Why we Inspect Bridges

- 1967 – Silver Bridge collapse (fracture of an eyebars at a pin connection)
- 1968 – National bridge inspection (NBI) program initiated (requiring regular and periodic inspections)
- 1971 – National bridge inspection standards (NBIS) adopted (prescribe how, with what frequency, and by whom bridge inspections must be completed)
- 1987 – Schoharie Creek collapse (scour)
- 2007 – Minnesota I-35W collapse (undersized gusset plate design)
• Structures must carry vehicular traffic open to public.
• Greater than 20 feet in length
• Owned by the public. (*State, County, City, Housing Association, Port, etc.*)
Oregon NBI Bridge Count

- ODOT Owned = 2742
- County Owned = 3432
- City Owned = 623
- Other State Agencies = 57
- Railroad Owned = 6
- Local Toll Owned = 2

Total NBI Bridges = 6862
Types of Inspections and Frequency

- **NBI Inspection** *(2 Year Max)*
- **Element Level Inspection** *(2 Year Max)*
- **Fracture Critical Inspection** *(2 Year Max)*
- **Fatigue Prone Inspection** *(Not to exceed 10 years)*
- **Timber Boring** *(Not to exceed 8 years)*
- **Under Water** *(Not to exceed 5 years)*
- **Cross Channels** *(Not to exceed 10 years)*
- **Scour Inspections** *(As Needed)*
- Multiple Other Specialty Types of Inspections.
# Oregon Department of Transportation

## Bridge Inspection Report

**District:** 2B  
**Fac Crossed:** UPRR  
**Owner:** State Highway Agency  
**Suff Rating:** 43.1  
**AC Depth:** 0.00  
**Bridge Length:** 2251.07 ft  
**Record Type:** 1  
**Inspector 1:** Robert May (267)  
**Inspector 2:** Kevin Shoarline (GDOT)  
**Fac Carried:** I-5 (HWY 091) NB  
**County:** Multnomah  
**Mile Point:** 301.70 mi  
**Imp Date:** 02/26/2017

<table>
<thead>
<tr>
<th>Element</th>
<th>Structure Unit</th>
<th>Environment</th>
<th>Quantity</th>
<th>Units</th>
<th>CS1</th>
<th>CS2</th>
<th>CS3</th>
<th>CS4</th>
<th>Temp</th>
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<tbody>
<tr>
<td>12-Re Concrete Deck</td>
<td>1</td>
<td>3</td>
<td>92687</td>
<td>(SF)</td>
<td>91036</td>
<td>1824</td>
<td>27</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1091-Quilt</td>
<td>1</td>
<td>3</td>
<td>24</td>
<td>(SF)</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1120-Exposed Rebar</td>
<td>1</td>
<td>3</td>
<td>1824</td>
<td>(SF)</td>
<td>0</td>
<td>0</td>
<td>1824</td>
<td>0</td>
<td>0</td>
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<tr>
<td>513-Rigid Wearing Surface</td>
<td>1</td>
<td>3</td>
<td>86297</td>
<td>(SF)</td>
<td>25249</td>
<td>40303</td>
<td>20016</td>
<td>0</td>
<td>0</td>
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<tr>
<td>16-Re Cono Top Flange</td>
<td>1</td>
<td>3</td>
<td>4202</td>
<td>(SF)</td>
<td>4178</td>
<td>24</td>
<td>0</td>
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<td>1058-Delamination/Spall/Patched Area</td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>(SF)</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0</td>
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</tr>
<tr>
<td>1090-Exposed Rebar</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>(SF)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>1120-Exposed Steel</td>
<td>1</td>
<td>3</td>
<td>15</td>
<td>(SF)</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>0</td>
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<tr>
<td>513-Rigid Wearing Surface</td>
<td>1</td>
<td>3</td>
<td>3564</td>
<td>(SF)</td>
<td>3561</td>
<td>3</td>
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<tr>
<td>105-Steel Opn Girder/Beam</td>
<td>1</td>
<td>3</td>
<td>11317</td>
<td>(LF)</td>
<td>3165</td>
<td>8152</td>
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<tr>
<td>1000-Corrosion</td>
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<td>3</td>
<td>8151</td>
<td>(LF)</td>
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<td>8151</td>
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<td>0</td>
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<td>1020-Connection</td>
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<td>3</td>
<td>1</td>
<td>(LF)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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---

