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TRANSPORTATION RESEARCH BOARD

Using Drones to Inspect Bridges

July 28, 2021

@NASEMTRB
#TRBwebinar

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- 2.0 Professional Development Hour (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
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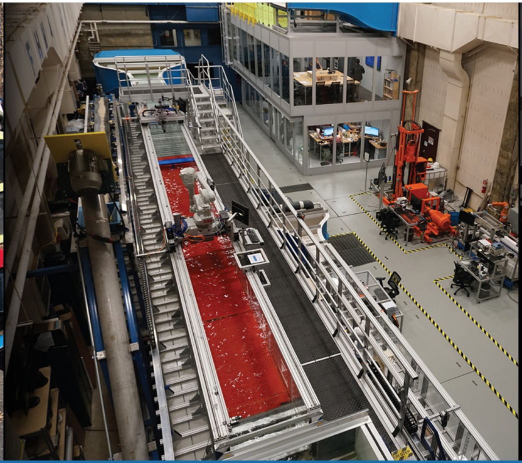
Learning Objectives

1. Describe ways transportation agencies leverage UAS technology to supplement bridge inspections

2. Identify how UAS technology reduces time and costs and increases safety


All Images Source: FHWA.

OFFICE OF RESEARCH, DEVELOPMENT, AND TECHNOLOGY

WORKSHOP 1008: APPLICATION OF UNMANNED AERIAL SYSTEMS (UAS) FOR CONDITION ASSESSMENT OF HIGHWAY ASSETS

Transportation Research Board (TRB)

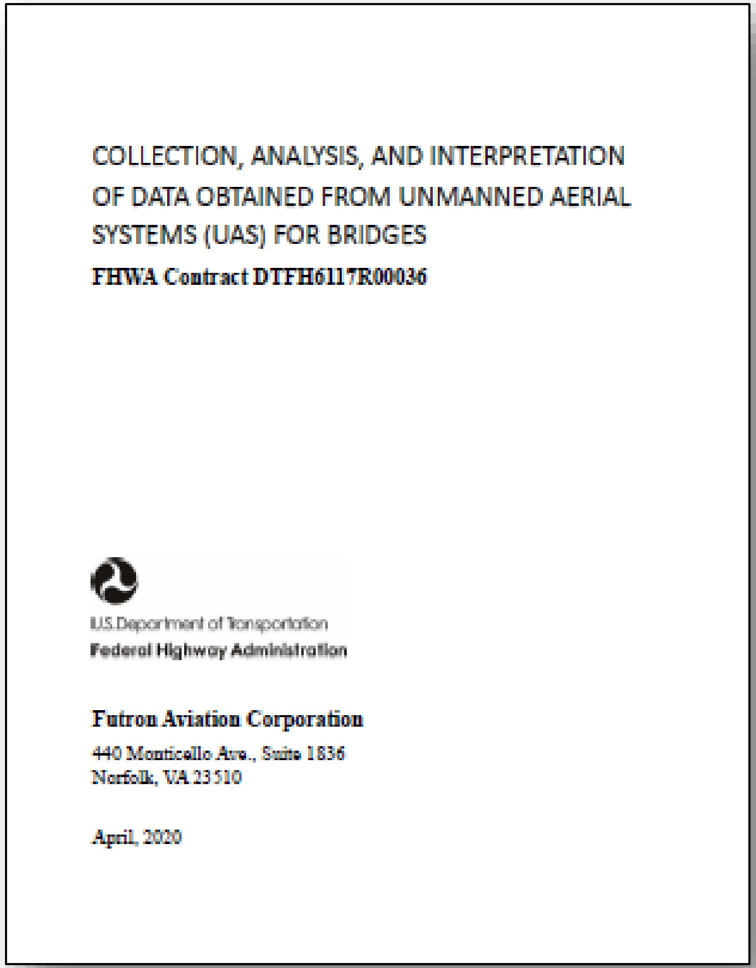
Hoda Azari, Ph.D.

Nondestructive Evaluation (NDE) Research

Program Manager

Infrastructure Analysis and Construction Team

FHWA UAS RESEARCH PROJECT



COLLECTION, ANALYSIS, AND INTERPRETATION OF DATA OBTAINED FROM UNMANNED AERIAL SYSTEMS (UAS) FOR BRIDGES

FHWA Contract DTFH6117R00036

U.S. Department of Transportation
Federal Highway Administration

Futron Aviation Corporation

440 Monticello Ave., Suite 1836
Norfolk, VA 23510

April, 2020

Source: FHWA.

- The report provides a thorough review of UAS technologies and applications for bridge inspections.
- 4 TechBriefs:
  - *Best Practices for Routine Bridge Inspections Using Unmanned Aerial Systems*
  - *Controlled-Environment Testing of UAS Digital Camera Sensor Specifications and Operational Parameters for Bridge Safety Inspections*
  - *Effective Practices for Managing Bridge Inspection Data Captured by UAS*
  - *Effective Practices for Using UAS During Bridge Construction*

PROJECT OBJECTIVES

- Document the State data collection using UAS.
- Assess data quality assurance needed to perform a satisfactory bridge inspection and assessment.
- Identify best practices and guidelines for:
  - Payload sensors.
  - Assessment, presentation, storage, and management of data.
- Explore data collection/reporting needs for various users.
- Document how UAS capabilities compare bridge owners needs and traditional inspection techniques.
- Conduct field and laboratory testing toward the establishment of standards for UAS use.

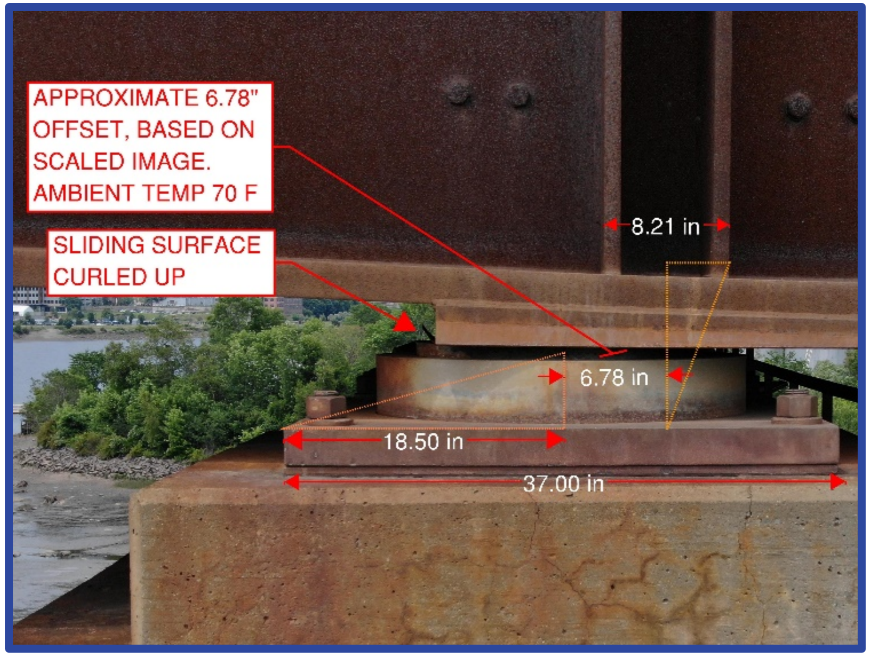
UAS AS AN INSPECTION TOOL

WHAT UAS CAN DO

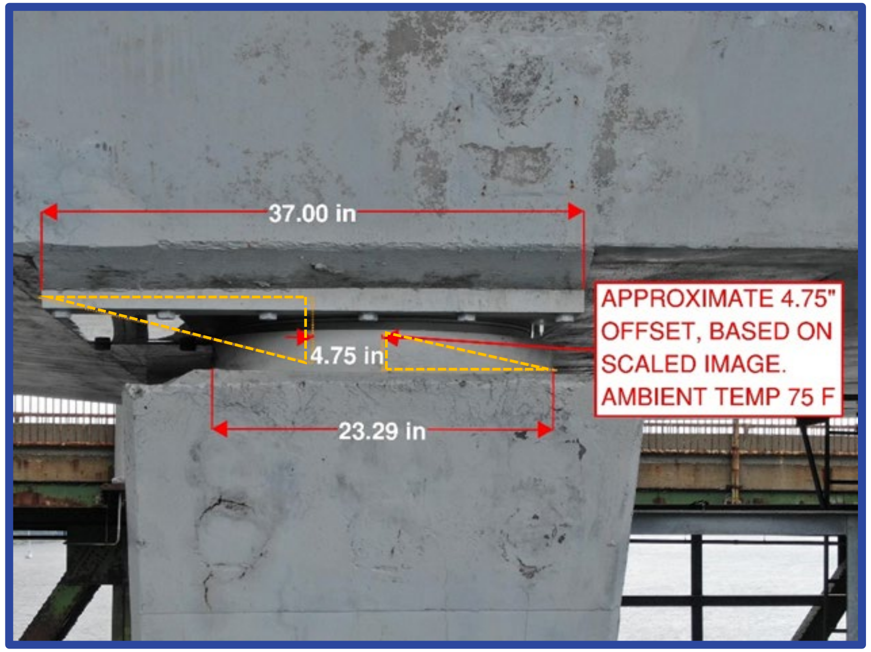
- Augment and enhance visual bridge inspections.
- Reach difficult to access areas.
- Reduce risk by reducing under-bridge inspection truck (UBIT) use, climbing, and other potentially high-risk access methods.
- Lower costs by reducing time spent on the inspection, eliminating or reducing traffic control, and reducing the need for costly access methods (such as UBIT).
- Enhance safety for the inspection team and the public.

