Overview of Unmanned Aerial Systems (UAS) Use Nationally

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Unless otherwise noted, FHWA is the source for all images.

Overview

- What is Every Day Counts?
- Why use UAS?
- What are the Proven Use Cases?
- What is FHWA doing to advance UAS use?
- How is FHWA using UAS?

What is “Every Day Counts”(EDC)?

State-based model to identify and rapidly deploy proven but underutilized innovations to:

- ü shorten the project delivery process
- ü enhance roadway safety
- ü reduce congestion
- ü improve environmental sustainability

- § EDC Rounds: two year cycles
- § Initiating 5th Round (2019-2020) - 10 innovations
- § To date: 4 Rounds, over 40 innovations

For more information: *https://www.fhwa.dot.gov/innovation/*

FAST Act, Sec.1444

Why Use UAS?

- Improved Safety
- Increased Efficiency
- Increased Quality
- Reduced Costs

"An average cost savings of 40% over traditional inspection methods"

- Minnesota DOT

"Workforce was 45% more productive and the project was completed ahead of schedule"

- Utah DOT

"Reduced lane closures and increased safety for both workers and the traveling public"

- New Jersey DOT

What are the Proven Uses for UAS?

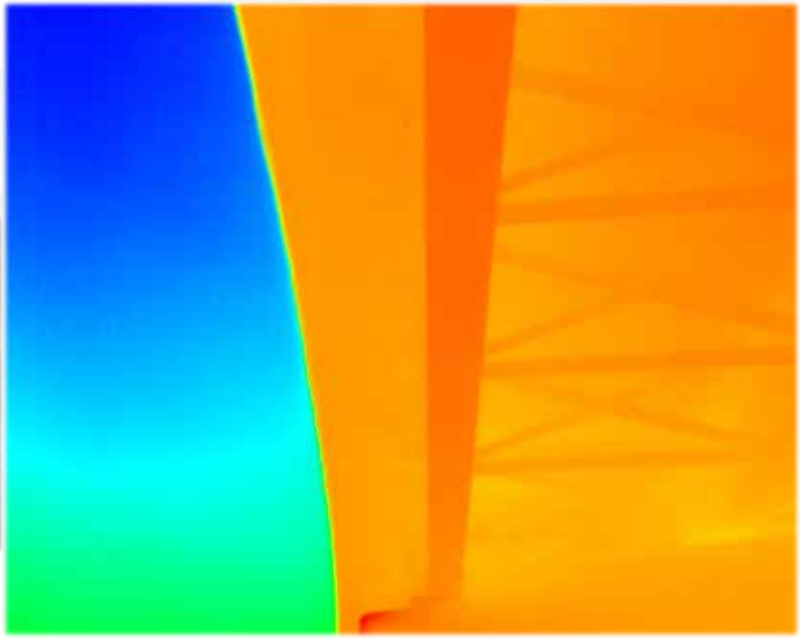
- Structural Inspections
- Construction Inspections
- Emergency Response

Structural Inspection

- Bridge Inspection
- High Mast Lighting
- Confined Space Inspection
- Retaining Walls
- Tunnels

Photo Credit: Ohio DOT

Photo Credits: Iowa State University



Construction Inspection

- Surveying
- Routing Inspection
- Construction Quantities
- Pre-Construction/Project Scoping
- Work Zone Traffic Monitoring

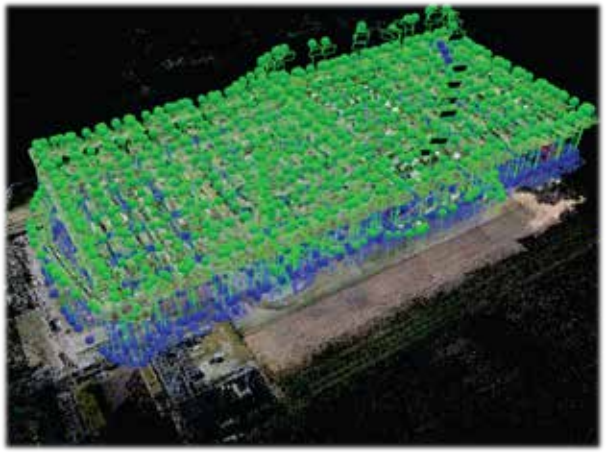


Photo Credit: Ohio DOT

Photo Credit: Ohio DOT

Emergency Response

- Flooding Events
- Wind Events
- Earth Movement (landslides, mudslides, volcanoes)
- Fire Events
- Earthquakes

Photo Credit: North Carolina DOT

Photo Credit: Ohio DOT

What Is FHWA Doing to Advance UAS?

Ongoing Efforts	Planned Efforts
q FHWA National UAS Peer Exchange q PIARC Report and Webinar q Domestic SCAN q Tech Brief Development q Bridge Inspection Data Management Project	q Peer exchanges q Webinars q Regional Workshops q Local Workshops q YouTube Videos q College Curriculum q International Review and Report

Thank You!

FHWA UAS Website for Resources:

- https://www.fhwa.dot.gov/uas/

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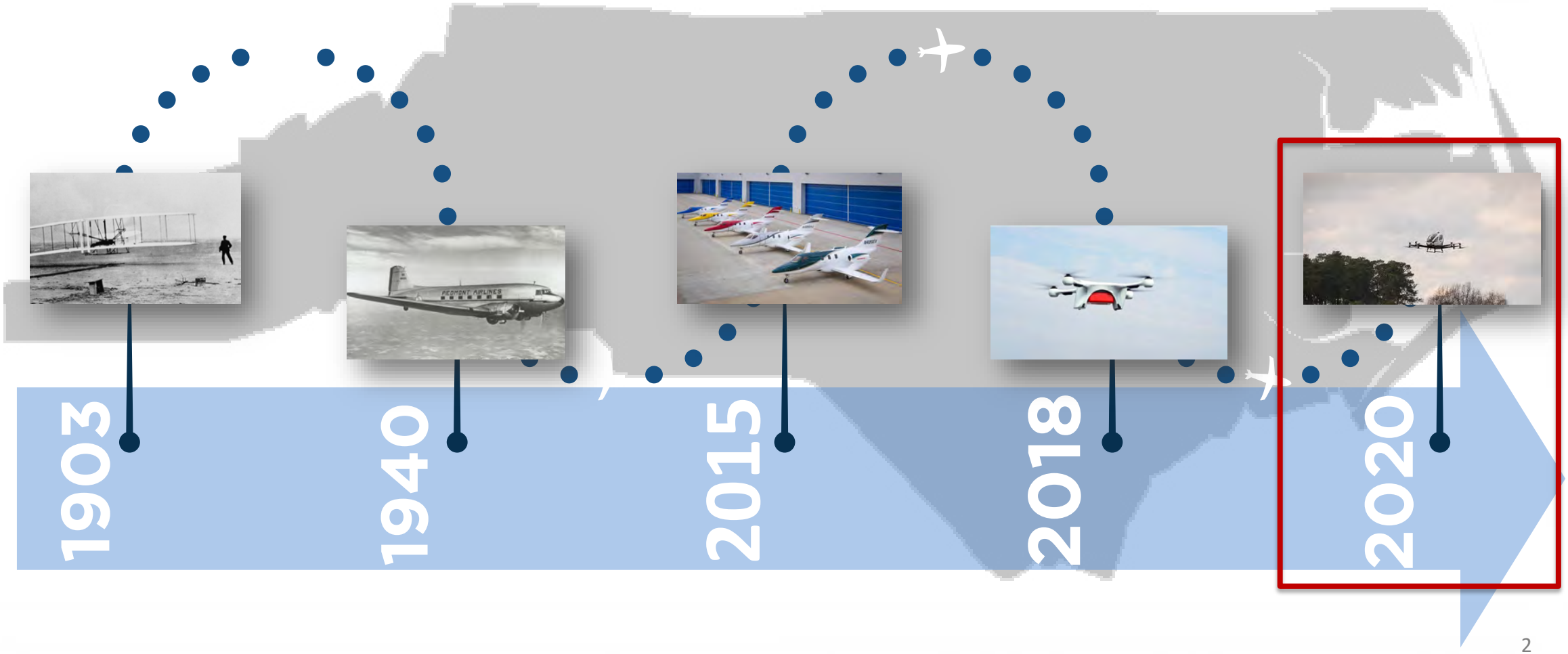
North Carolina - UAS Program Overview

Basil Yap, UAS Program Manager

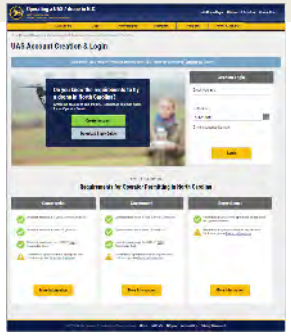
DOT Division of Aviation

North Carolina Aviation Timeline



Current Areas of Focus

1. Knowledge Testing and Permitting



2. NCDOT Drone Operations

3. State Agency Drone Support

4. FAA Integration Pilot Program

5. Statewide Unmanned Traffic Management

6. Economic Development

7. Public Education

NCDOT Drone Operations

Safely integrating beneficial drone use across the Department






NCDOT Drone Operations

Results to Date

- ✓ Quarterly UAS introduction classes offered to NCDOT employees since 2017
- ✓ NCDOT employees trained in drone operations
- ✓ NCDOT-wide policy approved 2018
- ✓ UAS Working Group formed to steer process
- ✓ 14 NCDOT units currently using drones
- ✓ 5 of 6 NCDOT loaner drones in field
- ✓ 8 operators trained under interim certification program established in summer 2019
- ✓ Guidance for business units under development

Next Steps

- Implement training and certification program
- Launch Business Unit Opportunity Assessment
- Develop Fleet Management System
- Launch drone rental program through Equipment Depot

PROGRESS TO DATE

14 Units Using Drones

Chief Deputy Secretary
- Deputy Secretary of Multi-Modal Transportation
  - Aviation Division
  - Ferry Division
  - Rail Division
  - Bicycle & Pedestrian
- Transportation Planning Division
  - Traffic Forecasting

Communications & Community Outreach & Engagement
- Video/Photography

Human Resources
- Safety & Risk Management

Chief Operating Office
- Chief Engineer
  - Deputy Chief Engineer
    - Construction
    - Facilities Management
    - Materials & Tests
  - Director of Field Support
    - Right of Way
    - Structures Management Unit
  - Mobility & Safety
  - Roadside Environmental
  - Technical Services
    - Environmental Analysis Unit
    - Geotechnical Engineering Unit
    - Hydraulics Unit
    - Locations & Surveys
    - Photogrammetry
  - Deputy Chief Engineer East
    - Division 1
    - Division 2
    - Division 3
    - Division 4
    - Division 5
    - Division 6
    - Division 8
  - Deputy Chief Engineer West
    - Division 7
    - Division 9
    - Division 10
    - Division 11
    - Division 12
    - Division 13
    - Division 14

Currently operate drones
Future focus

NCDOT UAS Program Structure

NCDOT Departmentwide UAS Policy

Division of Aviation
UAS Program Office

Divisions/Business Units

UAS Safety Management System (SMS)

Operations

Training/Certification

Operations

Waivers

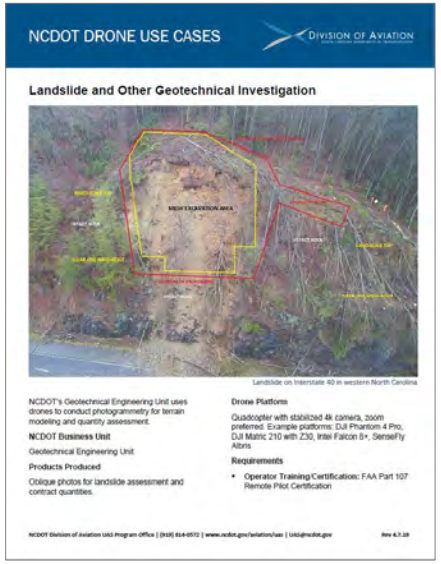
Feedback/Use Cases

Internal UAS Pilot Training

NCDOT Loaner Drone Program

Division of Aviation has a growing fleet of drones. Certain drones are available on a loaner program until a Division/Unit can purchase their own platform or are waiting for their drone to return from shop.

