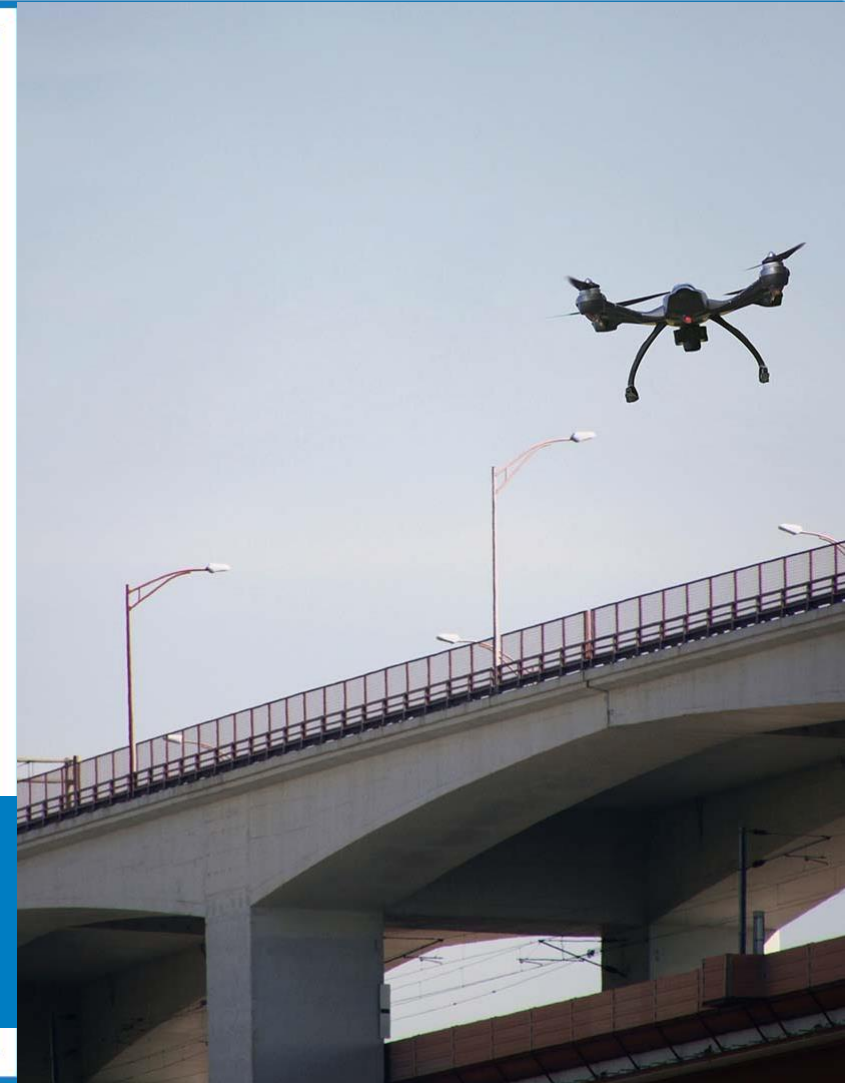


Breakout Session Track 2: Structural Inspection

Jennifer Wells, Minnesota DOT

Dr. Chris Parrish, Oregon State University

Jag Mallela (Moderator)



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Structure Inspections Utilizing UAS

Jennifer Wells, PE - State Bridge Inspection Engineer

Presentation Outcomes

- UAS Program Implementation Overview
- Understand Benefits and Limitations
- Participants will learn the current and future drone technologies that are effective for structure inspection
- Understanding of how to successfully implement drone technology into structure inspections
- Understand the costs associated with implementing drones and the cost savings that can be realized compared to traditional methods
- Understand drone data needs

UAS Program Implementation Overview

- Phased research began in 2015
 - Phase III completed in summer 2018
 - Published report - <http://www.dot.state.mn.us/research/reports/2018/201826.pdf>
- Metro District drone purchase – Elios
 - Phase IV – Project almost complete...
- FHWA EDC – 5 UAS Committee
 - STIC Grant
 - \$125k in drone purchases



Assessment of UAS Technology

- Inspection-specific UAS
- Object Sensing
- Capable of looking up
- Fly without GPS, under bridge decks
- Photo, Video and Thermal Imaging
- Confined Space



Assessment of UAS Technology

Commercial Drones (\$20,000 - \$35,000)

- Intel Falcon 8+
- DJI Matrice 210
- Flyability Elios

Benefits

- Sensor Size
- Reliability
 - Dual Batteries
- Durability
- Purpose Built for Inspection



Assessment of UAS Technology

Consumer Level Drones (\$500 - \$2000)

- DJI Mavic
 - Object Avoidance
- Parrot Anafi
 - Thermal

Benefits

- Low cost
- Small size
- More risk tolerance

Limitations

- Non-professional perception
- Reliability
- Small sensor sizes
- Less sophisticated flight planning





Sensor Size Importance



Assessment of UAS Technology

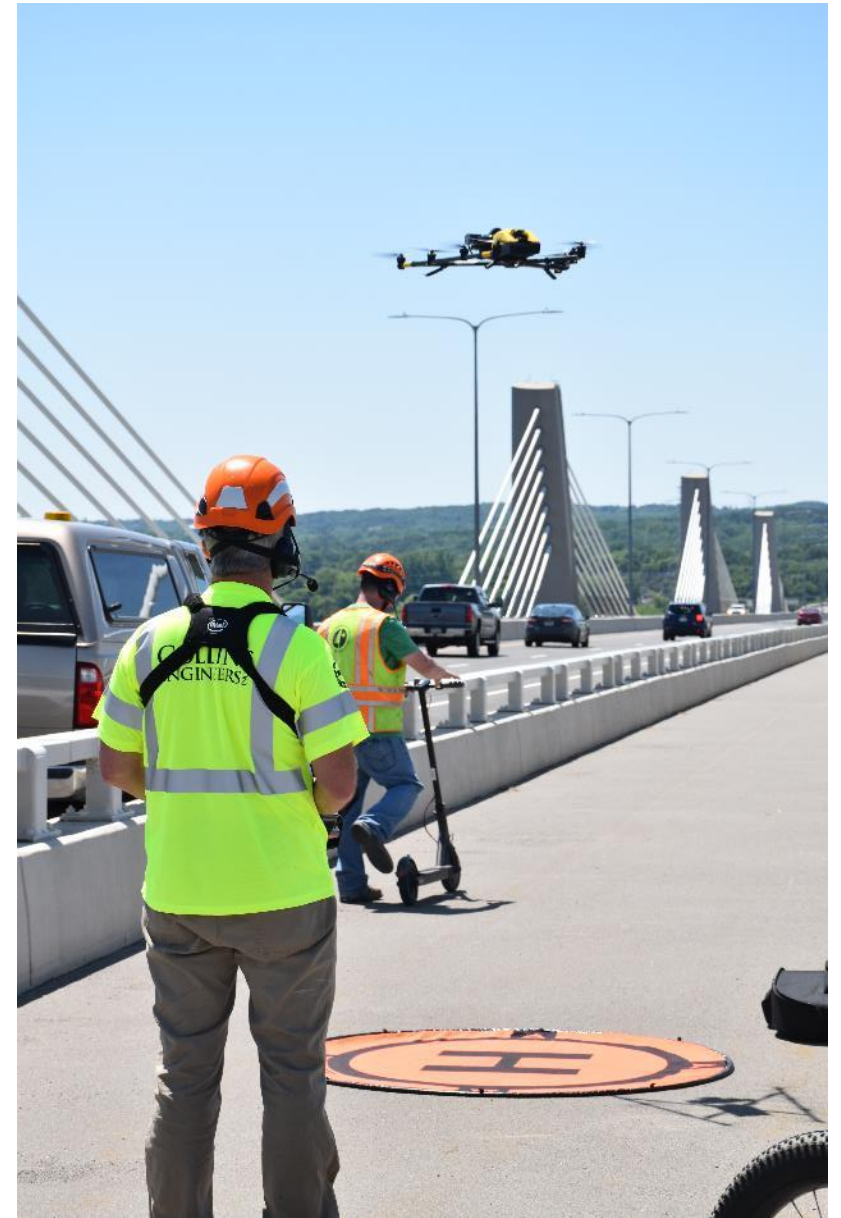
Propeller Aeropoints

- Automatic Ground Control Points
- Provides precision ground control
- Adds ability to accurately geolocate assets and inspection results



Structure Inspection Goals

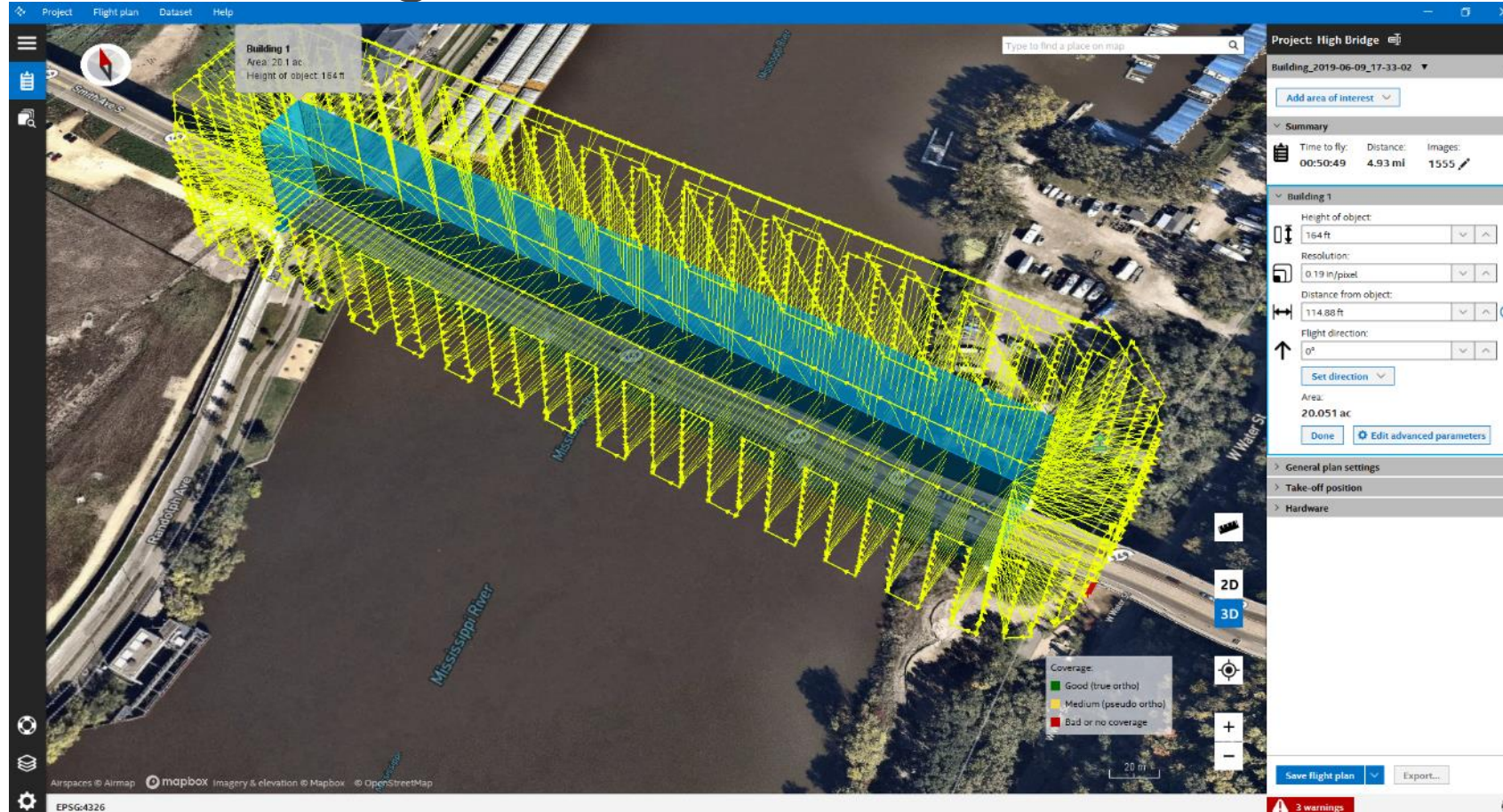
1. Inspection Planning
2. Detect Conditions and Deficiencies
3. Document
4. Communicate



1. Inspection Planning with UAS

Flight Planning

- 3D Autonomous Flights



2. Detection of Defects and Deficiencies

- Use UAS as an access tool
- Traditional Access Tools
 - Aerial Work Platforms (AWP's)
 - Rope Access and Structure Climbing
 - Ladders
 - Binoculars



3. Document Conditions and Deficiencies

- Reality Modeling Software
 - Pix4D
 - Context Capture
- Input
 - Images
 - Ground Control
- Output
 - Orthomosaics
 - GeoTIFF, DSM, DTM
 - Point Clouds
 - Classified by AI
 - 3D Mesh
 - CAD



3. Document Conditions and Deficiencies

Deliverables – Orthomosaic

The screenshot displays a software interface for documenting bridge conditions using an orthomosaic. The main map view shows a bridge deck with various annotations, including lines and polygons, labeled with measurements in feet and inches. The left sidebar contains a 'Layers' panel with a search filter and a list of layers: 'Annotations 2', 'Element 300', 'Line 181', 'East Joint', 'Pier 15A Joint', 'Joint Filled with Debris', 'Delamination', and several 'Polygon' layers. The right sidebar shows an 'Inspection' panel with a search filter, a list of inspection points, and a 'SAVE INSPECTION AS ANNOTATION' button. The bottom right corner displays coordinates: 44.97134° N 93.29724° W and Elevation: -.

Layers

Filter by name or tag...

