Utilizing Unmanned Aircraft Systems (UAS) for Bridge Inspections

Presented by:
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Barritt Lovelace, Collins Engineers

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Phase I Project Background

- MnDOT Bridge Office identified Unmanned Aircraft Systems (UAS) as a potential useful technology
- Additional Research Dollars Available
- Project was scoped, funded and completed in two months
Project Team

- Beverly Farraher, MnDOT State Bridge Engineer
- Jennifer Zink, MnDOT Office of Bridge and Structures
- Bruce Holdhusen, MnDOT Research Services
- Nancy Daubenberger, MnDOT Engineering Services Division Director
- Cassandra Isackson, MnDOT Office of Aeronautics Services Director
- Tara Kalar, MnDOT Office of Chief Counsel
- Scott Thiesen, MnDOT Office of Bridges and Structures
- Joe Fishbein, MnDOT Office of Bridges and Structures
- Rich Braunig, MnDOT Office of Aeronautics
- Chris Meyer, MnDOT Office of Aeronautics
- Barritt Lovelace, Collins Engineers
- Cory Stuber, Collins Engineers
- Garrett Owens, Collins Engineers
- Terrance Brown, Collins Engineers
- Keven Gambold, Unmanned Experts
- Dave Prall, Unmanned Experts
- Matthew Wichern, Unmanned Experts
- Dan Stong, RDO
- Adam Zylka, Sensefly

Presentation Overview

- Project Scope
- FAA Rules
- Assessment of Current Practices
- Assessment of Phase I and Phase II UAS Technologies
- Project Planning
- Phase I Results
- Phase II Study
- Phase III
- Conclusions and Recommendations
- Public Response
Demonstration Project Scope

• Evaluate UAS safety and effectiveness as it applies to bridge inspection.
• Utilize UAS technology in the inspection of four bridges at various locations throughout Minnesota.
• Investigate UAS effectiveness in improving inspections and reducing inspection costs.
• UAS technologies were investigated to evaluate their capabilities as they relate to bridge inspection.
• Research report written for the MnDOT Research Services Office.

Three types of UAS operations

1. Public operations (governmental)
2. Civil operations (non-governmental)
3. Model aircraft (hobby or recreational ONLY)
   • Parameters of model aircraft operations: http://www.faa.gov/uas/model_aircraft/
   • Minnesota’s commercial operations ≠ FAA civil

WHICH WERE WE?
Commercial UAS Use

FAA requires:
- Section 333 Exemption and
- Civil COA or Special Airworthiness Certificate (SAC)

Minnesota requires:
- Aircraft registration
  - Aircraft with an “N” number
  - Annual fee and insurance
- Commercial operators license
  - Fee and insurance

Governmental UAS Use

FAA Requires:
- Certificate of Waiver or Authorization (COA)
- Allows operations of a particular aircraft, for a particular purpose, in a particular area.

Minnesota requires:
- Aircraft registration
  (fees waived)
FAA Part 107 Rule Change – August 2016

Current FAA Rules
• Remote pilot certificate with small UAS Rating.
  – Pass an aeronautical knowledge test and a TSA background check.
• UAS must be operated within line of sight.
• Operations during daylight and twilight if UAS has lights.
• Cannot fly directly over non-participants.
• Max speed 100 mph; Max height 400 ft.
• Operations in Class B, C, D and E airspace allowed with ATC permission
• Some restrictions can be lifted with an FAA waiver

Assessment of Current Practices

Access Methods
• Aerial Work Platforms (AWP’s)
• Rope Access and Structure Climbing
• Ladders

NBIS and MnDOT Requirements
• Hands On Inspection
• Non Hands on Inspection
• Measurements/Testing
Assessment of UAS Technology

• Phase I Technology
  – Not capable of looking up
  – Unable to fly without GPS
  – Photo, Video and Thermal Imaging

• Phase II Technology
  – Inspection-specific UAS
  – Object Sensing
  – Capable of looking up
  – Fly without GPS, under bridge decks
  – Photo, Video and Thermal Imaging

Project Planning

Approvals
• Governors Office
• FAA
  – 333 Exemption
  – Certificate of Authorization
• MnDOT Aeronautics
• National Park Service
• CN Railway
• Bridge Owners Coordination
Project Planning

Bridge Selection Criteria
• Rural vs. Urban
• Variety of Bridge Sizes
• Variety of Bridge Types
• Bridge Location
• Bridge Owner Cooperation
• Limit Public Contact

Bridge Inspection Methods and Results

Bridge 13509 – Chisago County
• Small Local Bridge
• Prestressed Concrete Beam Bridge
• National Park Service Permission
• Unable to Fly Under Bridge
• Infrared Images
• Orthographic Mapping
### Bridge Inspection Methods and Results

