Applications of UAVs for transportation infrastructure assessment

Colin N. Brooks,
Senior Research Scientist
Environmental Sciences Lab Manager
Michigan Tech Research Institute (MTRI),
A research center of Michigan Technological University
cnbrooks@mtu.edu
734-913-6858 (desk)
734-604-4196 (cell)
www.mtri.org

MichiganTech Research Institute

Implementation of the Aerial Unpaved Roads Assessment (AURA) System

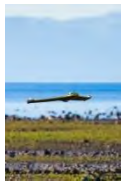
Colin N. Brooks, Michigan Tech Research Institute
cnbrooks@mtu.edu 734-604-4196
Rick Dobson, Chris Roussi, Tim Colling, Joe Garbarino, David Dean, David Banach, Valerie Lefler, Brian White

P16-1275
Sensing Technologies for Transportation Applications workshop (160)
Sunday, Jan. 10th, 2016

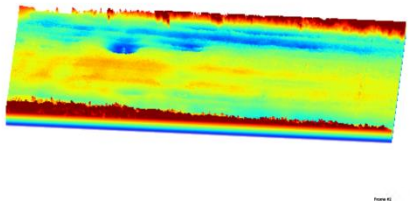
Center for Technology & Training

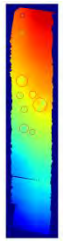
www.mtri.org

Project team



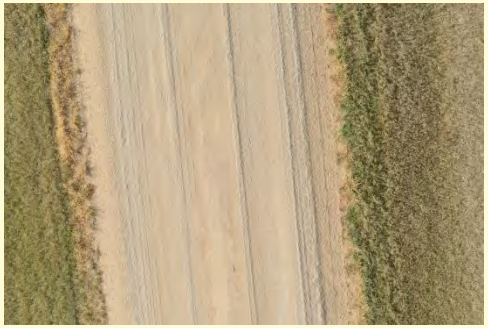
- Michigan Tech Research Institute (MTRI team – Colin Brooks, Rick Dobson)
- Michigan Tech Center for Technology & Training (CTT – Dr. Tim Colling)
- Integrated Global Dimensions (Valerie Lefler)
- Also working with Woolpert Inc., U. of Vermont
- www.mtri.org/unpaved and www.auramtri.com

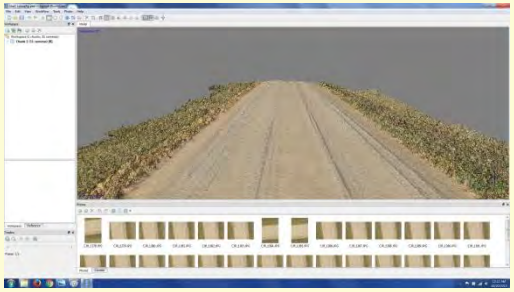


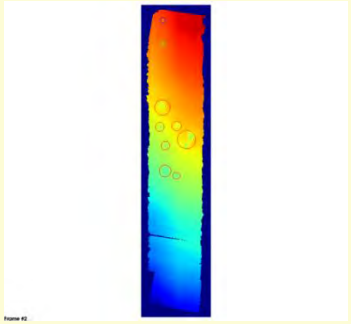


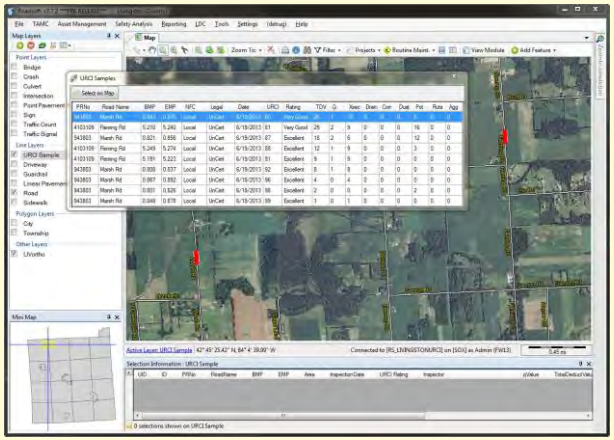
RESEARCH GOAL

AURA™
Aerial Unpaved Road Assessment system





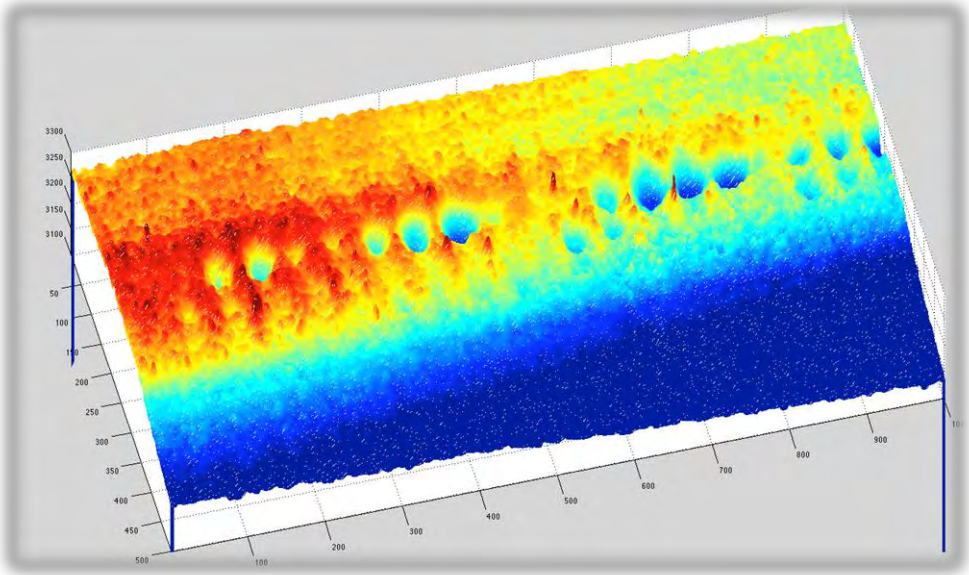




Project Goal: develop an unpaved road assessment system

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

DISCLAIMER: The views, opinions, findings and conclusions reflected in this presentation are the responsibility of the authors only and do not represent the official policy or position of the USDOT/OST-R, or any State or other entity.

