Michigan Tech Research Institute

Michigan Bridge Conference Workshop:
1. Applications of UAVs for transportation infrastructure assessment
2. Environmental assessment with UAVs
3. The 3D BRIDGE Application

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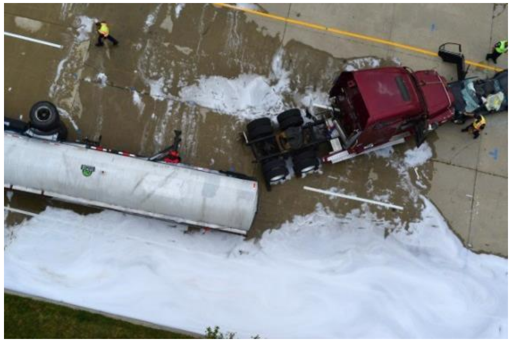
Evaluating the Use of Unmanned Aerial Vehicles for Transportation Purposes

MDOT research project, contract no. 2013-067, Auth. No. 1, OR13-008

Michigan Tech team members: Colin Brooks (cnbrooks@mtu.edu, 734-604-4196), Thomas Oommen, Timothy C. Havens, Theresa M. Ahlborn, Richard J. Dobson, Dave Dean, Ben Hart, Chris Roussi, Nate Jesse, Rudiger Escobar Wolf, Michelle Wienert, Blaine Stormer, John Behrendt

MDOT program manager: Steve Cook; MDOT Research Manager: André Clover

http://www.mtri.org/mdot_uav.html



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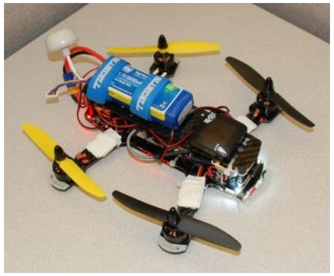
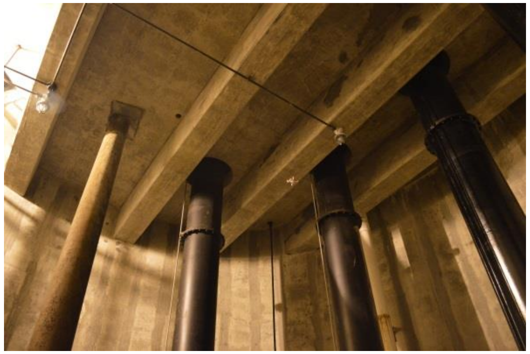
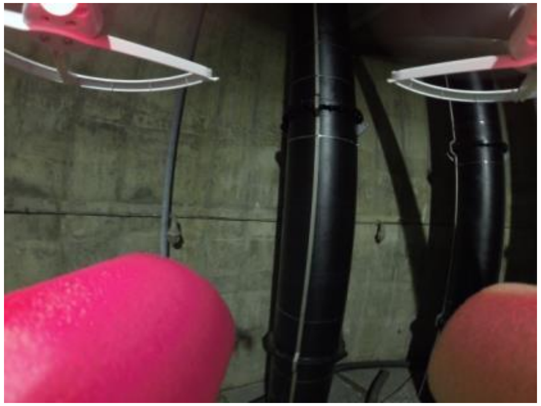
Confined space inspection

- Initial flights - understand capability to fly in confined spaces; later flights - smaller UAVs
  - MDOT Pump Station
  - 4’ culvert (1.2m)
- Is it safe to send a person into the pump station?
  - Eventually: unlit, retrieve through opening
- DJI Phantom 1, Walkera QR W100S, Helimax 1Si; Blackout Mini H Quad ready to fly

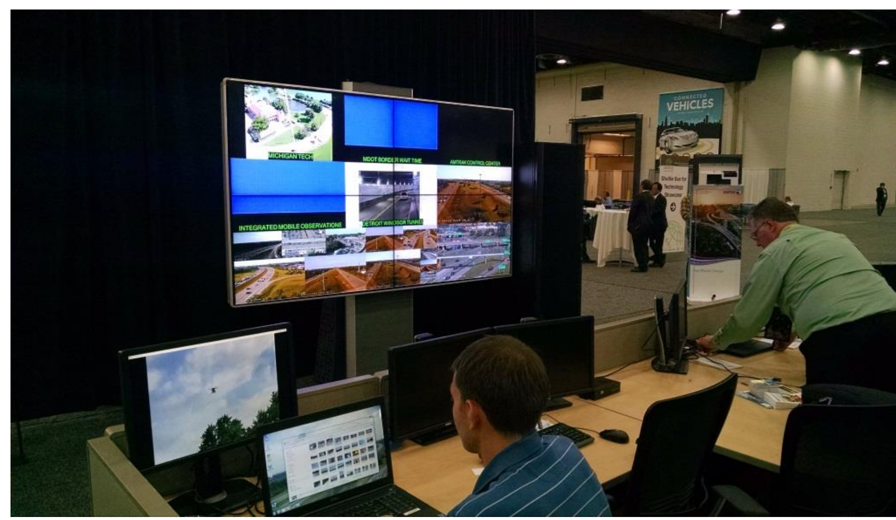






Tethered Blimps for Traffic Monitoring

- 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



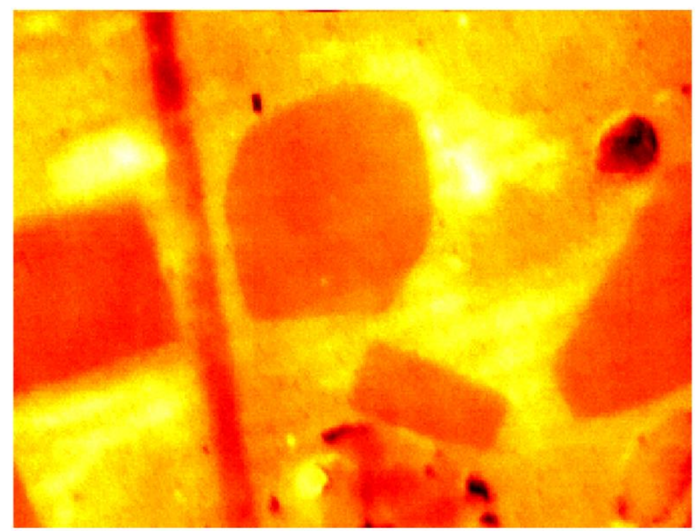
Support for emergency response

Post-spill response; crash scene reconstruction

Bridge asset management & condition assessment imagery: collecting data

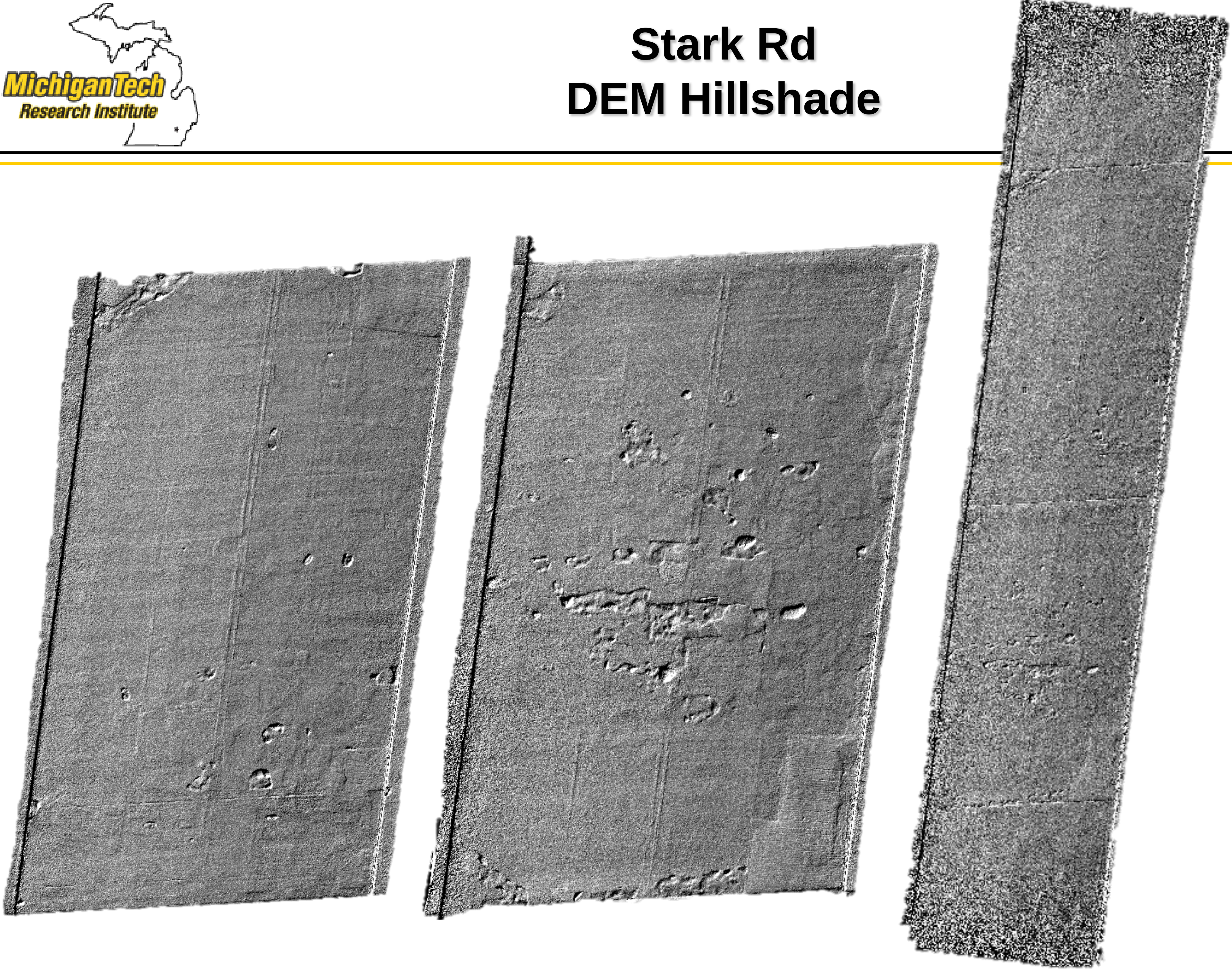
Bridge asset management & condition assessment imagery: examples

985



Stark Rd
Orthophoto – 2.5mm

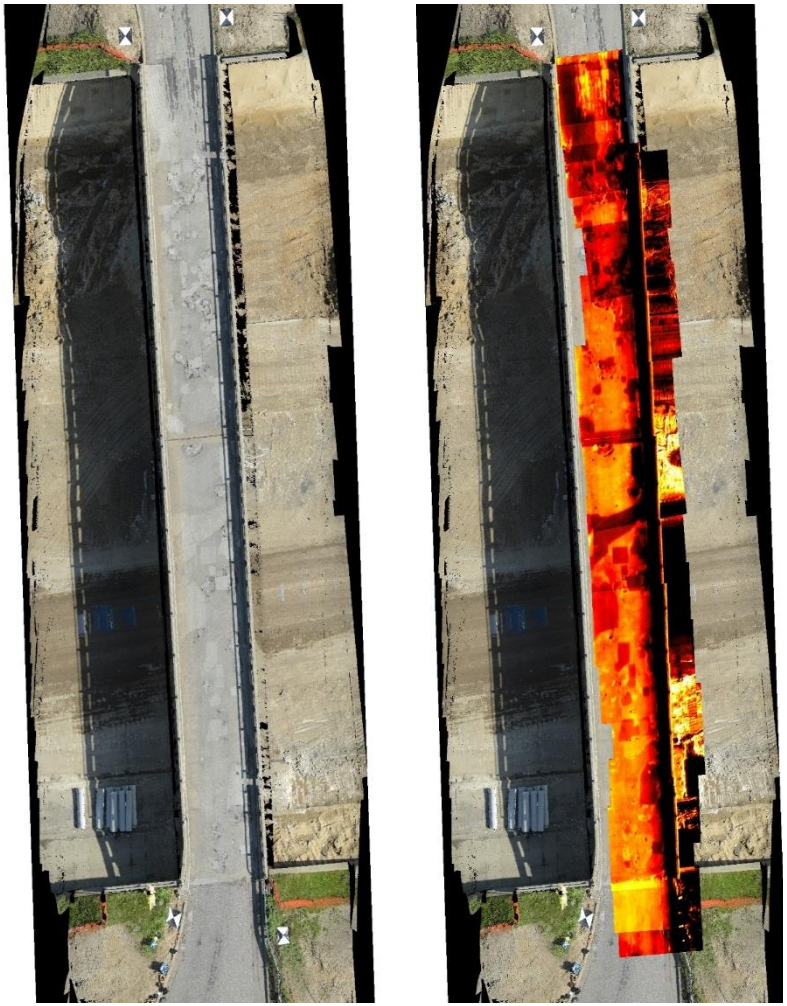
Stark Rd
DEM Hillshade



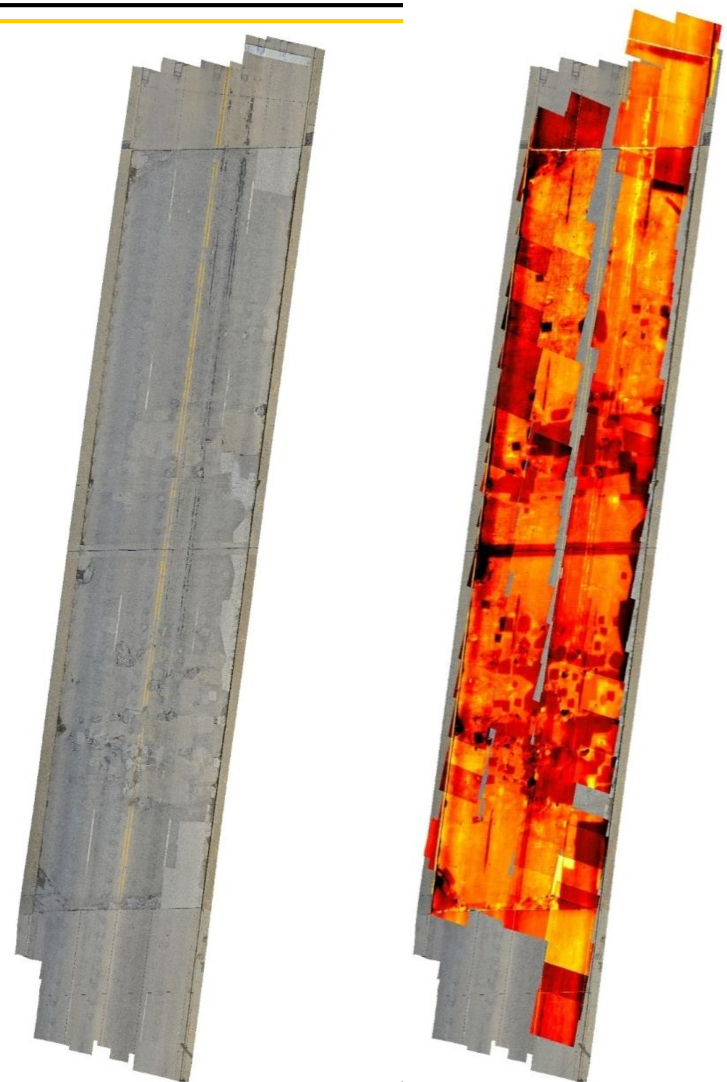
Automated spall detection

- Automated spall detection algorithm (developed by Brooks, Dobson)
- Applied to high-resolution 3D elevation model (DEM) for Merriman East (pictured), Stark Road bridges.
- Merriman East: 4.4% spalled (150.0 square feet)

Combined thermal data for 2 bridges



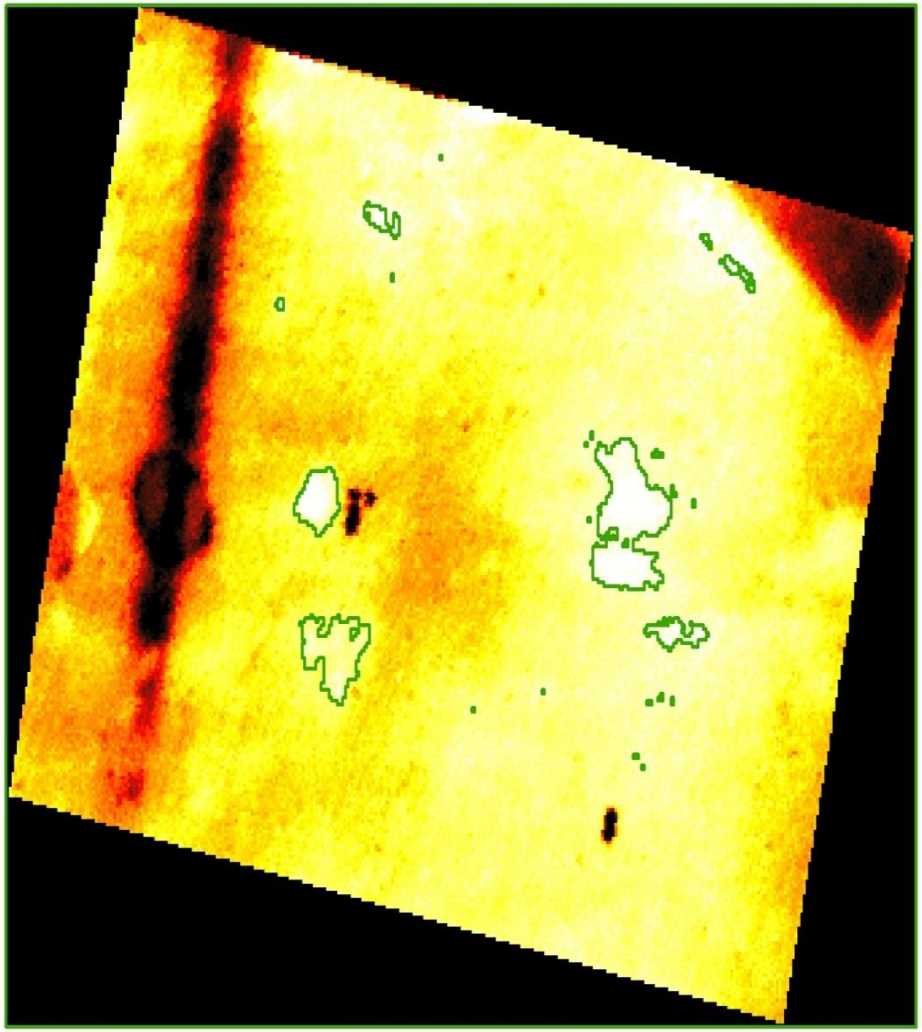
Merrim
an



Stark

Automated delamination detection

Delamination should be evident in thermal but not in visible!



