

Structure Inspections Utilizing UAS

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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





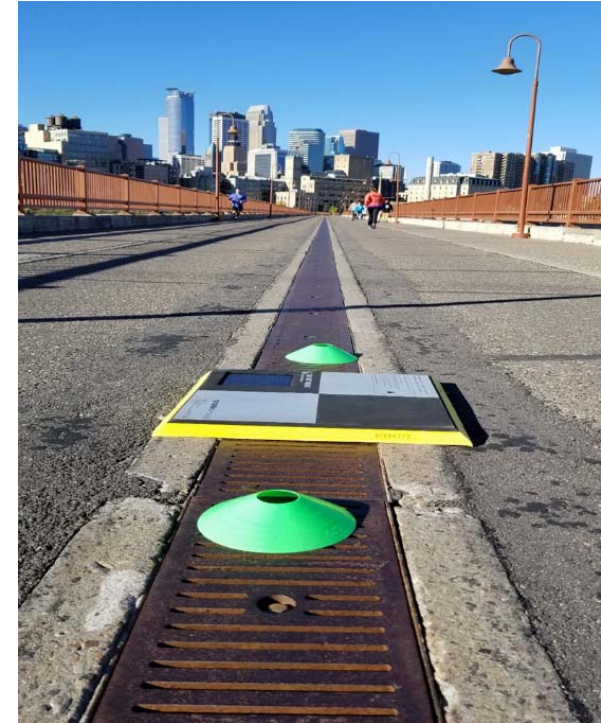
Sensor Size Importance



Assessment of UAS Technology

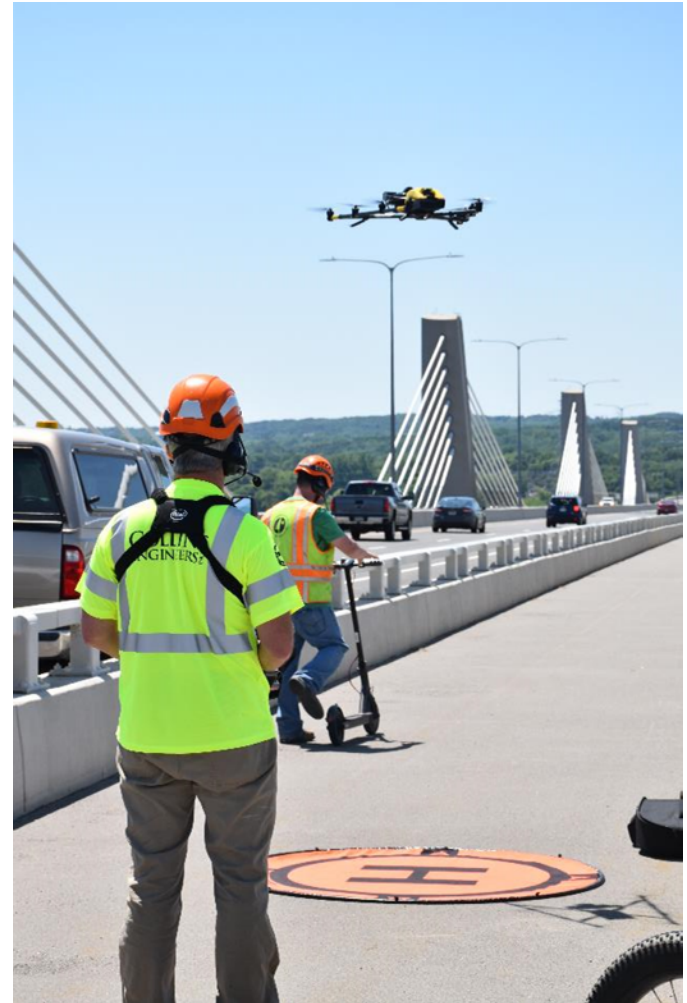
Propeller Aeropoints

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



Structure Inspection Goals

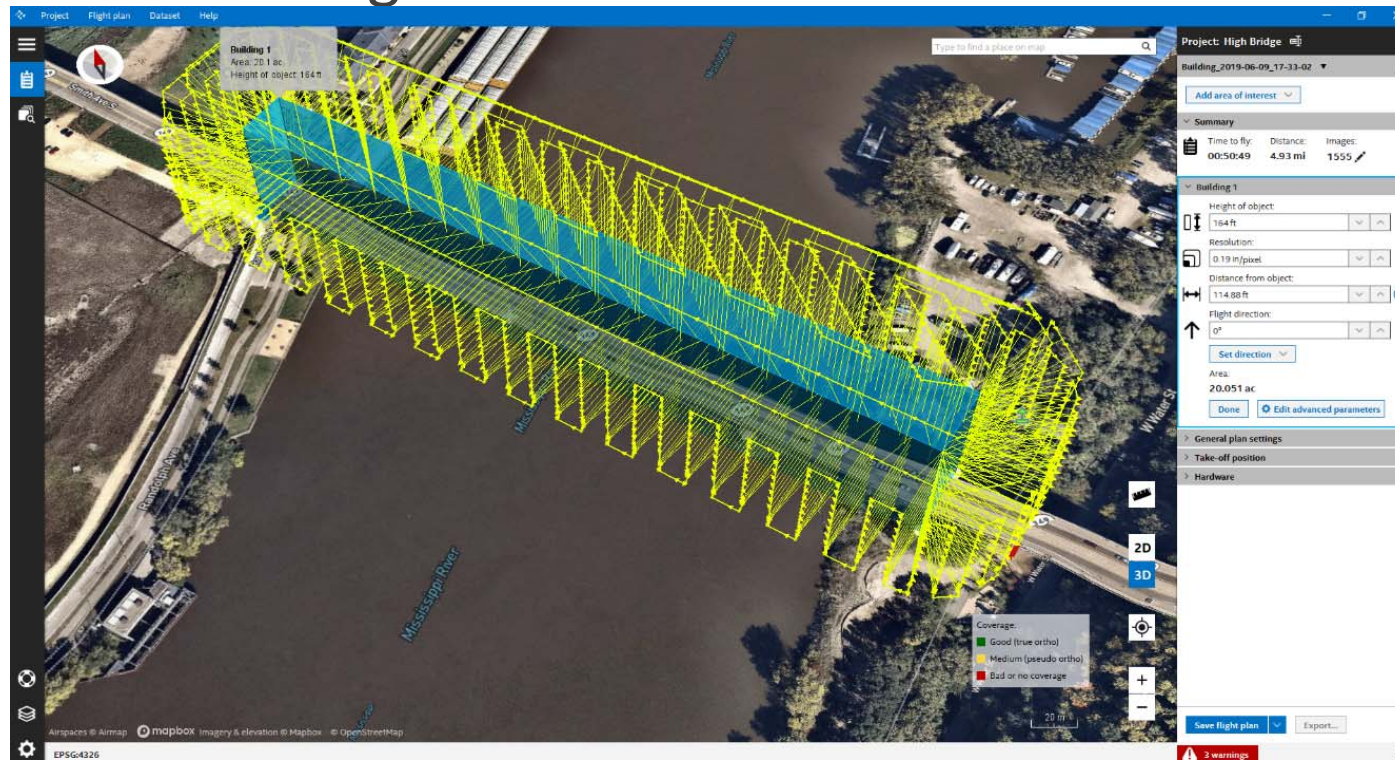
1. Inspection Planning
2. Detect Conditions and Deficiencies
3. Document
4. Communicate



1. Inspection Planning with UAS

Flight Planning