**DoA will assist in platform selection during purchase based on business unit's needs*


NCDOT DRONE USE CASES

DIVISION OF AVIATION

Landslide and Other Geotechnical Investigation

Landslide on Interstate 40 in western North Carolina

NCDOT's Geotechnical Engineering Unit uses drones to conduct photogrammetry for terrain modeling and quantity assessment.

NCDOT Business Unit

Geotechnical Engineering Unit

Products Produced

Oblique photos for landslide assessment and contract quantities.

Drone Platform

Quadcopter with stabilized 4k camera, zoom preferred. Example platforms: DJI Phantom 4 Pro, DJI Matric 210 with Z30, Intel Falcon 8+, SenseFly Albris

Requirements

- Operator Training/Certification: FAA Part 107 Remote Pilot Certification

PROGRESS TO DATE

Wide Range of Use Cases Tested and Deployed

- Transportation infrastructure inspection
- 3D visualization for project design and public engagement
- Project assessment and documentation
- Coastal shoreline mapping
- Disaster response management and monitoring
- Threatened and endangered species counts
- Herbicide spraying
- Subaquatic vegetation mapping
- Traffic counts and monitoring
- Wetlands delineation
- Worksite safety analysis
- Airport infrastructure inspection
- Bus terminal assessments
- Ferry route assessment
- Pedestrian walkway project documentation
- Port stockpile assessment and documentation
- Rail corridor mapping

Environmental Analysis Unit

- Successful utilization of a drone to spray an herbicide to treat Australis phragmites at Bodie Island Lighthouse
- North State Engineering supported effort
- First time approved by National Park Service

Construction Monitoring

- Project documentation
  - Highway & multi-modes
- Storing and sharing data in the cloud
- Easy win!

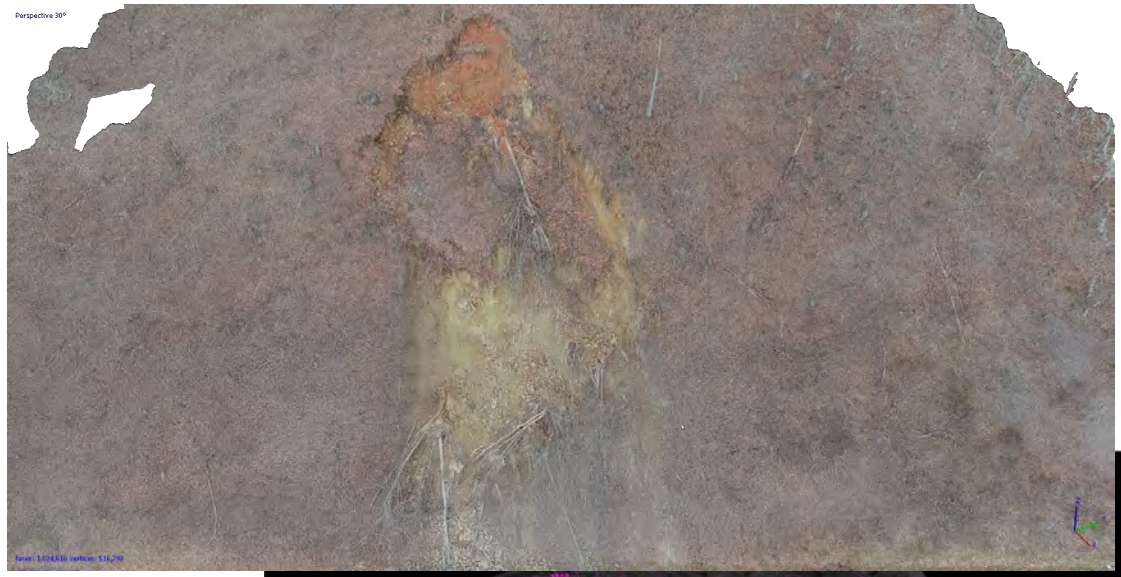
Division Level Support

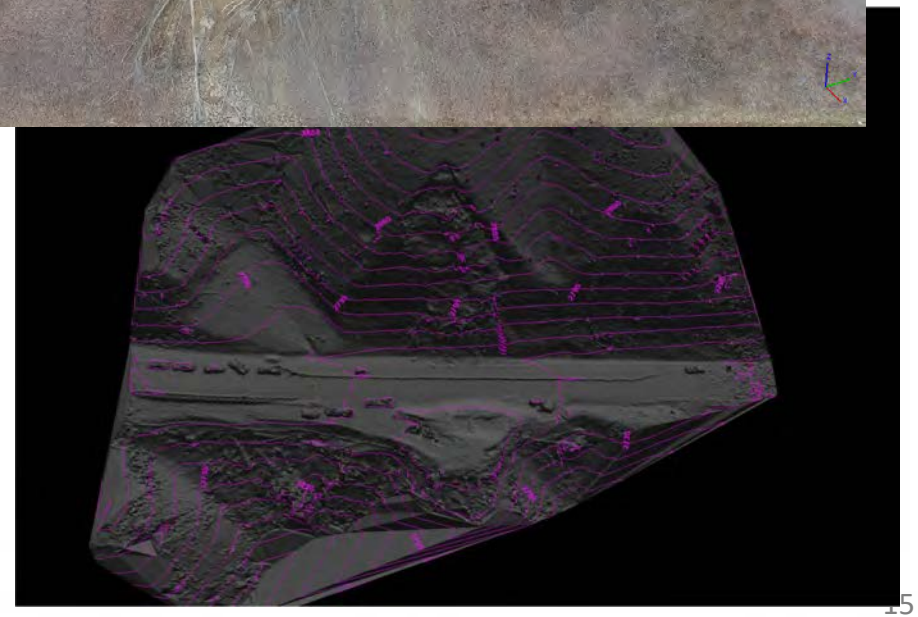
- Use cases
  - Project Documentation
  - Site Safety Assessment
  - Post-Storm Assessment

Safety Assessment

NCDOT Geotech

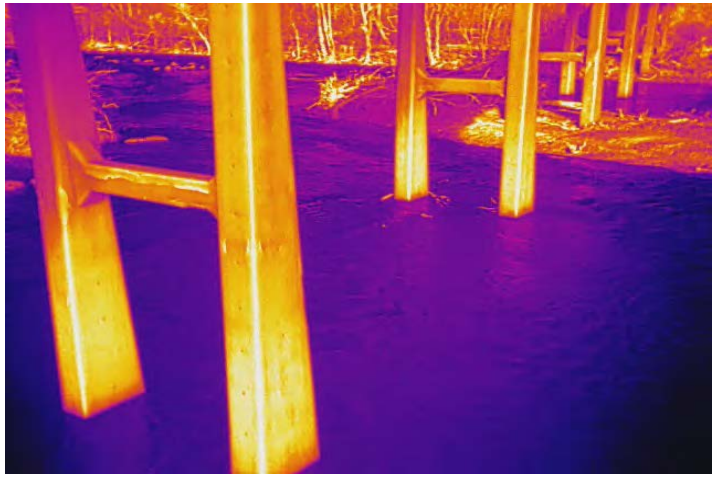
- Geotechnical Unit
  - Western NC
  - Landslide response
  - Inspection/Maintenance





NCDOT GeoTech

Bridge Inspection



Bridge Inspection

Erosion Control Monitoring

State Agency Drone Support

Results to Date

- ✓ Launched in 2017 with State Highway Patrol use case research (drone collision reconstruction cuts time, saves money, reduces risk to people)
- ✓ Emergency management response unit set up for Hurricane Florence in 2018, expanded for Dorian in 2019 (added airspace deconfliction)
- ✓ Over 360 drone missions flown for state agencies
- ✓ Advisory services provided for N.C. departments of Public Safety, Insurance and Environmental Quality and universities

Next Steps

- Replicate NCDOT Drone Operations protocol, once complete, to other agencies

FAA Integration Pilot Program

Results to Date

- ✓ Achieved nation's most challenging drone operations with FAA waivers for Operations Over People, Beyond Visual Line of Sight (BVLOS) and multi-ship operations
- ✓ First routine U.S. medical package delivery over people for pay (4,000+ medical specimens delivered to date)
- ✓ First U.S. drone airline (Part 135) package delivery operation
- ✓ Robust hurricane response with 260+ flights, including BVLOS and ops in and near controlled airspace for Florence, 47 for Dorian
- ✓ Extensive testing of new operations (BVLOS, multi-ship, etc.) and training enabling companies to operationalize in N.C. airspace
- ✓ 1,700+ IPP missions to date
- ✓ Advise/serve on national transportation and standards-setting boards to shape the future of drone use across the nation

Next Steps

- Plan and implement first routine food package delivery
- Plan and implement NCDOT BVLOS and operations over moving vehicles
- Complete Zipline blood delivery pilot in western North Carolina

N.C. Unmanned Traffic Management (UTM)

Results to Date

- ✓ Developed UTM and aircraft deconfliction for hurricanes Florence and Dorian emergency response
- ✓ Proposed participation in NASA Grand Challenge to pilot medical and patient transport
- ✓ Drafted first in nation Concept of Operations proposal for N.C. UTM with FAA, companies and partners
- ✓ Tabletop exercise with NCDOT and FAA

Next Steps:

- Complete Concept of Operations for N.C. UTM
- Pursue NASA Space Act Agreement MOU to gain resources for piloting UAS/UAM
- Implement UTM in North Carolina

Economic Development

Results to Date

- ✓ Partner companies created 25 N.C. jobs, $4.9 million annual impact since program inception, recouping state investment
- ✓ Developed community college curriculum to propel talent pipeline
- ✓ Positioned state at forefront of drone industry through two summits with more than 900 industry and government participants
- ✓ Presented N.C. drone innovations to national/international groups
- ✓ Participated in booths at trade shows and conferences
- ✓ Contributed articles and publications for mainstream and trade media
- ✓ Received national awards for drone innovations
- ✓ Helped launch NCDOT Mentor-Protégé Program to engage minority companies
- ✓ Collaborated with Aviation Business Development Manager to expand drone-related investment in North Carolina

Next Steps

- Collaborate with Aviation Business Development Manager to develop a plan for growing N.C.'s economy through drone investments

Public Education

Results to Date

- ✓ Hosted public education workshops cross North Carolina to raise awareness of beneficial uses of drones
- ✓ Educated the public about beneficial drone use, legislation and restrictions through intense social media outreach
- ✓ Assessed public attitudes about drone integration through drone surveys (38,000+ responses to date)
- ✓ Produced reports and presentations to inform state officials and public drone use opportunities and status
- ✓ Served as subject matter experts for extensive media coverage of this emerging industry

Next Steps

- Continue media and social media campaigns for seasonal and issue-focused outreach
- Continue serving as subject matter experts for legislative and state agencies on drone-related policy and integration

Thank you

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Data collection and integration for UAS, impacts on future applications

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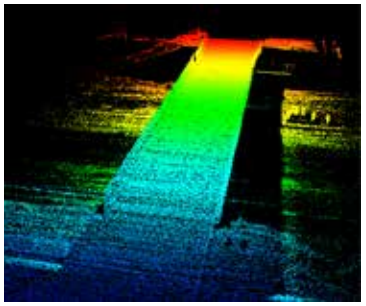
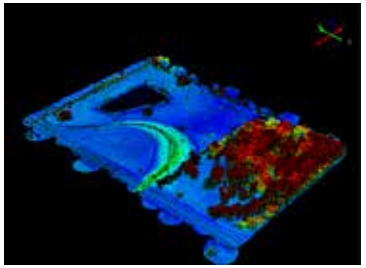
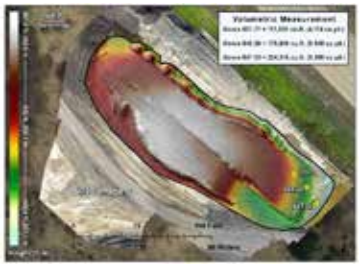
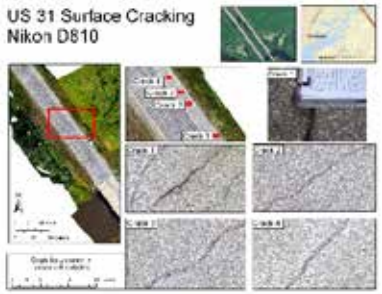
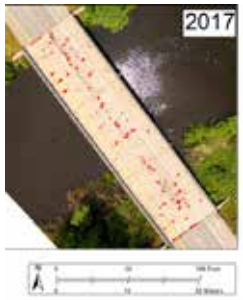





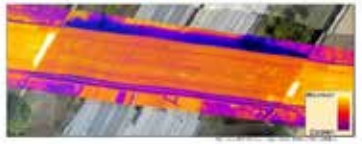














Focus on developing, demonstrating, and implementation UAS-enabled applications: Examples from working with the Michigan Department of Transportation (MDOT)

A. **Overall goal of developing applications is to enable everyday usage of UAS** to meet critical systems operations and maintenance data needs.

