



# 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

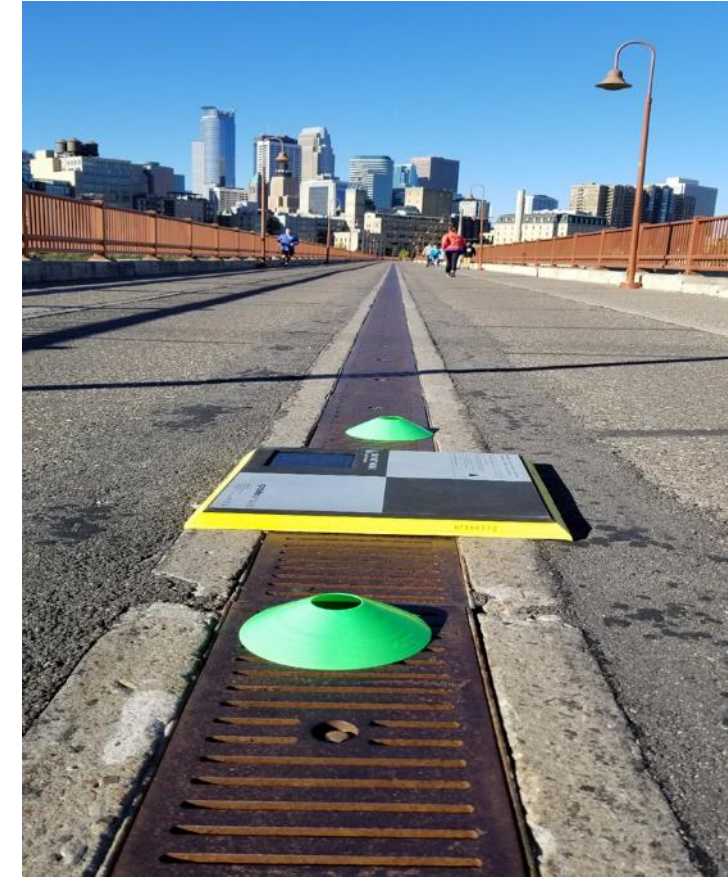




# Assessment of UAS Technology

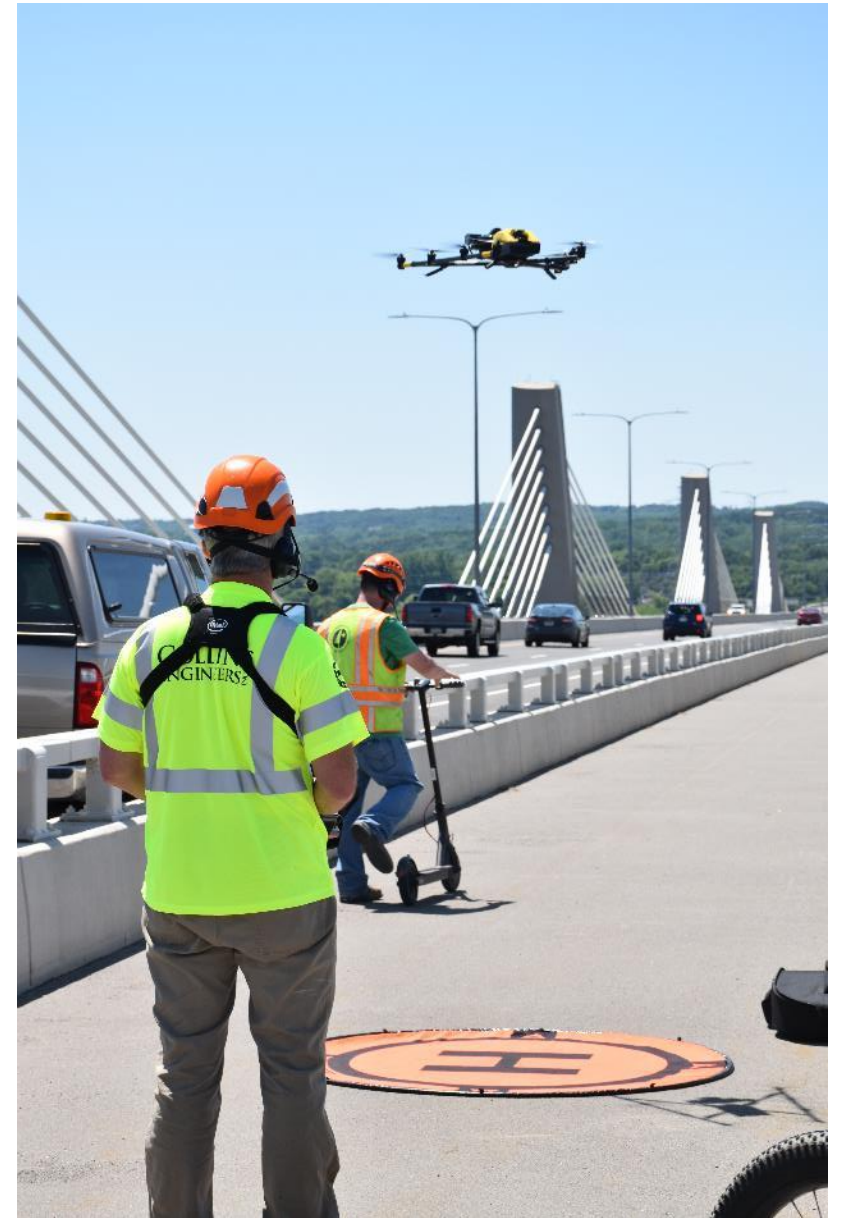
## Propeller Aeropoints

- 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

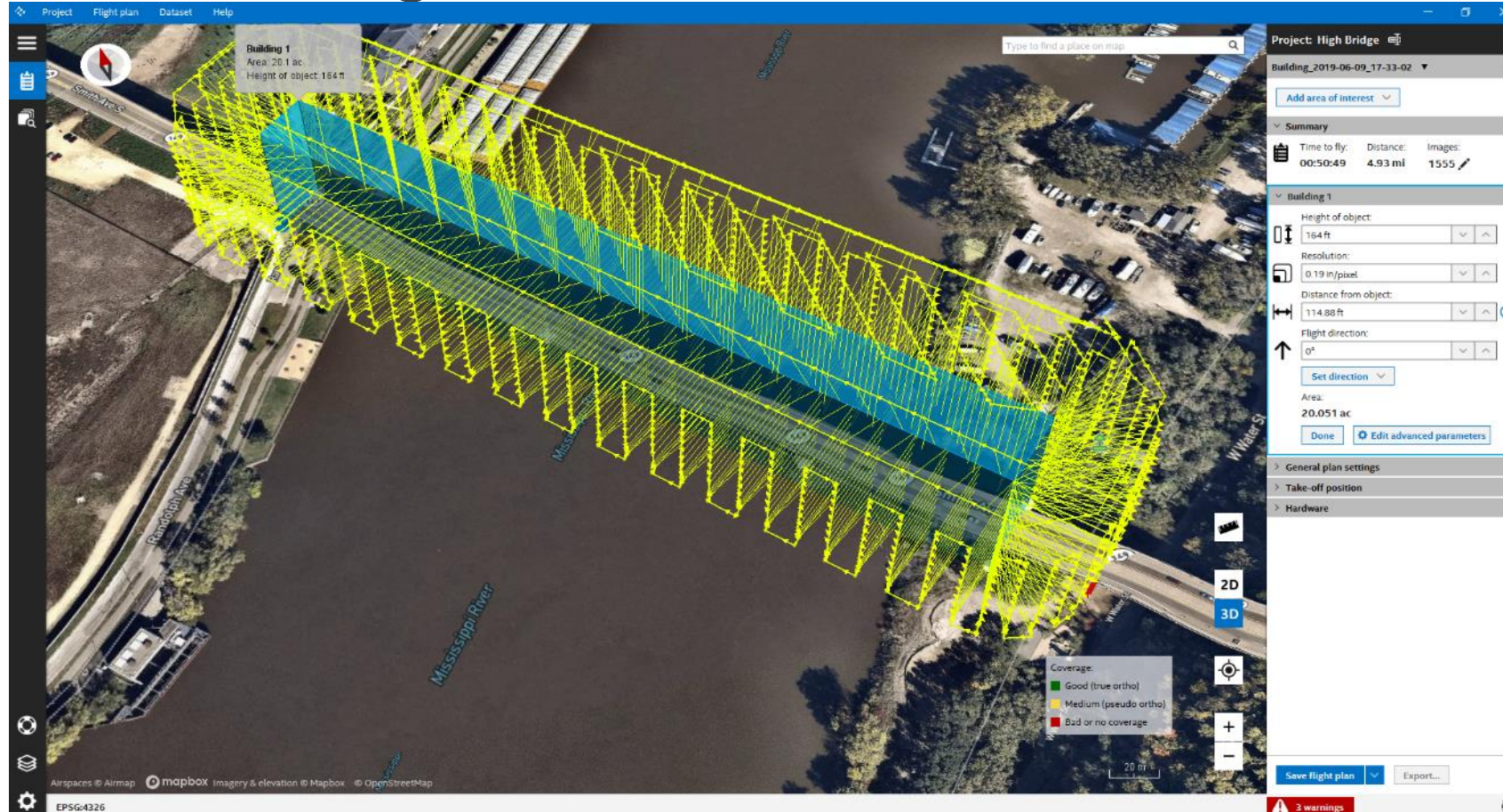




# 1. Inspection Planning with UAS

## 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

The screenshot displays a software interface for documenting bridge conditions using an orthomosaic. The interface is divided into three main sections:

- Left Panel (Layers):** Contains a list of layers and a search filter. The layers include:
  - Annotations 2 (checked)
  - Element 300 (checked)
    - Line 181 (checked)
    - East Joint (checked)
    - Pier 15A Joint (checked)
    - Joint Filled with Debris (checked)
  - Delamination (unchecked)
    - Polygon 6 (checked)
    - Polygon 5 (checked)
    - Polygon 4 (checked)
    - Polygon 3 (checked)
    - Polygon 2 (checked)
    - Polygon (checked)
    - Concrete Delamination (checked)
    - Concrete Delamination (checked)
- Central Map View:** Shows an aerial orthomosaic of a bridge deck. Numerous blue lines and polygons are overlaid on the image, representing annotations. Each annotation is labeled with a numerical value in feet (e.g., 2.0612 ft, 2.6987 ft, 1.31234 ft). A large orange polygon highlights a specific area of the bridge deck.
- Right Panel (Inspection):** Contains a search bar with the text "DSC02398\_156129...", a green 'X' mark on a close-up image of the bridge deck, and a button labeled "SAVE INSPECTION AS ANNOTATION". Below the button, a message states: "We found 19 images matching the selected point of the model. They will be included in the inspection annotation." The panel also includes fields for "Name" (Inspection) and "Inspection".

At the bottom of the interface, there is a status bar showing coordinates: "44.97134° N 93.29724° W Elevation: -".



