TECH**BRIEF**

Effective Practices for Using UAS During Bridge Construction

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This document is one in a series of technical summaries that accompany the forthcoming Federal Highway Administration report *Collection of Data with Unmanned Aerial Systems (UAS) for Bridge Inspection and Construction Inspection.*

INTRODUCTION

Unmanned aerial systems (UAS) and the sensors they can carry as payload are being integrated into bridge inspection processes by a number of State departments of transportation (DOTs) as well as the engineering and construction firms contracted to build new bridges and refurbish existing ones. The UAS applications supporting bridge construction are new but growing. This document discusses some of the ways UAS have been used to support construction projects; the most successful of these ways are presented as noteworthy practices. These practices have been used in high-visibility bridge projects in Maine and New Hampshire and for a smaller bridge construction effort in South Dakota.

BACKGROUND

Bridge construction encompasses a vast number and variety of tasks over the lifecycle of a project, from the beginning of the planning process through the completion of the structure and its final acceptance by the owner. Such projects are often of great interest not only to the project stakeholders but also to the general public. In recent years, bridge owners and the contractors who perform bridge construction have been exploring ways to integrate the use of UAS-based digital imaging into their processes to improve the effectiveness of certain required tasks, reduce time and costs, and enhance safety for members of the construction team.

In the early stages of UAS integration into new bridge construction and inspection processes, the most common uses have been monitoring and documenting project progress, capturing imagery and video to enhance public outreach efforts, and inspecting structural components of the bridge that present safety hazards to inspectors when traditional inspection methods are used.

These practices are best represented by looking at the construction of the Sarah Mildred Long (SML) Bridge over the Piscataqua River between Maine and New Hampshire (figure 1). This project was a joint effort between the Maine and New Hampshire DOTs. Construction

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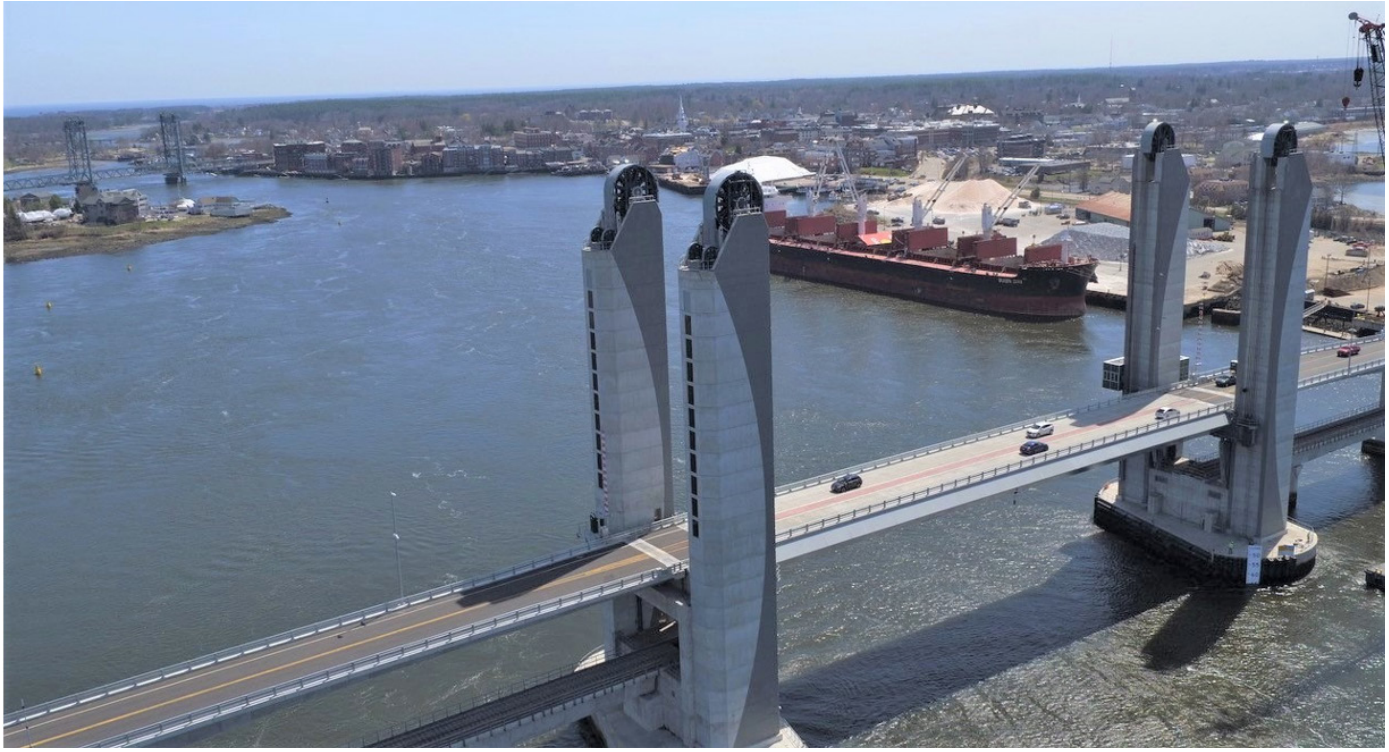
Figure 1. Photo. UAS photo of the SML Bridge.



began in 2013, and the bridge opened to both vehicle and rail traffic in 2018 (Maine DOT 2018). UAS were used for a number of purposes during the course of the project by the prime contractor and a subcontracted UAS service provider. The bridge owner and the prime contractor primarily used the UAS to inspect the four towers toward the end of the project, with UAS imagery also being used to present impressive pictorials of the finished project on public websites.

