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Project No. NCHRP 12-122

PROPOSED AASHTO GUIDELINES FOR APPLICATIONS OF UNMANNED AERIAL SYSTEMS TECHNOLOGIES FOR ELEMENT-LEVEL BRIDGE INSPECTION

IMPLEMENTATION OF RESEARCH FINDINGS AND PRODUCTS

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Abstract

This report documents and presents the results of a study to develop guidelines for applications of UAS for collecting element-level data during bridge inspections. The overarching objective of this research was to develop draft language for consideration by American Association of State Highway and Transportation Officials (AASHTO). The proposed guidelines are to be used by Departments of Transportation (DOT) and other bridge owners for implementing unmanned aircraft systems (UAS) into Code of Federal Regulations (CFR)-specified inspections to assess bridges using element-level condition states.

This research objective was divided into the following sub-tasks:

- Develop a selection process for UAS technologies
- Develop operator and team qualifications
- Develop a comparison between UAS and conventional element-level data collection methods
- Develop guidelines and a standalone roadmap for holistic UAS implementation

The outcome of this research and the resulting guidelines is a document that provides a means for the standardization of UAS in the bridge inspection industry while ensuring that the data fidelity meets acceptance criteria that align with the AASHTO Manual for Bridge Element Inspection.

Implementation of Research Findings and Products

NCHRP 12-122

November 2023

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Introduction

The overarching objective of this research was to develop draft language for consideration by American Association of State Highway and Transportation Officials (AASHTO). The proposed guidelines are to be used by Departments of Transportation (DOT) and other bridge owners for implementing unmanned aircraft systems (UAS) into Code of Federal Regulations (CFR)-specified inspections to assess bridges using element-level condition states.

The use of UAS has increased dramatically in recent years as technological advances have developed the technology as a tool for diverse applications. The capabilities of controlled flight and onboard camera systems make UAS an ideal instrument to perform bridge inspections, which typically require visual observation and documentation in locations that are challenging to safely and economically access. With the continuous evolution in airframes, sensors, and onboard computing, UAS have become more readily available to the industry and have therefore seen dramatic growth in applications for bridge inspections.

Due to various stages of implementation across the country, standards for data collection and evaluation have been localized and non-comprehensive. In addition, the specific application for the collection of element-level bridge data had not been thoroughly evaluated. Evaluation and assessment of flight and data collection capabilities that align with the requirements of the AASHTO Manual for Bridge Element Inspection provide needed guidance for the standardization of UAS in the bridge inspection industry while ensuring that the data fidelity meets acceptance criteria.

This research objective was divided into the following sub-tasks:

