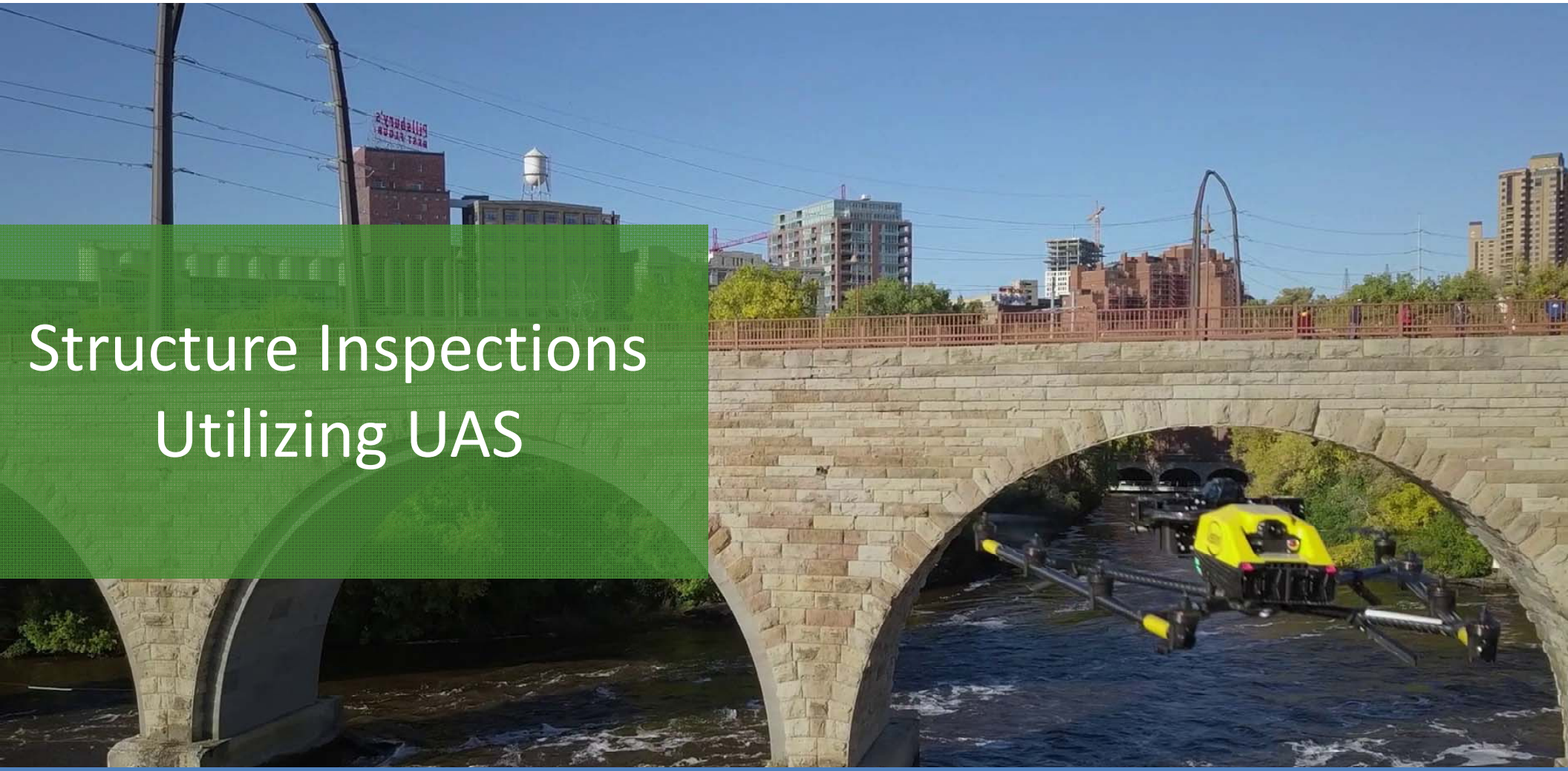


Structure Inspections Utilizing UAS

Jennifer Wells, PE - State Bridge Inspection Engineer

DEPARTMENT OF TRANSPORTATION

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

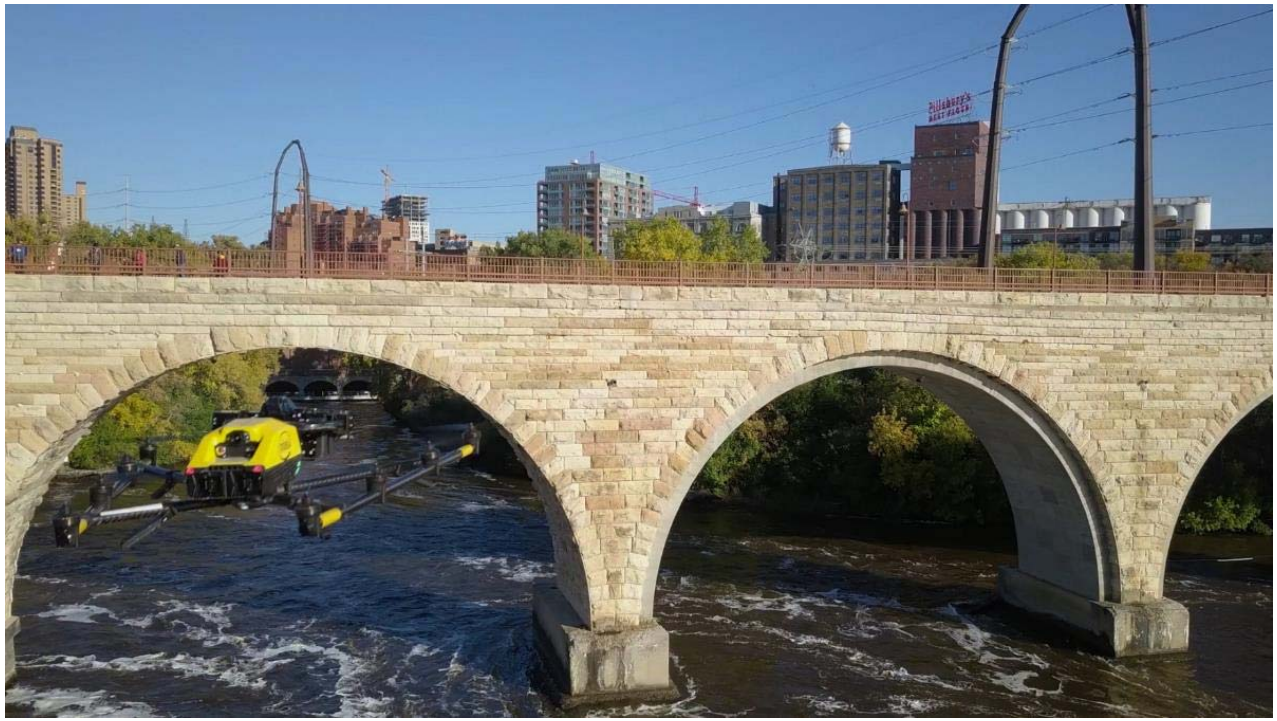
Assessment of UAS Technology

- 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

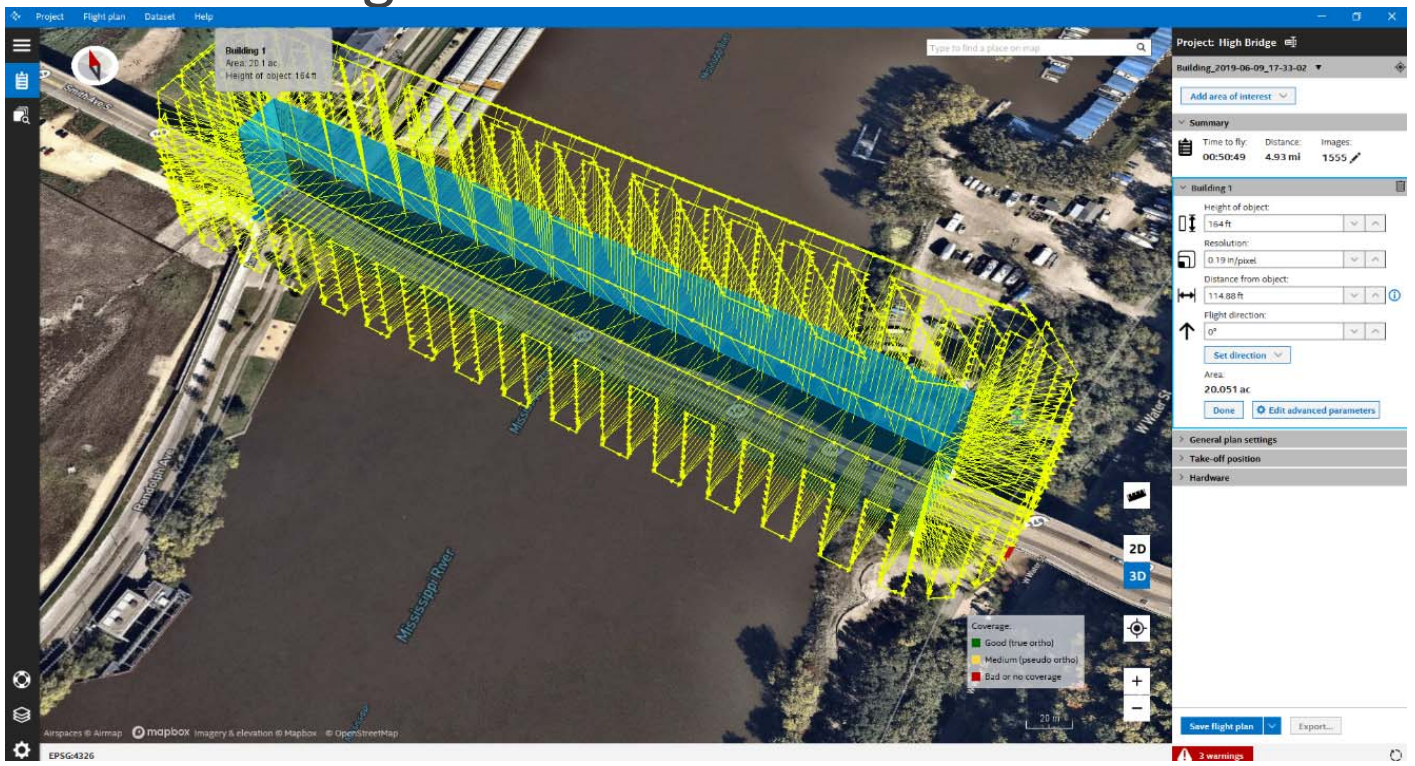
Structure Inspection Goals

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

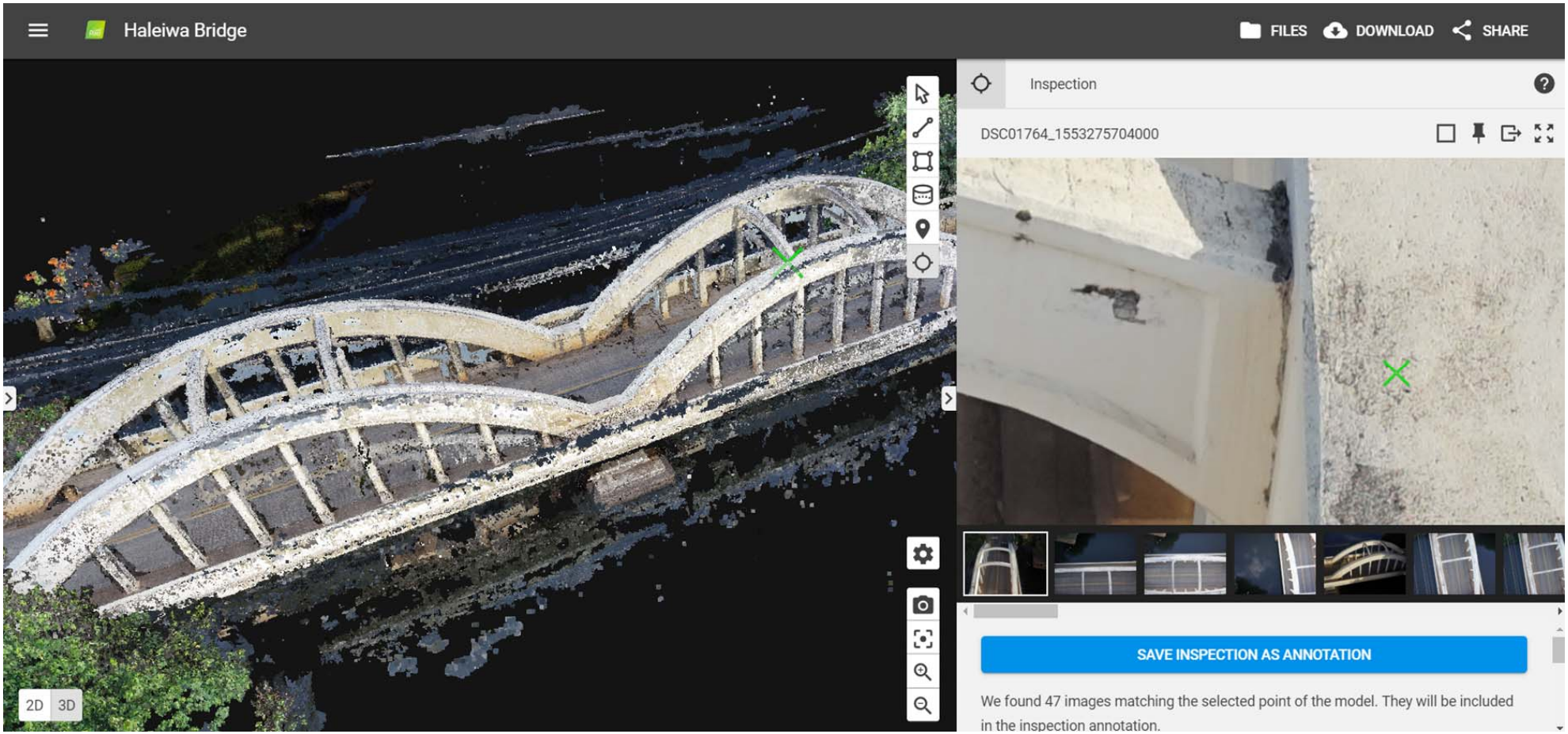
3. Document Conditions and Deficiencies

Deliverables – Orthomosaic

3. Document Conditions and Deficiencies

Deliverables – Point Clouds

4. Communicate Conditions and Deficiencies



4. Communicate Conditions and Deficiencies

