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Development of an Integrated Unmanned Aerial Systems Validation Center

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Unmanned Aerial Systems (UAS) have the potential to drastically change how civil infrastructure is inspected, monitored, and managed. Deployment of UAS in areas such as bridge inspection and accident reconstruction will likely have far-reaching impacts and evolve over time, with new uses and users emerging as technology matures. However, with any new technology, limitations exist until new protocols are established, and industry must move forward with an appropriate level of caution. For example, statements regarding the ability of a UAS to replace a human bridge inspector are frequently observed in trade magazines, presentations, and in the literature, though no objective tests or standards exist in order to substantiate the claims. With no standard tests to verify such claims, agencies are left to rely upon vendors' promotional material when making decisions about UAS deployment. The Joint Transportation Research Program at Purdue University is working with the Indiana Department of Transportation and other state departments of transportation to develop an Integrated Unmanned Aerial Systems Validation Center that will create a structured validation process for civil UAS operators. This project will conduct a beta version of the validation center at Purdue University's Center for Aging Infrastructure (CAI) and the Steel Bridge Research, Inspection, Training, and Engineering Center (S-BRITE). Stakeholders including engineers, emergency response personnel, academics, and pilots will work together to determine the appropriate performance criteria needed to validate related civil UAS operations.

Literature Review

The Federal–Aid Highway Act of 1968 created the National Bridge Inspection Program to address growing concerns of aging infrastructure in the United States. Federal requirements mandated that states inspect public bridges that exceed 20 feet every 24 calendar months to collect data on the composition and condition of these structures (USDOT, 2007). A majority of these inspections are conducted by inspectors using non-destructive techniques to visually inspect the structures. To conduct these inspections, inspectors use Under Bridge Inspection Vehicles (UBIV) or commonly known as "snooper trucks" (MnDOT, 2018). UBIVs are expensive vehicles that can range in cost from $500,000-$1 million, and which require lane closures to operate. Closing lanes on roads and highways introduces a significant safety threat to inspectors and commuting traffic. While there are no statistics on the effect of UBIVs on traffic flow and accident rates, incidents and accidents from using these vehicles are not uncommon.

Unmanned Aerial Systems (UAS) have the potential to drastically change how civil infrastructure is inspected, monitored, and managed. In the context of this research project, a UAS is comprised of an Unmanned Aerial Vehicle (UAV), the imaging or scanning technology it carries, and the pilot or crew. Recent technological advancements in unmanned aviation and imagery capabilities have made these aircraft more useful than ever before. UAVs have the unique ability to fly into confined spaces that normally require bridge inspection vehicles and inspection crew. Implementing UAS for bridge inspections could reduce or remove the need for expensive UBIVs and the related operating costs.

Many state transportation departments are beginning to invest in research to determine the effectiveness of UAS for bridge inspection applications. The Minnesota Department of Transportation (MnDOT) has launched a multi-phase project to implement UAS for bridge inspections. MnDOT has used UAS to inspect 39 bridges throughout the state, with plans to expand UAS use. MnDOT has citied up to 40% in cost savings and an increase in inspection deliverables (Lovelace, 2018). Programs like these are committed to discovering the ability of UAS to replace a manual inspection of bridges and other civil structures.

Purpose of an Integrated UAS Validation Center

As UAS technology continues to grow, it is important to note that there are still limitations that exist until new protocols are established to ensure the industry moves forward with the appropriate level of caution. Many statements have been made in trade magazines, presentations, and literature that unmanned aircraft have the complete ability to replace humans in bridge inspection. Despite these claims, there are currently no objective tests or standards to substantiate them. Without any standards to verify these claims, agencies are left to rely on the promotional material when making decisions on UAS integration in bridge inspections.