# 3. Document Conditions and Deficiencies

## Deliverables – Point Clouds





The screenshot displays the software interface for bridge inspection. The main window shows a 3D model of the Haleiwa Bridge, a concrete arch bridge. A green 'X' marks a specific point on the bridge's structure. The interface includes a top navigation bar with 'FILES', 'DOWNLOAD', and 'SHARE' options. A sidebar on the left contains various tool icons. The right panel shows a detailed view of the selected point, labeled 'DSC01764\_1553275704000', with a green 'X' indicating the inspection point. Below this, a row of thumbnail images shows other views of the bridge. A blue button labeled 'SAVE INSPECTION AS ANNOTATION' is visible, along with a text box stating: 'We found 47 images matching the selected point of the model. They will be included in the inspection annotation.'



# 4. Communicate Conditions and Deficiencies

- Traditional Reporting

BR 3459 -- Span #3 Field Notes		
Location	North (upstream) Truss	South (downstream) Truss
<b>L0-L1 Bottom Chord</b> (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><b>[2017] Pitting on the upper legs of the chord inside the panel point. (Photo 20)</b></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>
<b>L0-L1 Lower Lateral Bracing</b>	<p>[2004] Lower lateral bracing members replaced.</p> <p>[2011-2015] No deficiencies noted.</p>	
<b>L1 Gusset Plates</b> (1/2" thick)	<p>[2004] Repainted - L0/L1 &amp; 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>
<b>L1-U1 Vertical</b> (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><b>[2017] 3/16" pitting at L1N (Photo 21)</b></p>	<p>[2011] No deficiencies noted.</p> <p>[2015] Paint failure throughout.</p>



## 4. Communicate Conditions and Deficiencies

The screenshot shows a 3D model of the Tettegouche Bridge 3459. The bridge is a green steel truss structure spanning a river. A yellow crane is positioned on the bridge deck. The interface includes a top bar with the title 'Tettegouche Bridge 3459', a right sidebar with metadata for 'L2-L3 Bottom Chord', and a bottom status bar showing coordinates and elevation.

**Top Bar:** Tettegouche Bridge 3459

**Right Sidebar:**

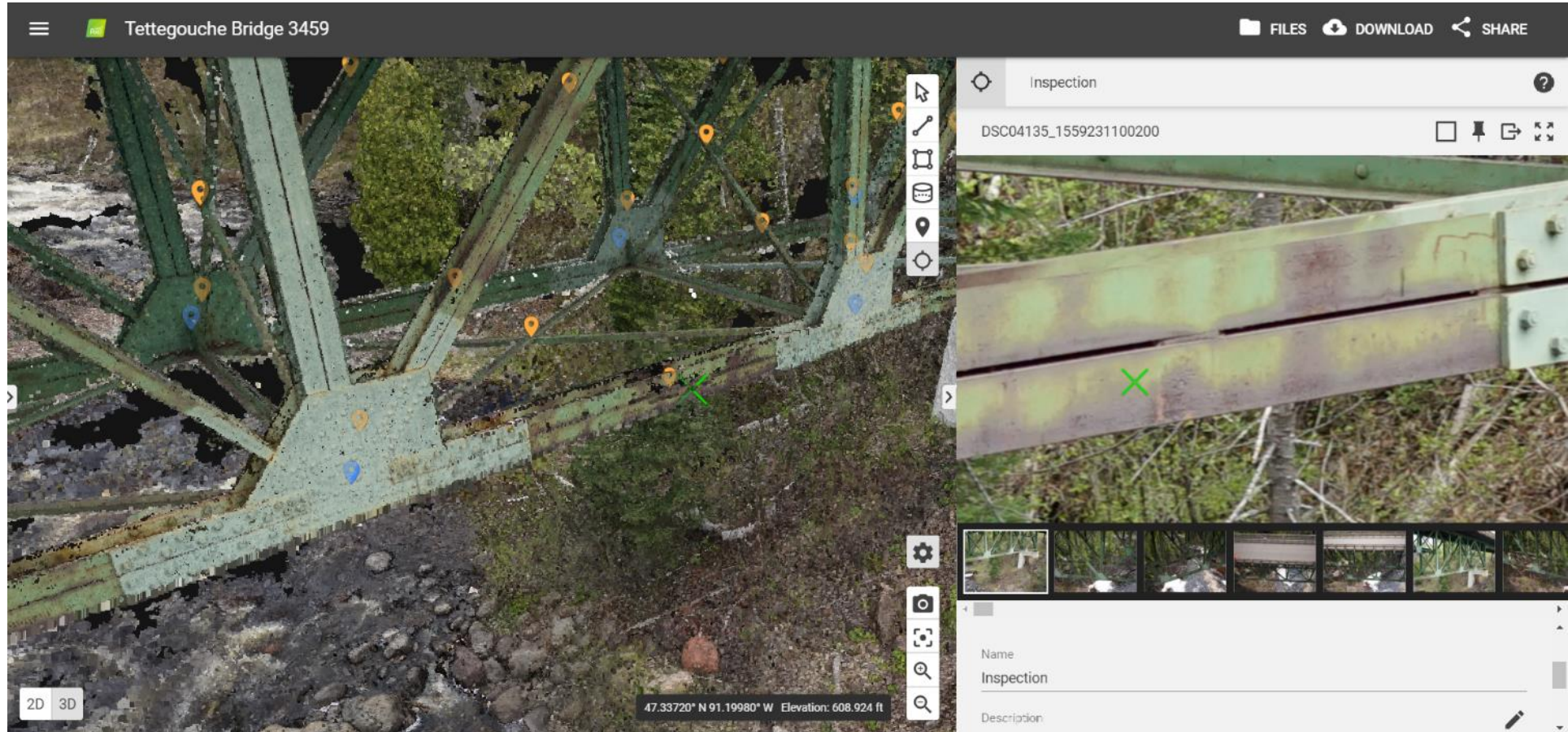
- Name: L2-L3 Bottom Chord (4 angles, 6" x 4" x 7/16") South
- Description: [2017] 1/4" pitting on the upper leg inside L3S.
- Tags:
- Color: Orange
- Measurements:
  - Coordinates (WGS84): 47.33714° N 91.19981° W
  - X: 3095750.224770546
  - Y: 639215.0043449402
  - Z: 639.4789887666702
  - Elevation: 639.469 ft