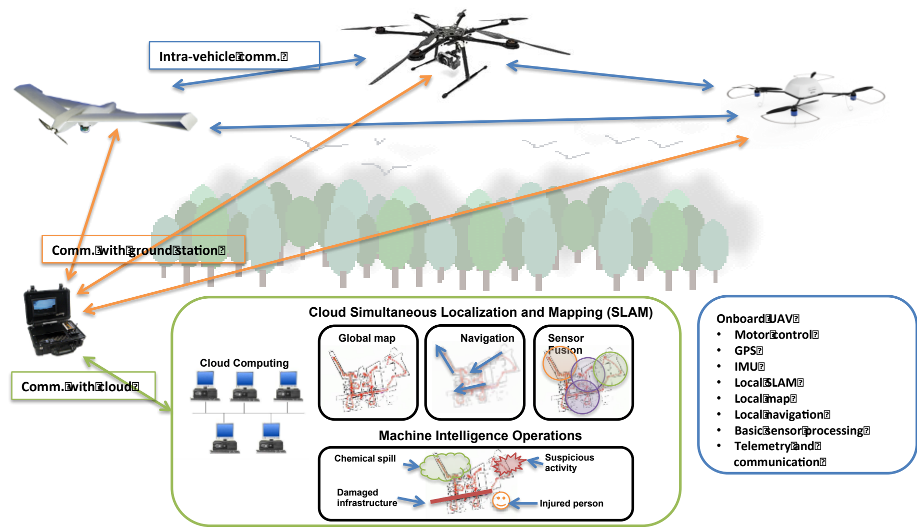
Criteria can be added: eliminate small areas (e. g. single pixels, pixels with low number of neighbors, etc.), look at individual bands, etc.

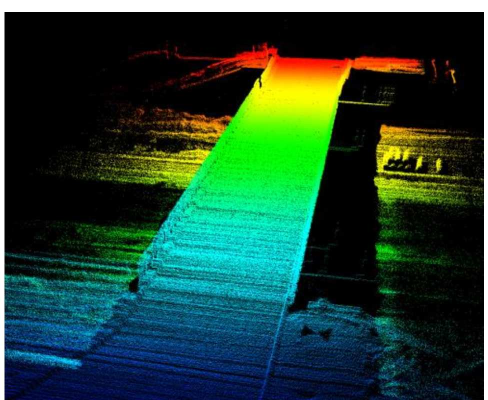
Only pixels with more than 6 neighbors.

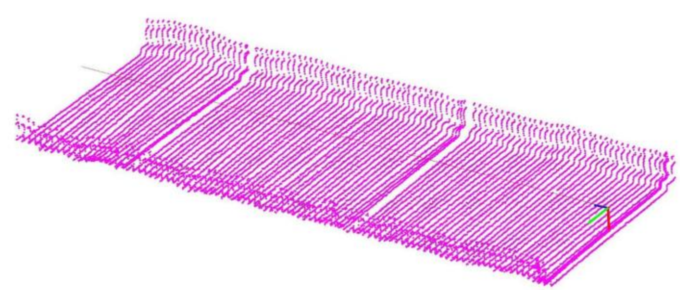
Area = 0.18 m^2

UAV-Based LiDAR

- LiDAR sensor pod developed
  - Hokuyo UTM-30LX LIDAR
  - VectorNAV MEMS IMU
  - Beaglebone Black onboard computer
  - WIFI bridge
  - LiPo battery power
- Three-dimensional Simultaneous Localization and Mapping (SLAM) algorithms developed





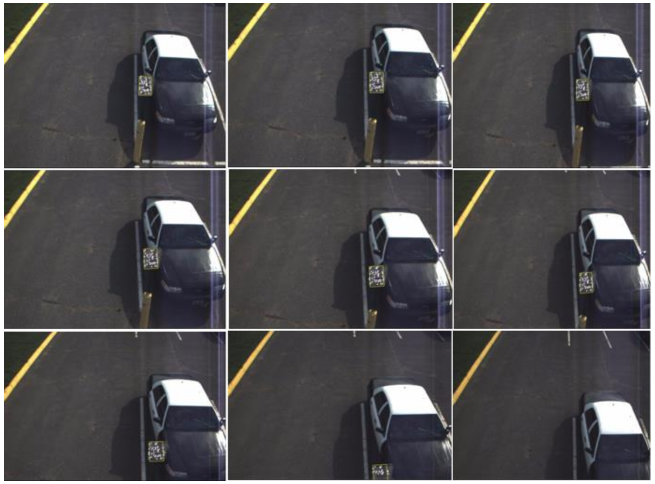


Bridge with linear interpolation assumption

Roadway asset detection from UAV demonstration

- Featured-based algorithms & classifiers tested
- Classifiers can be “trained” with examples of roadway assets (road furniture)
- Examples of detecting no-parking signs tested; could be used for other assets (guard rails, lamps, etc.)

Detection of asset data in training imagery – stop signs, handicap signs, traffic lights

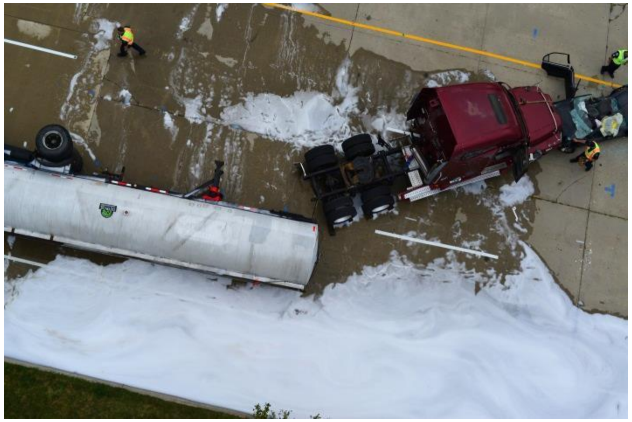


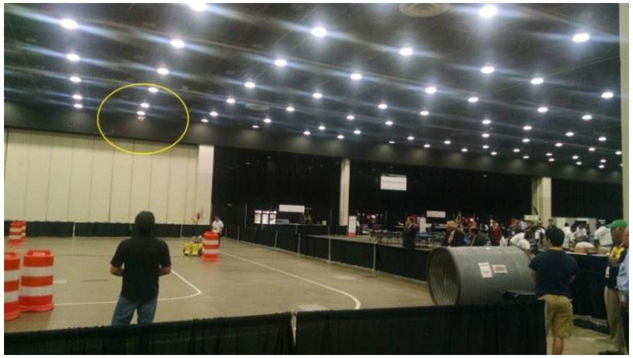
No Parking sign detected & tracked from UAV imagery

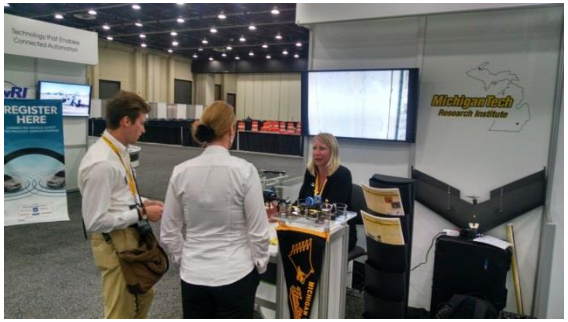
No parking sign – side view detection & tracking from UAV

ITS World Congress 2014 demonstrations

- Indoor flights at the indoor Test Track by the Demo Launch area
- Live video feed of Belle Isle from blimp displayed in MDOT Traffic Operations Center at Cobo Hall
- Outdoor demonstrations at Belle Isle – Technology Showcase
- Spotlight, technical session talks
- Mock Incident participation – UAV, blimp demos







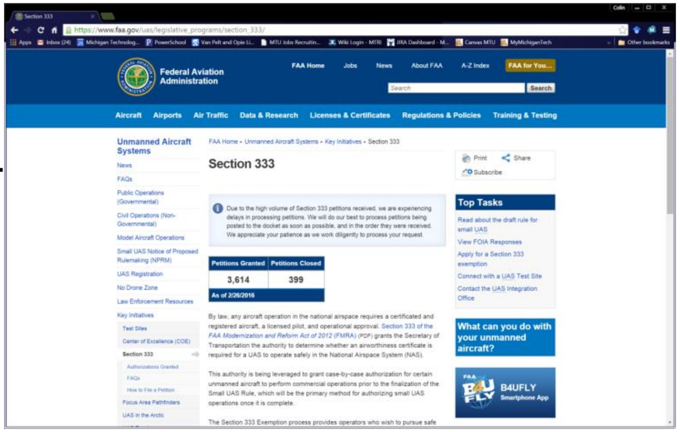
Next steps: Implementation

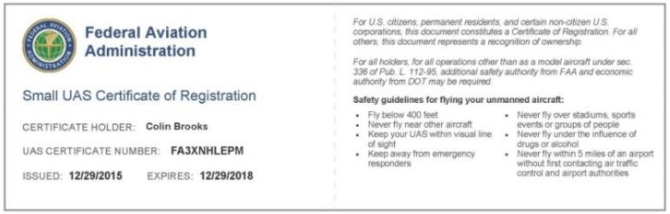
- Michigan Tech selected for Phase II MDOT UAV project
- Focused on implementation
- Starting May 2016 (2 years)

- Objectives:
  - Develop, deploy, and implement near-time data collection communication backhaul and data storage capabilities proof of concept for the most viable UAV platforms and sensing capabilities.
  - Develop, deploy, and implement (via pilot projects) UAV data uses, analysis, and processing systems delivered from on-board sensors for two (2) to three (3) specific business functions/activities identified by MDOT.
  - Demonstrate, deploy, and implement (via pilot projects) data quality protocols to ensure data collected is accurate and within tolerance requirements when compared to current data collection systems at MDOT for the same two (2) to three (2) specific business functions/activities identified by MDOT.
  - Demonstrate a proof of concept for data collection uses UAVs for transportation purposes, beyond those proven during Phase 1, from various highway assets.
  - Coordinate/leverage ongoing and past research of UAV sensing and data collection technologies. Provide device training and deployment/implementation plan, including a user/operation guidance document.
  - Determine the return on investment (benefit/cost analysis) performed on UAVs and sensory technologies deployed for pilot studies performed for this research project.
  - Secure a Federal Aviation Administration (FAA) Certificate of Authorization (COA) to complete the below tasks and deliverables.

FAA rules have been developing; more practical use enabled

- **FAA Section 333 program** has enabled over 3,600 commercial exemptions for use of small UAVs
  - up from 548 in July, 2015 and 13 in Dec., 2014!
- **New "Small UAS" (sUAS) rules** proposed by FAA Feb. 2015… finalized in 2016/2017? No pilot's license.
  - Line of sight, daytime operations, below 500', UAV operators permit
- **U.S. UAV registration rule** implemented by FAA on 12/21/15 ($5 cost)
- **Online sUAS Registration System** is scheduled to open by summer 2016 for:
  - Recreational Small Unmanned Aircraft owned by a company or non-individuals, and
  - Small Unmanned Aircraft used for commercial or non-recreational purposes.
- **Sen. Peters bill** – provide standard operations for most University research & education (out of committee)
- **Beyond line of sight testing** - FAA Pathfinder program – a few efforts so far:
  - BNSF – railroads, CNN – newsgathering, PrecisionHawk – agriculture
  - In the future through exemptions?
- **Continued need for R&D efforts** –
  - new sensors, new platforms,
  - automated feature detection – data into useful information;
  - role for consortiums of University applied research teams
  - we are looking for partners, projects





Where next for UAVs?

- Move UAVs into day-to-day operations – new rules, more capable systems, more trained operators, defined workflows, common applications
  - MDOT UAV Applications Phase II project, 2016-2018
- Developing national ruleset for UAVs will enable easier use
  - Beyond line of sight is key
- Michigan has a UAS testing center – the Northern Michigan Unmanned Aerial Systems Consortium (NMUASC), headquartered at Alpena airport – affiliated with Griffiss-NUAIR (Rome, NY) (I'm on the Board)
  - http://www.northernmichiganunmannedaerialsystemsconsortium.com/
- Infrastructure inspection, traffic monitoring, environmental assessment – my focus areas
- Common for aerial firms, engineering companies, others to offer UAV-enabled services

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www.mtri.org/unpaved

3D BRIDGE app overview
Michigan Bridge Conference Workshop
MDOT #2013-0067, Auth. No. 2

Michigan Tech team members: Colin Brooks (cnbrooks@mtu.edu, 734-604-4196), Tess Ahlborn, Reid Sawtell, Glenn Sullivan, Richard J. Dobson, Nate Jesse, and Helen Kourous

MDOT program manager: Rich Katherns; MDOT Research Manager: Michael Townley

Michigan Department of Transportation

www.mtri.org

The Problem

- Faced with an aging bridge inventory and increasing federal regulations for collecting element level data, MDOT wishes to increase the efficiency and reliability of collected data.

The Problem

- Current bridge inspection practices at the Michigan Department of Transportation (MDOT) utilize paper forms followed by a manual data entry step to populate their database.

The Problem

- Additionally, photographs documenting bridge deterioration are collected and stored separately from inspection data.

The Problem

- MDOT inspectors must also carry reference manuals and past inspection reports to help verify the accuracy of the data they are collecting.

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The Problem

- The exact locations of bridge defects are not stored which creates an inconvenience as the data are difficult to visualize.
- Federal regulations now require inspectors to collect AASHTO Element level data. Current processes do not allow for the efficient collection of this data.