FIELD EXPERIENCE AND RESULTS

Extracting displacement measurements



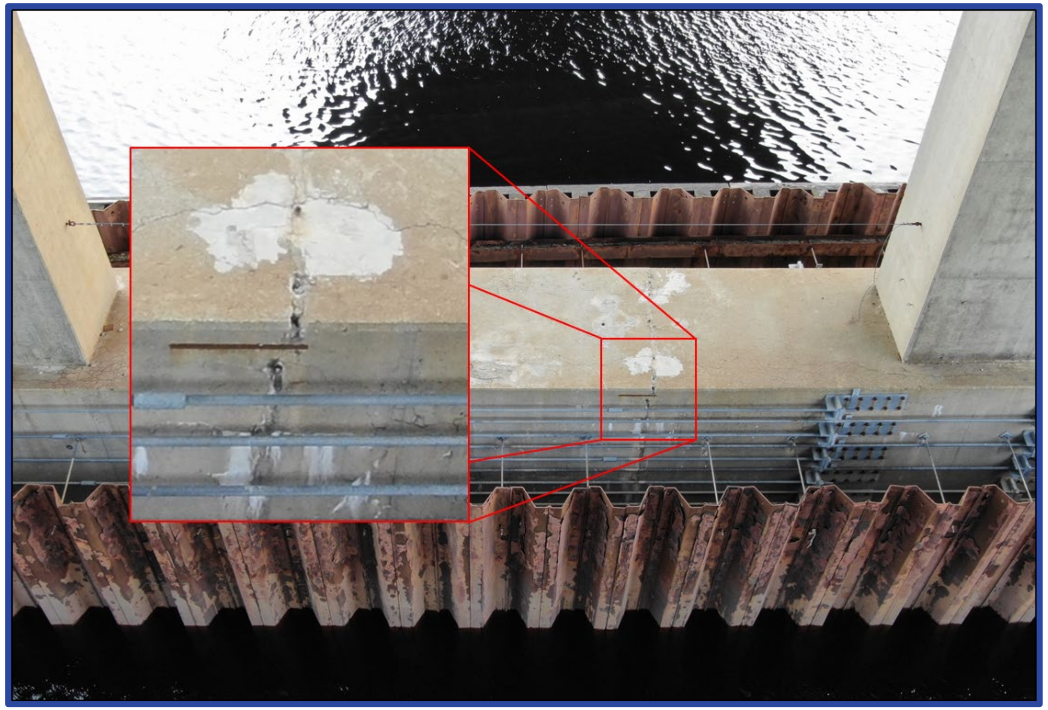
Veterans Memorial Bridge, Bangor, Maine



Sagadahoc Bridge, Bath, Maine

FIELD EXPERIENCE AND RESULTS

Accessing areas that would normally require a boat



Veterans Memorial Bridge, Bangor, Maine

WHAT UAS CAN'T DO

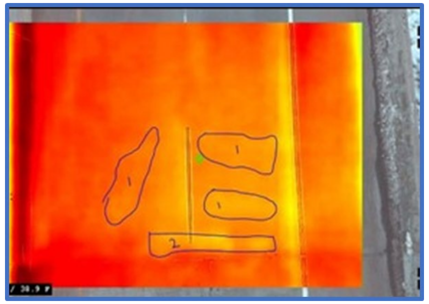
- Replace the expertise of an experienced and qualified NBIS inspector.
- Replace tactile inspection.
- Operate outside of regulations.

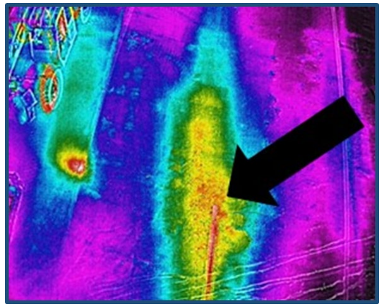
SENSOR TYPES

Commonly used sensors:

- Electro-optical.
- Infrared sensors.

© VHB.





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UAS INFORMATION PRODUCTS

INFORMATION PRODUCTS

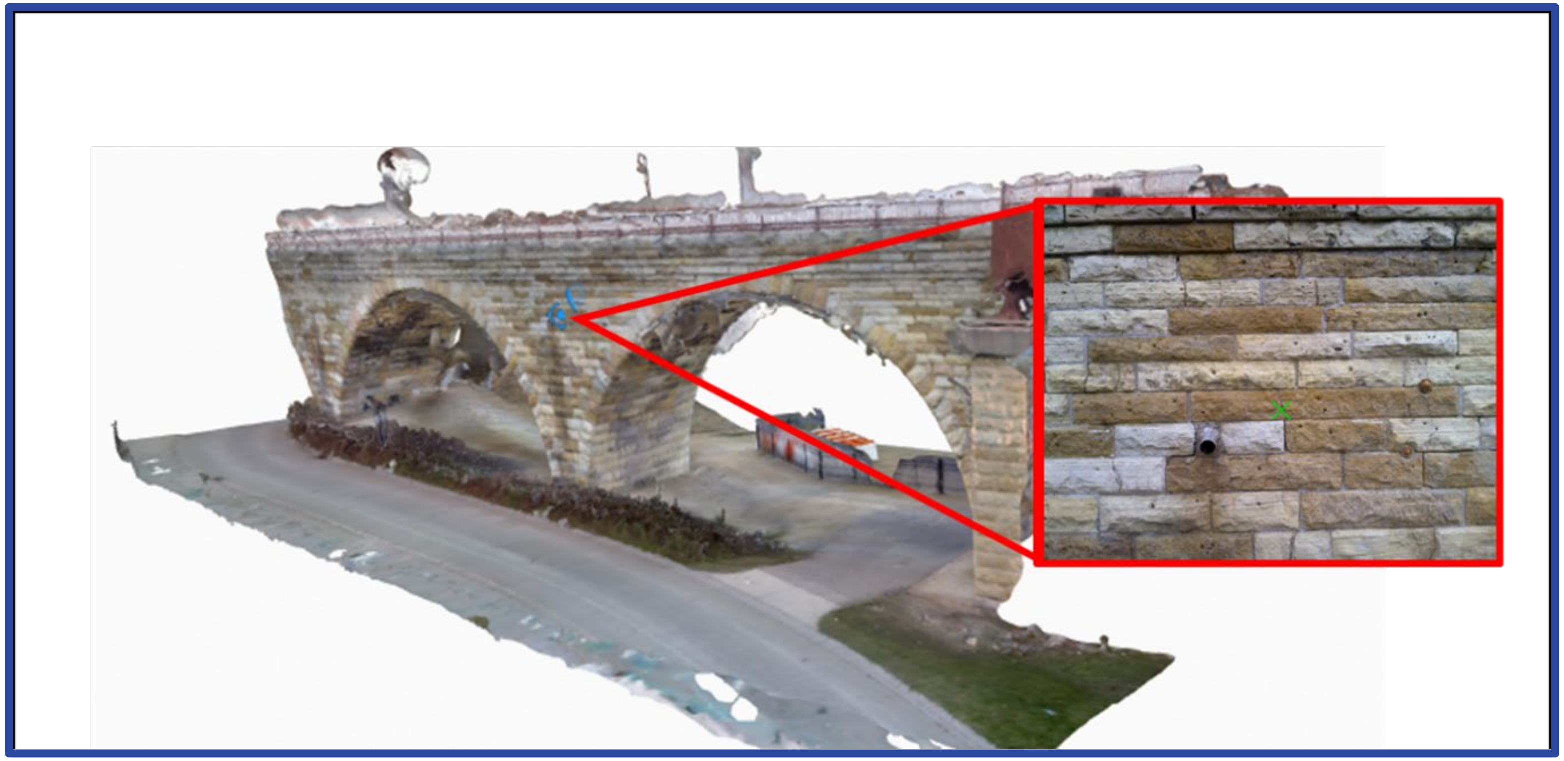
Digital imagery supports the inspection reports.

Ticonic Bridge, Winslow, Maine

Coos Canyon Bridge, Maine

INFORMATION PRODUCTS

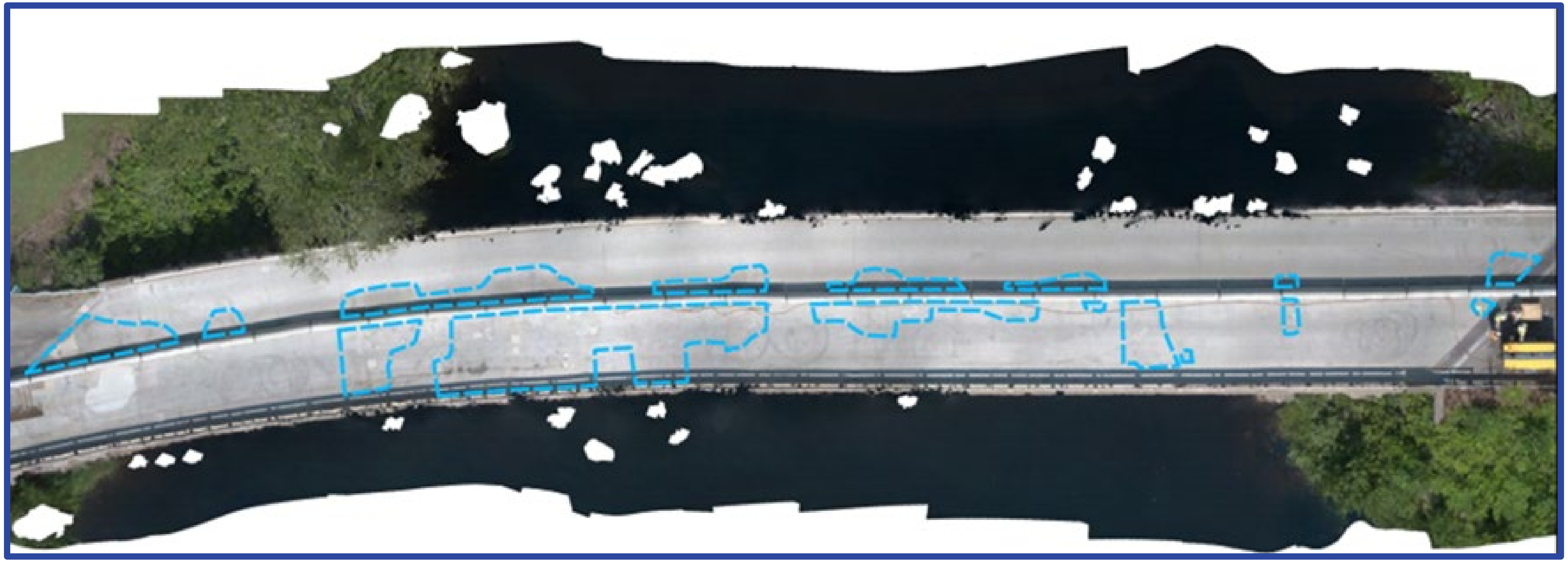
The 3D models support planning.



https://sketchfab.com/3d-models/stone-arch-bridge-11-28-17-d8c81870e00f48a8af7832d52434abcb

INFORMATION PRODUCTS

Orthographics or orthoimages support planning.



DATA MANAGEMENT

Field collection.

Image tracking and documentation.

Flight Number/ Time	Equipment	UAS Location (Take off)- Ambient Conditions	Flight Path		Photo/Video ID
Flight 6	210	Bridge #1558	Fly from A1 to A2 across bridge looking across		5
7/10/2019			bridge at upstream rail and median barrier ???		
		26.7°C (80°F)			
		2 Knots Wind			
		(2.3 MPH)			
Flight 7	210	Bridge #1558	A1 to A2 looking at upstream rails, then		1
7/10/2019			going back from A2 to A1 looking down at		2
3:20-3:49		26.7°C (80°F)	bridge drain		3
P.M.		2 Knots Wind			4
		(2.3 MPH)			

EFFECTIVENESS

Routine.