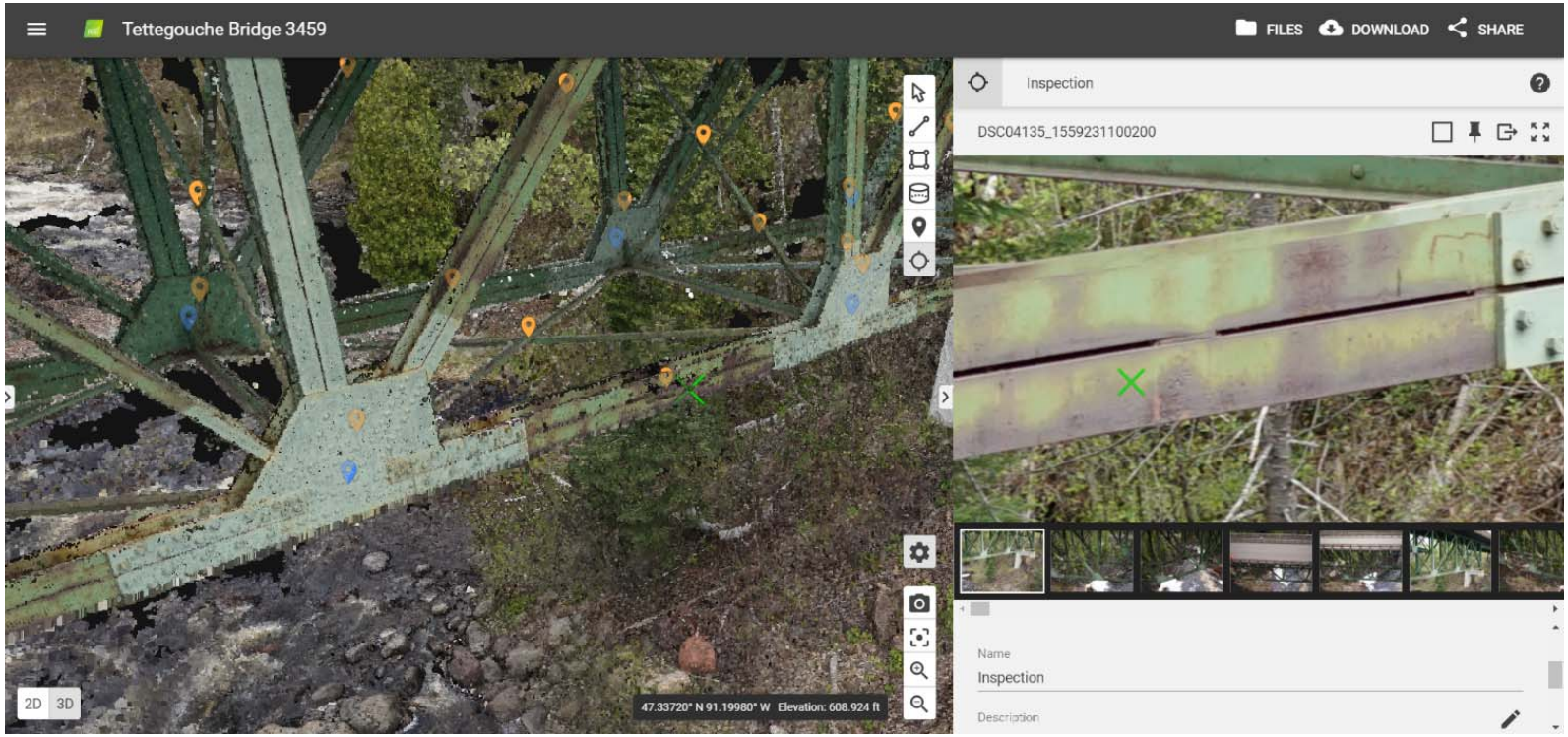
- Traditional Reporting

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")	[2004] Bottom chord angles reinforced (bolted plates) at L0, L1 and at the center. [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. [2011] No change. [2015] Through corrosion top horizontal leg of bottom exterior angle west of retro fit. **[2017] Pitting on the upper legs of the chord inside the panel point.** (Photo 20)	[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. [2011] No change. [2015] Pitting 3/16" deep at L0. Through corrosion on bottom interior angle horizontal leg inside panel point L0. Pitting ¼" deep on top interior horizontal legs inside L1.
L0-L1 Lower Lateral Bracing	[2004] Lower lateral bracing members replaced. [2011-2015] No deficiencies noted.	
L1 Gusset Plates (1/2" thick)	[2004] Repainted - L0/L1 & L1/L2 connections reinforced (bolted plates). [2011] No deficiencies noted. [2013-2015] 1/8" bow on EGP from PR.	[2004] Repainted. [2010] Minor corrosion. [2011] No change [2013-2015] IGP has 1/4" PR distortion over upper angle of lower chord, E side.
L1-U1 Vertical (4 angles, 3" x 2-1/2" x 1/4")	[2008] Vertical has minor section loss at L1. [2011] No deficiencies noted. [2013] NC to section loss @ L1. [2013-2015] Paint failures over upper half of N face of both flanges. **[2017] 3/16" pitting at L1N** (Photo 21)	[2011] No deficiencies noted. [2015] Paint failure throughout.