- ☒ Annotations 2
- ☒ Element 300
 - ☒ Line 181
 - ☒ East Joint
 - ☒ Pier 15A Joint
 - ☒ Joint Filled with Debris
- ☒ Delamination
 - ☒ Polygon 6
 - ☒ Polygon 5
 - ☒ Polygon 4
 - ☒ Polygon 3
 - ☒ Polygon 2
 - ☒ Polygon
 - ☒ Concrete Delamination
 - ☒ Concrete Delamination

All changes saved

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Inspection

DSC02398_156129...

SAVE INSPECTION AS ANNOTATION

We found 19 images matching the selected point of the model. They will be included in the inspection annotation.

Name
Inspection

44.97134° N 93.29724° W Elevation: -

3. Document Conditions and Deficiencies

Deliverables – Point Clouds



4. Communicate Conditions and Deficiencies

- Traditional Reporting

BR 3459 -- Span #3 Field Notes		
Location	North (upstream) Truss	South (downstream) Truss
L0-L1 Bottom Chord (4 angles, 5" x 3-1/2" x 5/16")	<p>[2004] Bottom chord angles reinforced (bolted plates) at L0, L1 and at the center.</p> <p>[2008] There is pitting and section loss (painted over) just west of the center section reinforced in 1994 - the horizontal legs of the two exterior angles have rusted through.</p> <p>[2011] No change.</p> <p>[2015] Through corrosion top horizontal leg of bottom exterior angle west of retro fit.</p> <p>[2017] Pitting on the upper legs of the chord inside the panel point. (Photo 20)</p>	<p>[2008] Upper angle is bent at mid-panel. [2008] The horizontal legs of the truss bottom chord angles have pack rust (minor section loss) at L0. [2008] The vertical leg of the bottom interior angle has pack rust (section loss) along the edge of the interior L0 gusset plate.</p> <p>[2011] No change.</p> <p>[2015] Pitting 3/16" deep at L0. Through corrosion on bottom interior angle horizontal leg inside panel point L0. Pitting 1/4" deep on top interior horizontal legs inside L1.</p>
L0-L1 Lower Lateral Bracing	<p>[2004] Lower lateral bracing members replaced.</p> <p>[2011-2015] No deficiencies noted.</p>	
L1 Gusset Plates (1/2" thick)	<p>[2004] Repainted - L0/L1 & L1/L2 connections reinforced (bolted plates).</p> <p>[2011] No deficiencies noted.</p> <p>[2013-2015] 1/8" bow on EGP from PR.</p>	<p>[2004] Repainted. [2010] Minor corrosion.</p> <p>[2011] No change</p> <p>[2013-2015] IGP has 1/4" PR distortion over upper angle of lower chord, E side.</p>
L1-U1 Vertical (4 angles, 3" x 2-1/2" x 1/4")	<p>[2008] Vertical has minor section loss at L1.</p> <p>[2011] No deficiencies noted. [2013] NC to section loss @ L1.</p> <p>[2013-2015] Paint failures over upper half of N face of both flanges.</p> <p>[2017] 3/16" pitting at L1N (Photo 21)</p>	<p>[2011] No deficiencies noted.</p> <p>[2015] Paint failure throughout.</p>

4. Communicate Conditions and Deficiencies

Tettegouche Bridge 3459

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2D 3D

47.33732° N 91.20030° W Elevation: 682.382 ft

Navigation icons: pan, link, share, location, zoom in, zoom out

Settings icon

Camera icon

Full screen icon

Search icon

Search icon

L2-L3 Bottom Chord (4 angles, 6" x 4" x 7/16")

Name

L2-L3 Bottom Chord (4 angles, 6" x 4" x 7/16") South

Description

[2017] 1/4" pitting on the upper leg inside L3S.

Tags

Color

Measurements

Coordinates (WGS84)

47.33714° N 91.19981° W

X

3095750.224770546

Y

639215.0043449402

Z

639.4789887666702

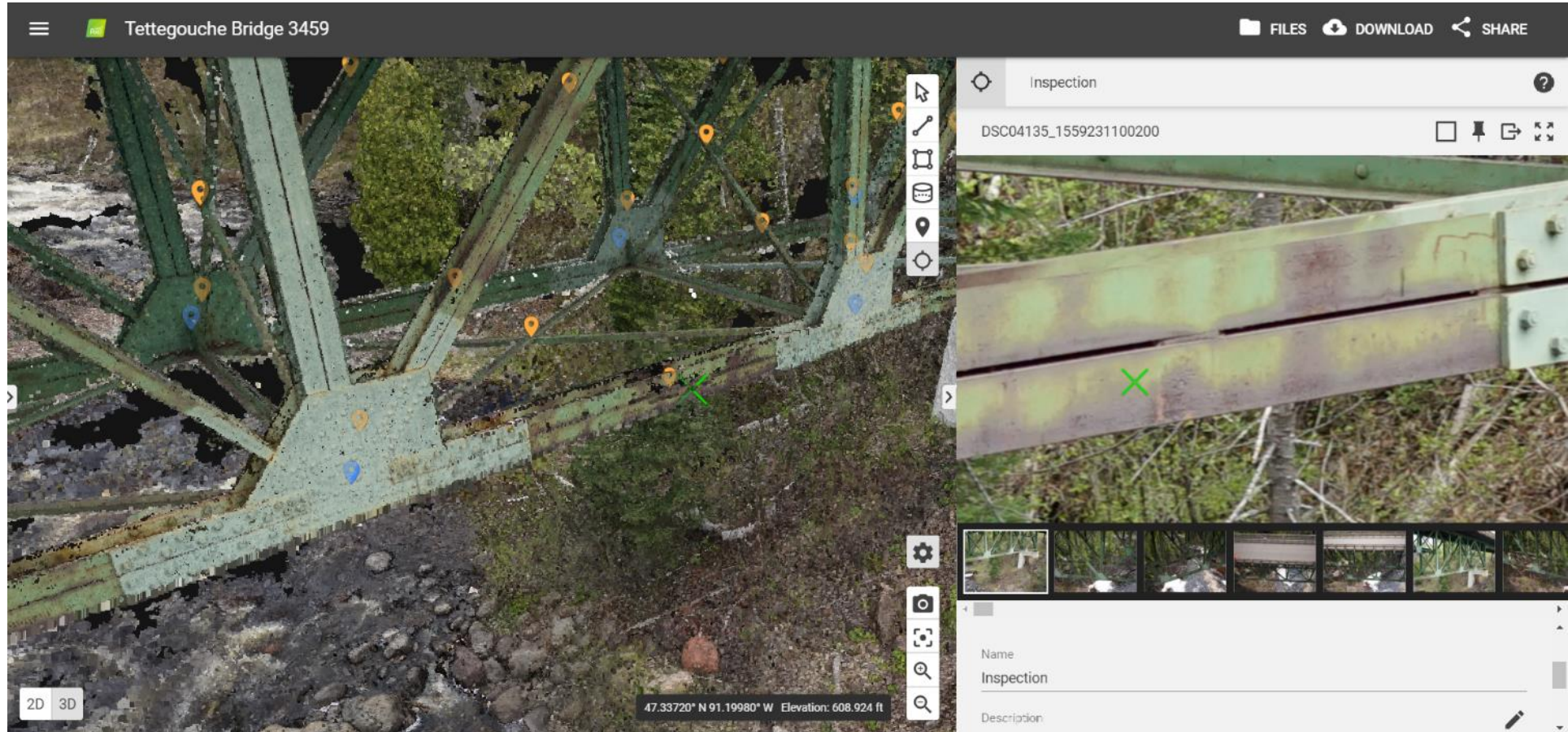
Elevation

639.469 ft

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4. Communicate Conditions and Deficiencies

- Cloud Sharing

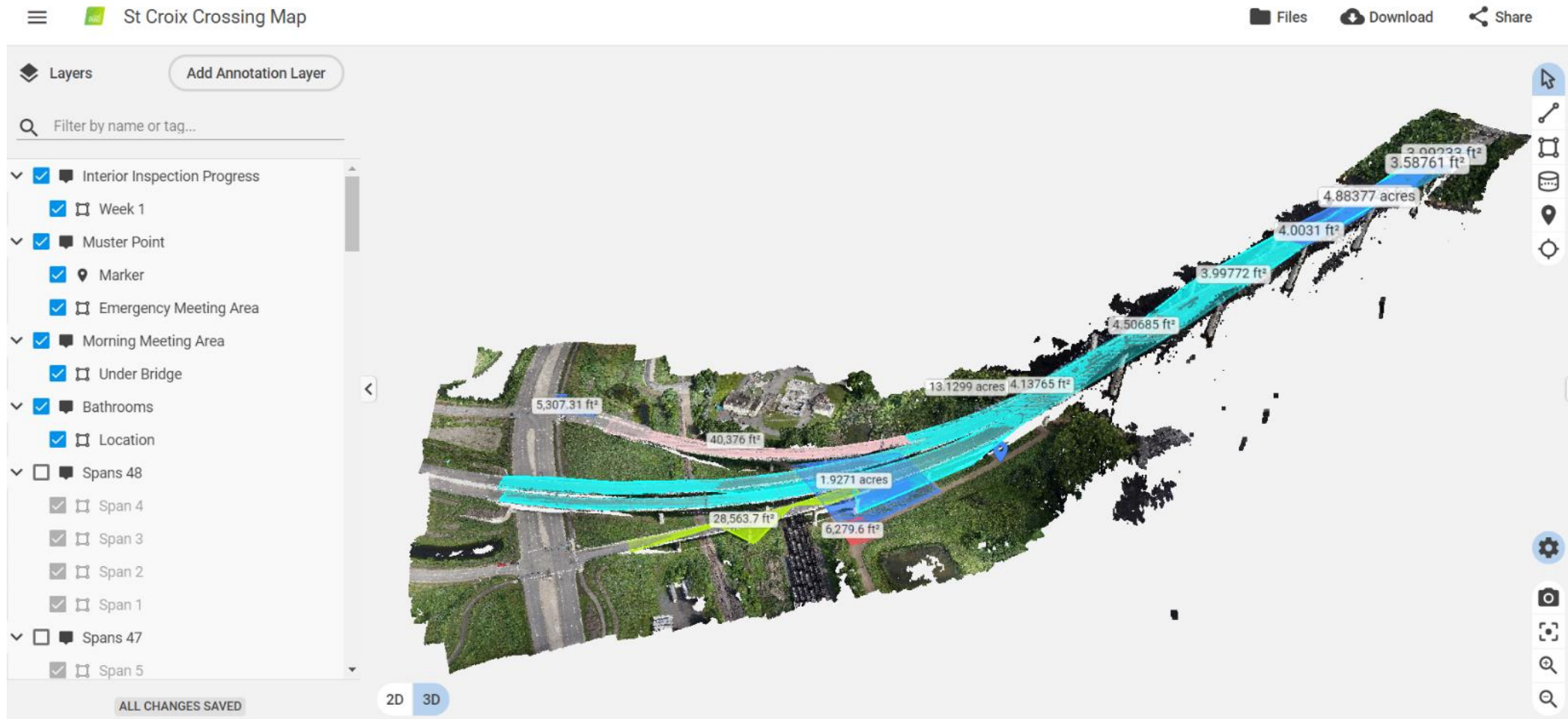


Case Study – St. Croix Crossing Extradosed Bridge

- Crosses the St. Croix Scenic Riverway
- Construction complete in July 2019
- Scope – Routine Inspection



Case Study – St. Croix Crossing Extradosed Bridge



<https://cloud.pix4d.com/pro/project/507277/model?shareToken=352346c7-7098-44ca-9b52-07f1c9ecee1>

- Intel Falcon 8+
- Capable of looking up
- Fly without GPS,
under bridge decks
- High wind tolerance
- High Resolution
Images
- Propeller Aeropoint
Automatic GCP's



Deliverables

- 3D Models and High resolution photolog

The screenshot displays a software interface for inspecting a bridge pier. The main view on the left shows a 3D point cloud model of a concrete pier with a height measurement of 67.7493 ft. A blue line indicates the vertical axis, and a green 'X' marks a specific point on the pier. The interface includes a top navigation bar with a menu icon, a 'St Croix Pier' title, and buttons for 'FILES', 'DOWNLOAD', and 'SHARE'. On the right, a panel titled 'Inspection' shows a file ID 'DSC06263_1562084087000'. Below this, there is a section titled 'Protecting the Watershed' with text about the St. Croix River and a map of the watershed. A blue button labeled 'SAVE INSPECTION AS ANNOTATION' is visible, along with a message stating: 'We found 38 images matching the selected point of the model. They will be included in the inspection annotation.' The bottom right corner features the Minnesota Department of Transportation logo.

St Croix Pier

FILES DOWNLOAD SHARE

Inspection

DSC06263_1562084087000

Protecting the Watershed

The St. Croix River was one of the first rivers protected under the Wild & Scenic Rivers Act. This legislation was prompted by the fact that decades of damming, development and diversion on America's rivers had taken an toll on the landscape and drinking water. The National Wild and Scenic Rivers System strives to preserve certain rivers with outstanding natural, cultural and recreational values in a free-flowing condition for the enjoyment of present and future generations.

Today, 130 miles of the St. Croix are protected as a national park. Another 23 miles, from Stillwater to the St. Croix's confluence with the Mississippi, are managed by the states of Minnesota and Wisconsin. The reasons for the river's wild and scenic designation are found along its length, from its character and use of the river changes. From splashing hand-ferry across stretches to the wide lake-like conditions here, from quiet paddles to man-o-war, the Riverway is a place to be enjoyed and treasured while protecting its resources.

An unspoiled river is a very rare thing in this Nation today. Their flow and vitality have been harnessed by dams and too

SAVE INSPECTION AS ANNOTATION

We found 38 images matching the selected point of the model. They will be included in the inspection annotation.

