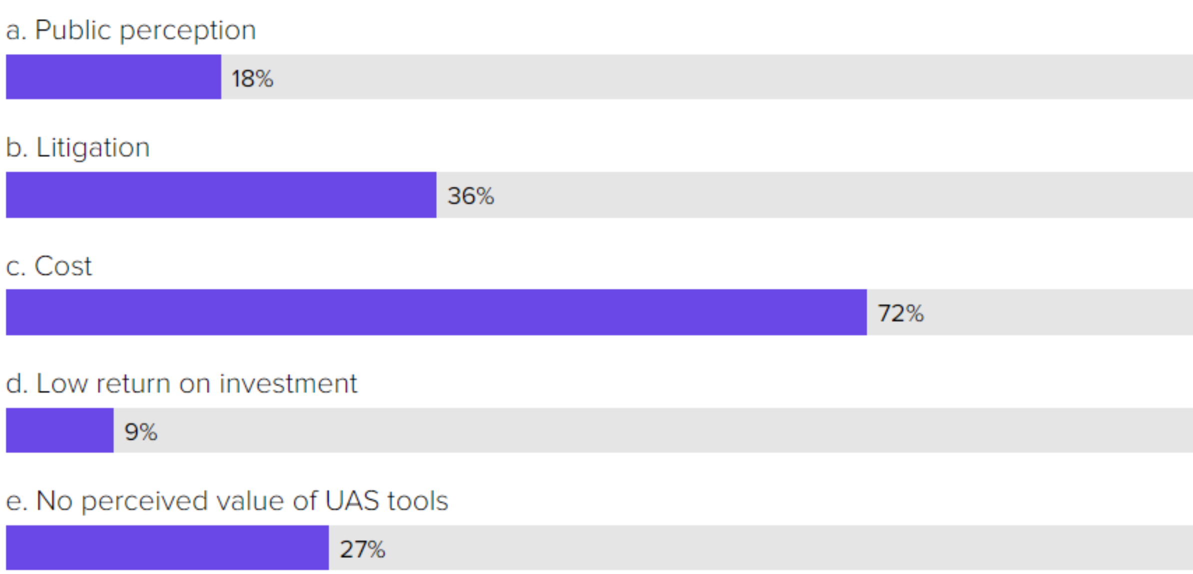
d. Don't know

82%

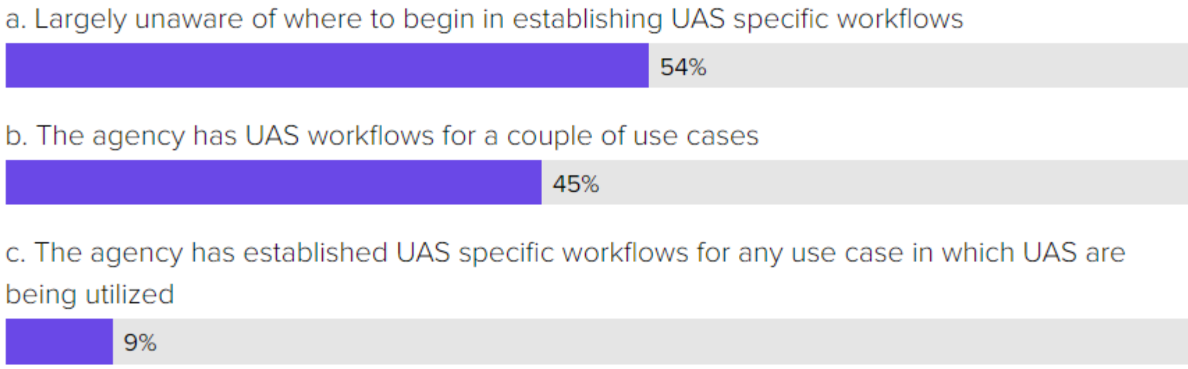
22. What benefits do you think UAS utilization will contribute to the most?



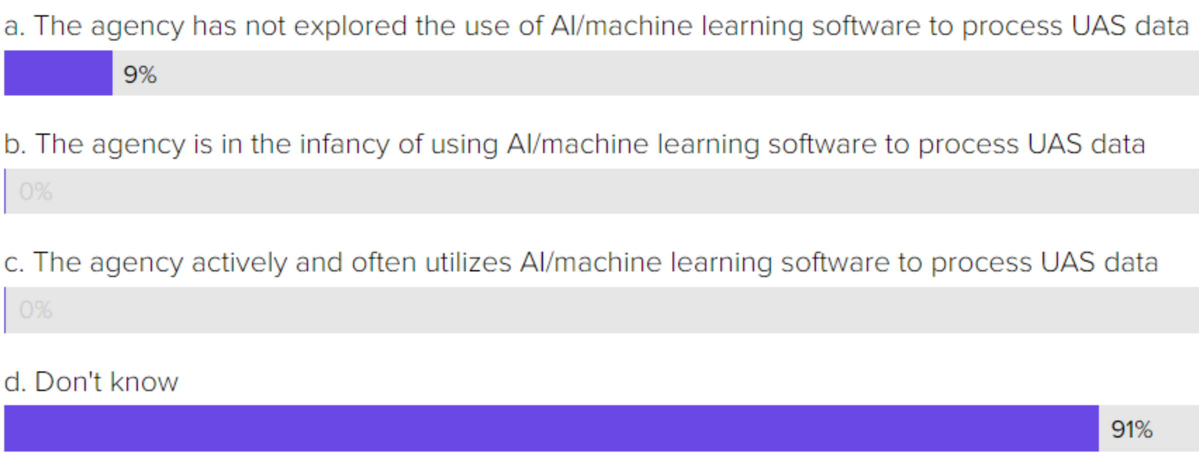
23. What is the greatest concern about UAS use?



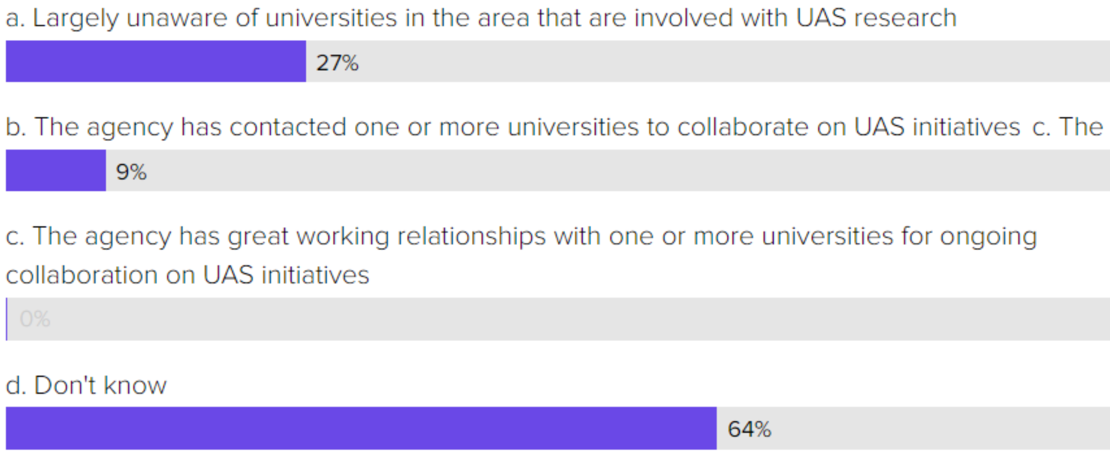
24. Does the agency have established UAS workflows for specific use cases?



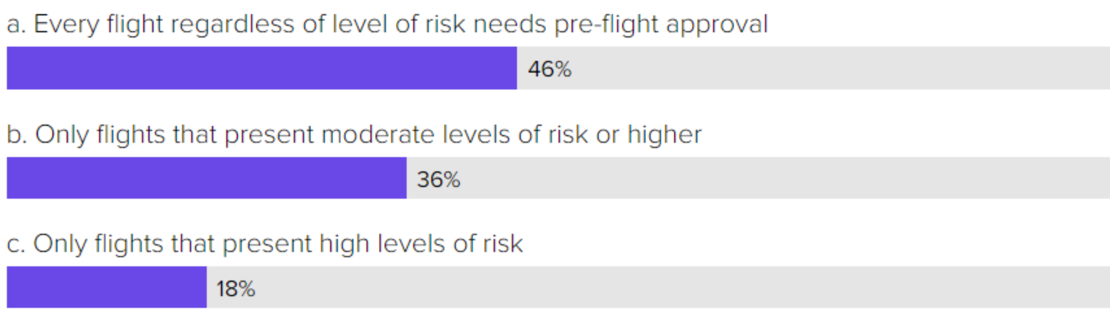
25. Does the agency utilize any Artificial Intelligence (AI) or Machine Learning software for UAS data processing?



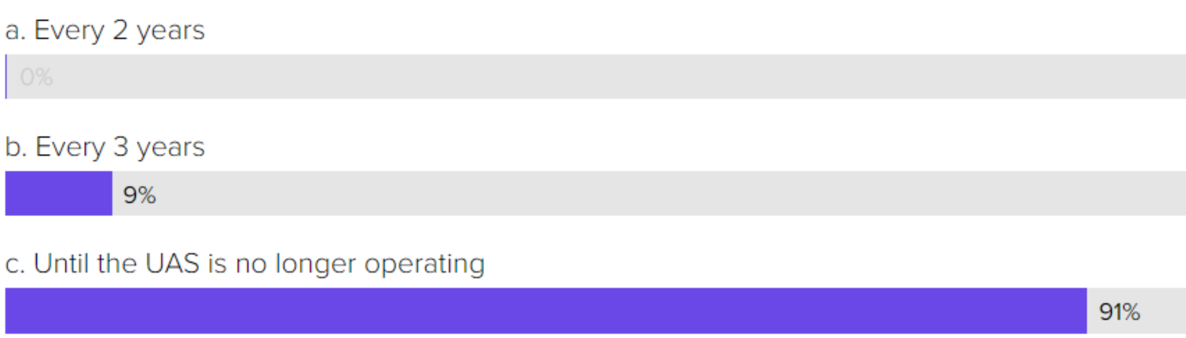
26. Does the agency have relationships or partnerships with academic institutions related to UAS integration or research?



27. What level of pre-flight approval should be required?



28. In your opinion, how should the UAS fleet be replaced?



APPENDIX E:

Task 1b Interim Report – UAS Use Case Study and Analysis

New Hampshire Department of Transportation

Development of an Unmanned Aircraft Systems (UAS) Program 43272B

Task 1b Interim Report – UAS Use Case Study and Analysis

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

3D	three-dimensional
DOT	Department of Transportation
EOC	Emergency Operations Center
FAA	Federal Aviation Administration
GIS	Geographic Information System
GPS	Global Positioning System
ID	Identification
IT	Information Technology
LiDAR	Light Detection and Ranging
NHDOT	New Hampshire Department of Transportation
RGB	red, green, blue
TSMO	Traffic Systems Management and Operations
UAS	Uncrewed Aircraft Systems

15.0 INTRODUCTION

The objective of Task 1b is to design and conduct up to six use case studies on select transportation applications ripe for Uncrewed Aircraft Systems (UAS)[2] technology integration within the New Hampshire Department of Transportation (NHDOT). The use case descriptions provided in this report were developed based on information collected during a 2-hour virtual interview for each use case and a 1-hour process mapping session. Use cases covered in this report include the following:

- Surveying and Mapping.
- Structures Inspection.
- Construction Monitoring.
- Traffic Operations and Incident Management.
- Asset Maintenance and Operations.
- Emergency Response.

The intent of each use case study is to evaluate traditional workflows (data and process) to identify areas that can be enabled using UAS technology. The interview for each of the identified use cases provided qualitative data regarding challenges, opportunities, perceptions, and potential benefits associated with integrating UAS into the different operational areas.

The research team developed an interview guide that it used across all interviews. The team used a semi-structured interview approach to allow the interviewees to speak freely and for follow-up questions to be asked in a conversational manner. This approach resulted in some similar themes across the interviews. However, there were enough differences in responses that each subsection below describes the use case and is organized using the themes raised by the interviewees; therefore, no two sections address exactly the same issues. The anticipated benefits of UAS integration are outlined for each use case.

Overall, this report provides valuable insights into the integration of UAS into various operations within NHDOT. The information reported herein lays the foundation for the completion of the Task 2 report that provides detailed recommendations and considerations for addressing the challenges and maximizing the benefits of UAS technology in various NHDOT bureaus. By leveraging UAS capabilities, NHDOT aims to enhance efficiency, safety, and data-driven decision-making across all operations.

[2] UAS is more popularly defined as “unmanned aerial systems” today. However, the industry is showing sensitivity to gender-neutral terms and terms that can also be broadly applied to telerobotic-controlled or autonomous vehicles.

16.0 SURVEYING AND MAPPING

The primary interviewee for the surveying and mapping use case was the NHDOT Chief of Survey and Mapping. Also participating in the interview was the current UAS Program Manager. This primary interview was supplemented with an interview with a Highway Design CADD Technician who also has many years of survey experience. The CADD Technician represented a key piece of the data life cycle where the collected survey data are processed in a way to make them usable to designers. Also participating in the supplemental interview was the Senior Aviation Planner from the Bureau of Aeronautics.

At the time of these interviews, NHDOT had completed only one test survey project with UAS. The project was originally surveyed by traditional means and by UAS, collecting photos with a red, green, blue (RGB) camera to be processed using photogrammetry software. In spring 2023, the project was surveyed again using UAS with a Light Detection and Ranging (LiDAR) sensor. At the time of this report, the UAS collected data were being processed to compare them to traditionally collected data. Although the sample size for the UAS survey test project is only one, these interviews shed light on potential challenges in UAS integration, including technical concerns, staff perceptions, data management, funding, equipment, and the UAS program structure.

16.1 Challenges in UAS Implementation and Technical Concerns

The greatest challenges or concerns regarding the use of UAS in surveying, is two-fold:

1. Can the UAS-collected data achieve the accuracy needed to meet NHDOT survey requirements.
2. Will the current lack of expertise and/or software needed to convert UAS-captured data into a format usable by surveyors, designers, and engineers hinder analysis.

16.2 Staff Perceptions and Adoption

The surveying and mapping team used to include staff members who were resistant to adopting new technologies, including UAS; however, in the past five years, staff turnover has left a staff who are more receptive to UAS implementation and who recognize the potential for increased safety and time savings. The Chief of Survey and Mapping discussed the challenges he is currently facing in hiring entry level or experienced surveyors—there are currently six open positions, and some of these positions have been open for more than six months. The struggle to attract new workforce is likely due to the high demand for surveyors in the private sector. The goal is that by adopting UAS technologies as another tool for surveyors to use, the increased efficiency will help lighten the burden of the decreased workforce. The hope is also that by using UAS, the technology itself can serve as an attractant to recruit younger workforce members to work for the State DOT.

16.3 Data Management

The current process for managing traditionally collected survey data is to place them on the NHDOT server in the relevant project folder, using standardized file naming conventions. If survey data are collected with UAS, a similar data management process is followed. As UAS operations throughout NHDOT increase, the amount of data will increase, and the current data management process may need to be adapted. When asked if there were concerns about the server(s) having enough capacity, the CADD Technician shared that there will eventually be a movement to cloud-based solutions, and storage capacity should not be an issue. Conversations with the Information Technology (IT) department are recommended as a UAS data management plan is developed.

16.4 Equipment and Funding

If survey crews were to have UAS as another tool at their disposal, trucks would need to be properly equipped. Currently, survey trucks are not equipped with power inverters or sufficient power to charge UAS batteries in the field while also running other key equipment such as a laptop; however, one interviewee noted that modifying these trucks with the proper equipment using internal mechanical services within NHDOT is an obstacle that could be relatively easily overcome.

The Bureau of Aeronautics has already procured a DJI M300 equipped with a LiDAR sensor that would be helpful to the survey team. The unit, equipped with a high quality RGB camera and a LiDAR sensor, offers exceptional surveying capabilities by providing highly accurate and detailed three-dimensional (3D) point cloud data. Using RGB for structure for motion and LiDAR technology enables efficient mapping of terrain, structures, and objects, and facilitates precise measurements and volumetric calculations for various surveying applications. With the DJI M300's robust flight stability and extended battery life, it can cover large areas and capture comprehensive survey data with ease, enhancing productivity and accuracy in surveying operations. As the UAS program or the data needs grow, a higher quality LiDAR sensor for more accurate data and more returns may be beneficial to reduce noise in the data and provide accurate mapping through vegetation.

When asked about funding for UAS platforms, sensors, and software, the Chief of Survey and Mapping noted that funding largely depends on the overall organizational structure of the UAS program. If the UAS program is structured in a way that survey crews are certified as Remote Pilots and can use UAS as another tool for collecting data, then the UAS equipment would likely be treated like any other equipment request. Another option discussed in the interview was pursuing additional Federal Highway Administration grants. If the UAS program is housed only under the Bureau of Aeronautics and there is not an embedded surveyor who is a certified UAS Remote Pilot, then funding could be challenging due to the inability to mix highway funds and general funds from the Bureau of Aeronautics.

16.5 Program Structure

The topic of how the UAS program could be structured and the associated advantages and disadvantages of the different models were thoroughly discussed throughout the interview. When asked about which model would work best, the consensus was that embedding UAS Remote Pilots into functional departments, like surveying, would work best because UAS Remote Pilots housed only in the Bureau of Aeronautics would likely lack the highly specific and technical expertise to properly meet the survey and mapping data needs. Interviewees expressed a preference for training a veteran surveyor on how to use UAS and becoming a Federal Aviation Administration (FAA)-certified Remote Pilot.

NHDOT's FAA-certified Remote Pilot(s) are currently employed within the Bureau of Aeronautics. These UAS operators can be used on surveying projects and can continue to test UAS use in this use case and help integrate UAS into surveying projects. However, for UAS to become an accepted part of the surveying use case, it is critical that each UAS mission be coordinated across the various missions and project stakeholders throughout NHDOT. As UAS operations expand within NHDOT, the increasing demands of data collection may exceed the capacity of a single person. In such cases, additional pilots will be necessary to fulfill the requirements efficiently. By bringing in more pilots, NHDOT can effectively manage and distribute the workload associated with data collection across its growing operations.

There are unknowns and concerns regarding the preferred model of training surveyors to use UAS. Interviewees noted that it can be difficult to add licenses, certifications, or even just responsibilities to current job descriptions—this has been attempted in a different situation for a survey position and has not progressed in more than 12 months. If a new position were created that required UAS certification and survey duties, the concern is there would be an insufficient pool of candidates who have both survey knowledge and UAS certification.

16.6 Anticipated Benefits

The use of UAS at a State DOT for surveying and mapping purposes is expected to bring numerous benefits. UAS can significantly enhance the efficiency and accuracy of surveying and mapping operations. Equipped with high-resolution cameras and LiDAR sensors, UAS can capture detailed aerial imagery and topographic data of large areas in a fraction of the time it would take traditional surveying methods. This allows the State DOT to quickly gather comprehensive data for infrastructure planning, maintenance, and construction projects. The precise and up-to-date information obtained through UAS can aid in detecting potential issues, optimizing designs, and making informed decisions, leading to improved project outcomes, reduced rework, and cost savings.