4. Communicate Conditions and Deficiencies

4. Communicate Conditions and Deficiencies

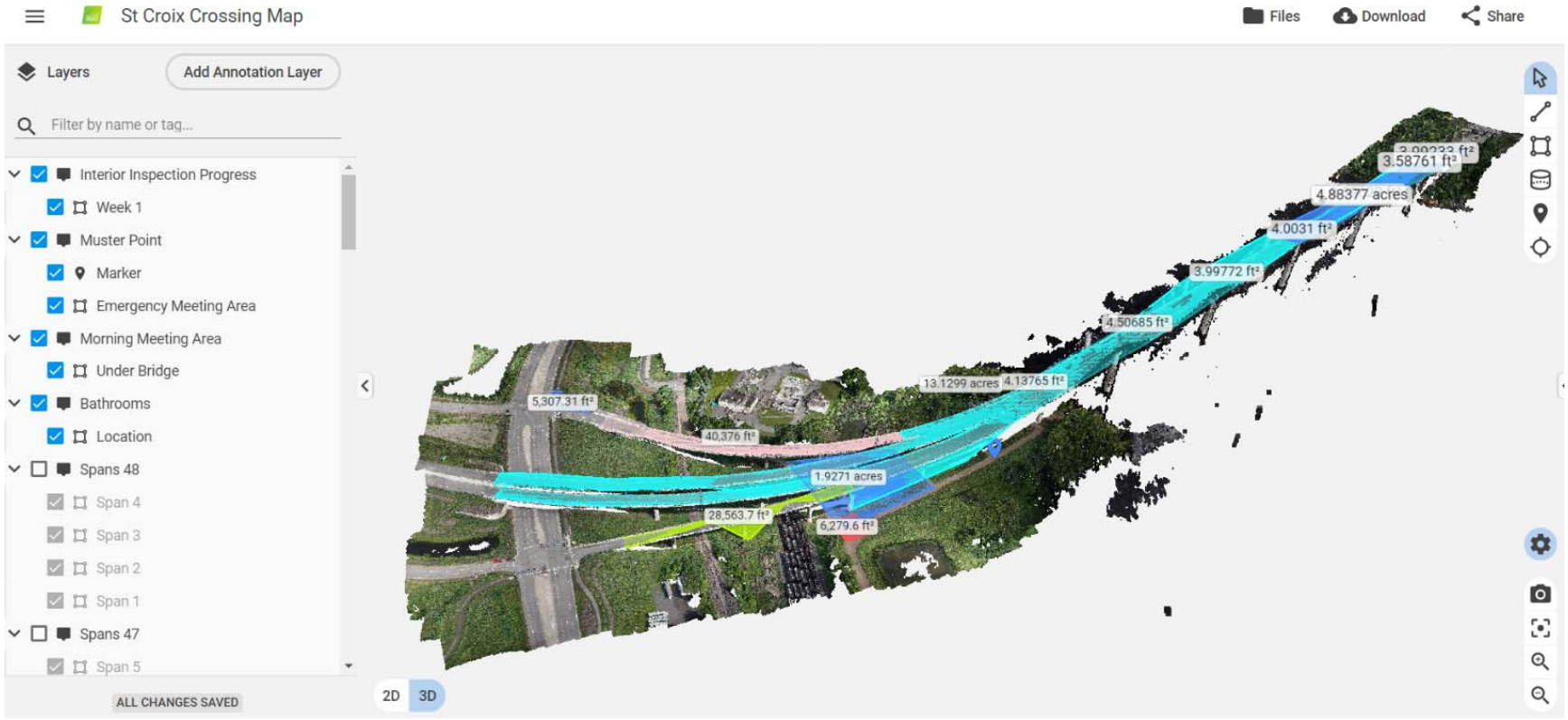
- Cloud Sharing



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

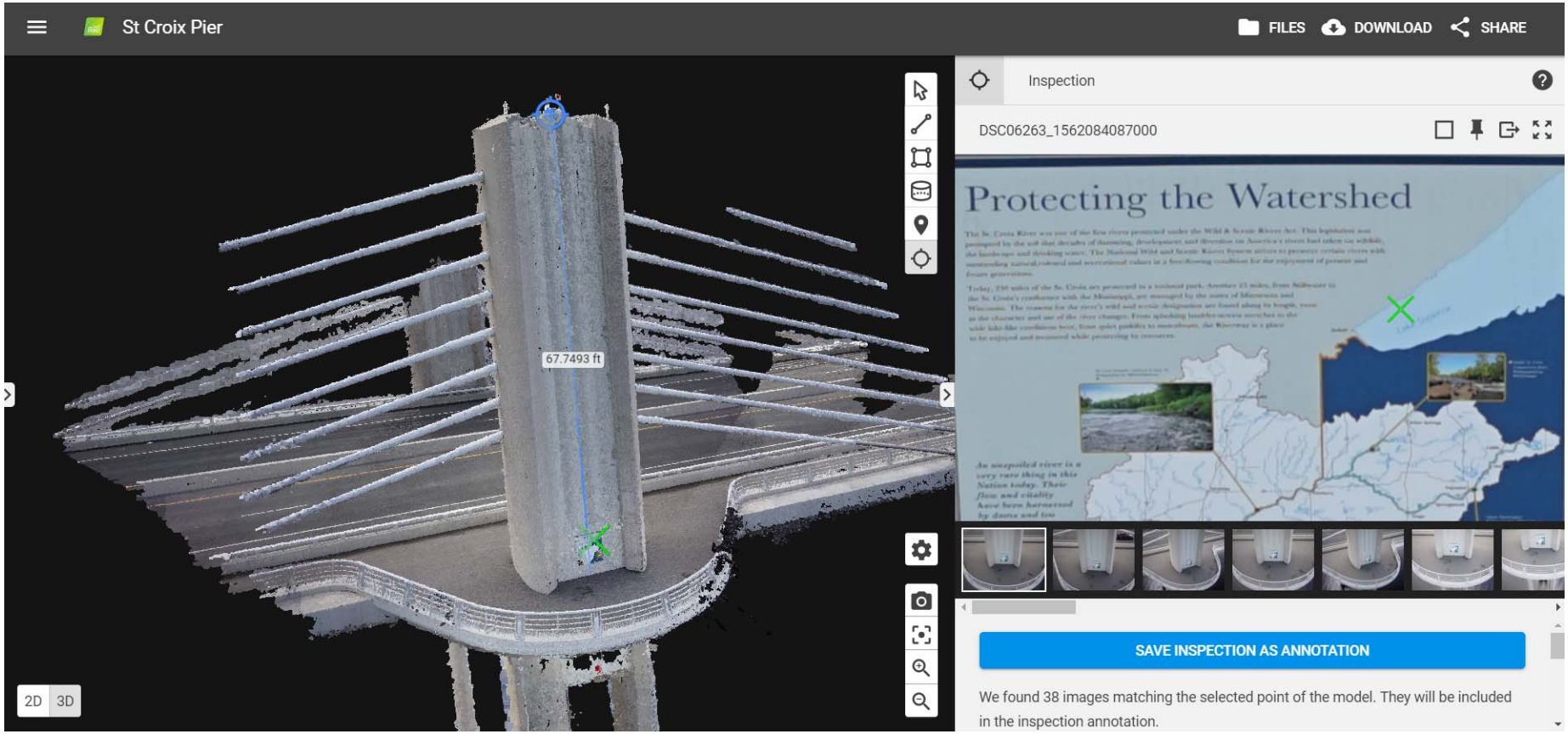


https://cloud.pix4d.com/pro/project/507277/model?shareToken=352346c7-7098-44ca-9b52-07f1c9eecee1