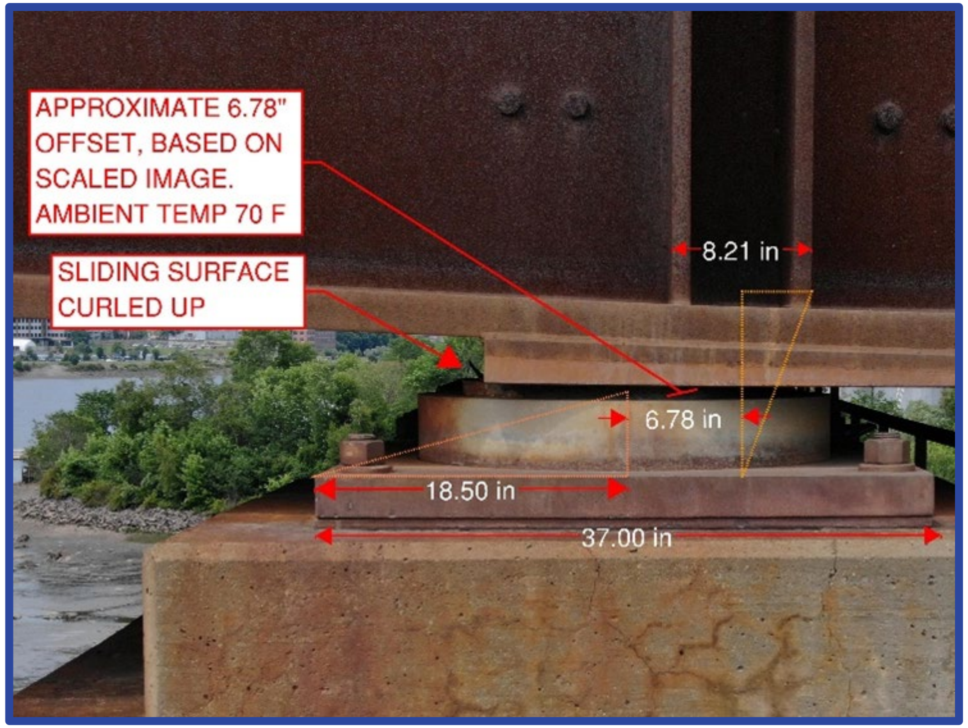
Fracture critical.

Veterans Memorial Bridge, Bangor, Maine

ROUTINE—EFFECTIVE

© VHB.

Post-processing



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Veterans Memorial Bridge, Bangor, Maine

EFFECTIVENESS

Routine.

Fracture critical.

Max Wilder Memorial Bridge, Arrowsic, Maine

FRACTURE CRITICAL—EFFECTIVE OR NOT?

UAS

Inspector

UAS OPERATIONAL PLANNING

Develop the plan:

- Preinspection planning.
- Flight operations/inspection plan and flight estimates.
- Postdata collection steps.
  - Field review steps.
  - Field review equipment.

CASE STUDIES AND TESTING

© Futron Aviation.

FIELD TESTING RECOMMENDATION

Minimum Camera Specifications:

- Sensor resolution—12 MP.
- Aperture—f/2.8 fixed.
- Ability to adjust internal camera settings.
- ISO range 100–3200.

UAS Specifications:

- Multirotor.
- GPS.
- Optical stabilization, indoor stabilization.

UAS Controller:

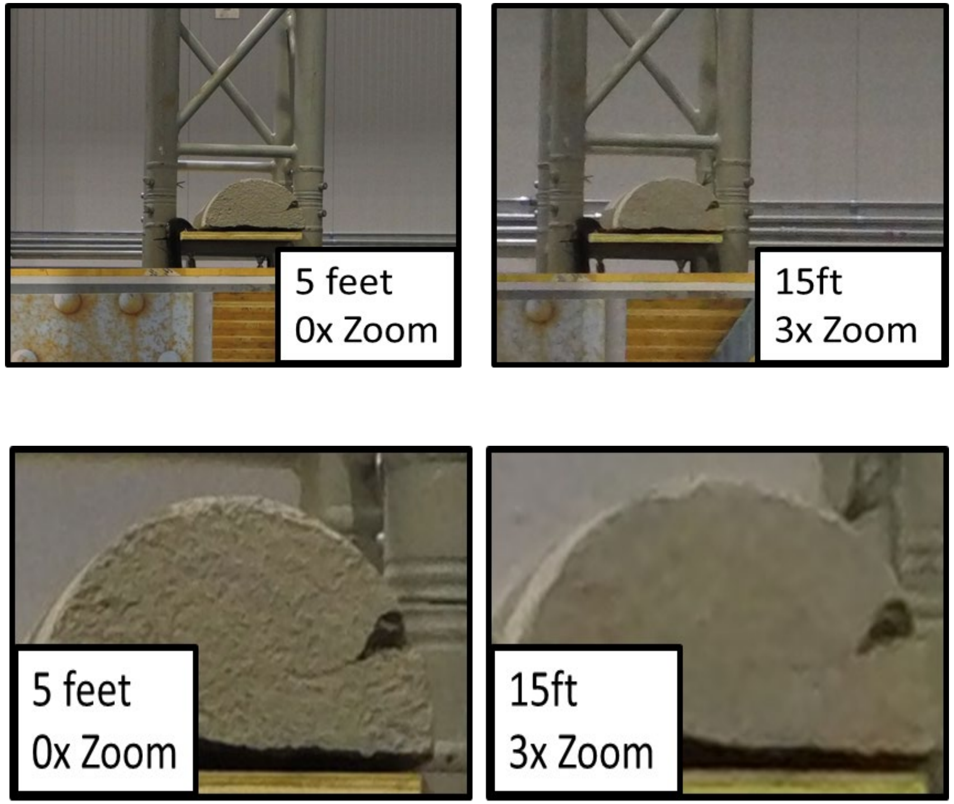
- The minimum control setup is one controller.
- The optimal setup for controlling the camera and the platform is to have two controllers.
- The minimum screen resolution for the controller is 720 pixels.

- **Camera Settings:**
  - Automatic settings as the default for the camera.
  - ISO—primary setting for improving image quality in low light conditions.
- **Standoff Distance:**
  - A 6 to 8-foot distance will be dependent on the skill of the pilot at the controls.
- **Environment:**
  - UAS effective in winds below 15 knots.
  - UAS manufacturer recommendations for specific environmental condition limits to consider when working around bridge structures.

ISO = International Organisation for Standardisation

CONTROLLED ENVIRONMENT TESTING CRITERIA

- Internal sensor settings.
- External lighting augmentation.
- UAS stabilization (GPS and non-GPS).
- Wind velocity.
- Maximum distance away from the structure using zoom capability.
- Minimum standoff distances under static and dynamic wind conditions.
- Maximum lateral speed for defect detection.



CONTROLLED ENVIRONMENT FINDINGS AND RECOMMENDATIONS

- Use minimum sensor resolution of 12 MP.
- Use sensor automatic settings.
- Adjust sensor settings manually when greater definition adds value.
- Adjust ISO to provide the best result.
- Avoid adjusting the shutter speed.
- Use a standoff distance of 5 feet to produce usable imagery.
- Use zoom to aid the inspector.
- Use external lighting to improve image quality.
- Use a stable, stationary platform to produce the highest quality imagery.

SUMMARY AND CONCLUSIONS

UAS serve as an additional tool for the inspector.

- Effective for augmenting routine visual inspections.
- Limited application for fracture critical for some bridge conditions at present.
- Advanced technology and robotics may change this.

UAS provides flexibility for bridge owners.

- Increased availability of data.
- Enhanced modelling and archiving for future comparisons.
- Enhanced safety for inspection teams and public.

Additional testing could further value to the industry.

- Enhanced understanding of specifications for EO.
- Increased understanding of IR capabilities.

CONTACTS

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Source: FHWA.

DISCLAIMER

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Bridge Inspections Utilizing UAS

Jennifer Wells, PE - Minnesota State Bridge Inspection Engineer

Presentation Outcomes

- Understand Benefits and Limitations
- Learn current and future drone technologies that are effective for bridge inspection
- Understanding of how to successfully implement drone technology.
- Understand the costs associated with implementing drones and the cost savings that can be realized compared to traditional methods.
- Understand drone data needs

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


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TRANSPORTATION
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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