In addition, using UAS for surveying and mapping can enhance worker safety and reduce risks associated with traditional surveying methods. Surveying often involves working in hazardous environments such as busy roadways, steep slopes, or remote areas. By deploying UAS, the State DOT can eliminate or minimize the need for personnel to physically access these dangerous locations, mitigating potential accidents and injuries. UAS also offer the advantage of being able to access hard-to-reach or inaccessible areas, such as bridges, tunnels, or rugged terrains without the need for extensive manual labor or specialized equipment. This not only improves safety but also reduces project timelines and costs by streamlining field operations and minimizing the impact on traffic flow or public disruptions. Additional benefits and the associated costs for UAS platforms and sensors specific to surveying and mapping are provided in detail in the Task 2 Report.

17.0 STRUCTURAL INSPECTIONS

The primary interviewee for the structural inspection use case was a Bridge Inspection Engineer who serves as a member of the bridge design team. The interview revealed several insights into the challenges, opportunities, and concerns surrounding the implementation of UAS into the NHDOT inspection process. While the Bridge Inspection Engineer initially expressed skepticism about the usefulness of UAS, he acknowledged the potential benefits in reaching difficult-to-access bridges.

17.1 Bridge Inspections

Currently, the NHDOT bridge inspection approach involves sending inspectors close to the bridges to measure cracks and other damage. However, the Bridge Inspection Engineer acknowledges that there are bridges that are difficult to reach, making UAS potentially helpful in such cases.

Ninety percent of the inspection schedule for bridges follows a 24-month cycle, with more frequent inspections for bridges in poor condition or those on the red list. The team focuses solely on bridges that interface with the highway system and reports facing challenges when inspecting bridges over railroads because of the need to coordinate with the railroad and schedule railroad flaggers.

17.2 Staff Perceptions

When asked about the usage of UAS in their inspections, the Bridge Inspection Engineer indicated that the group has not used internal UAS resources (i.e., within the Bureau of Aeronautics). Consultants that are hired to conduct inspections on certain bridges may have used UAS, but NHDOT has not employed consultants specifically to deploy UAS. NHDOT bridge inspectors' current methods involve manual inspection; however, throughout the interview, the benefits of UAS for bridge inspections were discussed.

The team currently employs a snooper truck for under-bridge inspections and consults climbers for specific bridges that require detailed inspections. In the case of a bridge strike, the bridge maintenance team and bridge inspection team work together and determine who should assess the situation based on various factors. Unfortunately, bridge hits occur more frequently than desired, particularly on covered bridges.

Visual inspections are primarily conducted to assess bridge deck lamination, with additional sounding as needed. The bridge team structure consists of a central engineering team and four inspection teams spread throughout the state; team members live in the areas they inspect. The data collected by the inspection teams are stored locally on laptops for a few days to a couple of weeks before being transferred to the central office.

The managerial staff over the bridge inspectors is interested in UAS for data clarity and reliable access. The seasoned inspectors are not always enthusiastic about learning new technology; however, the inspection teams recently transitioned from point-and-shoot cameras to iPhones for capturing inspection photos. These photos are stored in folders and processed using specialized software to create reports. The staff makes notes in the photo captions, associating them with specific bridge inspections.

The interviewee noted that another concern of the bridge inspectors is the potential for job loss or outsourcing to consultants if UAS are introduced. The staff is also uncertain about the funding for acquiring UAS equipment for each team, especially since the department already struggles with budget constraints. Additionally, the team faces upcoming turnover, as five of the eight inspectors plan to retire within the next six months to two years. The department is preparing for this turnover through on-the-job training and by attracting individuals with bridge maintenance backgrounds to fill the positions. The interviewee indicated that the new workforce may be younger and more open to embracing UAS technology.

On-the-job training is essential for new hires, and several individuals with bridge maintenance backgrounds are interested in transitioning to bridge inspections. A two-week bridge inspection course is available, but there is no specific commercial driver's license training provided, and the snooper truck has one designated operator.

The internal vision for UAS implementation into bridge inspections remains uncertain, with the possibility of relying on external consultants for limited UAS usage or equipping each bridge inspection team with its own UAS if they become more common. Funding constraints present a significant challenge for acquiring UAS, and the team tends to be cautious about adopting new technologies until compelled to change.

17.3 Data and Equipment Management

Equipment-wise, three teams have trucks with caps, while one team uses a van. Boats are sometimes borrowed from the bridge maintenance team for inspections on bridges over water.

Data management involves storing digital data indefinitely on the server since the team shifted from paper inspections to scanning and saving everything digitally. The department is considering switching from its current software, BrIM, to InspectTech because of some issues it has been facing. The photos are stored in folders, and software is used to process the photos and generate reports. The data, including JPEG files, are stored on a server, and there is a Microsoft Access database for easy retrieval.

Inspectors make notes in the photos' captions, associating each note with a specific bridge inspection. They also store general notes for close-up photos, indicating issues like delamination. The Bridge Inspection Engineer noted that the bridge inspection team is gradually transitioning from physical records to digital data storage, scanning and saving inspection records digitally to address physical space limitations.

Server space concerns are handled by the IT department. However, the impact of UAS implementation on server space requirements remains uncertain. The inspection team does not track costs for bridge inspections but estimates expenses based on the number of bridges inspected and the corresponding labor costs.

The department currently tracks its bridges and their inspection status using a combination of manual methods and software. There is ongoing discussion about the efficacy of the current laptop capabilities. The laptops, which were recently upgraded after five or six years, are considered to be average in terms of processing power. No CAD experience is required for bridge inspectors because their role focuses on bridge expertise rather than technical design skills.

17.4 Anticipated Benefits and Challenges

The Bridge Inspection Engineer identified two main scenarios where UAS could prove advantageous: (1) reducing inspection time while providing high-quality data when inspecting larger structures that require detailed examination; and (2) mitigating risks associated with inspections over railroads or in situations where a bridge has been struck by a vehicle or affected by a natural disaster. By deploying UAS to evaluate the safety of a bridge, inspectors can avoid unnecessary risks before sending personnel onto or under the structure.

Each bridge inspection team consists of two people, inspecting two to four bridges per day. Larger structures may require coordination and involve four to six inspectors. Fortunately, the team has not encountered any traffic control incidents or collisions, and the inspectors prioritize safety. The potential use of UAS to assess safety before sending personnel onto or under bridges could help avoid risks associated with inspections over railroads and in dangerous situations.

Overall, the bridge inspection team displays mixed perceptions toward UAS adoption. While managerial staff expresses interest in UAS for its data clarity and reliable access, the inspectors themselves, who are primarily experienced in traditional bridge inspection methods, were hesitant. Public concern about UAS usage on certain bridges, along with landowners' potential objections, may pose challenges. The team does not currently send letters to the public before inspections and focuses solely on conducting their inspections, occasionally fielding questions from curious onlookers.

18.0 CONSTRUCTION AND MATERIALS MONITORING

The interview for the construction use case was with the Process Review Engineer and one of the District Construction Engineer, both from the NHDOT Construction Bureau. The NHDOT Bureau of Aeronautics UAS Program Manager also participated in the interview. Discussions during the interview explored the current usage of UAS, staff perceptions, challenges and opportunities, and future plans for incorporating this technology into construction workflows. For the materials and research monitoring use case, the interviewee was the Administrator for Materials and Research, who provided additional insight on the processes for materials testing and compliance. He oversees the pavement management, materials testing, and geotechnical sections of NHDOT.

18.1 Current Usage and Perceptions

The interviewees recognize the opportunity to increase UAS use in NHDOT construction projects and indicated that current use is somewhat limited. NHDOT construction projects began using UAS about 6 years ago as consultants or contractors started integrating them into projects. UAS have primarily been used for photogrammetry to create detailed maps, generate point clouds, and obtain accurate measurements of construction sites. Internal use of UAS, with the Bureau of Aeronautics has been more limited, a few projects have been flown, and all interview participants agree they would like to increase internal use of UAS rather than relying on consultants.

When asked about the perceptions of the estimated 80 NHDOT construction staff toward UAS technology, a common theme emerged. The interviewees reported there is likely a discrepancy in enthusiasm between the younger and more experienced staff members. The younger demographic is eager to use newer technologies like construction Global Positioning System (GPS) rovers and would likely be more excited about embracing UAS technology. The more experienced staff may be more hesitant about UAS and UAS-processed data. Interviewees expressed concern that as the more seasoned employees gradually retire, the lack of experience among the younger staff could present challenges in fully maximizing the benefits of UAS technology in their construction endeavors. They recognize the need to bridge this knowledge gap and ensure a smooth transition, enabling the organization to integrate UAS effectively and efficiently.

The Administrator for Materials and Research discussed the various departments within his group, which encompass research, pavement management, geotechnical analysis, the asphalt lab, and the soils and concrete lab. He also addressed the current use of rovers and other tools in construction to accurately measure quantities on the ground or the current processes used in the materials section. The existing team is situated either on-site to gather cores or at batch plants, strategically positioned on platforms that provide convenient accessibility for employees to inspect the loads carried by vehicles. Materials testing may provide limited opportunities for UAS use at this time but there could be potential for non-destructive testing methods with UAS equipped with advanced sensors, such as thermal cameras and LiDAR, which could be used on various materials used in transportation infrastructure.

18.2 Opportunities and Challenges

Interviewees noted that the state of New Hampshire as a whole is entering a savings and preservation mode, rather than a spending and building mode. Currently many of the construction projects are focused on restriping so there was discussion about how internal use of UAS on these projects during the pre-striping planning phase could be beneficial. UAS could assist in providing high-resolution imagery to document current conditions and assess necessary changes before putting projects out for bids.

Other potential opportunities for using UAS in construction were discussed such as assisting in the production of project weekly or quarterly reports, progress photos, quantity calculations, thermal sensor applications, construction traffic control, and providing completed project data for as-builts that can be used throughout the asset management life cycle. However, interviewees noted the need to overcome challenges related to project size, workforce experience, data management, workflow integration, and public perception to fully leverage the advantages of UAS technology in construction projects.

NHDOT faces challenges in integrating UAS into existing workflows and determining the need for UAS on different construction projects. While some construction team members may show interest and initiative about using UAS, the Construction Bureau is still primarily relying on the only designated UAS operator within NHDOT, the UAS Program Manager. As UAS use expands, NHDOT will need to consider how to address the growing requests from different bureaus for the UAS Program Manager's time to provide UAS services. While the organizational structure of the UAS program is yet to be finalized, the Construction Bureau can see how it would be beneficial to incorporate UAS into existing crews and workflows effectively.

Another identified challenge is around data management. NHDOT currently uses a hybrid model with ExeVision and a central server for data storage, but there have been concerns about the process in the past. The transition from individual servers to a central server in Concord at the end of projects raises questions about how UAS data should be organized. Proper data management is crucial for efficient project documentation and retrieval. As NHDOT consolidates its UAS data on a central server in Concord, it becomes imperative to establish a systematic approach to data organization. Effective data management practices will help ensure that UAS data are structured, labeled, and stored in a way that facilitates easy retrieval, analysis, sharing among divisions, and long-term accessibility.

18.3 Workforce Collaboration and Integration

The Process Review Engineer described the collaborative relationship between the construction and design teams. He noted they work well together and help each other; the design team has recently become increasingly reliant on the construction team because of staffing shortages on the design side. Although the Construction Bureau experiences fewer workforce shortages, it occasionally supplemented its team with consultants. This well-established working relationship is another reason it could make sense to embed UAS pilots directly into the construction crews who provide data directly to the design teams for processing. The idea of integrating UAS technology into the existing workflow and allowing specific individuals to operate UAS alongside their current responsibilities was discussed. Additional compensation would not be considered, but the opportunity to use UAS would be seen as another tool to help increase efficiency, safety, and provide cost savings.

The interview revealed that the NHDOT Construction Bureau is in the early stages of incorporating UAS technology into its operations. While current usage is limited, bureau staff recognize the potential benefits of UAS, especially in current restriping projects, pre-stripping plans, and data collection. The interview confirmed information gathered in other interactions with NHDOT personnel that NHDOT as a whole has a willingness to adapt to new technology, this was reflected throughout this interview. With further exploration and planning, the construction team aims to leverage UAS as another valuable tool in its construction toolbox.

18.4 Anticipated Benefits

Numerous anticipated benefits of using UAS for construction monitoring at NHDOT were mentioned. UAS may enhance the efficiency and accuracy of construction monitoring activities. UAS are equipped with high-resolution cameras and sensors, allowing them to capture detailed images, videos, and data of construction sites from various angles and altitudes. These comprehensive visual data can be used for monitoring the progress of construction projects, identifying potential issues or delays, and assessing compliance with safety and environmental regulations. UAS can be used in quantity estimations of materials on construction project sites; the UAS-collected data can then be used to check contractor invoicing and other documentation. By providing real-time and up-to-date information, UAS enable DOT officials to make informed decisions promptly, leading to improved project management and cost control.

In addition, UAS may offer significant cost and time savings compared to traditional monitoring methods. In the past, construction monitoring typically required manual inspections by personnel on the ground or expensive aerial surveys using helicopters or planes. These methods often required significant time and resources, as well as increased safety risks. UAS, on the other hand, can rapidly collect data over large areas in a fraction of the time and at a fraction of the cost. They can quickly survey extensive stretches of highways, bridges, or other infrastructure projects, providing a holistic view of the construction progress. For materials testing, UAS may be used to monitor and evaluate materials in real-time. For example, UAS equipped with multispectral or hyperspectral cameras can capture high-resolution imagery to assess the condition and quality of road surfaces and identify cracks, potholes, or areas requiring maintenance. UAS can also monitor erosion, vegetation encroachment, or soil stability in geotechnical applications, providing valuable data for infrastructure planning and maintenance. Additionally, UAS may offer the advantage of accessing hard-to-reach or hazardous areas that may be difficult or dangerous for inspectors or technicians to reach. By using UAS, DOT personnel can inspect materials in remote locations, at great heights, or over water bodies without putting themselves at risk. This accessibility improves the efficiency of inspections, reduces costs, and minimizes disruptions to traffic or operations. Third-party software providers are available that allow construction crews to make notes in UAS-created progress reports, which allows pins to be placed directly on photos or 3D models of the project that then open to detailed notes regarding areas of concern or progress in general. This accelerated data collection process not only reduces labor costs but also minimizes the disruption caused to ongoing construction activities. Overall, the utilization of UAS at a State DOT for construction monitoring leads to improved efficiency, cost-effectiveness, and safety in infrastructure development. Additional benefits and the associated costs for UAS platforms and sensors specific to the construction use case are provided in detail in the Task 2 Report.

19.0 TRAFFIC OPERATIONS AND INCIDENT MANAGEMENT

The interviewee for the traffic operations and incident management use case was an ITS Project Manager, who works within the NHDOT Traffic Systems Management and Operations (TSMO) team. The NHDOT UAS Program Manager also participated in the interview. The TSMO team started using UAS via consultants about 6 years ago, leveraging the engineering on-call. These UAS uses have been sparse, and the interview discussion shed light on various potential use cases that could be implemented to assist NHDOT with traffic operations and incident management throughout the state.

19.1 Potential UAS Use for TSMO

The ITS Project Manager reported that the TSMO team is responsible for a variety of structures, although not all of these structures are included in the inspection schedule. However, he noted that using UAS for inspections may enhance asset management capabilities. UAS can also be used for inspection if existing equipment, such as traffic cameras, if they stop working or malfunction. By deploying UAS, the TSMO team can efficiently assess the condition and functionality of these cameras, ensuring optimal performance and identifying any maintenance or repair needs. This can be helpful in identifying what the true needs are before sending a bucket truck and operator to make repairs.

Another potential use of UAS for the NHDOT TSMO team is sight-line analysis for new camera placement. By employing UAS, the team can gather aerial data and imagery to evaluate the line-of-sight from prospective camera locations. This analysis can help identify optimal positions for the placement of new cameras and maximize their coverage and effectiveness in monitoring traffic conditions.

The interviewee noted that the Division of Operations also oversees numerous radio towers. The team can employ UAS for line-of-sight analysis of the radio waves for the radio towers it oversees throughout New Hampshire. UAS can capture aerial views and perform assessments to determine the quality and obstruction of microwave paths. This analysis will help ensure reliable communication and connectivity for the radio towers and support efficient and effective communication networks across the state.

During the interview, recent conversations that members of the Transportation Incident Task Force have had regarding establishing UAS corridors for emergency response was discussed. The idea entails setting up dedicated UAS monitoring corridors along stretches of roads to monitor traffic and report back crucial information. This approach can be particularly valuable during peak commute times, with UAS programmed to fly specific routes and continuously monitor traffic conditions. By gradually implementing this phased approach, the TSMO team can assess the effectiveness of UAS monitoring and refine its strategies accordingly.

The bird's eye view provided by UAS can offer valuable insights during an active accident response. Deploying UAS at accident scenes provides first responders with a comprehensive understanding of the situation, aiding in determining the most appropriate response and resource allocation. This perspective can facilitate post-accident response debriefs and identify opportunities and areas for improvement in handling similar incidents in the future.

Additionally, UAS can be used for mapping accidents to support accident reconstruction and investigation efforts. By capturing aerial imagery and data, UAS can provide highly effective visual documentation of accident scenes. This information can assist authorities in reconstructing the sequence of events and understanding the factors contributing to the accident. Consequently, this efficient data collection can expedite the investigation process, leading to quicker clearance of accidents and reopening of roads for smoother traffic flow.

19.2 Workforce Collaboration and Integration

TSMO staff appear open to using UAS and understand the potential of UAS and the utility that could be provided. Interviewees reported high levels of collaboration and a long history of working closely with the New Hampshire State Police and partnering with third-party agencies who help facilitate the efforts of the Motor Safety Patrol. The TSMO team works closely with the NHDOT Bureau of Turnpikes, which has a turnpike-specific Motor Safety Patrol and there is also a non-turnpike safety patrol. One path for integration of UAS would be to equip these safety patrol units with UAS to support TSMO and State Police with incident response. Another avenue for integration would be to equip only a select number of safety patrol units with UAS based on geography or roadway traffic use and to establish protocols for when UAS should be a part of the response.

Regarding the various potential use cases, TSMO would be most interested in using internal UAS services for the traffic camera sight line analysis rather than using consultants. The UAS program manager and other future Bureau of Aeronautics UAS pilots could provide these services internally to the TSMO team. As TSMO use cases increase over time, a member of the TSMO team could become an FAA Remote Pilot, and the Bureau of Aeronautics can provide UAS training services and supplemental UAS flight services as needed.

19.3 Data Recording and Privacy Concerns

Regarding data management, the ITS Project Manager explained that state law prohibits the recording of roadway camera feeds, allowing only live feeds on most of the traffic cameras. However, recordings can be made at certain bridges that cross state lines, at bus stations, and at other specific locations for security and safety purposes. These recorded data follow a prescribed data management plan and are automatically deleted after a set amount of time. The interview explored the possibility of live-streaming incident data and subsequently recording it for training purposes and after-action reports, where the recorded data could follow the already established protocol. NHDOT needs to consult its legal counsel when determining how UAS incident response recorded data should be managed.