**Bottom Status Bar:** 47.33732° N 91.20030° W Elevation: 682.382 ft



# 4. Communicate Conditions and Deficiencies

- Cloud Sharing



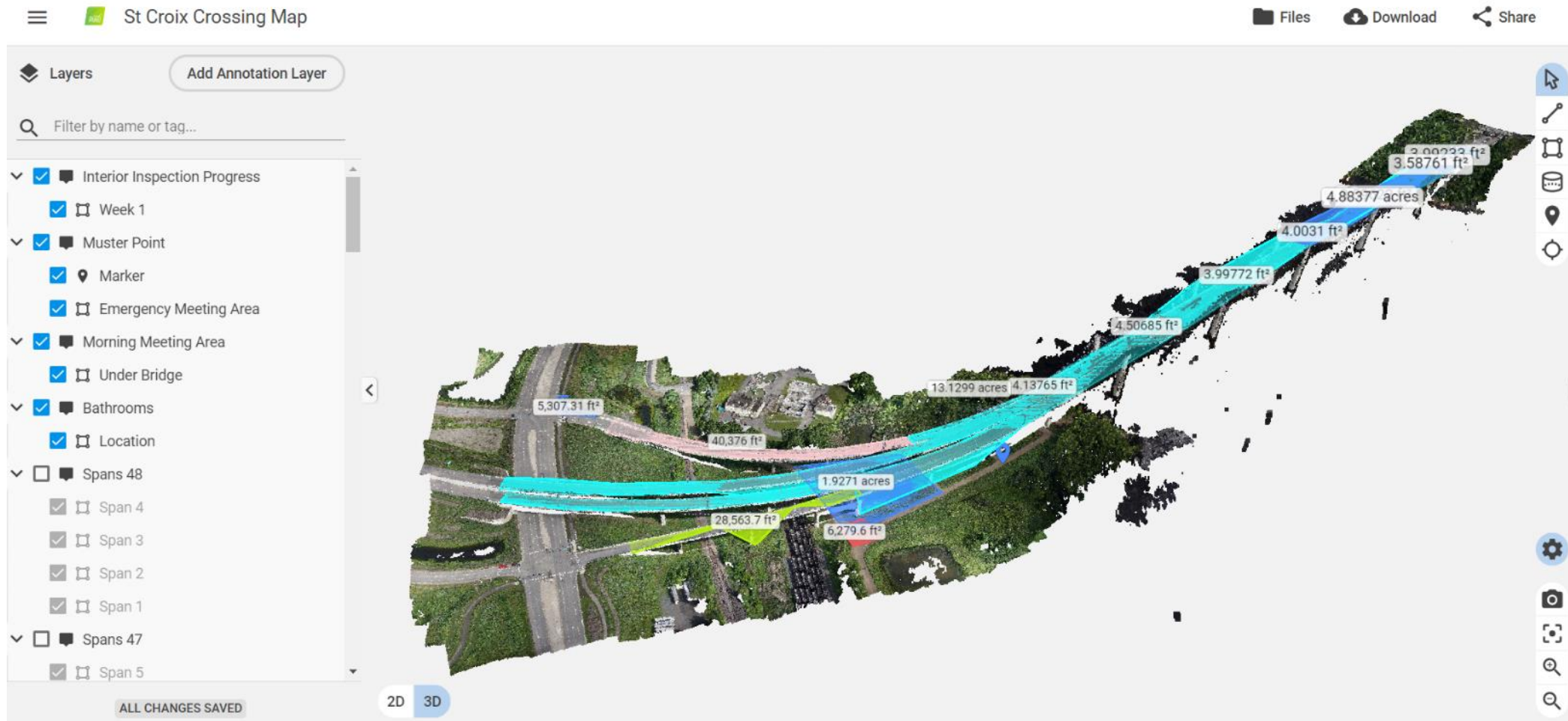
# Case Study – St. Croix Crossing Extradosed Bridge