- 3D Autonomous Flights



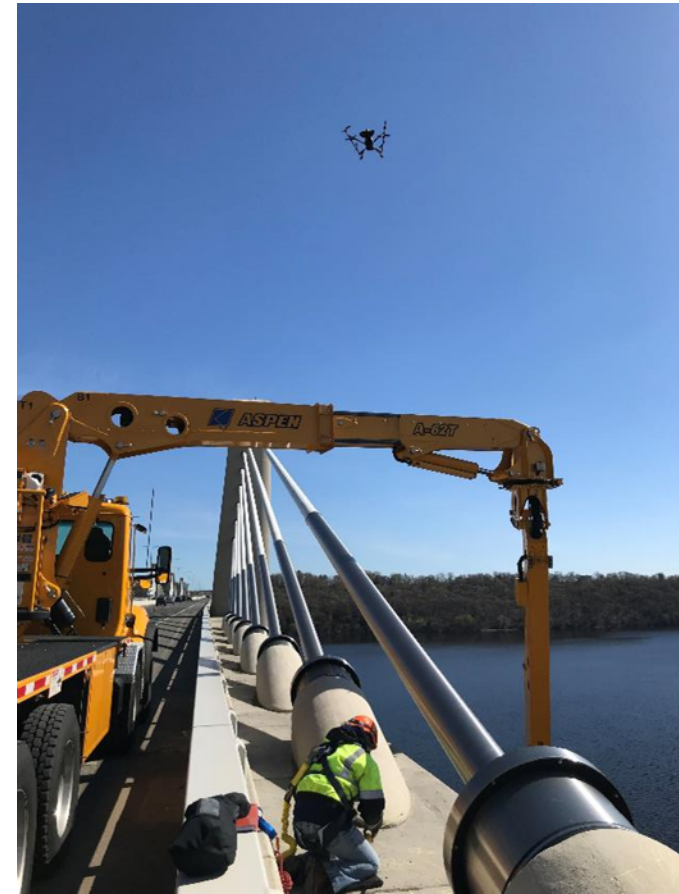
2. Detection of Defects and Deficiencies

- 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




3. Document Conditions and Deficiencies

Deliverables – Point Clouds




4. Communicate Conditions and Deficiencies


 Haleiwa Bridge







FILES






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SHARE

 2D





 3D














Inspection

DSC01764_1553275704000










SAVE INSPECTION AS ANNOTATION

We found 47 images matching the selected point of the model. They will be included in the inspection annotation.