## Oregon Department of Transportation

**Structure Inventory and Appraisal Report**

**Bridge No:** N8588E  
**Inspection Date:** 02/26/2017

<table>
<thead>
<tr>
<th>(2) Highway District</th>
<th>District 2B</th>
<th>(42A) Type Service On</th>
<th>(75) Type of Work</th>
<th>331</th>
</tr>
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<tbody>
<tr>
<td>(3) City</td>
<td>59900</td>
<td>(43) Struct Main</td>
<td>3 Steel 02 Stringer/Girder</td>
<td>(99) Inspection Date</td>
</tr>
<tr>
<td>(5) Traffic Int</td>
<td>UPRR</td>
<td>(44) Number Main Spans</td>
<td>22</td>
<td>(90) Critical Flt Imp</td>
</tr>
<tr>
<td>(6) Location</td>
<td>0.2 M N OF BURNIDE BR</td>
<td>(45) Maximum Span Length</td>
<td>21.23 ft</td>
<td>(95) Roadway Improvement</td>
</tr>
<tr>
<td>(10) Vert Clearance</td>
<td>19.50 ft</td>
<td>(49) Structure Length</td>
<td>2251.07 ft</td>
<td>(96) Project Completion</td>
</tr>
<tr>
<td>(11) Mile Post</td>
<td>301.70 mi</td>
<td>(50A) Sidewalk Width LT</td>
<td>0.00 ft</td>
<td>(97) Year of Improvement</td>
</tr>
<tr>
<td>(12) Base Highway Network</td>
<td>1</td>
<td>(50B) Sidewalk Width RT</td>
<td>0.00 ft</td>
<td>(106) Distance Between Highways</td>
</tr>
<tr>
<td>(13) LRS Inventory Route</td>
<td>000100200500</td>
<td>(81) Bridge Roadway / Waterway</td>
<td>31.33 ft</td>
<td>(107) Parallel Structure</td>
</tr>
<tr>
<td>(16) Latitude</td>
<td>45° 31'-37.00&quot;</td>
<td>(52) Deck Width</td>
<td>33.73 ft</td>
<td>(102) Direction of Traffic</td>
</tr>
<tr>
<td>(17) Longitude</td>
<td>122° 39'-54.88&quot;</td>
<td>(55) Vert Clear Over Deck</td>
<td>16.67 ft</td>
<td>(103) Temporary Structure</td>
</tr>
</tbody>
</table>

*Signature:*
What Kind of Defects Do We Look For

Collision
What Kind of Defects Do We Look For

Cracks

Decay
What Kind of Defects Do We Look For

Scour
What Kind of Defects Do We Look For

Corrosion and Paint Condition  Damaged and or Frozen Bearings
Access is Expensive and at Times Inconvenient

- Average Cost Traffic Control Per Day $2,500
- Average Cost of a Under the Bridge Inspection Truck (UBIT) $2,000 per day
- Busy Routes Allows Only Night Time Lane Closures
Motivation

• New tool in bridge inspector’s tool box to help:
  • Provide mechanism to remotely view bridge elements at high resolution, while keeping both feet on ground
  • Reduce lane closures, snooper crane use, and climbing in some inspections
  • Enhance safety and reduce costs in some inspections
UAS for Structural Inspections
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO
Oregon State University

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED

Operation of small Unmanned Aircraft System(s) weighting less than 55 lbs., in Class G airspace at or below 400 feet Above Ground Level (AGL) under the provisions of this authorization. See Special Provisions.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE
N/A

STANDARD PROVISIONS
1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

Note—This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.

SPECIAL PROVISIONS

Special Provisions are set forth and attached.

This certificate, 2016-WSA-101-COA, is effective from May 12, 2016 through May 11, 2018 and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative. Should a renewal become necessary, the Proponent shall advise the Federal Aviation Administration (FAA), in writing, no later than 45 business days prior to the requested effective date.

BY DIRECTION OF THE ADMINISTRATOR
FAA Waivers

• Oregon State University received a **nationwide COA** for using UAS for research purposes
  • < 400 ft., Class G Airspace
  • Line-of-sight
  • Operators must be “OSU Certified”

• Oregon State University can also fly under a nationwide COA under the FAA Pan-Pacific Test Range
  • Provides opportunities for “more-complicated” types of flights

• Aircraft have been registered with FAA and the State of Oregon
FAA – Part 107

Easier/Less Restrictive

• Pilot license replaced with remote pilot certificate
• Airworthiness certification not required
• NOTAM not required practice
• Visual observer not required
• Coordination with airports in Class G uncontrolled airspace not required
• Use of UAS educational purposes allowed

Requirements

• Aircraft must be registered
• VLOS
• Daylight and civil twilight only
• May not operate over nonparticipants
• < 400ft AGL (or within 400ft of a structure)
• Class G airspace only without waiver
• Min wx visibility of 3 miles
Unmanned aircraft systems