B. Need to work closely with MDOT Sections 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, specifically including **Bridge Inspections, Design Surveys, Traffic Operations Surveillance Monitoring, and Construction Inspection** by working closely with Subject Matter Experts (SME).

D. **Deploy and integrate the use of UAS capabilities and data usage as part of day-to-day operations**, including implementation-focused case studies and technology transfer training sessions.

E. **Recommend how to effectively work with the private sector** to take advantage of rapid developments in sensors, platforms, data, applications, and tools for operations and maintenance.

UAS for transportation infrastructure assessment:
What kind of platforms and sensors are used?
What data are collected? Why are they needed?

Example Platforms

Bergen Hexacopter

Bergen Quad-8

DJI Mavic Pro

DJI Phantom 3A

Example Sensors

Nikon D810

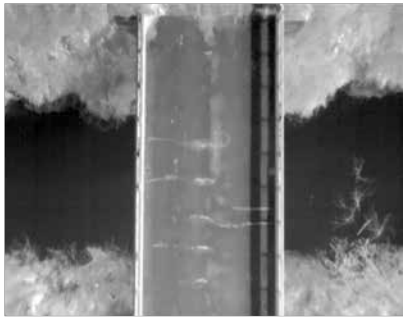
FLIR Vue Pro / R

Velodyne Puck

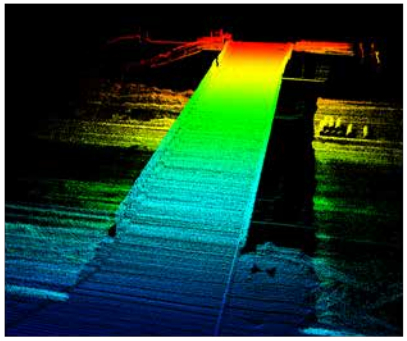
Example types of data collected

Optical

Thermal



LiDAR

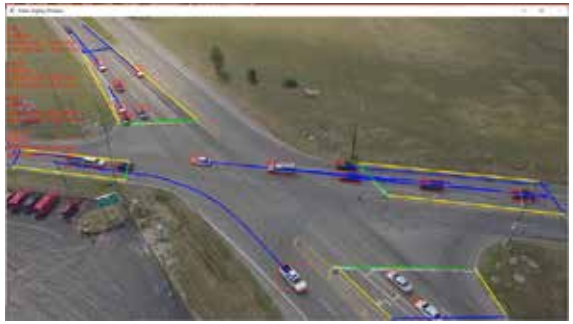


Traffic Monitoring

Ground Control

MDOT Application: Automated Traffic Monitoring

- Initial work: Aerostats/Blimps
  - Long loitering time on station – up to several days
  - Can be sized to payload requirements
  - Tethered, lower FAA requirements for flight operations, can operate at night
  - Area needed for launch and recovery
  - Some designs can operate in windy weather
  - Less need for permanent equipment
- UAS for shorter periods, stronger winds
  - Tethered solutions under investigation
- Developed algorithms & tools for automated traffic ID & counting from UAV data



Traffic information that can be create from UAV data

- Data that can be can calculated:
  - Vehicle speed
  - Cumulative number of vehicles entering / exiting the road
    - Volume (during a specific time period)
  - Traffic in-flow, out-flow rate
    - # passing by a specific point in an hour
  - Traffic density
    - # of vehicles (per mile, etc.)
  - Space mean speed
- Example results:

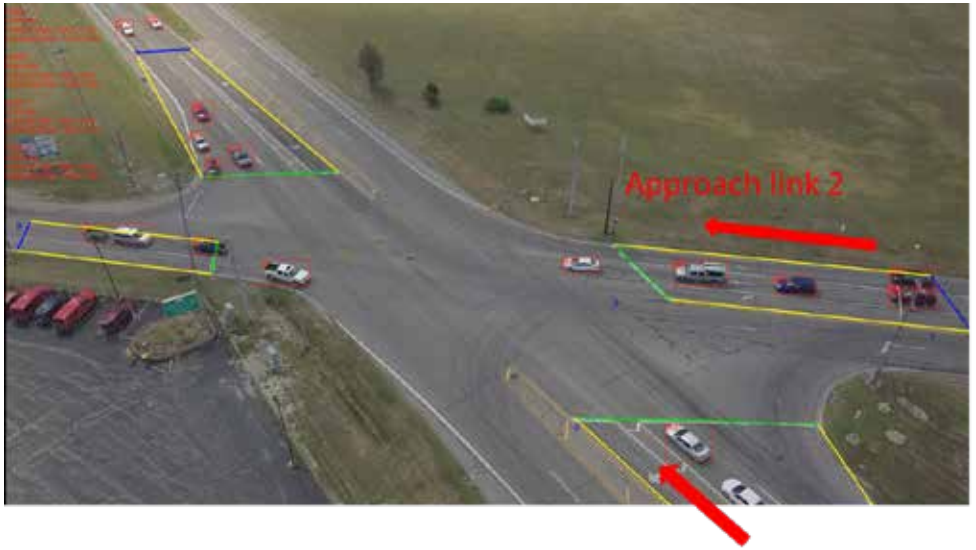
- Next steps:
  - Different traffic / weather conditions
  - Move traffic operations data tool to full automation
  - Move tool online (feeding it live video)
  - Demonstrate deployment at a Transportation Operations Center (TOC)

Video name	Road No.	Duration (min)	Volume (veh)	Flow (veh/hr)	Space mean speed (mph)	Speed limit (mph)	Road length(feet)
DJI_0058.MOV	1	03:47	85	1348.02	65.97	70	400

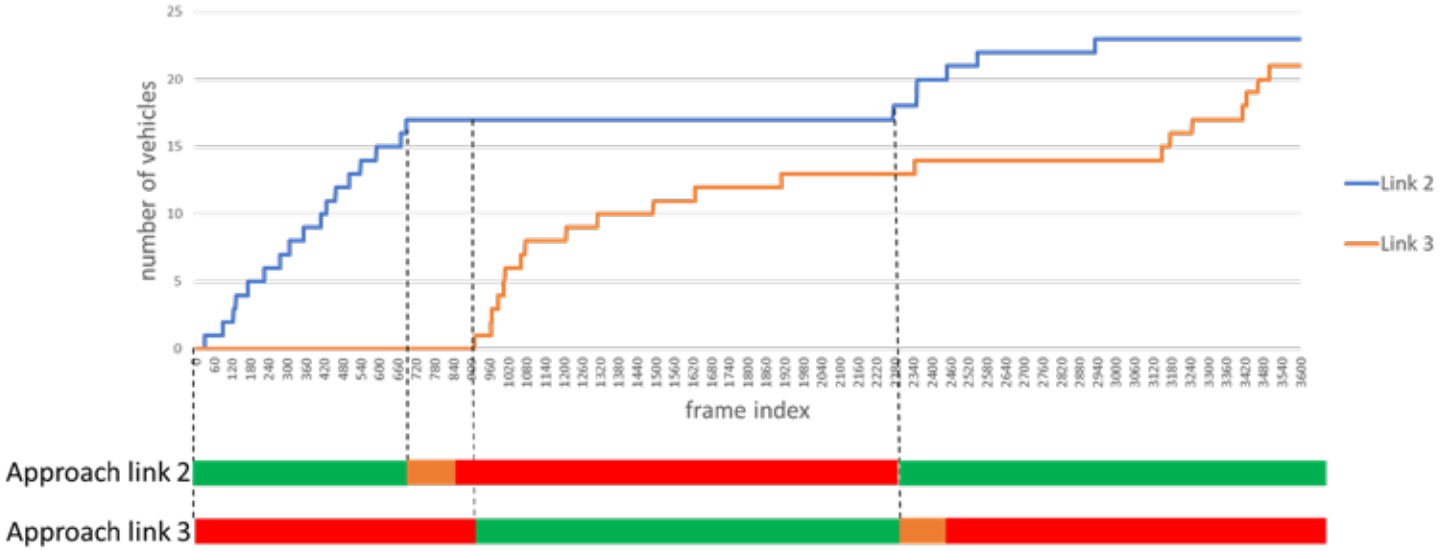
Video name	Road No.	Duration (min)	Volume (veh)	Flow (veh/hr)	Space mean speed (mph)	Speed limit	Road length(feet)
DJI_001.MOV	1	09:24	113	721.28			341