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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

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

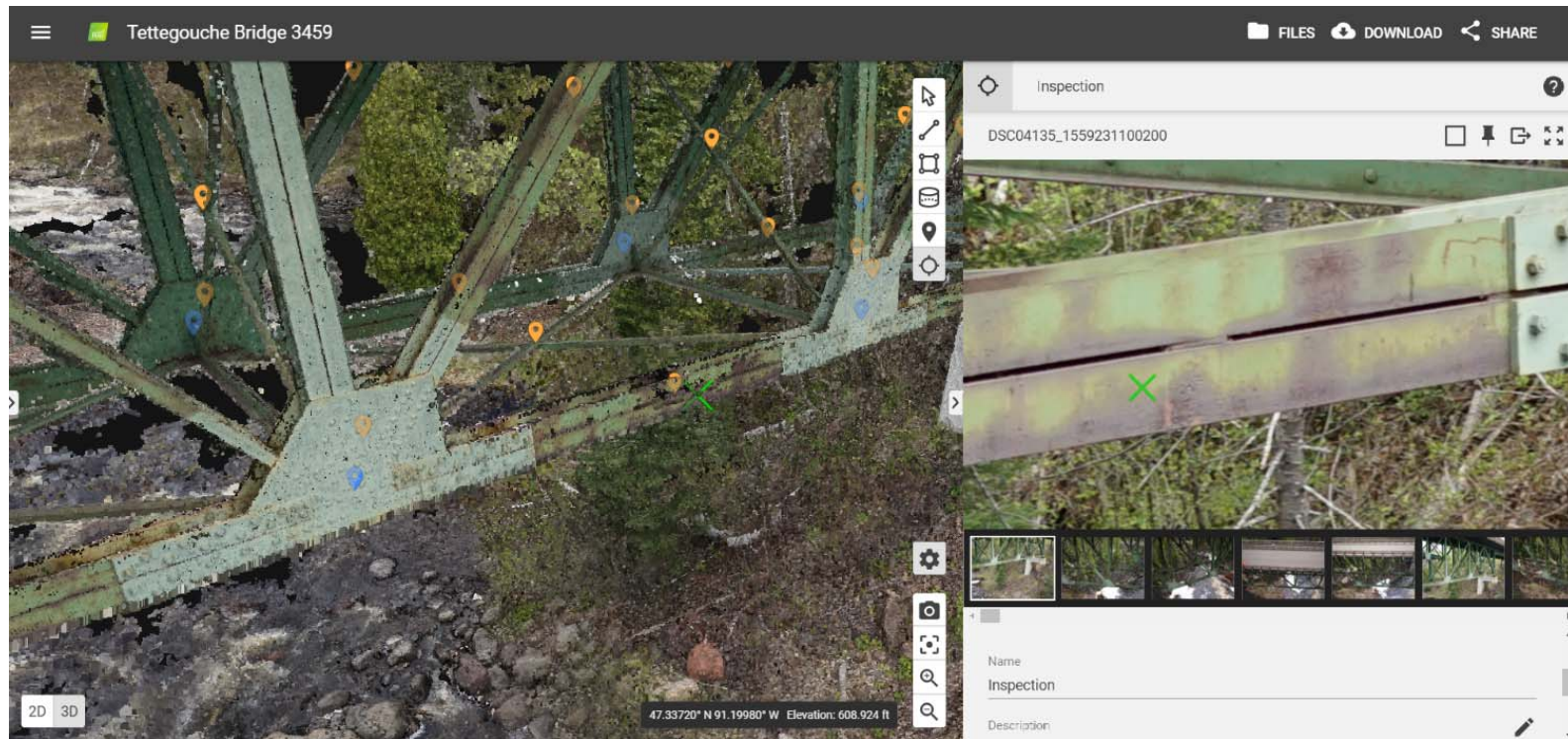
639.4789887666702

Elevation

639.469 ft

4. Communicate Conditions and Deficiencies

- Cloud Sharing