Purdue University has created a Pooled Fund Study in collaboration with the Indiana Department of Transportation and six other state DOTs to develop an UAS validation center. Faculty and students from Purdue's School of Aviation and Transportation Technology and College of Engineering are creating the validation center. Each school is providing subject matter experts in aviation and civil engineering to develop performance criteria. The center is developing basic standards, protocols, and testing requirements applicable to all UAS utilized in the inspection of civil infrastructure. Currently, the use of UAS for civil engineering applications is completely unregulated. This project is in the process of creating validation criteria to set standards for UAV operators conducting bridge inspections. In order to identify performance criteria, Purdue has hosted stakeholder workshops, with participants consisting of engineers, owners, DOT representatives, and pilots. The ultimate goal of this validation center is to create an accredited course to properly train and certify UAS bridge inspectors.

Performance Criteria

As previously noted, Unmanned Aerial System includes the pilot, aircraft, and imaging capabilities. In order for a specific operator to be validated, that operator should demonstrate appropriate skills in all aspects of operating UAS for the particular bridge inspection application. Evaluation criteria for pilots include many of the same criteria for pilots of manned aircraft. Proper aeronautical knowledge of weather, airspace, air traffic control phraseology, aerodynamics, etc., should be expected of UAV operators. Additional technical subject areas such as crew resource management, aeronautical decision making, and flight planning will be applied to the UAS operation. Pilots will also be expected to demonstrate their ability to successfully conduct fundamental and task-specific flight maneuvers.

The aircraft itself must be able to handle the environmental factors related to operating in close proximity to structures (Figure 2). Electromagnetic interference from structures can disrupt GPS reception and signaling used by aircraft flight control systems. Aircraft that are heavily reliant on GPS for positioning information may be unacceptable for bridge inspection applications due to the frequent loss of GPS reception that can occur near large metal structures.

Safety must remain paramount for all UAS operations. Emergencies and abnormal flight situations will be introduced to operators to validate that appropriate contingencies have been considered and may be safely executed. In many urban environments, multipath interference can disrupt connections between aircraft controllers and the UAV. To demonstrate a UAS's ability to handle a loss of connection event, Faraday-cage devices are being developed that will simulate the effect such signal losses could have on a UAS.

Pilots and their aircraft must be able to demonstrate the ability of operating in adverse weather conditions such as high winds, extreme temperatures, and light-to-moderate precipitation. Wind moving over and under bridges creates turbulent airflow, and the ability to compensate for this air disruption must be compensated for by the UAS. All of these environmental factors are currently experienced by inspectors using traditional UBIV's; as such, UAS operators should be able to match their capabilities.

Throughout many inspection research projects, a common concern tends to be the variability of inspection results between inspectors. Previous research has highlighted this variability by comparing crack detection rates against various human factors for bridge inspectors (Campbell, 2019). The results of this research are shown in Figure 1. The goal of UAS for bridge inspections is to use sensors and algorithms to remove this variability. Operators will demonstrate their ability to use on-board sensing and imagery equipment to detect fatigue cracks, impact fractures, etc. When applicable, technology such as thermal imagery and LIDAR should be used in order properly detect and document structural defects beyond the visual spectrum. Data collection from inspections is crucial and the UAS should be able to properly identify and document structural deficiencies in the structure.

