



# Bridge Inspections Utilizing ROV - Implementation Program

Mr. Wells, PE - Minnesota State Bridge Inspection Engineer

# Implementation 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 savings that can be realized compared to traditional methods

Understand drone data needs

Understand how to utilize drone data into digital twins



# 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 -  
50,000)

Intel Falcon 8+

DJI Matrice 210

Autonomous Elios

Benefits

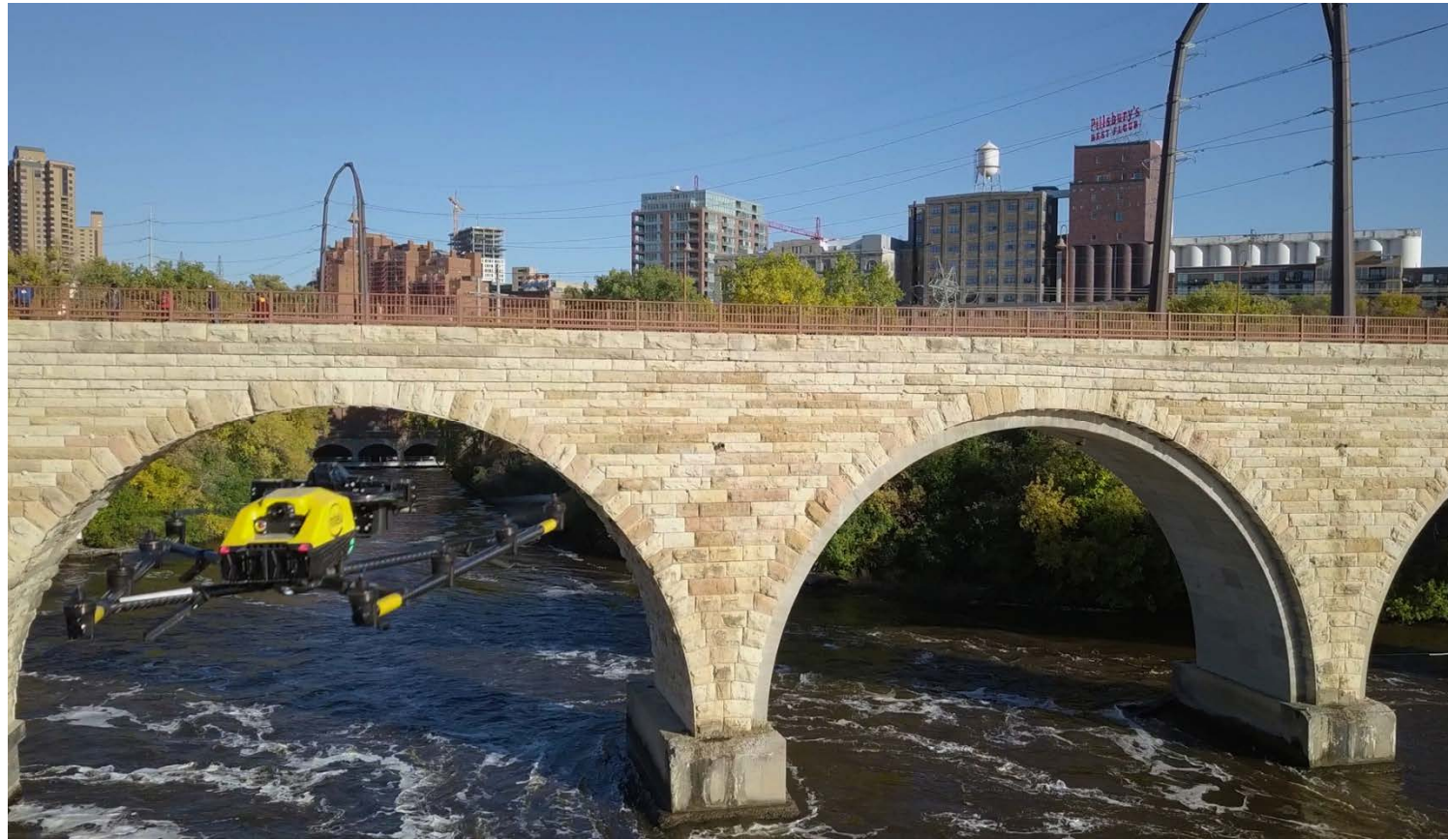
Sensor Size

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





m1  
DEPARTMENT OF  
TRANSPORTATION  
217714

# Sensor Size Importance



# Assessment of UAS Technology

Propeller Aeropoints

Automatic Ground Control  
Points

Provides precision ground  
control

Adds ability to accurately  
relocate assets and  
inspection results



# Bridge Inspection Goals

Inspection Planning

Detect Conditions and Deficiencies

Document

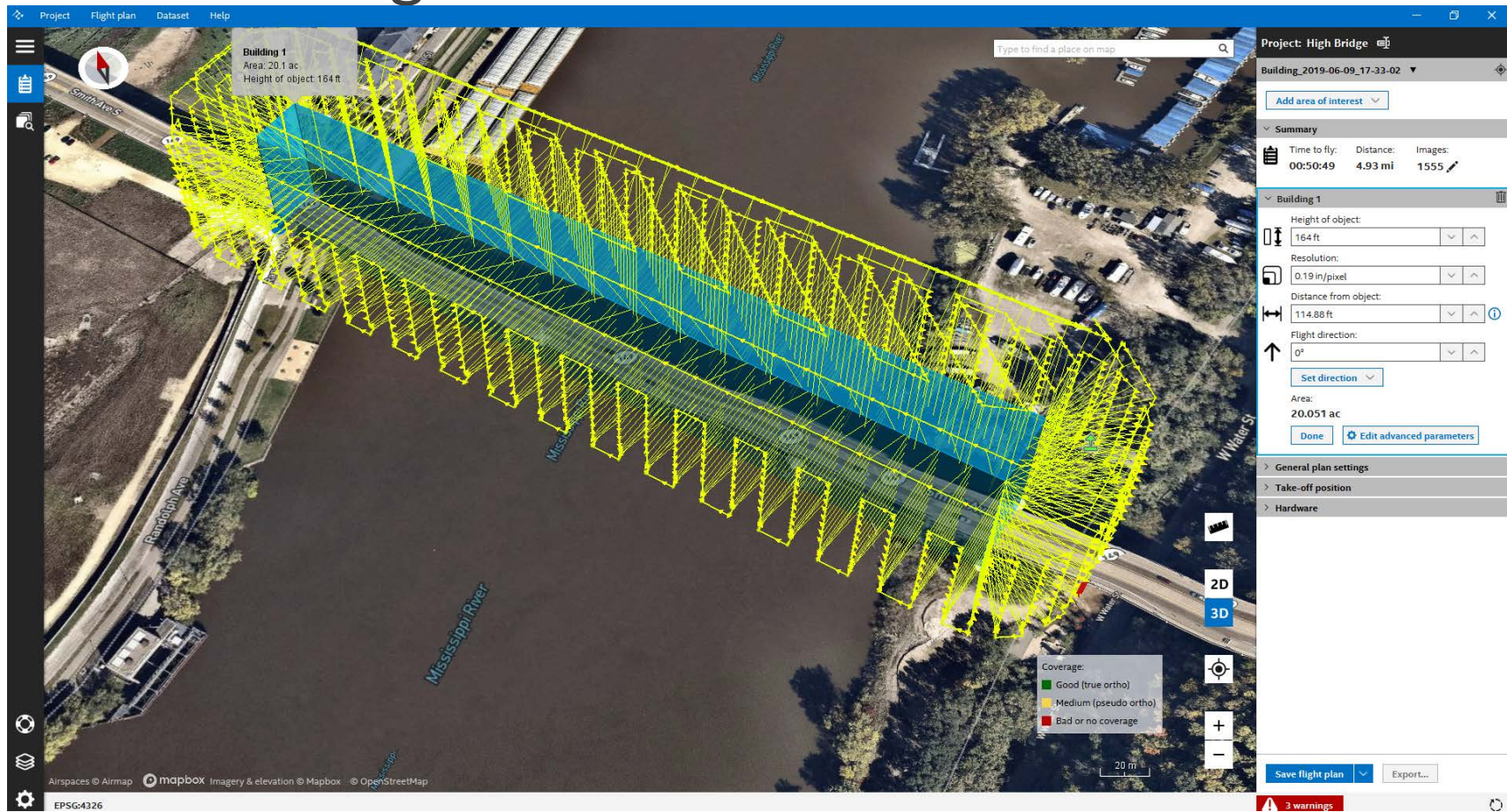
Communicate



# Inspection Planning with UAS

## Flight Planning

## 3D Autonomous Flights



# 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



# Document Conditions and Deficiencies

Quality Modeling Software

Pix4D

Context Capture

Output

Images

Ground Control