Concerns regarding public perception and privacy issues were acknowledged, particularly when deploying UAS in residential areas. Public pushback could occur, but the key is to engage with the public and educate them on the use of UAS. As these concerns are addressed and minimal intrusion on citizens' privacy is ensured, UAS can be seamlessly integrated as another tool for the many agencies responding to traffic incidents throughout the state.

19.4 Anticipated Benefits

UAS can provide a State DOT TSMO team with real-time situational awareness and enhanced data collection capabilities. By deploying UAS, the State DOT can gather aerial imagery and video footage of traffic conditions, accidents, and congestion, allowing for quicker response times and more accurate decision-making. These real-time data can be used to identify traffic bottlenecks, optimize signal timing, and improve incident management, ultimately leading to reduced congestion and improved traffic flow.

As noted for other use cases, UAS can enhance safety and efficiency during incident management. UAS equipped with thermal imaging cameras and other sensors can quickly assess the severity of accidents and identify potential hazards, such as spills or damaged infrastructure. This information can be shared with incident responders on the ground, enabling them to take appropriate actions and allocate resources more effectively. UAS can also be used to quickly map accident scenes and collect data that can be used in accident reconstruction, which allows the scene to be cleared faster, restoring traffic flow to normal as soon as possible. Other State DOTs have reported great success with using UAS to clear accident scenes more efficiently. Utah DOT reports a 33% increase of efficiency on clearing fatal accidents, and up to four times faster clearing on other accidents (UDOT, 2023). The North Carolina DOT credited a 300 percent-time savings over traditional 3D laser mapping when using UAS (Jodoin, et al, 2021).

Additionally, UAS can help monitor traffic diversions, detours, and work zones, ensuring compliance with safety regulations and minimizing disruptions to traffic flow. The ability to rapidly deploy UAS and gather real-time information empowers State DOTs to proactively manage incidents, improving safety for both drivers and emergency responders while reducing incident duration and associated costs.

20.0 ASSET MAINTENANCE AND OPERATIONS

This section summarizes the key points discussed during an interview with a Business Systems Analyst, who was interviewed for the asset maintenance and operations use case. The Business Systems Analyst has experience in planning, Geographic Information System (GIS), and asset management. Also participating in this use case interview was the UAS Program Manager. The interview included a conversation about current GIS team involvement with UAS data, the perception of the GIS team toward UAS, data management practices, and future plans for UAS integration.

20.1 UAS and GIS Working Together

UAS have revolutionized the field of GIS and can play a crucial role in NHDOT operations. UAS can collect high-resolution aerial imagery and LiDAR data quickly and cost effectively. These data can then be used to create detailed and up-to-date maps of transportation networks, including roads, bridges, and other infrastructure. By integrating UAS with GIS, NHDOT can improve its asset management systems, identify areas in need of repair or maintenance, and plan more efficiently for future development and expansion projects.

In addition to data collection, UAS can enhance the analysis and visualization capabilities of GIS. With the aid of UAS, NHDOT can perform 3D modeling and terrain analysis, which helps identify potential safety hazards, optimize roadway designs, and assess the impact of construction projects on surrounding areas. Leveraging UAS and GIS technologies together provides NHDOT with a comprehensive understanding of transportation infrastructure, assists in making data-driven decisions, and improves overall operational efficiency and effectiveness. The integration of UAS and GIS represents a powerful combination that can empower NHDOT to tackle the challenges of managing and maintaining its transportation networks in a more accurate, timely, and informed manner.

20.2 Staff Perception and Integration

Similar to the other bureaus, the GIS team is also experiencing a workforce shortage and currently has several open positions. The Business Systems Analyst noted his awareness of UAS and what a powerful tool it can be—he shared a recent experience he had at a regional innovation conference where staff from Massachusetts DOT presented on their successful integration of GIS and UAS. The NHDOT GIS team's perception is positive, and they appear open to embracing UAS technology for GIS applications.

To date, there has only been one GIS-specific UAS operation. A GIS use case that could be integrated initially is to use UAS to supplement the NHDOT aerial imagery. Every five years, the GIS team uses a fixed-wing aircraft to fly over the state to collect aerial data that are then used in asset management. UAS could supplement this traditional fixed-wing aerial data collection. The traditional aerial data is collected at 6-inch ground sampling distance, whereas UAS can provide higher resolution of 1-inch ground sampling distance or less. Furthermore, the interview touched upon the need for improved asset data collection. Currently many of these data collection efforts are being carried out by one individual with a tablet. The team expressed a desire for better data collection methods and delivery mechanisms and agrees that UAS can play a big role in improving these data collection efforts.

20.3 Data Management

The GIS team currently uses internal servers for data storage, with plans to migrate to cloud-based solutions in the future. While there were no concerns expressed about bandwidth or large amounts of UAS data, further assessment and planning may be required as the volume of data increases.

20.4 Anticipated Benefits

The anticipated benefits of using UAS across the operations and maintenance of NHDOT's transportation infrastructure are largely similar to the benefits outlined in the other use cases. The biggest anticipated benefit of UAS and GIS working together is enabling a powerful, up-to-date, and detailed statewide infrastructure database. By combining the aerial capabilities of UAS with the spatial analysis capabilities of GIS, NHDOT can capture high-resolution imagery and data of infrastructure systems such as roads, bridges, utilities, and buildings. This powerful combination enables the creation of an up-to-date and detailed repository of geospatial information, providing a wealth of knowledge for planning, maintenance, and emergency response. The UAS-GIS partnership ensures that infrastructure databases are regularly updated, enabling decision-makers to make informed choices based on accurate and timely information. This synergy brings unprecedented efficiency, cost savings, and improved infrastructure management across the state, ultimately leading to enhanced public safety and a more resilient and sustainable future.

21.0 EMERGENCY RESPONSE

The information for the emergency response use case was compiled from multiple interviews with NHDOT staff, including a Research Engineer, the ITS Project Manager, the Senior Aviation Planner, and UAS Program Manager. UAS can be deployed for disaster response and recovery efforts, allowing State DOTs to rapidly assess damage, monitor traffic flow, and make informed decisions to ensure public safety and minimize disruption to transportation networks. NHDOT plays a crucial role in emergency response efforts within the state. This section describes current practices and outlines potential future use cases for UAS to assist with emergency response.

21.1 Current Practice

During emergencies, NHDOT relies on mandates issued by the Governor of New Hampshire, which are then followed by directives issued to the Bureau of Aeronautics from the NHDOT Emergency Operations Center (EOC). Currently the EOC may call upon the Civil Air Patrol for UAS data acquisition as part of the emergency response, and there is a growing recognition of UAS being a valuable tool internally.

The Administrator of the Bureau of Aeronautics sits on the EOC committee. Her involvement in the committee ensures that aviation-related matters, including UAS usage, are considered during emergency response planning and decision-making processes. The Administrator of the Bureau of Aeronautics monthly participation in the EOC committee meetings demonstrates the commitment of the Bureau of Aeronautics to collaborate closely with internal and external emergency management stakeholders.

During active emergencies, the Bureau of Aeronautics maintains a team of four individuals who are on-call and ready to support the needs of the EOC. These services may include issuing Temporary Flight Restrictions to ensure airspace safety or coordinating UAS operations as needed. This on-call support helps streamline communication and coordination efforts between the Bureau of Aeronautics and the EOC during critical situations.

Efficient coordination of UAS and other aviation assets is essential for effective emergency response. The Bureau of Aeronautics maintains an aviation asset list for NHDOT owned aircraft, which allows it to track UAS and other relevant resources which enables efficient coordination with other agencies such as the State Police, National Guard, and Civil Air Patrol. This comprehensive tracking system ensures that the bureau can deploy resources efficiently and leverage UAS capabilities when required.

21.2 Potential Uses

While New Hampshire may experience minor earthquakes, the primary emergency concerns lie in erosion, landslides, and flooding. UAS technology can aid in assessing and monitoring these situations by providing real-time aerial imagery and data that enable a rapid response and data-informed decisions.

One common weather-related emergency is severe winter storms, which can result in heavy snowfall, blizzards, and freezing temperatures. These conditions often lead to road closures, power outages, and stranded individuals in remote areas. UAS can play a crucial role in emergency response during these events. Equipped with thermal imaging cameras, UAS can assist in locating stranded individuals, assess road conditions, assess avalanche conditions, and provide real-time situational awareness to emergency personnel.

Another weather-induced emergency in New Hampshire is flooding, particularly during the spring thaw or heavy rainfall events. Flooding can result in swift and dangerous currents, road washouts, and the displacement of residents. UAS can aid in flood response by conducting aerial surveys to assess the extent of the flooding, identify blocked or damaged infrastructure, and help prioritize rescue and relief efforts. UAS equipped with high-resolution cameras and LIDAR sensors can quickly gather detailed imagery and elevation data to assist emergency management teams in making informed decisions.

New Hampshire is also prone to severe thunderstorms that can produce high winds, lightning strikes, and even tornadoes. These storms pose a significant risk to public safety and can cause property damage and power outages. UAS can assist in post-storm assessments by capturing aerial footage of affected areas and helping emergency responders identify downed power lines, damaged structures, and areas in need of immediate attention.

21.3 Anticipated Benefits

UAS can provide invaluable situational awareness during emergency situations. Equipped with high-resolution cameras and sensors, these aerial vehicles can swiftly gather real-time data and imagery of affected areas, allowing emergency responders to assess the extent of the damage, identify potential hazards, and formulate effective response strategies. This enhanced situational awareness leads to a more efficient allocation of resources and a coordinated and effective emergency response.

UAS can also play a crucial role in conducting rapid damage assessments following natural disasters or other emergencies. These aerial platforms can cover large areas in a short period, capturing detailed images and footage of affected infrastructure such as roads, bridges, and buildings. By analyzing this data, DOT personnel can swiftly identify critical damage and prioritize repair and recovery efforts to expedite the restoration of essential transportation infrastructure, enables emergency services to reach affected areas faster; and facilitates the safe and timely movement of goods, services, and personnel. Many of the UAS platforms and sensors used for structural inspections, surveying, mapping, and construction monitoring can also serve the needs of emergency response situations. These platforms and sensors are presented in detail in the Task 2 Report.

22.0 SUMMARY AND CONCLUSION

In summary, this report offers insights into the integration of UAS into various operations of NHDOT, including surveying and mapping, structures inspection, construction monitoring, traffic operations, incident management, asset management, and emergency response. The interviews with NHDOT stakeholders representing these identified use cases provide valuable information about the challenges, opportunities, perceptions, and potential benefits associated with incorporating UAS technology.

For surveying and mapping, the challenges include ensuring data accuracy and the lack of expertise and software for processing UAS-captured data. However, the adoption of UAS is seen as a way to enhance efficiency, potentially attract a younger workforce, and improve safety. Data management and funding were also discussed as important considerations for UAS implementation.

In the case of structural inspections, the potential benefits of UAS include reaching difficult-to-access bridges and gathering detailed data efficiently. However, the inspection team appears more resistant to adopting new technologies. Funding constraints and uncertainties about UAS implementation were identified as key challenges to integration for this use case.

In the Construction Bureau, the interviewees acknowledged the potential benefits of UAS in construction projects, particularly on striping or restriping projects and the potential for integration in areas such as photogrammetry, project mapping, and site measurements. In addition, for materials there may be opportunities for non-destructive testing, and remote sensing for various materials. Current use of UAS is somewhat limited, with reliance on consultants. The Construction Bureau is initially prepared to work with the Bureau of Aeronautics for UAS services but is open to integrating UAS into its existing workflows. The Construction Bureau identified key challenges related to project size, workforce experience, data management, workflow integration, and public perception.

The TSMO team recognizes several potential use cases for UAS, including inspections of structures, assessment of traffic camera functionality, line-of-sight analysis for camera placement, analysis of radio tower communication paths, and UAS corridors for emergency response and traffic monitoring. The team is open to integrating UAS into its operations but will likely rely on the Bureau of Aeronautics for UAS services. Workforce collaboration and integration are key, with the possibility of equipping safety patrol units with UAS and using internal UAS services for camera sight line analysis. The team identified data management and privacy concerns, as well as public perception, as issues to be addressed when deploying UAS in residential areas.

In asset maintenance and operations, UAS can significantly enhance GIS capabilities by providing high-resolution aerial imagery and LiDAR data. These data can be used to create detailed and up-to-date maps of transportation networks and support asset management. UAS can be used to supplement data collection via traditional aircraft during the five-year cycle. The integration of UAS and GIS can improve data collection, mapping, asset inventories, and decision-making processes.

For the emergency response use case, UAS can greatly aid in disaster response and recovery by enabling rapid damage assessment, real-time monitoring of traffic flow, and informed decision-making to ensure public safety and minimize disruption to transportation networks. Interviewees emphasize the importance of efficient coordination between NHDOT, the Bureau of Aeronautics, and external stakeholders during emergencies. They identified various potential use cases for UAS, including assessing erosion, landslides, and flooding; responding to severe winter storms; addressing flooding situations; and assessing damage after severe thunderstorms. The anticipated benefits of UAS in emergency response include enhanced situational awareness, faster damage assessments, and more efficient allocation of resources, ultimately leading to a coordinated and effective response.

Overall, the report highlights the potential of UAS technology to enhance efficiency, safety, and data-driven decision-making in transportation operations at NHDOT. It emphasizes the need for careful consideration of challenges, such as data management, funding, and staff perceptions, while maximizing the benefits of UAS integration. The insights provided in this report will serve as a foundation for future recommendations and considerations in addressing these challenges and leveraging UAS technology effectively.

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APPENDIX F:

Task 2 Interim Report – Capability Gap Analysis and Business Model Analysis

New Hampshire Department of Transportation

Development of an Unmanned Aircraft Systems (UAS) Program 43272B

Task 2 Interim Report – Capability Gap Analysis and Business Model Analysis

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ACRONYMS AND ABBREVIATIONS

AI	Artificial Intelligence
3D	Three-dimensional
AID	Accelerated Innovation Deployment
CFR	Code of Federal Regulations
CMM	Capability Maturity Model
DOT	Department of Transportation
FAA	Federal Aviation Administration
FARs	(FAA) Federal Aviation Regulations
FHWA	Federal Highway Administration
FOV	Field of View
GNSS	Global Navigation Satellite System
LiDAR	Light Detection and Ranging
ML	Machine Learning
IT	Information Technology
NHDOT	New Hampshire Department of Transportation
PPK	Post-Processing Kinematic
RGB	Red, Green and Blue
ROI	Return on Investment
ROW	Right-of-way
RTK	Real-Time Kinematic
SMS	Safety Management System
SOP	Standard Operating Procedure
UAS	Uncrewed Aircraft Systems
UASIS	Unmanned Aircraft Systems Integration for Safety Program

24.0 INTRODUCTION

The objective of Task 2 is to work collaboratively with the New Hampshire Department of Transportation (NHDOT) Bureau of Aeronautics and understand the current Uncrewed Aircraft Systems (UAS)[3] program capability maturity in four key organizational dimensions including people (e.g., capacity, competencies, culture), processes (e.g., procurement, Federal Aviation Administration [FAA] coordination, UAS technology deployment), technology (e.g., UAS technology, support systems), and policy (e.g., UAS, data, safety,). The WSP research team developed a UAS Capability Maturity Model (CMM) assessment to assist in evaluating the program's current maturity level and outline the target maturity level for the program.

Information for the UAS CMM assessment was gathered via interview with the NHDOT UAS Program Manager. The goal of assessment was to assist in identifying the gaps in NHDOT's current UAS program and identified numerous ways UAS can assist the agency as the program matures. The assessment contains six critical success factor categories and is scored using a weighted average. NHDOT received a score of 71 percent placing it in the "Slow-Go" category, which aligns with the steady progress the agency has made since the inception of the UAS program. Section 2 of this report thoroughly explains the details of the development, deployment, scoring, and analysis of the UAS CMM.

Upon completion of the CMM assessment, the research team established a detailed UAS business model and recommendations for the NHDOT UAS program. The comprehensive business model incorporates four core elements:

a) Defining the specific mission for UAS operations.

b) Identifying the appropriate UAS platform and sensors to accomplish the mission (with accompanying maintenance schedules).

c) Outlining the necessary data management and analysis tools required (because UAS technology generates a vast amount of data that must be collected, analyzed, and stored).

d) Detailing operational expenses, benefits, risks, and potential cost savings.

Section 3 of this report expounds on these four main elements and includes recommendations regarding leadership support, organizational structure, UAS hardware and software, UAS fleet management, maintenance schedules, training program, data management, and the anticipated associated costs and benefits of a mature UAS program.

[3] UAS is more popularly defined as "unmanned aerial systems" today. However, the industry is showing sensitivity to gender-neutral terms and terms that can also be broadly applied to telerobotic-controlled or autonomous vehicles.

25.0 CAPABILITY GAP ANALYSIS

A successful UAS program is largely based on leadership support and a robust implementation plan. The foundation of a UAS implementation plan is understanding the agency's capabilities and limitations or gaps that will need to be addressed to ensure effective integration. As noted in chapter 1, the research team developed a CMM assessment tool to assist in understanding and defining the current level of capability maturity of the NHDOT UAS program.

This assessment tool was developed based on the Capability Maturity Framework that was initially developed in the 1980s by the software development industry (Mallela et al., 2020). CMMs were also developed under the framework and are widely used throughout the Information Technology (IT) industry. The CMMs has been refined and tailored for use throughout many industries, including surface transportation. The Federal Highway Administration (FHWA) uses CMMs to understand the successes and concerns regarding the adoption of Transportation Systems Management and Operations (Capability Maturity Frameworks Overview, n.d.).

CMMs are a long-standing and proven method that provide several benefits to organizations.

1. Process Improvement: CMMs help organizations assess and improve their processes, leading to increased efficiency, productivity, and quality. They provide a structured framework to identify areas for improvement and establish best practices.
2. Performance Measurement: CMMs enable organizations to measure their performance against a set of defined standards and benchmarks. They help in setting realistic goals, monitoring progress, and identifying areas of strength or weakness.
3. Risk Mitigation: By following a CMM, organizations can reduce risks associated with project failures, cost overruns, and quality issues. CMMs provide guidelines and controls that help in mitigating risks through better planning, monitoring, and control of processes.
4. Consistency and Predictability: CMMs promote consistency in processes and practices across different projects and teams. They ensure that organizations follow a standardized approach, leading to predictable outcomes and improved customer satisfaction.
5. Continuous Improvement: CMMs foster a culture of continuous improvement within organizations. They encourage regular assessment and refinement of processes, enabling organizations to adapt to changing business needs and technological advancements.
6. Enhanced Communication and Collaboration: CMMs provide a common language and framework for communication among team members, stakeholders, and different organizational units. They facilitate better collaboration, knowledge sharing, and alignment of goals and expectations.