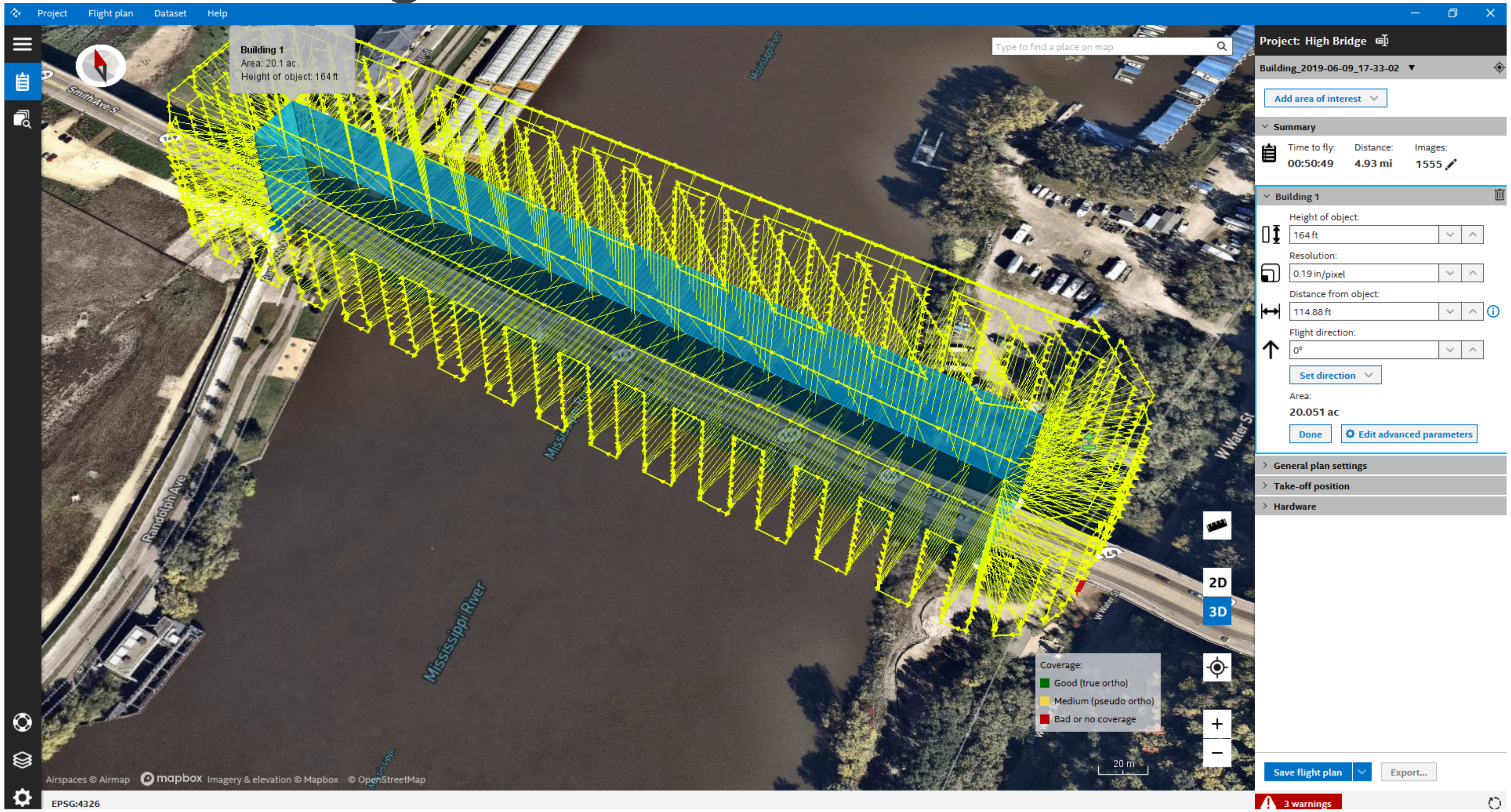
Bridge Inspection Goals

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

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

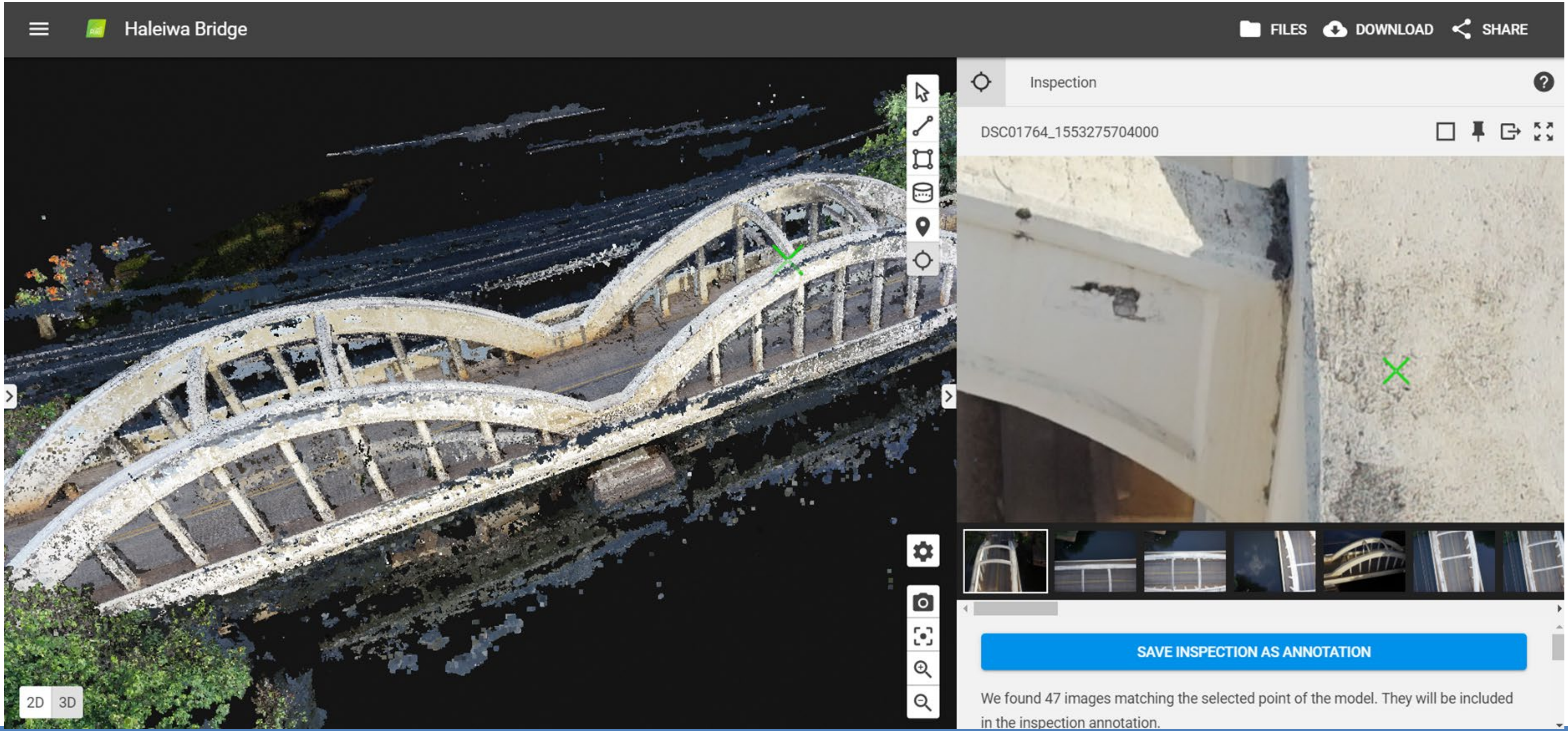
3. Document Conditions and Deficiencies

Deliverables – Orthomosaic

2. Document Conditions and Deficiencies

Deliverables – Point Clouds

4. Communicate Conditions and Deficiencies



4. Communicate Conditions and Deficiencies

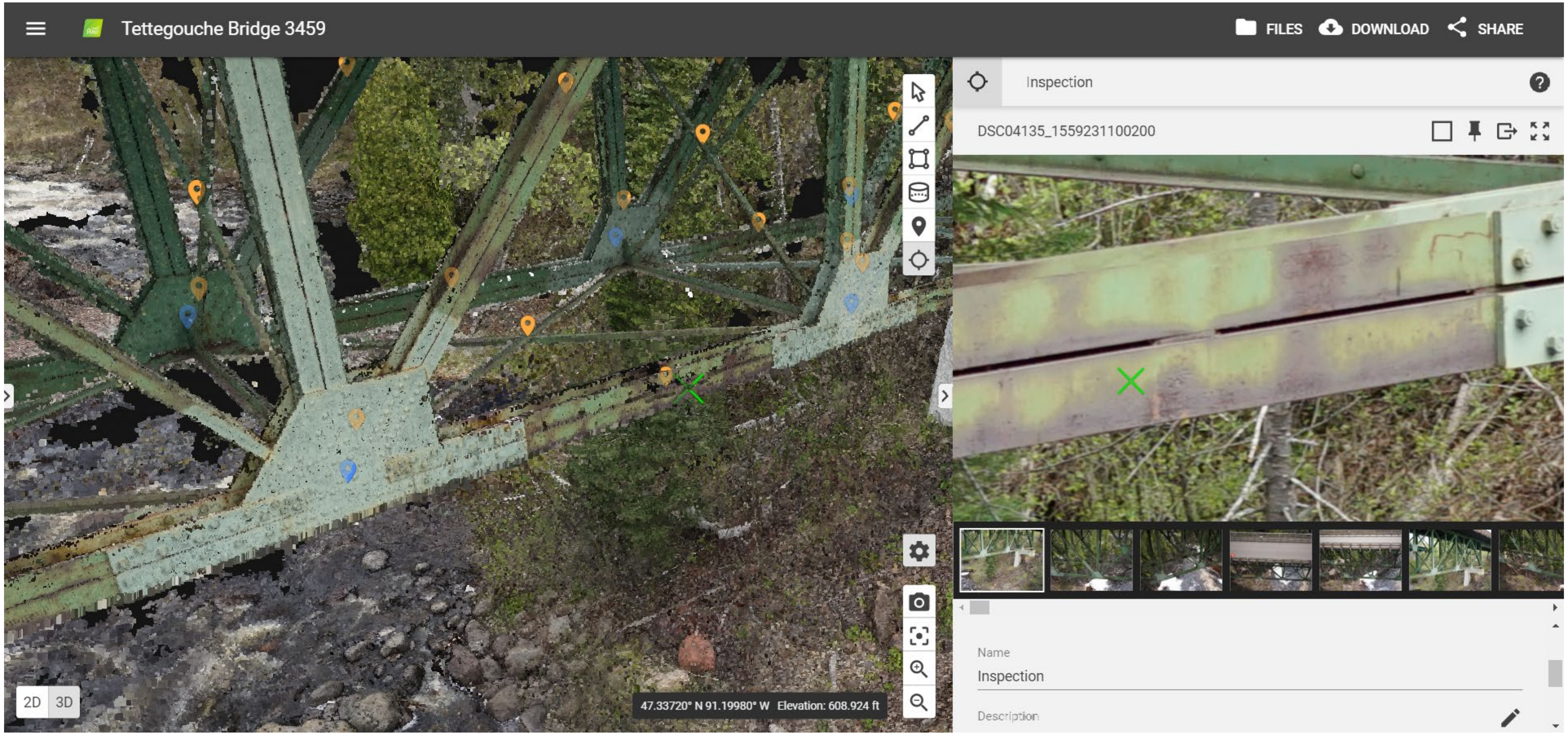
- Traditional Reporting

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

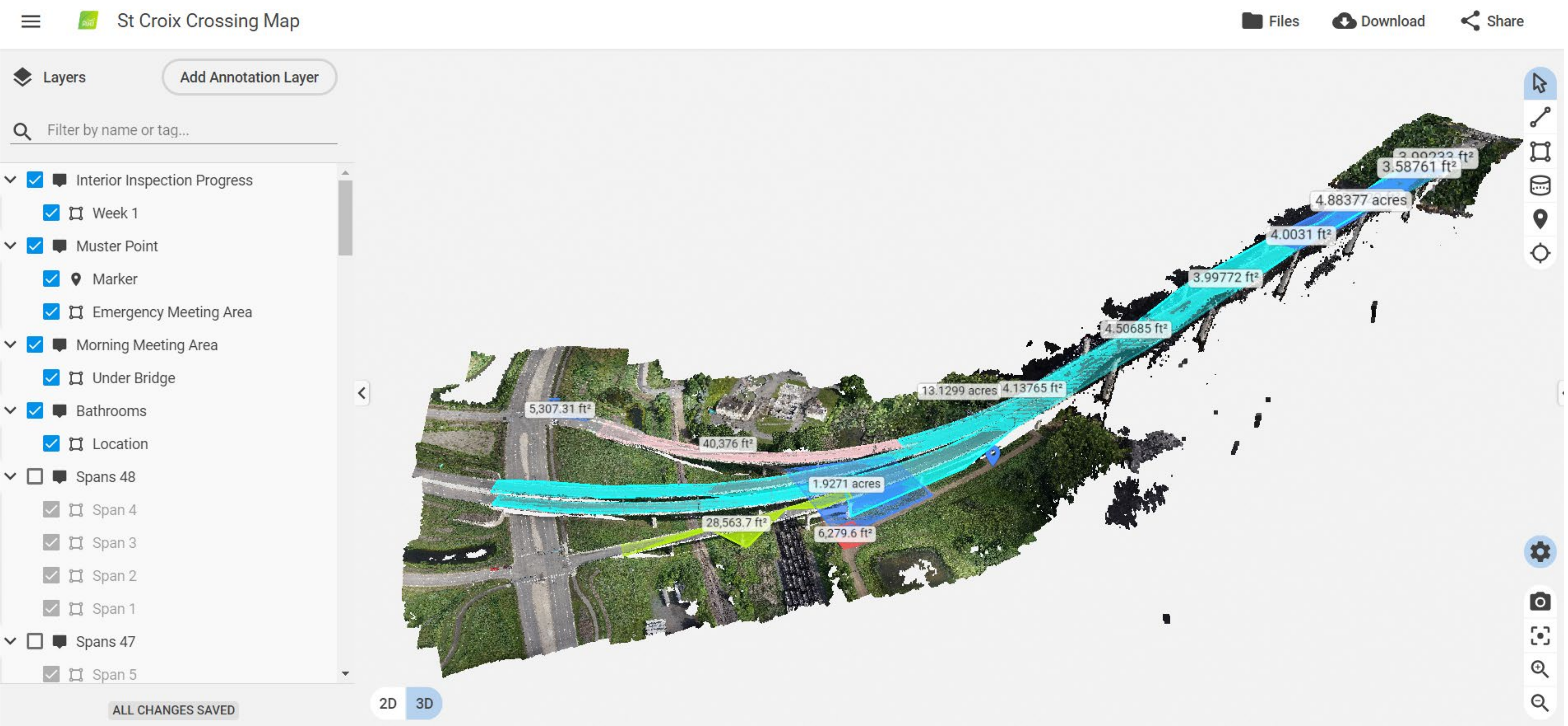
- Cloud Sharing



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

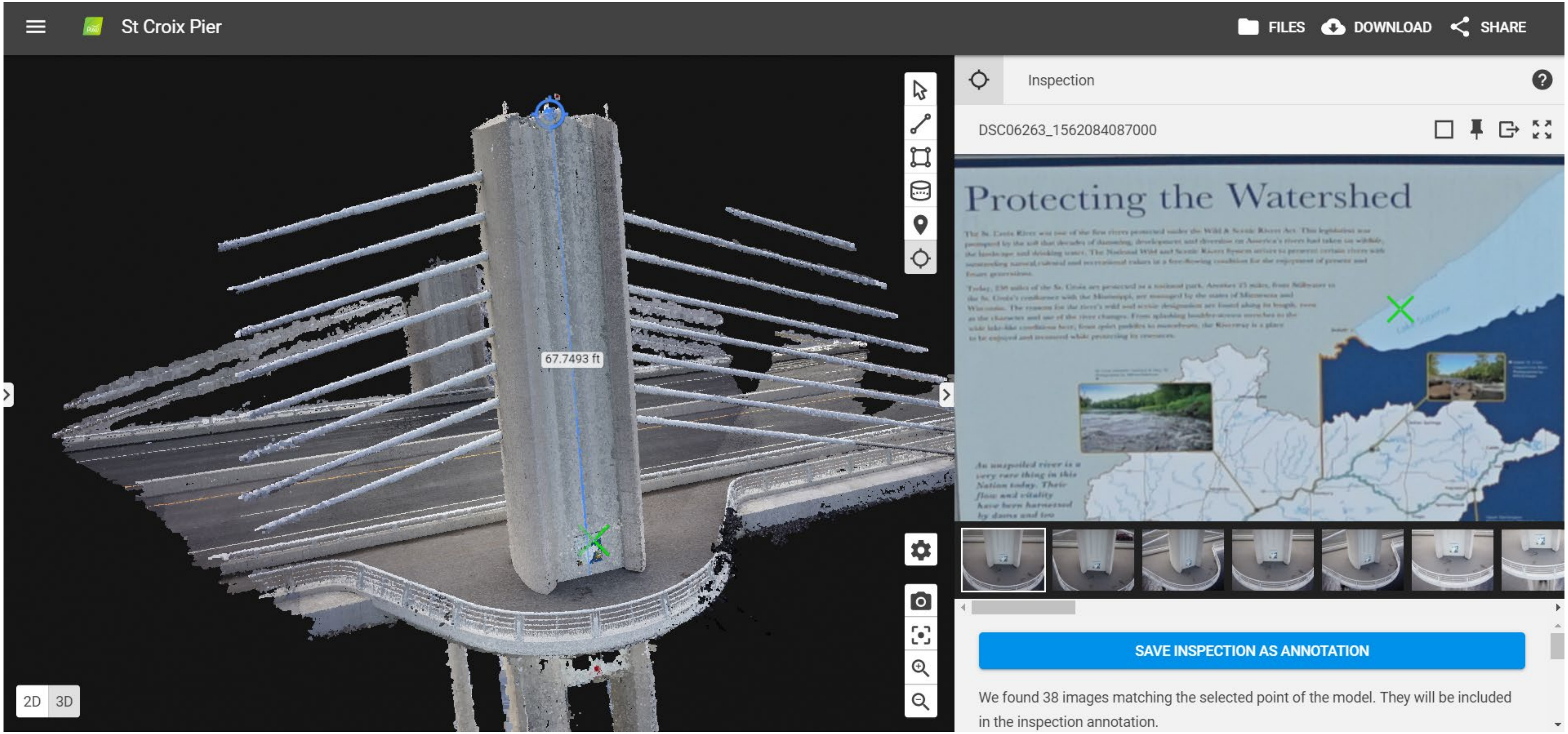


https://cloud.pix4d.com/pro/project/507277/model?shareToken=352346c7-7098-44ca-9b52-07f1c9eecee1

- 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



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%**

Bridge Candidates

Works Well

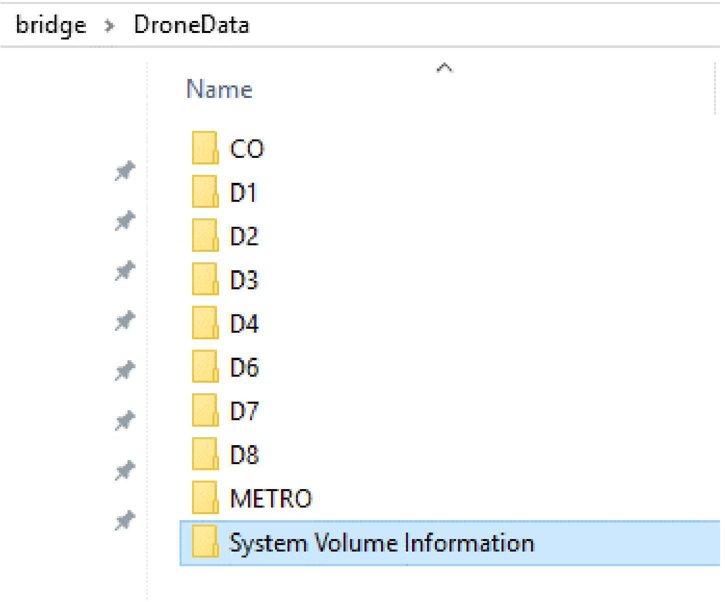
- Large Bridges
- Bridge in open areas
- Bridges that depend on traffic control and UBIV's for inspection

Does not Work Well

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

Data Storage

- Super Computer
- Super Storage
- Security



AI & Digital Twins

- Microsoft HoloLens
- Bridge Digital Twins

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

Phase IV Report Published

- https://www.dot.state.mn.us/research/reports/2021/202113.pdf

MnDOT Office of Aeronautics UAS Policy/Info

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

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QUESTIONS?

Using UAS to Inspect Bridges and other Transportation Infrastructure: Michigan Department of Transportation (MDOT) Case Study

July 28, 2021

TRB Webinar

Steven J. Cook, P.E., Michigan Department of Transportation, cookS9@michigan.gov

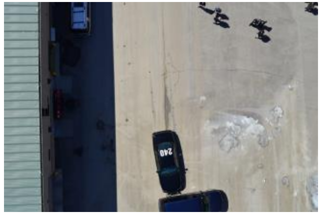