Output

Orthomosaics

GeoTIFF, DSM, DTM

Point Clouds

Classified by AI

3D Mesh

CAD



# Document Conditions and Deficiencies

## Deliverables – Orthomosaic

The screenshot displays a software interface for documenting bridge conditions using an orthomosaic map. The main map area shows a bridge deck with various annotations, including lines and polygons, labeled with measurements in feet and inches. The interface includes a sidebar on the left with a 'Layers' panel and a 'Filter by name or tag...' search bar. The 'Layers' panel lists several layers, including 'Annotations 2', 'Element 300', 'Line 181', 'East Joint', 'Pier 15A Joint', 'Joint Filled with Debris', and 'Delamination'. The 'Delamination' section is expanded, showing a list of polygons (Polygon 6 through Polygon 1) and 'Concrete Delamination' annotations. A '2D' button is visible at the bottom left of the map. The top right of the interface features a dark header with a menu icon, a title 'Dunwoody Bridge 27831A Deck', and buttons for 'FILES', 'DOWNLOAD', and 'SHARE'. On the right side, there is an 'Inspection' panel with a search bar, a map view, and a 'SAVE INSPECTION AS ANNOTATION' button. Below this button, a message states: 'We found 19 images matching the selected point of the model. They will be included in the inspection annotation.' The bottom right corner shows coordinates: '44.97134° N 93.29724° W Elevation: -'.

**Layers** **ADD ANNOTATION LAYER**

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

**FILES** **DOWNLOAD** **SHARE**

**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: -

# Communicate Conditions and Deficiencies

## Additional 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>

# Communicate Conditions and Deficiencies

Tettegouche Bridge 3459

FILES DOWNLOAD



**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")

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

47.33732° N 91.20030° W Elevation: 682.382 ft

# Benefits

Quality Improvements

Inspectors

Public

Quality Gains

Cost Savings

# Challenges

Learning Curves

Hands On

Acceptance

Codes 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

AS are a way to remove personnel from the ROW

AA is focused on airspace safety but need to look at overall risk

# Cost Savings

Cost Savings up to 72%

Most cost savings were traffic control and excess equipment can be reduced or eliminated.

Structure	Traditional Inspection Cost	UAS Assisted Inspection Cost	Savings +/-	Savings Percent
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