Overall, the benefits of using a CMM include improved process efficiency, higher quality outputs, reduced risks, and enhanced organizational performance. The research team used the above outlined benefits as guiding principles in the development of the UAS CMM assessment tool employed to evaluate and rank the maturity level of the NHDOT UAS program. The completed assessment helps inform the existing gaps and identifies where there is room for improvement to advance maturity throughout the UAS program.

25.1 UAS CMM Assessment

The foundation of the UAS CMM assessment is based on six critical success factors that are defined in Table 1. These success factors serve as the six different sections of the assessment—each section is supported by a variety of questions used to gauge the agency's maturity as it relates to the specific critical success factors. These critical success factors play a pivotal role in successful integration of UAS into a State DOT's operations.

Table 1. UAS CMM Critical Success Factors.

Critical Success Factor	Explanation
General Awareness of UAS	Understanding of the general state of practice, technology, and innovative trends and the position of the agency in its practice.
Overview of Current Level of UAS Integration	Awareness of the agency's current level of UAS integration and how to increase the levels of UAS integration across the functional departments of the State DOT.
UAS Program – People Analysis	Understanding the roles of leadership, defining a UAS champion, roles within the UAS program, staff capacity, and workforce development needs.
UAS Program – Processes Analysis	Overview of processes, systems, programs, and budgets in place to support UAS implementation.
UAS Program – Technology Analysis	Overview of the agency's use of data processing software, level of proficiency with data processing software, UAS fleet management technology, Artificial Intelligence (AI) software, and other innovations within the UAS program.
UAS Program – Policy Analysis	Ability to navigate the processes in place to establish UAS policy and procedures.

The research team used a methodological process to assign weights to each critical success factor category and a structured decision-making technique to prioritize and rank criteria based on their relative importance. In the context of CMM, this methodology enabled the research team to assign weights to different critical success factor categories and associated criteria, and to establish a scoring system to evaluate and measure the agency's progress. By incorporating the assigned weights into the scoring system, agencies can measure their maturity level and progress in a more structured and consistent manner.

Each criterion within a critical success factor category is also scored by being ranked at one of three levels, adapted from Mallela et al. (2020).

- Level 1 – The agency is in a relatively weak position to advance UAS operations with significant gaps in capability.
- Level 2 – The agency is in a potentially tenable position to advance UAS operations but should address some gaps in capability that could pose risks to a successful implementation.
- Level 3 – The agency is well-positioned to advance UAS operations.

The scoring across these three levels is split equally from 100 percent, meaning each one is worth 33.3 percent. If an agency ranks at a level 2, it would be given a score 66.6 percent for that criterion, and if the agency reaches a level 3, it would be given a score of 100 percent. The sum of the criteria scores for each category are then divided by the number of criteria in that specific critical success factor category. This number is then multiplied by the weighted percentage for that critical success factor category to provide a percentage score for the entire category. These final category scores are added up at the end for a total CMM assessment score.

Assessments based on the CMM can be conducted in a variety of ways, including by conducting a self-assessment. In this approach, the agency's staff evaluates their processes against the CMM criteria. This can be done through questionnaires, workshops, or collaborative discussions. While self-assessments may lack the objectivity of a formal outside review, they can still provide valuable insights and serve as a starting point for process improvement efforts.

The research team conducted an outside, formal review using informal interview techniques. Conducting a CMM assessment through an informal interview process involves engaging with the key subject matter expert(s) within the agency. The interview was conducted with NHDOT's current UAS Program Manager. This approach allowed for a flexible and interactive evaluation of NHDOT's processes and practices in general and specifically its UAS operations. During the interview, the interviewer was able to ask targeted questions related to CMM dimensions and collect information about the organization's current practices, challenges, and areas for improvement.

This informal interview approach provided the opportunity for open dialogue and fostered collaboration and knowledge sharing. It is important to note that an informal interview process can have limitations in terms of objectivity and consistency compared to more structured assessment methods. These limitations were mitigated by the research team having a clear understanding of the UAS CMM assessment and maintaining a structured approach during the interview to ensure a comprehensive evaluation.

Subject matter experts with proficiency in a variety of disciplines related to UAS programs conducted the interview, and the interview was recorded to enable a comprehensive analysis. The research team completed the UAS CMM assessment using the interview notes, interview recording, and extensive qualitative data. The scored assessment is detailed in Table 2, the determined level for each criterion is highlighted in blue.

Table 2. NHDOT's UAS CMM Assessment.

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
1. Awareness of UAS Weight: 10%	Context Awareness: *FAA Code of Federal Regulations (CFR) 14 Part 107 Regulations concerning the use of small UAS and FHWA Everyday Counts-5 UAS Initiative*	Largely unaware or very limited awareness and interest.	Some awareness and moderate interest in following the fundamental and applied research and development.	High level of awareness and keen interest in closely following fundamental and applied research and development in this area.	
	Specific Awareness: *State DOTs integration of UAS across operations. How UAS have been used by other State DOTs; Where it should work well; Where it might not apply; level of effort and resources required (staffing, expertise, facilities, equipment, time, and budget)*	Largely unaware of UAS and how it could impact the DOT's operations.	Some awareness of UAS and experience among a couple of UAS use cases.	Closely tracking other State DOT's UAS initiatives and experiences in testing and trials across multiple UAS use cases.	
					10%

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
2. General Overview of Current Level of UAS Integration Weight: 25%	The agency utilizes UAS across many use cases throughout infrastructure inspections, construction inspections, emergency management, asset management, etc. How many UAS use cases is the agency actively utilizing UAS?	1 to 2 UAS use cases	3 to 5 UAS use cases	6 or more UAS use cases	
	Does the agency have a UAS Steering Committee?	The agency is largely unaware of who should be included in forming a UAS committee or the reasons for needing one.	The agency recognizes the need for a UAS committee but has been unable to establish a formal committee or regularly meet as a committee.	The agency has a diverse UAS Steering Committee that meets regularly to establish UAS program goals and to develop, review, and approve UAS-related policies.	
	Does the agency have relationships or partnerships with academic institutions related to UAS integration or research?	Largely unaware of universities in the area that are involved with UAS research.	The agency has made contact with one or more universities to collaborate on UAS initiatives.	The agency has great working relationships with one or more universities for ongoing collaboration on UAS initiatives.	

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
	Access to Funding	Access to funding in support of such practices is ad hoc and ill-defined, in the absence of any established budgetary process or program geared toward funding UAS integration.	Although there is no established budgetary process or program geared toward funding this type of practice, there are recognized opportunities to make the case as a "special project" outside of regular processes.	The opportunity for making the case for such practices is through established budgetary and program processes that encourage innovation advocates to compete for funding.	
	Alignment with Agency Performance Goals	Unclear if UAS integration addresses priority problems of the agency.	UAS integration addresses recognized problem(s), and an inferred performance goal(s) of the agency.	UAS integration addresses significant problems and explicit performance goals of the agency.	
	How many waivers has the agency obtained to date?	The agency is unaware if there is a need to obtain waivers at this time.	The agency has identified a need for waivers but needs assistance obtaining waivers.	The agency has identified a need for waivers and has successfully navigated the waiver process.	
	Is the agency using a system to track the number of UAS operations?	The agency does not currently have a system in place to track UAS operations.	The agency is exploring options for establishing a tracking system for UAS operations.	The agency has a reliable and working system that allows for the efficient tracking of UAS operations.	
					20.8%
3. UAS Program – People Analysis Weight: 30%	Leadership Support; Collaboration and Teamwork; Receptivity to New Ideas; Dedication to Continuous Improvement	Largely absent.	Present only in select divisions of the DOT involved in UAS initiatives.	Pervasive throughout the agency.	

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
	Champion(s): Combination of technical expertise, passionate interest and ability to lead UAS initiatives	There are staff members with some technical expertise and interest in participating or potentially leading UAS initiatives, but no clear choice in terms of level of interest.	There is at least one staff member whose technical expertise, level of interest and leadership ability are sufficient to lead UAS initiatives, but no backup if this person were to leave.	There is a clear choice of who should lead UAS initiatives within the organization on the basis of technical expertise, level of interest and leadership skills, and one or more others who could step in if this person were to leave.	
	Staff Capacity	Insufficient capacity in number of people and levels of expertise within the agency or accessible through outsourcing to undertake UAS initiatives.	The capacity in numbers of people and levels of expertise available within the agency or accessible through outsourcing to undertake UAS initiatives is barely sufficient, but can be expected to increase with the advancement of the practice.	Sufficient capacity in numbers of people and levels of expertise available within the agency or accessible through outsourcing to undertake maturing UAS initiatives.	
	Assistance from Support Functions: IT, human resources, and procurement units and supporting systems	Gaining assistance in the form of administrative and technical support, particularly for new initiatives, can be arduous to achieve.	Gaining assistance in the form of administrative and technical support requires patience and persistence, particularly for new initiatives, but is typically achievable.	Gaining assistance in the form of administrative and technical support is readily achievable, even for new initiatives.	

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
	New Workforce	Minimal opportunities to attract new workforce or outside factors that prohibit sustainable workforce for UAS initiatives within the organization (e.g., high cost of living, minimal available housing, limited human resources).	Moderate opportunities for new workforce for UAS initiatives. May require supplementation to attract workforce (e.g., subsidized or employer provided housing, fringe benefits, sustainable cost of living and quality of life in community).	The agency proactively provides opportunities for new workforce recruitment efforts. The cost of living is sustainable, or means are provided to supplement negative externalities. (e.g., subsidized or employer provided housing, fringe benefits, sustainable cost of living and quality of life in community).	
	New Workforce Outreach	The agency has no established outreach programs or relationships with local high schools and universities to educate the next generation about career opportunities within the agency.	The agency is in the initial stages of establishing outreach programs or relationships with local high schools and universities to educate the next generation on career opportunities within the agency.	The agency has robust outreach programs or established relationships with local high schools and universities and is actively educating the next generation on career opportunities within the agency.	
	Existing Workforce Development	Minimal opportunities and funding are provided to existing workforce within the agency for additional training, certificates, and overall development.	Moderate opportunities and funding are provided to existing workforce within the agency for additional training, certificates, and overall development.	The agency proactively provides opportunities and funding for the existing workforce to develop professional, attend additional training, and earn industry certifications.	
	Does the agency have a UAS Program Manager?	No specific UAS Program Manager.	There is a UAS Program Manager, but this person shares duties and lacks bandwidth.	There is a full time, sole duty UAS Program Manager.	

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
	Does the agency have a UAS Training Manager?	No specific UAS Training Manager.	There is a UAS Training Manager, but it is a shared duty with the UAS Program Manager or other personnel.	There is a full time UAS Training Manager.	
					18%
4. UAS Program – Processes Analysis Weight: 10%	FAA Coordination	Little to no coordination with the FAA regarding UAS.	Infrequent coordination with the FAA regarding UAS.	Frequent and ongoing coordination with the FAA regarding UAS.	
	Procurement	The procurement process is extremely cumbersome and difficult, making procurement of UAS nearly impossible.	The procurement process is somewhat difficult to navigate but purchasing UAS is straightforward.	The procurement process is easily navigated and purchasing UAS is simple to do.	
	Approval of UAS Flights	The agency does not currently have a system in place to approve UAS flights.	The agency is exploring options for establishing an approval system for UAS flights.	The agency has a reliable and working system that allows for seamless approval for UAS flights.	
	Process to Change Standard Operating Procedures (SOPs)	The process used to change SOPs is very difficult to navigate and time-consuming which makes it difficult to update the document.	The process used to change SOPs is somewhat difficult to navigate which makes updating the document challenging.	The process used to change SOPs is straightforward and can easily be accomplished, which allows SOPs to be a living document, easy to update.	
	UAS Crew Communications Procedures	The agency does not currently have established UAS communications procedures.	The agency has a framework for UAS communications procedures.	The agency has robust and establish UAS communications procedures in place.	

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
	Cross Division Collaboration	Largely absent.	Present only between select divisions within the DOT.	Pervasive throughout the agency.	
	Emergency Procedures	The agency does not currently have established UAS emergency procedures.	The agency has a framework for UAS emergency procedures.	The agency has robust and establish UAS emergency procedures in place.	
					8.3%
5. UAS Program – Technology Analysis Weight: 10%	Does the agency own any small UAS?	No small UAS are owned.	1 to 5 small UAS are owned.	6 or more small UAS are owned.	
	Does the agency have a dedicated UAS fleet management software or process in place?	No formal UAS fleet management software or process.	Somewhat of a fleet management process and exploring fleet management software.	Established use of a fleet management software and written and adopted fleet management processes.	
	Does the agency utilize any UAS data collection processing software?	No processing software is being utilized to processed UAS-collected data.	The agency is in the infancy of using UAS processing software.	The agency is actively using a variety of software options to process UAS-collected data and create various deliverables.	
	Does the agency utilize any Artificial Intelligence (AI) or machine learning (ML) software for UAS data processing?	The agency has not explored the use of AI/ML software to process UAS data.	The agency is in the infancy of using AI/ML software to process UAS data.	The agency actively and often utilizes AI/ML software to process UAS data.	

Critical Success Factor	Component	Level 1	Level 2	Level 3	Weighted Score
					5%
6. UAS Program – Policy Analysis Weight: 15%	Does the agency have written and adopted UAS policies and procedures?	Largely unaware of where to begin in establishing UAS policy and procedures.	The agency has UAS policy and procedures that are in development.	The agency has robust policies and procedures governing the agency's UAS operations.	
	Does the agency have established UAS workflows for specific use cases?	Largely unaware of where to begin in establishing UAS-specific workflows.	The agency has UAS workflows for a couple of use cases.	The agency has established UAS-specific workflows for any use case in which UAS are being utilized.	
	Does the agency have a UAS data management plan?	Largely unaware of how to best manage the large amounts of data that may come from UAS.	The agency has begun coordinating with internal resources (IT department) and/or has a UAS data management plan in development.	The agency has coordinated with internal and/or external resources to establish a thorough data management plan for all UAS-collected data.	
	Is there coordination with the chief data management officer within the organization?	No collaboration has been initiated with the agency's chief data management officer.	Initial contact has been established with the agency's chief data management officer.	Ongoing collaboration is established with the agency's chief data management officer and team to establish UAS data management best practices.	
	Does the agency have a Safety Management System (SMS) related to UAS operations?	Largely unaware of where to begin in establishing an SMS for UAS operations.	The agency has an SMS for UAS operations in development.	The agency has developed an in-depth SMS that has been implemented throughout the agency's UAS operations.	
					9%
Total Score:					71%

The weights of the critical success factors and scoring of the criteria in each category are defined above. The total final score of the NHDOT UAS CMM assessment was 71 percent. This score places NHDOT's UAS Maturity Level at a *Level 3 – Slow-Go* as seen in Table 3.

Table 3. UAS CMM Assessment Score and Go/No-Go Decision.

State DOT UAS CMM Assessment Score (%)	State DOT UAS Maturity Level
75%–100%	Level 4: Go-Now
50%–75%	Level 3: Slow-Go
25%–50%	Level 2: Not-Now
0%–25%	Level 1: No-Go

The maturity level and associated go/no-go recommendation informs a State DOT on its present status and potential future steps to advance the maturity of its UAS practice. The levels have been adapted from Mallela et al. (2020).

1. **No-Go**: Decide not to advance the UAS practice at the time of this result because of:
    a. Insufficient interest.
    b. Insufficient capability.
    c. Insufficient resources.
    d. Inability to overcome the existing barriers.
    e. Inability to mitigate identified risks to can acceptable level.
    f. Some or all of the above.
2. **Not-Now**: Continue to monitor progress with UAS program development and application elsewhere, as well as all of the above factors that led to a "not-now" decision at this time. Discuss how these factors can be addressed and when it would be appropriate to revisit the decision. Include a discussion of the consequences and ramifications of not implementing UAS at this time.
3. **Slow-Go**: Decide to advance the maturity of the agency's UAS program but for some combination of reasons, do so at an "evolutionary" pace by naturally incorporating the emerging practice into the agency's other day-to-day operations as it becomes relatively mainstreamed. Include a discussion of the consequences and ramifications of a "slow-go" decision, alongside the conversation about how to address the outstanding gaps in maturity.
4. **Go-Now**: Decide to expeditiously advance UAS utilization into the agency's various operations and practices, including an expedited testing and evaluation phase, potentially in collaboration with others interested in advancing it within the transportation sector.

The NHDOT UAS program maturity scored at a 71 percent resulting in a "Slow-Go" recommendation. This reflects the efforts and progress the agency has made to date and provides insight into outstanding gaps that can be addressed to advance maturity and lead to successful implementation of UAS across multiple use cases throughout the agency.

25.2 Gap Analysis

The gap analysis section aims to identify the gaps between the current maturity level (identified through the comprehensive UAS CMM assessment) and the desired highest maturity level with full UAS implementation. 'This section presents the key findings from the CMM assessment and highlight the gaps that were identified in each critical success factor category. This analysis serves as a foundation for developing targeted strategies and a comprehensive implementation plan to be developed in Task 3, which will bridge the identified gaps and enhance the organization's overall maturity level.

25.2.1 General Awareness of UAS

The General Awareness of UAS category is weighted at 10 percent, and only two criteria are used to gauge the current awareness of UAS practice. One of the criteria refers to general understanding of the FAA regulations that govern the use of UAS, found in Code of Federal Regulations (CFR) 14 Part 107. NHDOT was scored at a level three because the current UAS Program Manager demonstrated high levels of knowledge of CFR 14 Part 107 throughout the assessment interview. The second question refers to the agency's current understanding of how UAS are being used by other State DOTs across the country. The UAS Program Manager demonstrated knowledge of other states' current practice with UAS and has collaborated with several State DOTs UAS programs. NHDOT received a score of 10 percent in this category.

A repeating theme emerged throughout the assessment interview. There appears to be a general awareness of UAS throughout the NHDOT as a result of the Bureau of Aeronautics' efforts in providing presentations and demonstrations centered around the utilization of UAS. NHDOT commissioners have expressed support for UAS implementation, and there is excitement and momentum regarding the implementation of UAS across the identified use cases. Many throughout NHDOT are open to the use of UAS but want to see more UAS data processing and review the overall reliability or use of the processed data.

25.2.2 Overview of Current Level of UAS Integration

The Overview of the Current Level of UAS Integration section of the assessment is weighted at 25 percent using seven criteria. This category provided insight into the accomplishments and groundwork to date of NHDOT's Bureau of Aeronautics regarding UAS program establishment. Figure 2 provides a timeline of the accomplished milestones since the program's inception in 2019.