2D 3D

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Bridge Candidates

Works Well

- Large Bridges
- Bridge in open areas
- Bridges that depend on traffic control and UBIV's for inspection

Does not Work Well

- Bridges over high ADT roadways
- Bridges in heavily wooded areas

Other Applications – Confined Spaces



Other Applications – Confined Spaces



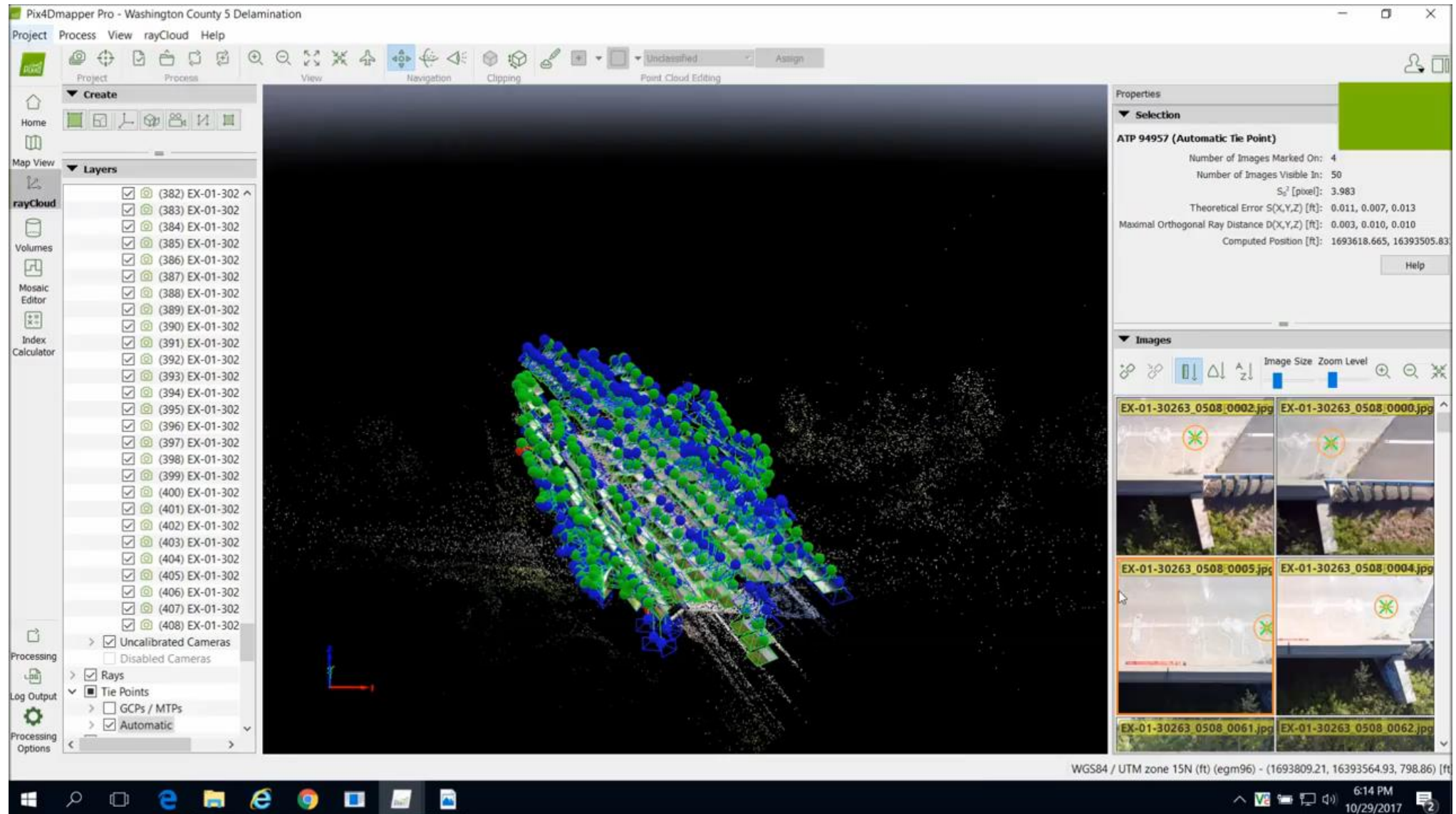
Other Applications - Infrared



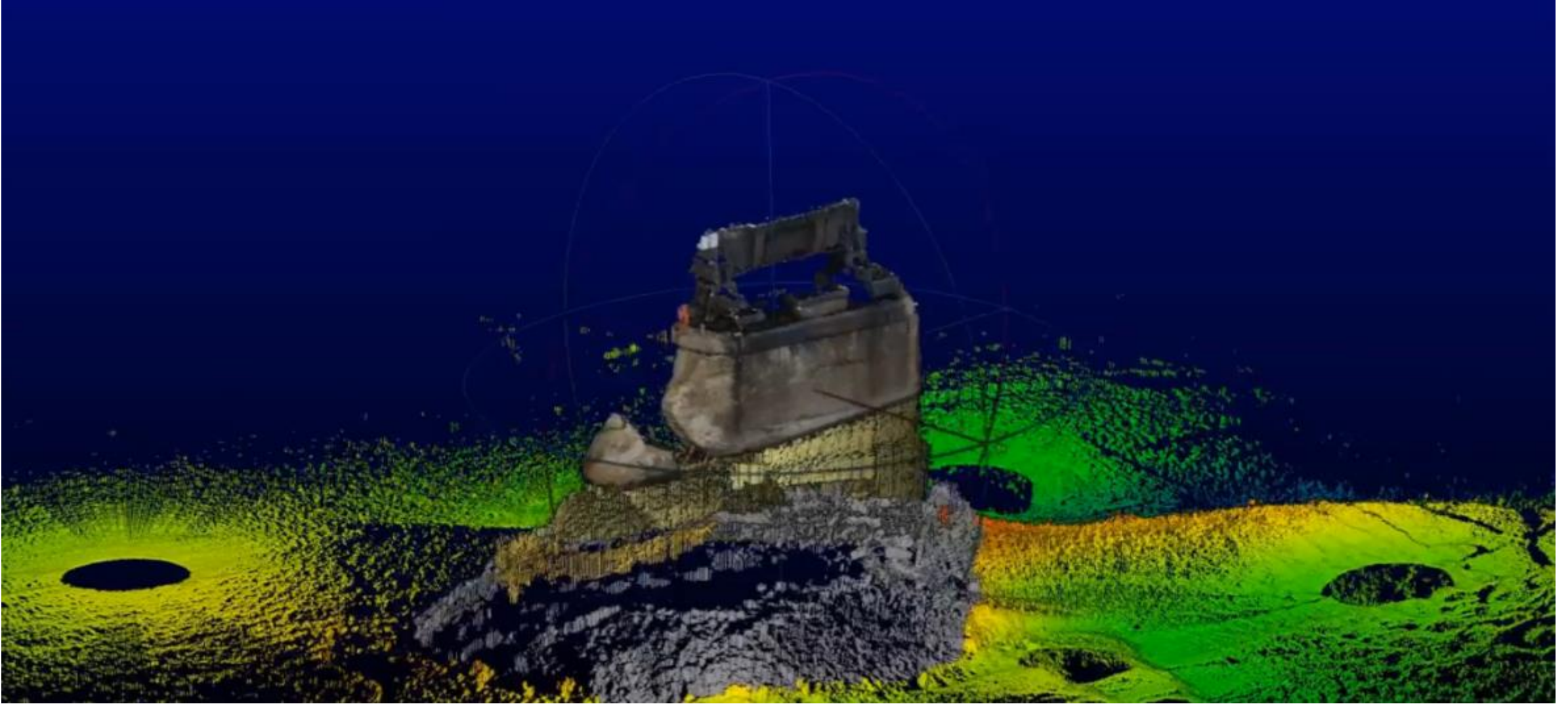
Other Applications – 3D Modeling



Other Applications – 3D Modeling (Photo Log)