# a Storage

per Computer

per Storage

curity

OneData

Name

- CO
- D1
- D2
- D3
- D4
- D6
- D7
- D8
- METRO
- System Volume Information



# & Digital Twins

Microsoft HoloLens

Edge Digital Twins



averse

tual space where we  
visit, meet and  
bordinate

ered around a digital

, measure, annotate  
share

orm virtual inspections

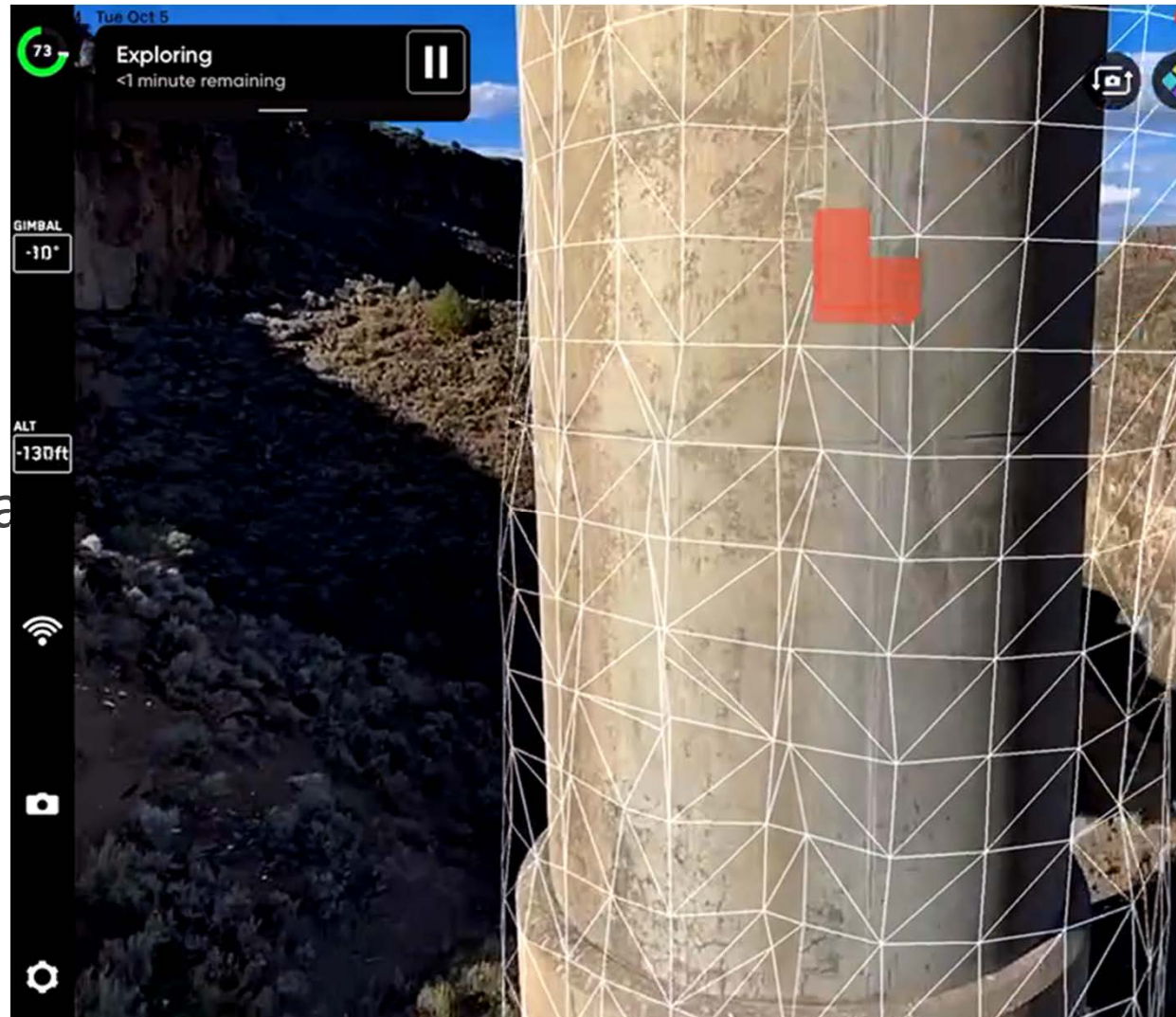
e for design and load

g



# Drone Data Collection

Drones collect data orders of magnitude faster than humans  
Drones utilize sensors and input GPS, Inertial Measurement (IMU), compass, cameras, sonar to fly with only directional input from pilot  
Drones and robots can now collect data almost entirely autonomously