with support of Michigan Technological University, Surveying Solutions Inc., and Collins Engineers

Colin N. Brooks, Ph.D., Michigan Tech Research Institute, cnbrooks@mtu.edu

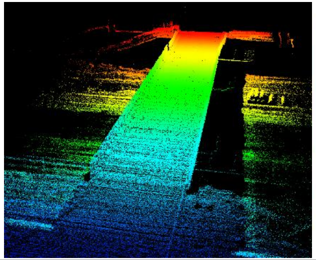
Objectives for MDOT UAS Integration project (2019-2022)

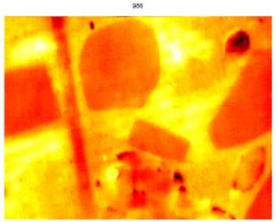
A. Enable everyday usage of UAS in Michigan DOT business areas and workflow
B. Work closely with MDOT Sections SME to get UAS capabilities into their hands through efficient access to UAS collected data, platforms, sensors, and software tools
C. Develop and deploy four use cases from MDOT Sections:
    A. Traffic Operations Surveillance Monitoring
    B. Bridge Inspection (today's focus)
    C. Construction Inspection
    D. LiDAR for Design Surveys
D. Deploy and integrate the use of UAS capabilities and data usage as part of day-to-day operations,
E. Recommend how to effectively work with the private sector to take advantage of rapidly developing sensor and platform technologies

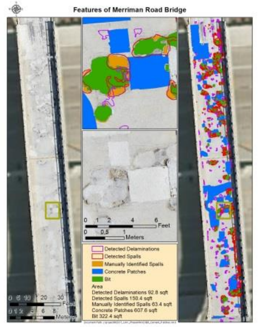
Summary of MDOT UAV Phase I (2013-2015)



- Project Tasks:
  - Performed Confined Space Inspection Demonstration using micro UAVs
  - Performed Traffic Monitoring Demonstration
    - Using tethered blimp UAS, the team was able to broadcast near real time traffic imagery to a ground receiver
  - Explored non-destructive evaluation methods including:
    - **Bridge delamination detection using thermal imaging**
    - **Spall, pothole and crack detection using optical imagery**
  - Demonstrated UAV based LiDAR inspection of transportation infrastructure, including creating 3D models of bridges

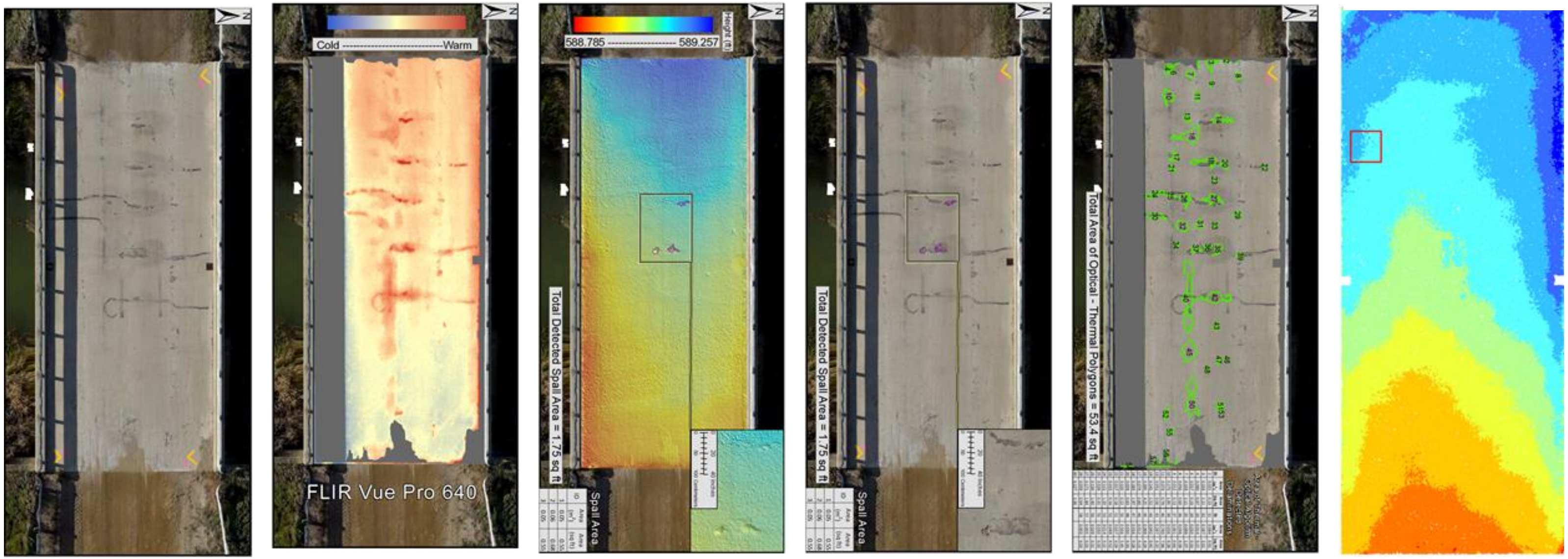






Seven standard geospatial outputs for UAS sensing of bridge decks

Optical | Thermal | Hillshade & DEM | Detected Spalls | Detected Delaminations | Point Cloud from 3D Optical