#### Bridge Element Comparison

**Table 5: Bridge Inspection Elements**

<table>
<thead>
<tr>
<th>Bridge Name</th>
<th>Condition State</th>
<th>Previous Inspect Note</th>
<th>Obstacle(s) From UAV/Video/Photo/Bl</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>012 Top of Center Deck</td>
<td>2SF FT2 CS1</td>
<td>25% of Deck in place</td>
<td>Yes, part is clearly visible in photos, now at 50%</td>
<td></td>
</tr>
<tr>
<td>010 Piscine (Concrete Center of Base)</td>
<td>3SF FT CS1</td>
<td>None</td>
<td>Yes (but only)</td>
<td></td>
</tr>
<tr>
<td>213 Retained Concrete Abutment</td>
<td>7SF FT CS1</td>
<td>None</td>
<td>No, unable to fly under deck</td>
<td></td>
</tr>
<tr>
<td>311 Expansion Bearing</td>
<td>8 EA CS1</td>
<td>Three quarter bolts missing</td>
<td>No, unable to fly under deck</td>
<td></td>
</tr>
<tr>
<td>313 Fire Hose</td>
<td>6 EA CS1</td>
<td>Five broken bolts missing</td>
<td>No, unable to fly under deck</td>
<td></td>
</tr>
<tr>
<td>311 Retained Concrete Bridge</td>
<td>57 FT FT CS2</td>
<td>Minor deflection cracks</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>311 Assorted Steel</td>
<td>1 EA CS1</td>
<td>None</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>300 Secondary Structural Elements</td>
<td>5 EA CS1</td>
<td>Most/All removed</td>
<td>No, unable to fly under deck</td>
<td></td>
</tr>
<tr>
<td>017 Retained Concrete Wall</td>
<td>6 EA CS1</td>
<td>None</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

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#### Bridge 448 – Oronoco Bridge

- Historical Concrete Arch Bridge
- Prestressed Concrete Beam Bridge
- Unable to Fly Under Bridge
- Able to fly in Rain
Bridge Inspection Methods and Results

Table 5.2 Bridge 49553 Inspection Element Table

<table>
<thead>
<tr>
<th>Bridge Element</th>
<th>Condition State</th>
<th>Previous Inspection Note</th>
<th>Damage/Non-Damages/Photo of Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 Top of Concrete Deck – FPI</td>
<td>1/25 CS I</td>
<td>Deck was found and no delamination was found.</td>
<td>No FRA requirements only allowed flight over the level barrier.</td>
</tr>
<tr>
<td>300 Strip Seal Joint</td>
<td>9/25 CS I</td>
<td>South and West side 1 3/8”, East side 2”, North and West side 1 1/2” East side 1 1/2” West side 1 3/8”</td>
<td>No FRA requirements only allowed flight over the level barrier.</td>
</tr>
<tr>
<td>501 Rollin</td>
<td>5/20 CS 1</td>
<td>Minor crack at 1/2” crack at the top of the bridge</td>
<td>Yes</td>
</tr>
<tr>
<td>100 P.S Concrete</td>
<td>4/20 CS 1</td>
<td>1 1/2” crack at the top of the bridge</td>
<td>Yes</td>
</tr>
<tr>
<td>144 Concrete Arch</td>
<td>3/20 CS 1</td>
<td>Spall at the top of the bridge</td>
<td>Yes</td>
</tr>
<tr>
<td>155 Concrete Foundation</td>
<td>4/20 CS 1</td>
<td>1/2” crack at the top of the bridge</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Bridge Element Comparison

Bridge 49553 – Morrison County Pedestrian Bridge
- Large Steel Truss
- Difficult to access with UBIV
- Great detail in images
- Pack rust visible
- Concrete deterioration visible
Bridge Inspection Methods and Results

Bridge Element Comparison

<table>
<thead>
<tr>
<th>Bridge Element</th>
<th>Condition State</th>
<th>Previous Inspection Date</th>
<th>Deficient Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 Timber Deck</td>
<td>B4/F1/E2</td>
<td>CE 1</td>
<td>6/15/15</td>
</tr>
<tr>
<td>407 Expansion Joint</td>
<td>1 EA CS 1</td>
<td>4/19/15</td>
<td>Repaired</td>
</tr>
<tr>
<td>524 Metal Rail</td>
<td>129 FT CS 1</td>
<td>Placed 1200 ft of guard rail, 10/15/15</td>
<td>Yes</td>
</tr>
<tr>
<td>117 Timber Stairs</td>
<td>108 FT CS 1</td>
<td>Constructed 6 x 6 in. x 10 ft timber</td>
<td>Yes, partially</td>
</tr>
<tr>
<td>33 Piers St 553 Deck</td>
<td>108 FT CS 1</td>
<td>10/14/15</td>
<td>Deck &amp; rail supports</td>
</tr>
<tr>
<td>34 Expansion Bearing</td>
<td>1 EA CS 1</td>
<td>10/14/15</td>
<td>Bearing has movement in it, 10/15/15</td>
</tr>
</tbody>
</table>