High-Risk Bridge Inspections

The SML Bridge is a 2,800-ft-long, concrete, vertical-lift bridge with a 300-ft lift span. The bridge features upper-level vehicle lanes stacked over a lower-level railroad track. Four 200-ft-tall towers house the lifting mechanisms and cables that support the lift span. The towers were constructed using precast sections stacked atop one another.

Prior to the project's completion, an integrity inspection of each tower was required. Such an inspection was traditionally performed by personnel ascending the towers through the use of barged lift cranes. According to the UAS service provider contracted to perform the flights, this process presented serious safety risks for the inspectors, and the cost of crane rental was very expensive: $30,000 for the 4 days of crane use needed to fully inspect the towers.

The use of UAS not only removed this hazard but also reduced the time and cost required to complete the inspection. The team supporting the inspection was able to operate the UAS platform from the bridge deck and record the outside of all four towers in less than a day for a cost approximately one-tenth the expense of the barged cranes.

The UAS team was able to record each face of the towers (figure 2) as well as the mechanisms at the top of each tower (figure 3). They then delivered the video and still images via digital media, organizing the imagery data according to the tower, face, and structural segment (e.g., pier 2, north face, segment 4).

While the task of the UAS was to record only the outside of the towers so the engineers could examine the visual data to identify proper tower segment alignment and any cracks in the segments, the UAS team said that the inside of the towers could have been recorded as well.

While the SML Bridge is an example of best practices for using UAS during new bridge construction, the South Dakota and North Carolina DOTs have also used UAS in similar ways (albeit for smaller projects) but primarily to keep the public informed of bridge construction and repair projects for key travel routes. This document also discusses these uses as examples of best practices.

Figure 2. Photo. UAS photo of a tower face on the SML Bridge.

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Figure 3. Photo. UAS photo of the lifting mechanisms atop the SML Bridge.

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MONITORING PROJECT PROGRESS DURING CONSTRUCTION

An effective use of UAS is to track project progress during bridge construction. This task is critical to ensuring the bridge is constructed according to its approved design and that construction phases are completed on time. In many cases, photographs of construction progress are needed to inform decisions and identify problem areas. Additionally, for high-visibility projects, UAS imagery has been used to keep the public informed on the progress of bridge construction.

Project Monitoring

Capturing imagery using UAS is an effective means to efficiently document construction progress. The ease and rapidity with which a UAS can be launched and flown over the construction site to capture desired images can result in reduced operating costs and time. Additionally, the practice mitigates safety risks by decreasing the number of personnel needed in the field for monitoring purposes, thus reducing or eliminating the need to expose them to hazardous conditions.

The prime contractor for the SML Bridge stated that using UAS during such a complex project, as well as during subsequent bridge projects, was the best means to document construction activity at the site. A key benefit of capturing site imagery on a regular basis was that it made photographic evidence available for documentation purposes should contractual claims arise. During the SML Bridge project, UAS augmented a land-based system of fixed-position cameras the contractor used to capture and record imagery of the bridge as construction progressed. During follow-on projects, the contractor flew the UAS and imaged bridge sites once per week. This practice has reduced costs for both the company and the bridge owner compared with past projects.

For consistency purposes, project-monitoring flights can be conducted using preplanned flight routes. Programming waypoints into the UAS flight-planning software allows the bridge owner to obtain repeatable, uniform imagery of the construction site.

Public Outreach

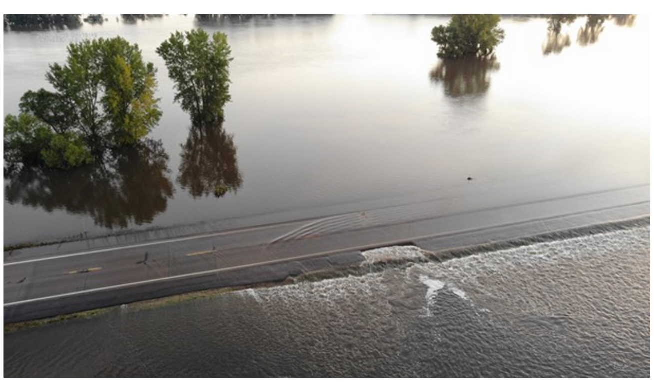
Bridge owners have also found that capturing and sharing imagery using UAS is an effective way to inform the public about the progress of bridge construction. For high-visibility projects, the ability of UAS to collect visual information for rapid distribution can serve as a proactive means of reaching out to the local public and providing answers to their questions. Additionally, for construction projects impacted by environmental events that can damage or destroy bridges and culverts, such as flooding, UAS imagery can aid in analyzing damage to heavily used bridges. The imagery, together with amplifying information disseminated via various means, such as news broadcasts, web sites, and social media, can be especially effective for local communities whose mobility and access to needed supplies may be directly impacted by such an event. UAS imagery and the additional information it provides can help raise public awareness and improve communication between the responsible agency and the citizens.