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 2304	SAFETY INSPECTION REPORT - CORE ELEMENTS		B02-23092
Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
M-99 NB	42.630728 / -84.622691	23123092000B020	Fair Condition(6)
Feature	**Length / Width**	**Owner**	
GRAND RIVER	180 / 45.9	Region: University(6)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.5 MI S OF HOLT RD	1978 / / 2008 / 2008	Lansing(6A)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Eaton(23)	3 Steel / 02 Stringer/Girder	05/07/2013 / BDYT	3 SC - Unstable

NBI INSPECTION BDYT

Inspector Name	Agency / Company Name	Insp. Freq.	Insp. Date
Janiene DeVinney	MDOT INSPECTOR	24	05/07/2013

CoRE ELEMENTS (English Units)

Element Number	Element Name	Total Quantity	Unit	State 1	State 2	State 3	State 4	State 5
Decks/Slabs								
18/ 3	Conc Dk Thn Epoxy Ov	8267	(SF)	8267 100%	0 0%	0 0%	0 0%	0 0%
Joints								
400/ 3	Strip Seal Exp Joint	92	(LF)	92 100%	0 0%	0 0%	xxxxx xxxxx	xxxxx xxxxx
401/ 3	Pourable Joint Seal	92	(LF)	0 0%	92 100%	0 0%	xxxxx xxxxx	xxxxx xxxxx
Superstructure								
107/ 3	Pnted Stl Girder /Bm	1079	(LF)	1074 100%	5 0%	0 0%	0 0%	0 0%
161/ 3	Paint Stl Pin/Hanger	12	(EA)	12 100%	0 0%	0 0%	0 0%	0 0%
331/ 3	Concrete Bridge Rail	361	(LF)	269 75%	92 25%	0 0%	0 0%	xxxxx xxxxx
Bearings								
311/ 3	Movable Bearing	12	(EA)	12 100%	0 0%	0 0%	xxxxx xxxxx	xxxxx xxxxx
313/ 3	Fixed Bearing	12	(EA)	12 100%	0 0%	0 0%	xxxxx xxxxx	xxxxx xxxxx
Substructure								
205/ 3	Reinf Conc Column	6	(EA)	4 67%	2 33%	0 0%	0 0%	xxxxx xxxxx
215/ 3	Reinf Conc Abut	105	(LF)	80 76%	25 24%	0 0%	0 0%	xxxxx xxxxx
234/ 3	Reinf Conc Pier Cap	105	(LF)	92 88%	13 12%	0 0%	0 0%	xxxxx xxxxx
Other Elements								
321/ 3	Reinf Conc Appr Slab	2	(EA)	2 100%	0 0%	0 0%	0 0%	xxxxx xxxxx

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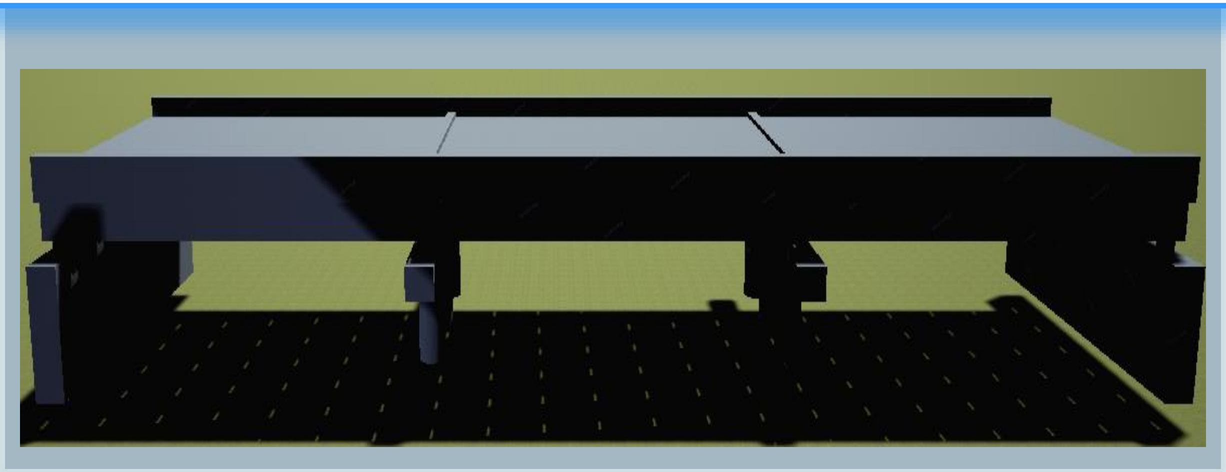
MDOT's Solution

3D Bridge inspection tool



- A tablet application for MDOT Bridge Inspectors for the collection, display, and summarizing of Bridge Inspection Data.

3D BRIDGE App

Allows MDOT Bridge Inspectors to Enter Element-level Condition State Data by Interacting with a 3D Bridge Model

Michigan Tech Research Institute

MDOT Michigan Department of Transportation

Michigan Tech — Michigan Technological University, Department of Civil & Environmental Engineering

Purpose

Replace paper inspection forms
Display past inspection data, including photos
Integrate with MDOT Bridge Reporting System
Enable future Remote Sensing data

Approach

Design user interface around interactive model of the bridge
Employ context-sensitive elements
Leverage 3D game rendering framework to develop a portable native mobile application

Benefits

Observations (e.g., cracks) are tagged to 3D locations on bridge, replacing current practice of aggregating cracks for an entire element (e.g., deck)
Eliminates field-to-office double data entry

Database to 3D Model

Bridge Management Database → *Bridge structure data* → **Query by BridgeID**

Bridge Engineering Domain Knowledge → *List of bridge components* → **Apply Bridge Rules**

Calculate Scale and Position

Bridge Model Engine

Bridge XML Schema — http over 3G/4G

Primitive Library → *Static Meshes* → **3D Rendering Engine**

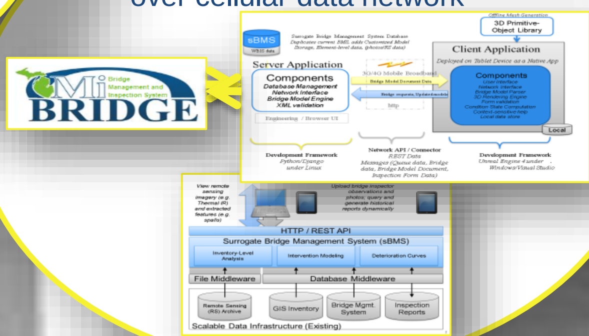
3D Bridge Model
Generated on the fly

Native Tablet Application

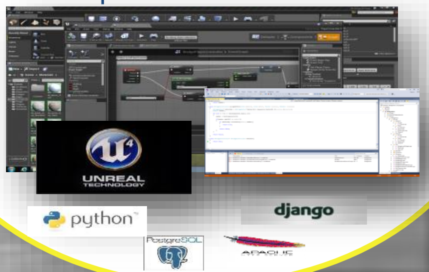
Interact with and mark up a true 3D representation of bridge

Add GPS-tagged photos and remote sensing data

Integrate with MDOT Bridge Management system over cellular data network



Leverage 3D game engine and open source tools

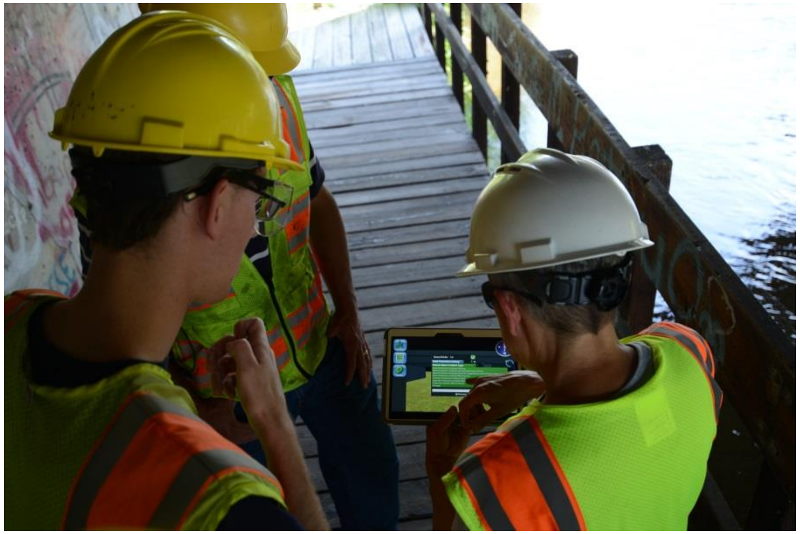


Creating the future… of MDOT bridge inspections

Project Interns: Glenn Sullivan (UM), Samuel Aden (MTU), David Morehouse (MTU)
Poster Design Helen Kourous

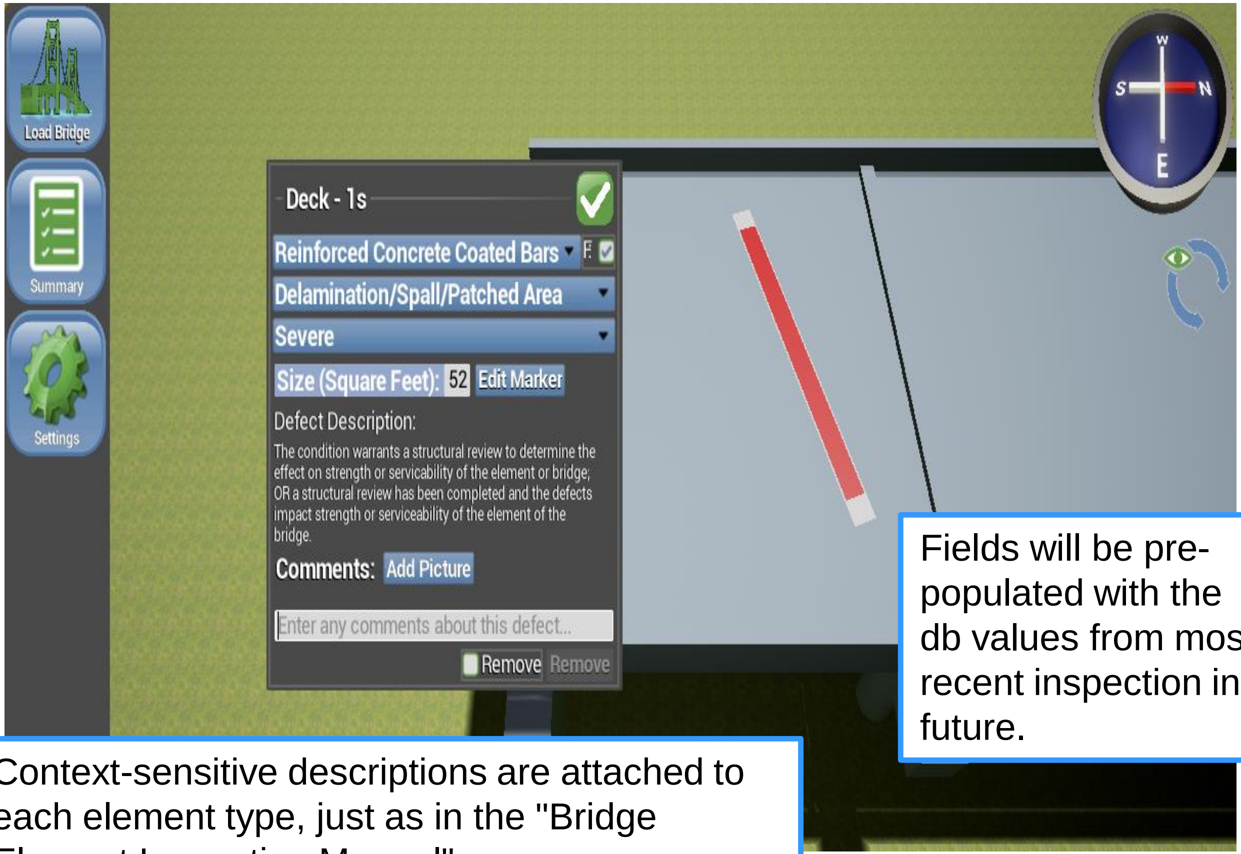
The 3D BRIDGE app

- The 3D BRIDGE app helps MDOT take advantage of the advances in portable data entry technologies, reduce the need for field staff time to collect bridge inspection, and facilitate the bridge inspection process



3DBRIDGE tool's Use

- The 3D BRIDGE tool allows bridge inspectors to collect and record all of the necessary data for the bridge inspection process in one tool.

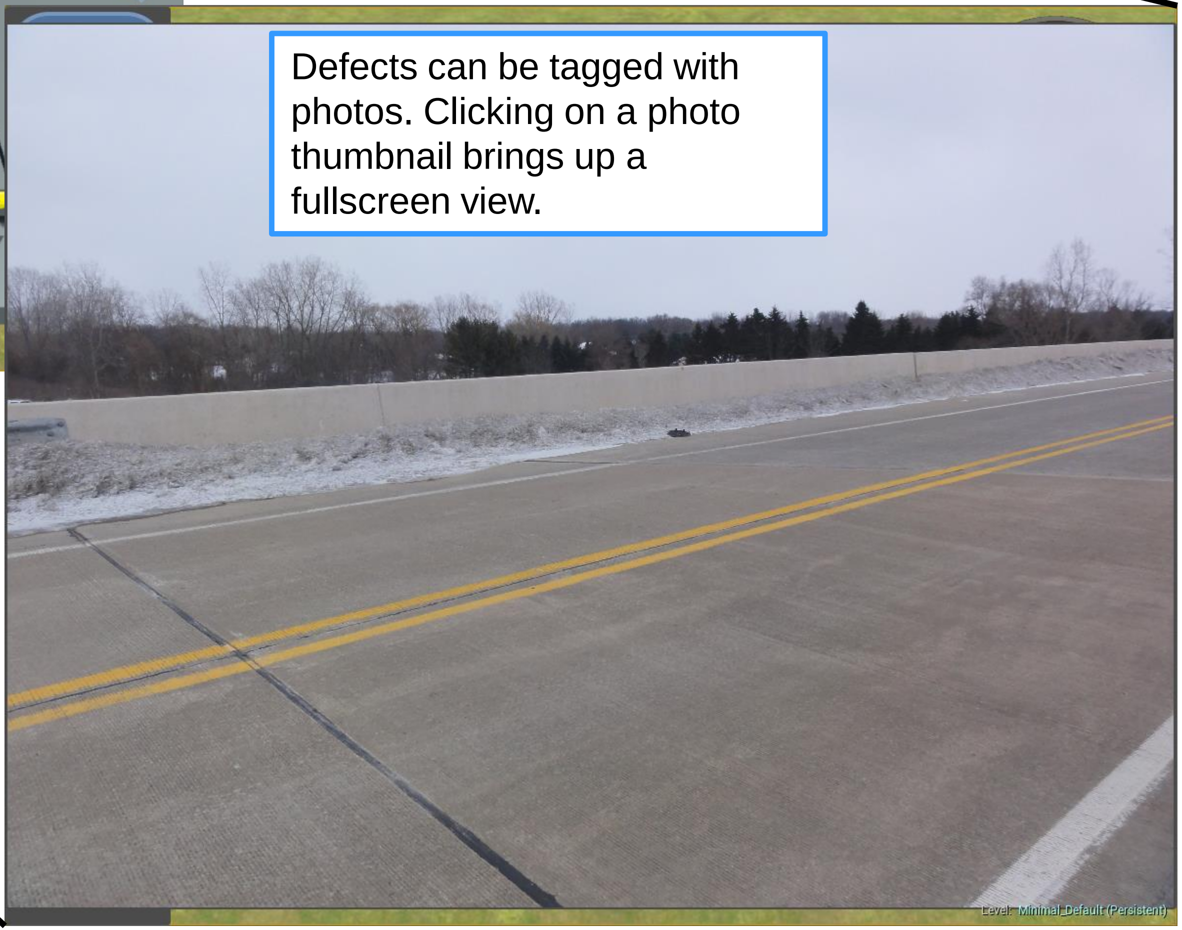


- Each individual defect can be annotated with a description, photos, and quantity.

Fields will be pre-populated with the db values from most recent inspection in future.