Traffic Data Analysis Results

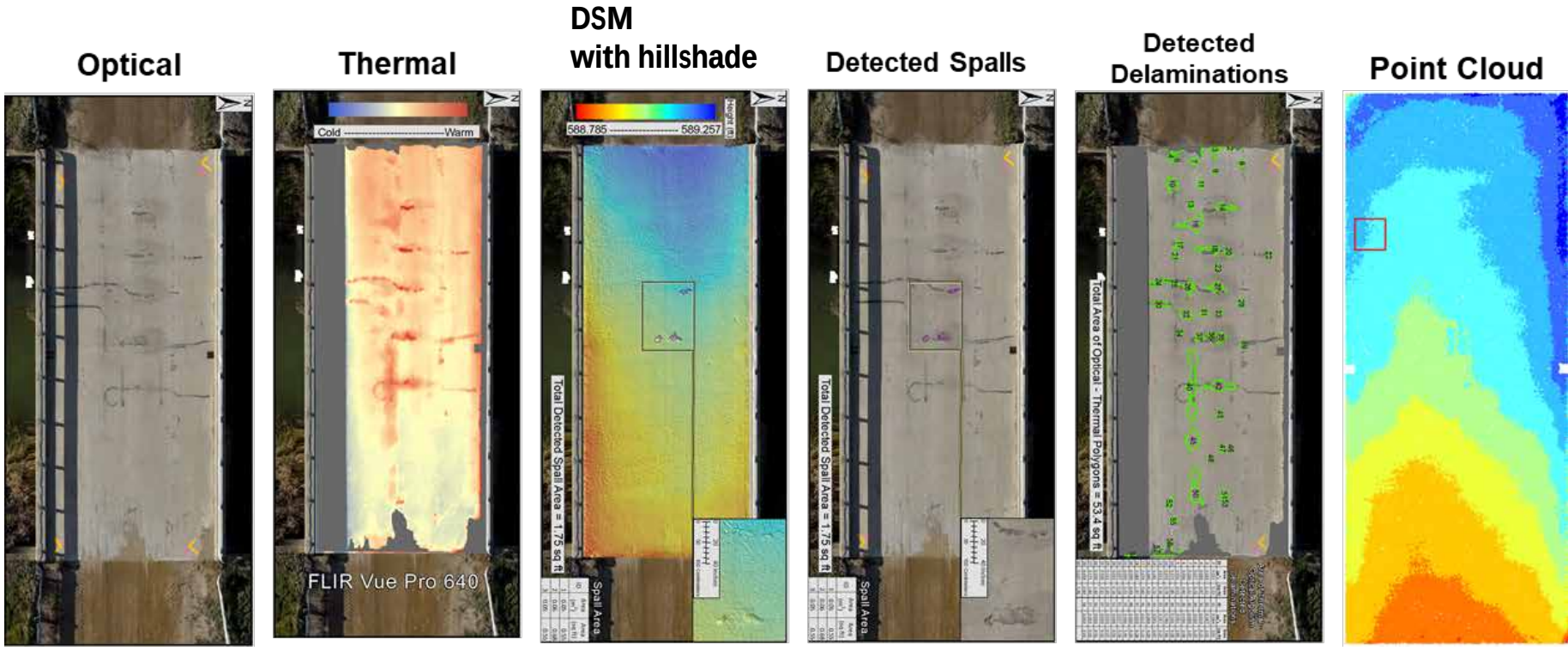
Traffic Volume Studies



Cumulative Number of Vehicles



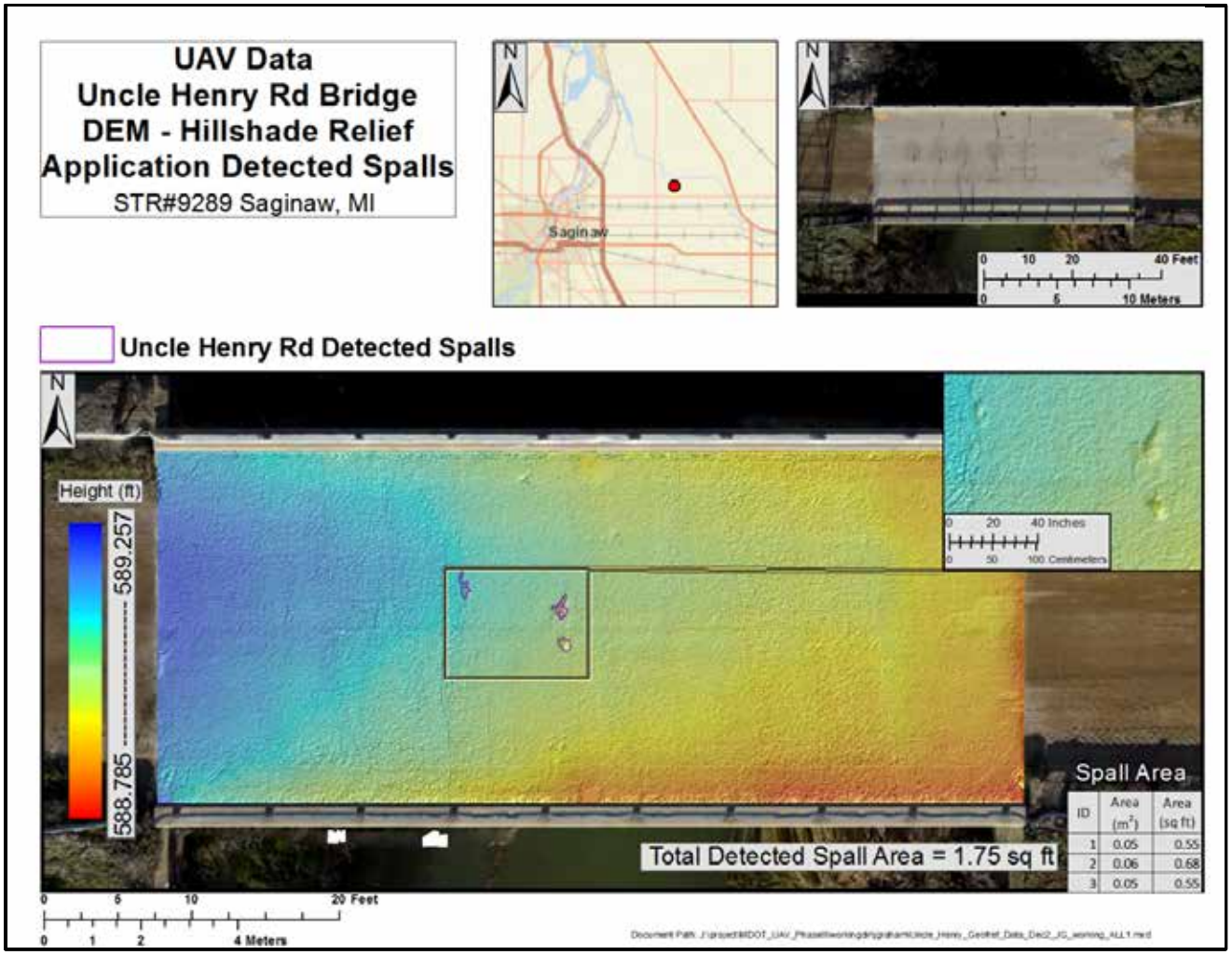
MDOT Application: Bridge Inspection

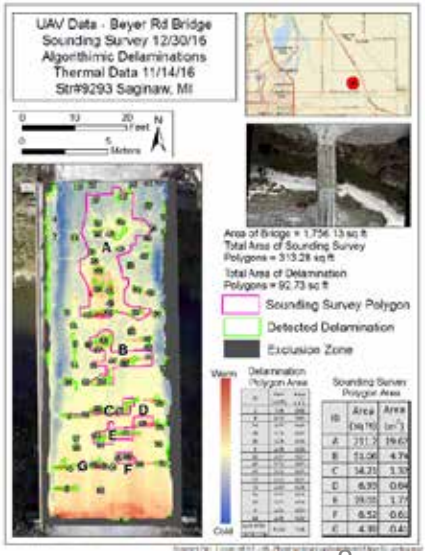


Outputs: Ready to use, standardized datasets

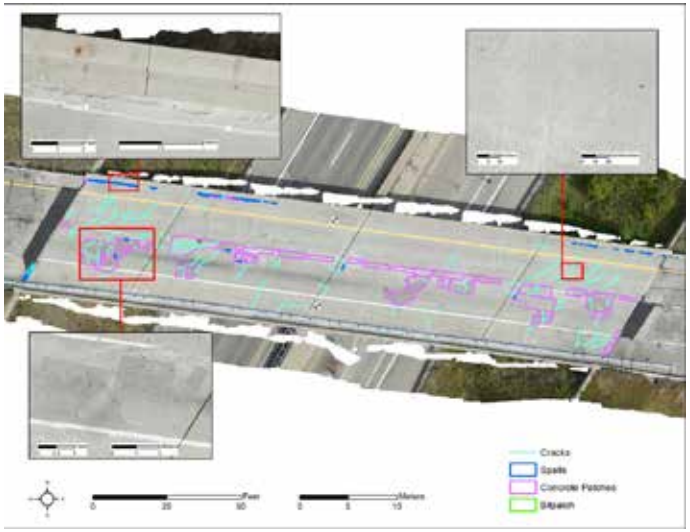
- Fit state & federal data reporting needs
- Contribute to cost-effective asset management

Bridge Inspection results



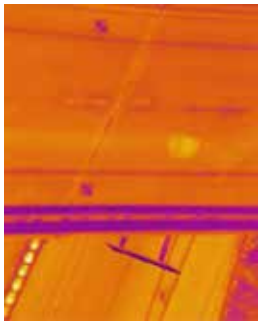


Bridge inspections, fall 2019

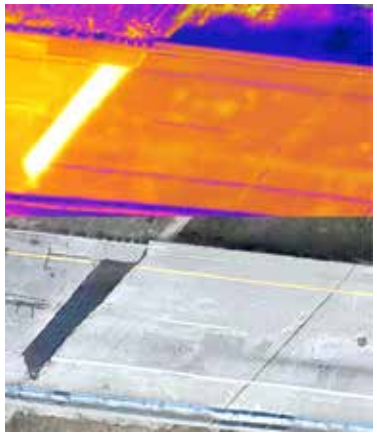


Defect mapping on bridges

Visual inspection of welds



FLIR Vue Pro R & Duo Pro R



Testing radiometric thermal cameras (delaminations)

Flyability Elios

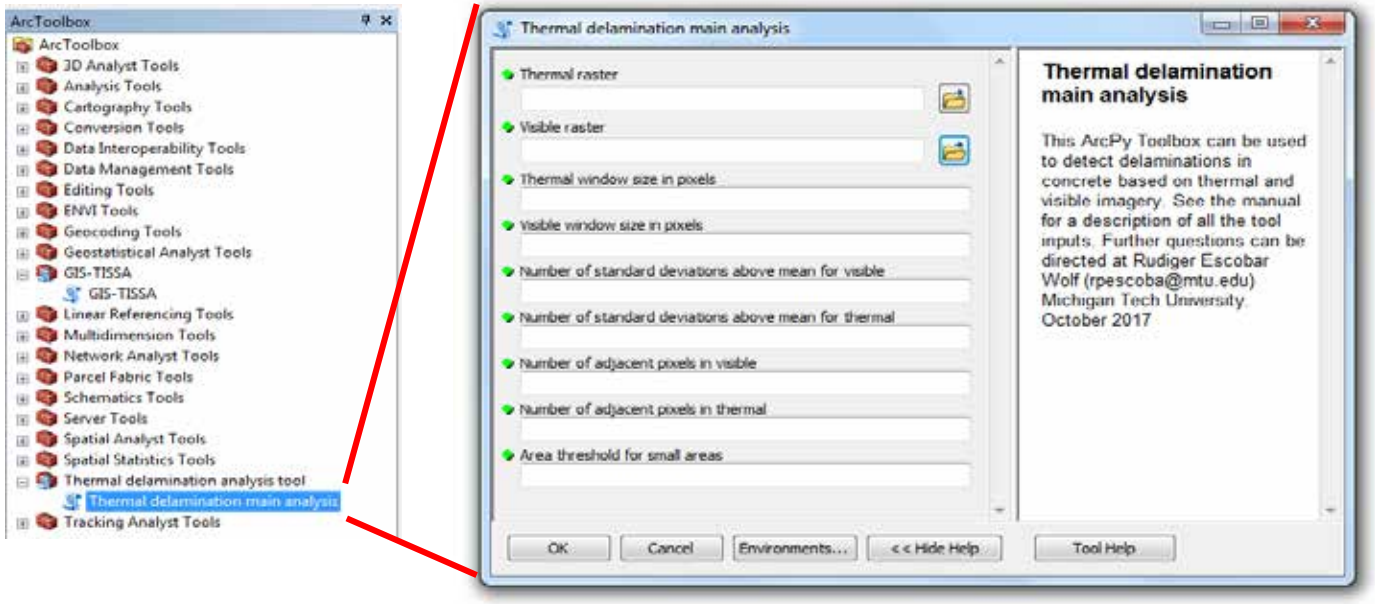
Intel Falcon 8+

DJI Mavic 2 Pro

Additional UAS platforms

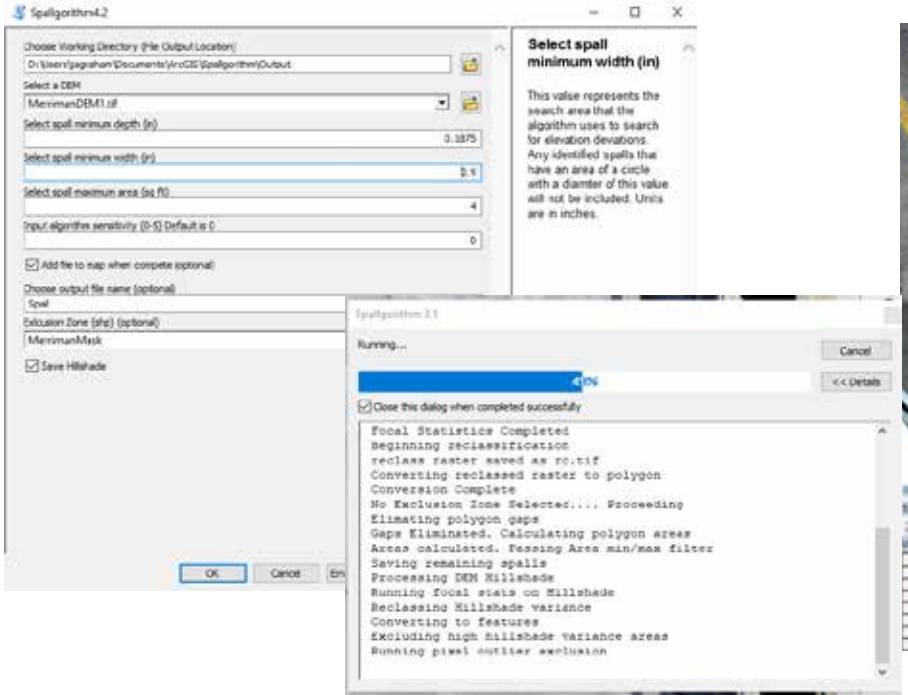
Bridge Inspection: data processing & outputs