Bridge 49553 – Morrison County Orthographic Mapping
Bridge Inspection Methods and Results

Bridge 49553 – Morrison County Orthographic Mapping

Arcola Railroad Bridge
- Large Complex Bridge
- Normally inspected using rope access
- National Park Service Permission
- Difficult to access
Bridge Inspection Methods and Results

Arcola Railroad Bridge – Image Detail

Bridge Inspection Methods and Results

Arcola Railroad Bridge – Image Detail
Bridge Inspection Methods and Results

Arcola Railroad Bridge – Image Detail

Bridge Inspection Methods and Results

Arcola Railroad Bridge – Image Detail
Bridge Inspection Methods and Results

Arcola Railroad Bridge

Phase II Study

- Cost comparison with UBIVs, traffic control
- Explore inspection specific technology including the Sensfly eXom
- Compile a best practices document
- Incorporate into an actual inspection
- Use UAS in the planning of an inspection
- Use a secondary display for bridge inspector
- Deck surveys with zoom camera
- Culvert and Box Girder Inspection
- IR Deck Delamination Assessment at Dawn
- Paint Assessment
- Data on how many hours UAS vs. other methods
Phase II Study

Blatnik Bridge Inspection

- Second Largest Bridge in Minnesota
- Crosses Duluth Harbor adjacent to Lake Superior
- Challenging wind and weather
Phase II Study

Nielsville Bridge 5767

- Infrared Imaging
- Thermal Camera results were similar to high end Flir cameras
- Drone has the ability to map chain drag markings for quantities in CAD
Phase II Study

Nielsville Bridge 5767 3D Point Cloud

Phase III – Project Goals

• Statewide UAS Inspection Contract – based on the MnDOT Bridge Access Inspection Policy list
• Overall Cost Effectiveness – at a statewide level for both District and local agency bridges
• Inspection Quality and Safety Improvements – close-up, 3D, and thermal imagery
• Identification of Sustainable Future Funding
Phase III – Schedule & Cost

- **Task I** – Finalize Bridge Work Plans/Approvals
  - 9 months beginning **July 2016**
- **Task II** – Field Work and Evaluation
  - 9 months – **April to December 2017**
- **Task III** – Documentation/Final Study Report
  - 6 months – **Ending June 2018**
- **COST** - $100,000
  - Task I - $30,000
  - Task II - $50,000
  - Task III - $20,000

Conclusions

- UAS can be used in the field during bridge inspections safely.
- Image quality allows for the identification of defects.
- Tactile functions cannot be replicated using UAS.
- UASs can be cost effective.
- UASs can provide a very efficient way to collect infrared images.
- Safety risks could be minimized with the use of UASs.
- UASs can be utilized to determine channel conditions.
- UASs can provide important pre-inspection information.
- “Off the shelf” UAS’s have limited inspection capability.
- Current FAA rules are onerous.
**Recommendations**

- Based on the information presented in this report the following recommendations are made:
  - The use of UASs for bridge inspection should be considered when a hands on inspection is not needed.
  - Should be considered for routine inspections to improve the quality of the inspection.
  - Should also be considered where they can increase safety for inspection personnel and the traveling public.
  - A set of best practices and safety guidelines should be prepared.
  - Should be considered for interim inspections or to monitor areas of concern.
  - Should be considered for emergency inspections.

**Other Civil Engineering Uses**

- Mapping
- Dam Inspection
- Earthwork Volume Calculations
- Traffic Control Monitoring
- Construction Site Assessment
- River/Stream Inspections
- RR Track Inspection
- Pavement Inspection
- High Mast Light Inspection
- Utility Inspection
Public Response

- Almost 100 news articles and stories
- Overwhelmingly positive
- Safety, reduced closures and cost efficiency valued by public

Bridge Owners

A special thank you to all the bridge owners who made available their bridges for the inspection phase of the study:

- Joe Triplet, Chisago County
- Mike Sheehan, Olmsted County
- Kaye Bieniek, Olmsted County
- Benjamin Johnson, Olmsted County
- Jeff Busch, Olmsted County
- Kent Haugen, Olmsted County
- Cain Duncan, City of Oronoco
- Steve Backowski, Morrison County
- John Kостreba, Morrison County
- DJ Prom, Morrison County
- Sergio Zoruba, Canadian National Railway
- Peter de Vries, Canadian National Railway
- Albert Hines, Canadian National Railway
- Kevin Rohling, MnDOT District 1
Questions/Contact Information

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