Road Distresses

Float Aggregate

Potholes

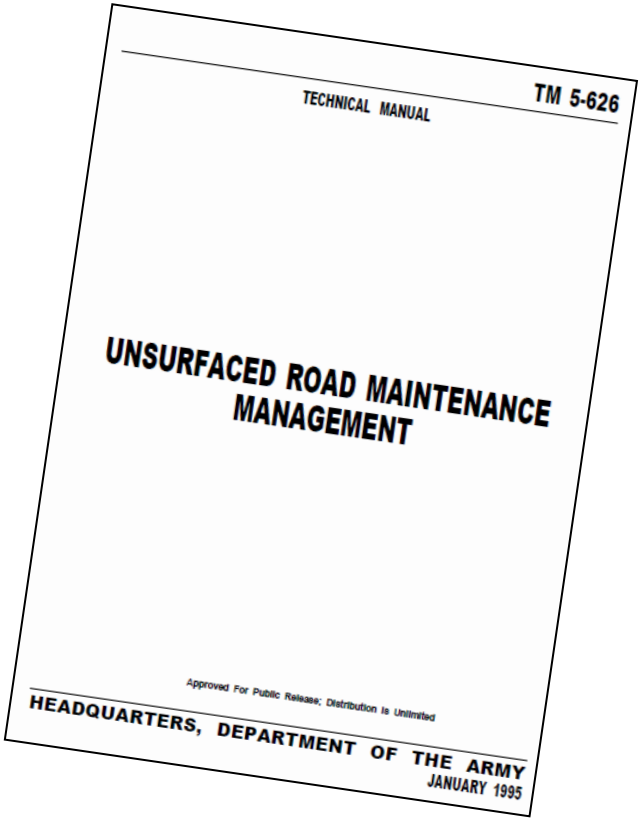
URCI	RATING
100	Excellent
85	Very Good
70	Good
55	Fair
40	Poor
25	Very Poor
10	Failed
0	

Washboard

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



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

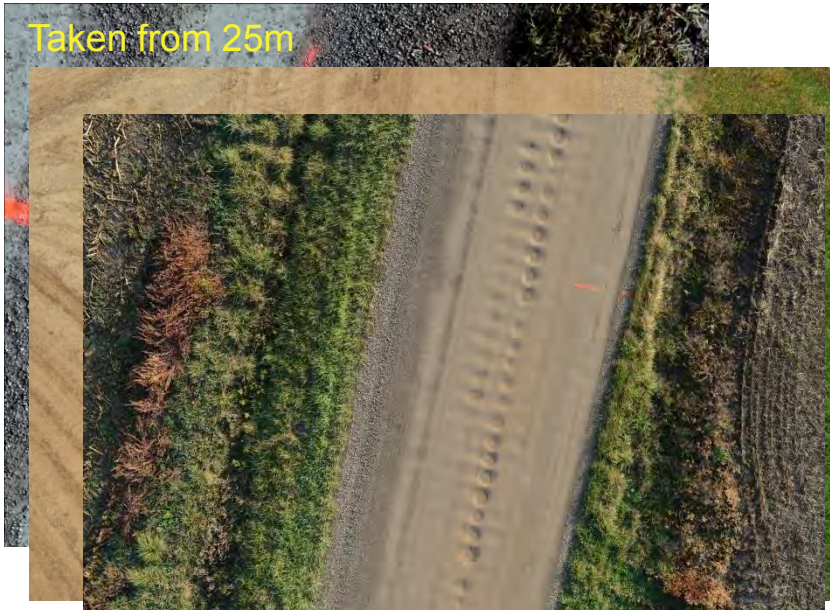
- Can fly for longer, further, but carries a lighter payload (lower resolution 18mp point & shoot camera vs. 36mp DSLR) – different systems can be right for different needs
  - Partnering with Dr. Jarlath O'Neil-Dunne, Univ. Vermont, also funded by USDOT
- Currently evaluating the tradeoffs of flight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