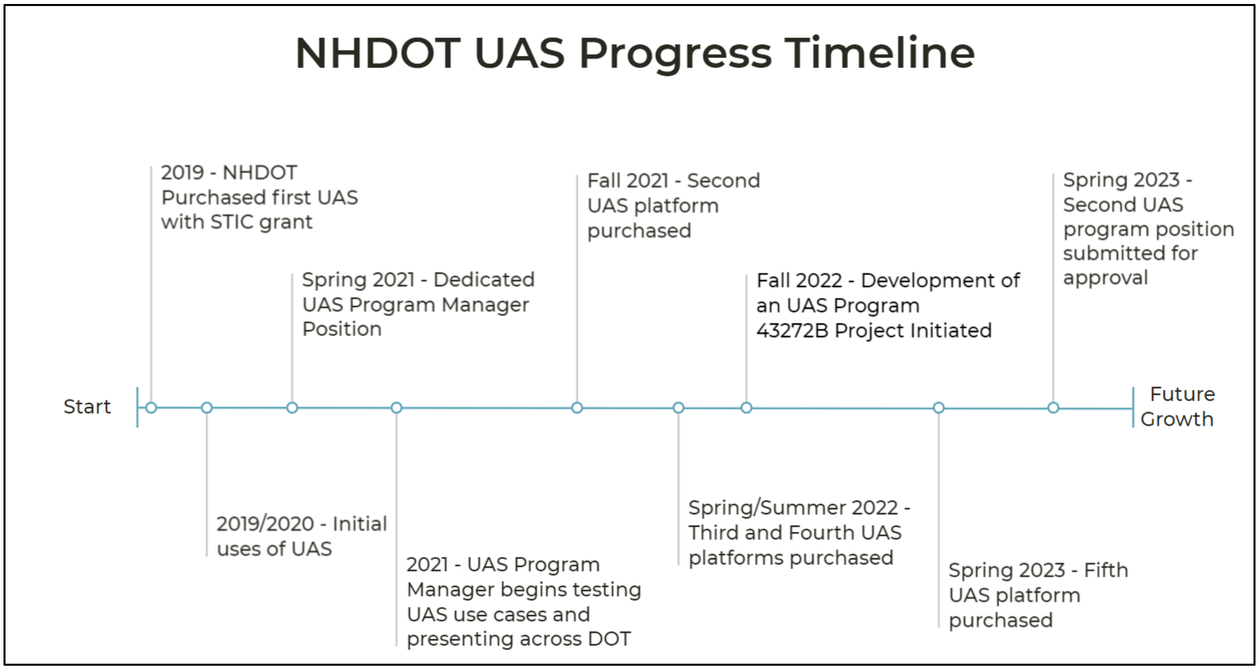

Figure 2. NHDOT UAS Program Progress Timeline.

Progress has been ongoing since the start of the UAS program, and NHDOT is in an ideal situation to continue to mature UAS implementation processes. The Bureau of Aeronautics has leveraged the use of State Transportation Innovation Council grants to purchase several of the agency's five UAS platforms. Using these UAS platforms, the UAS Program Manager has been able to begin testing between three and five use cases where UAS integration has the potential to greatly assist the agency. While testing these use cases, the UAS Program Manager has identified the need for airspace waivers and has demonstrated high levels of capability maturity navigating the FAA waiver process. The Bureau of Aeronautics goals to grow the UAS program aligns with overall NHDOT goals to become more efficient and effectively meet obligations with an estimated 25 percent decrease in workforce.

The UAS Program Manager is aware of relationships that NHDOT has with various academic institutions and is exploring collaboration initiatives as they relate to the UAS program. Another item being explored is the use of an internal tracking system to track UAS operations throughout the agency. Currently any consultants or contractors who need to fly in NHDOT's rights-of-way (ROW) must submit a form and receive permission from the UAS Program Manager. This system can be refined and further developed into a more robust tracking system for internal and external UAS operations.

The assessment shed light on two gaps within this category.

1. There is currently no UAS steering committee.
2. There is a lack of a dedicated budget to maintain and support the UAS fleet and program.

Many other State DOTs have found the use of a UAS steering committee to be helpful in developing, reviewing, and/or approving UAS policies and procedures. Recommendations on creating and using a committee and suggestions regarding ongoing funding will be provided in the Task 3 UAS Implementation Plan.

25.2.3 UAS Program – People Analysis

The UAS Program – People Analysis category is the highest graded category from the assessment; it is weighted at 30 percent using ten criteria. NHDOT earned 18 of the 30 possible percentage points in this category; the assessment exposed several areas where changes can be made to advance the overall maturity of the UAS program.

Leadership awareness and support of UAS integration is key to successfully starting and growing a UAS program. NHDOT leadership has expressed support for UAS implementation, but leaders from various functional departments are currently skeptical. They want to see the UAS-collected data processed and delivered in usable formats, which is certainly the goal as the UAS program continues to be developed. NHDOT has been proceeding with the establishment of the UAS program within the Bureau of Aeronautics, and the identified champion has made great progress within this division. The term "champion" is defined in the assessment as one who has the combination of technical expertise, passionate interest, and ability to lead UAS initiatives. The current UAS Program Manager, Jason Leavitt, is serving well as that champion; however, two gaps on this criterion were identified in the assessment. First is the fact that Jason is approaching retirement after a full career of service to NHDOT, and second is the growing concern of bandwidth given Jason's current responsibilities.

The UAS Program Manager position is currently a shared duties position that also includes traditional aeronautics division responsibilities (e.g., airport inspections). Currently Jason receives several UAS flight requests each week, participates in promoting the program via demonstrations and presentations, and is trying to actively mature the program. As the program grows and flight requests continue to increase across the identified use cases, it will likely become necessary to hire additional people to assist in flying these requests or rely on the other departments to integrate UAS internally. The UAS Program Manager can help supervise these efforts, but the needs of a growing program can quickly outgrow the capacity of one person. As the program grows, another need will be training responsibilities; currently there is no UAS Training Manager position. The Business Plan section below and the Task 3 UAS Implementation Plan will address the UAS Program Manager position, UAS Training Manager position, and cross training to ensure consistency through position changes.

Information provided during the CMM UAS assessment interview indicated that NHDOT is facing a 25 percent decrease in staff capacity, and it has been challenging to hire new workforce. UAS can be a tool to increase efficiency across multiple use cases that can help alleviate this current workforce challenge. However, to successfully integrate UAS as an effective tool, other people throughout NHDOT will need to be identified to champion the technology and advance the practice.

In addition to more UAS champions, the number of FAA-certified Remote Pilots. At the time of the assessment, the only certified Remote Pilot was the UAS Program Manager. During the Task 1a UAS Workshop held in February 2023, there was a discussion regarding if NHDOT would provide funding for the training and certification costs for the FAA Remote Pilot certifications. At the time of the workshop and at the time of the assessment, this question remained unanswered.

Other people typically needed to support a UAS program include staff from IT, Human Resources, the procurement office, and other supporting systems. The Bureau of Aeronautics has initiated conversations with several of these supporting bureaus, but a gap exposed during the assessment is the need for more robust collaboration. The current and future needs of the UAS program need to be identified and properly communicated to these supporting divisions.

25.2.4 UAS Program – Processes Analysis

The UAS Program – Processes Analysis includes seven criteria and is weighted at 10 percent of the total assessment. NHDOT scored 8 of the 10 percentage points in this category because it has made steady progress in the development of a draft Standard Operating Procedures (SOP) document that covers many of the category's criteria.

The successful integration of UAS often relies on ongoing coordination with the FAA. Demonstrating this coordination, the UAS Program Manager has effectively used the FAA's waivers process, ensuring compliance with regulations and obtaining necessary permissions. Moreover, the Bureau of Aeronautics has established reliable working relationships with the FAA and knows its designated point of contact. In addition to external coordination with agencies like the FAA, the UAS Program Manager has been coordinating with internal departments within NHDOT. This collaboration with other functional departments is crucial. While progress is being made in testing and implementing UAS-related initiatives, there remains some skepticism among certain departments, which will need to be addressed.

To enable UAS operations, the UAS Program Manager has navigated the internal procurement process to acquire the necessary equipment for several of the purchased UAS platforms. To approve external UAS flights within NHDOT ROWs, the Bureau of Aeronautics has implemented a systematic approach. Interested parties are required to submit forms requesting approval for UAS flights, ensuring that proper documentation and authorizations are in place. This established system provides a framework for evaluating and approving UAS operations, allowing the UAS Program Manager to ensure safety in the ROWs.

UAS crew communications procedures and emergency protocols are essential for safe operations. These processes are currently in draft form and await finalization and approval. The Bureau of Aeronautics recognizes the importance of having comprehensive guidelines in place that govern the UAS program and ensure effective communication and swift response during emergency situations. However, the process of finalizing and gaining approval for these procedures may be challenging and has yet to be navigated.

The process of approving or making changes to UAS SOPs within NHDOT's UAS operations is currently somewhat unknown, posing potential challenges. As the department continues to develop and refine its UAS program, clarifying the process for approving or modifying SOPs becomes crucial. By establishing clear guidelines and transparent procedures for SOP updates, the UAS Program Manager can mitigate potential difficulties and ensure the efficient adaptation of operational protocols in response to evolving requirements and industry best practices.

25.2.5 UAS Program – Technology Analysis

The UAS Program – Technology Analysis section is weighted at 10 percent with four criteria; NHDOT received 5 of the percentage points. NHDOT currently owns five UAS platforms, which positions the department to be in the middle range in terms of fleet size and capabilities according to the assessment. While possessing these UAS platforms is a positive step forward, the agency recognizes the need for further advancements in UAS data processing software. This aspect emerged as a recurring theme during the assessment, highlighting it as a current restriction that requires additional expertise and attention. Acknowledging this gap and actively seeking to enhance the data processing capabilities will assist in advancing the maturity of the program.

In terms of UAS fleet software, the agency does not currently have a formal solution in place. Existing options within NHDOT, such as the Work Order Fleet Inventor, are not considered viable alternatives, for UAS fleet tracking needs. The Work Order Fleet Inventor software would not meet the needs of the UAS fleet because the key is to closely track fleet health. Dedicated UAS fleet software integrates with telemetry data of the UAS and can provide specific details of the flight to be used for compliance and safety, and it also tracks things like battery health. As a result, the department will need to explore and adopt appropriate software solutions specifically tailored to the management and optimization of UAS operations.

Furthermore, the department has yet to use artificial intelligence (AI) or machine learning (ML) software in its UAS operations. While AI and ML technologies have the potential to revolutionize data analysis, predictive modeling, and decision-making processes, the agency is still in the early stages of UAS implementation, and AI tools can be evaluated at a later time. Recognizing the benefits that AI and ML can bring to UAS operations, the agency should consider investing in these technologies as the UAS program grows in maturity. These same tools could also be used in other areas throughout the agency to improve processes.

25.2.6 UAS Program – Policy Analysis

The final category in the CMM UAS assessment is the UAS Program – Policy Analysis category, which is weighted at 15 percent and has five criteria. NHDOT earned 6 percentage points in this category because like the SOPs, the UAS program policies are in draft form or have yet to be fully developed and approved.

It remains to be seen whether the existing data policy used to govern other data collection and storage throughout NHDOT will be applicable to the UAS program or if a specific UAS data management policy needs to be developed. The score in this category indicates that there is still a need for further deliberation and assessment to ensure that UAS data are handled in a manner that aligns with regulatory requirements, privacy concerns, and operational needs. By carefully considering these factors, NHDOT can establish clear guidelines and protocols for UAS data management that ensure compliance and promote effective use of the collected and processed data.

While there has been progress in drafting its Safety Management System (SMS) policy, further development and approval are still required. The SMS policy serves as a vital framework for managing safety risks associated with UAS operations. SMS considerations will be provided as part of the Task 3 UAS Implementation Plan,. Because the policy remains in the draft form, the Bureau of Aeronautics and UAS Program Manager can review what will be provided and work to finalize the SMS policy prior to submission for approval.

Furthermore, the ’Bureau of Aeronautics overall governing policies for its UAS program are currently in draft form and require refinement and approval. These governing policies serve as the foundation for ensuring standardized practices, compliance with regulations, and effective operational guidelines. Through collaboration, consultation, and careful consideration of industry best practices, the Bureau of Aeronautics can refine these policies and obtain the necessary approvals to provide clear guidance and structure for the successful implementation and management of UAS operations.

Moreover, NHDOT faces the challenge of developing specific workflows tailored to UAS operations. Currently, no UAS-specific workflows have been established for any of the identified use cases. During the assessment, and throughout the use case interviews in Task 1b, the various bureaus indicating that they are largely unaware of how to best approach the development of these UAS-specific operational processes. However, by leveraging expertise, conducting thorough analyses, drawing on industry standards, and collaborating with the subject matter experts of the use case, strong UAS workflows can be developed. These workflows will provide a structured framework that outlines step-by-step procedures, roles, and responsibilities, enabling efficient and standardized execution of UAS operations across various use cases.

25.2.7 Gap Analysis Summary

The gap analysis conducted through the UAS CMM assessment identified several gaps between the current maturity level and the desired highest maturity level with full UAS implementation. These gaps span different critical success factor categories and provide valuable insights into the areas that require attention and improvement. A summary of the identified gaps is as follows:

- General Awareness of UAS: While the UAS program demonstrates a general awareness of UAS and the national state of the practice, there is a desire for more UAS data processing and overall reliability of the processed data. The goal is to seamlessly integrate UAS-collected data into as many areas and department workflows as possible.
- Overview of Current Level of UAS Integration: NHDOT has made significant progress in establishing the UAS program and integrating UAS into various use cases. However, a UAS steering committee and a dedicated budget are needed to support the ongoing maintenance of the UAS fleet and overall growth of the program.
- UAS Program – People Analysis: Leadership support for UAS integration exists, but there is skepticism from various functional departments. The eventual retirement of the current UAS Program Manager and concerns regarding bandwidth present challenges. More UAS champions, FAA-certified Remote Pilots, and collaboration with supporting divisions are needed.
- UAS Program – Processes Analysis: While progress has been made in developing SOPs, there is a need for clarity in the process of approving or modifying them. Finalizing UAS crew communications procedures and emergency protocols as part of these processes also need to occur.
- UAS Program – Technology Analysis: Advancements in UAS data processing software and dedicated UAS fleet tracking software are needed. Other software tools can also be integrated to improve the efficiency of the data processing analytics. The use of AI and ML software has been tested on limited use cases for airport pavement analysis but may be considered in the future for other areas.
- UAS Program – Policy Analysis: UAS program policies, including data management and SMS policies, are in draft form and require further development and approval. Overall governing policies and UAS-specific workflows also need refinement and approval.

Addressing these gaps is crucial to enhancing the maturity level of the UAS program within NHDOT. Task 3 of this project, which involves developing targeted strategies and a comprehensive implementation plan, will be instrumental in bridging the identified gaps. This plan will include recommendations for establishing a UAS steering committee, securing dedicated funding, addressing leadership concerns, ensuring a smooth transition with personnel changes, finalizing SOPs and emergency protocols, adopting appropriate technology solutions, developing UAS-specific policies and workflows, fostering collaboration with supporting divisions, and other keys to overall program success.

By addressing these gaps and implementing the recommended strategies, NHDOT can advance its UAS program, improve operational efficiency, and leverage UAS as a valuable tool to meet its obligations effectively, which can help alleviate the impacts of variability in the labor market. With continued commitment and strategic planning, NHDOT can successfully achieve its desired highest maturity level with full UAS implementation.

26.0 BUSINESS MODEL ANALYSIS

UAS have emerged as an innovative tool that can transform many traditional work processes that are dangerous, dirty, or dull. State DOTs are increasingly adopting UAS technology to improve their operations and conduct various tasks such as infrastructure inspection, traffic monitoring, and disaster response, among others. This adoption of UAS technology has resulted in significant cost savings, improved safety, and enhanced efficiency. However, to accomplish these successes, a comprehensive UAS business model is essential to ensure the effective implementation of the technology.

A well-developed UAS business model for State DOTs incorporates four essential elements:

a) Definitions for specific mission for UAS operations.

b) Identification of the appropriate UAS platform and sensors to accomplish the mission (with accompanying maintenance schedules).

c) The necessary data management and analysis tools required (UAS technology generates a vast amount of data that must be collected, analyzed, and stored).

d) Operational expenses, benefits, risks, and potential cost savings.

Fully developed safety and training requirements are also an assumed aspect of any comprehensive business model and should be incorporated into every element of the plan.

Peripherally, the regulatory environment should also be addressed. Policies and procedures should be in place for unhindered flight operations that can be accepted by the communities in which the operations are conducted.

The successful implementation of UAS technology by State DOTs requires a comprehensive business model that considers various factors. A well-thought-out UAS business model will enable State DOTs to adopt and use UAS technology effectively and efficiently. By using UAS technology as a tool, State DOTs can improve their operations, reduce costs, and enhance the safety of their workers and the traveling public. Necessary components of a successful business model are described below.

26.1 Leadership Support (Element a)

Executive leadership support is crucial for the successful implementation of a State DOT UAS program. Executive leaders play a pivotal role in determining the vision and trajectory of UAS programs because they have the authority to allocate resources, set strategic priorities, and establish policies. Their support is necessary to provide the direction, guidance, and resources for the program's development and implementation.

Executive leaders are responsible for defining the vision of the UAS program. They set the overarching goals and objectives and identify how UAS technology can be integrated into the DOT's operations to enhance efficiency, safety, and effectiveness. Leaders work closely with stakeholders, including internal teams and external partners, to understand the potential benefits and challenges of implementing UAS and ensure alignment with the DOT's overall mission and objectives.

Lack of executive leadership support can significantly impede the utility of a UAS program. Without the backing of top-level decision-makers, the program may struggle to secure the necessary funding, resources, and personnel required for successful implementation. This lack of support can hinder the development of a robust UAS infrastructure, including training programs, operational guidelines, and regulatory frameworks.

Furthermore, without strong executive support, the perceived value of the UAS program may diminish both internally and externally. Internally, employees may be skeptical about embracing UAS technology if they do not see commitment and endorsement from top leadership. This lack of confidence can hinder adoption and limit the program's potential benefits to the State DOT's operations.

Externally, stakeholders and the public may question the legitimacy and credibility of a UAS program that lacks executive leadership support, which can lead to skepticism about the program's efficacy, hinder collaboration with external partners, and undermine public trust. Without strong executive backing, it becomes challenging to build relationships and partnerships necessary for the successful integration of UAS technology into the State DOT's operations.

At the time of this report, the upper management and top leadership within the New Hampshire DOT are offering strong support to the growing UAS program. This crucial leadership support has been earned through the efforts of the Bureau of Aeronautics as it has initiated UAS technology demonstrations, worked collaboratively with other Bureaus across potential use cases, and developed the framework for the UAS program to be successful. These efforts and others have been effectively communicated to leadership who is excited and supportive of integrating UAS into the NHDOT operations.

26.2 Organizational Structure (Element a)

NHDOT's UAS program is currently structured under the Bureau of Aeronautics and benefits from existing aviation expertise and resources within this bureau. The Bureau of Aeronautics provides valuable insights into airspace regulations, pilot licensing, safety protocols, and maintenance procedures. In addition, the Bureau of Aeronautics already has an existing relationship with the FAA. This alignment of state and federal agencies can lead to efficient integration of UAS operations into the existing State DOT framework, ensuring compliance with established standards and leveraging shared resources.