Context-sensitive descriptions are attached to each element type, just as in the "Bridge Element Inspection Manual"

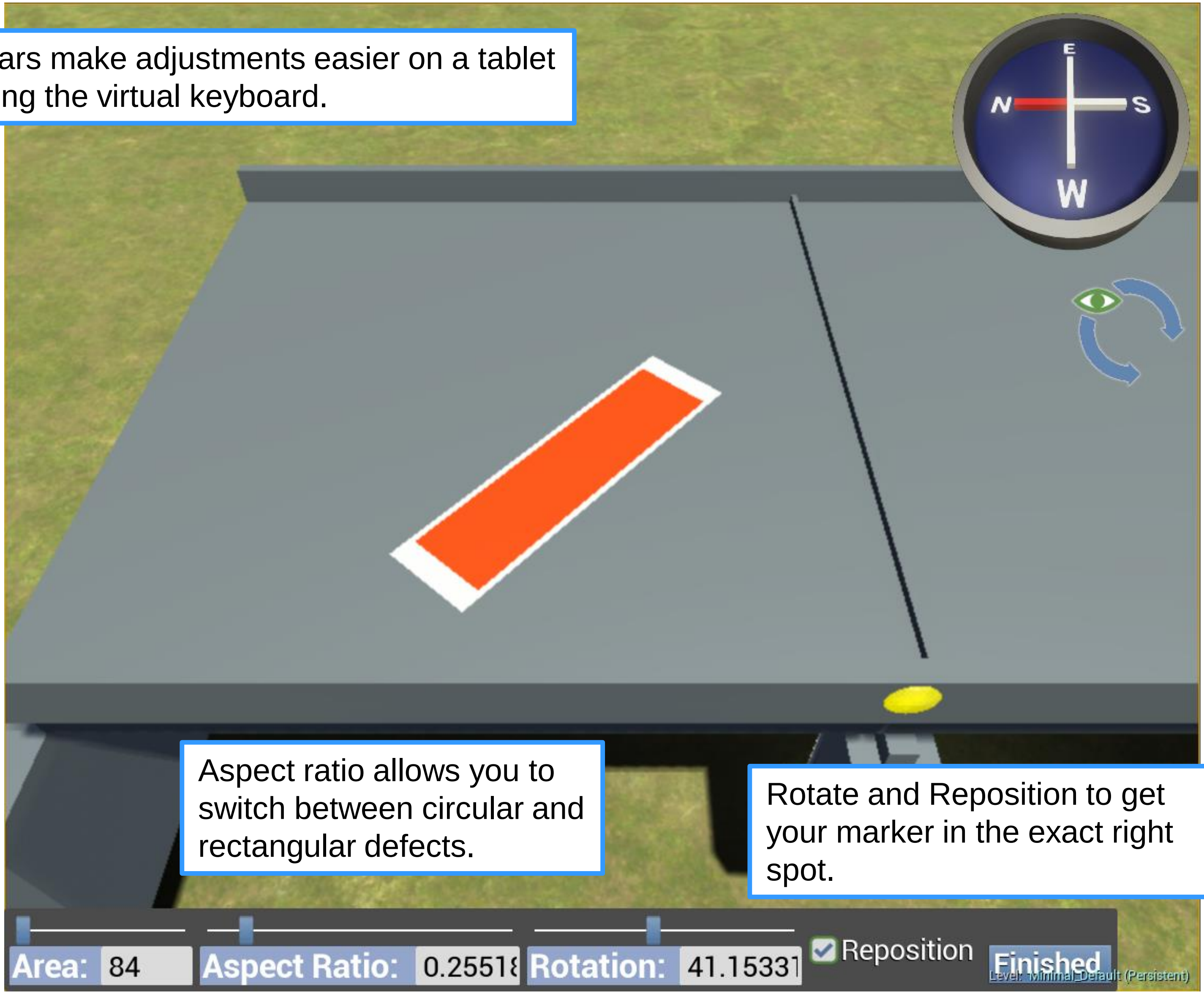
View Photos of the Desired Defect



Defects can be tagged with photos. Clicking on a photo thumbnail brings up a fullscreen view.

Customize the Defect's Size and Shape

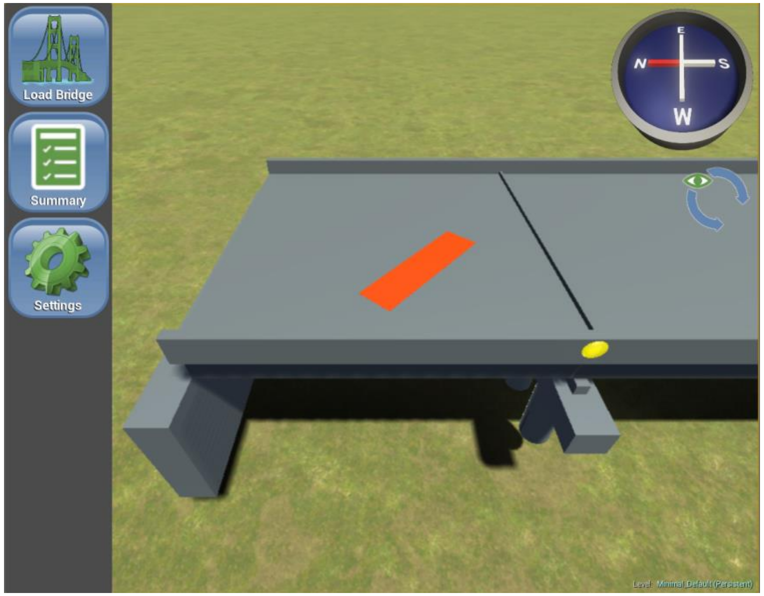
Slider bars make adjustments easier on a tablet than using the virtual keyboard.

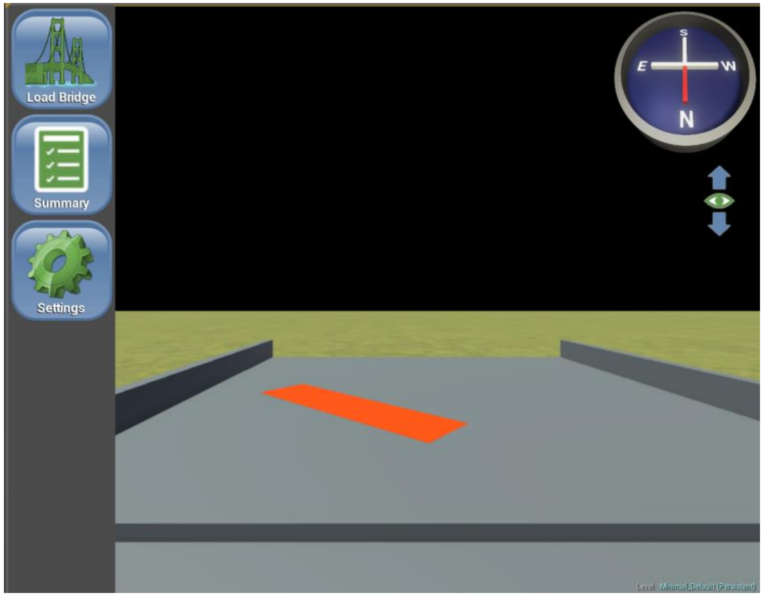


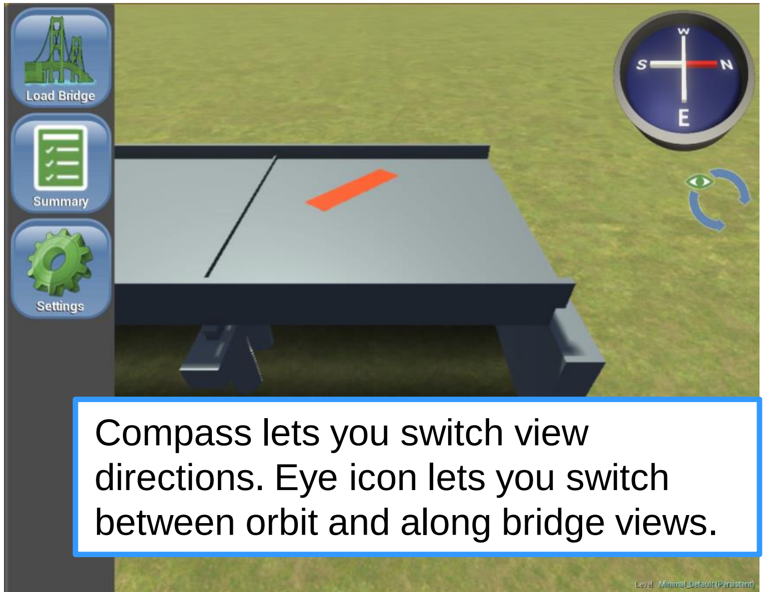
Aspect ratio allows you to switch between circular and rectangular defects.

Rotate and Reposition to get your marker in the exact right spot.

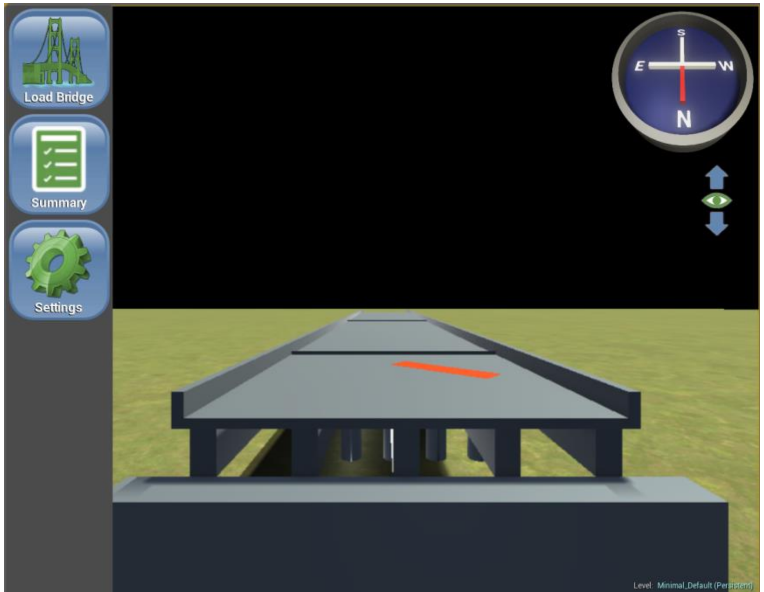
Saves the Defect's 3D Position For Future Inspections







Compass lets you switch view directions. Eye icon lets you switch between orbit and along bridge views.

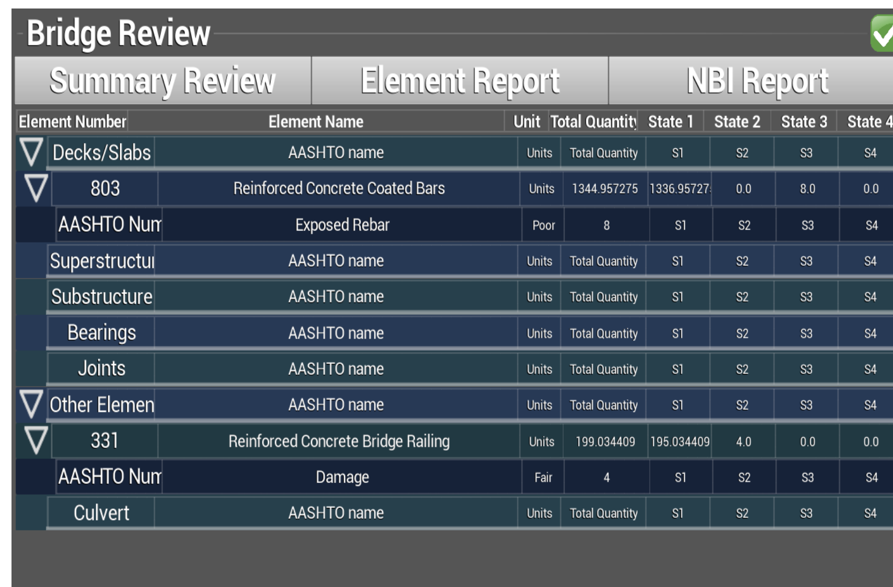


View Different Summaries of the Recorded Data

- Display and summarize the bridge inspection data with different views.

Bridge Review

AASHTO Element Level Data View



The Application is Cross-Platform

- The 3D BRIDGE app is compatible with Windows and Android, and is currently being developed for iOS.

The Future of Bridge Inspections

- 3D BRIDGE app is a key component towards the future goal of utilizing 3D models to monitor and review a bridge throughout its lifetime.

Evaluation of Bridge Decks using NDE at Near Highway Speeds for Effective Asset Management – *in progress*

(Supplemental Work – OR10-043)

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Subcontractor Jennifer Julien, GS Infrastructure
906-483-2670 x 303; Jennifer.Julien@gsinfrastructure.com

www.mtri.org

Project Objectives

- Demonstrate the capabilities of combined thermal and optical imaging at near highway speeds for condition assessment of large deck bridges.

- Demonstrate the accuracy of 3DOBS optical imaging for assessment of spalls and cracking on bridge decks.
  "*3-D Optical Bridge-evaluation System*"

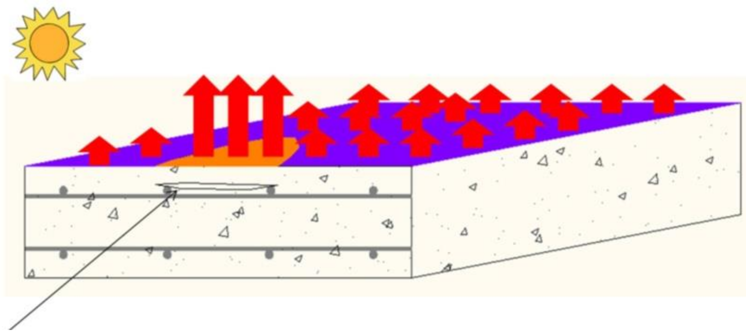
Tasks

1. Prep and Data Collection for Large Bridge Decks
2. Data Processing and Condition Assessment
3. Accuracy Assessment for 3DOBS optical imaging
4. Impacting Technology Transfer
5. Final Reporting

3DOBS Highway Speed Spall Detection

- Red-EPIC camera system
- 13.8 MP up to 60 frames per second
- $30,000 for the camera and its components

Passive IR Thermography (GS Infrastructure)

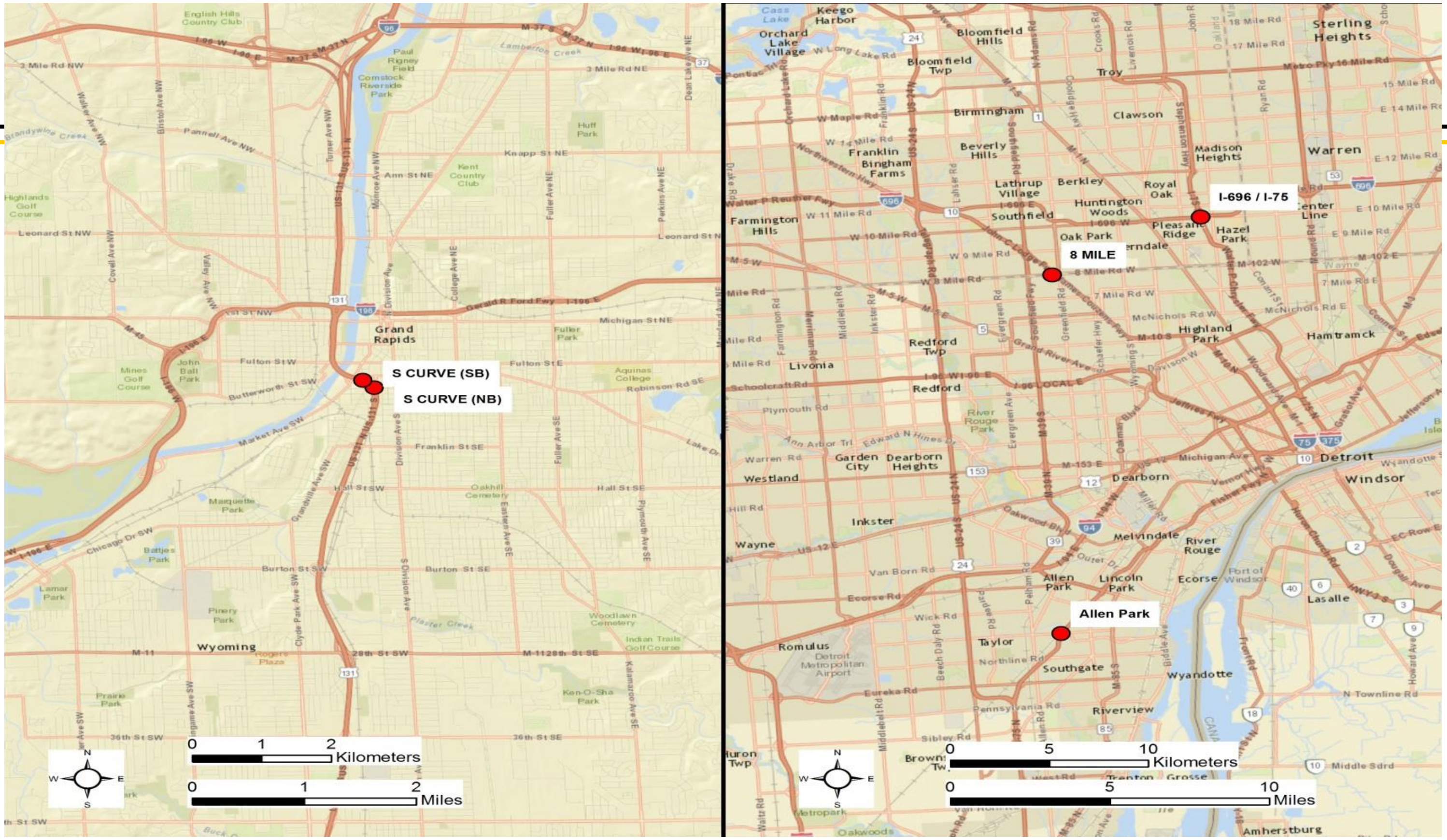


Delamination

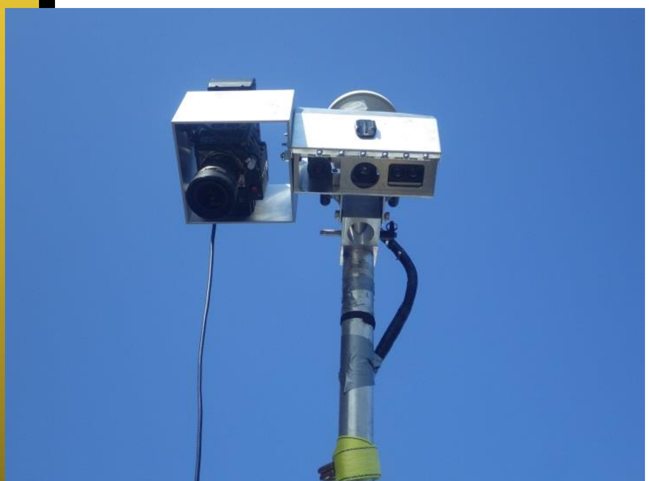
- Sun provides thermal impulse
- Heat transfers from surface to concrete interior
- Delaminations restrict heat transfer and appear as hot spots on thermal images during daytime hours
- Maximum contrast occurs during specific testing time window