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

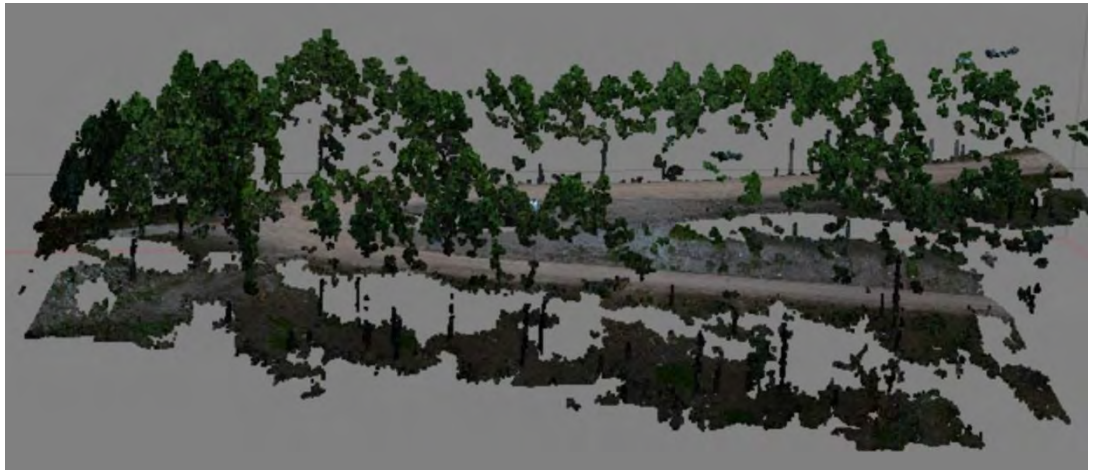
MTRI fixed wing tests, Oct. 2014

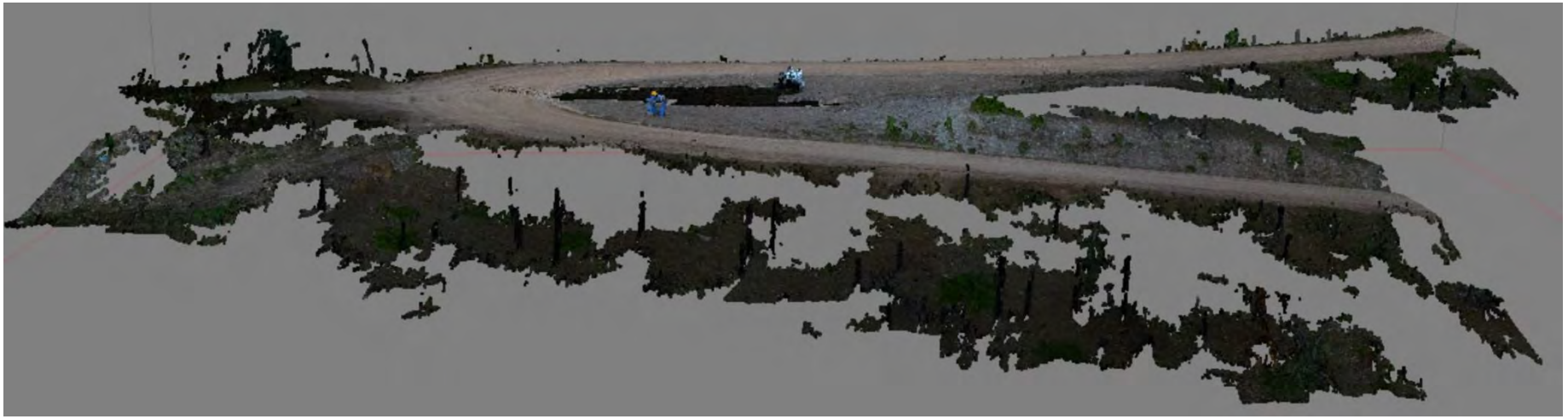
Orthoimage from Sensefly eBee system

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



Stratobowl: success in area with trees



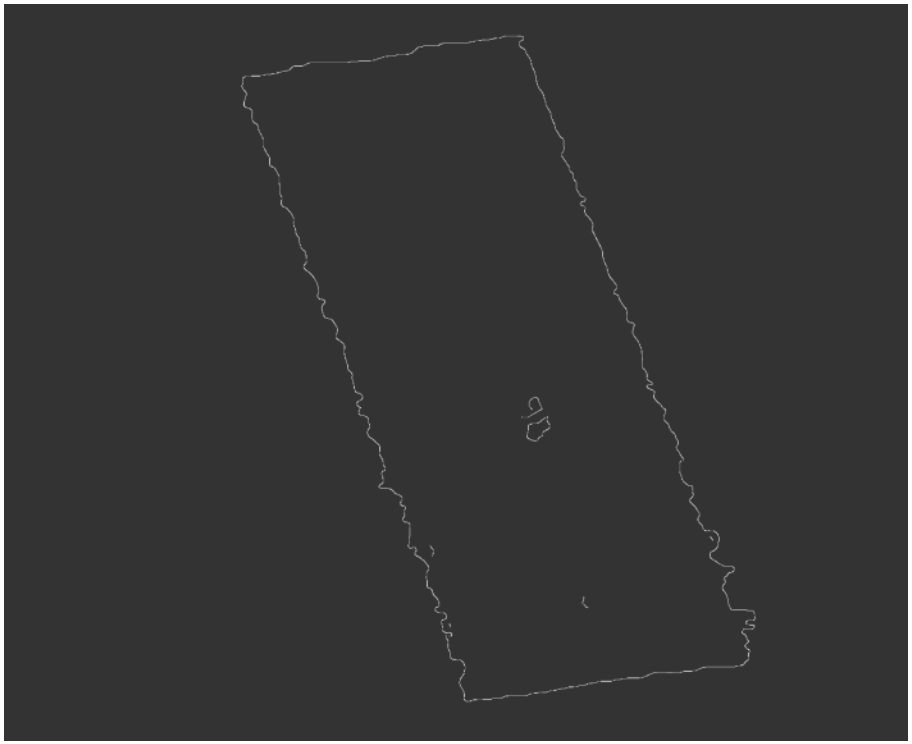


Automated Distress Detection example: Potholes (Remote Sensing Processing System)

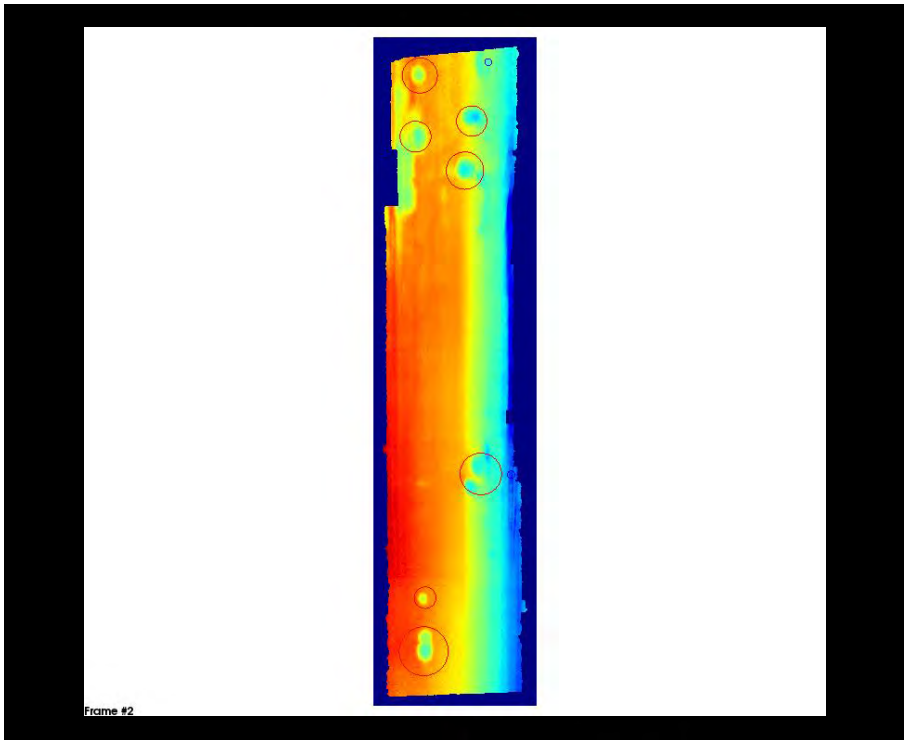
- Canny Edge Detection Used to Locate Edges
- Hough Circle Transform is Used to Locate Potholes
- Detected 96% of potholes