Other Applications – Pairing with Underwater 3D Modeling

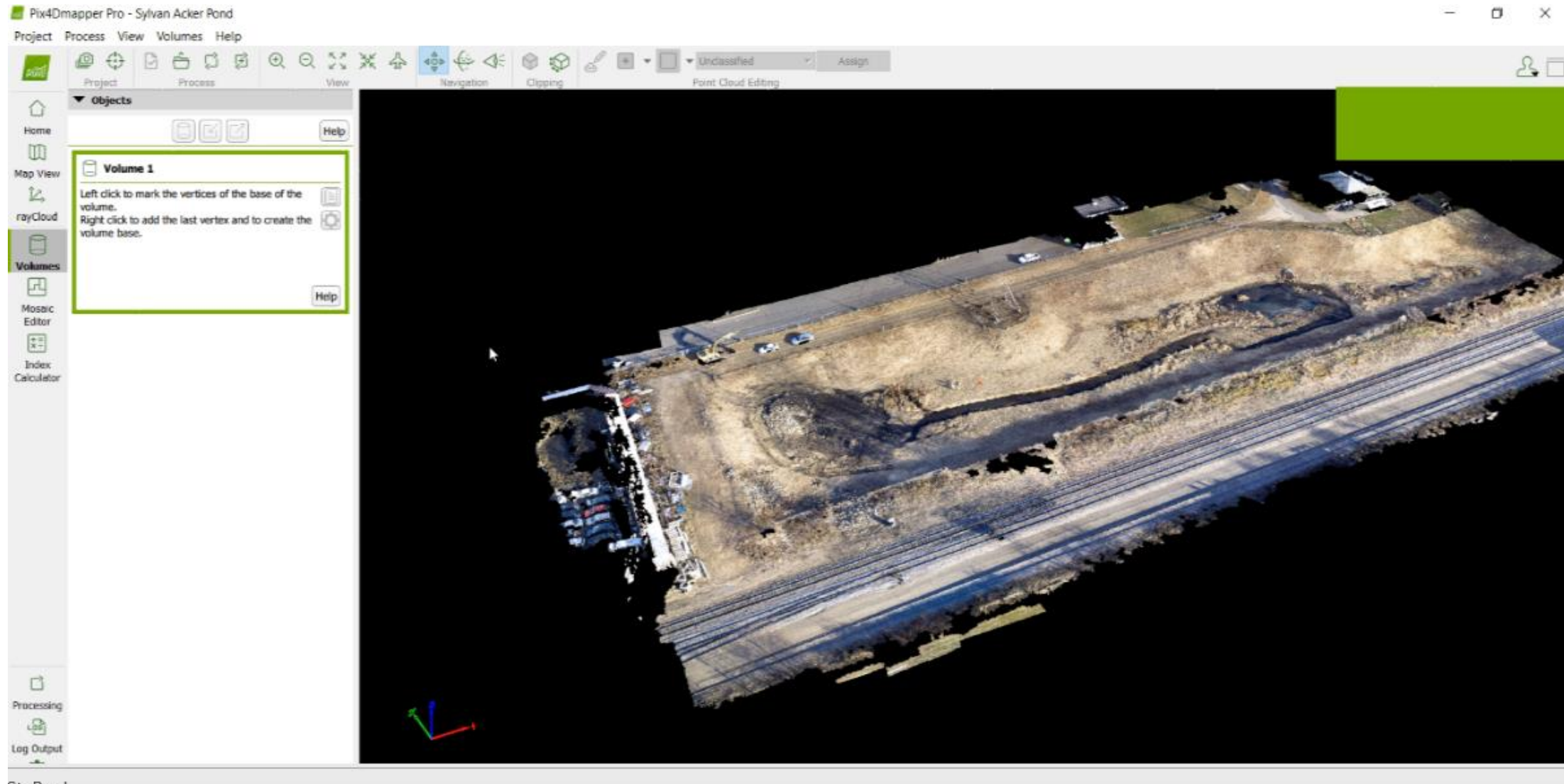


Other Applications – Corridor Modeling

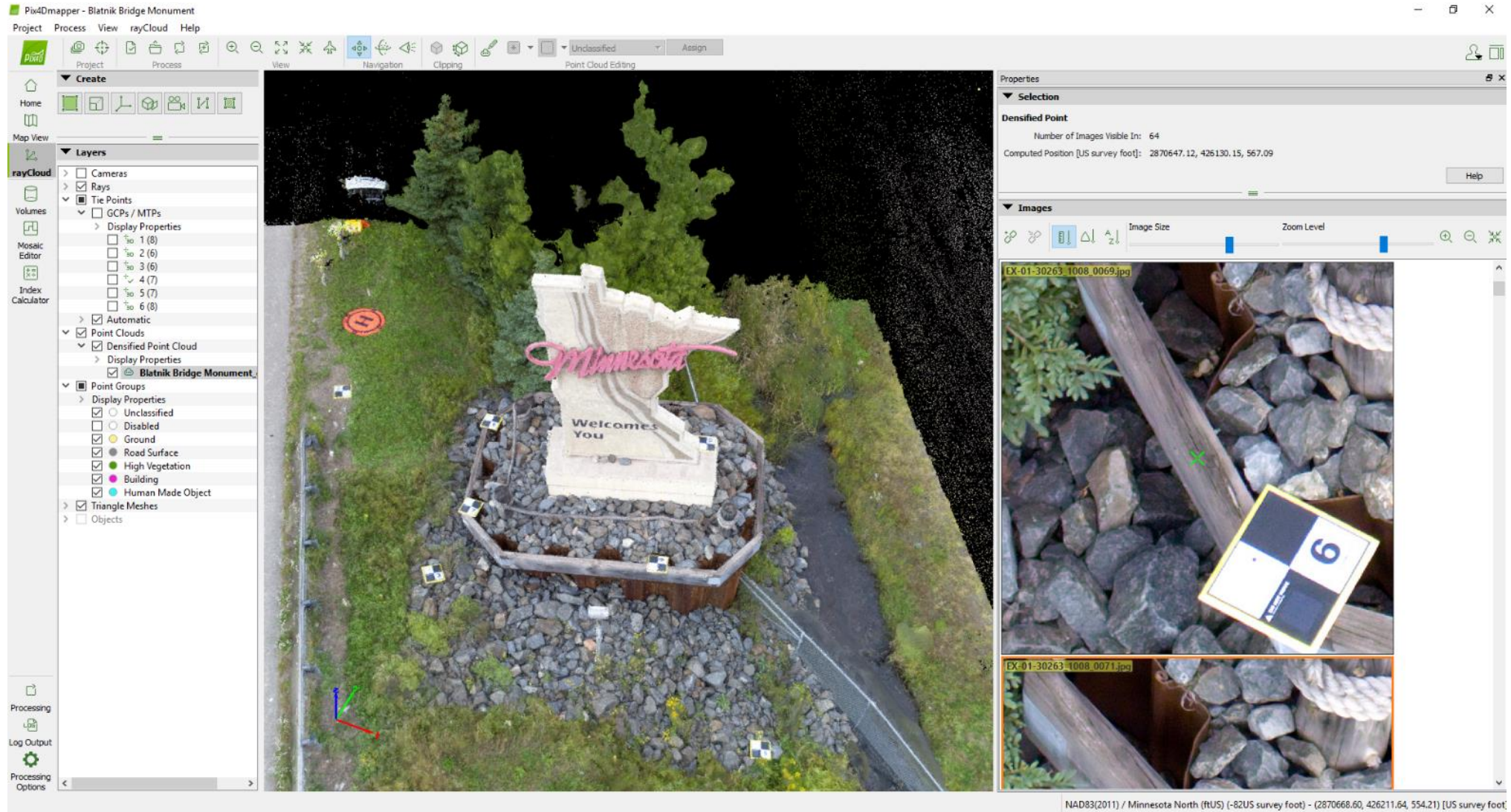


Other Applications – Overhead Signs

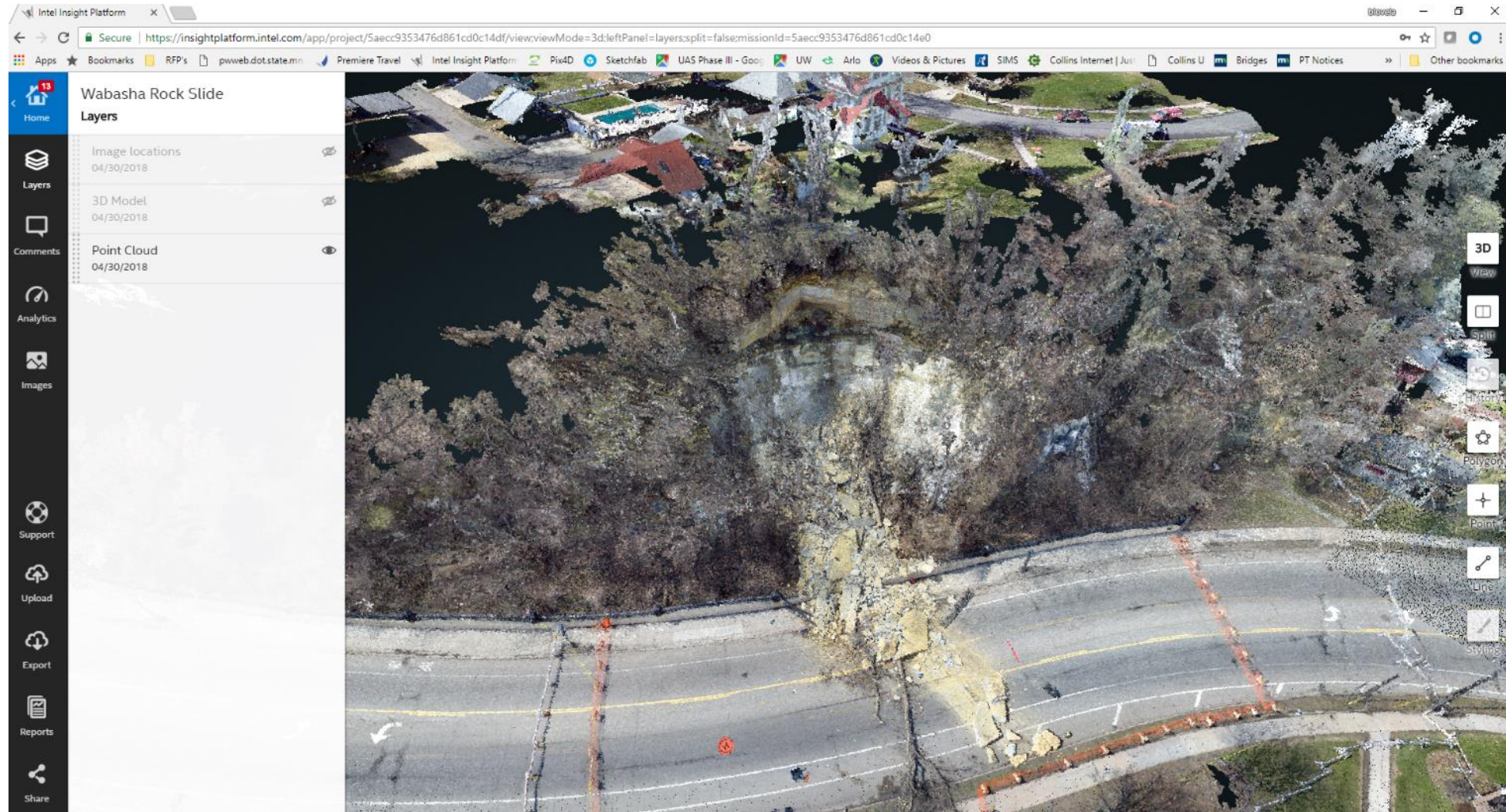
Other Applications – Volume Calculations



Other Applications – Monument Inspection/Inventory



Other Applications – Rock Slides/Scour Inspection



Other Applications – Roadway Mapping



Benefits

- Safety Improvements
 - Inspectors
 - Public
- Quality Gains
- Cost Savings

Challenges

- Learning Curves
- Not Hands On
- Acceptance
- Rules and Regulations
- Data Storage



Safety Analysis

- Remove inspectors from harms way
 - Heights
 - Traffic
- Reduced traffic control improves safety for inspectors and public
- Hundreds of Inspection Flights with no incidents or close calls
- Work zone accident occurs every 5.4 minutes in the United States
- In 2014 669 Fatalities in Work Zones
- UAS are a way to remove personnel from the ROW
- FAA is focused on airspace safety but need to look at overall risks

Cost Savings

- Cost Savings up to 40%
- Most cost savings where traffic control and access equipment can be reduced or eliminated.

Structure	Traditional Inspection Cost	UAS Assisted Inspection Cost	Savings +/-	Savings Percentage
19538	\$1,080	\$1,860	-780	-72%
4175	\$15,980	\$13,160	2,820	18%
27004	\$6,080	\$4,340	1740	29%
27201	\$2,160	\$1,620	540	25%
MDTA Bridges	\$40,800	\$19,800	21000	51%
2440	\$2,160	\$1,320	840	39%
27831	\$2,580	\$540	2040	79%
82045	\$2,660	\$1,920	740	28%
92080	\$2,580	\$1,350	1230	48%
92090	\$2,410	\$1,570	840	35%
62504	\$3,660	\$1,020	2640	72%
82502	\$3,240	\$2,400	840	26%

Average Savings 40%

Data Storage

- Super Computer
- Super Storage
- Security

bridge > DroneData

	Name
✦	C0
✦	D1
✦	D2
✦	D3
✦	D4
✦	D6
✦	D7
✦	D8
✦	METRO
✦	System Volume Information



Conclusions

- Know your intended purpose for the drone – “off-the-shelf” UAS has limited inspection capabilities
- Using UAS for access is important but documentation and communication of results is more compelling
- UAS can supplement inspections as a tool
- Does not need to replace entire inspection
- Collaborate with other owners to share knowledge and promote future advancement

Additional Information

- Phase III Report Published

- <http://www.dot.state.mn.us/research/reports/2018/201826.pdf>

- MnDOT Office of Aeronautics UAS Policy/Info

- <http://www.dot.state.mn.us/aero/drones/index.html>

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Improving Quality of Bridge Inspections Using Unmanned Aircraft Systems (UAS)

Status: Complete
Report Date:
08/02/2018



Summary:
MnDOT completed a small research project in 2015 to study the effectiveness of UAS technology applied to bridge safety inspections. The project team inspected four bridges at various locations throughout Minnesota and evaluated the UAS' effectiveness in improving inspection quality and inspector safety based on field results. A second research effort demonstrated UAS imaging on the Blatnik Bridge and investigated UAS use for infrared deck surveys. Additionally, a best practices document was created to identify bridges that are best suited for UAS inspection. It is the goal, based on this research, to implement a statewide UAS bridge inspection plan, which will identify overall cost effectiveness, improvements in quality and safety, and future funding sources for both state and local bridges. The project investigator will also investigate a collision tolerant drone for confined space inspections.

Final Report:
• [Report #2018-26](#)

Related Materials:
• [City Lab \(Atlantic\)](#) - (Video/Webinar)
• [Unmanned Aircraft Systems \(UAS\) - Metro District Bridge Inspection Implementation](#) - (Related Research)
• [New Project: Phase 3 of Drone Bridge Inspection Research Focuses on Confined Spaces](#) - (Article/Blog Post)
• [Phase 2 Study: Phase Two of Drone/Unmanned Aerial](#)

Project Personnel:
Principal Investigator: [Barry Lovelace](#)
Technical Liaison: [Jennifer Wells](#)
Project Coordinator: [Debra Fick](#)

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QUESTIONS?



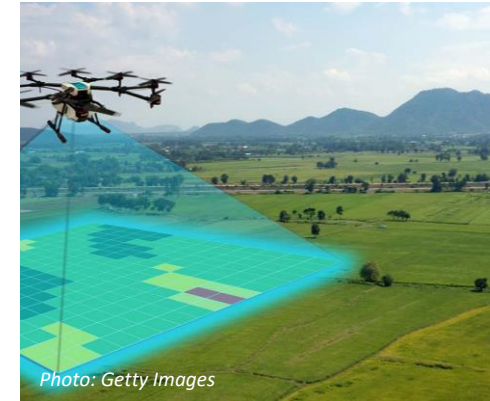
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U s e o f U A S i n B r i d g e I n s p e c t i o n

C h r i s t o p h e r P a r r i s h
O r e g o n S t a t e U n i v e r s i t y

FHWA – EDC-5



Oregon State
University

Outline

- Projects conducted to date
- Motivation for use of UAS in bridge inspection
- Operations
 - » Aircraft and sensor selection
 - » Workflow
 - » Safety plan
- Results of bridge inspections
- Cost-benefit analysis
- Key findings



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Projects



- OSU UAS Bridge Inspection Projects:
 - » PacTrans (2015): Cost-Effective Bridge Safety Inspection using Unmanned Aerial Vehicles
 - » Oregon DOT (2015-2018): SPR 787 - Eyes in the Sky: Bridge Inspections with Unmanned Aerial Vehicles
- Related projects
 - » FHWA (2015-2017): Effective Use of Geospatial Tools in Highway Construction (with WSP)
 - » PacTrans (2018): UAS in Transportation Expo
 - » PacTrans (2017-2019): An Airborne Lidar Scanning and Deep Learning System for Real-time Event Extraction and Control Policies in Urban Transportation Networks
 - » PacTrans (2020): Unmanned Aircraft Systems in Transportation: Research-to-Operation (R2O) Peer Exchange

Motivation

■ UAS

- » Simply one tool--but a potentially powerful one--for bridge inspection
 - Provides new method of remotely viewing bridge elements at high-resolution, while keeping both feet on the ground
 - Can reduce lane closures, use of bucket trucks, and climbing for some percentage of bridges to be inspected annually
 - ✓ *Enhance safety and reduce costs for some percentage of inspections*



Specific Project Goals (SPR 787)

- Evaluate performance of UAS for bridge inspection
- Identify inspection requirements that can and cannot be satisfied with UAS
- Provide cost-benefit analysis
- Develop SOPs
- Develop safety plan
- (Also extend analysis to inspection of communication towers)



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Aircraft and Sensor Analysis

- Main categories of remote aircraft:

Helicopters



Fixed-wing



**Best option for
structural inspections**

Multi-rotor

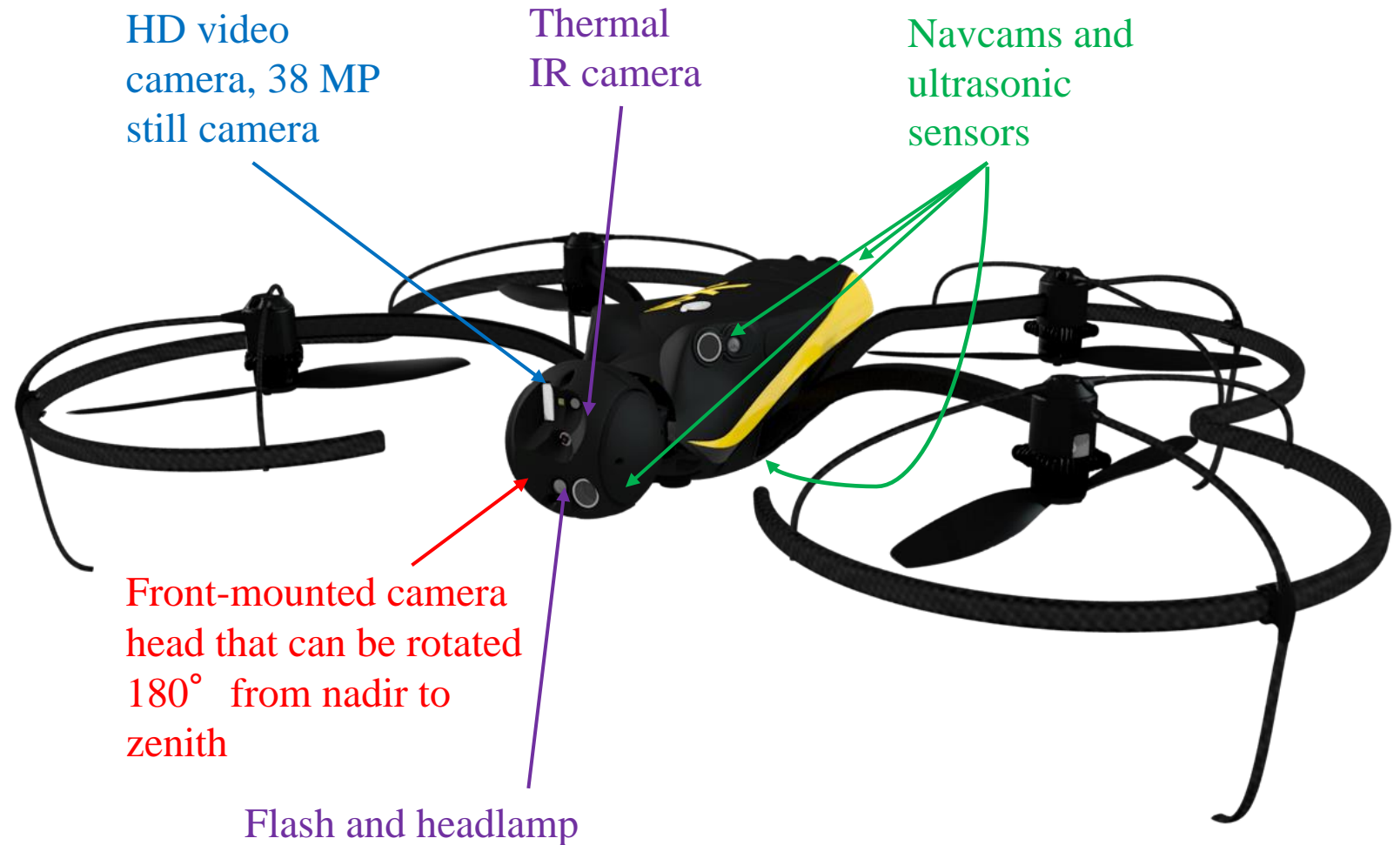


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Components of a UAS Designed for Structural Inspections



Flight planning software designed to facilitate inspection projects



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Importance of Rotating Sensor Head

A) Camera optical axis pointing down (nadir)

» Typical mapping configuration

B) Camera optical axis pointing horizontal

» Common in inspection work

C) Camera optical axis tilted up

» Common in inspection work



Importance of NavCams & Obstacle Avoidance

Navcams



Ultrasonic sensors

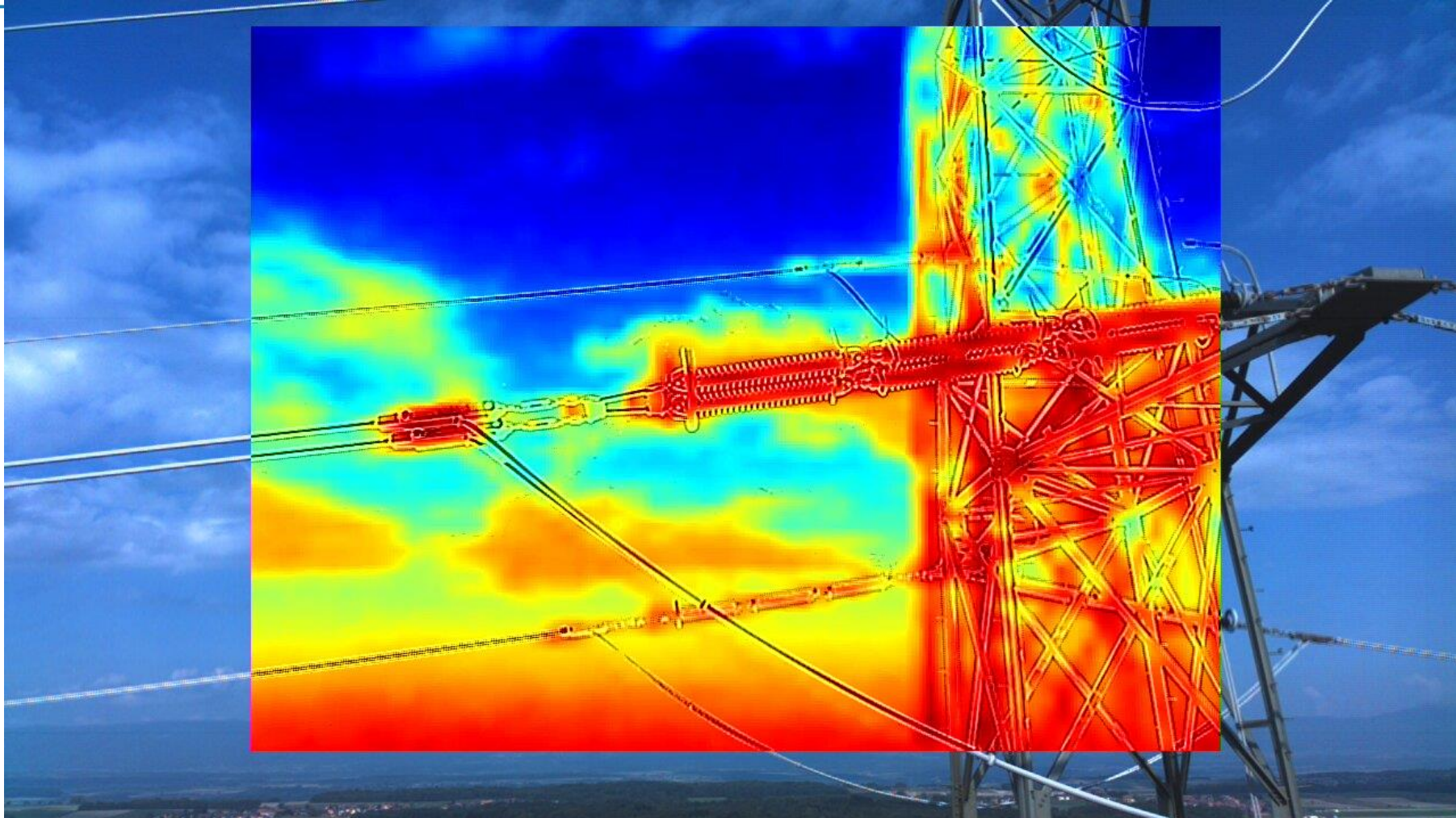


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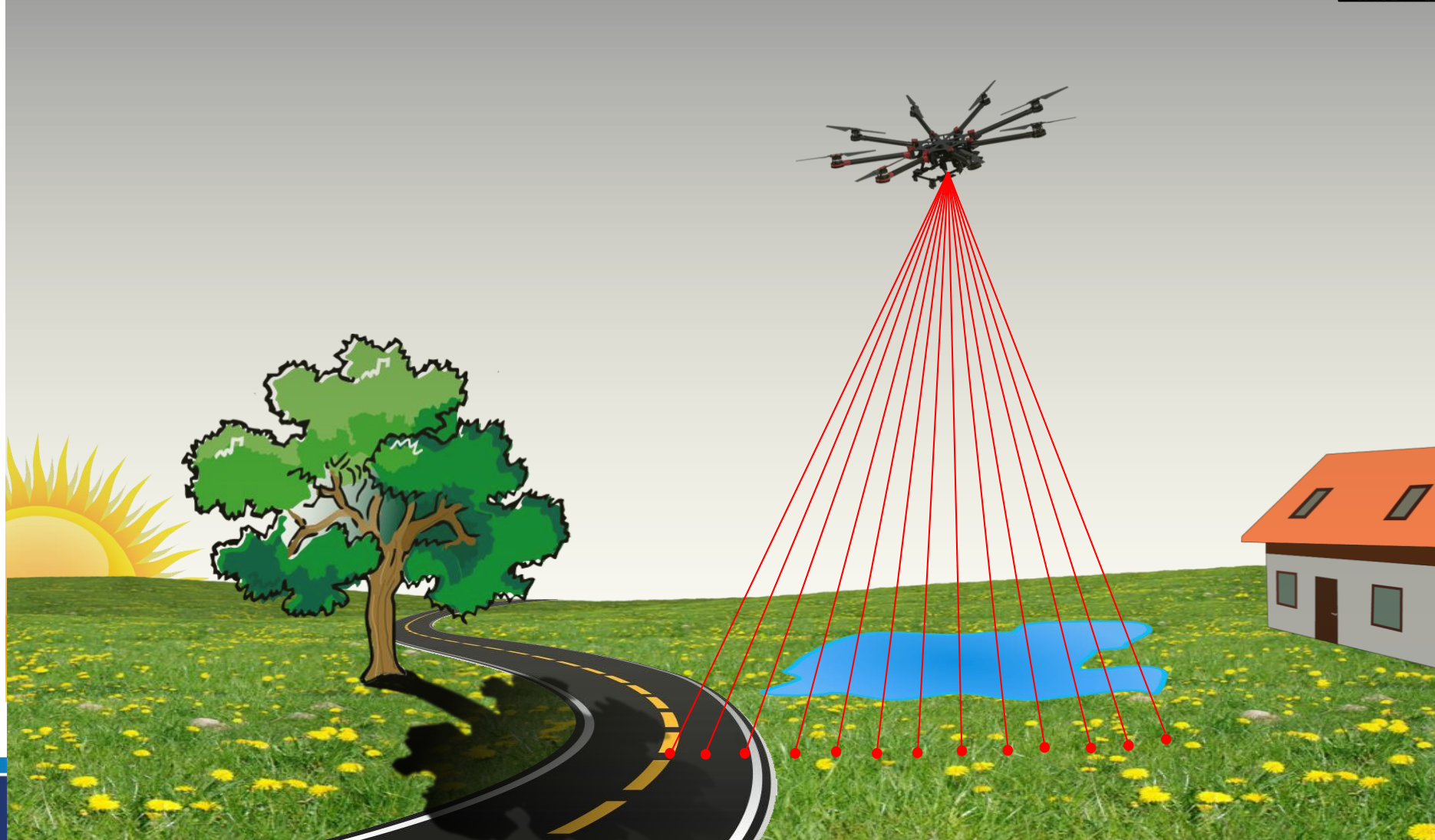


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Thermal Camera



Sensor Types: Lidar



Sensor Types: Cameras



Ground Control Station



Laptop/Computer

Datalink Antenna

Sun-Shade

Various Trays

Portable Music Stand

Marine Battery

- Takeoff and landing zone
 - » Large, clear, flat area
 - » Away from people
 - » Access permissions (!)