- 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-9b52-07f1c9eecee1>

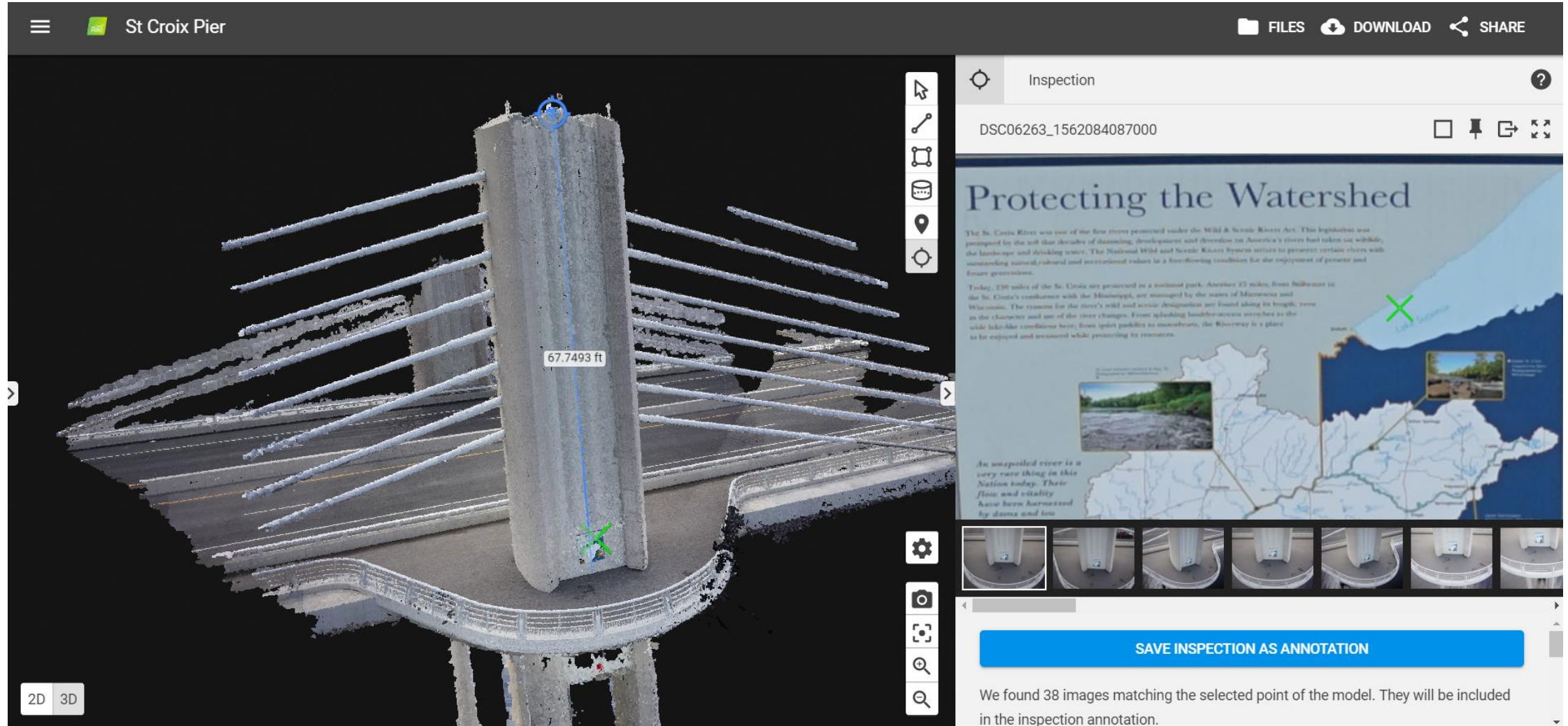
- Intel Falcon 8+
- Capable of looking up
- Fly without GPS,  
under bridge decks
- High wind tolerance
- High Resolution  
Images
- Propeller Aeropoint  
Automatic GCP's