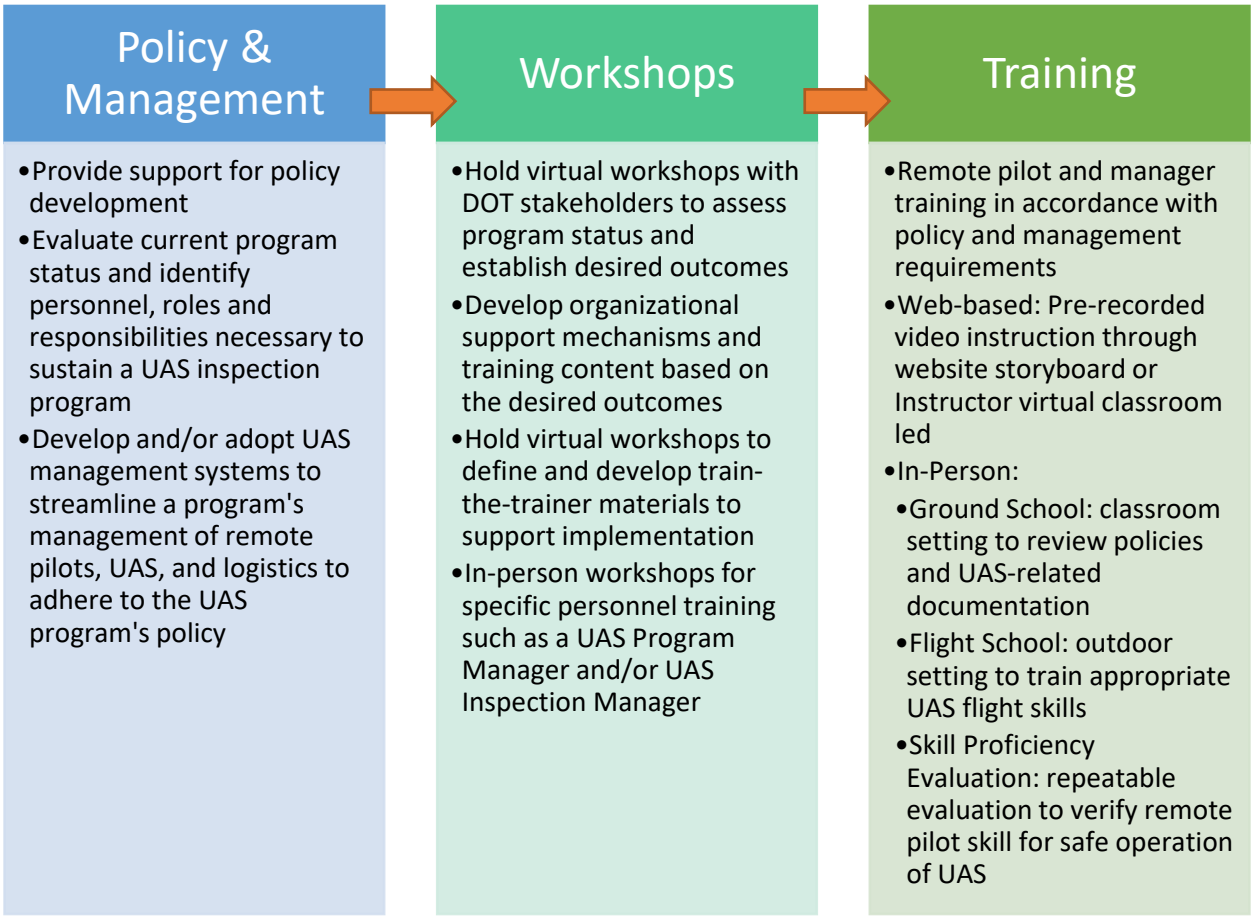
- Develop a selection process for UAS technologies
- Develop operator and team qualifications
- Develop a comparison between UAS and conventional element-level data collection methods
- Develop guidelines and a standalone roadmap for holistic UAS implementation

The resulting guidelines establish a suggested UAS organizational structure, UAS selection considerations, training recommendations for remote pilots performing inspections, example and recommended UAS inspection procedures on different elements, and options for data storage and security.

Recommendations to Put the Research Findings/Products into Practice

The research team recommends a robust and practical implementation strategy to encourage conformance in the transportation industry when utilizing UAS for inspections. Continued support from NCHRP for DOTs to implement the guidelines will be ideal for not only the agencies, but the UAS inspection industry as a whole. Structured as tiers of support for the different levels of personnel involved in a successful UAS inspection program, the approach for implementing the guidelines should be tailored to each type of personnel, including administrative, management, and field personnel.

For broad adoption of the guidelines, the research team recommends commissioning an Implementation Support Program (ISP) to initiate and pilot these instructional methods. The program will provide technical content for direct instruction from qualified persons, support for agency personnel necessary to sustain a UAS program, and a train-the-trainer model to expand the network of competent trainers. The objectives will include mechanisms to enhance the implementation process for participants through both virtual and in-person experiential learning. The following suggested framework can provide instruction within the industry and/or an individual organization.



Policy & Management

As a logical first step to UAS integration into a DOT, policy development is key to outlining roles and responsibilities, identifying the program administrator (department and/or person), and setting expectations for the quality and conduct of those performing UAS flights. This stage of implementation should also require a team of stakeholders, led by implementation specialists, to perform an evaluation of the current program structure and personnel in order to identify potential gaps. Streamlining the management of the UAS fleet, remote pilots, external flight requests, historical flight data, and safety procedures will be a key factor in program success and sustainability. Implementation of procedures, workflows, and safety documentation at the administrative and management personnel levels will be imperative. The guidelines outline recommended policy components as well as an example policy for a UAS inspection program. But, the nuances of each DOT may make the implementation of those components more challenging. The management of a UAS inspection program will likely become more complex as the program grows in size and scope. So, implementing management methods that are scalable will make the growth of the program a smoother process.