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

Edge Detection

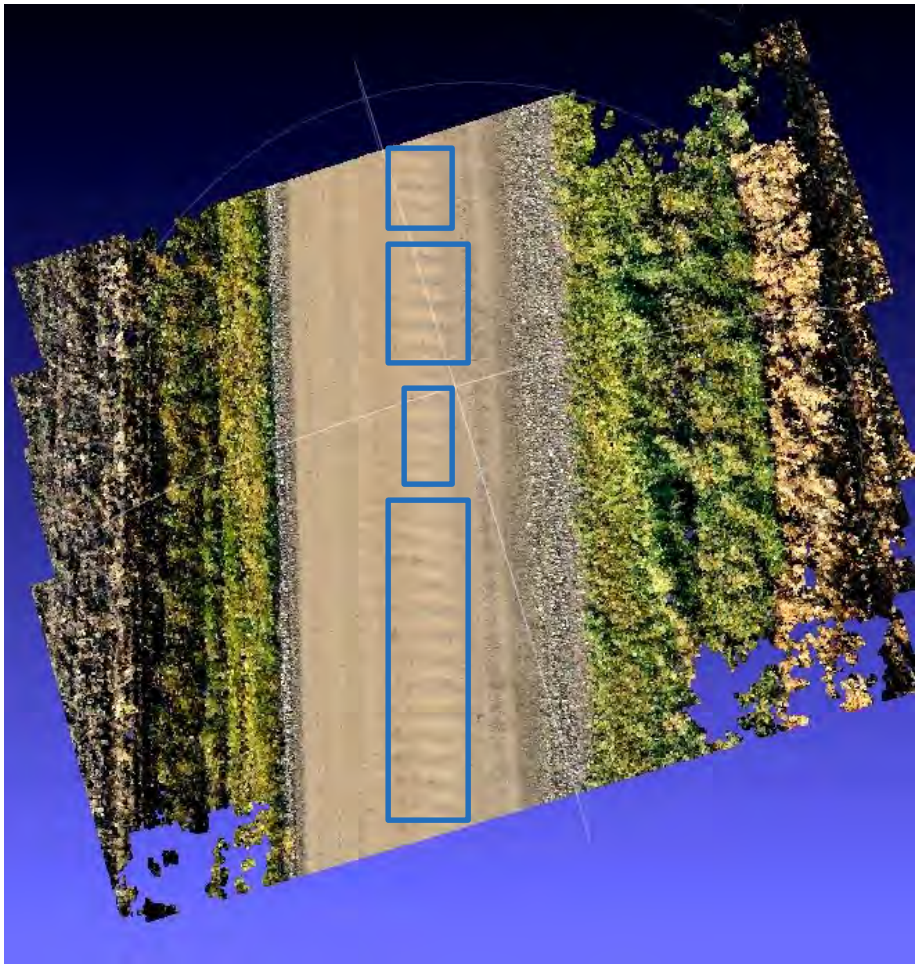


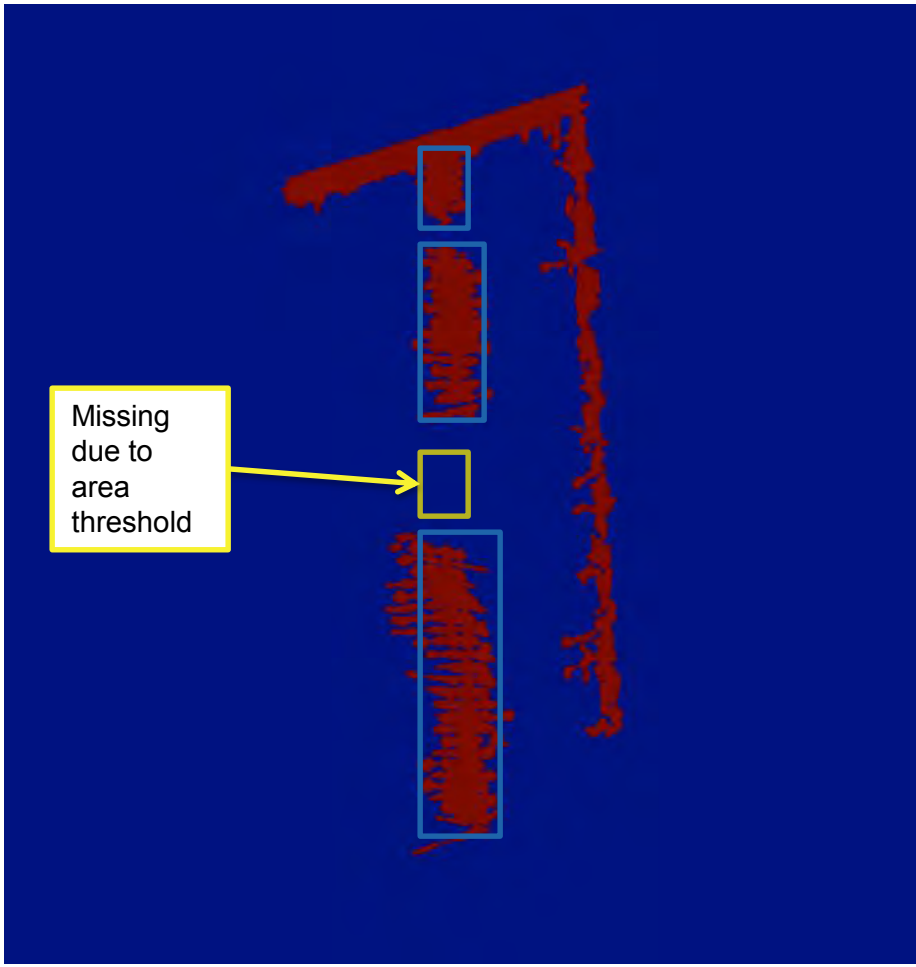
Identified Circles



Note: circles near edges ignored.