# 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

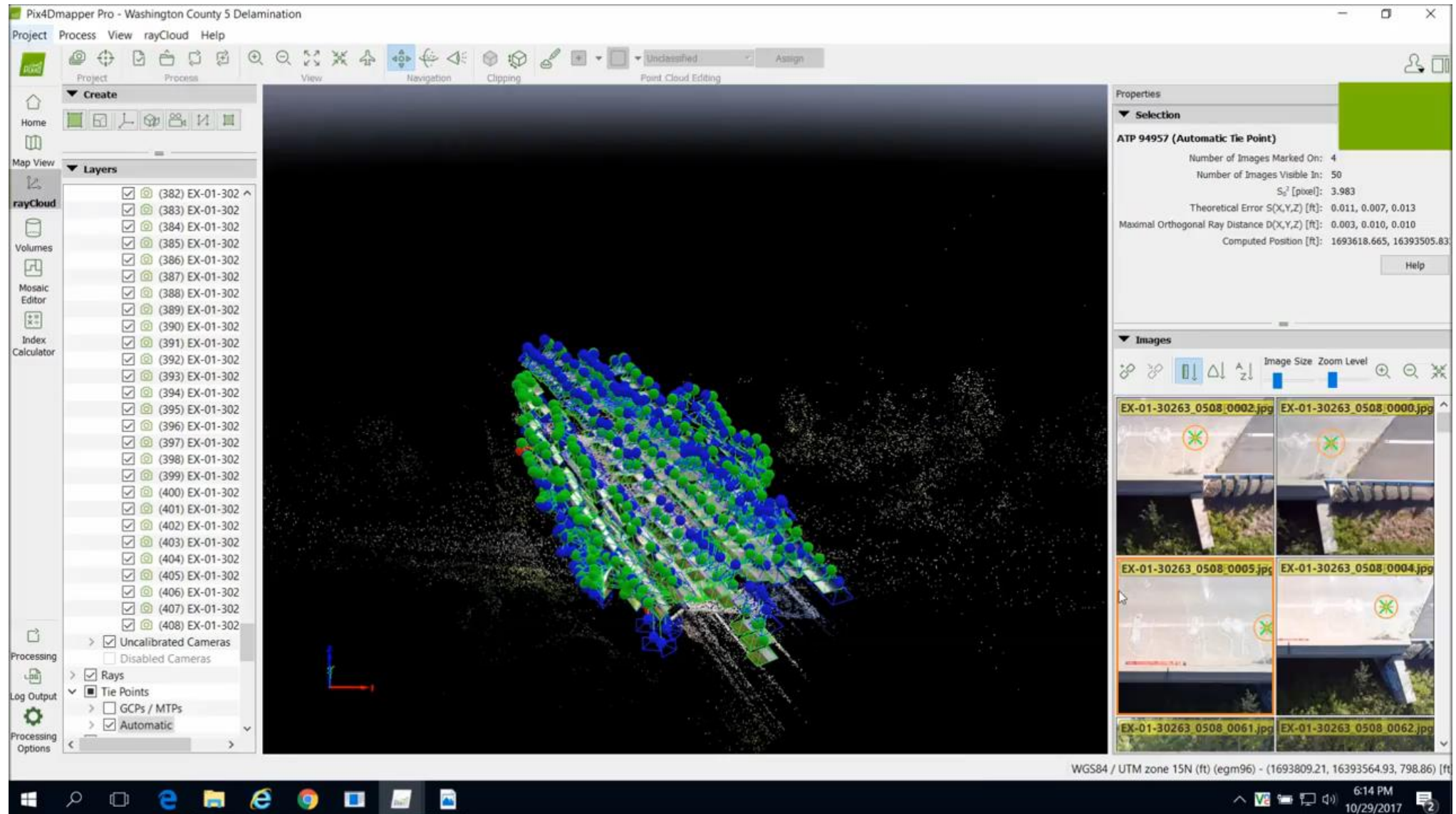


# Other Applications – 3D Modeling

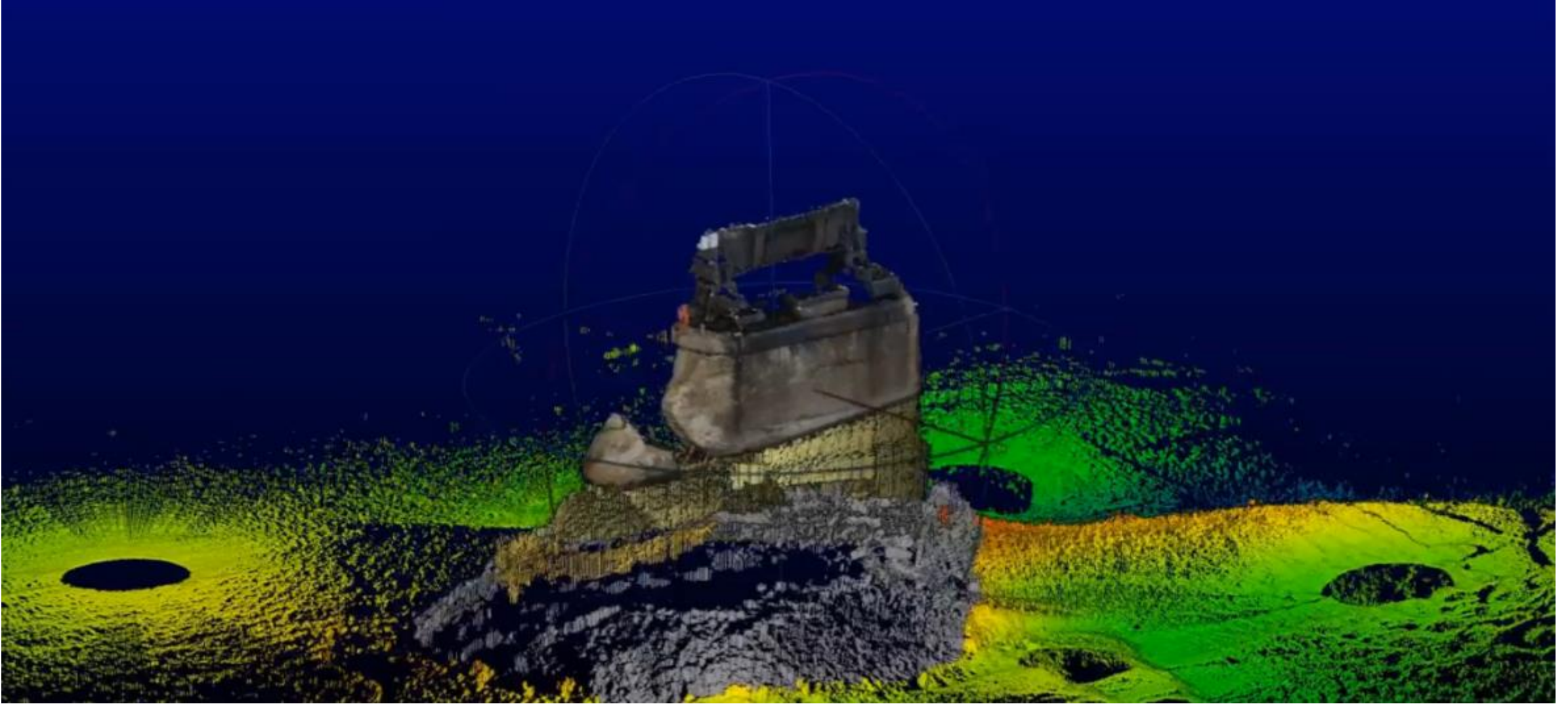




# Other Applications – 3D Modeling (Photo Log)



## Other Applications – Pairing with Underwater 3D Modeling





## Other