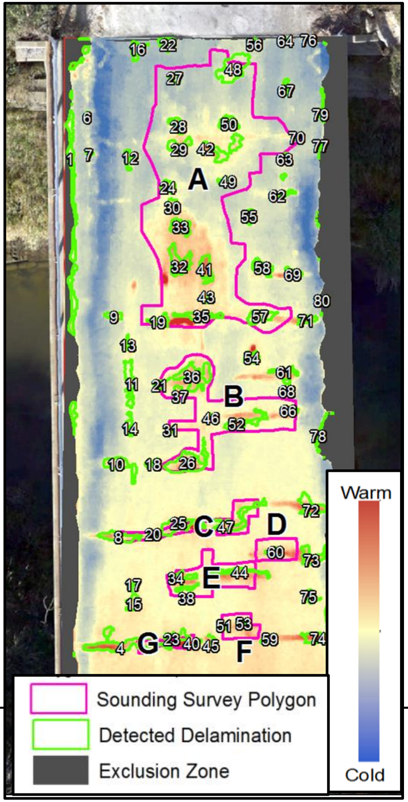
Summary of MDOT Phase II (2016-2018)

Spall Detection Algorithm

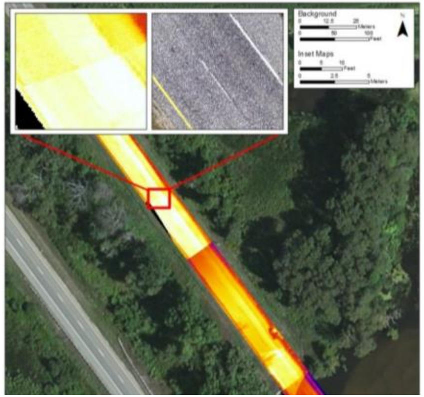
(Spallgorithm)

Bridge Area - 7,250ft2
Spall Areas
2014 - 33.6 ft2 (0.5% of the bridge deck)
2017 - 79.2 ft2 (1.1% of the bridge deck)

Thermal Bridge Inspection Data

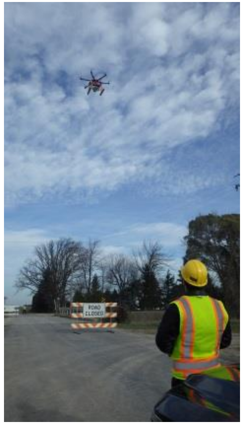


Thermal Road Corridor Analysis



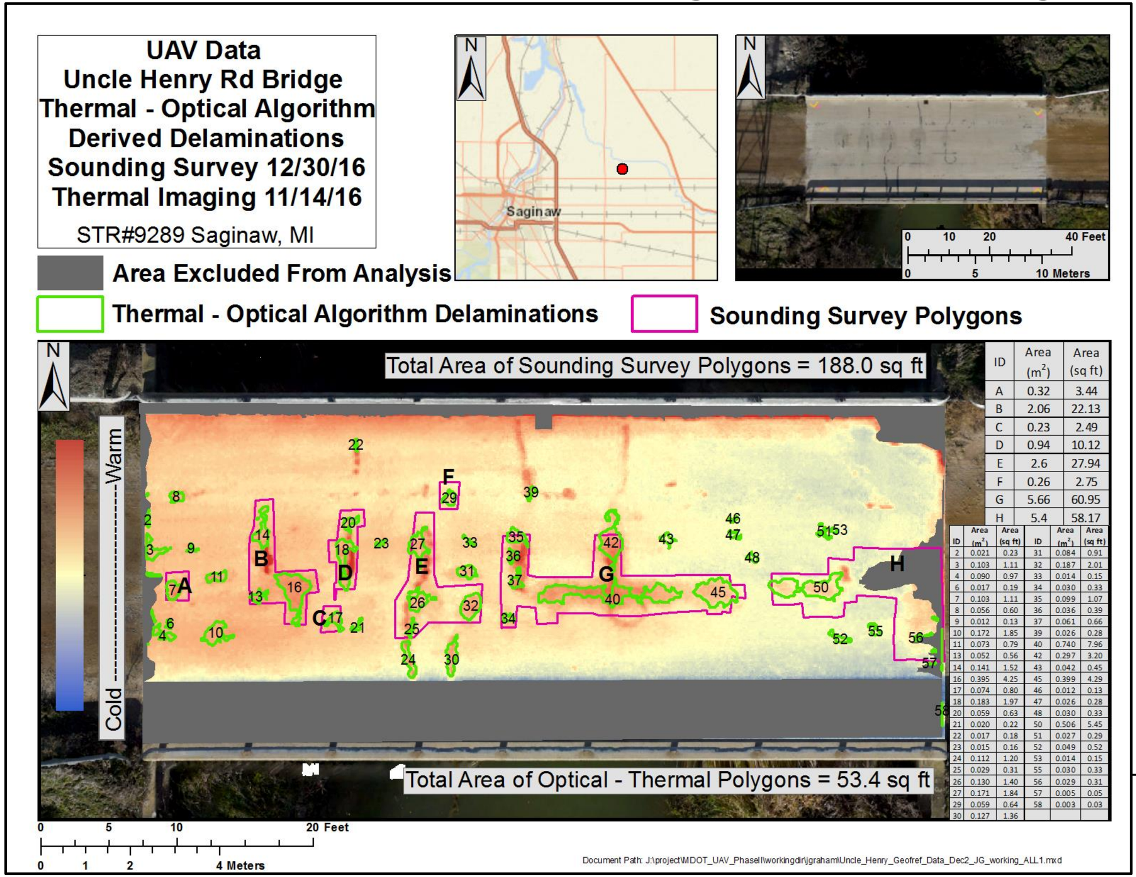
Traffic Monitoring

Phase II UAV Platforms



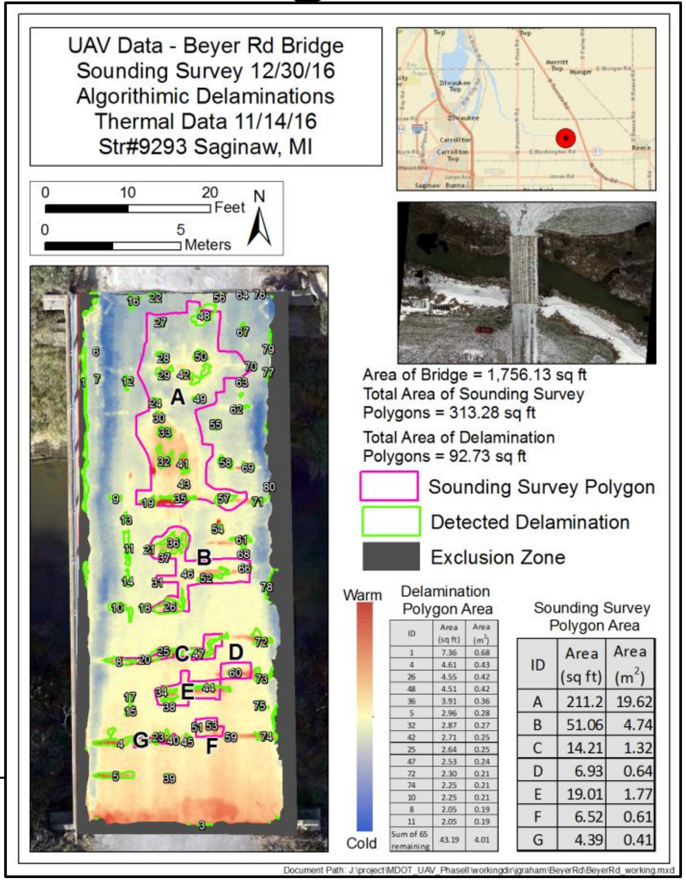
- Multiple platforms have been used based upon space and sensor size restrictions
- Bergen Hexacopter & Quad-8
- Aerostat / Tethered Blimp
- Imaging small quadcopters
  - DJI Phantom 3 Advanced
  - 3D Robotics IRIS+
  - Mariner, Splash2 (waterproof)
  - DJI Mavic Pro
- Micro-UAS quadcopters

Phase II Delamination Detection – Uncle Henry Rd & Beyer Rd bridges



ID	Area (m^2)	Area (sq ft)
A	0.32	3.44
B	2.06	22.13
C	0.23	2.49
D	0.94	10.12
E	2.6	27.94
F	0.26	2.75
G	5.66	60.95
H	5.4	58.17

ID	Area (m^2)	Area (sq ft)	ID	Area (m^2)	Area (sq ft)
2	0.021	0.23	31	0.084	0.91
3	0.103	1.11	32	0.187	2.01
4	0.090	0.97	33	0.014	0.15
6	0.017	0.19	34	0.030	0.33
7	0.103	1.11	35	0.099	1.07
8	0.056	0.60	36	0.036	0.39
9	0.012	0.13	37	0.061	0.66
10	0.172	1.85	39	0.026	0.28
11	0.073	0.79	40	0.740	7.96
13	0.052	0.56	42	0.297	3.20
14	0.141	1.52	43	0.042	0.45
16	0.395	4.25	45	0.399	4.29
17	0.074	0.80	46	0.012	0.13
18	0.183	1.97	47	0.026	0.28
20	0.059	0.63	48	0.030	0.33
21	0.020	0.22	50	0.506	5.45
22	0.017	0.18	51	0.027	0.29
23	0.015	0.16	52	0.049	0.52
24	0.112	1.20	53	0.014	0.15
25	0.029	0.31	55	0.030	0.33
26	0.130	1.40	56	0.029	0.31
27	0.171	1.84	57	0.005	0.05
29	0.059	0.64	58	0.003	0.03
30	0.127	1.36			