Distress Detection – Washboarding

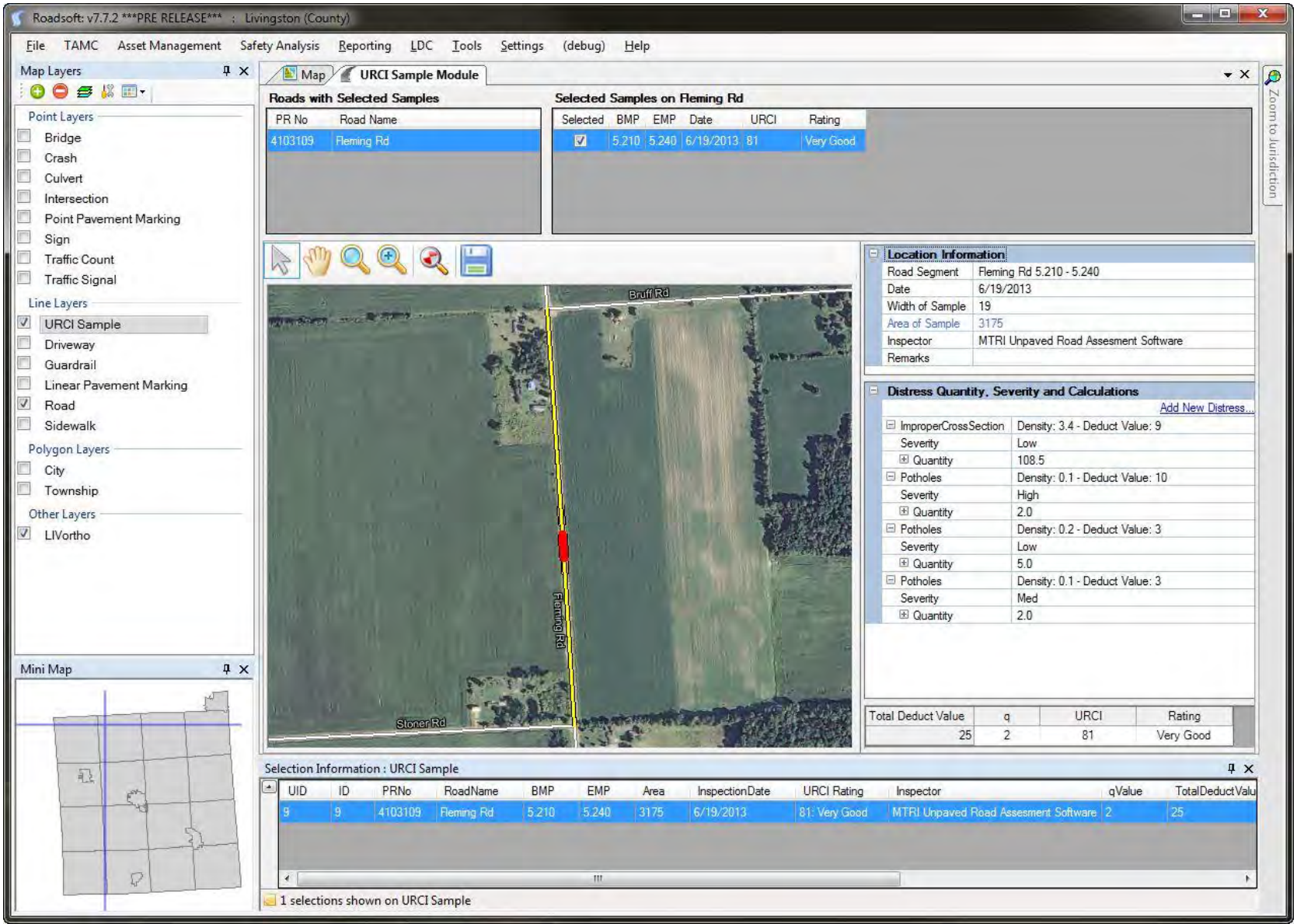




Ground Truth Corrugation Area: 19.6 sq. m

Computed Corrugation Area: 17.2 sq. m

Analyzed Data Integrated into RoadSoft GIS Decision Support System



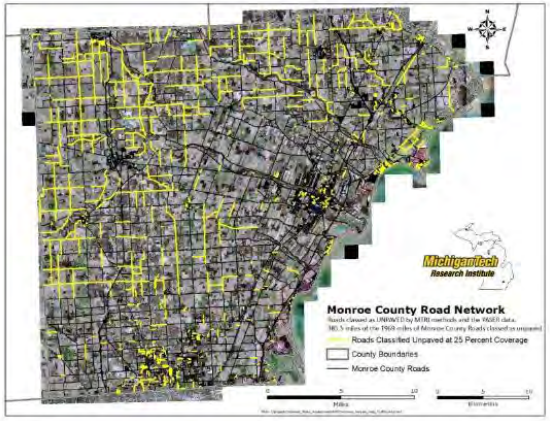
Cost comparison

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 **$0.74 per mile,** 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

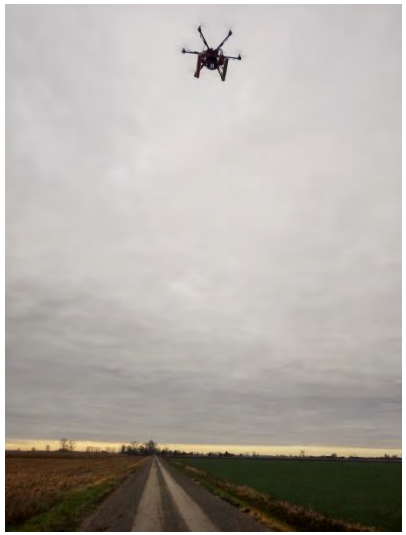
Inventory: Surface Type
Where are the unpaved roads?

- 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)



All of these together – components of the AURA system!

- Aerial Unpaved Road Assessment (AURA) system

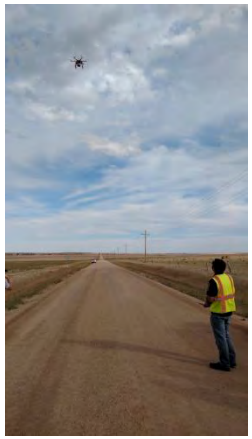
- www.mtri.org/unpaved (project details site)
- www.auramtri.com (public outreach site)

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

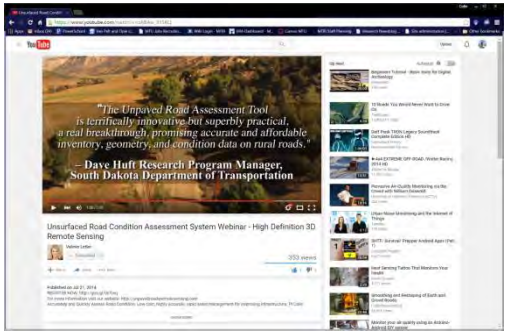


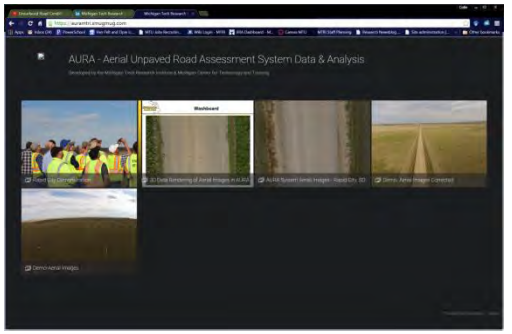
2015 Kansas demonstration photos

Task 7: October, 2015 Rapid City, SD demo: 30th Regional Local Roads Conference

Extended Professional Outreach

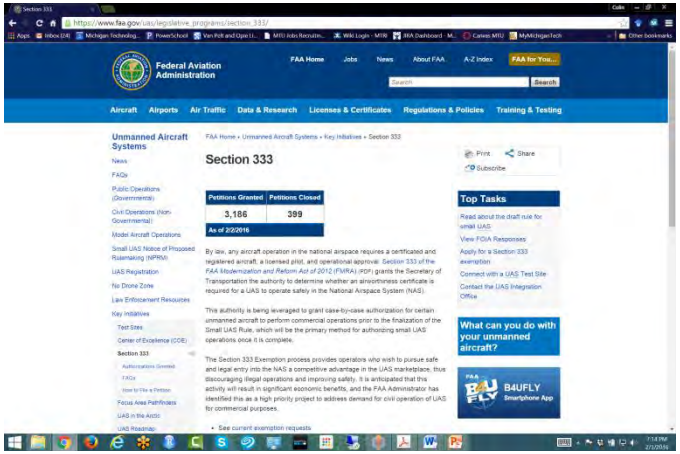
- Popular press articles (*Civil Engineering magazine, Urban Transportation Monitor, ARTBA Transportation Builder*)
- Questionnaire for potential users (results from technical demos)
- YouTube video: https://www.youtube.com/watch?v=zABAw_91SKQ (also shared at 2nd OKC commercialization meeting)
- Slideshare: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