Applications – Corridor Modeling



# Other Applications – Overhead Signs

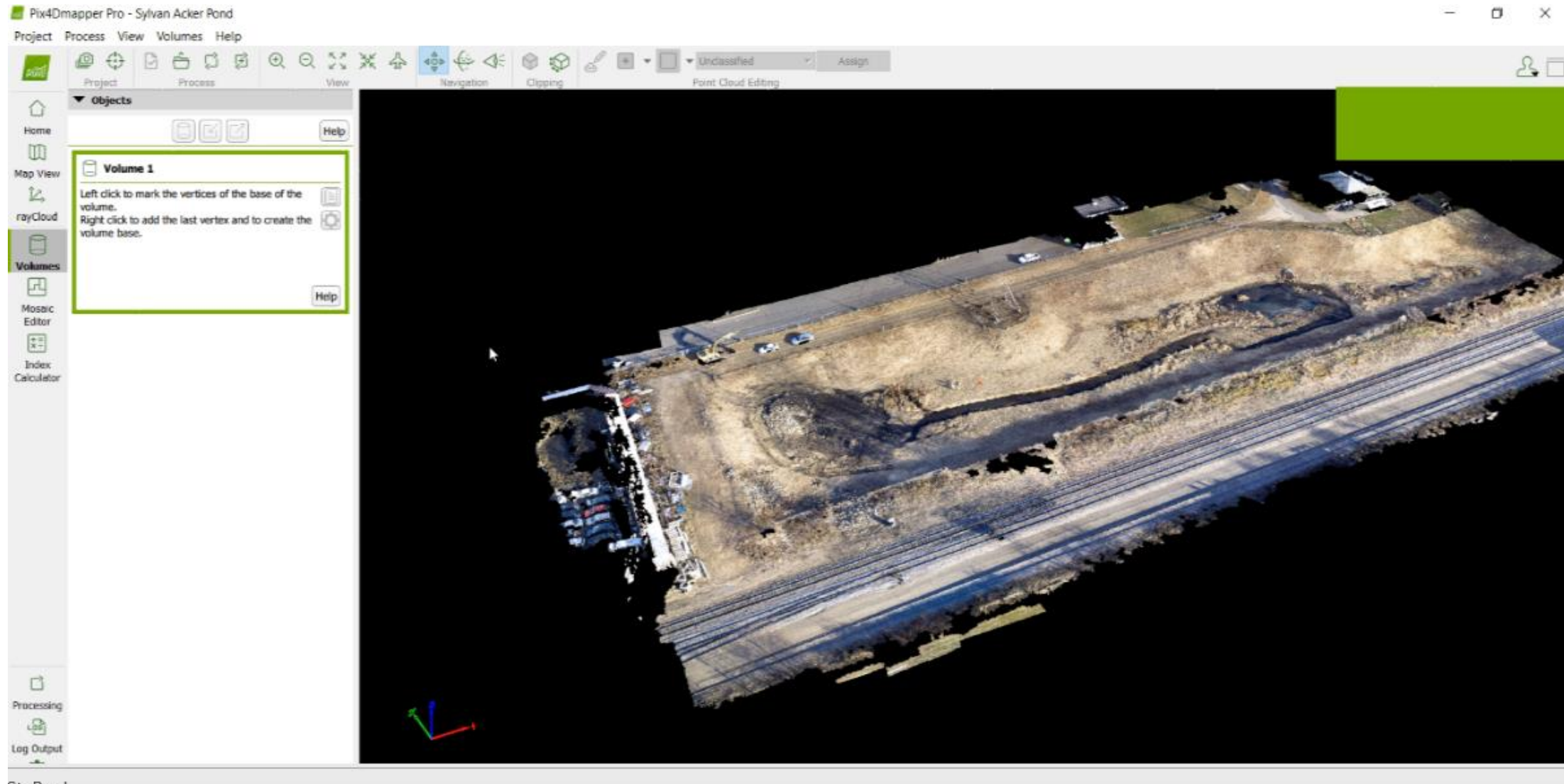
35W at 31st Street Corridor Map

DOWNLOAD SHARE

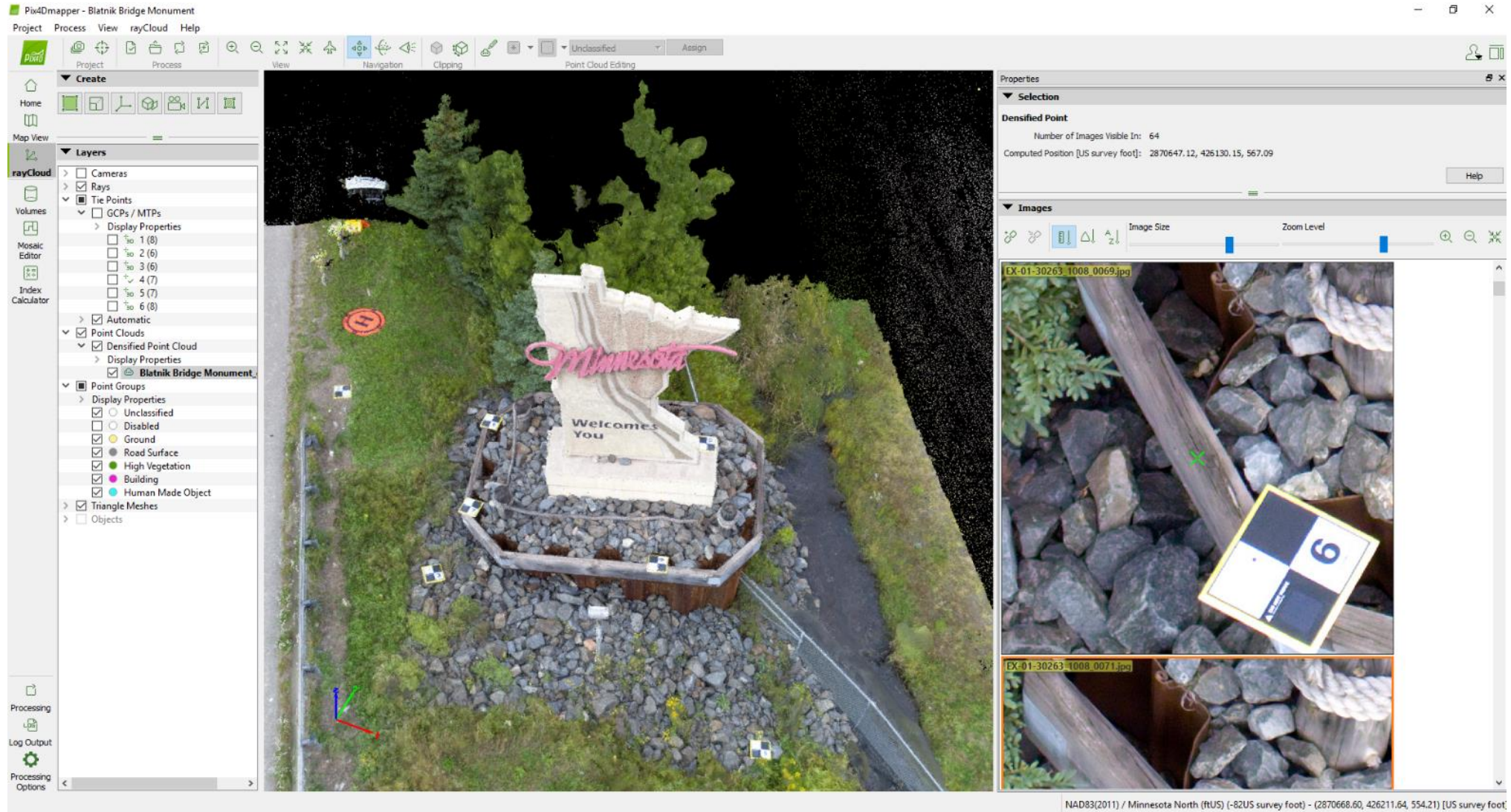
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# Other Applications – Volume Calculations