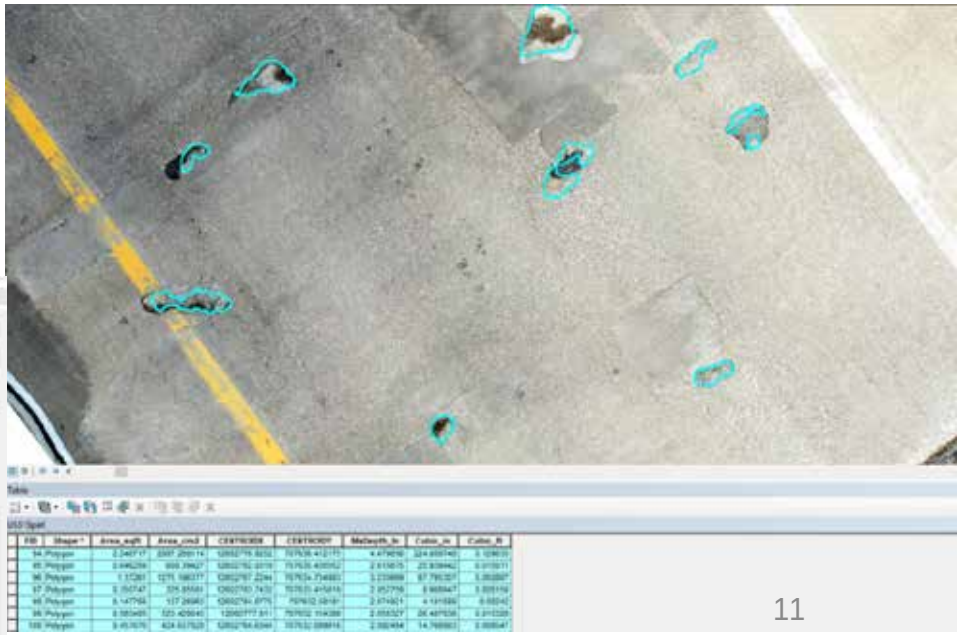
- Focus: Providing operational tools that can be used by MDOT for detecting delamination and spalling.
- Thermal Delamination Detection Algorithm (TDDA)
  - Developed an ArcPy tool based on the thermal-visible algorithm
  - User friendly (i. e. through standard ArcGIS Tool GUI)
  - Improvement underway:
    - Algorithm refinement through machine learning and pattern recognition
    - Porting to ArcGIS Pro
    - Comparing results from single sensor platform thermal systems with two cameras (FLIR Duo Pro) to type of multi-sensor setup used in Phase II (Nikon full-frame camera & FLIR Vue Pro R)
    - Document use cases and provide MDOT with revised user manual



Bridge Inspection: automated analysis

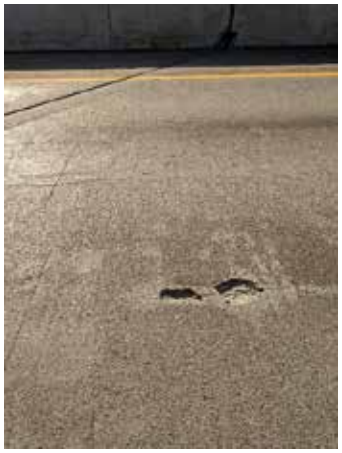
- Automatic spall detection algorithm (Spallgorithm)
  - ArcGIS toolbox
  - Generates a shapefile defining the location of the spalls and provides area, volume, and depth characteristics
  - Focusing on implementation by making it available on MDOT desktops as part of Bridge Inspection ArcGIS Pro toolbar

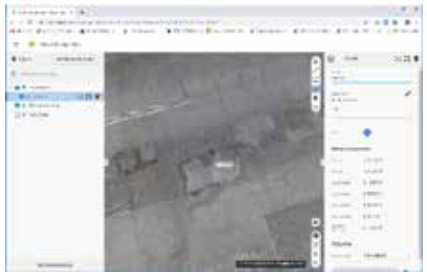


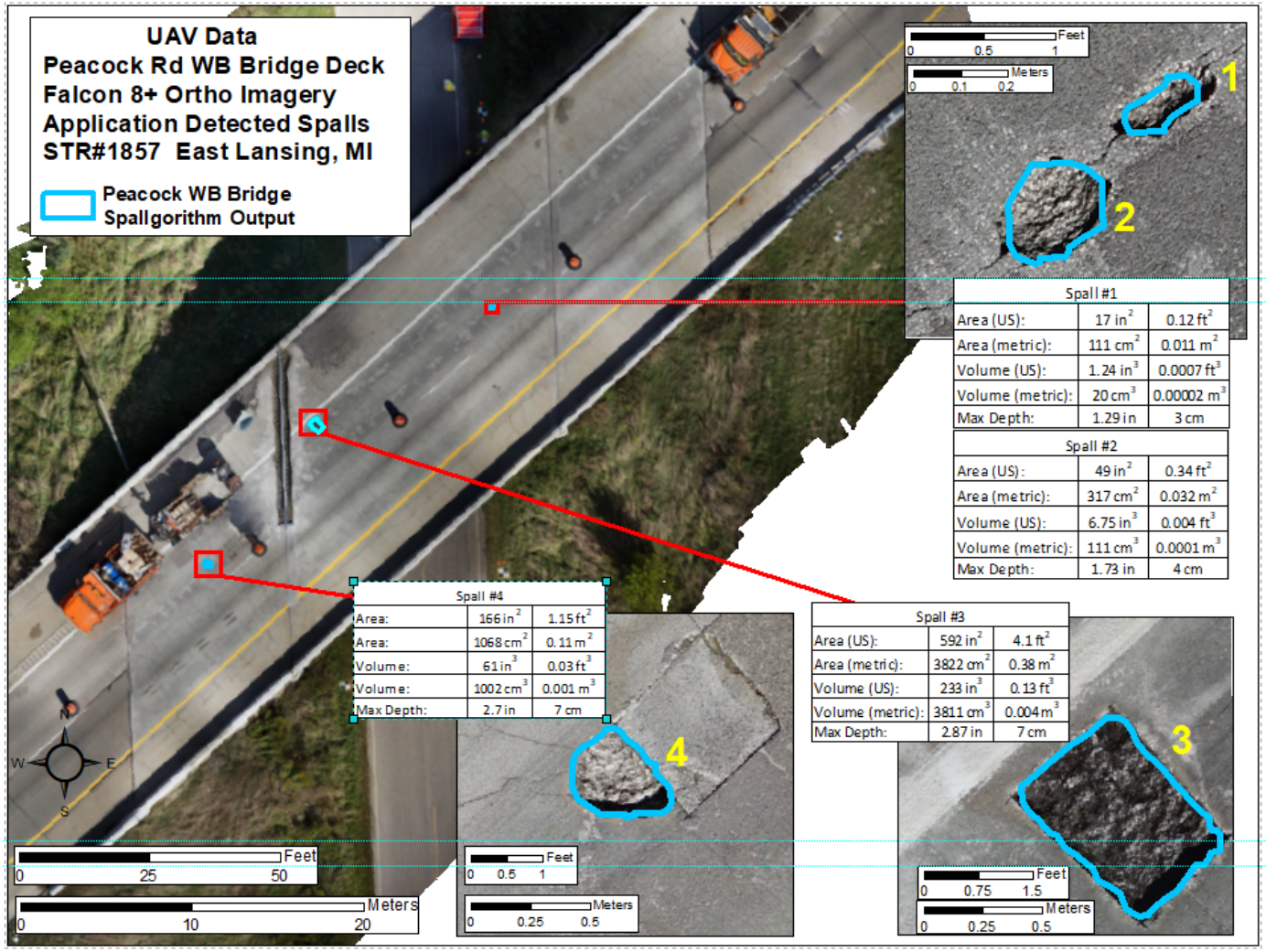


Bergen Hexacopter with 45.7 mp Nikon D850 & Aeropoint GCPs

Automated spall detection with quantitative information





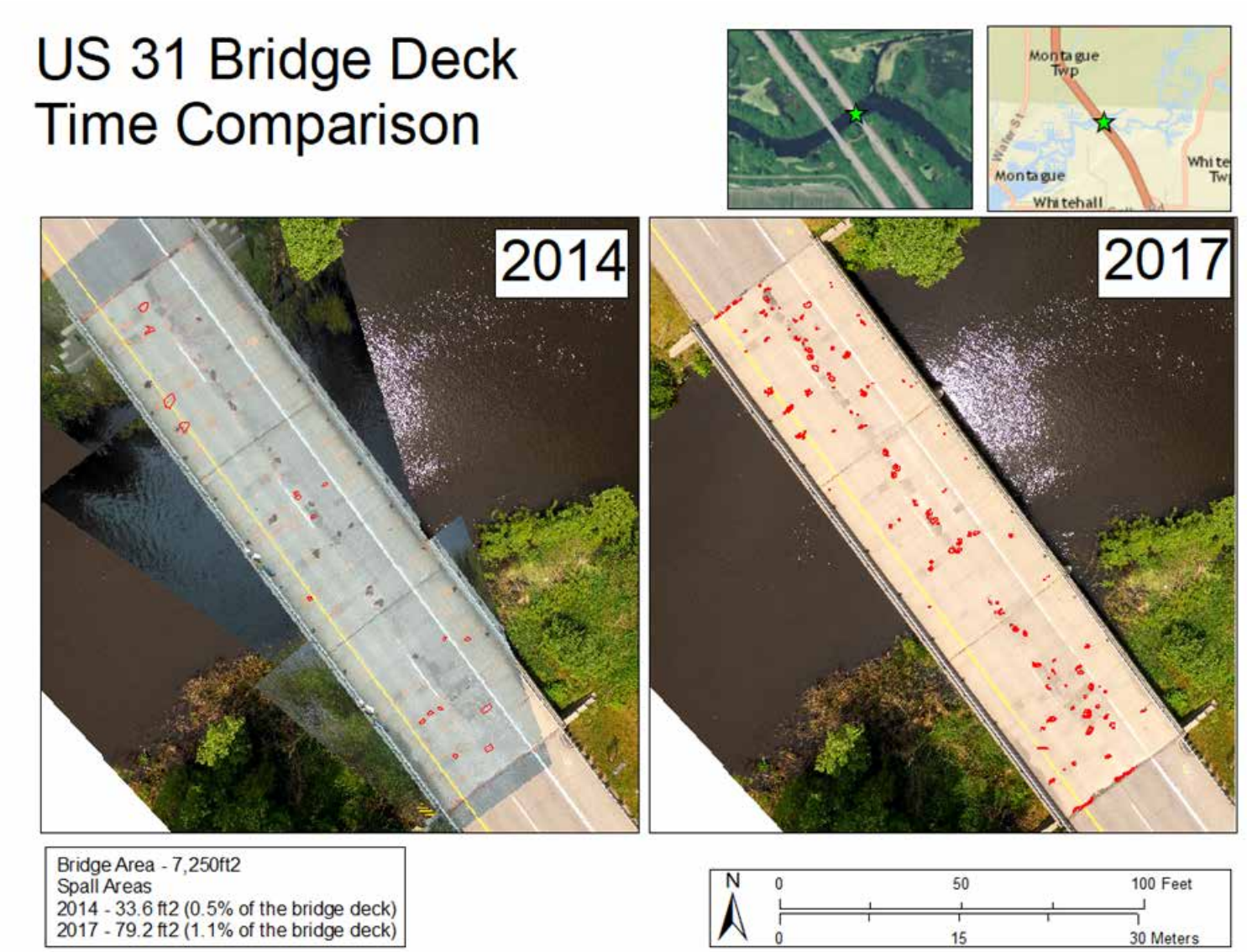


- 5.7 ft² of spalling (302 in³ volume)