The optimal organizational structure of a UAS program office within NHDOT would involve a dedicated team responsible for overseeing and managing UAS operations. This program office would ideally be structured as a separate unit within the DOT/Aeronautics Bureau to ensure focused attention on UAS-related activities and to facilitate streamlined decision-making and coordination. This organizational structure is known as the "Centralized UAS Department" model. Additional statewide UAS coordination and services provided by the NHDOT could be an option considered by Executive Management and State Legislature as the State increases the use of UAS technology.

In terms of staffing levels and structure, the UAS program office would require a multidisciplinary team with expertise in various areas and may include UAS operators, data analysts, safety officers, project managers, and regulatory compliance specialists. Staffing levels would depend on the scale and scope of the UAS program and would consider factors such as the number of UAS platforms, operational requirements, and the complexity of missions.

As the UAS program grows, impacts on staff time and availability will be felt. Additional resources may be required to handle the increasing workload associated with UAS operations, including flight planning, data analysis, and maintenance. Staff members may need to dedicate more time to UAS-related tasks, potentially requiring adjustments in their existing roles and responsibilities.

The funding levels necessary for the UAS program also increase as the program expands. Funding includes not only the initial investment in UAS equipment and infrastructure but also ongoing costs for training, maintenance, and upgrading technology. NHDOT will need to allocate adequate funding to support the growth and sustainability of the UAS program, ensuring that financial resources align with the program's goals and objectives.

Effective UAS fleet management becomes crucial as the program expands. Fleet management involves maintaining an inventory of UAS platforms, managing their deployment for various missions, tracking maintenance schedules, and ensuring compliance with regulatory requirements. A well-structured fleet management system is necessary to optimize the utilization and performance of the UAS fleet, reduce downtime, and enhance operational efficiency.

In terms of statewide policies, NHDOT might consider developing comprehensive guidelines and regulations specifically addressing NHDOT's own use of UAS. This includes considerations such as airspace regulations, operational procedures, data privacy and security, safety protocols, and maintenance standards. Clear policies provide a framework for safe and responsible UAS operations within a State DOT and ensure compliance with applicable laws and regulations.

Community outreach efforts are also essential as a UAS program grows. NHDOT should engage with local communities, stakeholders, and relevant organizations to address concerns, educate the public about UAS operations, and foster transparency. Community outreach initiatives can include public meetings, informational sessions, and collaborations with community groups to build trust, gather feedback, and ensure that UAS operations align with community needs and expectations.

26.2.1 Program Manager

The UAS Program Manager for NHDOT plays a crucial role in overseeing and managing the UAS program. This position is responsible for a range of responsibilities related to the operation, safety, and compliance of UAS equipment.

One of the key responsibilities of the UAS Program Manager is to develop and provide rules and regulations regarding the operation of NHDOT UAS equipment. The UAS Program Manager is responsible for leading the establishment of guidelines and protocols that ensure safe and responsible UAS operations. This includes defining operational procedures, airspace restrictions, flight restrictions, and any specific requirements for UAS missions conducted by NHDOT.

Additionally, the UAS Program Manager is responsible for providing training guidelines to maintain flight proficiency among NHDOT UAS operators. These responsibilities could also fall under the purview of a separate position, such as a UAS Program Training Manager who works under the direction of the Program Manager and can develop training programs and standards that ensure operators have the necessary skills and knowledge to operate UAS equipment effectively and safely. This involves conducting training sessions, organizing workshops, and staying updated on the latest best practices in UAS operations and technology. A separate Training Manager may be needed depending on the growth and maturity of the UAS program—the bandwidth of the UAS Program Manager quickly thins as the program grows.

To fulfill their responsibilities effectively, the UAS Program Manager needs to stay informed about the relevant FAA Federal Aviation Regulations (FARs), including regulations such as 14 CFR Part 107, which governs the commercial operation of small UAS, and any other applicable regulations that pertain to NHDOT's UAS operations. The Program Manager must keep up with any updates, amendments, or changes to these regulations and ensure that NHDOT's UAS operations remain in compliance.

In addition to FAA regulations, the UAS Program Manager should also stay informed about other federal, state, and local regulations that may impact UAS operations within New Hampshire. This could include any specific rules or restrictions related to the use of UAS in certain areas or under certain circumstances. The Program Manager should actively monitor and interpret these regulations to ensure that NHDOT's UAS operations adhere to all applicable laws and requirements.

26.3 Fleet and Sensor Considerations (Element b)

For NHDOT various use cases involving UAS operations, several aircraft makes and models, as well as specific sensors, can be considered. Outlined below are some options that can meet the needs of the use cases described in the Task 1b Report; other subsidiary use cases are also included. Please note that UAS technology, including platforms and sensors, is consistently evolving, and the considerations below are only a sampling of what is available. State DOTs can work with UAS manufacturers to secure a trial period to ensure the technology will meet the department's needs. These trial periods are highly recommended.

1. **Aerial Survey, Aerial Imagery, and Topographic Mapping**

   Aircraft: DJI M300, Skyfish M4, Freefly Astro Map, Freefly Alta X, WingtraOne

   Sensors:

   DJI M300

   - L1 LiDAR sensor (LiDAR workflow)
     - Detection Range: 450 m at 80 percent reflectivity, 190 m at 10 percent reflectivity.
     - Point Rate: Single return: 240,000 points per second; multiple return: 480,000 points per second.
     - Accuracy Horizontal 10 cm, vertical 5 cm at 50 m.
   - P1 Sensor (Photogrammetry/Structure for Motion Workflow)
     - 45 megapixel full-frame sensor with three lens options (24/35/50 mm) for optimal mapping solutions.
     - Adjustable gimbal to capture data at multiple angles to accommodate detailed collection of 3D features.

   Skyfish M4

   - Sensor agnostic with real-time kinematic (RTK) capability, which can use multiple sensors including LiDAR, high-resolution red, green, blue (RGB) camera. The Skyfish M4 can accommodate a sensor up to 6 lbs to accommodate a maximum gross weight of 24 lbs, which will allow for an array of light weight LiDAR, RGB, thermal, or multispectral sensors.

   Freefly Astro Map

   - RTK Global Positioning System ground station to support RTK and post-processing kinematic (PPK) collection to improve accuracy and reduce ground control points.
   - Sony Alpha 7R IVA.

   Freefly Alta X

- The Alta X can carry up to 17 lbs to accommodate multiple sensors with a typical flight time of 41 minutes, which varies depended on weight carried.
- Truview 655 with Riegl Mini-Vux (LiDAR Workflow).
- Sony IMX-183 (Photogrammetry/Structure for Motion Workflow).

Wingtra One GenII

- Sensor agnostic: The Wingtra One GenII is designed to be compatible with various sensors, including the Sony RX1 RGB camera, which is ideal for aerial imagery and mapping collection.
- Sony RX1 RGB Camera.
    - *Camera Resolution:* The Sony RX1R II RGB camera has a full-frame sensor with a resolution of 42 megapixels.
    - *RTK Capability:* The Wingtra One GenII sensor has RTK capability that provides precise positioning and accurate data collection.
    - *Weight Capacity:* The Wingtra One GenII can accommodate a sensor weighing up to 6 lbs, allowing for the integration of the Sony RX1 RGB camera.
    - *Maximum Gross Weight:* The Wingtra One GenII has a maximum gross weight limit of 24 lbs, ensuring it can handle the weight of the Sony RX1 RGB camera along with other lightweight sensors if desired.
    - *Versatile Sensor Support:* In addition to the Sony RX1 RGB camera, the Wingtra One GenII can also support other sensor options, such as LiDAR, thermal, or multispectral sensors.
    - *High-Resolution Imaging:* With the Sony RX1 RGB camera, the Wingtra One GenII can capture high-resolution imagery for detailed aerial mapping and inspection applications.
    - *Integration:* The Wingtra One GenII seamlessly integrates with the Sony RX1 RGB camera, enabling efficient data acquisition and post-processing for various industries and applications.
- PPK or RTK Onboard

These models are specifically designed for mapping and surveying applications. They offer high-precision RGB and/or LiDAR sensors and advanced flight planning software, ensuring accurate data collection for detailed land surveys and topographic mapping.

When selecting specific aircraft models and sensors, it is important to consider factors such as flight time, payload capacity, data accuracy and resolution, as well as compatibility with the required software and data processing workflows. The suggested choices are based on factors such as flight capabilities, payload capacity, sensor compatibility, data quality, reliability, and industry reputation. However, it is important for NHDOT to conduct thorough evaluations, consider the agency’s specific requirements, and consult with industry professionals to make the best-informed decision for its UAS fleet. A recommendation would be to request a demonstration of the UAS platform and sensor; many UAS providers allow State DOTs a trial period to use the technology prior to purchase. NHDOT can use these demonstrations or trial periods to conduct thorough evaluations of the equipment and make informed decisions as it adds UAS to its growing fleet.

2. **Structural Inspections:**

Aircraft: Skydio 2+, Matrice 300 RTK

Sensors:

- Skydio 2+ Sensor Specifications
    - *Camera:* The Skydio 2+ is equipped with a 12.3-megapixel Sony IMX577 1/2.3-inch Complementary Metal-Oxide Semiconductor (CMOS) sensor. It captures still photos with a resolution of 4056 x 3040 pixels.
    - *Video Resolution:* The UAS can record video at a maximum resolution of 4K (3840 x 2160 pixels) at 60 frames per second. It also supports various other video recording modes and frame rates.
    - *Image Stabilization:* The Skydio 2+ features a three-axis gimbal stabilization system, providing steady and smooth footage even during fast-paced flights.
    - *Field of View (FOV):* The camera has a fixed FOV of 78.8 degrees, providing a wide perspective for capturing expansive scenes.
- Matrice 300 H20T
    - The H20T sensor integrates multiple sensors into a single unit, providing a wide range of capabilities. The specifications include a high-resolution RGB camera with zoom capabilities, high-resolution thermal sensor, and built-in image stabilization to capture clear images of signs from various distances and angles.
    - *RGB Camera:* The H20T features a 20-megapixel RGB camera with a 23 mm focal length. It captures high-resolution still photos with excellent detail and color accuracy.
    - *Thermal Camera:* It is equipped with a 640 x 512-pixel thermal camera, allowing for thermal imaging and temperature measurements. The thermal camera provides valuable insights for detecting heat signatures and identifying potential issues.
    - *Laser Range Finder:* The H20T incorporates a laser range finder that measures distances with high accuracy. This feature is particularly useful for gauging the size and dimensions of objects or structures during inspections.
    - *Three-axis Stabilized Gimbal:* The camera system is mounted on a three-axis gimbal, providing stable and smooth footage even during turbulent flights. This ensures sharp and clear imagery for inspections.
    - *Zoom Capabilities:* The H20T offers a 23x hybrid optical zoom, allowing users to zoom in and capture detailed visuals from a distance. This feature is advantageous for inspections that require close examination without the need to fly the drone too close.
    - *Real-time Data Transmission:* The H20T supports real-time data transmission, enabling live streaming of video and thermal imagery to the ground station

during flights. This facilitates real-time monitoring and analysis of inspection data.

- *Compatibility:* The DJI H20T is designed specifically for the DJI Matrice 300 RTK. It seamlessly integrates with the aircraft's flight control system, enabling precise control and seamless data integration.

Both the Skydio 2+ and the Matrice 300 are platforms that excel in performing bridge inspections. The Skydio 2+ is a highly maneuverable and intelligent system equipped with an array of cameras and sensors, including a 4K60 High Dynamic Range camera and a 3D imaging system. Its autonomous flight capabilities and obstacle avoidance technology allow it to navigate complex bridge structures with ease, capturing high-resolution images and videos for detailed inspections. The sensor size is limited; however, because it can fly in close proximity, it can still capture accurate data. The Matrice 300 features a versatile payload capacity and a robust flight endurance. With its advanced imaging capabilities of H20T sensors that include thermal and zoom cameras, the Matrice 300 can capture precise and detailed visual data, making it ideal for detecting structural issues and performing thermal inspections. Both UAS offer powerful tools for bridge inspections, providing engineers and inspectors with valuable data to assess the condition and integrity of bridges safely and efficiently. Both models are versatile and reliable, offering advanced flight capabilities, long flight times, and a stable platform for aerial inspections. The Matrice 300 is not capable of operating into smaller spaces and relies on assessing the bridge from a distance and using its high-resolution zoom and RGB sensors to capture accurate data from a distance. Flying from a distance may work in many situations but at times may prove difficult to see every angle of the structure.

3. **<u>Overhead Sign Structure Inspections:</u>**

Aircraft: DJI Matrice 300, Autel Evo II

Sensors:

- DJI H20T - The H20T sensor integrates multiple sensors into a single unit, providing a wide range of capabilities. The specifications include a high-resolution RGB camera with zoom capabilities, high-resolution thermal sensor, and built-in image stabilization to capture clear images of signs from various distances and angles.
  - *RGB Camera:* The H20T features a 20-megapixel RGB camera with a 23mm focal length. It captures high-resolution still photos with excellent detail and color accuracy.
  - *Thermal Camera:* It is equipped with a 640x512-pixel thermal camera, allowing for thermal imaging and temperature measurements. The thermal camera provides valuable insights for detecting heat signatures and identifying potential issues.
  - *Laser Range Finder:* The H20T incorporates a laser range finder that measures distances with high accuracy. This feature is particularly useful for gauging the size and dimensions of objects or structures during inspections.
  - *Three-axis Stabilized Gimbal:* The camera system is mounted on a three-axis gimbal, providing stable and smooth footage even during turbulent flights. This ensures sharp and clear imagery for inspections.
  - *Zoom Capabilities:* The H20T offers a 23x hybrid optical zoom, allowing users to zoom in and capture detailed visuals from a distance. This feature is

advantageous for inspections that require close examination without the need to fly the drone too close.

  - *Real-time Data Transmission:* The H20T supports real-time data transmission, enabling live streaming of video and thermal imagery to the ground station during flights. This facilitates real-time monitoring and analysis of inspection data.
  - *Compatibility:* The DJI H20T is designed specifically for the DJI Matrice 300 RTK drone. It seamlessly integrates with the aircraft's flight control system, enabling precise control and seamless data integration.

- Autel Evo II Pro Zoom Sensor
  - *Camera:* The Evo II Pro with Zoom features a 1-inch CMOS sensor with a resolution of 20 megapixels. It captures highly detailed still photos and supports video recording up to 6K resolution at 30 frames per second.
  - *Zoom Capability:* This variant of the Evo II Pro is equipped with an optical zoom lens. It offers a 1-2x optical zoom and up to 8x digital zoom, allowing for closer inspection of objects and structures from a distance.
  - *Flight Time:* The Evo II Pro with Zoom offers a maximum flight time of up to 40 minutes. This extended flight time enables longer inspection missions without the need for frequent battery changes.
  - *Transmission Range:* It has an impressive operating range of up to 9 kilometers (5.6 miles), allowing for extended exploration and inspections in various environments.
  - *Real-time Data Transmission:* The Autel Evo II, like the Matrice 300, supports real-time data transmission, enabling live streaming of video imagery to the ground station during flights. This facilitates real-time monitoring and analysis of inspection data.
  - *Obstacle Avoidance:* The drone is equipped with a 12-sensor obstacle avoidance system, including forward, backward, sideward, and downward-facing sensors. This feature helps ensure safe and obstacle-free flights during inspections.
  - *Flight Stability:* The Evo II Pro with Zoom utilizes a dual-core flight control system and advanced algorithms for enhanced stability and precise control, even in challenging weather conditions.

Both models are equipped with high-quality cameras that provide clear and detailed imagery, allowing for close inspection of signs from varying distances. They offer stability and maneuverability, enabling precise and controlled flights. Due to safety considerations, it can be beneficial to have a zoom camera to capture minute details from a distance. These systems allow the UAS to hover over the side of the roadway without flying over traffic and/or causing distractions to motorists. Additional considerations are the gimbal stability while zoomed in because minute movements are compounded in the imagery, which can create unstable video or motion blur in images if the shuttle speed is not sufficient.

4. **Culvert Inspections:**

Aircraft: Skydio 2+, Flyability Elios 3

Sensors:

- Skydio 2+ Sensor Specifications
  - *Camera:* The Skydio 2+ is equipped with a 12.3-megapixel Sony IMX577 1/2.3-inch CMOS sensor. It captures still photos with a resolution of 4056 x 3040 pixels.
  - *Video Resolution:* The UAS can record video at a maximum resolution of 4K (3840 x 2160 pixels) at 60 frames per second. It also supports various other video recording modes and frame rates.
  - *Image Stabilization:* The Skydio 2+ features a three-axis gimbal stabilization system, providing steady and smooth footage even during fast-paced flights.
  - *Field of View:* The camera has a fixed FOV of 78.8 degrees, providing a wide perspective for capturing expansive scenes.
- Flyability Elios 3 Sensor Specifications
  - *Camera:* The Elios 3 is equipped with a 12.3-megapixel camera with a 1/2.3-inch CMOS sensor optimized for low-light performance.
  - *Video Resolution:* The UAS can record video at 4k Ultra HD: 3840 x 2160 at 30 feet per second: 1920 x 1080 at 30 feet per second.
  - *Real-time Data Transmission:* The live-streaming resolution capability is 1920 x 1080 at 30 feet per second.

These models combine the benefits of obstacle avoidance and ability to fly in confined spaces. They offer good communication systems, adequate flight times, and the ability to carry high-resolution cameras and thermal sensors for comprehensive assessments. A limitation of the Skydio 2+ is the need for illumination for the obstacle avoidance function to perform correctly. Without illumination, the obstacle avoidance system can malfunction and may fail, resulting in a crash. The Elios 3 has SLAM LiDAR to actively avoid obstacles and is not dependent on lighting conditions. Additionally, the Elios 3 is equipped in a rugged cage to allow flight into objects without crashing. The platform is also rated as IP-44, which allows flight into harsh conditions with less concern for water splashes and dust. The largest limitation for the Elios 3 is the limited flight time of 8 to 12.5 minutes or less depending on payload.

5. <u>Construction Inspections and Quantities:</u>

Aircraft: Matrice 300 with H20T, or L1 LiDAR, Freefly Astro Map, Wingtra One GenII

Sensors:

Matrice 300

- H20T
  - *RGB Camera:* The 20-megapixel camera captures high-resolution images for detailed visual inspection and documentation purposes.
  - *Thermal Camera:* The thermal camera, using radiometric technology, detects temperature differences and provides thermal imagery. This enables the identification of potential issues such as heat leaks, insulation problems, or water infiltration.

    - *Laser Rangefinder:* The integrated laser rangefinder measures distances accurately to facilitate precise measurements for construction quantities, land surveying, and other applications.
    - *Zoom Camera:* The H20T payload includes a 23x hybrid optical zoom camera that allows inspectors to capture detailed images from a distance, providing a closer look at specific areas of interest.
    - *Spotlight:* The spotlight function enhances visibility in low-light conditions by focusing a high-intensity light beam on the targeted area to aid inspections during nighttime or in poorly lit environments.
- L1 LiDAR
    - *Detailed 3D Mapping:* The DJI L1 LiDAR can create highly accurate and detailed 3D maps of construction sites. These maps help inspectors identify potential issues, monitor progress, and analyze the as-built conditions against digital models. By capturing precise measurements and identifying deformations or deviations, inspectors can assess the safety and quality of construction projects.
    - *Accurate Point Cloud Generation:* The LiDAR sensor in the DJI L1 captures millions of points per second, creating a highly dense and accurate point cloud representation of the surveyed area. This point cloud can be used to measure distances, volumes, and surface areas, assisting in quantity estimations and earthwork calculations.
    - *Height and Elevation Measurements:* The L1 LiDAR can provide precise measurements of heights and elevations, helping construction professionals determine clearance requirements, assess slopes, and ensure proper grading.