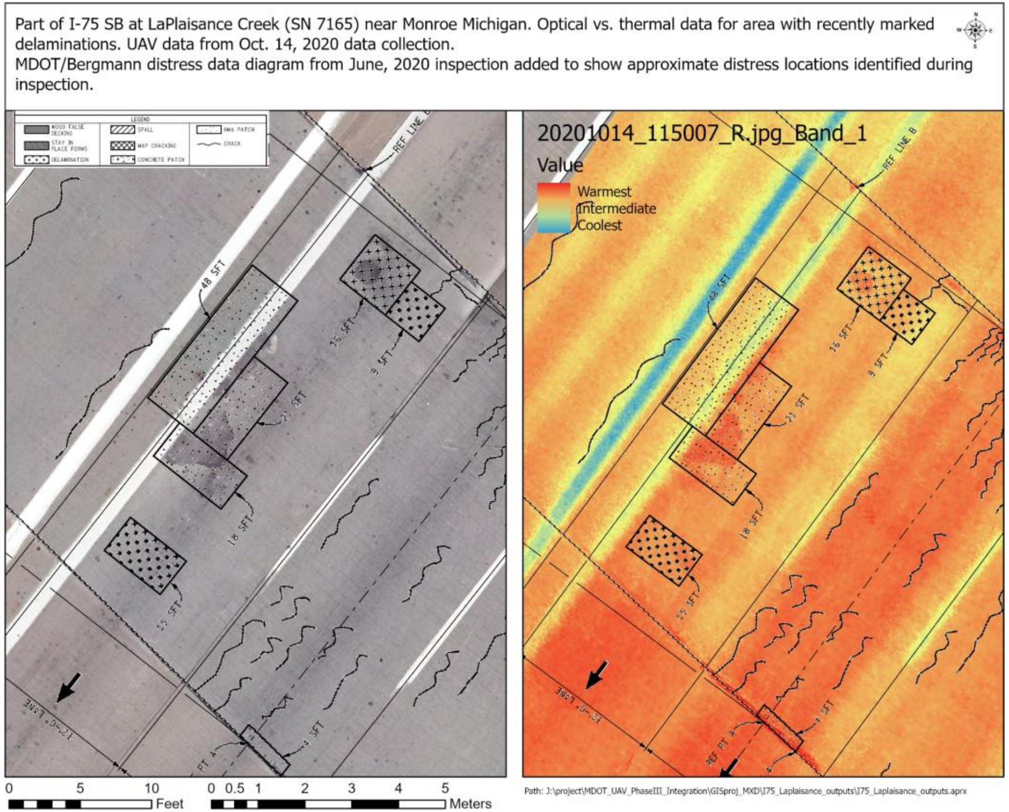
Delamination Polygon Area

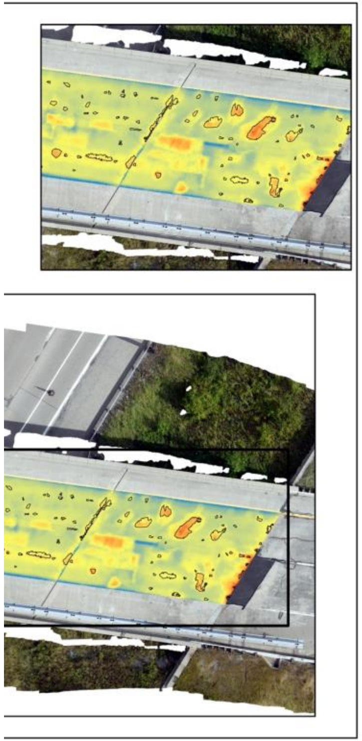
ID	Area (sq ft)	Area (m^2)
1	7.36	0.68
4	4.61	0.43
26	4.55	0.42
48	4.51	0.42
36	3.91	0.36
5	2.96	0.28
32	2.87	0.27
42	2.71	0.25
25	2.64	0.25
47	2.53	0.24
72	2.30	0.21
74	2.25	0.21
10	2.25	0.21
8	2.05	0.19
11	2.05	0.19
Sum of 65 remaining	43.19	4.01

Sounding Survey Polygon Area

ID	Area (sq ft)	Area (m^2)
A	211.2	19.62
B	51.06	4.74
C	14.21	1.32
D	6.93	0.64
E	19.01	1.77
F	6.52	0.61
G	4.39	0.41

Phase III (2019-2022): Use Case 2: Bridge Inspection Assessment - advancements



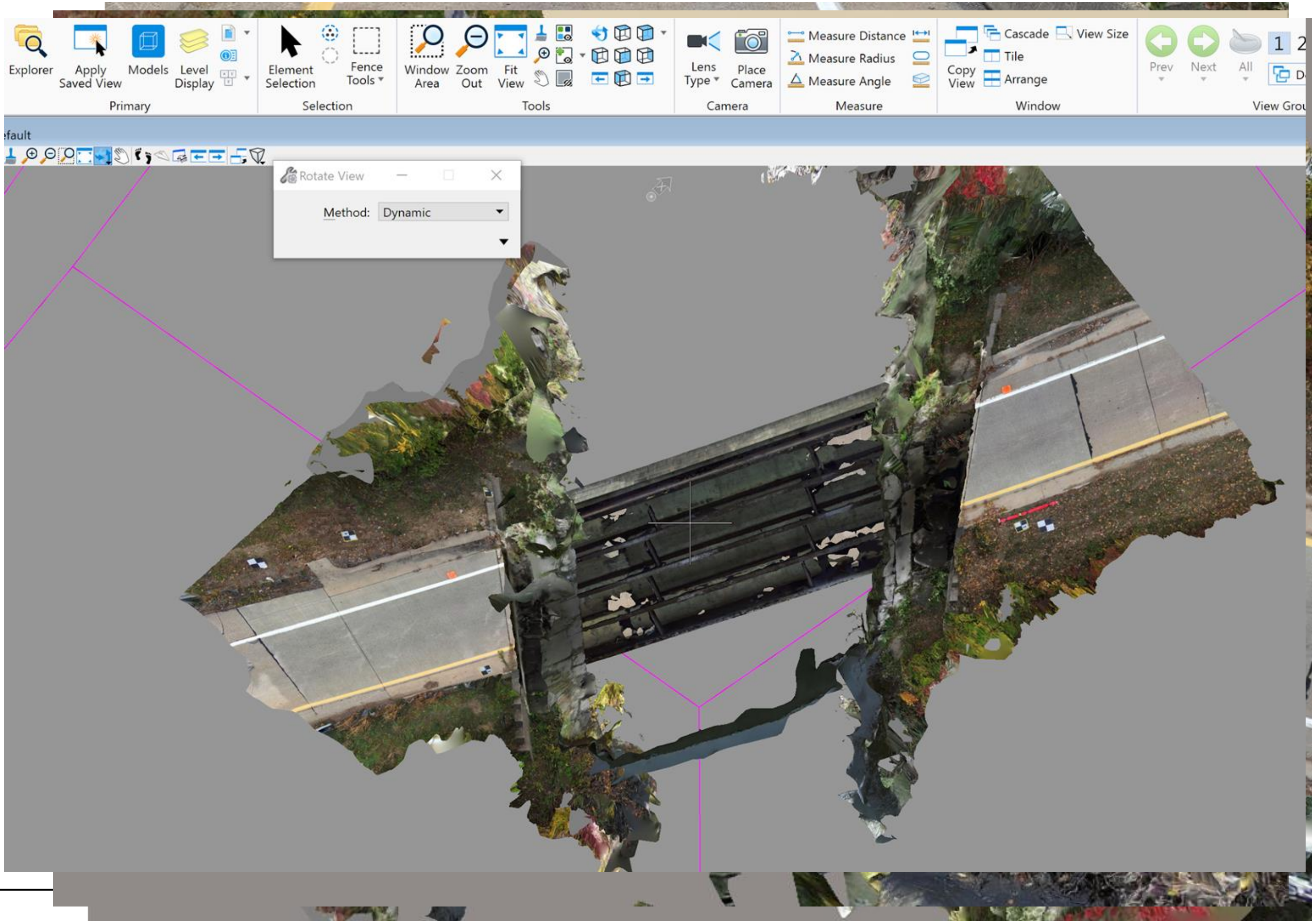


DJI Mavic 2 Pro Imagery - Billwood Hwy – difficult to access locations

Flyability Elios with Collins Engineers

- Designed for confined space inspection
  - Drone is surrounded by a cage
  - LED lighting for forward illuminating
  - HD/FPV camera (1920 x 1080 pixels) captures imagery at 30fps
  - Up to 10-minute flight time

Context Capture 3D Model from Skydio2 imagery



Michigan DOT UAS Program Summary (mainly managed by MDOT's Aeronautics Division)

- MDOT UAS Operations Policy, MDOT UAS Operations Manual
- 24 licensed pilot, 21 MDOT trained & approved for service
- 20 drones with 20 sensors/payloads
- Software Tools: Aloft for fleet/pilot management, DJI Pilot, DJI Go, DJI Go 4, Pix4D capture for flights
- Continued partnerships with research and contract agencies
- Final Report links: Phase I: https://www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249-353767--,00.html
- Phase II: https://www.michigan.gov/documents/mdot/SPR-1674_FinalReport_revised_631648_7.pdf
- Phase III project webpage (project completion, July 2022): https://www.mtu.edu/mtri/research/project-areas/transportation/infrastructure/mdot-uav-p3/

Unmanned Aerial Systems (UAS) for condition assessment of bridges and other transportation structures

PORT AUTHORITY OF NY & NJ (PANYNJ)

Engineering Department

Quality Assurance Division

07.28.2021

PORT AUTHORITY NY NJ

AIR LAND RAIL SEA

Agenda

1 General

#2 Bridge Structures

#3 Journal Square Transportation Center
(Train Station and Bridge over Commuter Rail)

#4 Vehicular Tunnel Ventilation Buildings

1 General

PANYNJ Drone Inspection

1. Drone inspections are considered an improvement on a traditional visual inspection with binoculars, not a replacement for hands-on inspection.
2. Fracture Critical Members are always inspected hands-on. Drone use not acceptable.
3. Corrosion of steel elements often renders drone inspection less effective.
4. A drone inspection may be sufficient for concrete structures with no or minor defects.
5. The PANYNJ does not own drones for the purpose of condition inspections.
6. FAA Permits are required at most of our facilities.
7. The PANYNJ also has used drones to inspect building facades and rock slopes.

2 Bridge Structures

Port Authority Major Vehicular Bridges Inspected with Drones

- George Washington Bridge – Suspension Bridge
- Bayonne Bridge – Steel Truss Arch
- Goethals Bridge – Cable Stayed Bridge
- Outerbridge Crossing – Through Truss

Drones are also used at two major rail bridges :Hackensack River Bridge and Passaic River Bridge. Drones are not used for smaller bridges.

2 Bridge Structures –George Washington Bridge

2 Bridge Structures –George Washington Bridge

<u>DRONE INSPECTIONS Limited to:</u>

- Steel Towers

  The interior of the towers are accessible from stairwells and platforms within. Drones are used in areas inaccessible without equipment or tethered climbing. Areas suspected of deficiencies are inspected hands-on.

2 Bridge Structures – Bayonne Bridge

2 Bridge Structures – Bayonne Bridge

DRONE INSPECTIONS Limited to:

- Steel Towers (that support the roadway framing at end of arch)
  To eliminate rigging and climbing, drone use to inspect the difficult areas to reach of the recently rehabilitated steel towers is an acceptable alternative.

- 10 Concrete Waterway Piers (5 to each side of steel towers).
  Drone inspection of columns and cap beams replaces binocular inspection from other pier tops or a boat. Areas of suspected deficiencies are inspected hands-on.

2 Bridge Structures – Goethals Bridge

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2 Bridge Structures – Goethals Bridge

<u>DRONE INSPECTIONS Limited to:</u>

- Prestressed Concrete Girders
  Drones are used to inspect the approach span 5 girder system

- Concrete Towers
  Portions of the exterior of the concrete towers were inspected with drones. Not the cables.

1 Bridge Structures – Outerbridge Crossing

2 Bridge Structures – Outerbridge Crossing

DRONE INSPECTIONS Limited to:

- Six Concrete Waterway Piers

  Drone inspection of columns and caps replaces binocular inspection from adjacent pier tops or a boat. Areas of suspected deficiencies are inspected hands-on.