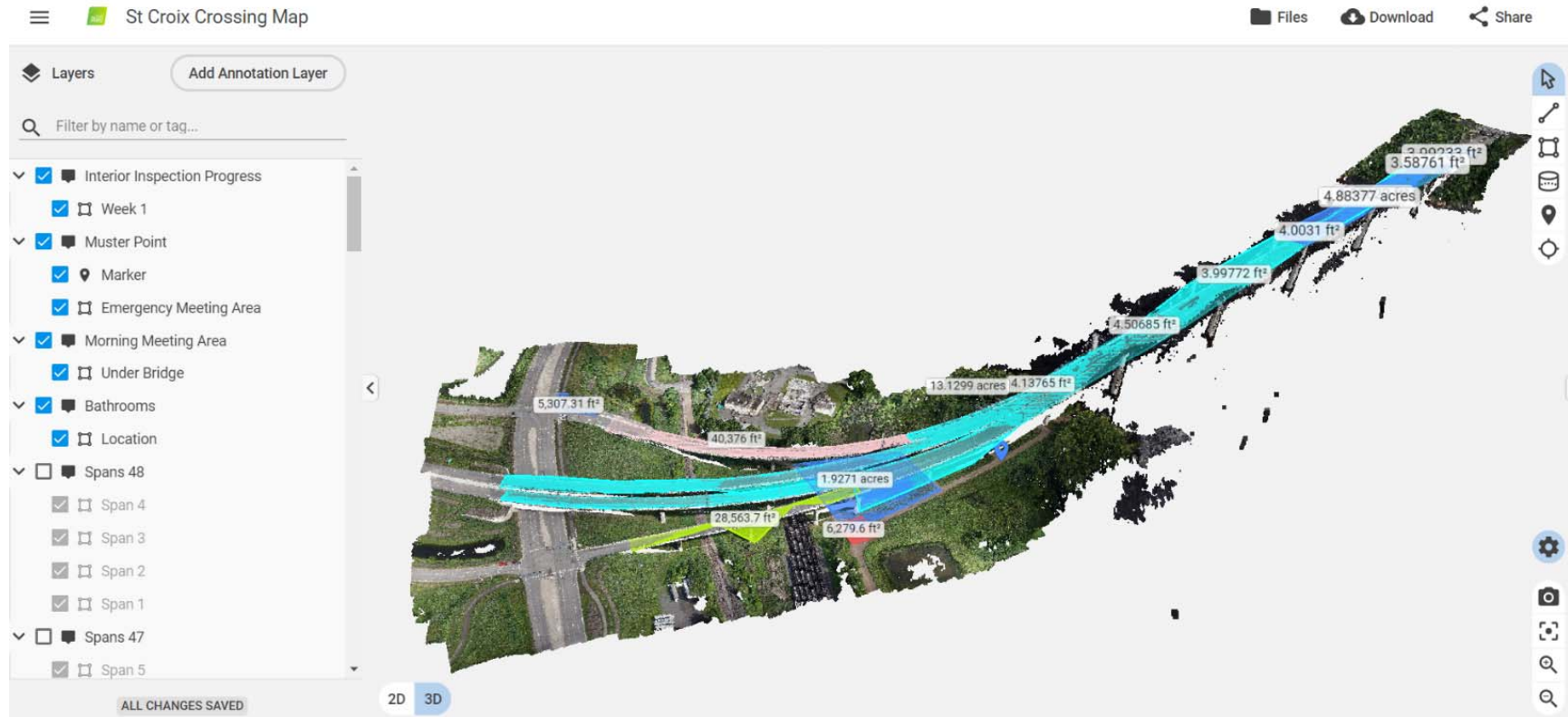


Case Study – St. Croix Crossing Extradosed Bridge

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



Case Study – St. Croix Crossing Extradosed Bridge



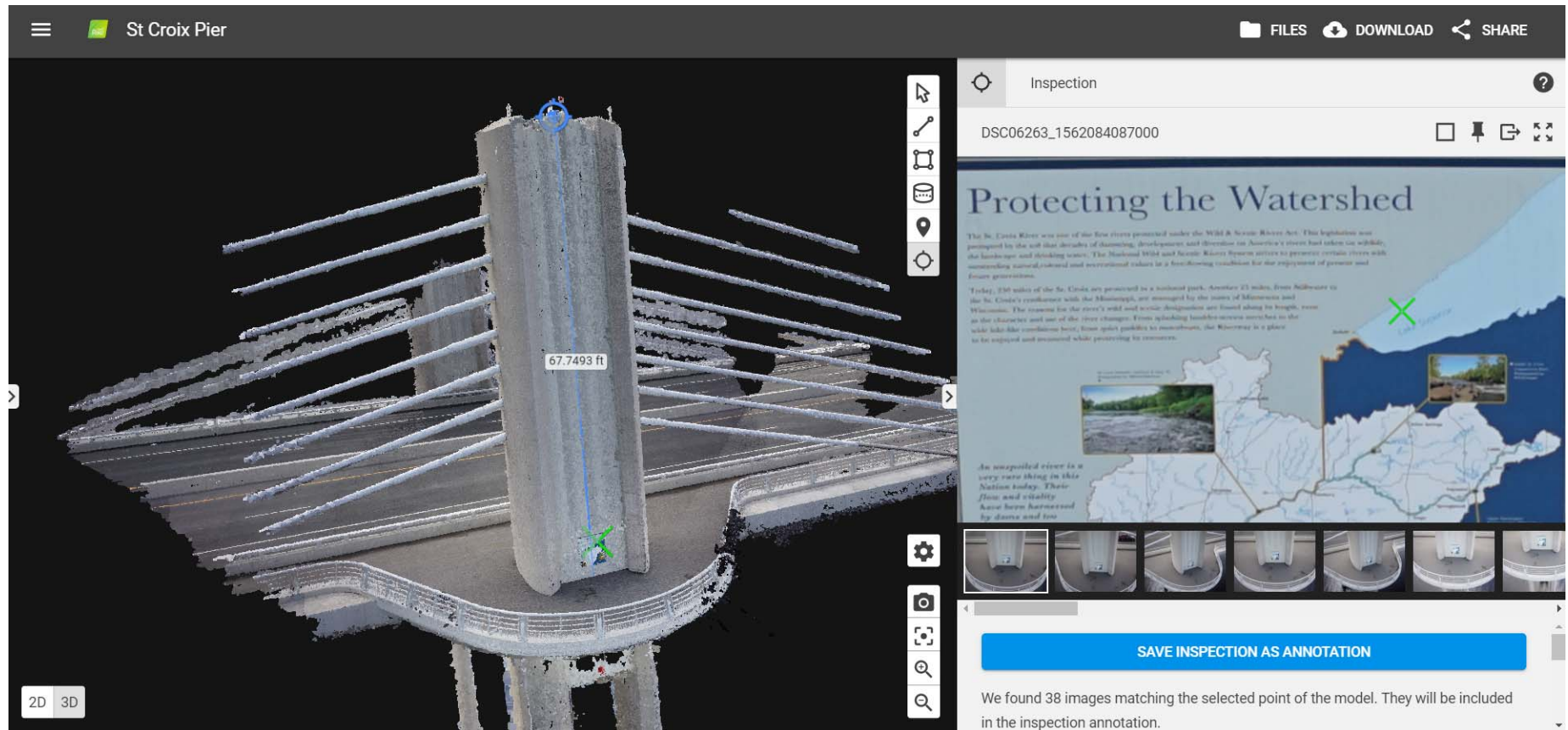
<https://cloud.pix4d.com/pro/project/507277/model?shareToken=352346c7-7098-44ca-9b52-07f1c9ecee1>