BVRCS

- Low cost (<$1,000) deployable system that provides visual analysis of bridge deck conditions at the time of data collection.
  - "Bridge Viewer Remote Camera System"
- Consists of two GoPro Hero3 cameras that can be mounted to any vehicle and used at multiple sites without any additional costs.
- Images are processed and geotagged through GeoJot+ Core
- Hyperlinks are set up using both ArcMap and GeoJot+ Core capabilities allowing for visualization of the condition of the bridge deck at defined locations



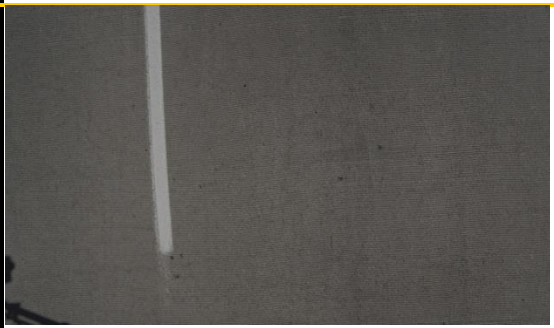
- Collection Locations: (Fall 2015)
  - 8-Mile (M-102)
  - US-131 (NB and SB)
  - I-75 (NB and SB)
  - I-696

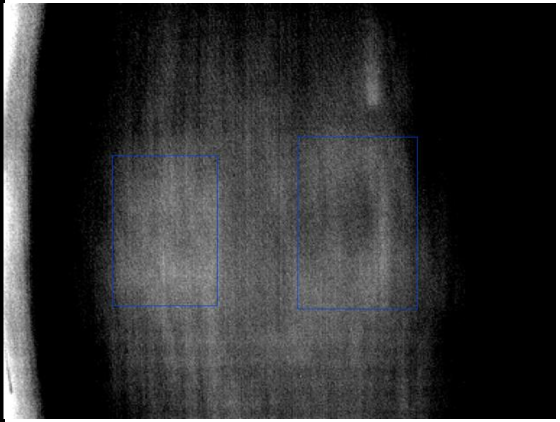


Fieldwork

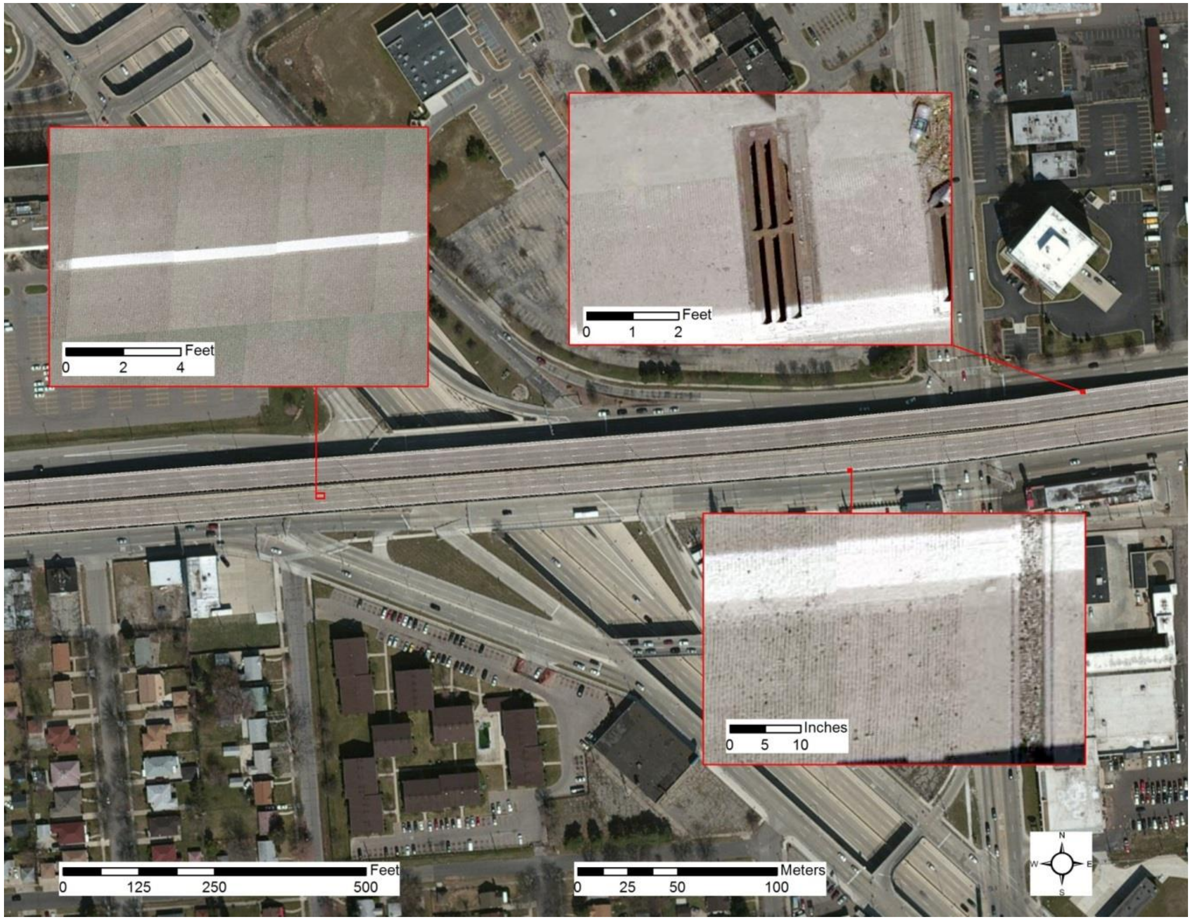
- Data collected using GS Infrastructure's vehicle with attached Red Epic optical sensor, thermal sensor, and GoPro cameras.
- Shadow vehicles (provided by MDOT) were used at the I-75 and I-696 locations to help provide traffic control and to keep vehicles from interfering with data collection.
- MDOT Individual Construction Permits for Operations within State Highway Right-of-Way were requested and granted for each bridge.

8 Mile

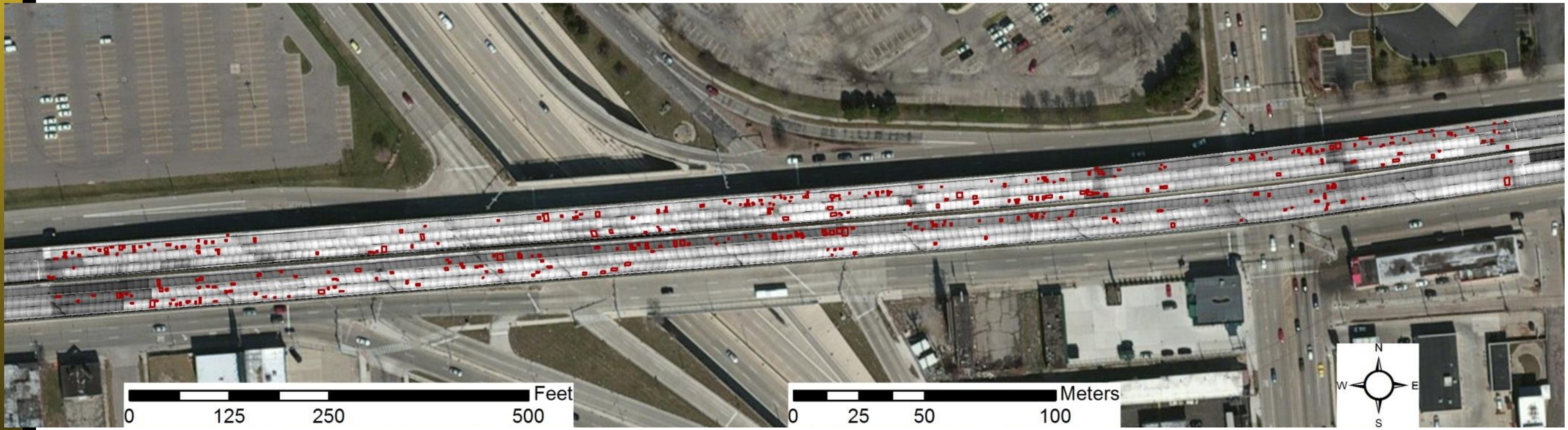




- Data collected on September 14, 2015



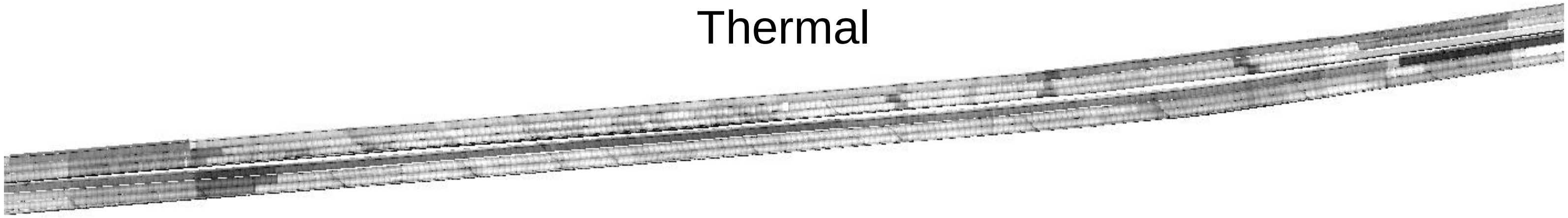
8-Mile Thermal Mosaic



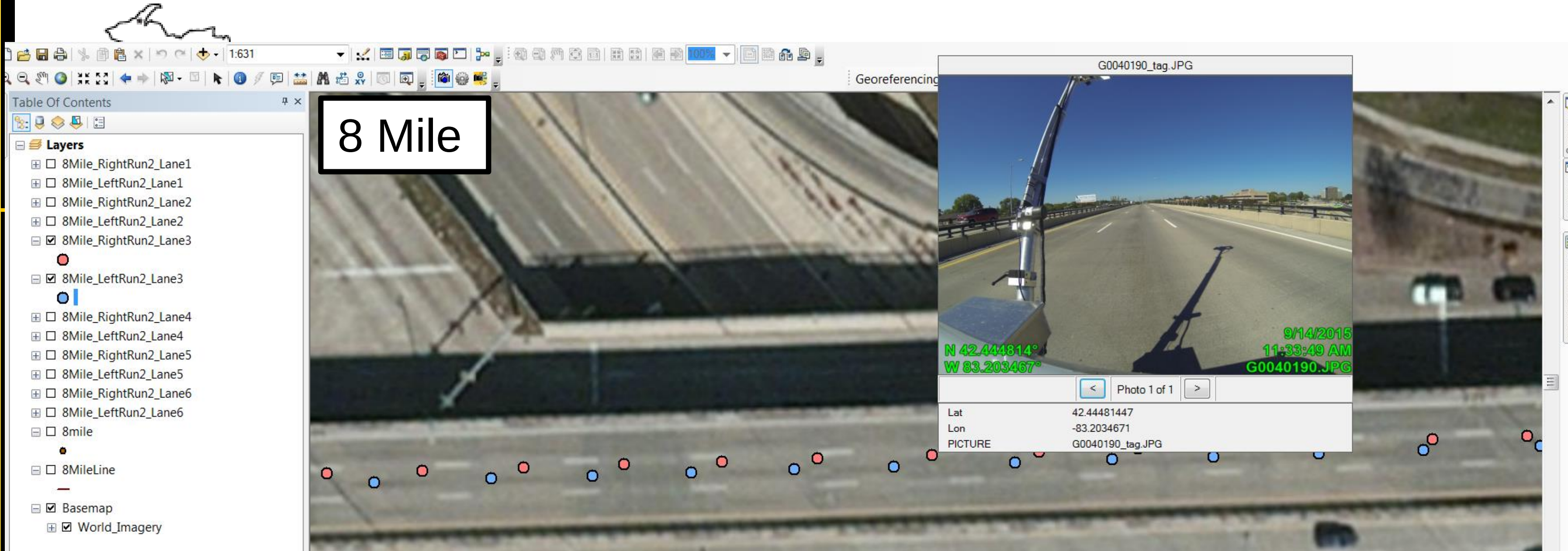
8 Mile Datasets

Orthoimage

Thermal



Delaminations


8 Mile
1:631
Georeferencing
Table Of Contents
Layers
8Mile_RightRun2_Lane1
8Mile_LeftRun2_Lane1
8Mile_RightRun2_Lane2
8Mile_LeftRun2_Lane2
8Mile_RightRun2_Lane3
8Mile_LeftRun2_Lane3
8Mile_RightRun2_Lane4
8Mile_LeftRun2_Lane4
8Mile_RightRun2_Lane5
8Mile_LeftRun2_Lane5
8Mile_RightRun2_Lane6
8Mile_LeftRun2_Lane6
8mile
8MileLine
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World_Imagery
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W 83.203467°
9/14/2015
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G0040190.JPG
Photo 1 of 1
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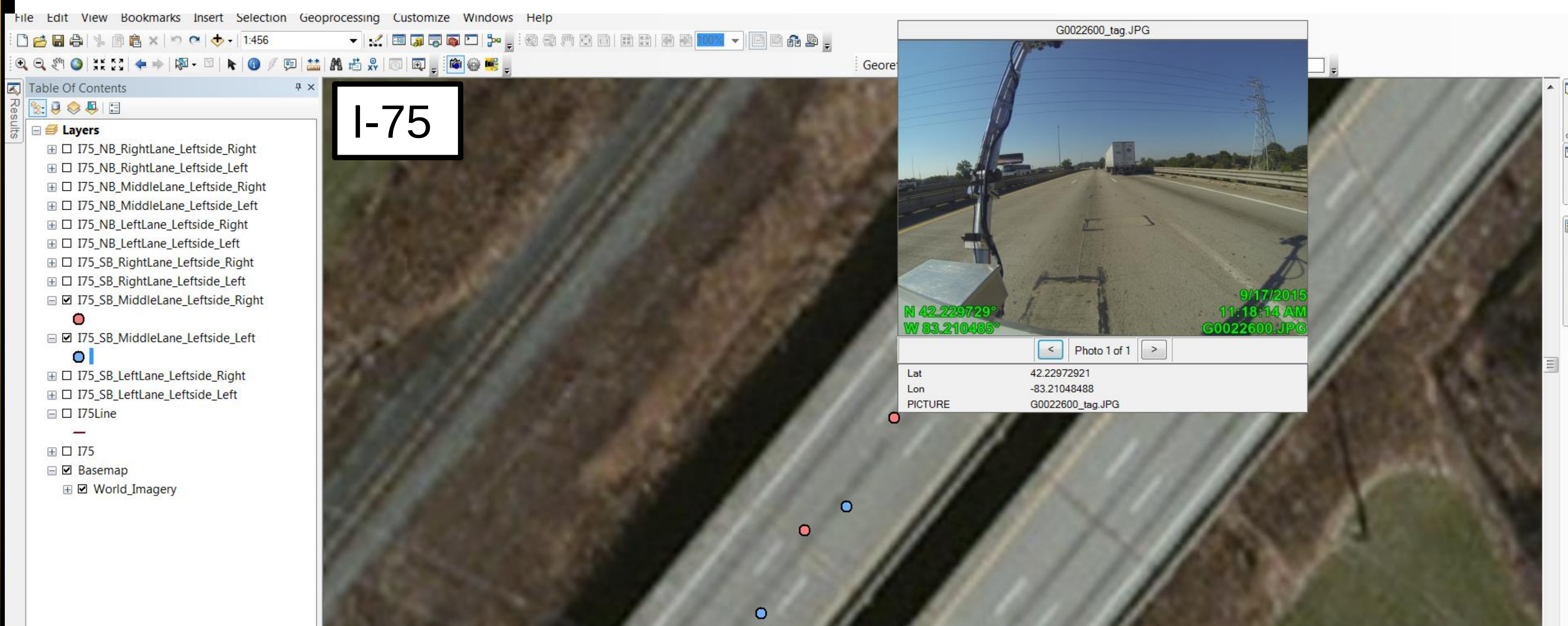
Lon -83.2034671
PICTURE G0040190_tag.JPG
Catalog
Search
Create Features