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Test Bridge Inspections

(1) Independence Bridge

(2) Crooked River Bridge

(3) Mill Creek Bridge

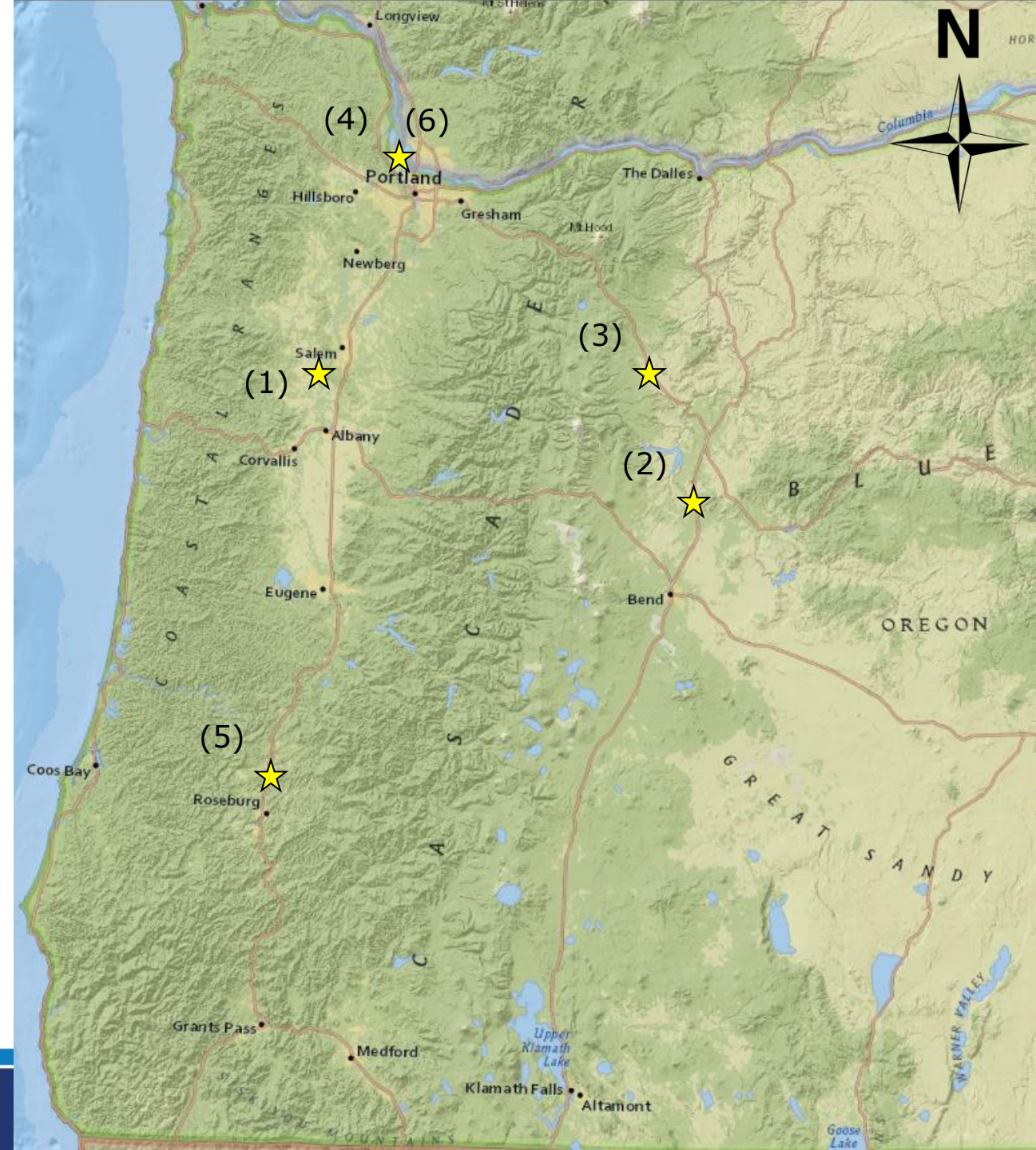
(4) St. Johns Bridge

» Preliminary

(5) Winchester Bridge

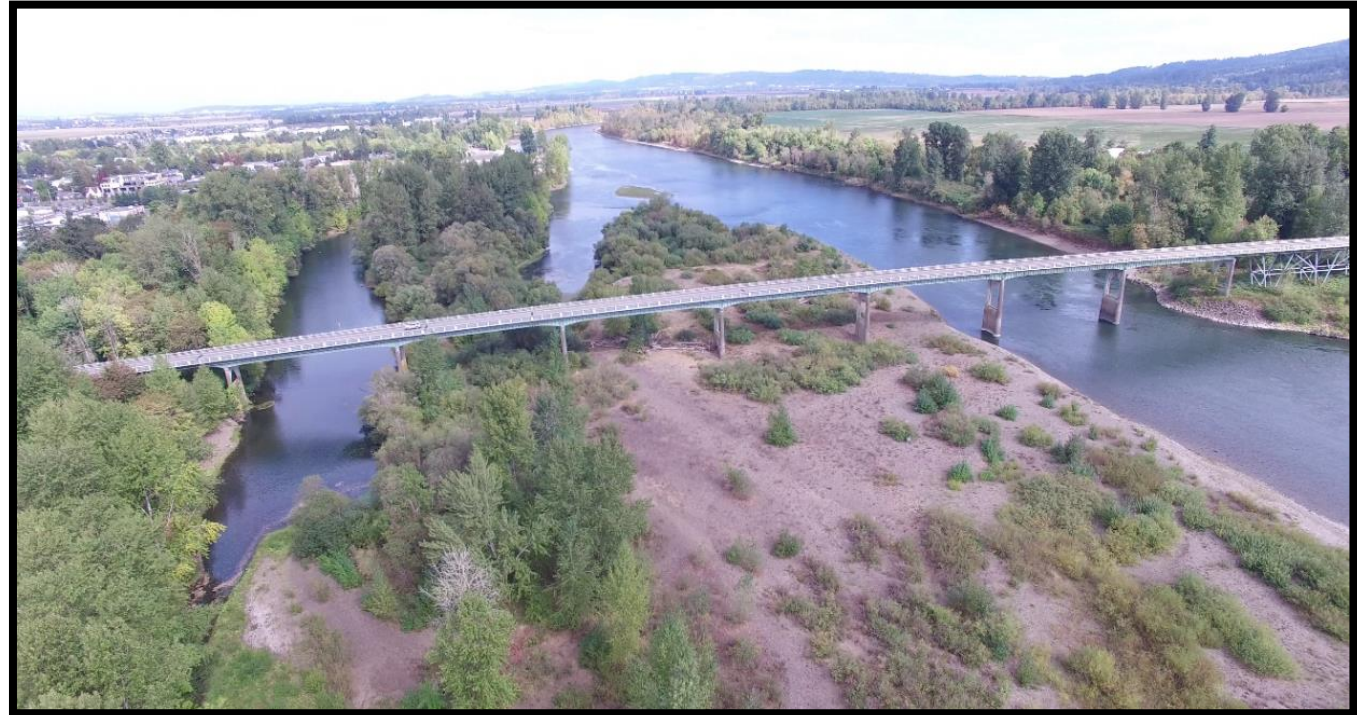
(6) St. Johns Bridge

» Detailed



Test Bridge Inspection: Independence Bridge, Sept 2015

- Location: Independence, OR
- Airframe: Phantom 3 Pro
- Flight objective
 - » Test bridge inspection workflow
 - » Capture still and video imagery
- Details
 - » Large deck plate girder bridge
 - 675.4 m long
 - Longest span: 46.3 m
 - » Classified as Fracture Critical



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Independence Bridge: Imagery Examples



Independence Bridge: Imagery Examples



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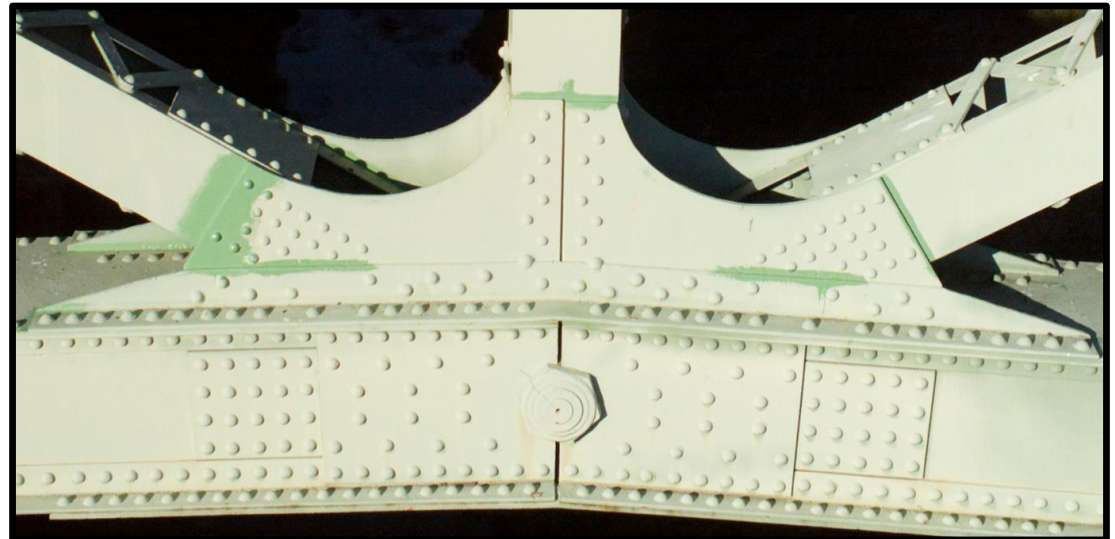
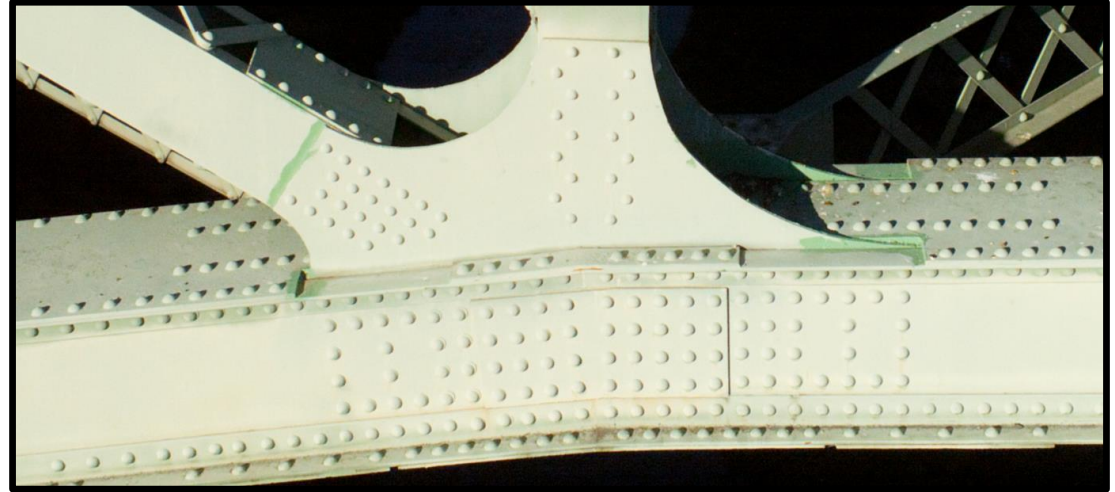
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Test Bridge Inspection: Crooked River Bridge, July 2016

- Location: 8 km north of Terrebonne, OR
- Airframe: senseFly Albris
- Flight objective
 - » Capture high-quality imagery for inspection purposes
 - » Targeting specific areas that are difficult to inspect using traditional methods
 - » Create 3D model via SfM
- Details
 - » Steel Arch Bridge
 - » 141 m long
 - Longest span: 100 m
 - » Pedestrian only



Crooked River Bridge: Imagery Examples



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Crooked River Bridge: Imagery Examples



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Crooked River Bridge: Mapping Flights



Crooked River Bridge: Point Cloud

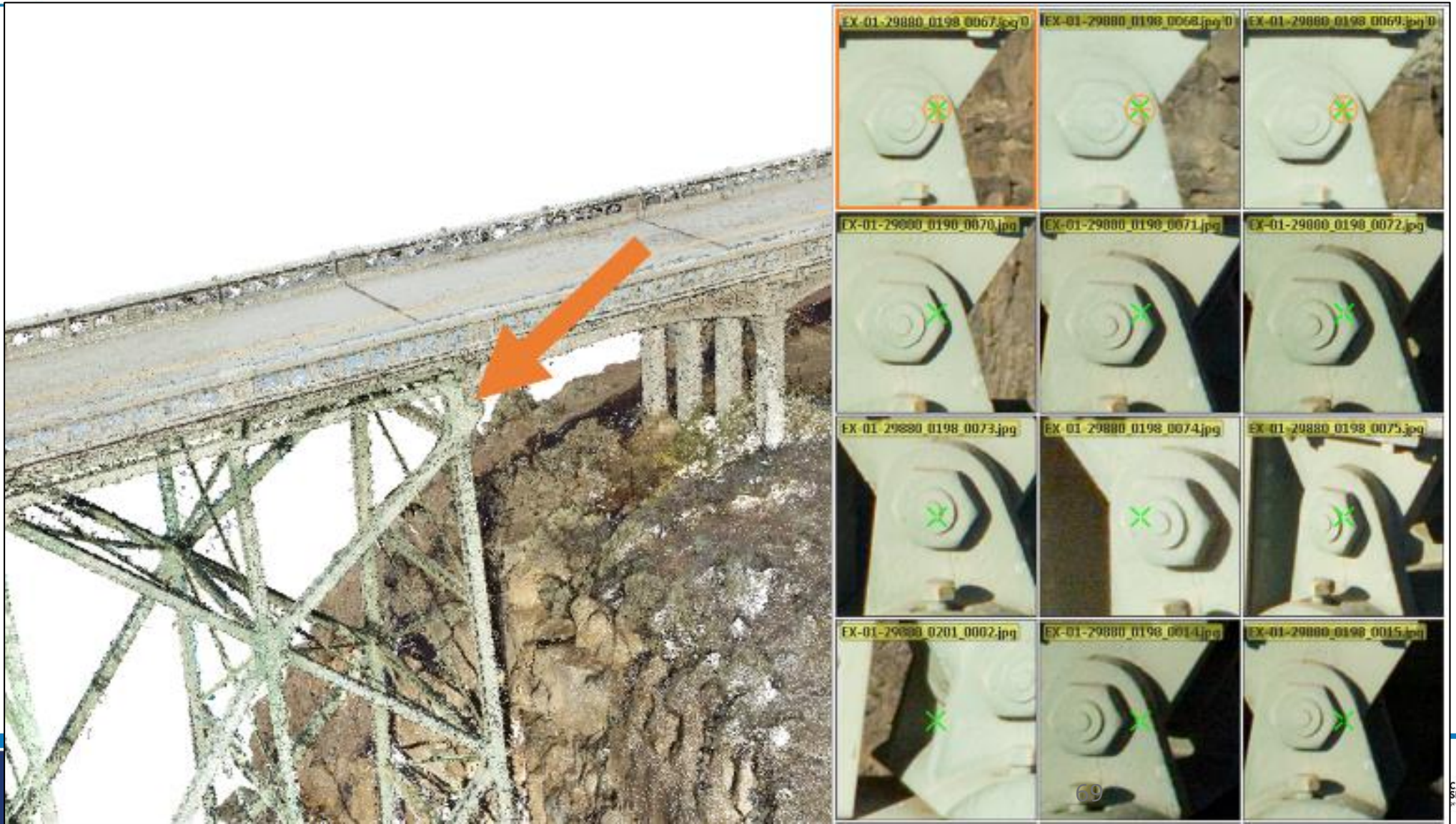


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Point Cloud ↔ Raw Imagery



Test Bridge Inspection: Mill Creek Bridge, July 2016

- Location: 17 km NW of Warm Springs, OR
- Airframe: senseFly Albris
- Flight objective
 - » Capture high-quality imagery for inspection purposes
 - » Targeting specific areas that are difficult to inspect using traditional methods
- Details
 - » Cantilevered Warren deck truss bridge
 - » 163 m long
 - Longest span: 50 m