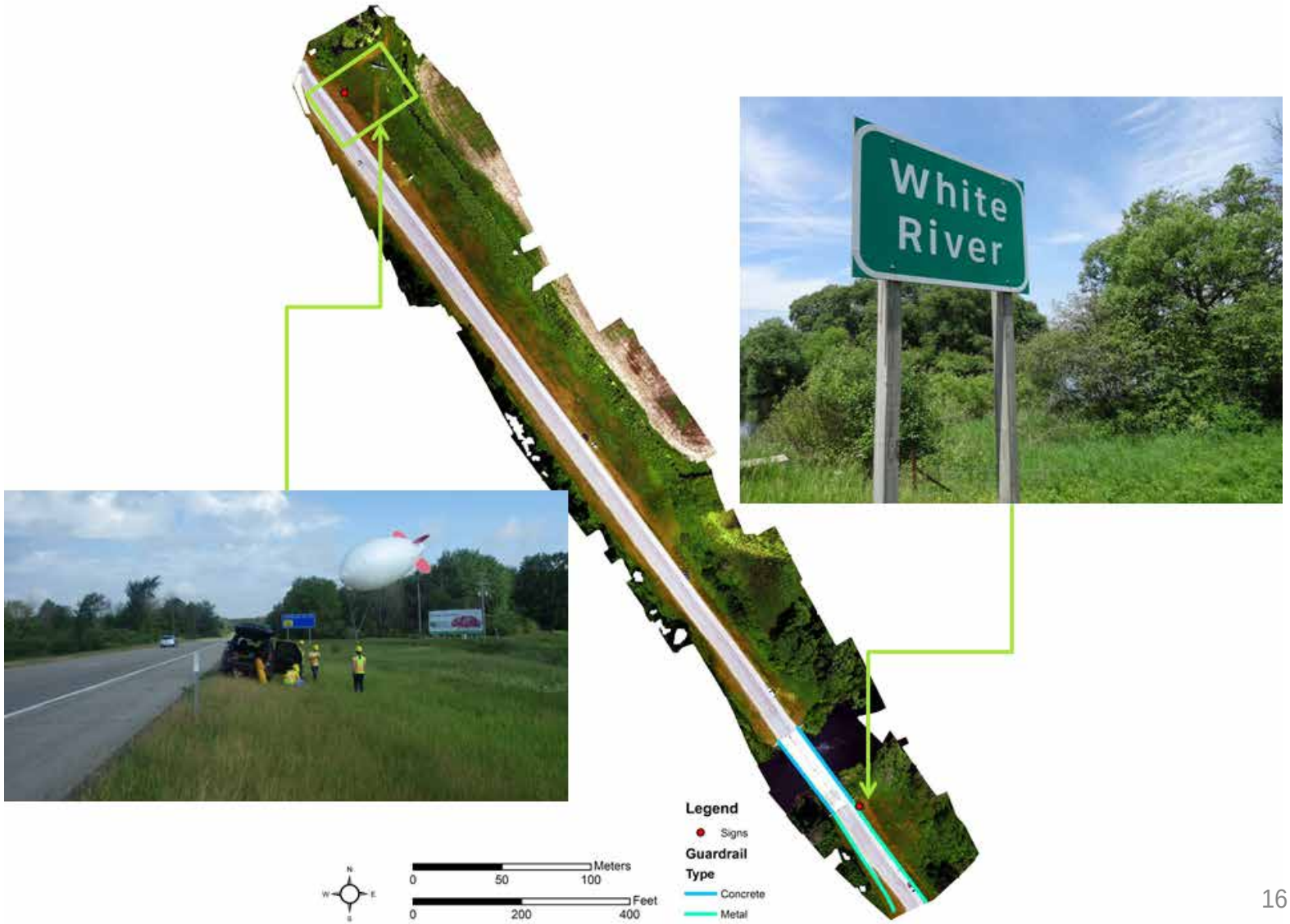
FHWA EDC5 UAS demonstration bridge inspection setup

Inspector-controlled headset showing UAS video during flights around bridge

MDOT application: US-31 White River Bridge - Spall Progression

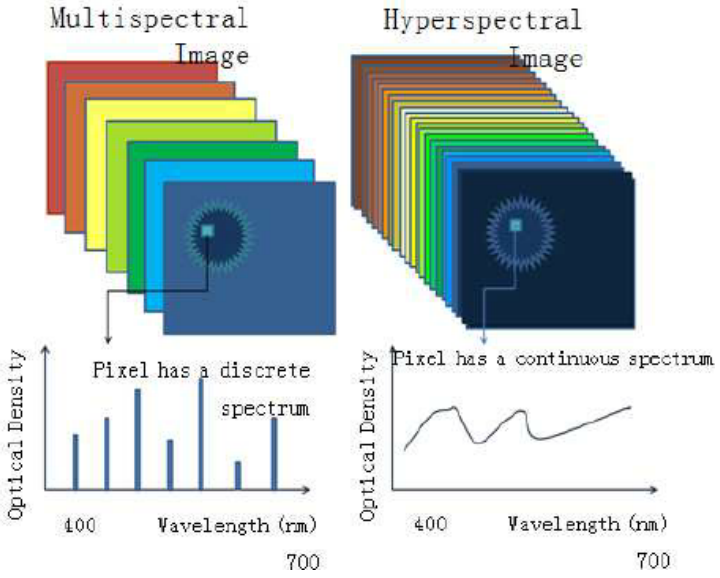


MDOT application: US-31 White River Bridge – identifying roadside features, adding to GIS asset management inventory



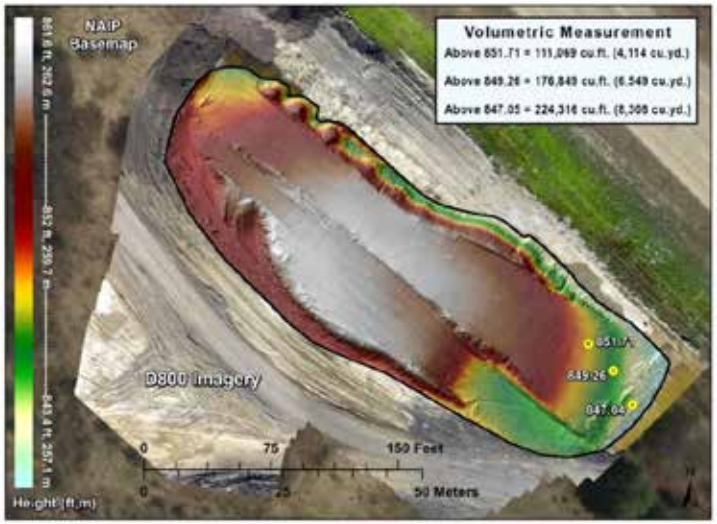
Pending test for Bridge Inspection – hyperspectral imaging

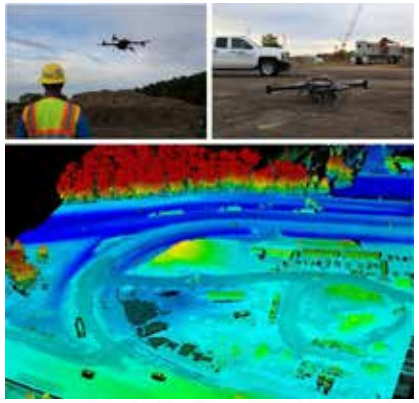
- Project team will perform a demonstration of the use of hyperspectral imaging to investigate its application from a UAS platform for bridge inspection.
- Test at least one concrete and one steel bridge.

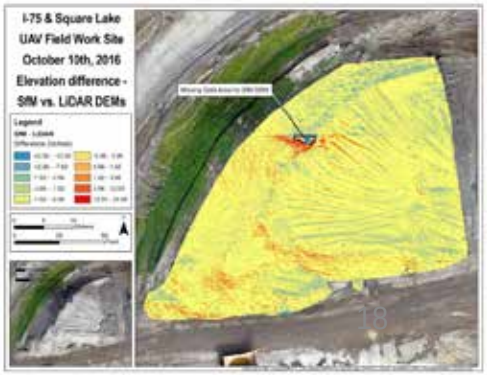


MDOT Application: Construction Inspection

- Change management
- Earthwork volumes
- Monitor construction progress
- Support potential mitigation
- Serve data to make universally accessible and useful



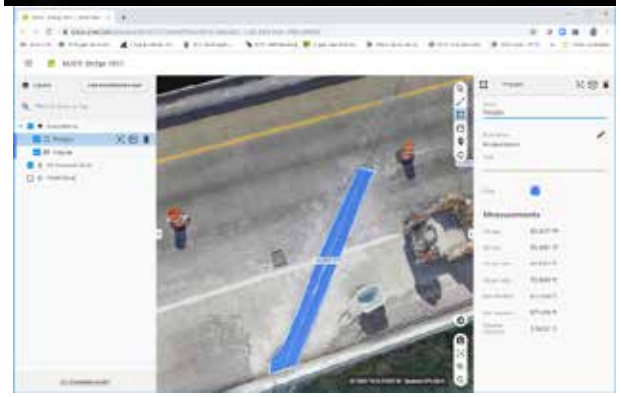


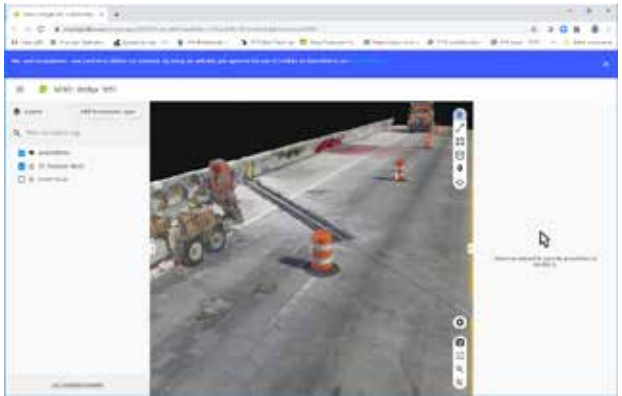


Construction Inspection (monitoring)

I-75 Segment #2

Construction Inspection





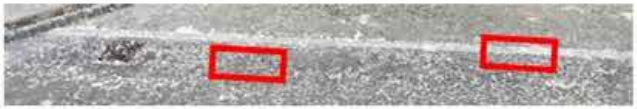
Development of workflows for integration of UAS data

Different UAV Data Types:
Photogrammetric, LiDAR, Point Cloud

Extracted Features:
Context specific

Bridge Structural Components

Bridge Deck Surface Characteristics



Parametric Information Models
e.g.: % spalling, % delamination

As-Built Information Models
Time Stamped for Long-term Monitoring

Construction Phase Monitoring
Time Stamped for short-term Monitoring

Decision-Making Aids
e.g.: Condition rating + recommendation for maintenance

MDOT Use Case: LiDAR UAS for Design Survey

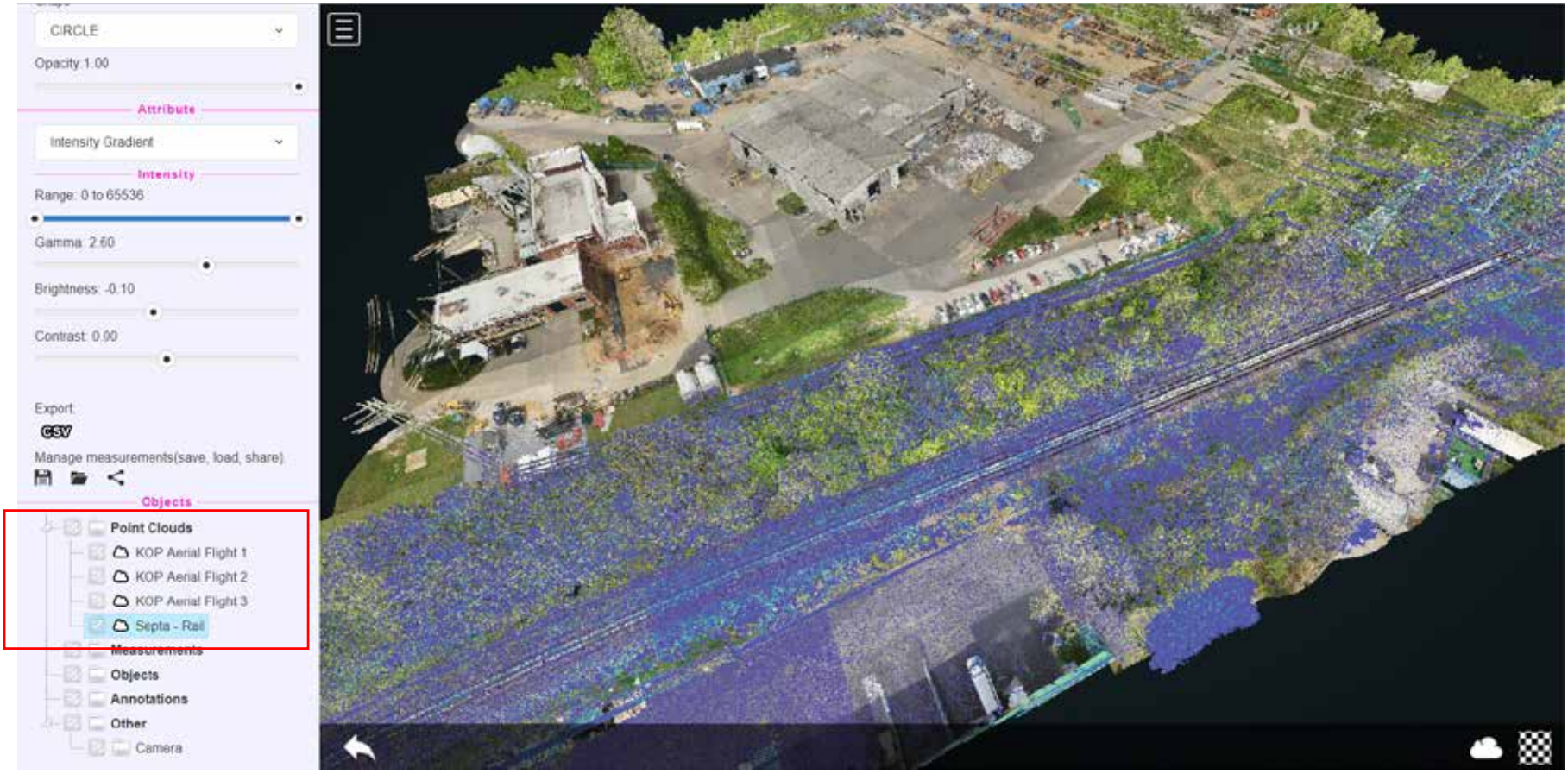
- Utilize to support supplemental Topo of greenbelt areas
- Re-use mobile LiDAR control for aerial operations
- Deploy multiple return system
- Comparing UAS LiDAR with mobile LiDAR