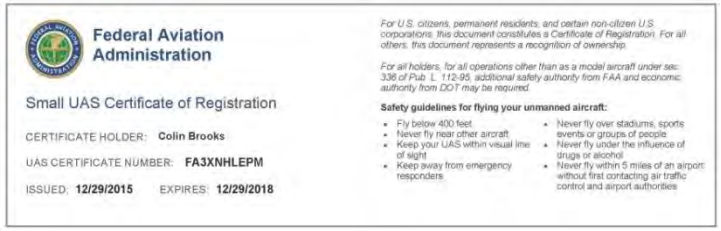


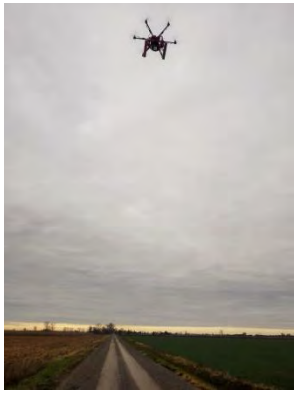


FAA rules have been developing; more practical use enabled

- **FAA Section 333 program** has enabled over 3,100 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 March 31 2016 for:
  - Recreational Small Unmanned Aircraft owned by a company or non-individuals, and
  - Small Unmanned Aircraft used for commercial or non-recreational purposes.
- **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
  - Looking for partners, projects







MichiganTech Research Institute

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

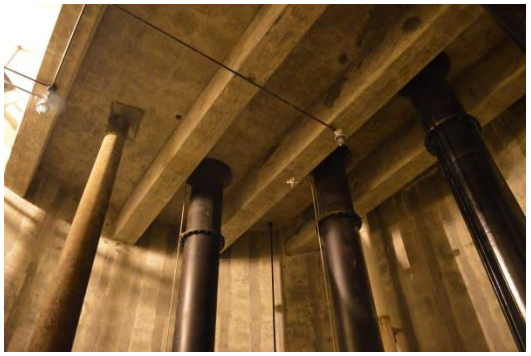
MDOT Michigan Department of Transportation