Freefly Astro Map

- Sony Alpha 7R IVA
    - *Sony Alpha 7R IVA Camera:* The Sony Alpha 7R IVA is a full-frame mirrorless camera known for its high-resolution capabilities. With its 61-megapixel resolution, it captures incredibly detailed still images, ensuring precise inspection and documentation of construction sites.
    - *Oblique and Overhead Imagery:* The versatile camera allows for oblique and overhead imaging, providing comprehensive coverage of construction sites from different angles. This enables inspectors to view and analyze structures and areas that may be inaccessible on foot.
    - *Photogrammetry Capabilities:* The high-resolution imagery captured by the Sony Alpha 7R IVA can be processed using photogrammetry software. By leveraging the camera's images, the Astro Map system can generate accurate 3D models, point clouds, and orthomosaic maps. These outputs can be used for measuring distances, volumes, and areas, facilitating quantity estimations and earthwork calculations.

Wingtra One GenII (suited for larger construction sites)

- The Wingtra One GenII, equipped with a Sony RX1 camera, is an advanced hybrid eVTOL fixed-wing UAS solution designed for larger sites and can be used for construction inspections, quantities, and measurements. The platform requires a larger vehicle to carry the UAS due to its larger case.
- *Sony RX1 Camera:* The Sony RX1 is a professional-grade camera known for its high-resolution imaging capabilities. It captures detailed images with its 42.4-megapixel full-frame sensor, ensuring precise inspection and documentation of construction sites.
- *Global Navigation Satellite System (GNSS):* The Wingtra One GenII integrates GNSS receivers for accurate positioning and geolocation. This allows for precise alignment of the captured imagery and enables seamless integration with existing mapping and surveying workflows.

For roadway construction inspections and quantities, the Matrice 300 with H20T payload offers a comprehensive solution. It combines a versatile and rugged UAS platform with a high-resolution camera, thermal imaging, zoom capabilities, and a laser rangefinder. This combination allows for visual inspections, thermal analysis, precise measurements, and volumetric calculations. Alternatively, the L1 LiDAR system provides accurate 3D mapping, point cloud generation, and distance/volume measurements, making it ideal for detailed analysis of roadway structures. The Freefly Astro Map with Sony RX1 excels in capturing high-resolution imagery and generating detailed maps through photogrammetry. Finally, the Wingtra One GenII offers a large coverage area, high-resolution imaging, and photogrammetry capabilities, making it suitable for extensive roadway inspections and accurate measurements. The choice depends on factors such as budget, specific requirements, and integration with existing workflows. These models are designed for efficient and accurate aerial surveys that can be used for construction inspections and quantities. They can also serve to monitor and document progress throughout the project. Furthermore, UAS may also be used as a supplemental tool for material quantity monitoring and inventory management. A smaller platform (e.g., an Autel Evo II) may also be used if there are space limitations.

6. **Traffic Operations and Incident Management:**

Aircraft: DJI Matrice 300, Mavic Pro 3, Autel Evo II Pro

Sensors:

- DJI Matrice 300 – H20T (details noted in previous section).
- DJI Mavic Pro 3.
    - *RGB Camera:* The Mavic 3 Pro features two cameras, a 20-megapixel RGB camera with a 24 mm equivalent focal length. It captures high-resolution still photos with excellent detail and color accuracy. It also includes a secondary camera that provides a 7x optical and up to a 28x hybrid zoom.
    - *Zoom Capability:* The UAS includes a secondary camera that provides a 7x optical and up to a 28x hybrid zoom.
    - *Transmission Range:* The Mavic uses the 03+ OccSync, which can provide 1080p HD video at a distance of up to 9.32 miles.
    - *Real-time Data Transmission:* The Mavic 3, similar to the Matrice 300, supports real-time data transmission, enabling live streaming of video imagery to the

ground station during flights to facilitate real-time monitoring and analysis of inspection data.

All three UAS models offer extended flight times and high-resolution imagery capabilities. However, the DJI Mavic 3 Pro and Autel Evo II Pro have the added advantage of being smaller and more portable. These compact UAS are easier to transport and may be less noticeable to the traveling public during monitoring operations. On the other hand, the DJI Matrice 300 is ideal for professional-grade applications and provides dual-operator control, but it is a larger platform that may require more logistic planning for transportation and may be more noticeable in public settings.

7. Asset Maintenance and Operations

The best UAS platform or sensor to be used for asset maintenance and operations largely depends on the asset needing to be analyzed. Many of the UAS discussed in previous use case sections (e.g., DJI M300, Mavic 3, and Autel Evo II) can also be used to meet the needs of asset maintenance and operations.

8. Emergency Response

Similar to the asset maintenance and operations use case, the best senor for emergency response depends on the situation. For example, UAS equipped with a thermal sensor could be helpful in flooding situations. If quick situational awareness through photos and videos is all that is needed, the Mavic 3 could be sufficient. If mapping areas are impacted by a disaster, a higher quality RGB sensor or LiDAR may be needed to accurately map and assess the damage. NHDOT may also consider UAS that have live-streaming capabilities, which offer invaluable benefits during an emergency response situation, allowing real-time situational awareness and enhanced decision-making for responders. The inclusion of Automatic Dependent Surveillance-Broadcast (ADSB) technology further amplifies these advantages by enabling seamless collaboration and coordination between multiple emergency response teams, fostering a more efficient and effective response effort. As NHDOT continues to add to its fleet of five UAS, it will be able to choose a UAS that best meets the needs of the emergency response situation.

26.4 Developing Aircraft and Operator Maintenance Schedules (Element b)

Maintaining the UAS fleet in optimal condition is essential for safe and efficient operations. An outline of an appropriate aircraft maintenance schedule, operator proficiency training intervals, and software update schedules for the recommended UAS fleet mix of NHDOT is provided below.

26.4.1 Aircraft Maintenance Schedule

- *Routine Inspections:* Perform pre-flight and post-flight inspections to ensure the aircraft's airworthiness. Closely check for any visible damage, examine each propeller, look for loose connections, and inspect for any abnormal behavior.
- *Manufacturer Guidelines:* Follow the manufacturer's recommended maintenance schedule for each specific UAS model, including periodic maintenance tasks, inspections, and component replacements as per the manufacturer's instructions.
- *FAA Regulations:* Comply with FAA regulations regarding maintenance and inspections, including any specific requirements outlined in 14 CFR Part 107 for commercial UAS operations.
- *Battery Maintenance:* Follow the manufacturer's guidelines for battery maintenance, including proper charging procedures, storage conditions, and regular battery health checks.
- *Component Calibration:* Regularly calibrate sensors, cameras, and other critical components as recommended by the manufacturer to ensure accurate data collection.

26.4.2 Operator Proficiency Training Intervals

- *Initial Training:* Provide comprehensive training to UAS operators before they begin their duties, covering topics such as flight operations, emergency procedures, airspace regulations, and maintenance protocols. This initial training can include a course to prepare individuals to pass the FAA Part 107 certification exam, or this information can be covered separately.
- *Recurrent Training:* Conduct recurrent training sessions annually or as recommended by the manufacturer to ensure operators stay updated on the latest procedures, regulations, and best practices. This includes simulator training, flight scenario practice, and knowledge assessments. Many State DOTs report that recurrent training at least every 90 days is more effective at maintaining pilot skills and ensuring safe UAS operations.
- *Proficiency Evaluations:* Conduct periodic proficiency evaluations to assess operator skills, decision-making, and adherence to safety protocols. These evaluations can help identify areas for improvement and reinforce proper operating procedures.

26.4.3 Software Update Schedule

- *Manufacturer Recommendations:* Stay informed about software updates and patches provided by the UAS manufacturer or third-party software companies that the program may be using. Follow the manufacturer's recommended schedule for installing updates to ensure optimal performance, bug fixes, and security enhancements.
- *Cybersecurity Considerations:* Stay vigilant regarding cybersecurity threats and implement necessary measures, such as updating firmware and using secure communication protocols to protect the UAS fleet from potential vulnerabilities.

26.4.4 Recommendations for Optimal Performance

- *Regular Maintenance Records:* Maintain detailed records of all maintenance activities, inspections, repairs, and component replacements. As previously mentioned, UAS-specific fleet management software and tools are available to optimize this process. These tools help track the maintenance history and ensure compliance with FAA regulations and manufacturer warranties.
- *Spare Parts Inventory:* Keep an inventory of critical spare parts and components to minimize downtime in the event of equipment failures.
- *Environmental Considerations:* Store and transport UAS equipment in suitable environmental conditions, following manufacturer guidelines for temperature, humidity, and protection against dust and moisture.
- *Operator Wellness:* Encourage operators to maintain a healthy work-life balance, manage fatigue, and report any physical or mental conditions that may affect their performance.

It is important to note that the specific maintenance schedule and training intervals may vary depending on factors such as UAS model, usage intensity, and manufacturer recommendations. Therefore, NHDOT should consult the manufacturer's guidelines, FAA regulations, and industry experts to tailor the maintenance and training programs to its specific needs and requirements.

26.5 Data Management Methods and Selection (Element c)

The recommendations below address data management and software to optimize the management of UAS LiDAR, point cloud, photogrammetry, and video data collected by NHDOT UAS operators.

26.5.1 Data Management Methods

- *Centralized Data Repository:* Establish a centralized data repository to store and organize all UAS data collected by NHDOT. This repository can be in the form of a secure cloud-based storage solution or an on-premises server infrastructure, depending on the organization's needs and security requirements.
- *Data Standardization:* Implement data standardization protocols to ensure consistency and interoperability across different data types. This includes adopting industry-standard formats such as LAS/LAZ for LiDAR data and common image and video formats such as RAW, JPG, or MP4.
- *Metadata Management:* Develop a comprehensive metadata management system to capture essential information about each data set, including flight details, sensor specifications, geolocation data, and any processing steps applied to facilitate efficient data search, retrieval, and analysis.

26.5.2 Specific Software Recommendations

- *LiDAR and Point Cloud Data:* Use software like TopoDOT, TerraScan, LP360, or CloudCompare to process and analyze LiDAR and point cloud data. These tools offer features such as filtering, classification, segmentation, and visualization of point cloud data that enable accurate terrain modeling and feature extraction.
- *Photogrammetry Data:* Consider software solutions like Pix4D, Agisoft Metashape, or Bentley ContextCapture for photogrammetry data processing. These tools generate highly detailed three-dimensional (3D) models and orthomosaics from aerial imagery that allow for precise measurements, volumetric analysis, and visual inspection.
- *Video Data:* Use video analysis software such as Pix4Dmapper or Virtual Surveyor to extract georeferenced data from video footage, including measurements, object tracking, and geospatial annotation. These tools enable efficient video analysis for asset inspection and monitoring purposes.

The recommended software tools have established reputations in the industry and are widely used for specific data applications. They provide robust features, efficient processing capabilities, and compatibility with industry-standard data formats. These software options have proven track records and are continually updated to support evolving UAS data processing requirements.

26.5.3 Additional Recommendations for Optimizing UAS Data Management

- *SOPs:* Develop SOPs that define data collection protocols, data storage practices, and quality control measures to ensure consistency, accuracy, and reliability in data management processes.
- *Data Backup and Redundancy:* Implement regular data backup procedures to protect against data loss or corruption. Consider redundant storage systems and periodic offsite backups for added security.
- *Data Security and Access Control:* Establish proper data security measures, including user authentication, role-based access control, and encryption to protect sensitive UAS data from unauthorized access or tampering.
- *Collaboration and Data Sharing:* Explore collaborative platforms and data-sharing mechanisms to facilitate seamless sharing of UAS data with internal departments, external stakeholders, and partners for effective project coordination and decision-making.

It is important for NHDOT to assess its specific data management requirements, consider budgetary constraints, and conduct trials or consultations with software providers to determine the best-fit solutions for the organization.

26.6 Associated Costs and Benefits (Element d)

Costs for UAS hardware may change over time and may change if the state can procure these items from a vendor that is already contracted with the state. Prices may also change due to market fluctuations and technological advancements. Nonetheless, Table 4 outlines rough estimations for the UAS equipment previously mentioned as well as some alternatives NHDOT may consider:

Table 4. UAS Platforms and Sensors Estimated Costs

UAS Platform	Estimated Costs	Payload Options
DJI Matrice 300 RTK	$10,000 to $14,000 (without payloads/additional accessories)	Zenmuse H20 Series, Zenmuse P1, Zenmuse L1
Autel Evo II	$2,000 to $3,000 (including basic accessories)	Autel Evo II Pro, Autel Evo II Dual
Freefly Alta 6	$12,000 to $14,000 (without payloads or additional accessories)	Depends on the specific camera or sensor used
DJI Mavic Pro 3	$2,000 to $4,000 (including basic accessories)	N/A (primarily used for aerial photography and videography)
Maptec Aquila	$30,000 to $40,000 (including basic accessories)	Customizable for various mapping and surveying applications
Skyfish M4	$42,000 to $45,000 (including mapping RGB camera/sensor)	Customizable for various mapping and surveying applications
Wingtra One	$20,000 to $25,000 (including basic accessories)	Customizable for aerial mapping and surveying tasks
Freefly Astro Map	$14,000 to $16,000 (including basic accessories)	Customizable for aerial mapping and surveying tasks
Freefly Alta X	$21,800 (including basic accessories)	Customizable for aerial mapping and surveying tasks
Skydio X2	$11,000 to $13,000 (including basic accessories)	N/A (primarily used for autonomous inspections and surveillance)
Skydio 2+	$1,000 to $1,500	Sony IMX577 sensor
Flyability Elios 3	$30,000 to $35,000 (including basic accessories)	Equipped with a high-resolution camera for confined space inspections
DJI Phantom 4 Pro RTK	$8,000 to $10,000 (including basic accessories)	N/A (primarily used for autonomous inspections and surveillance)

It is worth noting that the prices provided are approximate and may not include additional costs such as batteries, charging stations, spare parts, or software licenses. These additional expenses should be factored into the overall procurement budget.

Some estimated cost ranges for the additional items include:

- *Batteries:* Depending on the model, the cost of spare batteries can range from $100 to $300 per battery. It is advisable to have multiple batteries for each drone to ensure uninterrupted flight operations.
- *Charging Stations:* The cost of charging stations varies based on the number of charging ports and the charging speed required. Basic charging stations for smaller drones can range from $100 to $500, while more advanced multi-battery charging stations can cost between $500 and $1,500.
- *Spare Parts:* Spare parts costs vary depending on the specific UAS model and the parts needed. Generally, spare parts such as propellers, landing gears, and motors can range from $10 to $100 per part. It is helpful to have a stock of commonly needed spare parts to address any maintenance or repair issues quickly.
- *Software Licenses:* Software licenses for data processing and analysis tools range in price depending on the features and capabilities offered. Costs for software licenses can range from a few hundred dollars to several thousand dollars per year, depending on the complexity and usage requirements of the software. Some software providers also offer subscription-based pricing models.

In terms of additional equipment to complement the standard UAS hardware, NHDOT might consider investing in the following:

- *Ground Control Station:* A robust ground control station with advanced features for mission planning, real-time monitoring, and data management.
- *Enhanced Sensors:* Depending on the specific use cases, specialized sensors like thermal cameras, multispectral sensors, or LiDAR payloads to enhance data collection capabilities.
- *Data Processing and Analysis Software:* Software tools that enable efficient data processing, analysis, and visualization, such as Pix4D, Agisoft Metashape, or Bentley ContextCapture.
- *Maintenance and Repair Tools:* Essential tools and spare parts for routine maintenance and minor repairs, ensuring the longevity and reliability of the UAS fleet.
- *Training and Simulation Systems:* Training programs and simulation systems that allow operators to practice and improve their piloting skills in a controlled environment.

These additional components are not critical for flight operations but are good considerations. Also, it is important to contact suppliers or authorized dealers for up-to-date pricing information and to discuss any additional requirements or customization options.

26.6.1 Software Cost Considerations

NHDOT may already be using software alternatives associated with other divisions and other projects that could serve as alternatives to the following recommendations. It would be helpful to take the following list and compare it with the list of software NHDOT is already using and see where there is overlap to prevent duplication of effort and expenditures of funds.

The costs associated with UAS software as well as a brief cost benefit analysis for each is provided below:

- TopoDOT
  - *Pricing:* Pricing is typically customized based on the specific needs and requirements of the user. It is advisable to contact TopoDOT directly for a price quote.
  - *Benefits:* Known for its powerful tools for processing and analyzing LiDAR and point cloud data. It offers advanced features for feature extraction, data classification, and modeling, making it suitable for detailed engineering analysis and design workflows.
  - *Shortcomings:* May have a steeper learning curve because of its extensive functionalities. It is recommended for users who require in-depth analysis and have experience working with LiDAR data.
- TerraScan and LP360
  - *Pricing:* Offer software packages tailored for LiDAR data processing and analysis. The pricing for these software applications can vary depending on the specific edition and licensing options and can range from approximately $3,000 to $10,000 or more, depending on the specific package and additional modules required.
  - *Benefits:* Provide comprehensive tools for processing, analyzing, and visualizing LiDAR data. Both packages offer functionalities for point cloud classification, filtering, and feature extraction, enabling detailed terrain modeling and accurate measurements.
  - *Shortcomings:* Are more specialized for LiDAR data processing and may have a steeper learning curve. They are best suited for users who specifically work with LiDAR data and require advanced analysis capabilities.
- Cloud Compare
  - *Pricing:* Offers an open-source software available for free download and use.
  - *Benefits:* Provides a versatile tool for working with point cloud data. It offers functionalities for data registration, filtering, visualization, and basic analysis. Its open-source nature allows for customization and community support.
  - *Shortcomings:* May have a less polished user interface compared to commercial software options. It may require more manual steps for certain analyses, and advanced features may not be as extensive as in specialized LiDAR processing software.
- Pix4D, Agisoft Metashape, and Bentley ContextCapture
  - *Pricing:* Offer various pricing options based on different editions and licensing models. It is advisable to visit their respective websites or contact their sales teams for detailed pricing information.
    - Pix4D offers different pricing plans based on different editions and subscription options. The cost can range from approximately $2,000 to $9,000 or more per year, depending on the specific edition and features.
    - Agisoft Metashape's pricing ranges from approximately $179 to $3,499 or more, depending on the edition (Standard, Professional, or Enterprise) and licensing options.
  - *Benefits:* Are widely recognized in the field of photogrammetry for their ability to process aerial imagery and generate accurate 3D models, point clouds, and orthomosaics. They offer features for image alignment, dense point cloud generation, and advanced reconstruction algorithms.