UAS Definition (FAA)
• Not just the aircraft
• Also all associated
  • Support equipment
  • Control station
  • Data links
  • Telemetry
  • Communications
  • Navigation equipment
Aircraft Types

(a) Helicopters  (b) Fixed-wing  (c) Multi-rotor
SenseFly eXom (albris)

HD video camera, 38 MP still camera

Thermal IR camera

Navcams and ultrasonic sensors

Front-mounted camera head that can be rotated 180° from nadir to zenith

Flash and headlamp

Flight planning software designed to facilitate inspection projects
Albris navcams and ultrasonic sensors
Thermal imagery
Ground Control Station
Manual flights with sensor assistance
Waypoint missions
Horizontal mapping mission
## Flight Methods

<table>
<thead>
<tr>
<th>Manual Mode with Sensor Assistance</th>
<th>Waypoint Mission Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• Operator can carefully position the camera to view a specific feature of interest</td>
<td>• Overlapping photos can be developed into a 3D model</td>
</tr>
<tr>
<td>• Close-up photos</td>
<td>• Systematic flights assure features are fully photographed</td>
</tr>
<tr>
<td>• Less time</td>
<td>• Less human interaction</td>
</tr>
</tbody>
</table>
DJI S900

- 30x optical zoom camera (Sony WX500)
UAS Test Bridge Inspections Completed

(1) Independence Bridge
(2) Crooked River Bridge
(3) Mill Creek Bridge
(4) St. Johns Bridge
  - Preliminary
(5) Winchester Bridge
  - Detailed
(6) St. Johns Bridge
Cracks

Pin Connections
UAS Test Inspections Imagery

Paint Failure

Pack Rust
UAS Test Inspections Imagery
UAS Test Inspections Imagery
UAS Test Inspections Imagery
UAS Test Inspections Imagery
UAS Test Inspections Imagery
UAS Test Inspections Imagery
Structure from Motion (SfM)

- Relatively new photogrammetric approach
  - Leverages advanced image matching algorithms from the field of computer vision
- Many requirements are relaxed, as compared with conventional photogrammetry:
  - Can work with a wide range of viewing geometries and consumer-grade cameras
  - *Well suited to UAS imagery!*
  - Highly automated, easy to use software
Structure from Motion (SfM)

• Basic processing steps:
  • Image matching step
    • Algorithms, such as the scale invariant feature transform (SIFT) keypoint detector (Lowe, 2004)
  • Recovery of camera parameters and 3D reconstruction
  • Typically employs bundle adjustment
  • Dense point generation
  • Output products
    • Point clouds and orthoimages
Ground control – photo targets for SfM
Crooked River Bridge Point Cloud: fly-through
Point cloud of Crooked River Bridge
Point cloud of Crooked River Bridge
Orthophoto of Crooked River Bridge

An orthophoto of the profile of the Crooked River Bridge produced from processing the images using SfM. (from Javadnejad et al. 2017, with permission)
Imagery Management
Research Key Findings

- Sensor-assisted and waypoint-assisted flight modes are most useful flight modes for bridge inspection
  - But, unmanned aircraft pilots must be proficient in entirely manual flight, due to the possibility of losing GPS
- UAS with front-mounted, variable-tilt cameras are advantageous for bridge inspection
- Wind condition is the most important environmental variable in UAS bridge inspection
  - Illumination conditions and camera settings (ISO, f-stop and focal length) are critical to obtaining high-quality imagery
- UAS bridge inspection flight crews should have at least a basic level of expertise in photography
- UAS can assist to varying degrees in many required elements of a bridge inspection
  - Very well suited for initial and routine inspections and for satisfying report requirements related to geometry and structural evaluation
- Cracks, pack rust, connections, hardware and bearing locations were all determined to be readily-identifiable in the imagery collected in this project, with the recommended flight procedures
Acknowledgements

• ODOT and Pactrans funded this study
• Matt Gillins, OSU graduate student
• Erick Cain, ODOT bridge engineer
• Joe Li and ODOT TAC
• OSU graduate students Farid Javadnejad, Kory Kellum, and Richie Slocum assisted with UAS flights
In addition to Part 107 Regulations ODOT Requires:

- All flights will have a Pilot-in-Command (PIC) and Visual Observer (VO)
- ODOT Pilots can only operate public aircraft
- Currency on equipment must be maintained: 3 flights in 90 days
- A PIC must:
  - Attend agency approved training, and
  - Log all flights and aircraft maintenance

Data Use
- Use the data collected by Department-owned or contracted UAS only for the operation and maintenance of its assets and advancement of Department goals and objectives.
- Obtain, process and make data available in a timeframe consistent with its intended use.