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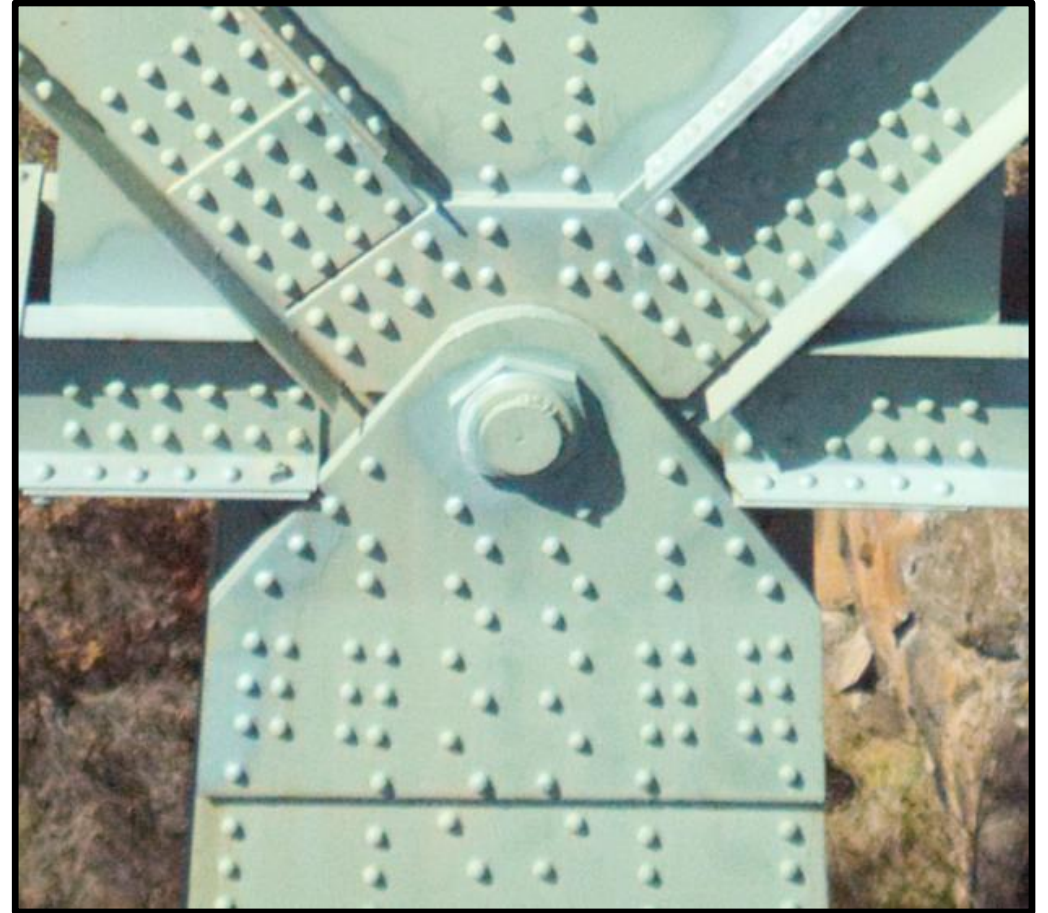


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Mill Creek Bridge: Imagery Examples



Mill Creek Bridge: Imagery Examples



Test Bridge Inspection: St. Johns Bridge (Prelim Test), Sept 2016

- Location: Portland, OR
- Airframes: senseFly Albris, s900 with Sony WX500 (30x optical zoom)
- Flight objective
 - » Test of optical zoom camera
 - » Capture high-quality imagery
- Details
 - » Metal Riveted Warren deck truss
 - » Wire Cable Suspension
 - » 1100 m long
 - Longest span: 368 m



St. Johns Bridge: Imagery Examples



St. Johns Bridge: Imagery Examples



St. Johns Bridge: Imagery Examples



Test Bridge Inspection: Winchester Bridge, March 2017

- Location: Winchester, OR
- Airframes: senseFly Albris
- Flight objective
 - » Capture imagery while receiving real-time input from inspectors
- Details
 - » Warren deck truss bridge
 - » Southbound bridge of I-5
 - » 500 m long
 - Longest span: 42 m



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Winchester Bridge: Imagery Examples



Winchester Bridge: Imagery Examples



Test Bridge Inspection: St. Johns Bridge (Detailed Test), April 2017

- Location: Portland, OR
- Airframes: senseFly Albris
- Flight objective
 - » Week-long, in-depth inspection
 - » Test inspecting directly under deck
- Details
 - » Metal Riveted Warren deck truss
 - » Wire Cable Suspension
 - » 1100 m long
 - Longest span: 368 m
 - » Flight limited to eastern 550 m from center of main span

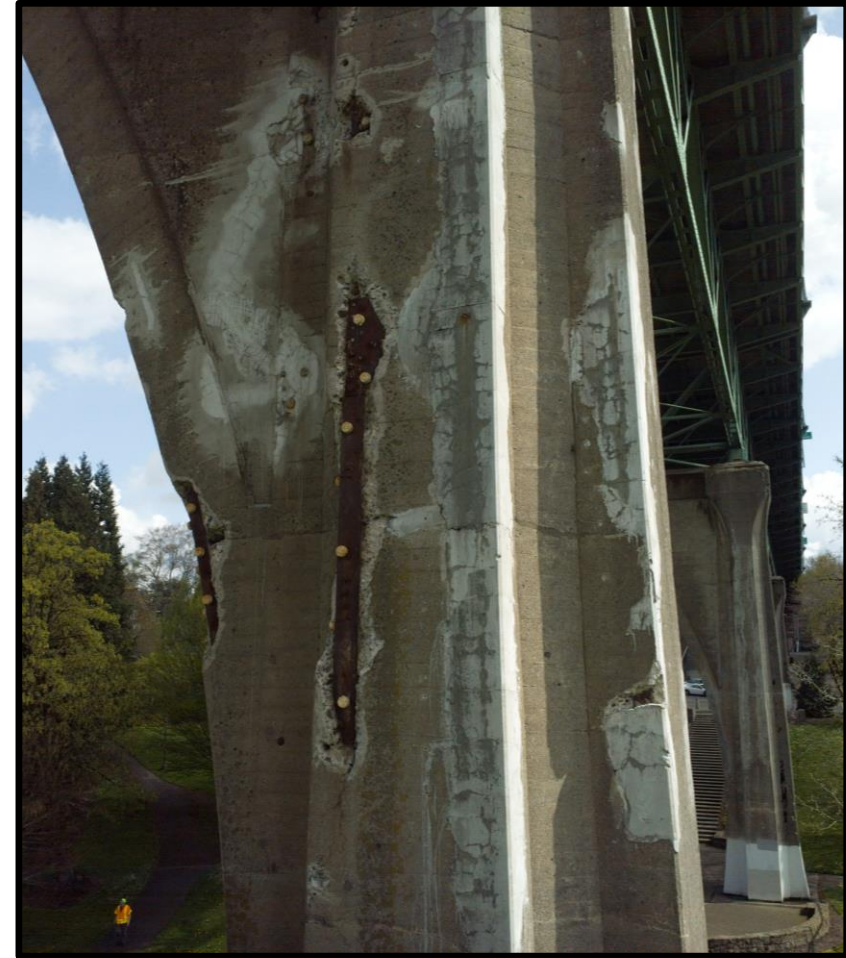


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St. Johns Bridge: Imagery Examples



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St. Johns Bridge: Imagery Examples



St. Johns Bridge: Imagery Examples



St. Johns Bridge: Imagery Examples



St. Johns Bridge: Imagery Examples



St. Johns Bridge: Imagery Examples



Cost-Benefit Analysis Procedures

1. Establish baseline costs for bridge inspections conducted *without* the use of UAS by compiling existing data from Oregon DOT
 - » 33 bridge inspection project budget spreadsheets
2. Determine the percentage of bridges that Oregon DOT inspects that are suitable for UAS inspection
 - » Airspace, proximity to populated areas, vegetation, size of bridge, etc.
3. Establish which project cost categories could be reduced (not eliminated) through use of UAS:
 - » Personnel time (field and office)
 - » Equipment rental/usage (e.g., snoopers trucks)
 - » Traffic control
 - » Travel (including lodging, meals and incidentals)



Cost-Benefit Analysis Procedures (cont'd)

4. Estimated annual cost savings = (average cost savings per suitable bridge) \times (# of bridges/yr inspected by ODOT) \times (percentage of bridges suitable for UAS inspection)

5. Estimate costs:

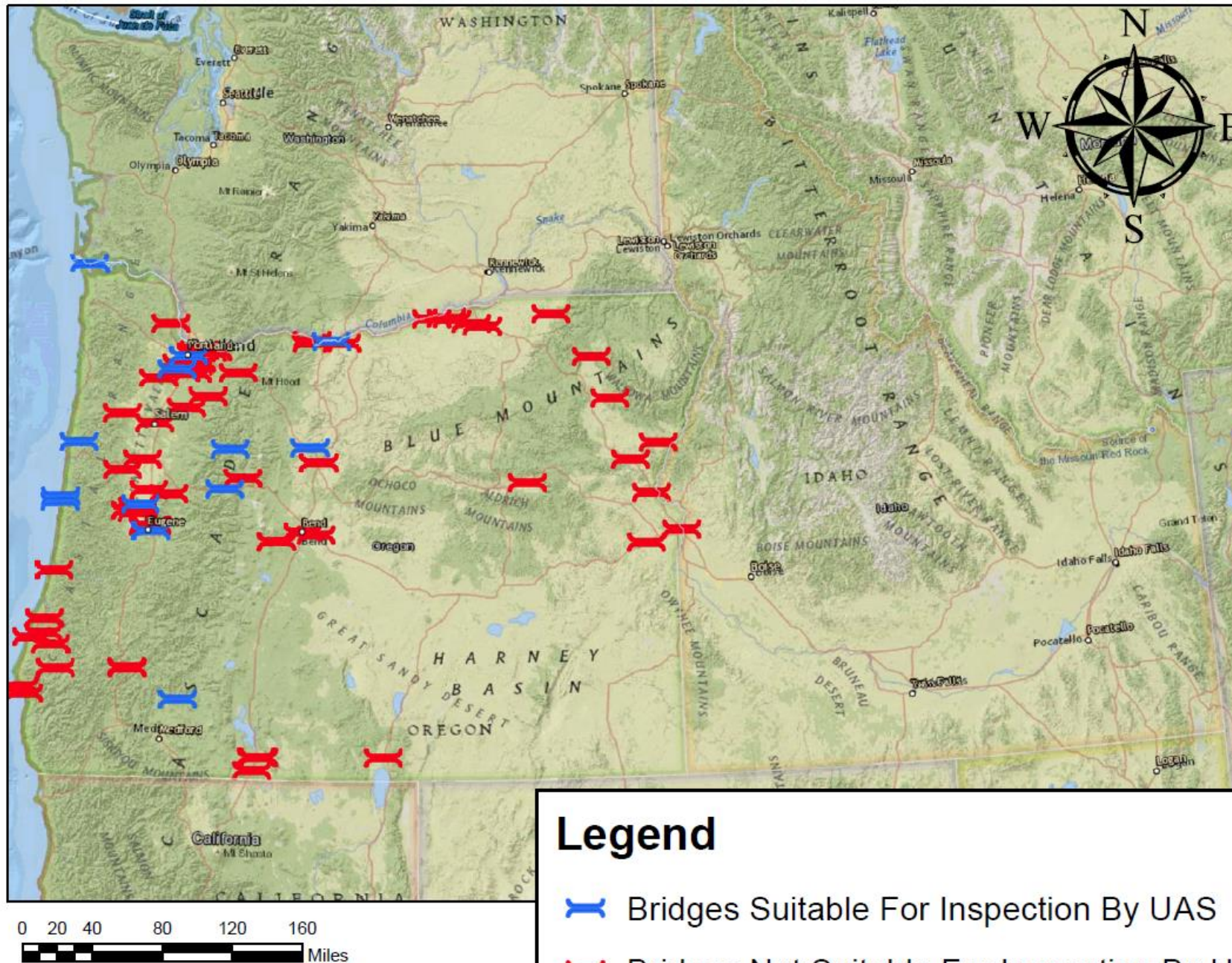
- » Cost of purchasing 3 UAS
- » Annual maintenance cost
- » Data storage

$$B = \$10,200(730 \times 0.16) = \$1,191,360$$

$$\sum C = \$117,237 + \$4,500 + \$5,700 = \$127,437$$

$$BCR = \frac{\$1,191,360}{\$127,437} \approx 9$$





- Reasons bridges were deemed “not suitable”
 - Low height, low clearance bridges, where it wouldn’t be worthwhile to use UAS
 - Airspace
 - Access issues
 - Vegetation poses risks to UAS
 - Lack of suitable takeoff/landing site

Key Project Findings

- 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
- Cost-benefit analysis provides strong indication of positive ROI for implementing UAS in ODOT's bridge inspection program
 - » Potential for >\$1M in savings/year from use of UAS in structural inspections in large bridge inspection program
 - » Should be refined as more data becomes available

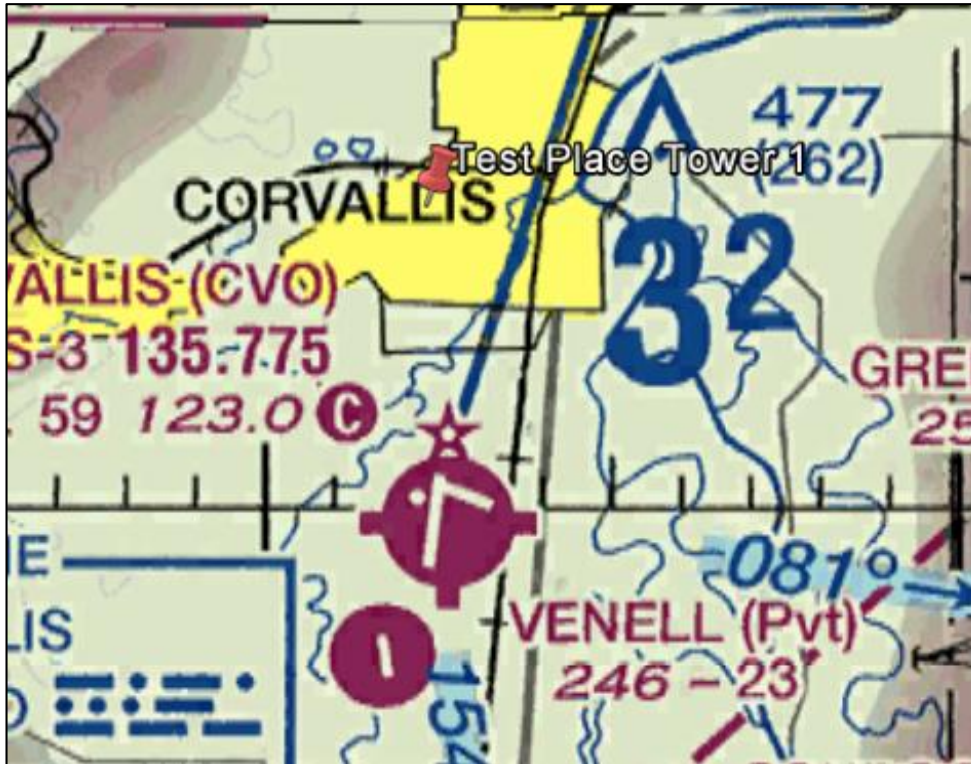


Practical Recommendations/Lessons-Learned

- Remote aircraft requirements
 - » Variable tilt (0-180°) camera
 - » Zoom lens
 - » Obstacle avoidance capabilities
 - » Establish max wind speeds for structural inspections (aircraft dependent)
- Personnel requirements
 - » UAS bridge inspection flight crews should have at least a basic level of expertise in photography
 - ISO, aperture, shutter speed
 - » Frequent practice (proficiency flights) *specifically for structural inspection*
 - Simulate: loss of GPS, wind gusts, operating near large structure