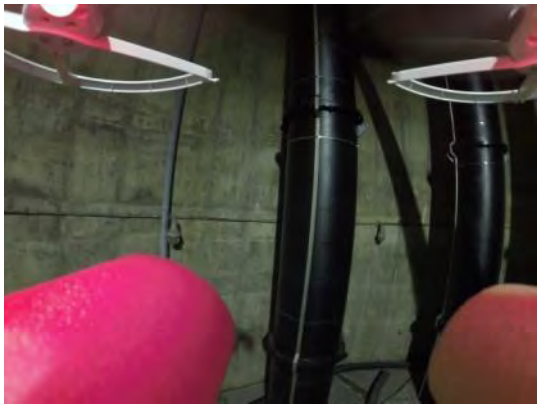
MichiganTech Research Institute

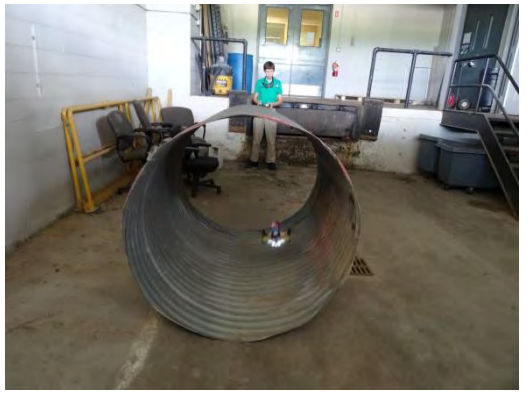
www.mtri.org

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





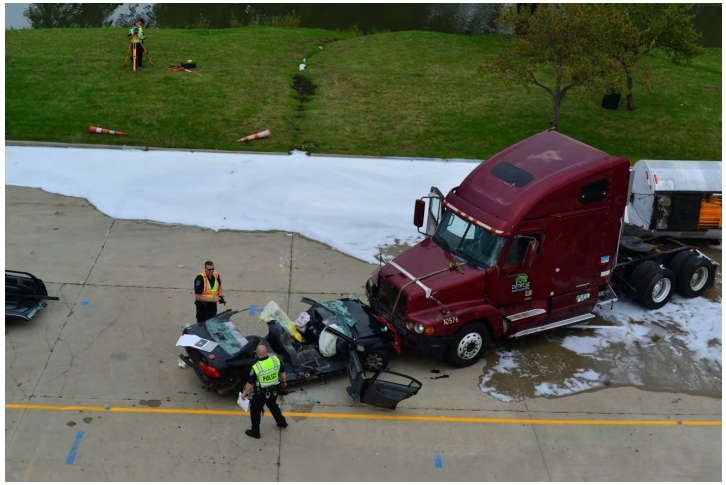


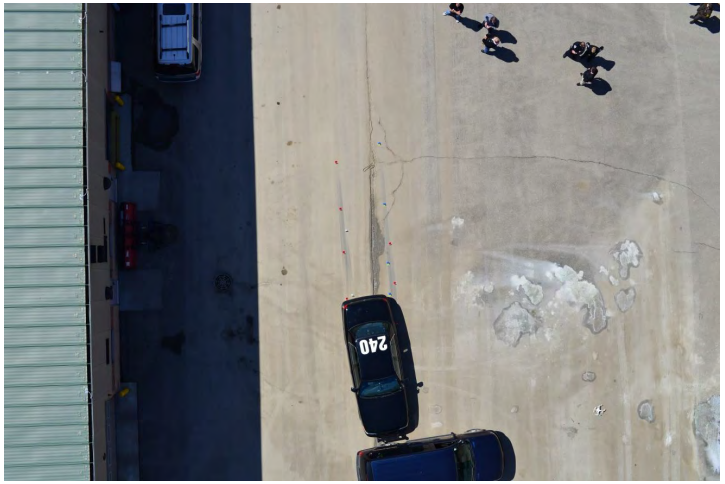
Tethered Blimps for Traffic Monitoring

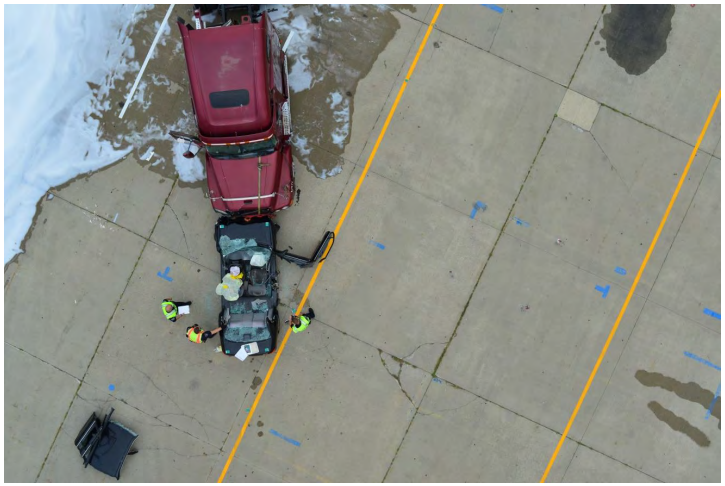
- Aerostats/Blimps
  - Long loitering time on station – up to several days
  - Can be sized to payload requirements
  - Tethered, lower FAA requirements for flight operations, can operate at night
  - Area needed for launch and recovery
  - Some designs can operate in windy weather
  - Less need for permanent equipment