- 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







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



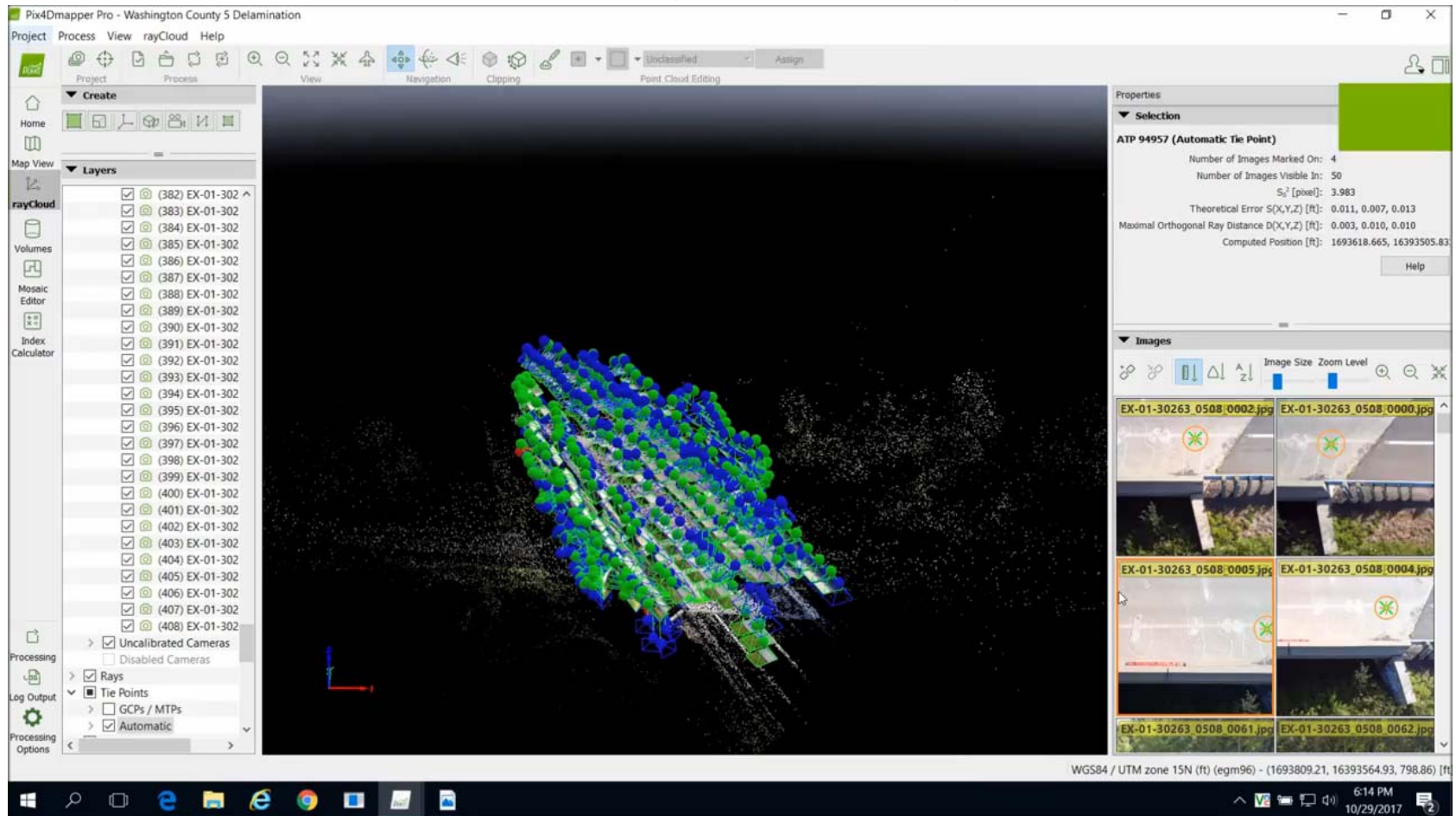
Other Applications - Infrared



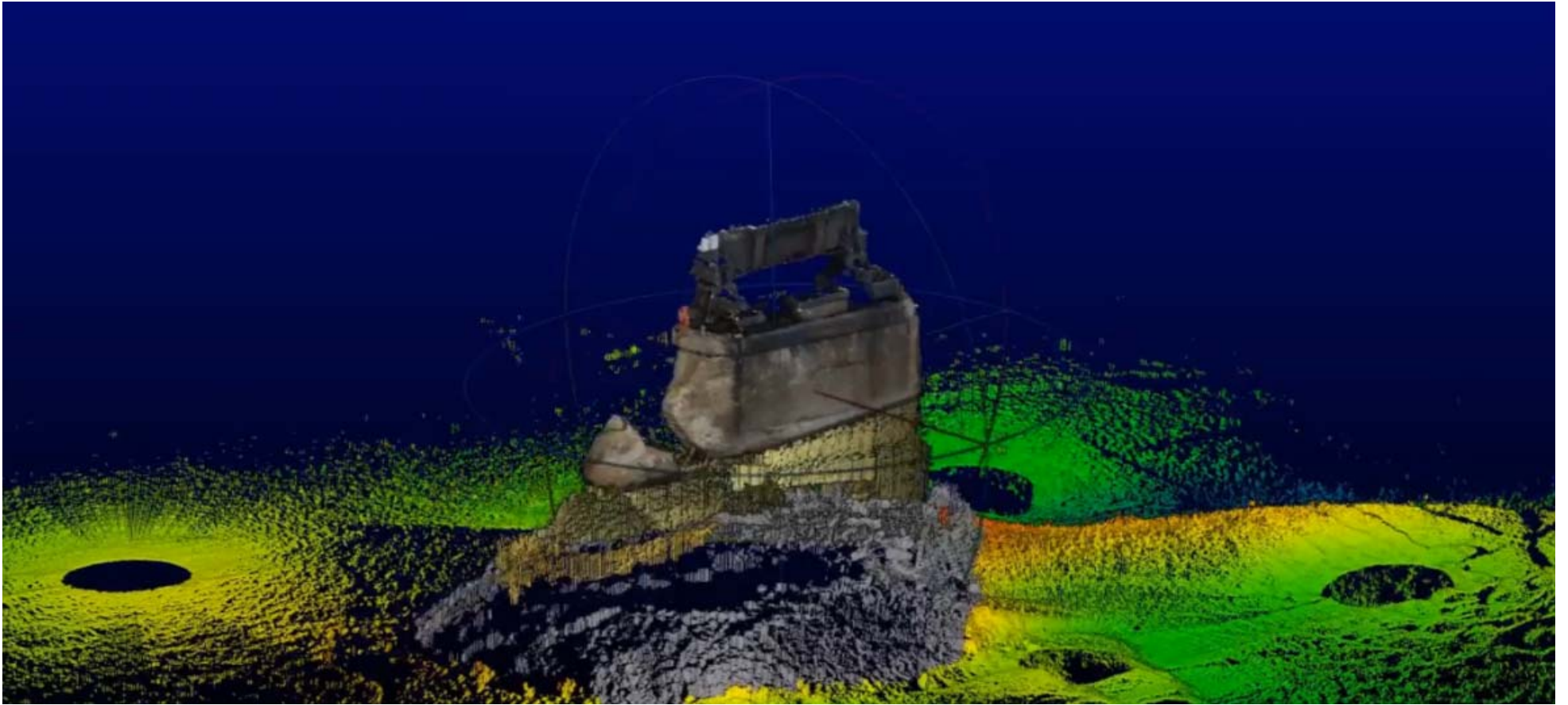
Other Applications – 3D Modeling



Other Applications – 3D Modeling (Photo Log)




Other Applications – Pairing with Underwater 3D Modeling



Other Applications – Corridor Modeling



Other Applications – Overhead Signs








35W at 31st Street Corridor Map

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Inspection

EX-01-30263_0626_00...