- 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

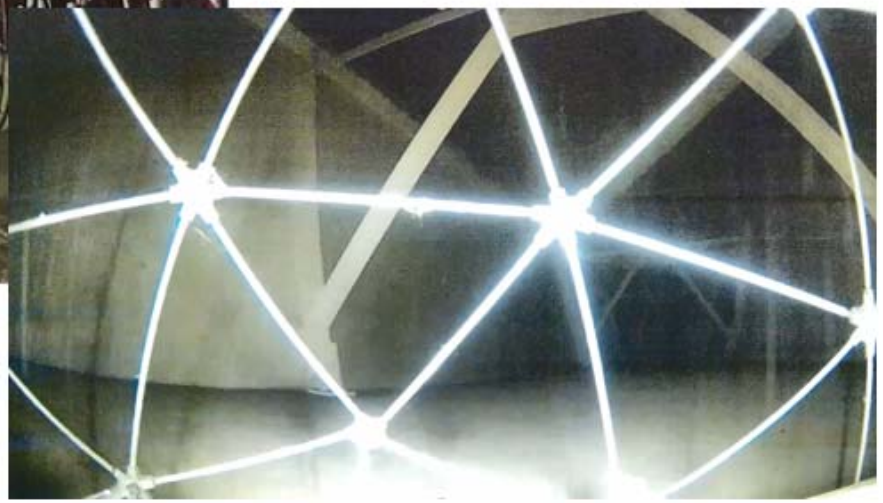
Works Well

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

Does not Work Well

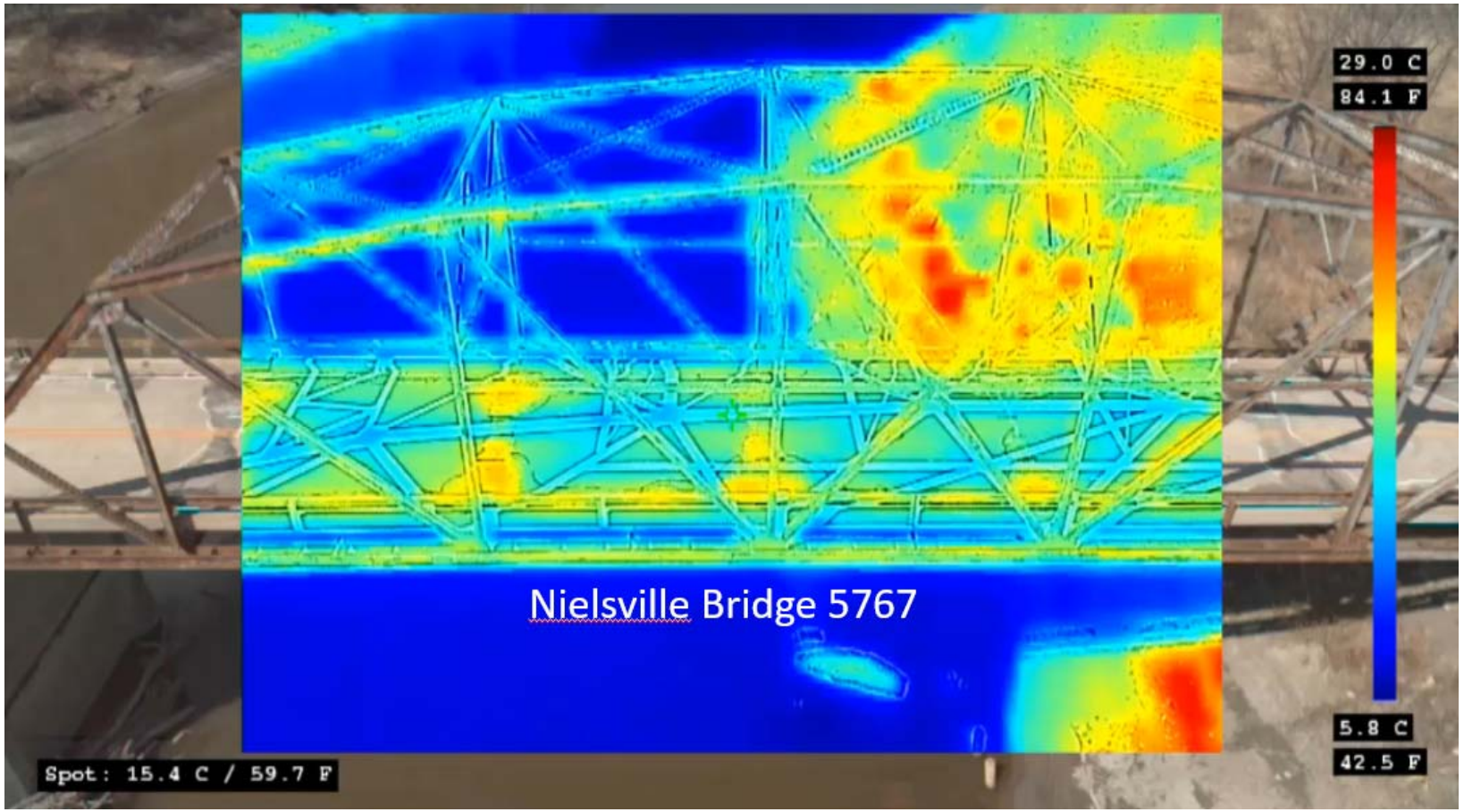
- Bridges over high ADT roadways
- Bridges in heavily wooded areas