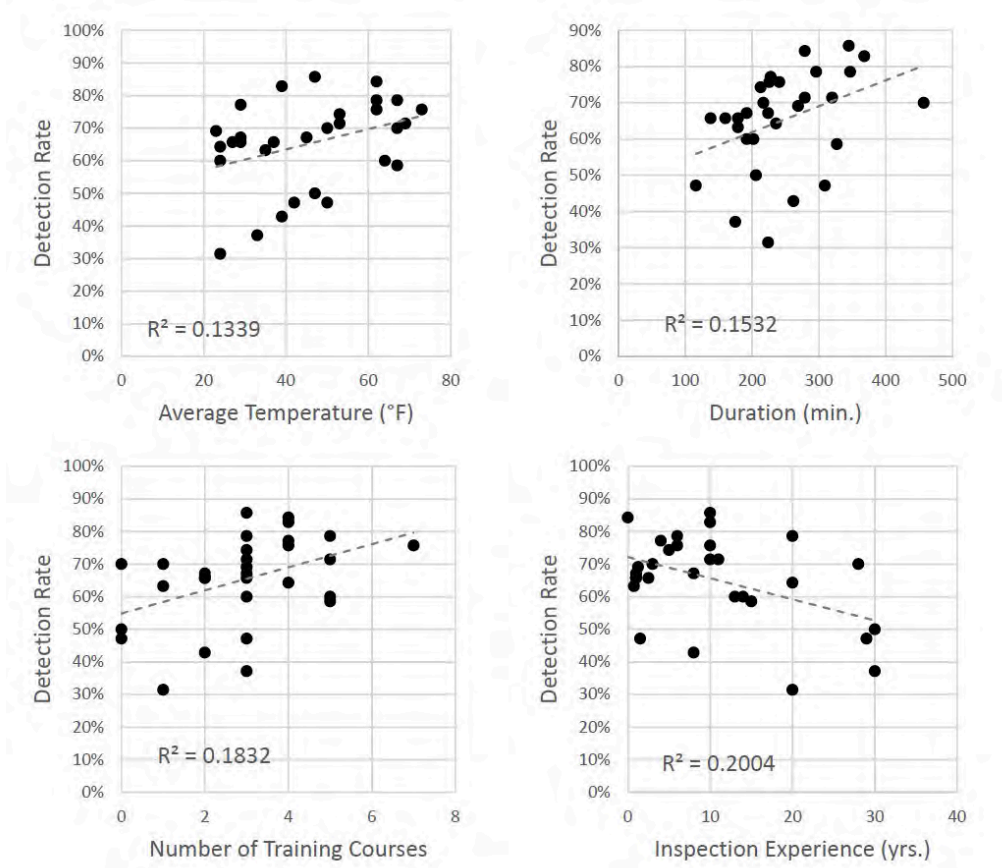

Figure 1. Human and environmental factors to detection rates (Campbell, 2019).

Figure 2. UAS bridge inspection training.

Facility for Validation Center

Purdue University's Center for Aging Infrastructure (CAI) and the Steel Bridge Research, Inspection, Training, and Engineering (S-BRITE) are being utilized in the creation of the UAS validation center. Purdue is uniquely equipped to perform the research described herein in part because of the existence of these facilities. S-BRITE is a multi-acre gallery of full-scale bridge structures, portions of complete structures, and individual components, with a host of common and uncommon details found among steel bridges (Figure 3). The S-BRITE Center provides the ability to inspect real world structures without complicating external factors such as costly traffic control requirements. Through CAI, engineers have documented all of the structural defects on each specimen. This information will be compared to the findings of UAS operators participating in the training and validation process to evaluate UAS performance.

S-BRITE is located 0.7 nautical miles from the Purdue University Airport. Purdue's airport is the second busiest airport in the State of Indiana and thus introduces many challenges to UAS operations at S-BRITE. Fortunately, Purdue has worked with the Federal Aviation Administration to obtain a Certificate of Authorization, giving the S-BRITE facility unique approval to operate unmanned aircraft for testing and validation purposes.

Figure 3. S-BRITE Facility.

Future Research

The utilization of Purdue University's facilities opens opportunities for future research in UAS applications. A major component of bridge inspections is the ability of the UAS to operate in urban environments near structures. Electromagnetic and multipath interference in these environments can restrict an unmanned aircraft's ability to operate. Further research into mitigation of multipath interference will be conducted through this center (Mott & Bullock, 2018). Turbulent airflow over bridges and other structures can produce many negative effects on aircraft stability; the extent of these effects will need to be researched, as well. To complete bridge inspections, aircraft design will have to be altered to accommodate capabilities such as inspecting directly underneath bridges and other structures. As the validation center continues to grow, so will Purdue University's commitment to further research UAS applications in civil infrastructure.

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