# Rehabilitation UAS Workflow

UAS Field Data Capture

Digital Twin Creation

Field Inspection

Rehabilitation Design and

Plans

Construction



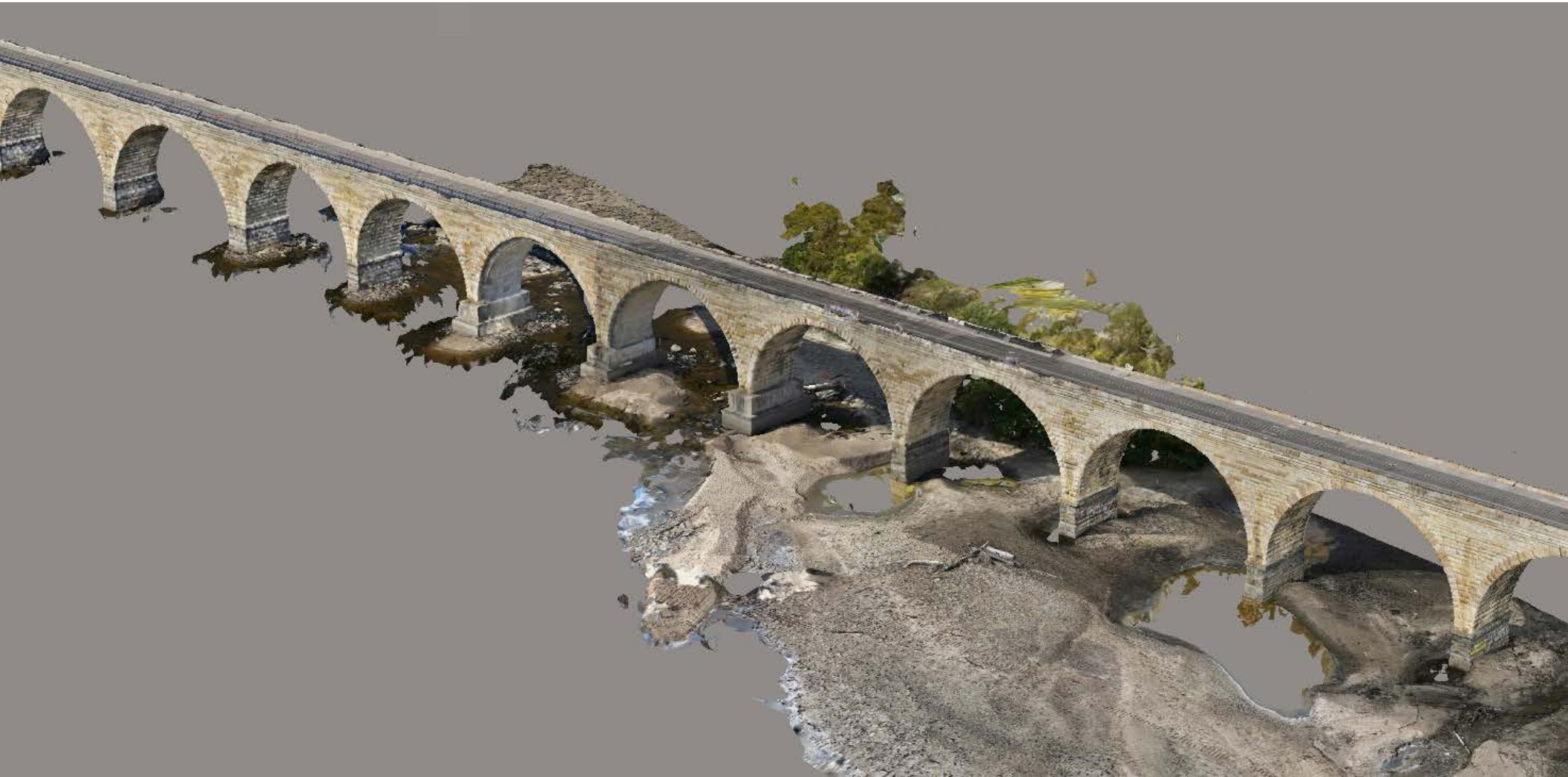
# y Model with Field Notes

Bentley Cloud Services   Assets   Projects   SP 2726-80  
Stone Arch Bridge Rehabilitation