Other Applications – Confined Spaces



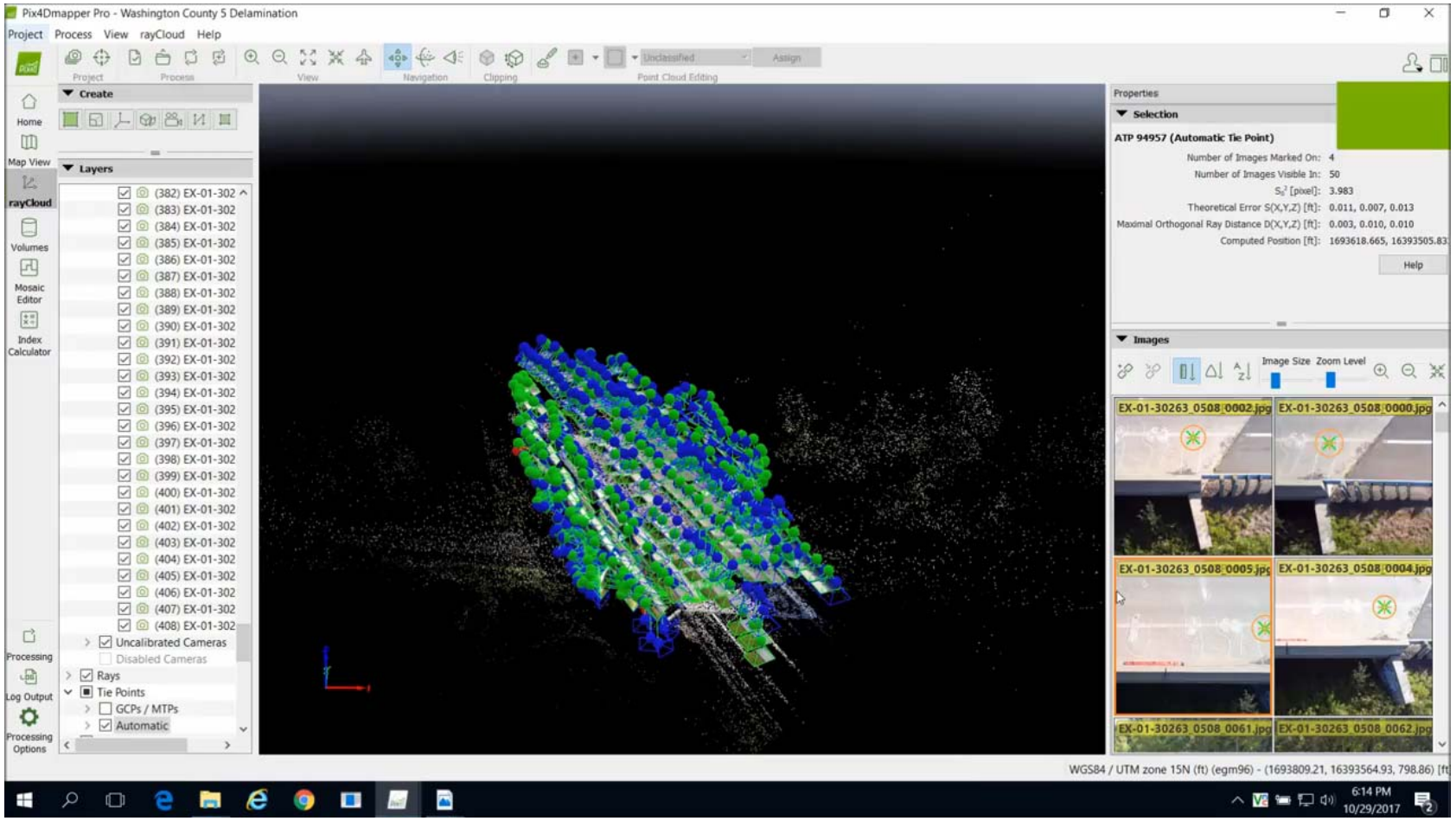
Other Applications – Confined Spaces

Other Applications - Infrared

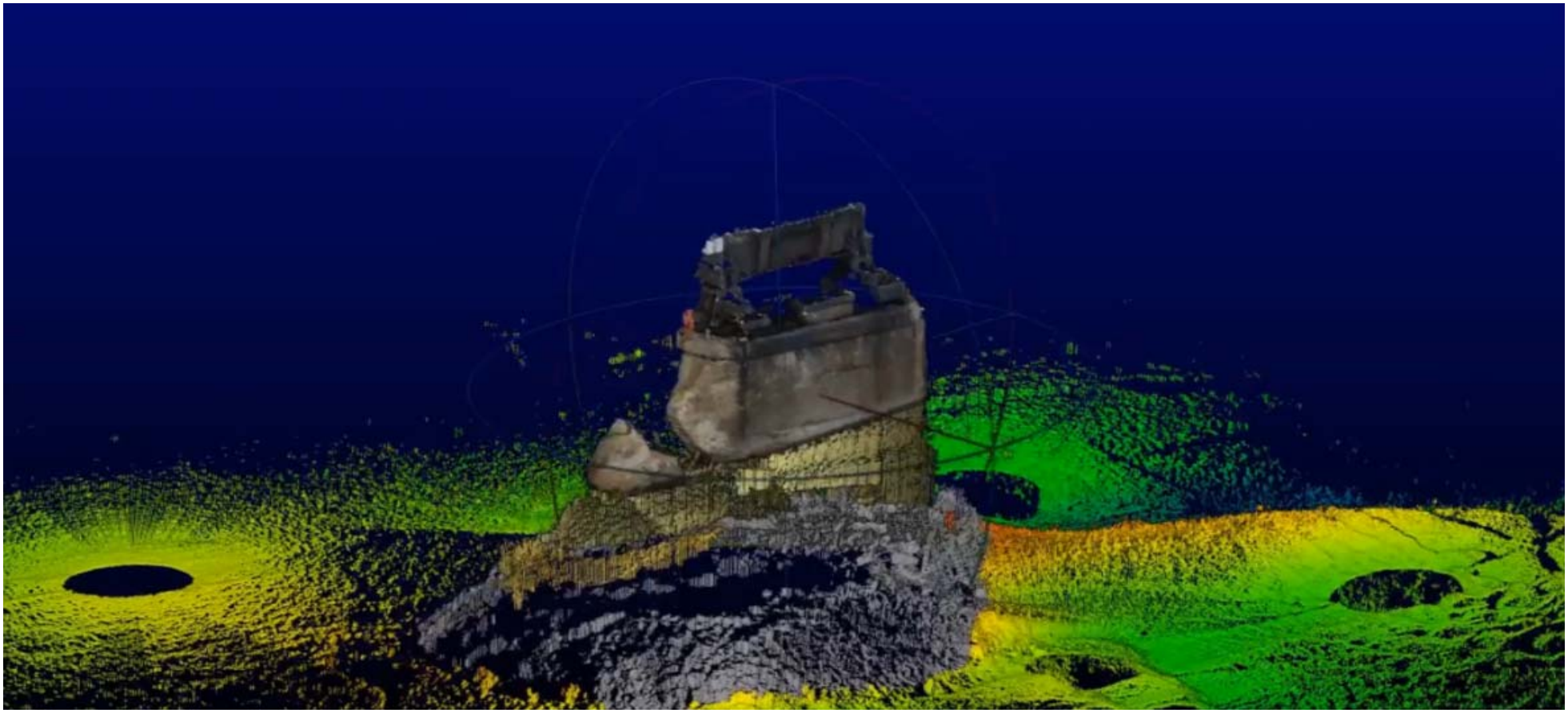


Other Applications – 3D Modeling

Other Applications – 3D Modeling (Photo Log)