    - *Shortcomings:* Costs may be relatively higher compared to some other options. Additionally, they may require a considerable amount of computational resources and longer processing times for large data sets.
- Pix4dmapper and Virtual Surveyor
    - *Pricing:* Offer pricing plans based on different editions and subscription options. Detailed pricing information can be obtained from their respective websites or by contacting their sales teams.
        - The cost of Pix4dmapper can range from approximately $350 to $3,500 or more per year, depending on the edition and subscription options.
        - Virtual Surveyor's pricing ranges from approximately $500 to $2,000 or more per year, depending on the edition (Essential or Pro) and licensing options.
    - *Benefits:* Pix4dmapper is known for its user-friendly interface and powerful capabilities for processing UAS-captured imagery and creating accurate two-dimensional maps and 3D models. Virtual Surveyor offers specialized tools for extracting survey-grade measurements and conducting detailed analysis on top of orthophotos and digital terrain models.
    - *Shortcomings:* Depending on the specific requirements, the cost of these software applications may be a consideration. While these applications provide powerful tools for UAS data processing, they may have certain limitations when it comes to advanced analysis or integration with other software platforms.

The cost benefit analysis and specific shortcomings provided above may vary based on individual requirements, preferences, and the complexity of the projects. Also, the cost estimates are approximate and can vary based on factors such as specific editions, licensing models, additional modules or features, and any discounts or promotions that may be available. NHDOT should contact the respective software providers directly or visit their websites for accurate and up-to-date pricing information.

26.6.2 Fleet Maintenance Schedules

As part of the business model, NHDOT must consider the operating and maintenance costs for replacement parts and scheduled service for each piece of hardware. Not all the hardware manufacturers provide detailed maintenance schedules, when provided it is best to rely on the manufacturer user manuals for each specific UAS. Industry best practices for maintenance schedules and parts replacement largely depend on the environment in which the UAS is being operated (e.g., if conditions are often dusty or windy). Another factor is how often the UAS is being used; daily use versus monthly use can affect the maintenance schedule. Best practices also call for pre-mission and post-mission inspections every time. The operator can carefully inspect the propellers, motors, sensor, and other components before and after each flight, which will inform the operator of needed maintenance. NHDOT should consider these factors for each UAS and determine maintenance needs accordingly.

The manufacturer warranties mentioned above typically cover parts and repairs for 12 months. However, manufacturer warranties can vary, and it is advisable to consult the specific warranty documentation provided by the manufacturer for each model to determine the exact terms and duration of the warranty coverage.

26.6.3 Operator Training Scheduling

NHDOT may provide initial 14 CFR Part 107 operator training in house, or it may be outsourced to a local institution. Either way, prior to operating a UAS for commercial or public purposes, pilots must be FAA certificated.

A recommended training schedule is provided, but the following recommendations are not mandated by any regulatory body.

Initial Training

- *Part 107 Remote Pilot Certification:* All UAS operators should complete the FAA Part 107 online training course and pass the exam to obtain a remote pilot certificate.
- *Manufacturer-Specific Training:* Provide operators with manufacturer-specific training for each model they will be operating. This training should cover UAS operation, maintenance, software usage, and safety procedures.
- *NHDOT-Specific Training:* Provide NHDOT UAS operators with NHDOT-specific SOPs, SMS plan, policies, regulations, and workflows should be discussed.

The Part 107 Remote Pilot Certification training can be done in house or outsourced to one of the following options.

- Part 107 Online Training Courses in New Hampshire:
    - Drone Launch Academy (www.dronelaunchacademy.com)
        - Cost: $199 (as of September 2021).
        - Strengths: Comprehensive online course, access to study materials, practice exams, and lifetime access to course updates.
        - Weaknesses: Limited in-person interaction and hands-on training.
- Part 107 In-person Courses in/near New Hampshire:
    - University of New Hampshire offers a certificate program in UAS that covers the fundamentals of UAS operation, including flight planning, navigation, and safety (UNH Drone Academy, 2023).
    - Plymouth State University offers a bachelor's degree in UAS that covers the fundamentals of UAS operation, as well as more advanced topics such as UAS design and development.
    - Keene State College offers a minor in UAS that covers the fundamentals of UAS operation, as well as more advanced topics such as UAS mapping and surveying.
    - Dronegenuity offers in-person Part 107 courses in Manchester, Nashua, and Portsmouth. Their courses cover all of the material that is covered on the FAA Part 107 exam, and they also offer hands-on flight training (*In-Person and Local Training*, n.d.).
    - UAV Coach offers in-person Part 107 courses in Manchester. Their courses are designed to be comprehensive and easy to understand, and they also offer a money-back guarantee if the attendee does not pass the exam (UAV Coach, 2022).
    - DartDrones in Boston (www.dartdrones.com)
        - Cost: Typically $670 but this varies depending on the course format and location.
        - Strengths: In-person instruction with hands-on flight training, customized courses for specific industries, experienced instructors.
        - Weaknesses: Higher cost compared to online courses, limited availability of in-person courses in specific locations. Not in New Hampshire.

Recurrent Training (Every 12 Months)

- *Flight Operations Review:* Refresh the basics of flight operations, including pre-flight checks, emergency procedures, and airspace regulations.
- *Advanced Flight Maneuvers:* Enhance skills in maneuvering the drone in various scenarios, such as complex airspace, obstacle avoidance, and emergency landings.
- *Equipment Maintenance and Troubleshooting:* Review maintenance procedures, firmware updates, and troubleshooting common issues.

Proficiency Evaluations (Every 6 Months)

- *Flight Demonstration:* Demonstrate operator proficiency in various flight scenarios, including takeoff and landing, navigation, obstacle avoidance, and emergency procedures.
- *Safety and Compliance Review:* Evaluate operators' knowledge of FAA regulations, airspace restrictions, and safe operating practices.
- *Data Collection and Processing:* Assess operators' ability to collect accurate data using different sensors, process these data, and produce quality outputs for further analysis.

The necessity of recurring training cannot be emphasized enough. Like any pilot skill, operating UAS in an environment and in a manner requiring precision flying is a perishable skill. Proficiency must be maintained.

The training costs mentioned above are approximate and can vary over time. NHDOT should visit the respective websites or contact the training providers directly for the most up-to-date pricing information and course availability.

26.7 Funding Options (Element d)

NHDOT and the Bureau of Aeronautics should consider various funding mechanisms to cover personnel salaries, equipment purchases, and operating budget items. Based on the unique requirements and opportunities in New Hampshire, some federal grants, and state funding mechanisms may be available.

Before discussing the possible funding mechanisms, it should be noted that if the UAS program continues to be housed within the Bureau of Aeronautics, per FAA Revenue Use Policy, New Hampshire, must not use aviation fuel tax revenues for the purchase, operation, and maintenance of the UAS program. According to the Aircraft Owners and Pilots Association, New Hampshire has a $0.04 cent excise tax on 100LL aviation fuel (AOPA, n.d.). However, the dedicated aviation fund is by donation only and the FAA mandates the use of aviation fuel taxes and takes revenue diversion quite seriously.

NHDOT could consider applying for federal grants through FHWA. Specifically, NHDOT could consider the Accelerated Innovation Deployment (AID) Demonstration Grants and continued use of SMART grants that the agency previously accessed to purchase UAS. Applications for the AID Demonstration program are being accepted under Opportunity Number FHWA-2016-21063 through Grants.gov.

Also, the DOT Unmanned Aircraft Systems Integration for Safety (UASIS) Program is a competitive grant program that provides funding to states and local governments to integrate UAS into the National Airspace System for the purpose of improving safety. The DOT has awarded a total of $10 million in UASIS grants to 10 states and local governments.

The Advanced Transportation Technologies and Innovative Mobility Development/Advanced Transportation Technology and Innovation grant program provides competitive grants to deploy, install, and operate advanced transportation technologies to improve safety, mobility, efficiency, system performance, intermodal connectivity, and infrastructure return on investment. Up to 80 percent of any project can be funded through this program. While UAS is not specifically mentioned in the eligible activities list, developing a UAS program would fall under "Advanced transportation technologies, in accordance with research areas described in the DOT's 5-year transportation research and development strategic plan…" (FHWA, n.d.).

Benefits of federal grants include access to substantial funding, potential for program expansion, and support from federal agencies. However, the competition for grants can be intense, and the application process can be complex and time-consuming.

State funding may come through the overall DOT budget request. One option is the State Infrastructure Bank, which is used for transportation-related projects. However, this may not be the best option since NHDOT administers this program and would essentially be loaning money to itself. The UAS program would also have to find a method of repaying the loan.

NHDOT could add the necessary funds to the overall larger DOT funding request through the normal budgetary process. This approach involves presenting a budget proposal to the state legislature and highlighting the program's potential benefits (e.g., improved efficiency in bridge inspections, traffic monitoring, and material quantity assessment). NHDOT might consider engaging with legislators and relevant committees to advocate for adequate funding.

To generate additional revenue for sustaining the UAS program, NHDOT could consider implementing a user fee model. This approach involves charging fees for specific UAS services provided to other state agencies, private entities, or municipalities. The fees could be based on the complexity and duration of the services rendered. Implementing a user fee model would require establishing fee structures, developing billing processes, and engaging stakeholders to ensure acceptance and compliance.

Benefits of state appropriations include custom tailored funding, potential for collaboration with local entities, and alignment with state priorities. However, securing appropriations may require significant advocacy efforts and is subject to budget constraints and competition from other programs year to year.

Considering the circumstances and opportunities in New Hampshire, the most effective funding approach for the NHDOT UAS program may be a combination of federal grants and state appropriations, supplemented by a user fee model. This mixed funding approach ensures a diversified funding base and mitigates reliance on a single source. Regular evaluation and adjustment of funding strategies would maintain the program's financial stability and long-term success.

26.8 Use Case Return on Investment (Element d)

The adoption of drones in highway construction, bridge inspection, and surveying work can offer several potential benefits and contribute to a positive return on investment (ROI) for State DOTs. The ROI for using UAS in DOT operations can vary depending on the specific tasks that are being performed. However, studies have shown that UAS can save State DOTs significant amounts of money in terms of time, labor, and equipment costs.

For example, an FHWA study found that UAS can save DOTs up to $1 million per year on bridge inspection costs. The study also found that UAS can reduce the time required for bridge inspection by up to 75 percent (Fischer et al., 2020).

Some key aspects to consider when analyzing the ROI of UAS integration include the following.

1. *Cost Savings:* UAS can significantly reduce costs compared to traditional methods. Some State DOTs are reporting 40 percent to 50 percent savings on projects costs as seen in figure 2. UAS can survey large areas quickly and accurately, eliminating the need for manual labor and reducing the time required for data collection. This efficiency can lead to cost savings in terms of labor, equipment, and operational expenses.

Figure 3. State DOTs See UAS Savings Across Use Cases.

2. *Improved Safety:* UAS can improve safety by minimizing the need for personnel to work in hazardous or hard-to-reach areas. With aerial capabilities, UAS can inspect bridges, monitor construction sites, and gather data without exposing workers to potential risks. This reduce both accident rates and their associated costs.

3. *Enhanced Data Quality and Accuracy:* UAS equipped with advanced sensors, such as LiDAR or high-resolution cameras, can capture highly accurate and detailed data. This improved data quality enables more precise measurements, better planning, and informed decision-making. Accurate data can help avoid costly errors, rework, and delays in project timelines.

4. *Increased Efficiency and Productivity:* UAS can expedite surveying and mapping processes, enabling faster project turnaround times. The ability to gather real-time data and generate high-quality imagery or 3D models can facilitate better project coordination, collaboration, and informed decision-making. Improved efficiency and productivity can reduce project timelines and associated costs.

5. *Long-Term Benefits:* The implementation of a UAS program within a State DOT can provide long-term benefits. Once the initial investment is made, ongoing operational costs tend to be relatively low compared to traditional methods. UAS can be used across multiple projects, offering continuous benefits and contributing to a positive ROI over time.

When conducting a comprehensive analysis of ROI, it is important to consider the initial investment costs for acquiring equipment, training personnel, and establishing necessary infrastructure such as data management systems and maintenance protocols. Ongoing costs such as personnel training, equipment maintenance, and software updates should also be considered.

By comparing these costs against the potential savings and benefits outlined above, NHDOT can assess the financial viability and overall ROI associated with integrating UAS into its SOPs.

Other states have conducted these assessments with positive results. Figure 3 outlines the reported ROI numbers across various states and use cases.

Minnesota Department of Transportation implemented a UAS program for bridge inspections and reported cost savings of up to 40 percent compared to traditional inspection methods. The agency highlighted reduced labor costs, improved efficiency, and the ability to access hard-to-reach areas as key factors contributing to these cost savings.

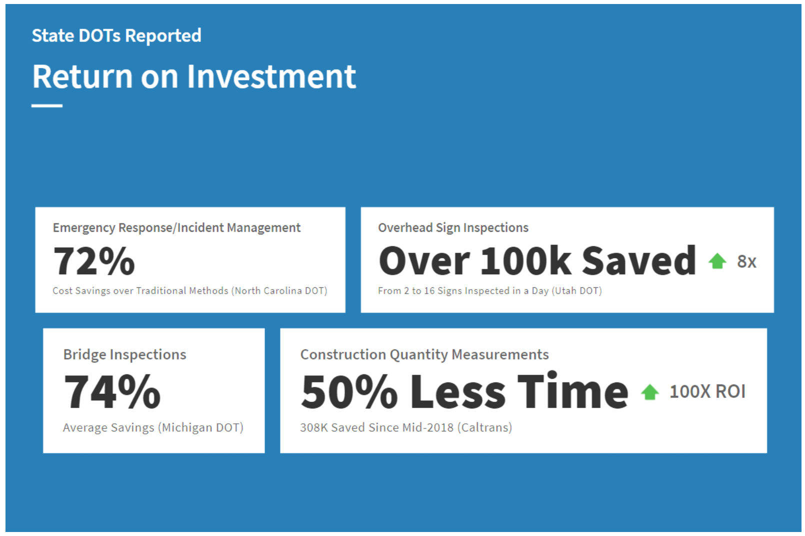

Figure 4. UAS ROI Examples.

North Carolina Department of Transportation uses UAS for various applications, including bridge inspections, storm damage assessments, and mapping. The agency estimated cost savings of more than $1 million by reducing the need for traditional inspection methods, such as specialized equipment and lane closures.

Texas Department of Transportation integrated UAS for surveying and mapping purposes. The agency reported substantial time and cost savings by reducing the time spent on data collection and processing. In one case, a UAS survey reduced a four-week project to just four days, resulting in significant cost savings.

Utah Department of Transportation employs UAS for bridge inspections, traffic management, and mapping and reported cost savings of up to 90 percent compared to traditional inspection methods. The reduced need for traffic control measures, improved worker safety, and faster data collection were cited as key factors contributing to the cost savings.

While the specific cost savings can vary depending on factors such as project scale, complexity, and regional considerations, examples like figure 4 from the Wyoming DOT highlight the potential for significant cost reductions when UAS are integrated into State DOT operations. It is worth noting that the cost savings are not limited to one particular area but can extend to various applications such as inspections, surveying, and mapping.

	Field Survey	Aerial Photography	UAV
Project Costs*	$10,000 - $12,000	$15,000 - $18,000	$6,000 - $8,000
*Costs include labor**, per diem, hotels, vehicle mileage, and camera/airplane equipment rates.			
**Labor includes travel time, setting and controlling survey monuments, and placing aerial targets.			

Figure 5. Wyoming DOT UAS Cost Savings Comparison for Surveying.

27.0 SUMMARY AND CONCLUSION

In summary, the NHDOT UAS CMM assessment reveals the agency's UAS program has achieved a maturity level of Level 3 - Slow-Go, with a final score of 71 percent. This score reflects the progress and efforts made by NHDOT in implementing UAS practices, as well as the gaps and areas for improvement that were identified in the CMM assessment and are discussed in this report.

The CMM assessment highlighted the gaps between the current maturity level and the desired highest maturity level with full UAS implementation. It also identified gaps in each critical success factor category of the assessment. These gaps serve as a foundation for developing targeted strategies and an implementation plan to bridge the identified gaps and enhance the overall maturity level of the UAS program.

Moving forward, it is crucial for NHDOT to address the identified gaps and focus on areas such as creating a UAS steering committee, securing dedicated funding for the UAS fleet and program, addressing any remaining skepticism or concerns, expanding the number of FAA-certified Remote Pilots, establishing robust collaboration with supporting divisions, finalizing and gaining approval for UAS SOPs, adopting appropriate UAS fleet and data processing software, and considering the potential use of AI and ML technologies. By addressing these identified gaps, NHDOT can further advance its UAS program, enhance operational efficiency, and effectively integrate UAS across multiple use cases throughout the agency.

This report also outlines the importance of a well-developed UAS business model that incorporates several essential elements. First and foremost, the specific mission for UAS operations must be clearly defined. This includes identifying the appropriate UAS platform and sensors, as well as outlining the necessary data management and analysis tools. Operational expenses, benefits, risks, and potential cost savings should also be thoroughly evaluated. Additionally, strong executive leadership support is crucial for the successful implementation of a UAS program because it provides the necessary direction, resources, and policies. Finally, the organizational structure of the UAS program office within NHDOT should be carefully designed to ensure focused attention, streamlined decision-making, and coordination.

The successful implementation of UAS technology by State DOTs can bring significant benefits, including improved operations, reduced costs, and enhanced safety of their workers and the traveling public. The use of UAS enables more efficient data collection, analysis, and storage, and can lead to better decision-making and improved asset management.

To ensure the smooth operation of UAS programs, several factors should be considered as part of the overall UAS business model. The optimal organizational structure for the UAS program office involves a dedicated team responsible for overseeing and managing UAS operations within the State DOT. This team should consist of multidisciplinary experts with the necessary skills and knowledge. Adequate funding is essential to support the growth and sustainability of the UAS program, covering not only initial investments but also ongoing costs for training, maintenance, and technology upgrades. Effective UAS fleet management, including maintenance schedules and operator proficiency training, is important for safe and efficient operations. Additionally, data management methods and software selection should be tailored to the specific needs of the State DOT, considering factors such as budgetary constraints and data processing workflows.

In conclusion, a well-thought-out UAS business model, supported by strong executive leadership and encompassing essential elements, is crucial for the successful implementation of UAS technology by State DOTs. By maturing its UAS program, NHDOT can improve its operations, reduce costs, and enhance safety. In the final task of this project, the research team will develop a framework for the strategic roadmap that includes the structure, sequence, timeline, and dependencies. The research team will review this framework with NHDOT for concurrence. The CMM will help inform the build out of the strategic roadmap, which will include a value-based vision and mission statement, goals and objectives, and actionable activities with milestones, metrics, and constraints/dependencies. The research team will also develop governance documents and policies for the UAS program including a program charter, UAS policy, privacy policy, safety management plan, and proposed legislation (using other states as an example). This tailored UAS implementation plan and strategic roadmap will enable NHDOT to continue to develop and mature its UAS program.

28.0 REFERENCES

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