I-75
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:456
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Results
Layers
I75_NB_RightLane_Leftside_Right
I75_NB_RightLane_Leftside_Left
I75_NB_MiddleLane_Leftside_Right
I75_NB_MiddleLane_Leftside_Left
I75_NB_LeftLane_Leftside_Right
I75_NB_LeftLane_Leftside_Left
I75_SB_RightLane_Leftside_Right
I75_SB_RightLane_Leftside_Left
I75_SB_MiddleLane_Leftside_Right
I75_SB_MiddleLane_Leftside_Left
I75_SB_LeftLane_Leftside_Right
I75_SB_LeftLane_Leftside_Left
I75Line
I75
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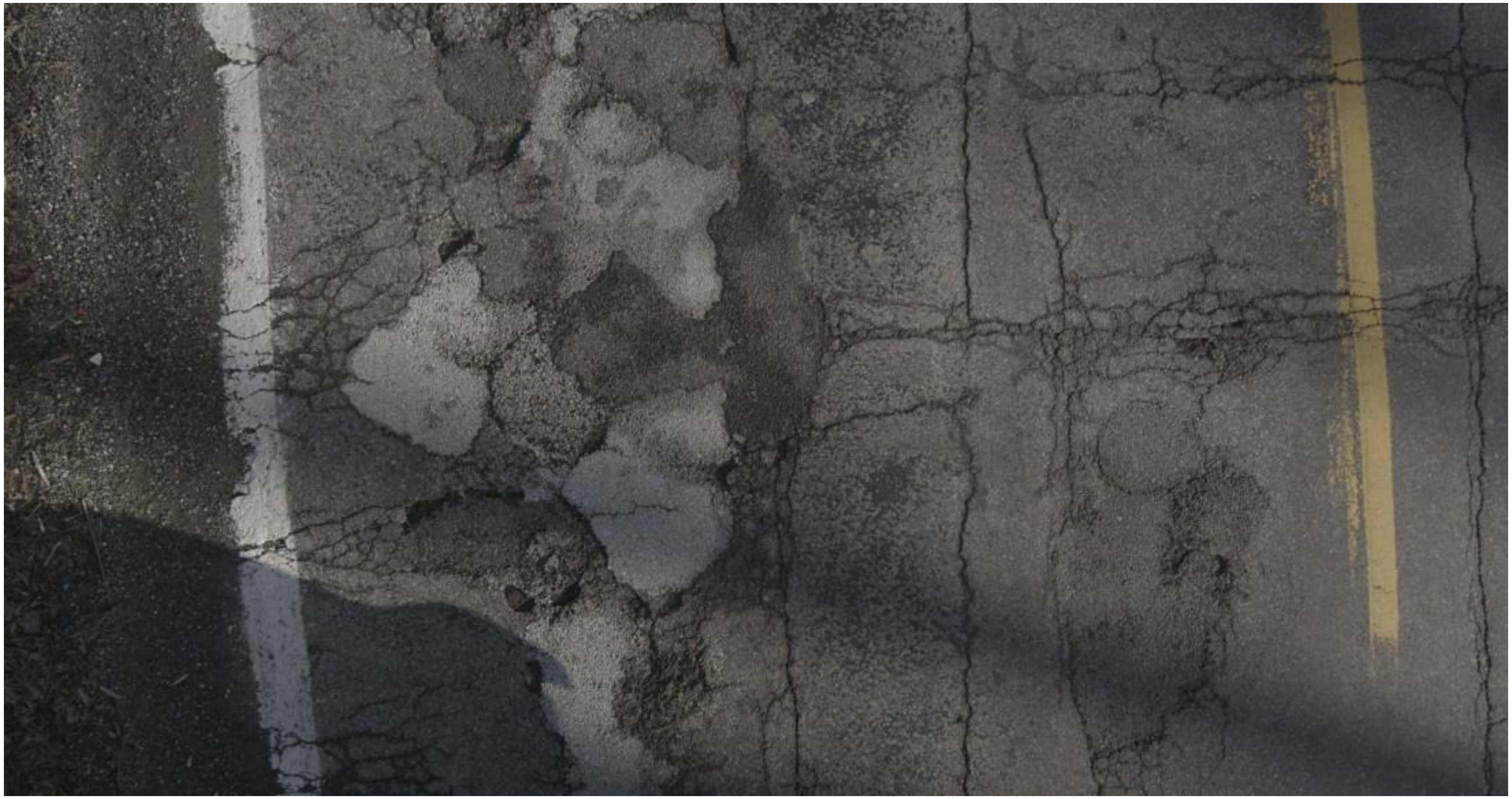
G0022600.JPG
Photo 1 of 1
Lat 42.22972921
Lon -83.21048488
PICTURE G0022600_tag.JPG
Catalog
Search
Create Features

3DOBS assessment

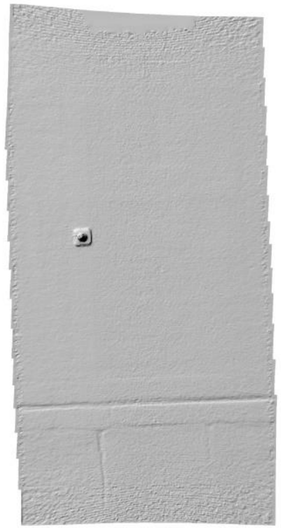
- Frame from RED Epic over Shield Rd. bridge
- Assessing accuracy of pothole detection, depth



High-resolution 3D reconstruction; next steps

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

- Final report in progress, including implementation plan (April 2016)
  - Defining when combined thermal + optical tools are of greatest value to MDOT operations & management

MichiganTech Research Institute

Implementation of the Aerial Unpaved Roads Assessment (AURA) System

Colin N. Brooks, Michigan Tech Research Institute

cnbrooks@mtu.edu 734-604-4196

Rick Dobson, Chris Roussi, Tim Colling, Joe Garbarino, David Dean, David Banach, Valerie Lefler, Brian White

P16-1275

Sensing Technologies for Transportation Applications workshop (160)

Sunday, Jan. 10th, 2016

igd integrated global dimensions See your work change the world

WOOLPERT DESIGN | GEOSPATIAL | INFRASTRUCTURE

Center for Technology & Training

MichiganTech Research Institute

www.mtri.org

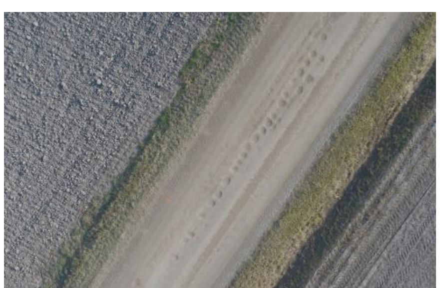
Transportation Asset Management Council MI Transportation Reporting Portal

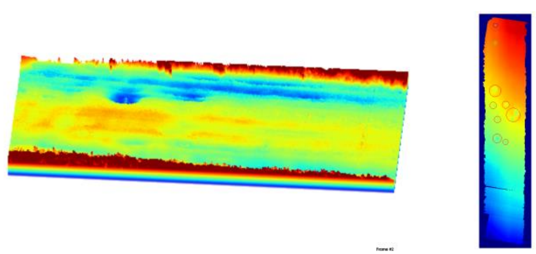
ROAD COMMISSION for OAKLAND COUNTY

SEMCOG Southeast Michigan Council of Governments

Project team

- Michigan Tech Research Institute (MTRI team – Colin Brooks, Rick Dobson)
- Michigan Tech Center for Technology & Training (CTT – Dr. Tim Colling)
- Integrated Global Dimensions (Valerie Lefler)
- Also working with Woolpert Inc., U. of Vermont
- www.mtri.org/unpaved and www.auramtri.com

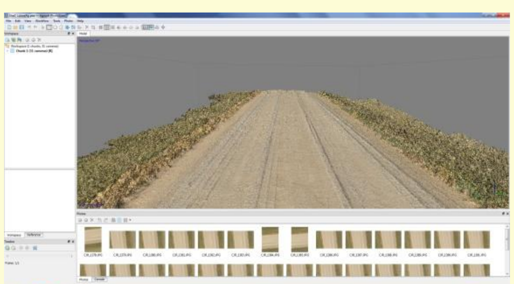


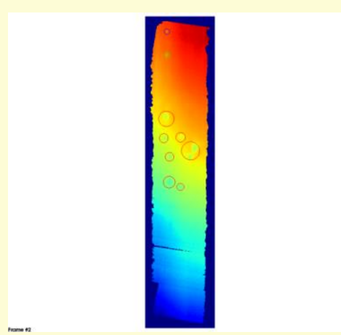


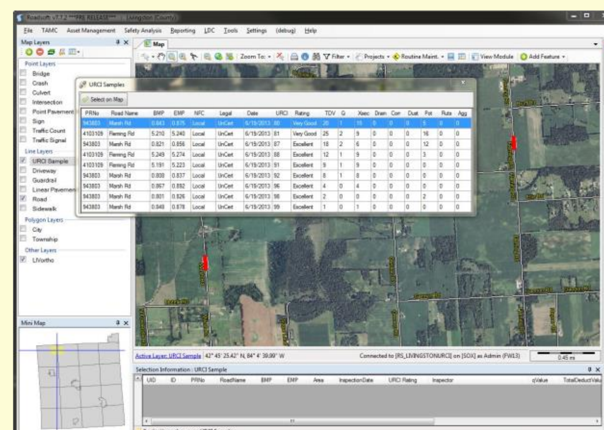
Aerial Unpaved Road Assessment system

RESEARCH GOAL

AURA™
Aerial Unpaved Road Assessment system



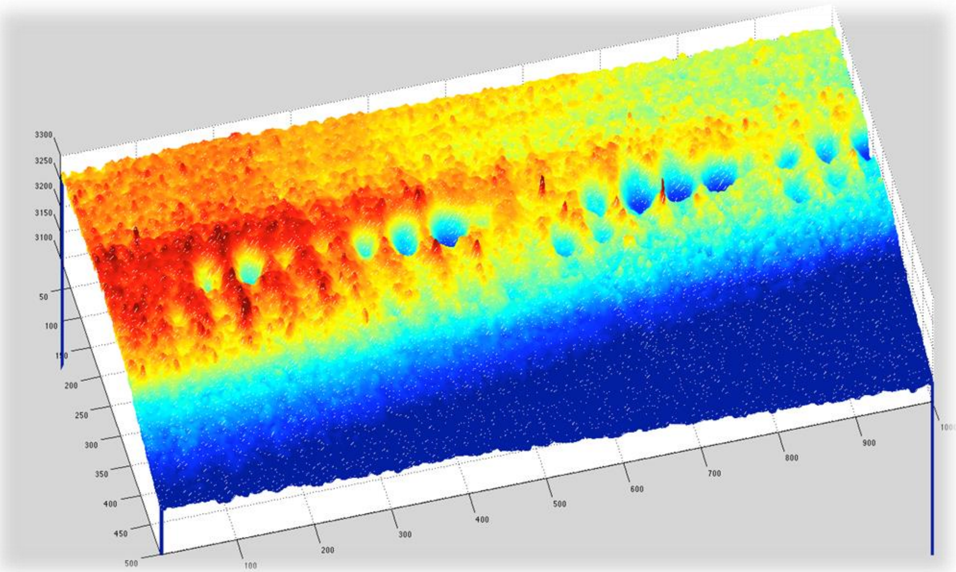




Project Goal: develop an unpaved road assessment system

Phase 1 summary: *enhance and develop an unpaved road assessment system*

Phase 2 summary: *a commercially-available, implemented system available to transportation agencies*



Funded by USDOT Commercial Remote Sensing and Spatial Information Program, Project #: RITARS-11-H-MTU1

Road Distresses

Float Aggregate

Washboard

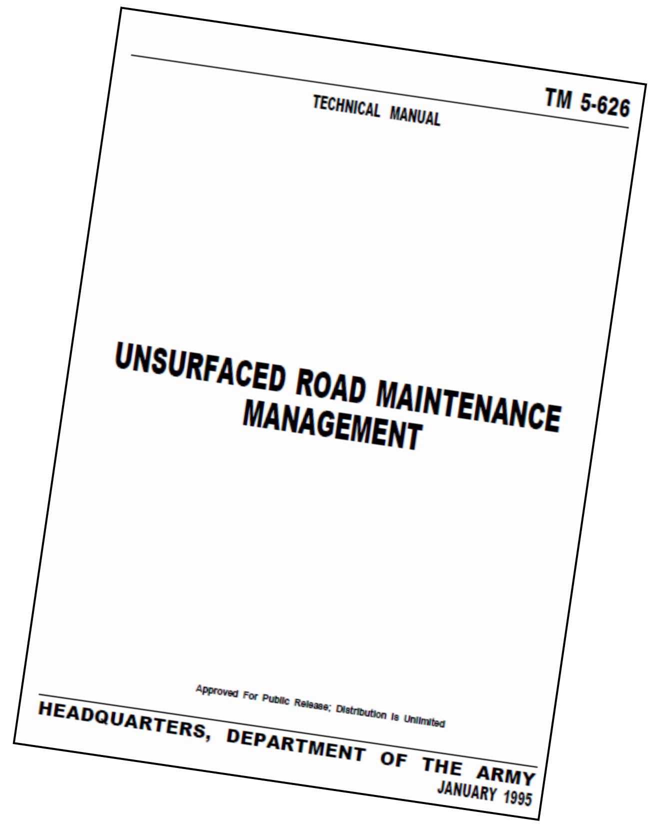
URCI	RATING
100–85	Excellent
85–70	Very Good
70–55	Good
55–40	Fair
40–25	Poor
25–10	Very Poor
10–0	Failed

Potholes

Ruts

Combined Methods: Dept. Army Unsurfaced Road Condition Index (URCI)

- Representative Sample Segments
- 2 Part Rating System
  - **Density**
    - Percentage of the Sample Area
  - **Severity**
    - Low, Medium, High
- Clear Set of Measurement Requirements
- Realistic Possibility of Collecting Most of the Condition Indicator Parameters
- Potential Applicability to a Wide Variety of U.S. Unpaved Roads
- Endorsed by TAC as Effective Rating System