Web Viewer | Stone Arch Bridge Rehabilitation > Stone Arch Spans 17-22



# e Arch Bridge Digital Twin

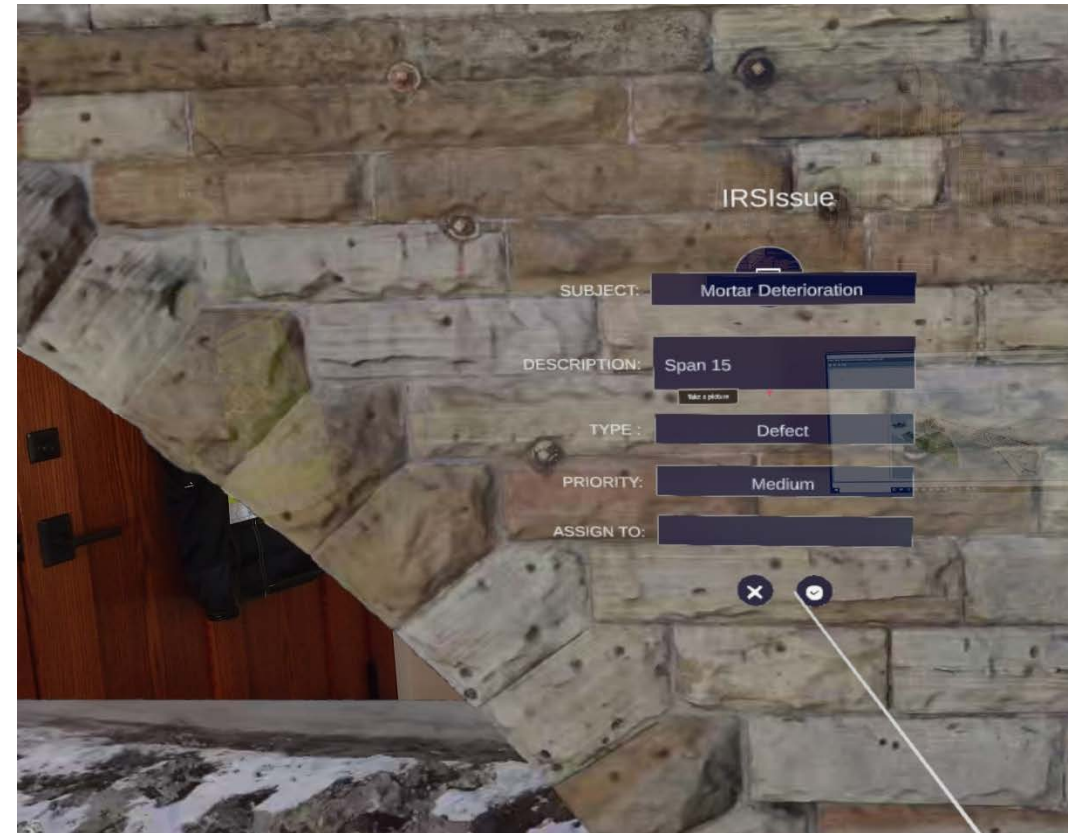




# ed Reality Inspections



Bentley – Microsoft HoloLens 2





# Arch Bridge Digital Twin Benefits

Improved Data Quality

Reduced Risk for Designers

Reduced Risk for Contractors

Greater Collaboration/Inclusion

Safety Improvements

Data Increase

Additional Bridge Report 6

gabytes

Digital Twin Bridge Inspection

Report 2 Terabytes

,333 x more data



## 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

Know where to store data and how to utilize it effectively



# Additional Information

## Phase III Report Published

<https://www.dot.state.mn.us/research/reports/2018/2018-20.pdf>

## Phase IV Report Published

<https://www.dot.state.mn.us/research/reports/2021/2021-23.pdf>

## MnDOT Office of Aeronautics S Policy/Info

<https://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 #2018-20](#)

**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 Drones/Unmanned Aerial](#)

**Project Personnel:**

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**QUESTIONS?**