Workshops

The next step in the implementation process goes hand in hand with the policy and management implementation step, and, depending on the organizational structure of the DOT, may need to happen concurrently. The research team recommends implementation specialists lead virtual workshops with the DOT's internal stakeholders, including departments that wish to contribute to the UAS inspection program's desired outcomes. Such workshops should be led by an ISP team or other qualified implementation specialists. This is important for overall acceptance and cohesion with other departments and provides insight into DOT UAS needs. With clearly defined target outcomes, the implementation team can recommend and/or develop organizational support tools and instructional content to achieve UAS inspection program success. Organizational support tools could include software, UAS equipment recommendations, web-based management, and integration tools for multi-department UAS needs. To define and develop train-the-trainer materials to support implementation, virtual workshops should be held to identify DOT-specific training requirements correlated with the content provided in the guidelines. Instructional materials could include videos, web-based programs, materials for virtual trainers, or in-person trainers and training materials.

Additionally, an internal UAS champion is common in successful UAS programs. In order to develop that skillset in a willing DOT employee, specific personnel training for the role of UAS Program Manager and/or UAS Inspection Manager may be necessary. This can be achieved in-person or virtually. But since there are some training components such as flight proficiency and UAS equipment familiarity that may need to take place, it's recommended to have some training and engagement in-person. The guidelines provide the information necessary for management personnel such as a UAS Program Manager or UAS Inspection Manager to conduct UAS inspection operations. But learning and adoption of all of the procedures, safety protocols, and training recommendations in the guidelines may not be fully realized without implementation assistance from an ISP team or other qualified implementation specialists.

Training

The final piece for implementation of the guidelines is training the personnel responsible for managing and conducting the UAS flights. A successful program begins with knowledgeable leadership to oversee safe operations. The implementation of manager training will provide the foundation for this success. Managers should possess a background in UAS or aviation to help navigate the legal and logistical conformance required for a compliant program. However, the evolving nature of the technology requires managers, who may or may not possess this background, to direct a complex and multi-faceted program. Manager training will scaffold the participants for success by learning the administrative roles of the program, relative to the technical aspects, such as remote pilot operations. Managers are encouraged to also have field experience and potentially engage in the pilot training for enhanced awareness.

Remote pilot training that follows the DOT's policy and data management requirements established in the previous two phases of implementation will provide the DOT with capable and knowledgeable personnel to perform UAS-aided inspections. It is recommended that repeatable training methods be developed through train-the-trainer materials, pre-recorded video instruction, web-based classroom-style learning, virtual-live instructor-style sessions, as well as in-person training options.

The (in-person and/or virtual) ground school training would include reviewing DOT UAS policies and learning to complete UAS-related documentation required for remote pilot operations. The research team recommends that the UAS flight training and skill proficiency evaluations be held in-person. The UAS flight school is typically conducted in an outdoor setting to closely align with the weather conditions, exposure, and other flight limitations that remote pilots may encounter when flying. Supervised flight time

to oversee and teach appropriate UAS flight skills described in the guidelines is best performed with an on-site instructor, such as the UAS Program Manager, the UAS Inspection Manger, a qualified ISP team member, or other qualified implementation specialist approved by the UAS Manager. Once the student has completed the training (consisting of *both* ground school *and* flight school), a skill proficiency evaluation should be administered by the on-site instructor to verify remote pilot skill for safe operation of UAS. This evaluation should be developed as described in the first two phases of the implementation plan, can be based on the recommended flight maneuvers suggested in the guidelines, and should be repeatable for all remote pilots wishing to be initiated into the UAS inspection program.

Training for specific inspection techniques may be performed separately or in concurrence with the initial flight training. Remote pilot skills grow with experience, flight time, and mentorship. Additional proficiency evaluations may be developed by the ISP team, an implementation specialist, and/or the DOT.

Dissemination

Additional recommendations to disseminate the research findings or products include:

- Promote the published guidelines in the AASHTO Daily Transportation Update, TRB Weekly newsletter, trade journals, and the ASCE Journal of Bridge Engineering
- Participate in TRB-hosted webinars or workshops with DOTs, the Federal Highway Administration (FHWA), and industry stakeholders
- Provide materials for presentations at the annual TRB meeting
- Participate in conferences sponsored by AASHTO, the International Bridge Conference, the National Bridge Preservation Partnership, the International Association for Bridge and Structural Engineering, and the Association for Uncrewed Vehicle Systems International.