SAVE INSPECTION AS ANNOTATION

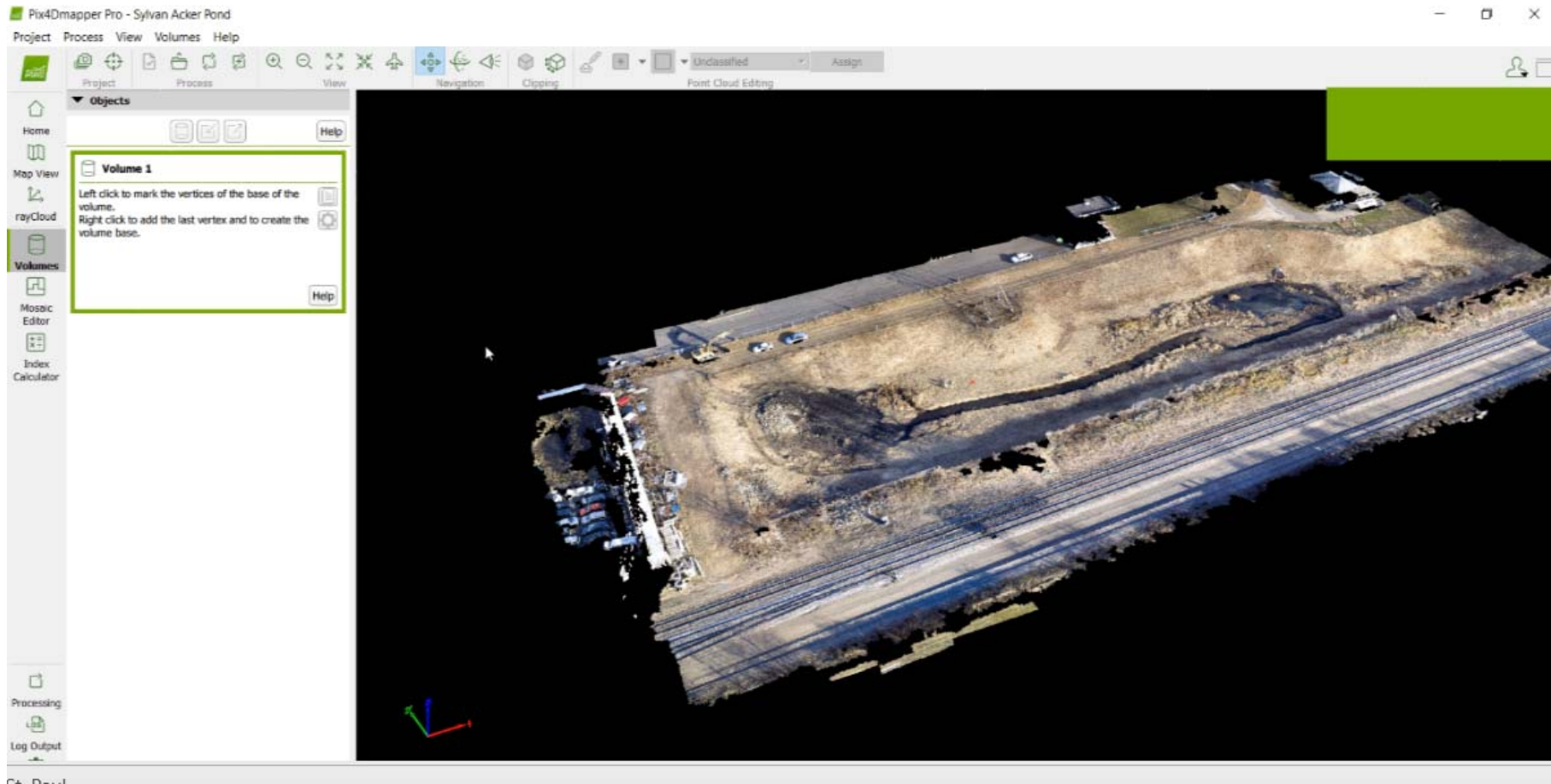
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Description