SSI Riegl miniVUX-1UAV

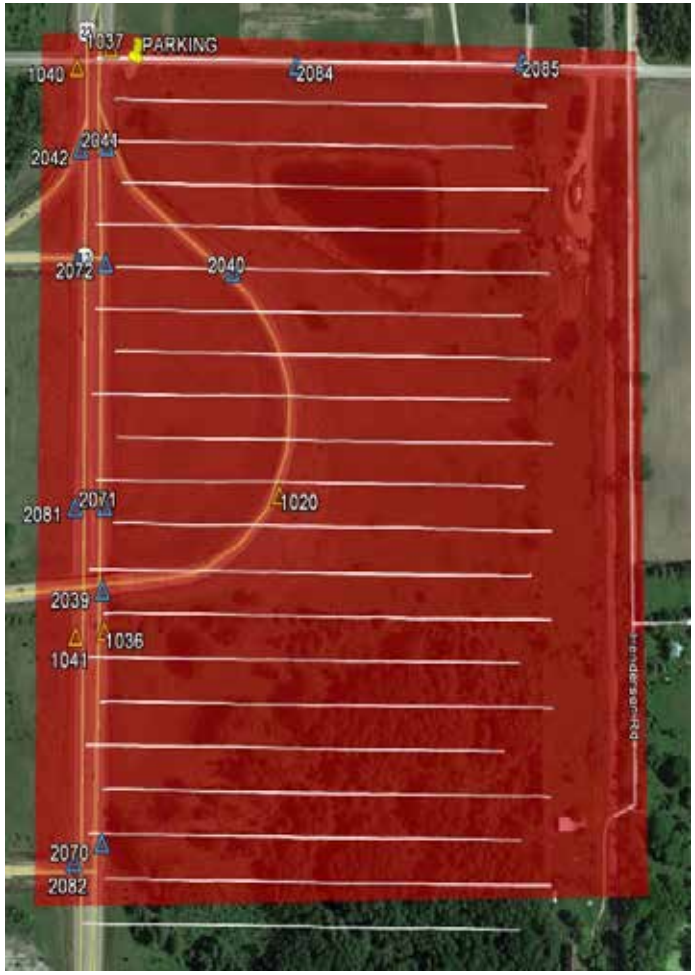
- What Design Survey needs can be met with UAS LiDAR with high-accuracy ground control?

LiDAR UAS for Design Survey

- Provide Aerial LiDAR directly to designer with accuracy documentation



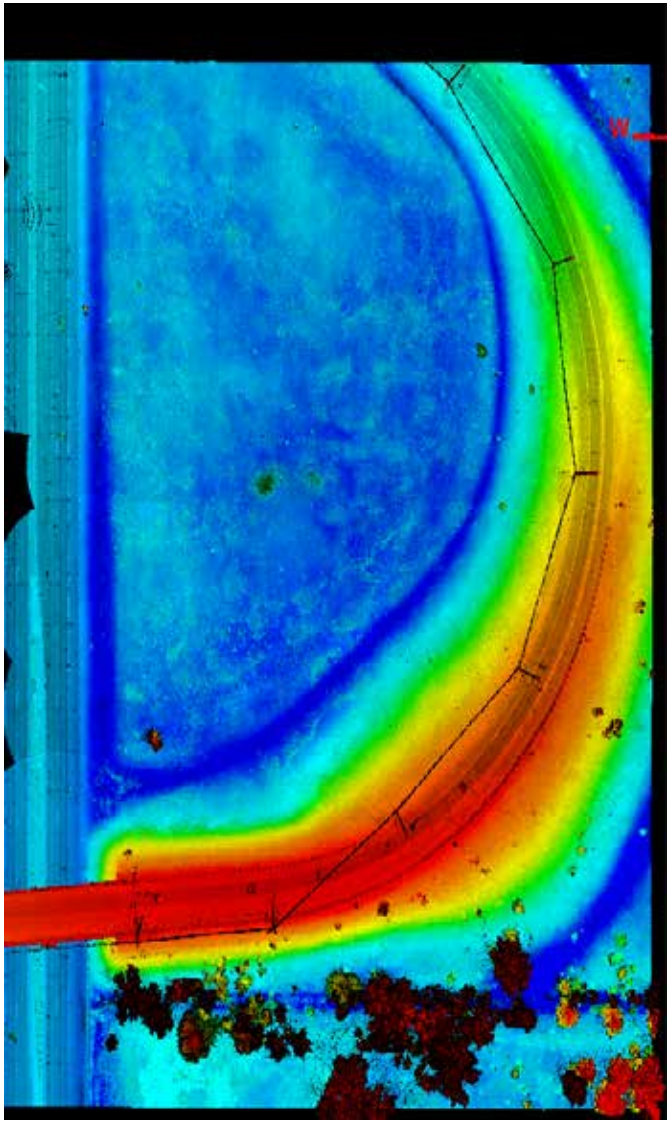
US-23 Connector Project Site

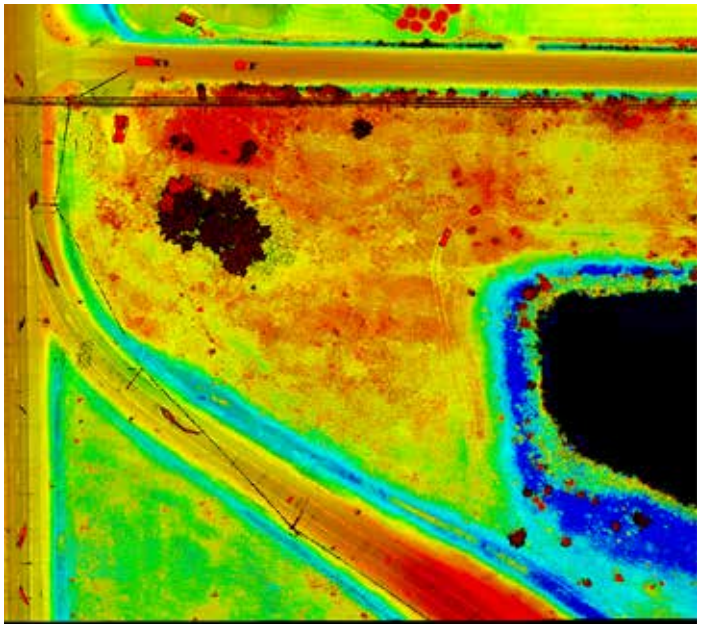


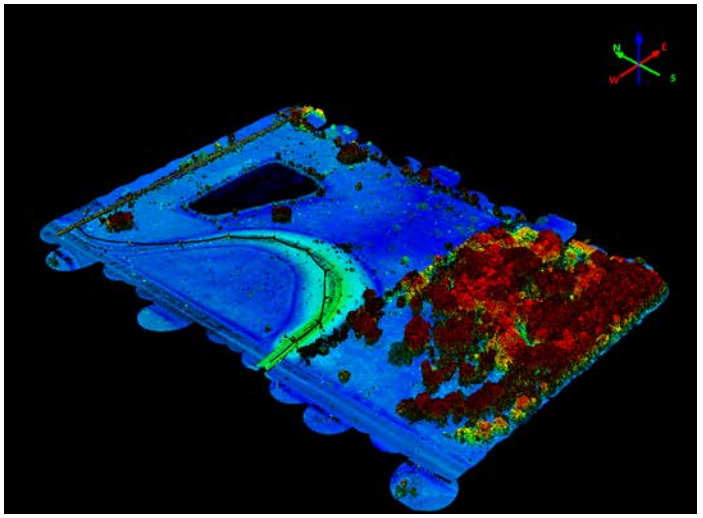
- White lines are the UAV trajectory
- Control from previous survey was still available
- Site met all the criteria specified
  - Recent MDOT Design Survey
  - Has a good variety of features normally encountered in a Design Survey (roads, embankments, fields, forests, water)
  - High Accuracy control readily available