Institutions that May Lead in Applying the Research Findings/Products

The following institutions have direct interest in these findings and therefore may lead the implementation of the guidelines:

- AASHTO
- DOTs and DOT UAS program officers
- FHWA

The research team recommends a leadership council consisting of agency, consultant, and academic partners to utilize the suggested implementation framework, participate in the implementation phases, and advise an ISP team on best strategies for implementation. Diverse industry experience will shed light on best practices and create opportunities for more successful implementation processes.

Issues Affecting Potential Implementation of the Findings/Products and Proposed Actions

Two major issues facing DOTs identified during the NCHRP 12-122 research are the available workforce and the incoming workforce pipeline. While the workforce has been discussed as a barrier more frequently in recent years, the research team believes the magnitude of these barriers can be reduced through a comprehensive and practical implementation strategy as defined above. Additional program management support can be provided through web-based systems and/or software to approve flight requests, manage pilots, manage the fleet of UAS, and track UAS usage program-wide.

Several strategies for establishing proficiency of UAS flight skills have been and are being proposed as UAS technology continues to be implemented in bridge inspections. The research team recommends that any flight proficiency training or testing be a practical, cost-effective, and in-situ evaluation of a remote pilot's ability to successfully operate the UAS to collect data. The UAS should be treated as another means of access, similar to an aerial lift or rope access. The research team suggests that the flight proficiency process should not test the inspector's or remote pilot's ability to inspect a bridge since this training and certification already exists through the National Highway Institute. A basic flight proficiency testing procedure for operating UAS in the transportation industry is currently being researched and developed through NCHRP. Any UAS bridge inspection proficiency rating should be an extension of the basic flight proficiency test if this process/procedure is adopted. In order to deconflict a potential UAS flight proficiency evaluation procedure, the research team recommends the implemented training program suggested in the previous section should serve as a demonstration of competencies for which an organization can then authorize a remote pilot to operate UAS for access similar to the training and competencies evaluation for safe access from a lift or rope access.

As the FAA continues to adapt the regulations to the ever-changing landscape of UAS applications, another potential hurdle for implementation could be significant changes to the current regulations pertaining to UAS operations. In addition, laws around privacy, beyond visual line of sight (BVLOS) rulemaking, future UAS Traffic Management (UTM) routes associated with UAS carrying cargo or people, utilization of categories of UAS for flight over people, state legislation banning foreign-made UAS, and Remote ID (effective September 16, 2023) will require a knowledgeable implementation team to guide DOTs through these ongoing changes and anticipated policy changes in coming years.

Since the foreign-made UAS ban has become effective in some states and proposed federal legislation is being considered, the research team recommends that the implementation strategy described in the policy and management section include diversified fleet recommendations, meeting the objectives of bridge inspections for critical and non-critical infrastructure. The training phase should include awareness and practical application of a breadth of UAS, which will give remote pilots experience on a multitude of UAS form factors should a certain UAS become banned.

Methods to Identify and Measure the Impacts Associated with Implementation of the Findings/Products

Successful implementation metrics should include ease of adoption, reduction in management time, safe operation, and number of programs created within a certain period.

The following methods will provide metrics on implementation and their impacts:

- A count of the number of downloads of the published guidelines.
- A survey can be administered to agencies and owners periodically as part of an ISP (for example, annually for five years) following the publication of the guideline document. The survey could include metrics to assess the impact such as:
    - Number of inspections throughout the organization utilizing UAS in the past 1-3 years
    - Types of bridges and elements most commonly inspected via UAS
    - Preferred UAS form factors (airframes)
    - Time savings by utilizing UAS in inspections per bridge or per agency
    - Cost savings by utilizing UAS in inspections per bridge or per agency.
- Attendance at workshops and webinars can be recorded and evaluated for trends in specific areas or agencies.

- If an ISP is funded, participation in training events can be utilized to determine agency engagement and acceptance of guideline criteria.
- Assessment and/or synthesis of publications describing implementation and case studies following guideline recommendations.

Conclusion

The comprehensive guidelines developed as part of NCHRP 12-122 give DOTs a framework for the documentation, safety procedures, and UAS inspection guidance necessary to operate a successful UAS inspection program. However, to maximize the impact of these guidelines and the project outcomes, a robust implementation plan is necessary. Putting a set of guidelines into practice takes diligence and an understanding of the content, which the research team recommends accomplishing by funding an ISP to aid states in their quest for efficient implementation.