TECHNICAL MANUAL TM 5-626

UNSURFACED ROAD MAINTENANCE MANAGEMENT

Approved For Public Release; Distribution Is Unlimited

HEADQUARTERS, DEPARTMENT OF THE ARMY
JANUARY 1995

Equipment Platforms

- **Bergen Hexacopter – our “workhorse” platform**
  - Total flight time: up to 20 minutes with small payloads
  - Weight: 4kg unloaded
  - Maximum Payload: 5kg
  - $5400 as configured, made in USA (http://www.bergenrc.com/)
  - Includes autopilot system, stabilized mount that is independent of platform movement, and first person viewer system (altitude, speed, battery life, etc.)
- **Nikon D800 36 mp DSLR, our main camera** ($3800 with 50mm prime lense)
  - Also testing Sony α7R, same resolution/cost, ½ the weight

Fixed-wing UAV options – ongoing evaluation

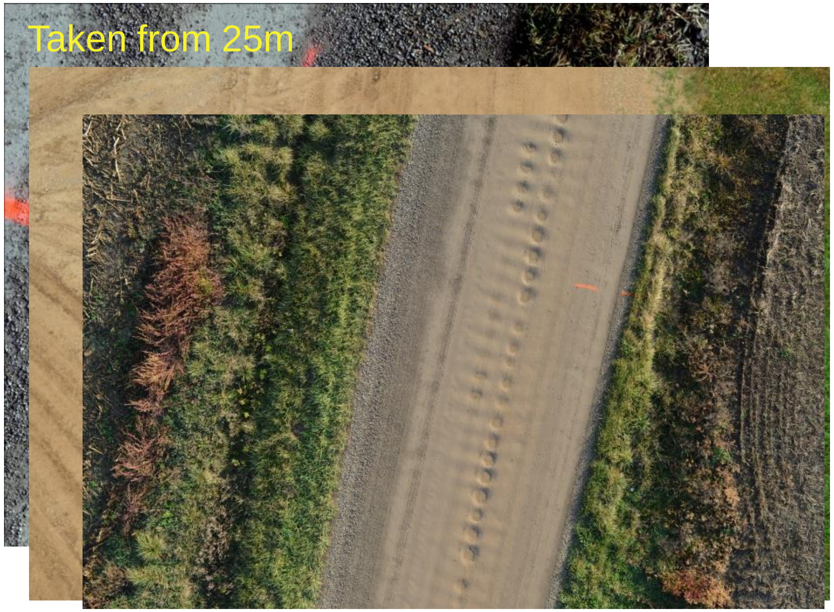
- Can fly for longer, further, but carries a lighter payload (lower resolution 18mp point & shoot camera vs. 36mp DSLR) – different systems can be right for different needs
  - Partnering with Dr. Jarlath O'Neil-Dunne, Univ. Vermont, also funded by USDOT
- Currently evaluating the tradeoffs of flight time vs. resolution

Sensefly eBee system – RTK GPS version, 40 min flight time - $51k

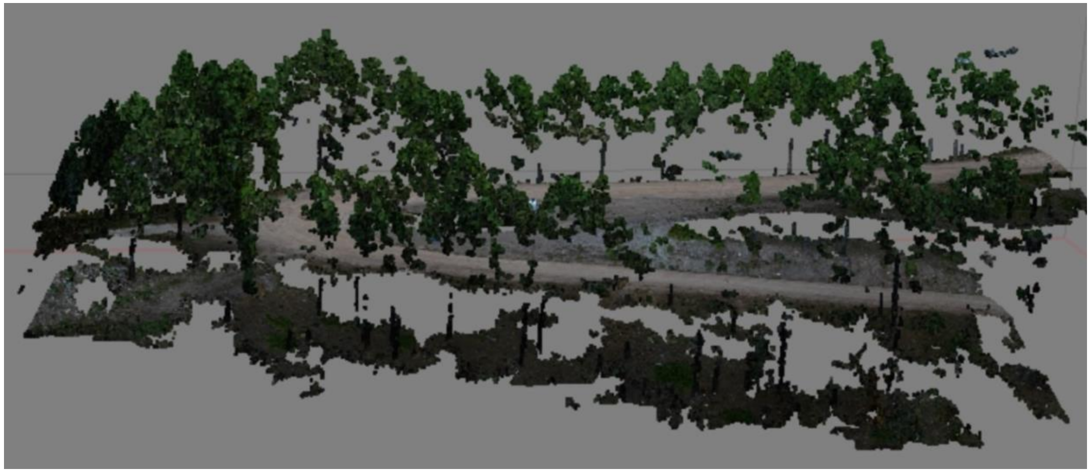
MTRI fixed wing tests, Oct. 2014

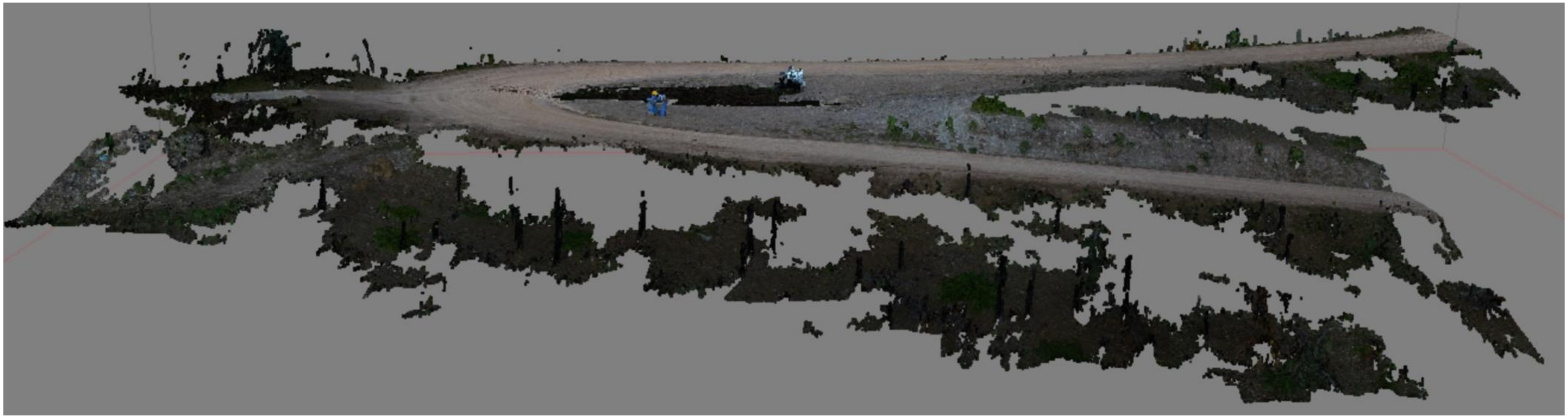
Orthoimage from Sensefly eBee system

Collected Imagery, 3D Reconstruction using close-range photogrammetry (SfM)



Stratobowl: success in area with trees



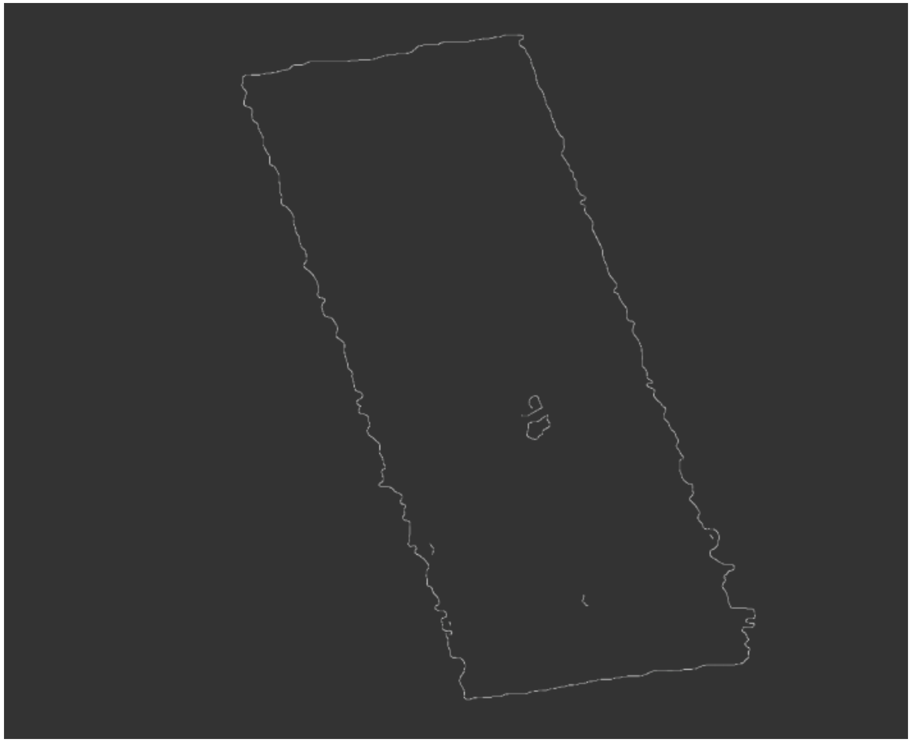


Automated Distress Detection example: Potholes (Remote Sensing Processing System)

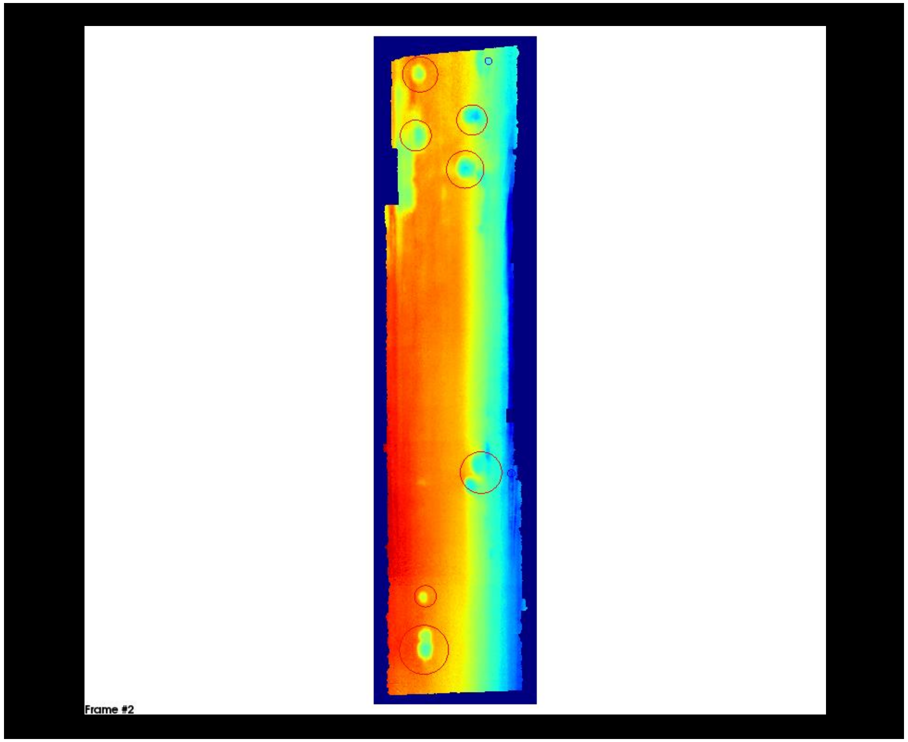
- Canny Edge Detection Used to Locate Edges
- Hough Circle Transform is Used to Locate Potholes
- Detected 96% of potholes

- AURA RSPS also automatically analyzes:
  - Washboarding / corrugation
  - Ruts / aggegrate berms
  - Crown % (sufficient crown)

Edge Detection

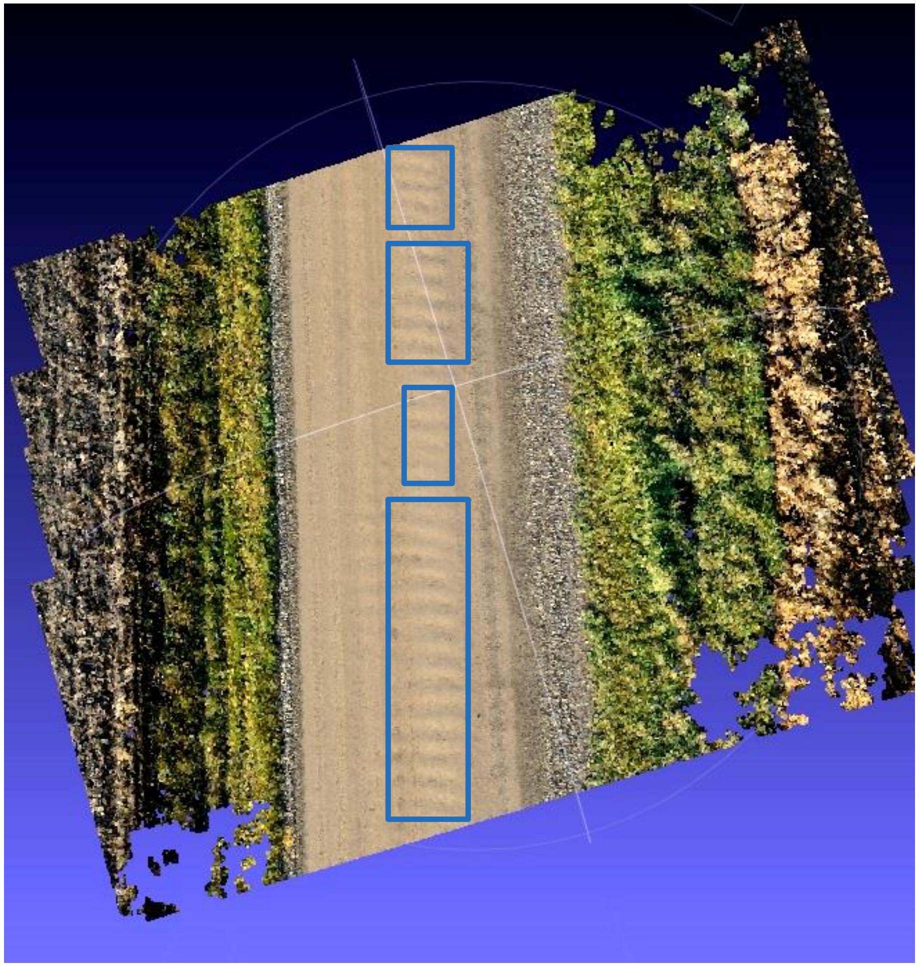


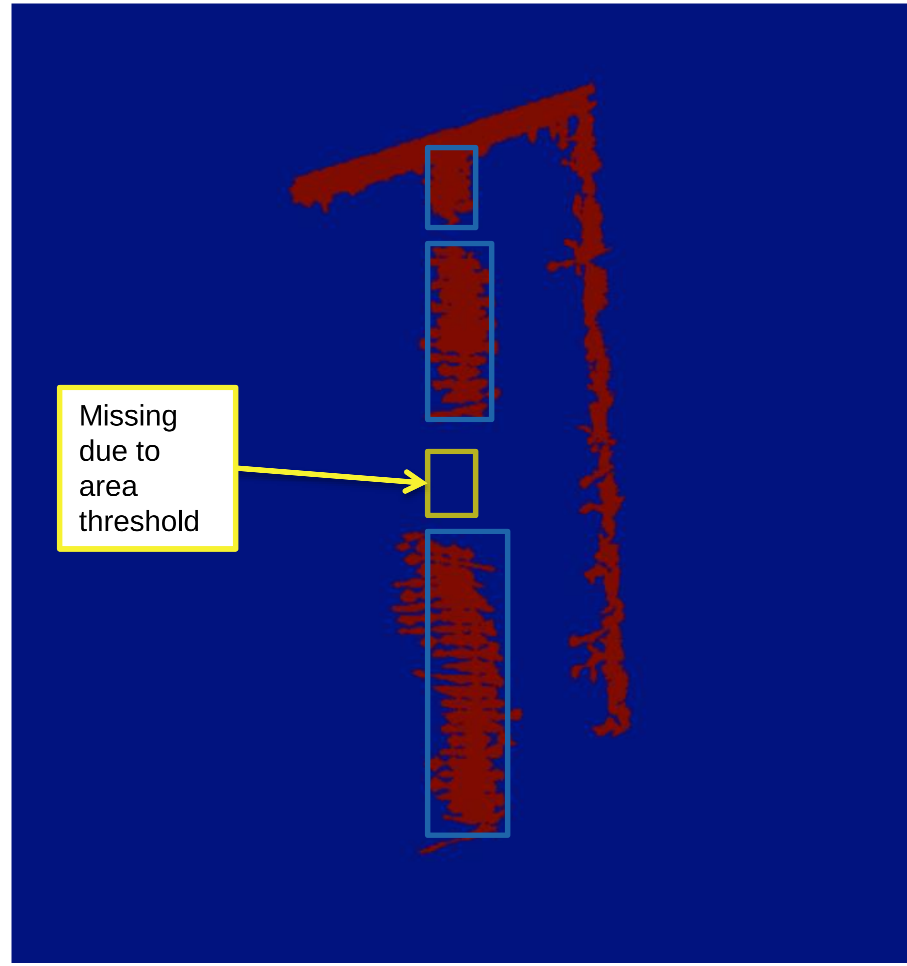
Identified Circles



Note: circles near edges ignored.