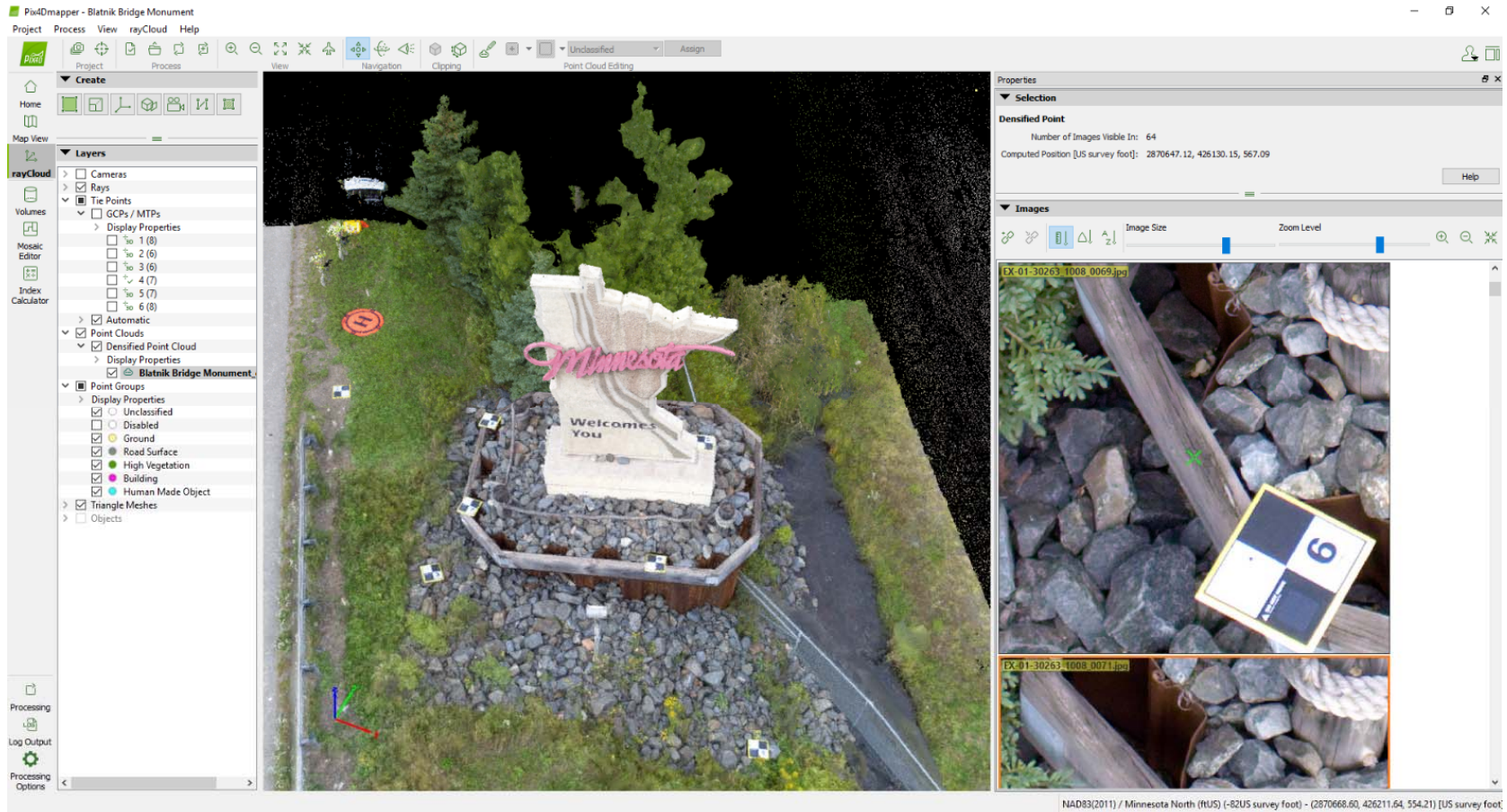
No Description

Annotations

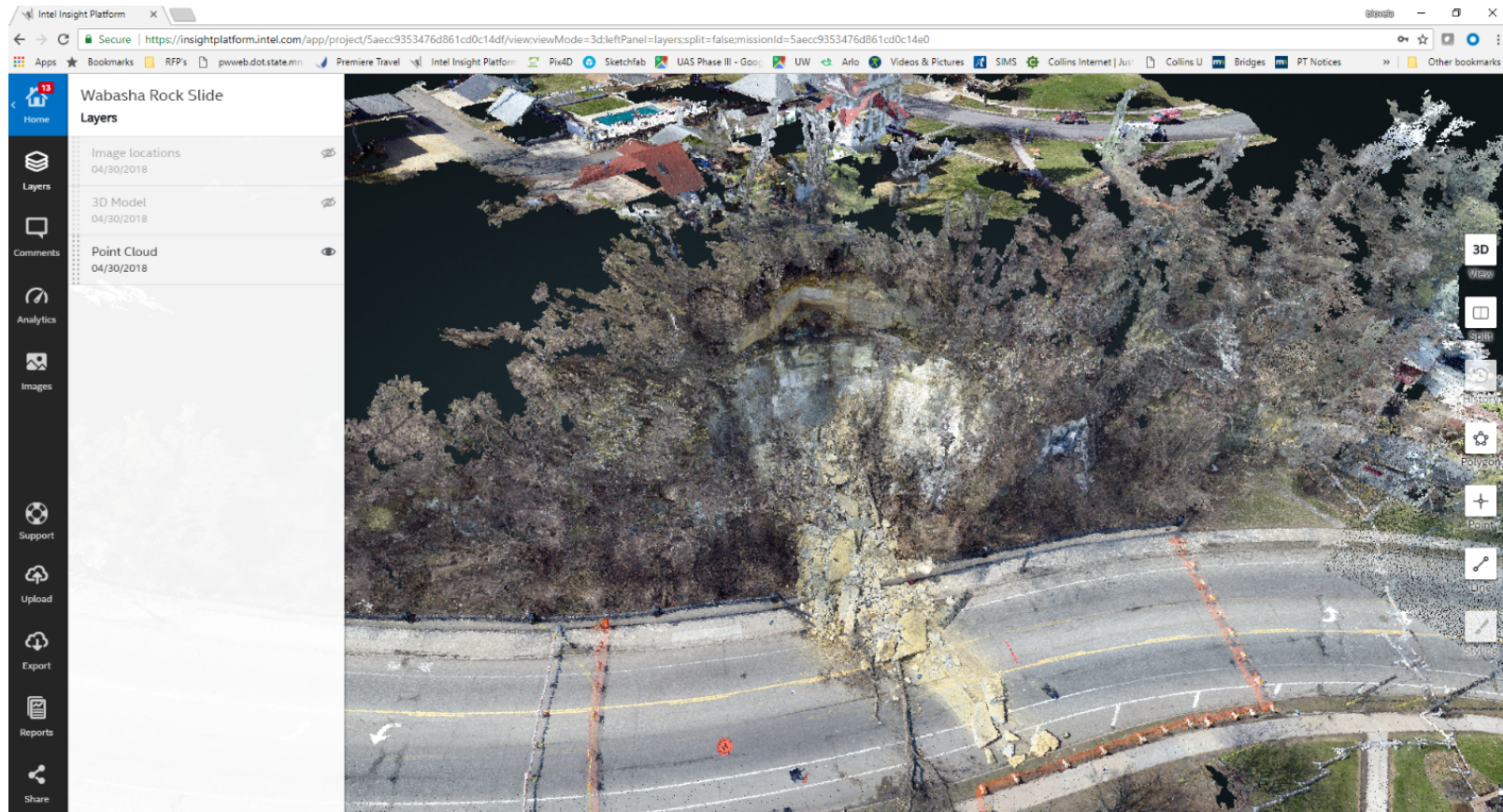
Other Applications – Volume Calculations



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
✦	CO
✦	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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Researcher(s)
Technical Liaison(s)

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:
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Project Coordinator: [Debra Fick](#)

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QUESTIONS?