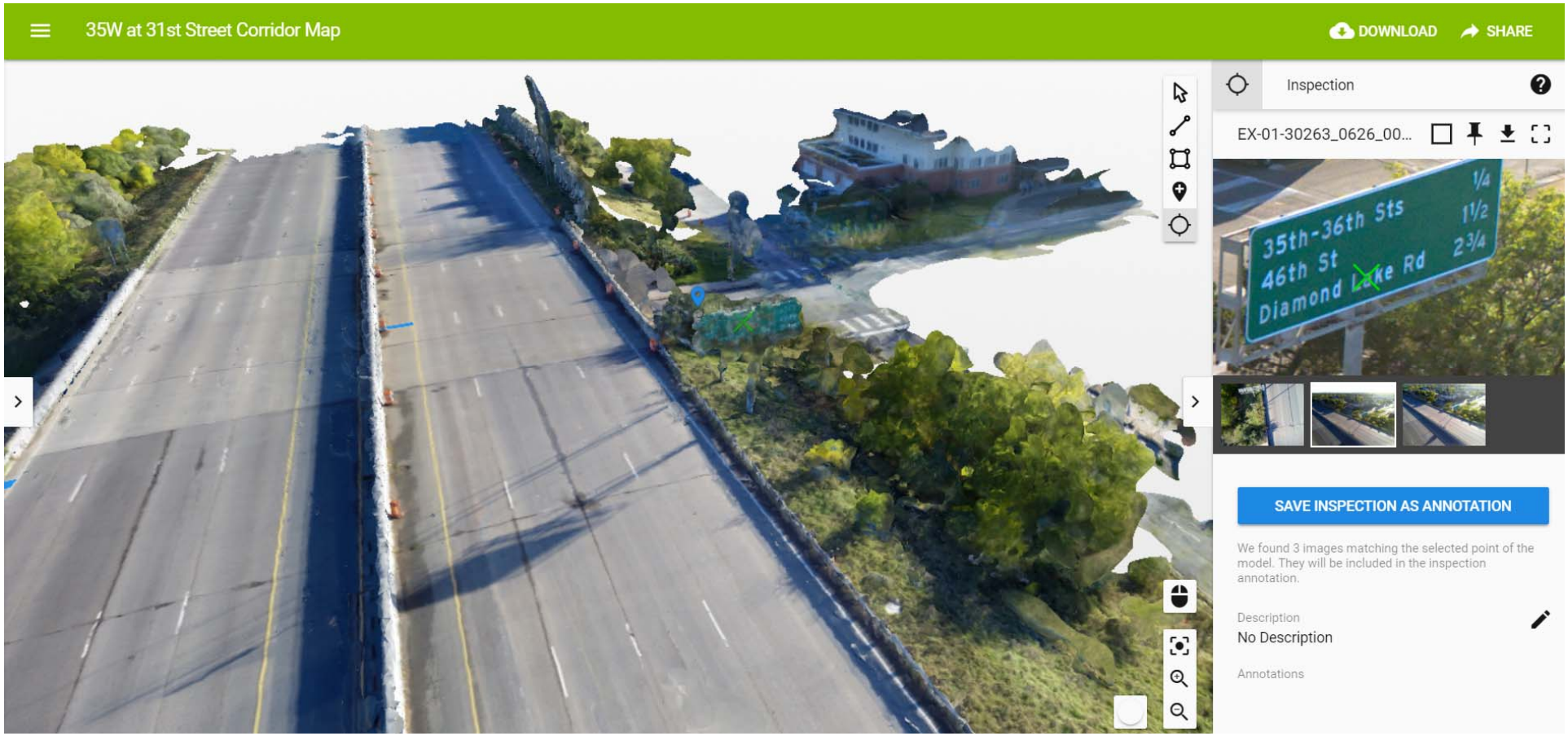


Other Applications – Pairing with Underwater 3D Modeling

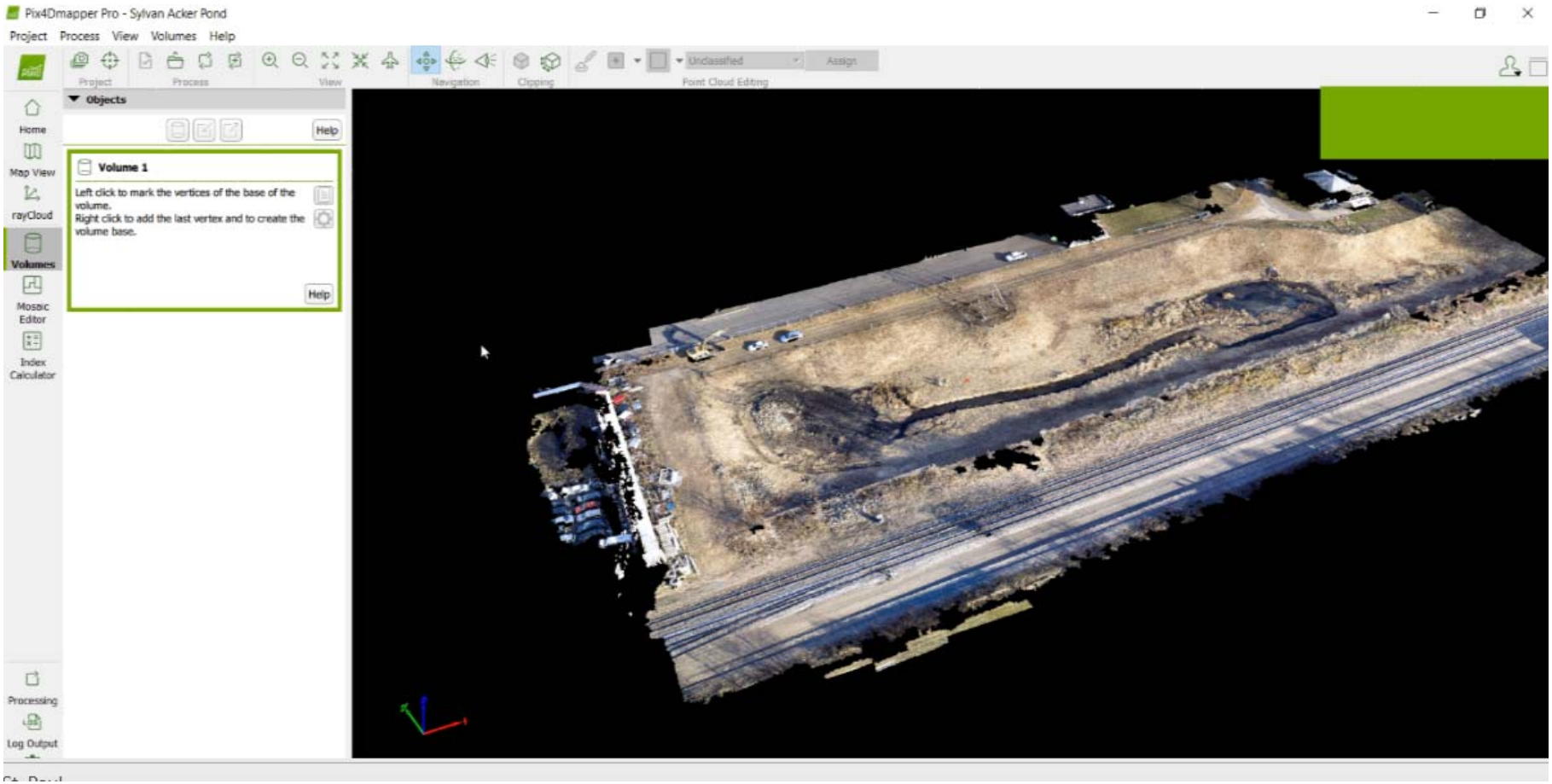


Other Applications – Corridor Modeling

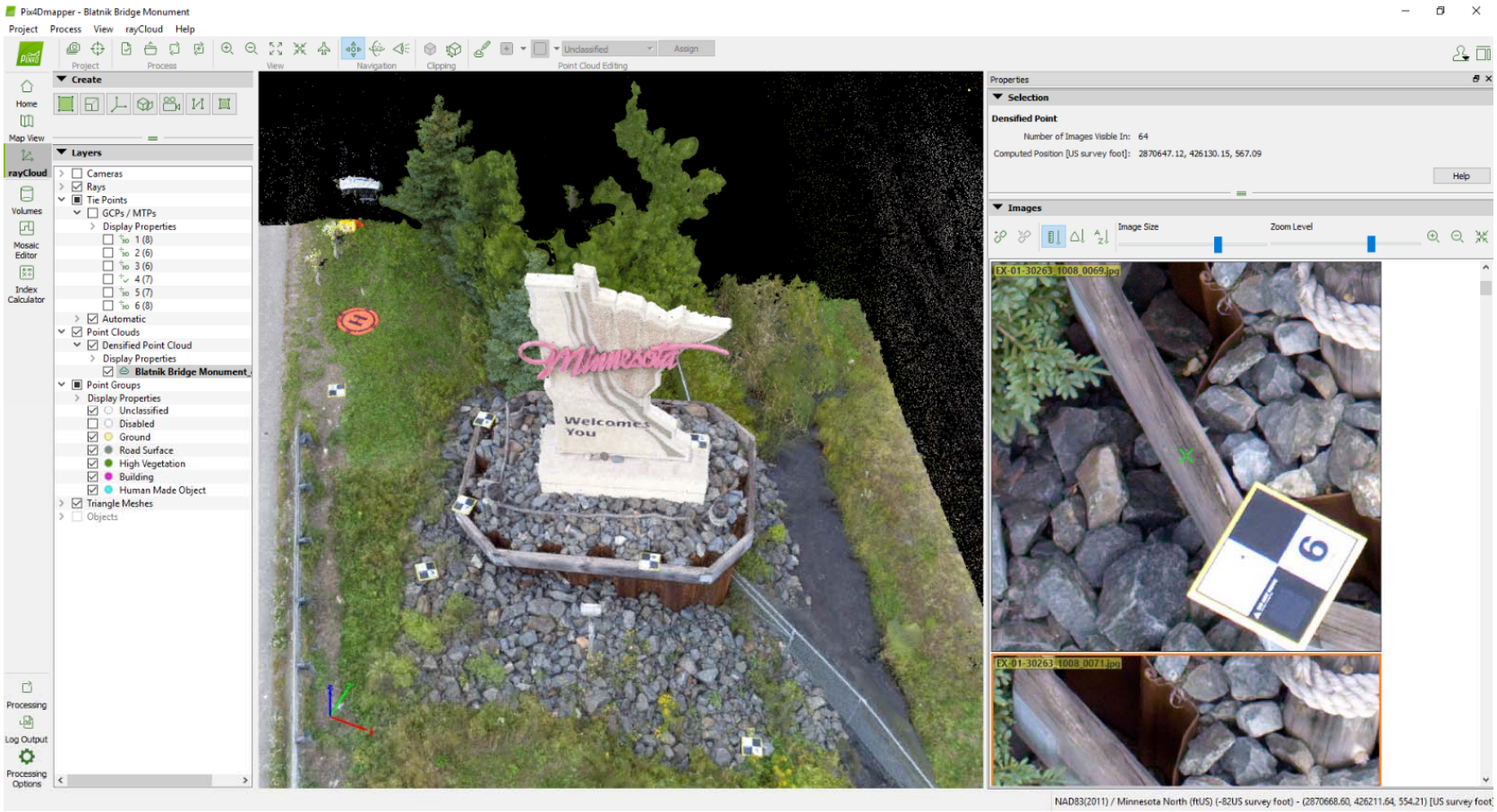
Other Applications – Overhead Signs



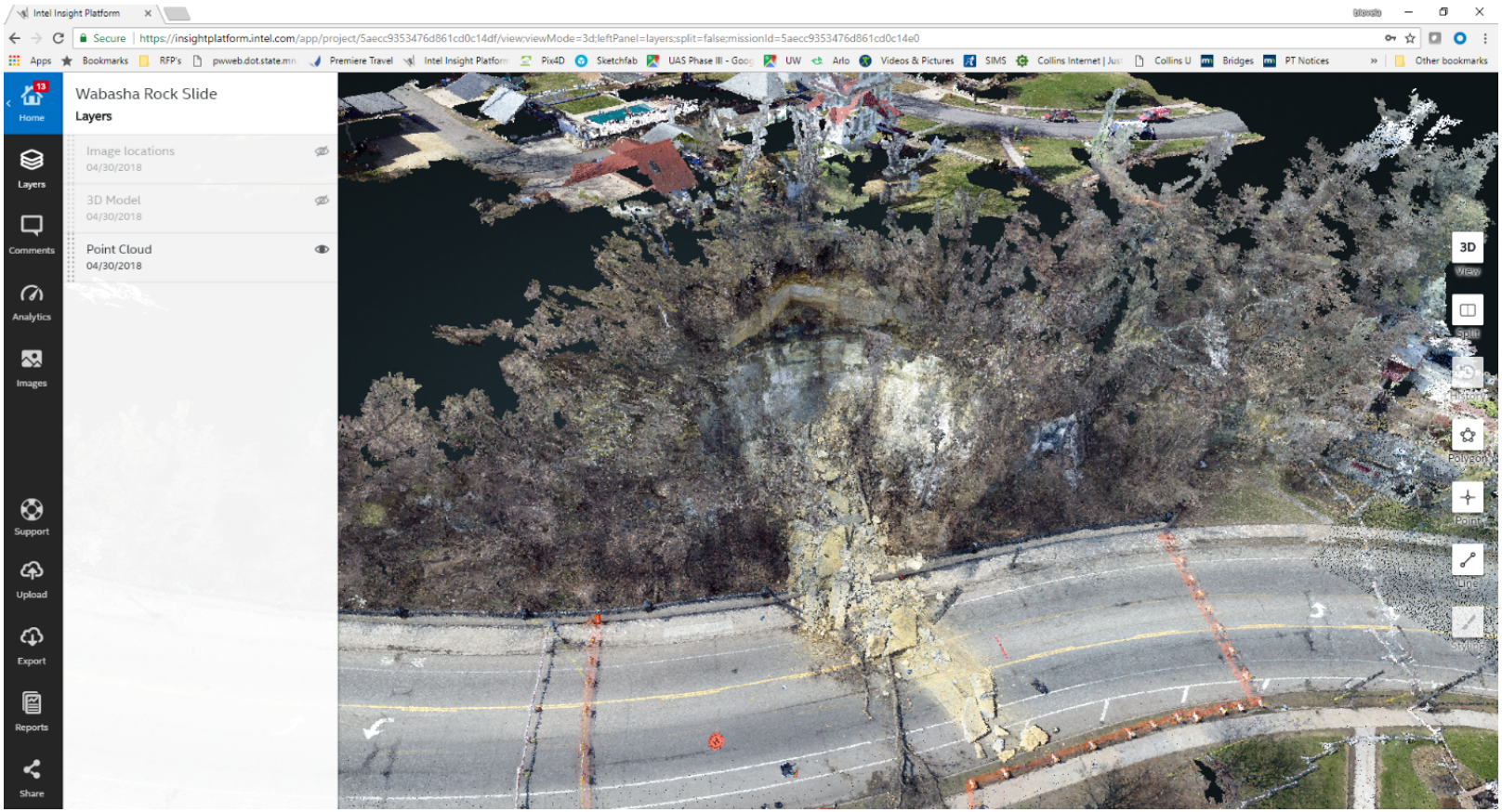
Other Applications – Volume Calculations



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

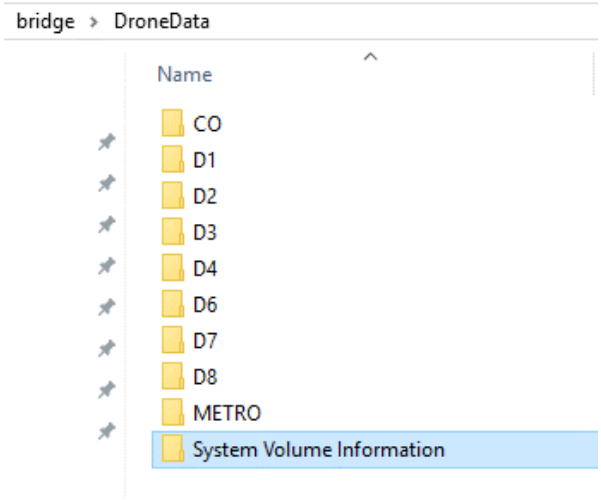
Cost Savings

- 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



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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QUESTIONS?