Data Storage
- Store data obtained by Department-owned or contracted UAS on electronic media in a location maintained and supported by the Department.
- Contract with external vendors for the storage of electronic records, including data obtained by UAS, where appropriate.
ODOT UAS Program

• Pilots
  • 18 Certified Remote Pilots
    • Organized throughout ODOT’s Regions

• Airframes
  • Aibotix Aibot X6V2 (Geometronics)
  • DJI Inspire 2 (Geometronics)
  • DJI Matrice 210 (Engineering Technology Advancement)
  • DJI Phantom 4 Pro (Engineering Technology Advancement)
  • GoPro KARMA (10) (ODOT Communications)

• Sensors
  • Sony A7R
  • Zenmuse X4S (2)
  • Zenmuse Z30
ODOT UAS Program

Joseph R. Thomas, PLS
Program Manager

Flight Operations Manager

Chief Pilot, Geometronics
- Pilot 1
- Pilot 2
- Pilot, n

Chief Pilot, ETA
- Pilot 1
- Pilot 2
- Pilot, n

Chief Pilot, Communications
- Pilot 1
- Pilot 2
- Pilot, n

Chief Pilot, Wireless
- Pilot 1
- Pilot 2
- Pilot, n

Chief Pilot, etc.
- Pilot 1
- Pilot 2
- Pilot, n
Building on OSU Research

Summer 2018

• 13 Bridges identified as test sites
• Focused in Region 2
• “Proving” OSU’s Research
• Members from Bridge and Engineering Automation Sections on research team
Next Steps

1. Can we fly the structure under rules defined in Part 107 and ODOT’s UAS Operation Manual?
2. Review airspace for each structure and request FAA authorizations if necessary
   A. Three structures are in Class D airspace
Next Steps

1. Can we fly the structure under rules defined in Part 107 and ODOT’s UAS Operation Manual?
2. Review airspace for each structure and request FAA authorizations if necessary
   A. Three structures are in Class D airspace
3. Identify equipment
   A. DJI Matrice 210 w/X4S and Z30
DJI Matrice 210

ADAPTABLE AERIAL IMAGING

The imaging platform that adapts to your needs

- SINGLE DOWNWARD GIMBAL
- DUAL DOWNWARD GIMBALS
- SINGLE UPWARD GIMBAL
- THIRD PARTY SENSORS

ADAPTABLE AERIAL IMAGING

The imaging platform that adapts to your needs

- SINGLE DOWNWARD GIMBAL
- DUAL DOWNWARD GIMBALS
- SINGLE UPWARD GIMBAL
- THIRD PARTY SENSORS

7 km
OPERATION RANGE

38 min
MAX FLIGHT TIME

IP43
INGRESS PROTECTION

2 KG
MAX PAYLOAD CAPACITY
DJI Matrice 210

- Zenmuse X4S
  - 1” CMOS Sensor
  - 20 MP Stills (DNG, JPEG, RAW)
  - 4K Video (MOV, MP4)
  - 8.8mm F2.8 Lens
  - 6 Stop Dynamic Range
  - Mechanical Shutter

- Zenmuse Z30
  - 1/2.8” CMOS Sensor
  - 2.13 MP JPEG Stills
  - 1080 Video (MOV, MP4)
  - 30x Optical Zoom
  - Electronic Shutter
  - [https://www.youtube.com/watch?v=bU6vlMrD32A](https://www.youtube.com/watch?v=bU6vlMrD32A)
Next Steps

1. Can we fly the structure under rules defined in Part 107 and ODOT’s UAS Operation Manual?
2. Review airspace for each structure and request FAA authorizations if necessary
   A. Three structures are in Class D airspace
3. Identify equipment
   A. DJI Matrice 210 w/X4S and Z30
4. Practice, practice, practice
   A. How does the equipment handle under a structure?
5. What does success look like?
   A. Can we see things with UAS that were impossible or difficult to see before?
Additional UAS at OSU: Transportation System Monitoring

- Investigate UAS-based lidar for detection & monitoring of transportation networks system.

- Use deep learning to process point clouds and extract features of interest.
Additional UAS at OSU: Shallow Bathymetric Mapping

• Investigate UAS-based SfM for mapping bathymetry in coastal environments.

• Develop standard operating procedures for optimal data collection and processing.

Buck Island, U.S. Virgin Islands – Richie Slocum
UAS in Transportation Expo

July 30\textsuperscript{th} – 31\textsuperscript{st}, 2018

Topics to include:

• UAS applications in transportation
• How to initiate a UAS program within a transportation agency/organization
• Flight Demonstration
• Hands on data processing workflow

For more info: blogs.oregonstate.edu/uasintransportation/
Questions?

Final Report Available here:
http://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR787_Eyes_in_the_Sky.pdf