2 Bridge Structures - OBX Drone Cost Analysis

<u>ROPE ACCESS ONLY</u>

Rope Access for Inspection of 6 Piers:

• Rope Access Provider – 4 Days	$12,000
• Team Leader – 4 Days	$6,120
• Safety Boat – 4 Days	<u>$5,200</u>
GRAND TOTAL	**$23,320**

2 Bridge Structures – OBX Drone Cost Analysis

DRONE AND ROPE CLIMBING

Drone:

- Drone Operator – 2 Days (6 Piers) $5,000
- On Site P.E. for Drone Review – 2 Days $3,060
- QC Office Review of Drone Footage – 1 Day <u>$1,530</u>

SUB-TOTAL $9,590

Rope Access - Hands-On Inspection:

3 Locations> 1 Location on 3 different Piers identified from Drone Inspection:

- Rope Access Provider – 1 Day $2,500
- Team Leader – 1 Day $1,530
- Safety Boat – 1 Day <u>$1,300</u>

SUB-TOTAL $5,330

GRAND TOTAL $14,920

2 Bridge Structures - OBX Drone Cost Analysis

<u>Outerbridge Crossing Cost Analysis</u>

DRONE AND ROPE CLIMBING ……………………….$14,920

ROPE CLIMBING ………………………………………. $23,320

DRONE SAVINGS……………………………………….. <u>$8,400</u>

DRONE USE WINS!!!!
(Of Course)

3 Journal Square Transportation Center

- Train station, bus terminal and parking garage span the PATH commuter train tracks
  1970’s Precast concrete Tee Beams supported by steel framing

- Adjacent 1920’s JFK Boulevard Concrete Arch Bridge also spans tracks

- The station has two platforms serving 4 tracks. However, there are an additional 12 track interlocking where trains are stored during non-rush hour periods.

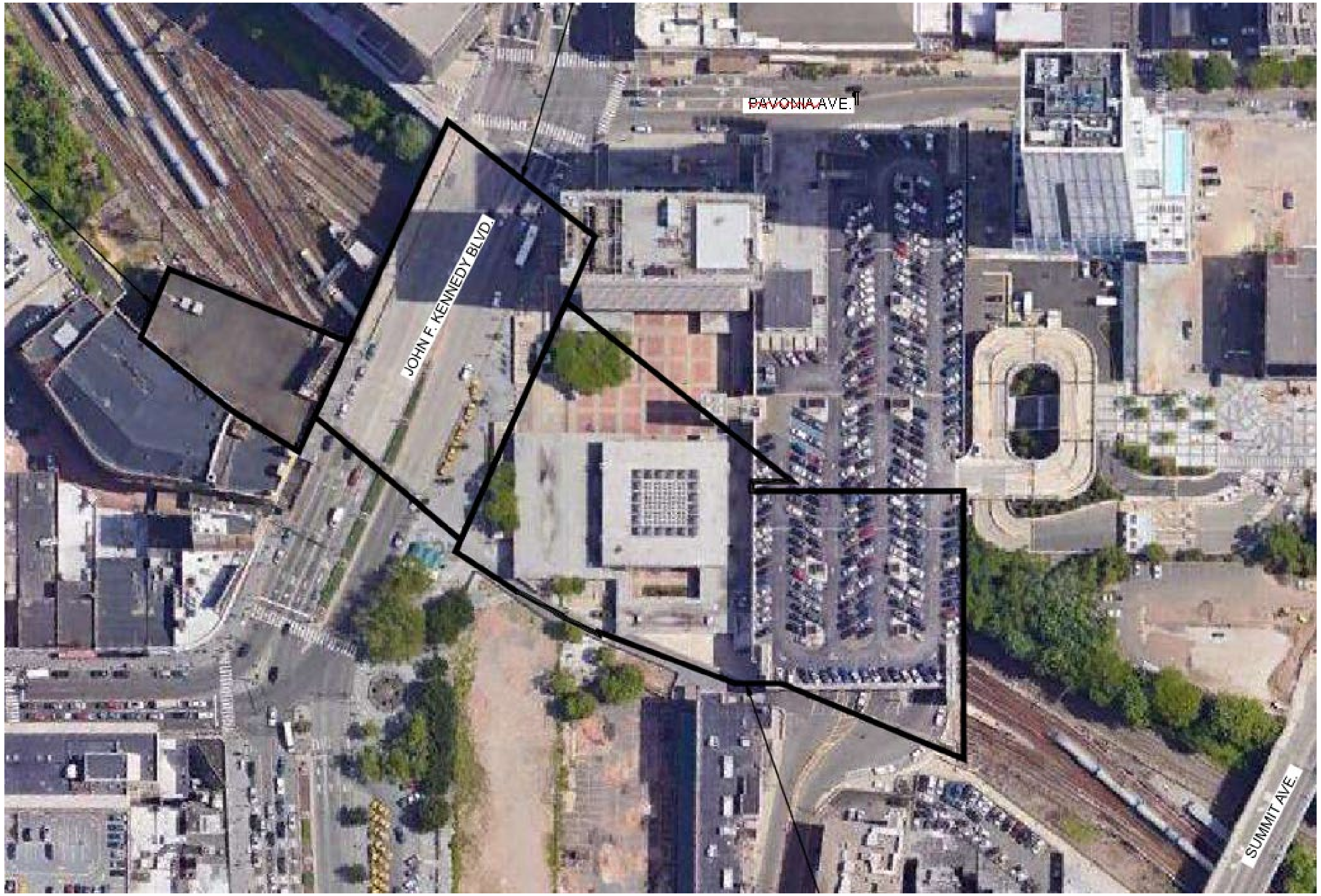
- Concrete construction of tee beams and bridge arches are prone to spalling. Sprayed-on fireproofing also prone to detaching from steel.

- Past procedure was to use a high rail vehicle on each track requiring significant railroad scheduling issues. Night work, equipment access to tracks, etc.

- Drone use during day on controlled tracks for visual inspection with follow up hands-on inspection from high rails reduced high rail use.

- Drone had to be “free flown” without GPS. Repeaters for extending GPS did not work.

3 Journal Square Transportation Center



3 Journal Square Transportation Center

3 Journal Square Transportation Center

3 Journal Square Transportation Center

4 Vehicular Tunnel Ventilation Buildings

- Holland Tunnel – 2 tubes – 4 Ventilation Buildings
- Lincoln Tunnel – 3 tubes – 5 Ventilation Buildings
- 41^{st} Street Tunnel – 1 tube- 1 Ventilation Building

The FHWA National Tunnel Inspection Standards require inspection of all aspects of the ventilation building that relates to tunnel ventilation. For structural elements, this includes the wall louvers that bring fresh air into the building and the evase stacks where air is exhausted from the building.

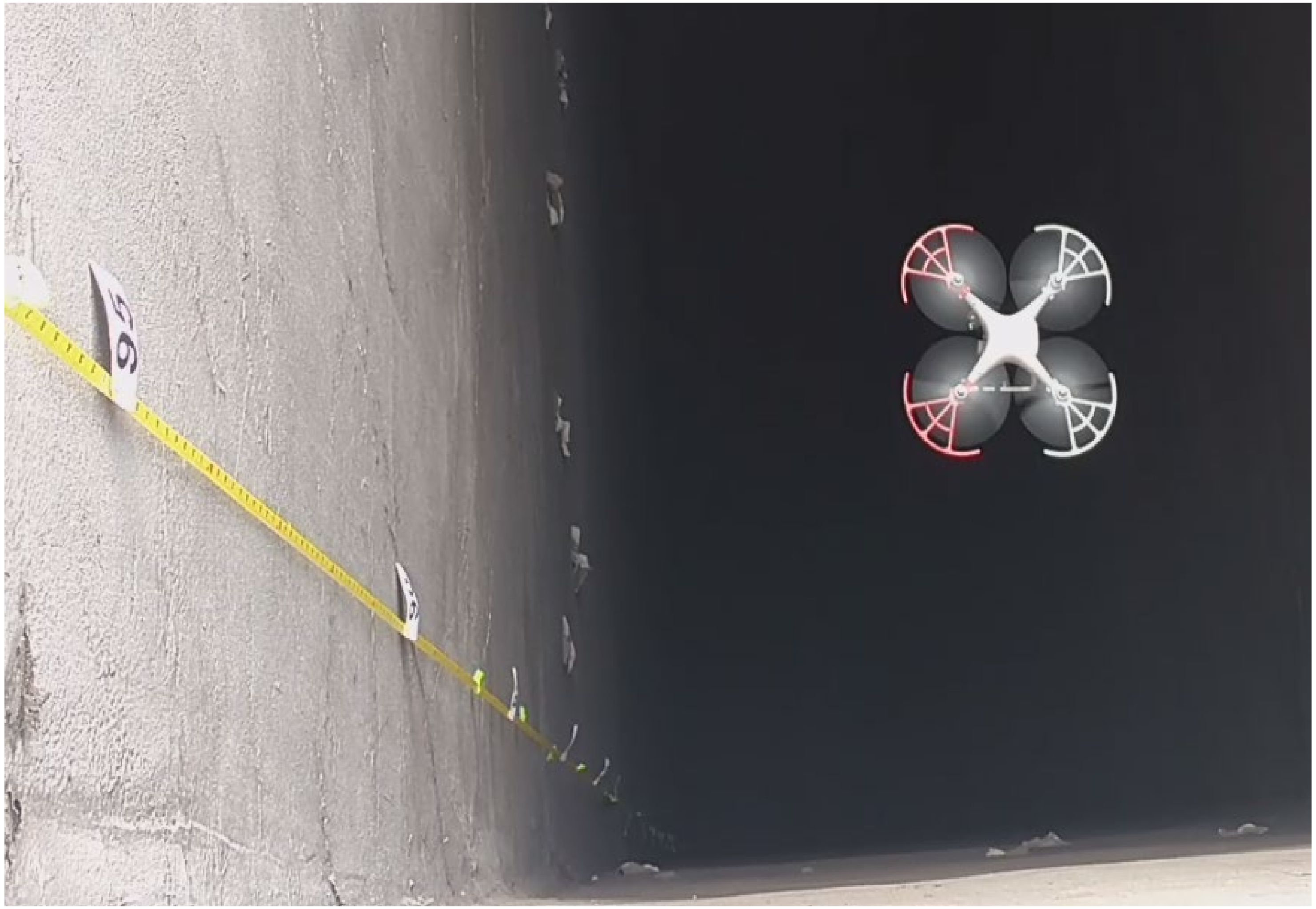
Drones are used to complete a visual inspection of the exterior of the wall louvers and the inside of the evase stacks.

4 Vehicular Tunnel Ventilation Buildings

Drone inspection of wall louvers at the Lincoln Tunnel New Jersey Ventilation Building.

4 Vehicular Tunnel Ventilation Buildings

Drone accessing evase stack inspection at the Lincoln Tunnel New Jersey Ventilation Building.



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Thank You!

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Today's Panelists

Moderator:
Sreenivas Alampalli,
Stantec

Jennifer Wells,
Minnesota DOT

Hoda Azari,
FHWA

Steven Cook,
Michigan DOT

Steve Vecchione,
Port Authority of New York and New Jersey

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