An example of this is a significant flooding event that occurred in Minnehaha County, SD, washing out a new bridge construction project (figure 4 and figure 5). This small bridge was on one of the two main routes of access to a town, thus creating detours and delays for traffic flowing to and from the town. The washout created major issues for the traveling public, which in turn created the need for the highway department to keep the public informed as to the progress of the bridge reconstruction. They did so through the collection and dissemination of images captured by a UAS flown over the site on a weekly basis, thus providing greater public awareness of the progress of the repairs. While

Figure 4. Photo. Minnehaha County bridge following construction site washout.

Figure 5. Photo. Minnehaha County bridge site showing project progression.

Figure 6. Photo. UAS photo of infrastructure damage to Minnehaha County road.



on the bridge site, the Minnehaha County UAS team was also able to capture UAS imagery on other county infrastructure (roads and structures) impacted by the flooding event (figure 6). County officials shared the imagery with the public via the county's official website and on its social media sites.[1]

Recently, North Carolina also employed UAS for the purpose of keeping the public informed after a culvert was washed out by flooding following a major hurricane that impacted most of the state. The information was gathered by the UAS weekly and used by the State secretary of transportation and chief engineer to rapidly assess damages and keep the public informed of the progress of repairs.

FUTURE USES FOR UAS DURING CONSTRUCTION

In addition to these applications, UAS offer capabilities that can augment other bridge construction processes as well.

Photogrammetric Volume Calculations

Today, stockpile quantities are often measured using traditional survey methods. This method is accurate, but it can be time consuming. UAS have the ability to reduce the time spent in the field gathering the required data, and their use for stockpile management is increasing—particularly in the mining and aggregate industries—due to their ability to collect the information rapidly.

Accurate measurements of stockpiles, large and small, can be obtained using UAS and the supporting photogrammetric software. These measurements provide a level of accuracy within 2 to 5 percent (PIX4D 2017), with some reported accuracies in the range of 1 to 3 percent (Tucci et al. 2019).

North Carolina DOT, while not currently using UAS for stockpile management or volume measurement, is in the process of developing that capability. In addition to stockpile management, the agency sees UAS as a means for inspecting tall columns and retaining walls for defects during construction, replacing traditional methods with UAS when it is practical.

Environmental Evaluation

The environmental impacts of construction in areas surrounding construction sites continue to be a major concern for the public and governments. Construction can lead to run-off of harmful chemical and waste materials that can damage the local ecosystem. Observing these areas using UAS to assess the site prior

[1] Telephone interview with Jacob Maras, Engineering Supervisor, Minnehaha County, SD, October 10, 2019.

to construction and during both the project-planning process and construction phases to monitor impacts to the surrounding environment can decrease project costs, increase overall efficiency, and reduce the potential for environmental damage.

Other uses may include creating an image database of the construction site prior to the start of the project that can be used postconstruction to ensure that the area surrounding the site is returned to its previous condition.

BENEFITS OF USING EFFECTIVE UAS PRACTICES

There are two main benefits to the bridge owner in applying the UAS practices discussed:

- **Safety:** UAS reduce the need for personnel to place themselves in hazardous situations, allowing them to observe or inspect the construction site or bridge structure while remaining in a safe location. The practice can replace or limit the need for cranes, under-bridge-inspection trucks (UBIT), rigging, or other traditional methods.
- **Cost:** The UAS service provider indicated the cost of a UBIT can be $4,000 per day; as previously noted, the cost of the cranes for the SML Bridge would have been $30,000 for 4 days. A UAS service provider contracted for imaging services ranges from $100 to $200 per hour, and the purchase of a UAS capable of providing high-resolution images starts at around $600.[2] Thus, UAS provide a cost-effective means of gathering visual data on new bridge projects.

LESSONS LEARNED

Even though using UAS for monitoring and inspecting bridge construction is relatively new, agencies that have adopted this technology have identified several lessons:

- Oblique images are the most useful for construction monitoring as they provide the inspector a more complete view of the area.
- Images collected provide a record for contract disputes, and a library of such images can be used to resolve claims.
- Weekly photos of the site aid in analysis of construction progress and can provide information to the local community.

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[2]Cost data were provided by the UAS service provider for the SML Bridge construction project.

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