Safety Plan



Date of Assessment:	04/25/2016	Personnel:	Pilot in Command:	Tom Normandy
Structure Type:	Communication Tower		Primary Observer:	Matt Gillins
Location of Structure:	44°26'10.8" N 122°59'07.1" W		Other Spotters:	Farid Javadnejad Dan Gillins Chris Parrish
Owner of Structure:	ODOT			
Owner's Contact info:	555 13th St NE Salem, OR 97301-6867 Phone (503) 986-2700		COA Number:	2015-AHQ-105-COA-TS
			Team 's Emergency Contact Number:	(818)-497-8576
Airport within 5 nm?	Yes: X	No:	Airport Manager:	Jacob Kropf
If Yes Which:	J & J airport		Manger Contact info:	(541)-766-6783
Distance from Airport:	3.2 nm		Radio Frequency Air Traffic Controller:	N/A UNICOM 123.0

Safety Inventory: Mark yes or no if any of the following hazards are potential for work site.

YES	NO	Equipment Hazards	YES	NO	Personal Hazards	YES	NO	Environmental Hazards
X		Nearby Vehicular Traffic		X	Twisting/Bending/Awkward Positions/ Heavy Lifting		X	Falling Debris
	X	Nearby Heavy Equipment Operations		X	Working Over water		X	Confined Space
	X	Transport/Launch of Boat/ATV/Etc.		X	Loose unstable footing	X		Weather Related
	X	Boat/Watercraft Operations	X		Slip/Trip/Fall Hazard	X		Live Stock/Wildlife
	X	ATV Operations		X	Ladders/Elevated Platforms	X		Transients
X		Other		X	Other		X	Other



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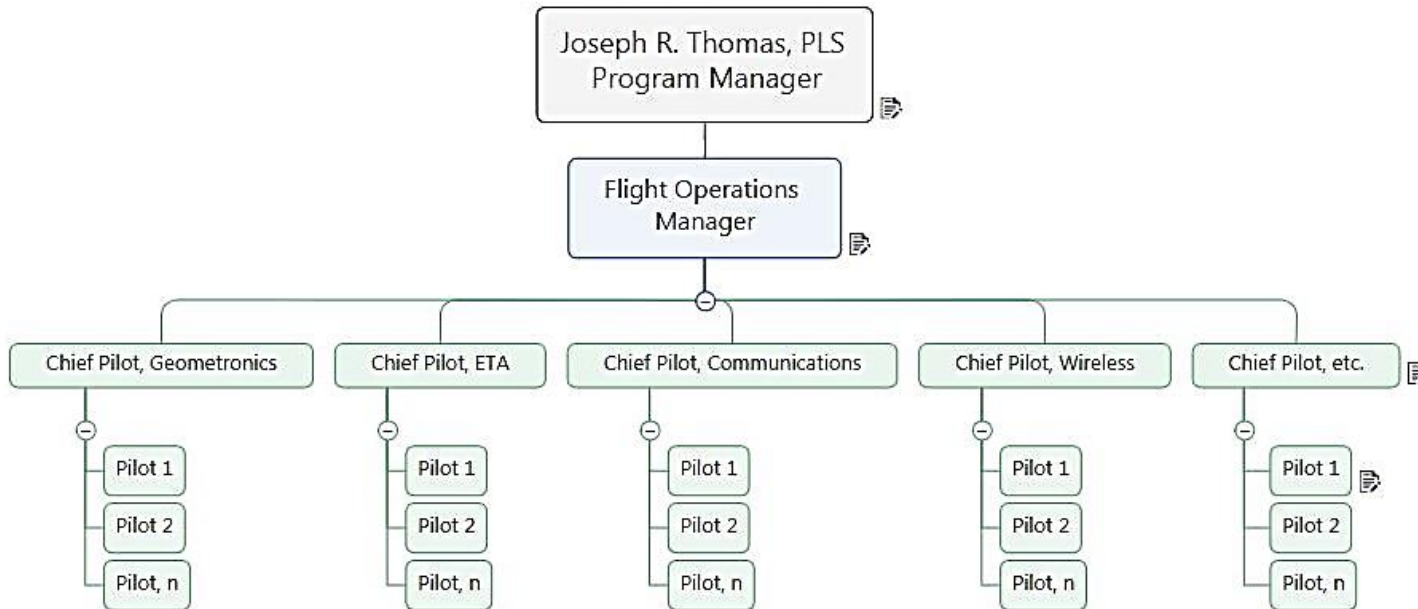
Oregon DOT UAS Program

UNMANNED AIRCRAFT SYSTEMS (UAS)

Operations Manual

July 2017

Oregon
Department of
Transportation



Courtesy of Chris Glantz, PLS, Oregon Department of Transportation

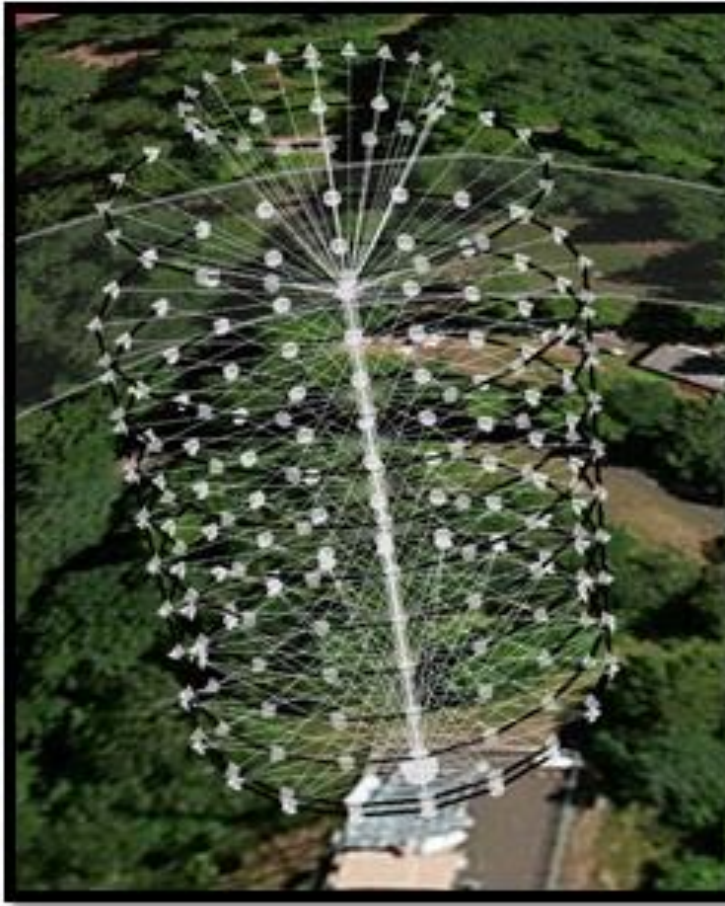


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Related Work: Communication Tower Inspections

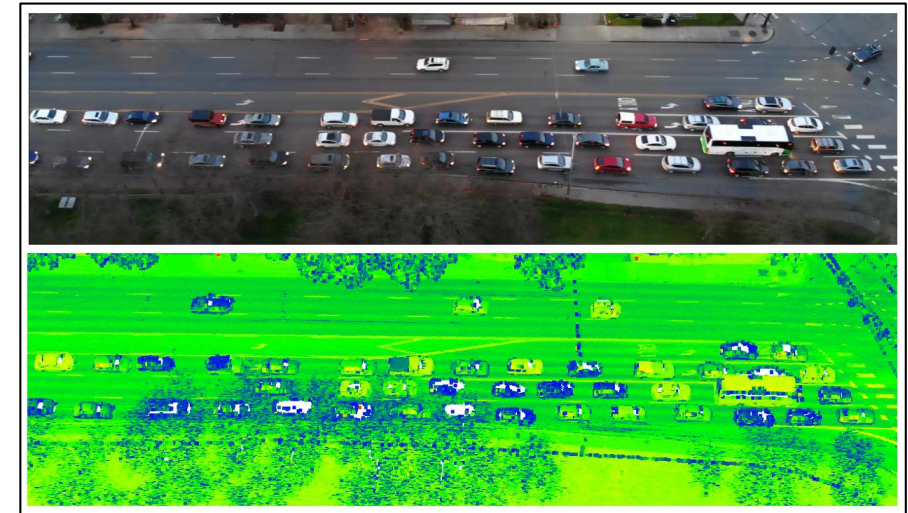
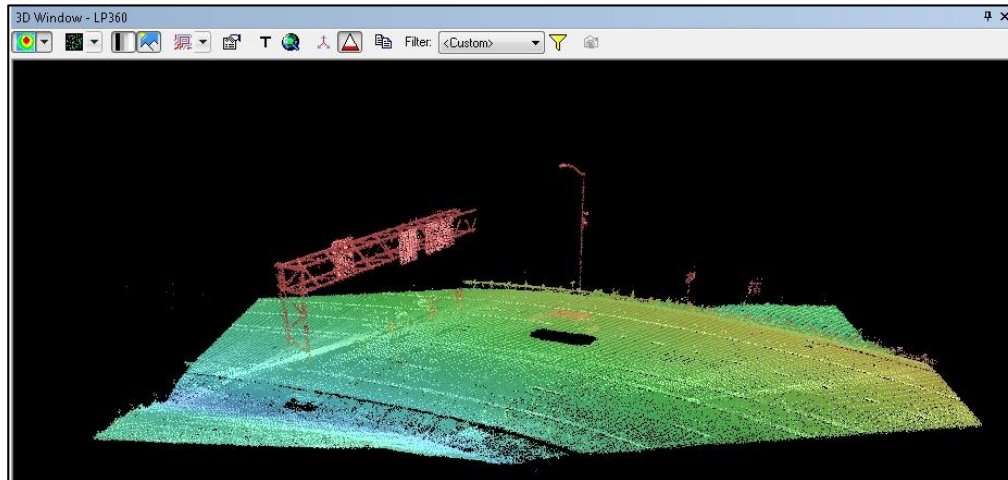
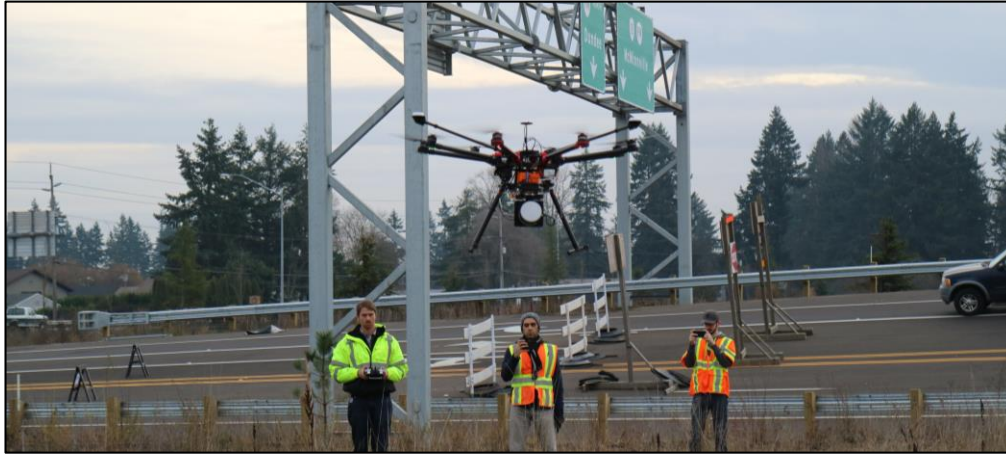


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Related Work: UAS Traffic Network Monitoring (PacTrans)



References

- Gillins, D.T., C.E. Parrish, and M.N. Gillins, 2018. *Eyes in the Sky: Bridge Inspections with Unmanned Aerial Vehicles, SPR 787 Final Report*. Oregon Department of Transportation: https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR787_Eyes_in_the_Sky.pdf
- Gillins, M.N., D.T. Gillins, and C. Parrish, 2016. Cost-Effective Bridge Safety Inspection using Unmanned Aircraft Systems (UAS). GEO Structures Congress 2016 14-17 Feb, Phoenix, Arizona.
- Parrish, C.E., D. Hurwitz, C. Simpson, S. Sorour, and A. Abdel-Rahim, 2019. *An Airborne Lidar Scanning And Machine Learning System For Real-time Event Extraction And Control Policies In Urban Transportation Networks*. PacTrans Final Project Report (in review).
- Parrish, C., R. Slocum, and C. Simpson, 2018. UAS in Transportation Expo Final Report, online: <http://depts.washington.edu/pactrans/wp-content/uploads/2018/11/UAS-in-Transportation-Report.pdf>



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Question & Answer



Jagannath Mallela
Moderator



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