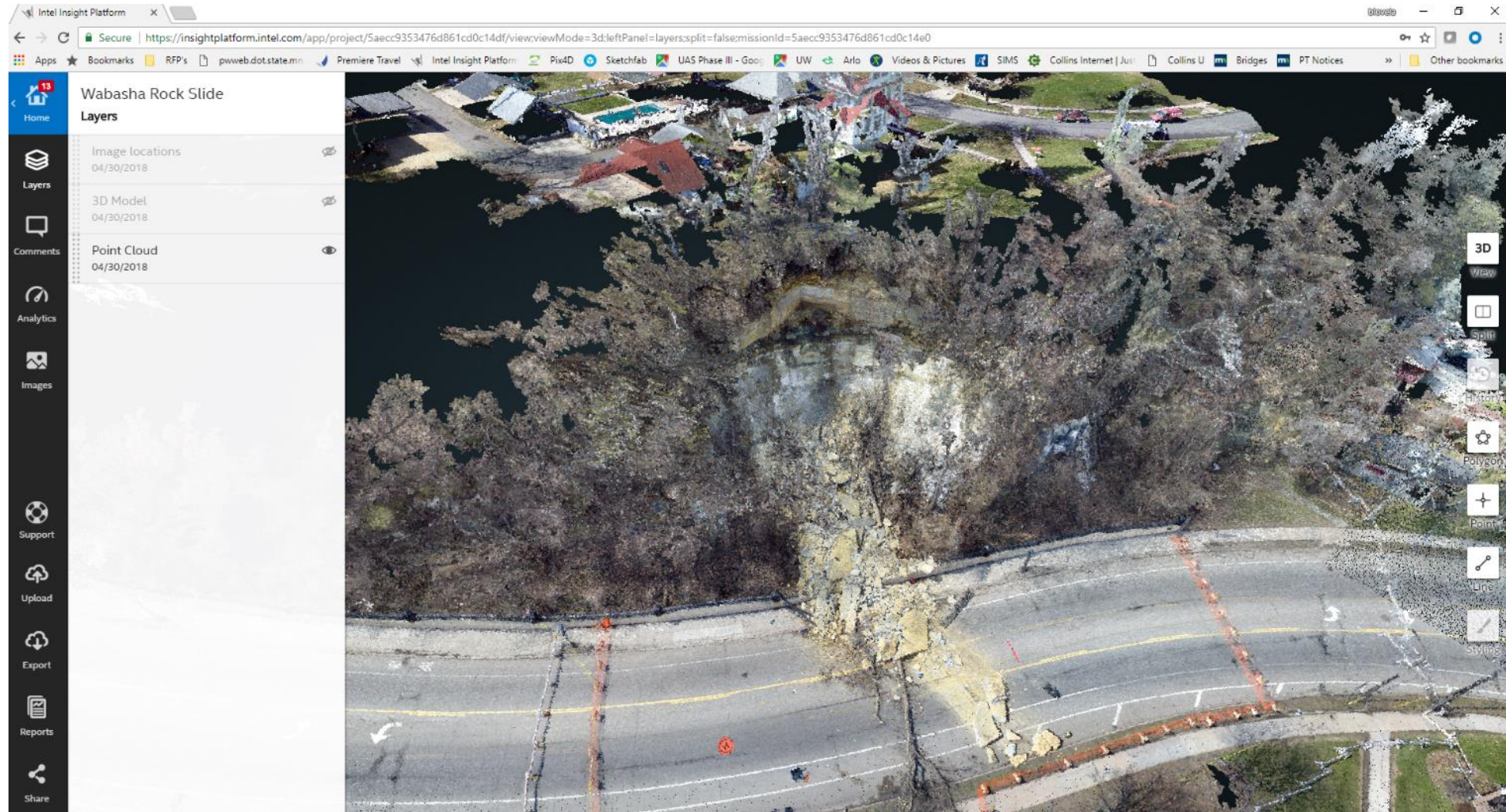


# Other Applications – Monument Inspection/Inventory





# 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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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:**

**Principal Investigator:** [Barry Lovelace](#)

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**Project Coordinator:** [Debra Fick](#)



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**QUESTIONS?**