Equipment Used

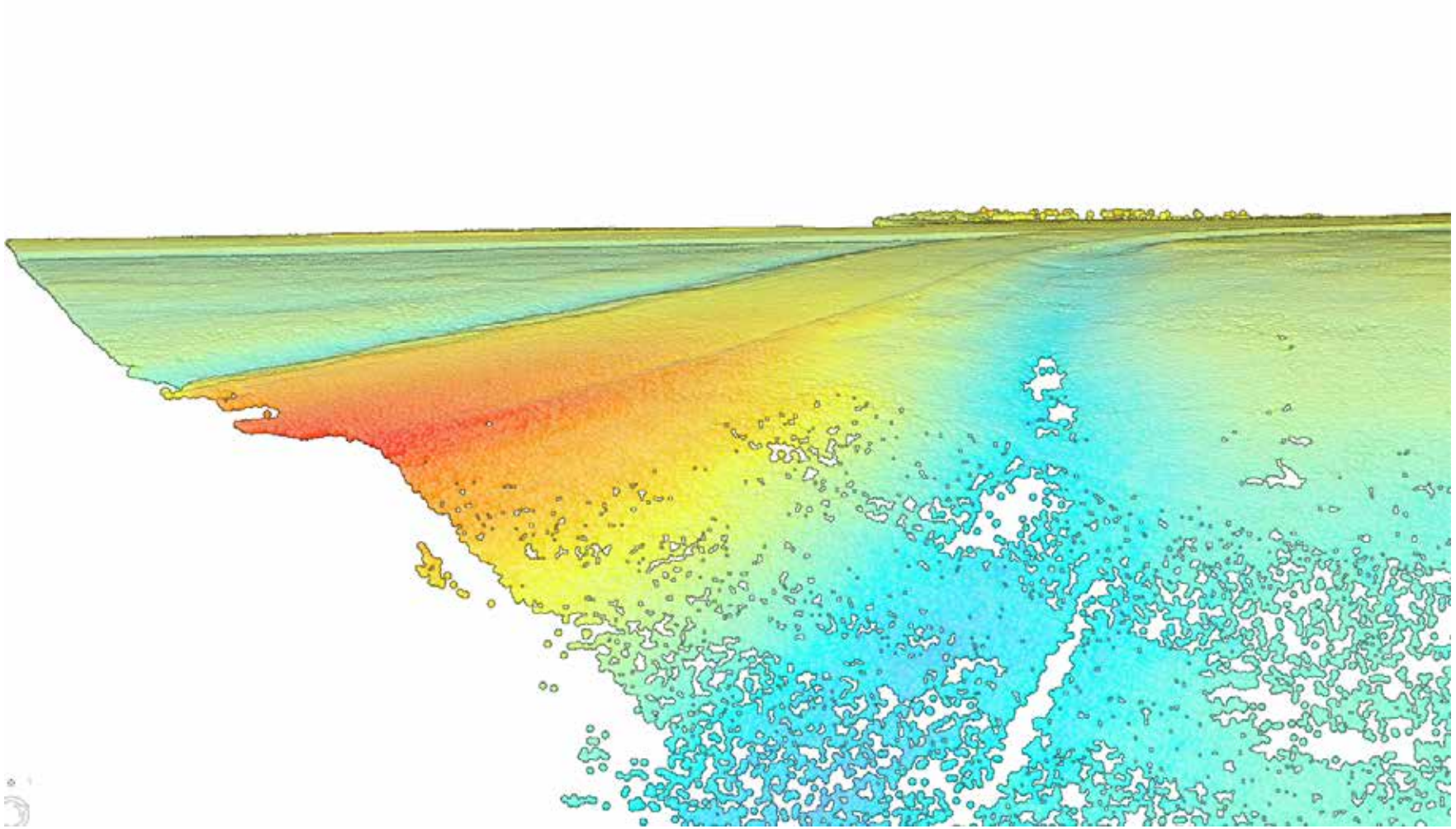
LiDAR data from UAV







3-D Point Cloud Elevation



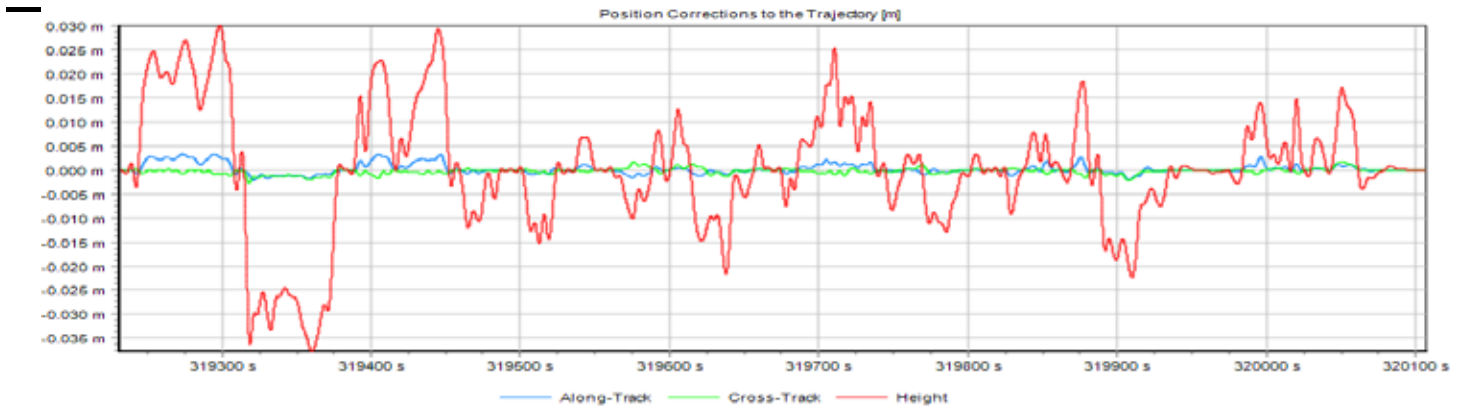
Processing of Data

Processed using Applanix POSPAC software

Riegl Ri-Process Software

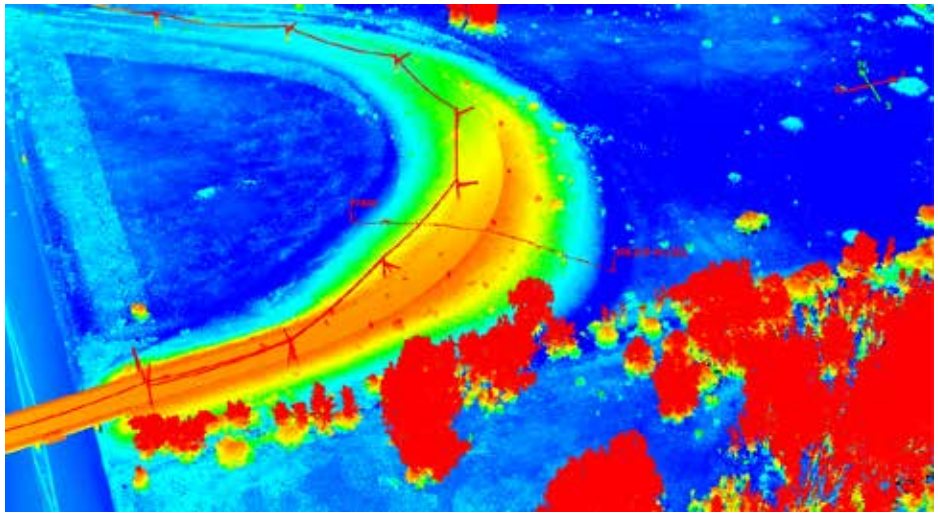
Tied to Ground Control Points (GCPs)

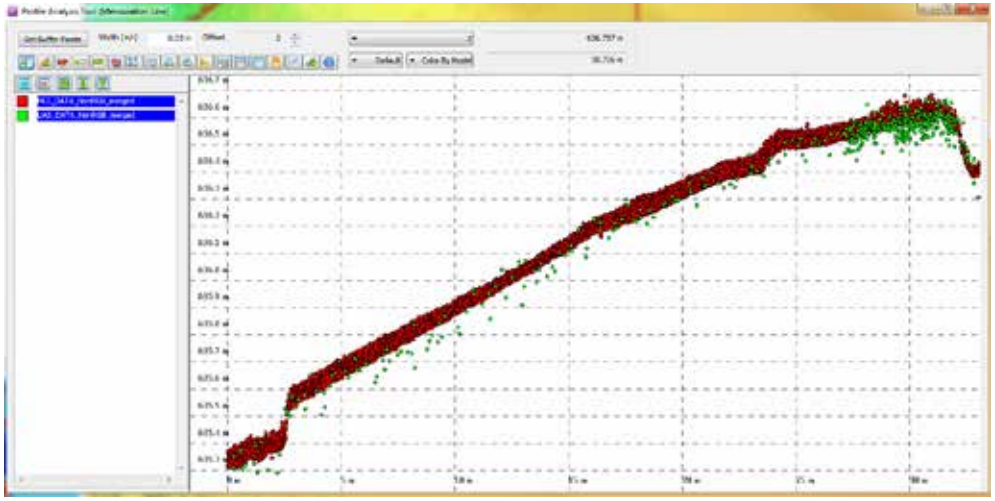
- Constrained to only 3 GCPs to verify the precision of the final product.



Most of the correction in Post Processing is in the Height

Comparing LiDAR data sets





Developing statistical comparisons of mobile LiDAR vs. UAS LiDAR Data quality to document appropriateness for different applications (design survey, as built)

ASPRS & NCHRP Accuracy Statements

Accuracy	HIGH < 0.05 m (< 0.16 ft)	MEDIUM 0.05 to 0.20 m (0.16 to 0.66 ft)	LOW > 0.20 m (> 0.66 ft)
Density	1A	2A	3A
FINE > 100 pts/m² (> 9 pts/ft²)	• Engineering surveys • Digital terrain modeling • Construction automation/ Machine control • ADA compliance • *Clearances** • *Pavement analysis* • Drainage/Flooding analysis • Virtual, 3D design • CAD models/Baseline data • BIM/BRIM** • Post-construction quality control • As-built/As-is/Repair documentation • Structural inspections	• *Forensics/Accident investigation** • *Historical preservation* • Power line clearance	• Roadway condition assessment (general)
	1B	2B	3B
INTERMEDIATE 30 to 100 pts/m² (3 to 9 pts/ft²)	• Unstable slopes • Landslide assessment	• General mapping • *General measurements* • Driver assistance • Autonomous navigation • Automated/Semi-automatic extraction of signs and other features • Coastal change • *Safety* • Environmental studies	• Asset management • Inventory mapping (e.g., GIS) • Virtual tourism
	1C	2C	3C
COARSE <30 pts/m² (<3 pts/ft²)	• *Quantities (e.g., earthwork)* • Natural terrain mapping	• *Vegetation management*	• Emergency response • Planning • Land use/Zoning • Urban modeling • Traffic congestion/ Parking utilization • Billboard management

**Network accuracies may be relaxed for applications identified in red italics.*
**BIM/BRIM: BIM = Building Information Modeling; BRIM = Bridge Information Modeling.
These are only suggestions; requirements may change based on project needs and specific transportation agency requirements.

Accuracy classifications for mobile LiDAR data from "Guidelines for the use of mobile LIDAR in transportation applications" (Table 1, Pg. 11)

The **Uncle Henry Road** dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 1.25 (cm) RMSEx / RMSEy Horizontal Accuracy Class. Actual positional accuracy was found to be RMSEx = 0.296 (cm) and RMSEy = 0.521 (cm) which equates to a Positional Horizontal Accuracy = +/- 1.037 at 95% confidence level.

The **Uncle Henry Road** data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 33.3 (cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 16.834 (cm), equating to a +/- 65.3 cm at 95% confidence level.

NCHRP Report 748

Based on Horizontal Accuracy Class
- Level 1A – High accuracy (< 0.05m), fine density point cloud

Based on Vertical Accuracy Class
- Left 3A – Lower accuracy (> 0.20m), fine density point cloud

ASPRS Accuracy Standards

Uncle Henry Horizontal and Vertical Accuracy									
	Measured Map Values (m)			Survey Check Points (m)			Residual Values (cm)		
Point ID	Easting	Northing	Elevation	Easting	Northing	Elevation	Error in Easting	Error in Northing	Error in Elevation
105	217567.405	4044411.058	589.156	217567.400	4044411.068	588.885	0.494	-0.938	27.100
106	217566.832	4044427.781	588.891	217566.831	4044427.780	588.916	0.061	0.137	-2.500
107	217561.417	4044427.792	588.857	217561.414	4044427.791	588.940	0.299	0.121	-8.300
108	217561.580	4044411.872	589.130	217561.581	4044411.868	588.950	-0.116	0.414	18.000
						Number of Check Points	4	4	4
						Mean Error	0.185	-0.066	8.575
						Standard Deviations (StDEV)	0.267	0.596	16.727
						Root Mean Squares Error (RMSE x or y or z)	0.296	0.521	16.834
						Radial RMSEr	0.599		
						NSSDA Horiz Accuracy at 95% Accuracy Level	1.037		
						NSSDA Vertical Accuracy at 95% Accuracy Level	32.995		

Orthophoto resolution = 0.8cm

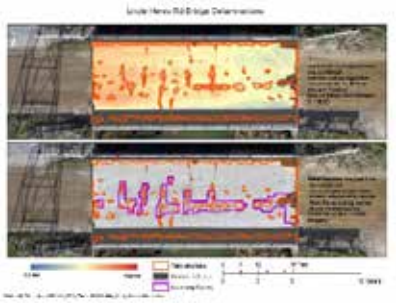
TABLE B.3 COMMON HORIZONTAL ACCURACY CLASSES ACCORDING TO THE NEW STANDARD[6]

Horizontal Accuracy Class $RMSE_x$ and $RMSE_y$ (cm)	$RMSE_r$ (cm)	Orthoimage Mosaic Seamline Maximum Mismatch (cm)	Horizontal Accuracy at the 95% Confidence Level (cm)
0.63	0.9	1.3	1.5
1.25	1.8	2.5	3.1
2.50	3.5	5.0	6.1

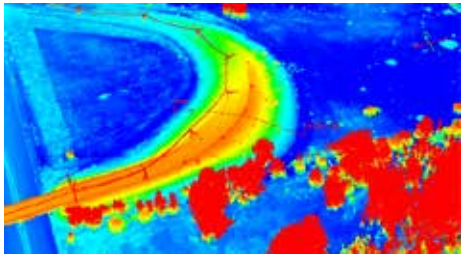
Next steps for UAS applications

- With appropriate documentation, UAS-collected data can meet many data needs:
  - Bridge inspection quantitative & qualitative data
    - Inform element-level data needs (area by Condition State)
  - Traffic operations data
  - Construction inspection & monitoring
  - Still developing LiDAR for design survey data analysis
- Making well-documented data available for MDOT operations in state databases
  - Michigan: DUAP => TerraForm Manager (TFM) w/ connected vehicle data, helping provide data for new applications
- Training for transportation agency staff
  - Understanding balance of in-house vs. 3rd party UAS services
  - Supporting integration of methods & results into operational workflows
- Understanding impacts of new / pending FAA regulations
  - Flights over people
  - Beyond visual line of sight (BVLOS)

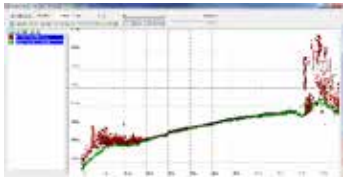






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