Distress Detection – Washboarding

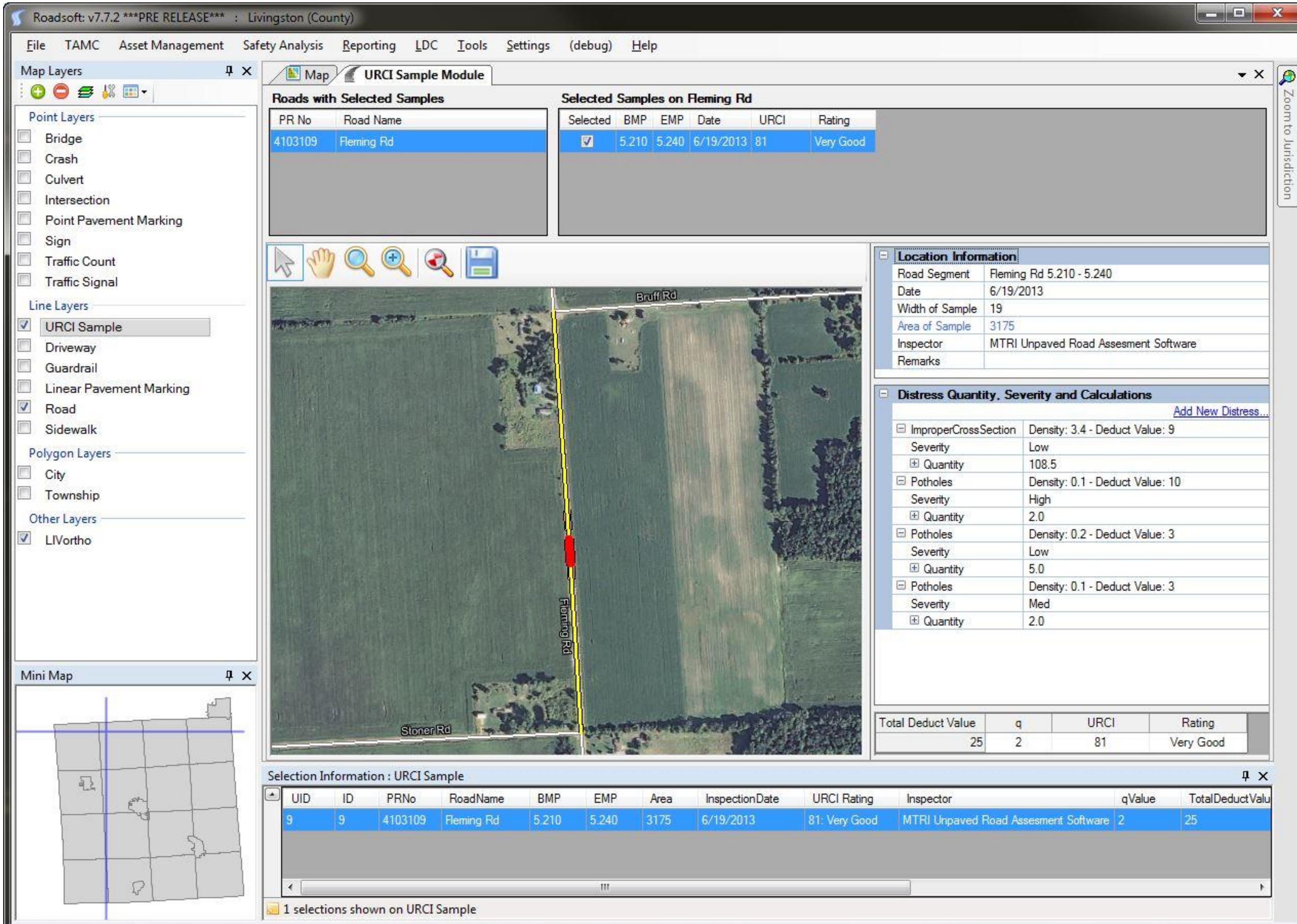




Ground Truth Corrugation Area: 19.6 sq. m

Computed Corrugation Area: 17.2 sq. m

Analyzed Data Integrated into RoadSoft GIS Decision Support System



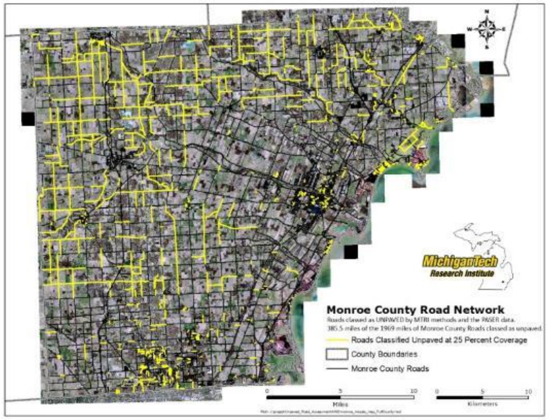
Cost comparison

Rating Method	$/sample segment	$/Mile
Wyoming Manual URCI (Huntington 2013)	$80	$160*
Manual URCI Ground Truth Collection moderate distress	$100	$200*
Manual URCI Ground Truth Collection high distress	$140	$280*
Army Cold Regions Automated PCI (Cline et al. 2003)	$34.23	$66.10
Army Cold Regions Manual PCI – low total area (Cline et al. 2003)	$50.84	$101.68
UNH/FHWA: RSMS – high productivity estimate (Goodspeed 2011 2013)	NA	$33.65
UNH/FHWA: RSMS – low productivity estimate (Goodspeed 2011 2013)	NA	$65.65
Wyoming Modifications of the PASER Method (Huntington 2011 2013)	NA	$8.55
Michigan PASER Method (CRAM MDOT n.d.)	NA	$8.05

- **UAV, high-resolution camera, and good-quality lens:**
  - Cost per mile rated $30,590/yr/1575 mi/yr = $19.42/mi rated.
  - HOWEVER…two 100-foot measured segments represent one mile of road, so 5,280 ft/200ft is 26.4. Therefore each mile of measured road represents a road network 26 times larger.
  - Therefore cost is **$<u>0.74 per mile</u>,** in addition to the cost of vehicle use ($0.55/mi)
    - 8 hours/day, 3 days/week, 21 week season to collect 300 road-miles of data segments

Inventory: Surface Type
Where are the unpaved roads?

- Original question: How many miles of unpaved road are there? Not all areas have this!
  - c. 43,000 miles in MI (old 1984 estimate) – need up-to-date inventory
- Methods: Extract using object-based classification from recent, high-resolution aerial imagery (4-band, color + NIR, 2’)
  - Add paved vs. unpaved roads attribute to existing GIS layer
- Completed 7 counties, Counties; shared with SEMCOG, added to RoadSoft GIS asset management tool, used by local county (St. Clair)
  - 87%-94% accuracy (upcoming paper)
  - Ex: Livingston Co.: 894 miles unpaved, 1289 miles paved
- ***2016 Phase II work: Demonstrating how we can now do rapid updating with the methods established in Phase I w/ 2015 PASER data, 2015 SEMCOG aerial imagery***
  - ***Peer-reviewed paper submitted to ASPRS Photogrammetric Engineering & Remote Sensing (PE&RS) journal under revision, documenting methods***



Range testing: Collect data for longer sections of road

- FAA rules currently restrict UAV usage to within line of sight
- How far can we reasonably fly? (longer distance road collections)
- Tested Bergen hex along a 1-mile section of road, flying from the midpoint
- Could reliably see, control, receive FPV transmissions for hex at up to 2500’ feet (1/2 mile / 760 meters / 830 yards)

Michigan Tech Research Institute

All of these together – components of the AURA system!

- Aerial Unpaved Road Assessment (AURA) system

AURA

Aerial Unpaved Road Assessment system

- www.mtri.org/unpaved (project details site)
- www.auramtri.com (public outreach site)

Implementation – licensing inventions to commercialization companies

- AURA system:
  - 1 UAV services firm in S. Dakota interested in licensing, discussing implementation
  - 2 engineering firms in Dakotas interested in licensing
  - 1 international UAV services firm interested in licensing for South American market (starting in Brazil)
  - Woolpert Inc. working with gravel mining firms, others in Ohio – haul road monitoring (offer as part of their UAV services)
- Working through Michigan Tech Office of Innovation & Industry Engagement (Jim Baker, Executive Director)
- Looking for implementation partners in other parts of the country

Implementation outreach

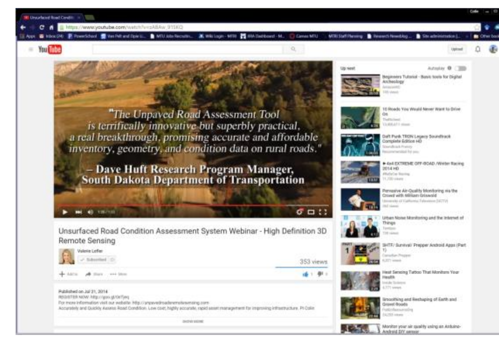
- "Get out of the office!" – 3 technical demo workshops
- Help from Valerie Lefler, IGD with professional outreach

October, 2015 Rapid City, SD demo: 30th Regional Local Roads Conference

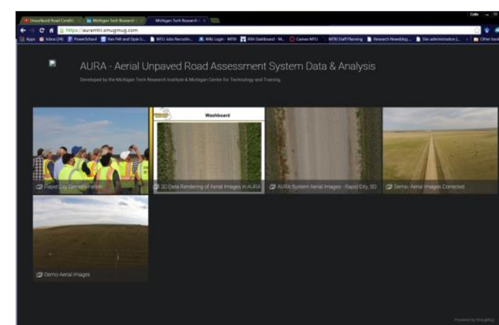
MichiganTech Research Institute

Extended Professional Outreach

- Popular press articles (*Civil Engineering magazine, Urban Transportation Monitor, ARTBA Transportation Builder*)
- Questionnaire for potential users (results from technical demos)
- YouTube video: https://www.youtube.com/watch?v=zABAw_91SKQ (also shared at 2nd OKC commercialization meeting)



- Slideshare: http://www.slideshare.net/MTRI-AURA - 355 presentation views
- Photo Site: https://auramtri.smugmug.com/ - 1,515 Photo Views from Sioux Falls, SD demonstration



- Helping with outreach to 3 companies in Dakotas interested in deploying / licensing AURA system (regular contact)

Applications of Unmanned Aerial Vehicles (UAVs) for Ecological Research

Colin N. Brooks
Senior Research Scientist, Environmental Sciences Lab Manager
BioSci PhD candidate
Michigan Tech Research Institute (MTRI),
A research center of Michigan Technological University
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734-604-4196 (cell)
www.mtri.org

Ice sensing – the view ahead

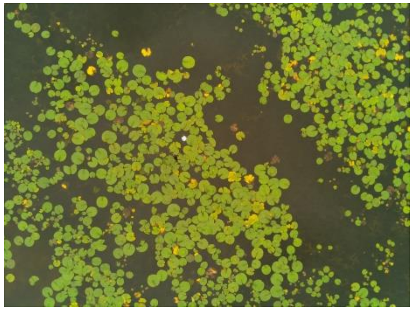
- NOAA GLERL, US Coast Guard

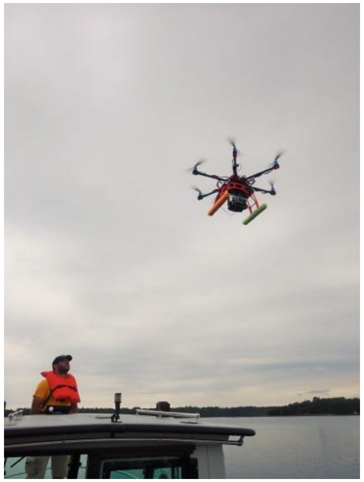
Application: Fieldwork Planning

- How difficult will an area be to access / survey for invasive plants?
- How is access for a mountainous site?
- Potential river / stream focus areas
- UAVs allow field analyst to look ahead 1000 ft.
- Testing “line of sight” flying – ½ mile to a mile
- Waterproof UAVs available <$2,000

Invasive Species Mapping

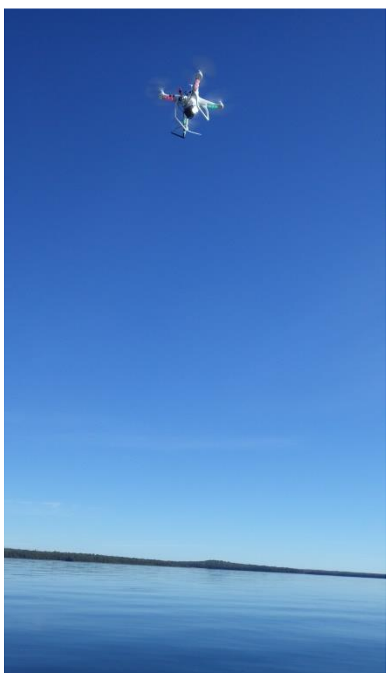
- Developed under a GLRI grant led by Dr. C. Huckins, being applied under MDNR grant, part of 2015 GLRI proposal
  - Torch Bay, Pike Bay, Les Cheneaux Islands
- Part of my PhD dissertation!

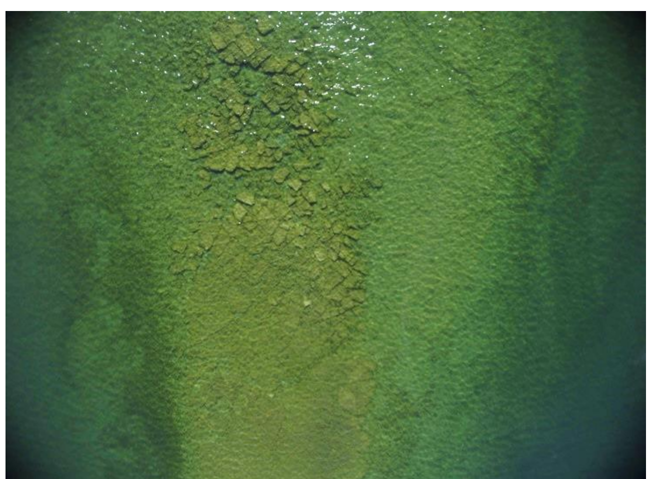


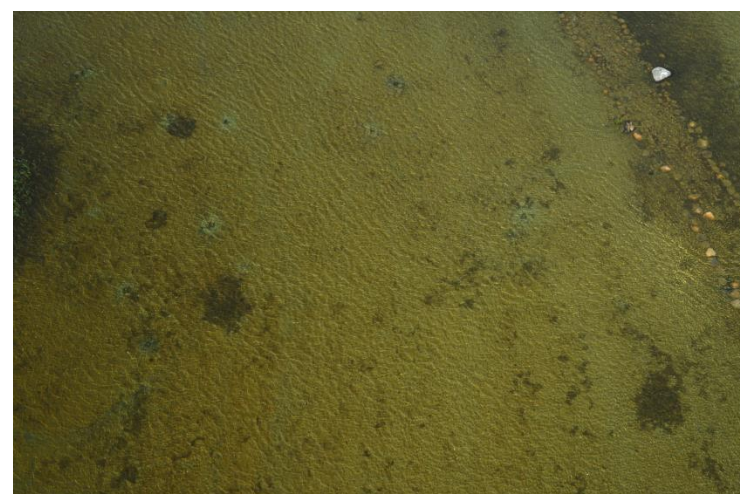


Lake Trout, Bass, Carp Spawning areas

- Flew over Lake Trout spawning habitat off of Drummond Island, Lake Huron, Sept. 2013
- Looking to map areas on reefs where Lake Trout spawn in late summer
- Higher resolution than available satellite imagery
- Bass, carp spawning redds Lake Huron in 2014, 2015 – can see them & spawning fish







UAV Imagery of Impacted Wetlands

- Alteration of flow pattern may cause flooding issues on one side of the road segment.

- Debris can clog culverts and alter the flow of water through the culvert system.

Contact Info

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