Support for emergency response

Post-spill response; crash scene reconstruction

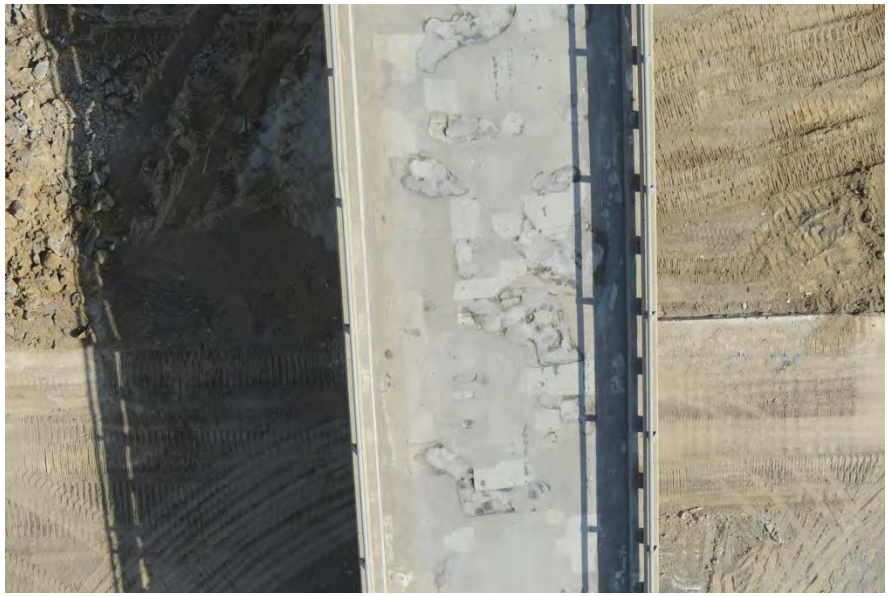






Bridge asset management & condition assessment imagery: collecting data

Bridge asset management & condition assessment imagery: examples



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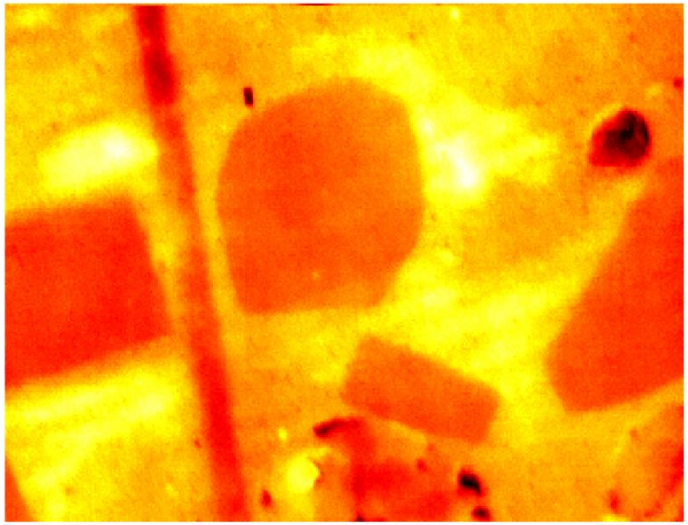
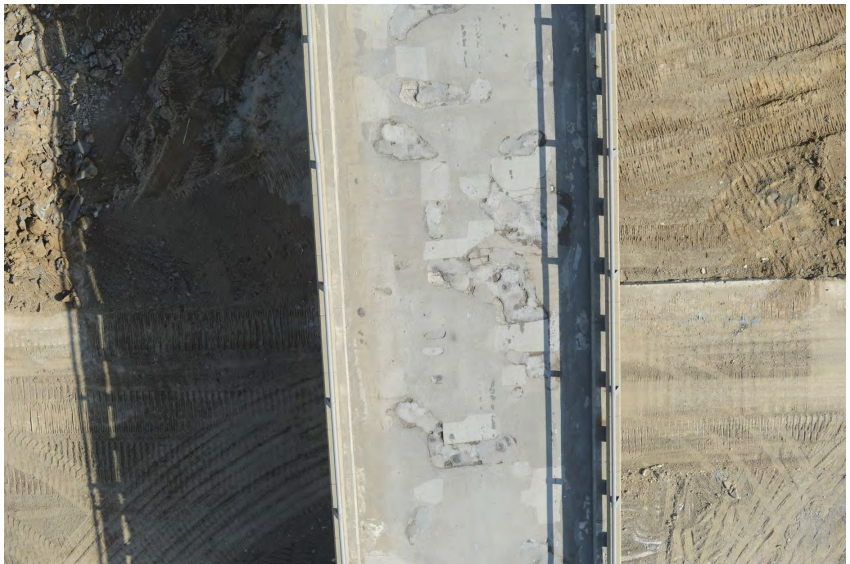
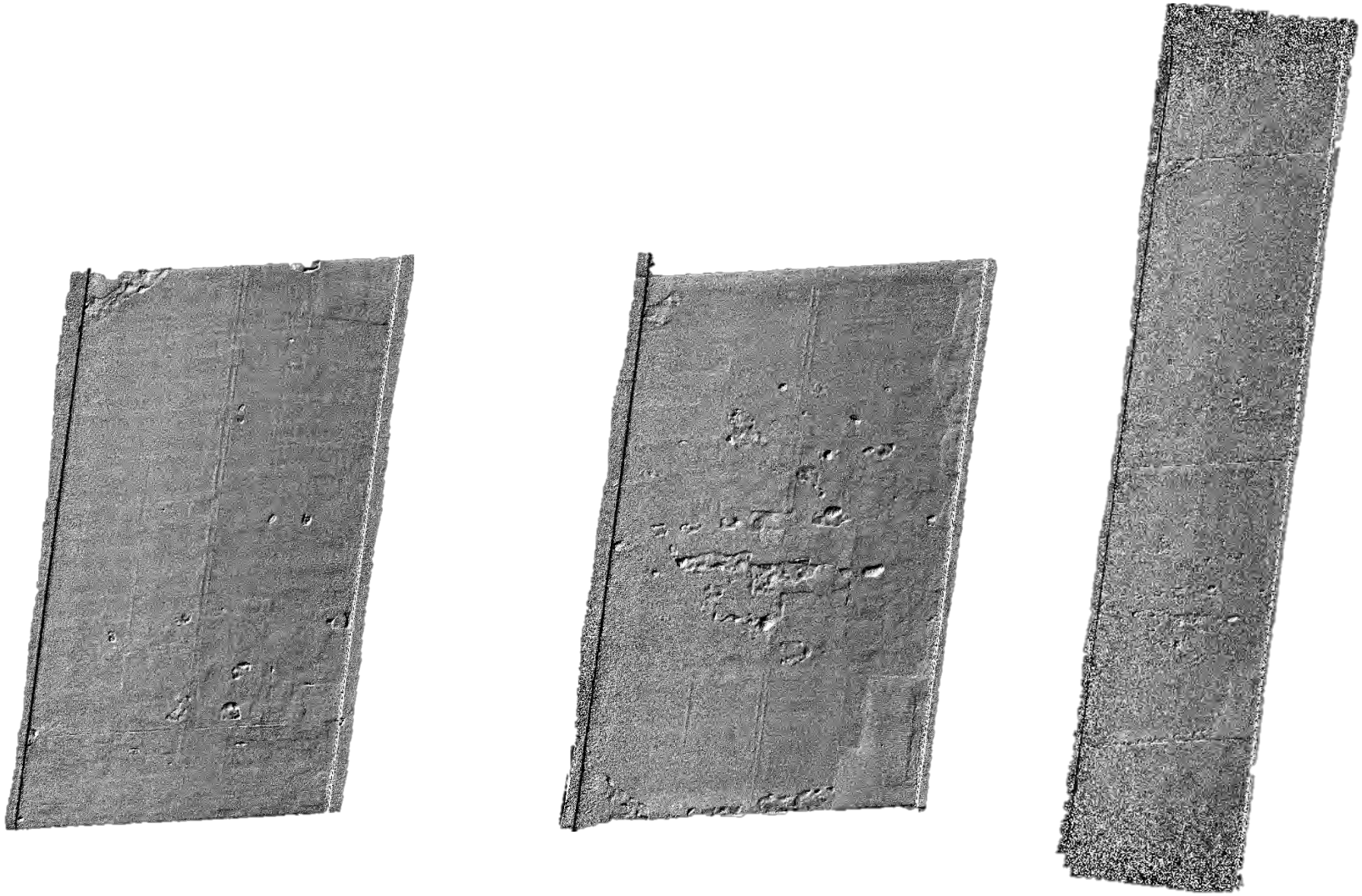


Bridge asset management & condition assessment imagery: add'l examples



Stark Rd
Orthophoto – 2.5mm

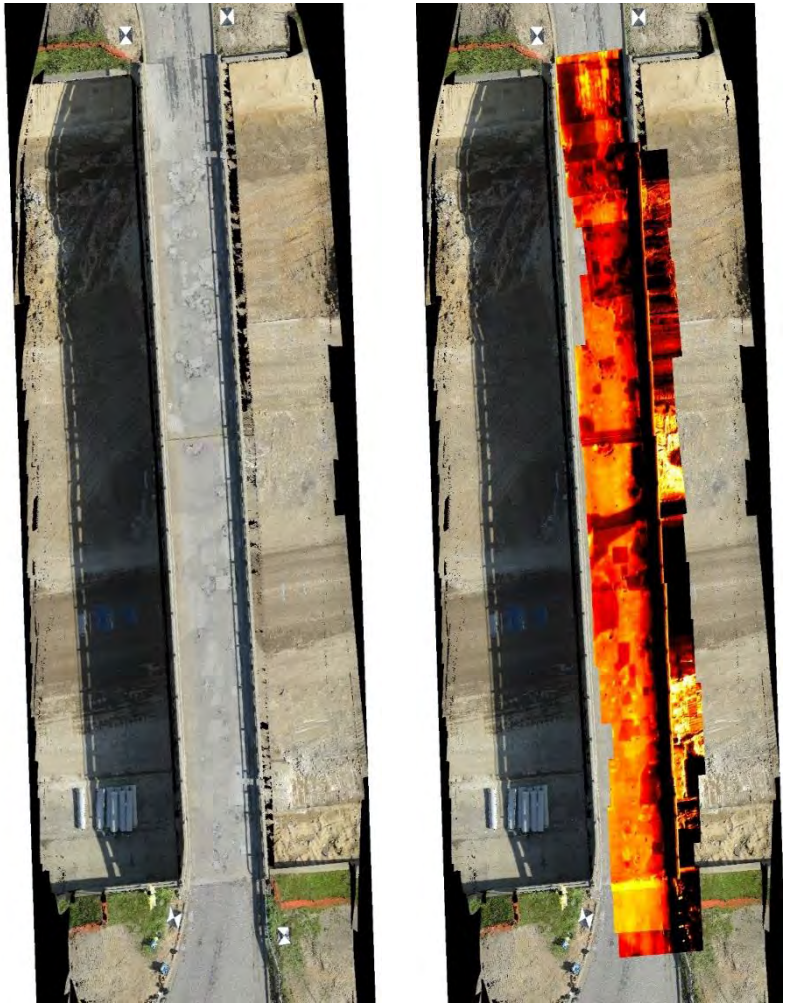
Stark Rd
DEM Hillshade



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

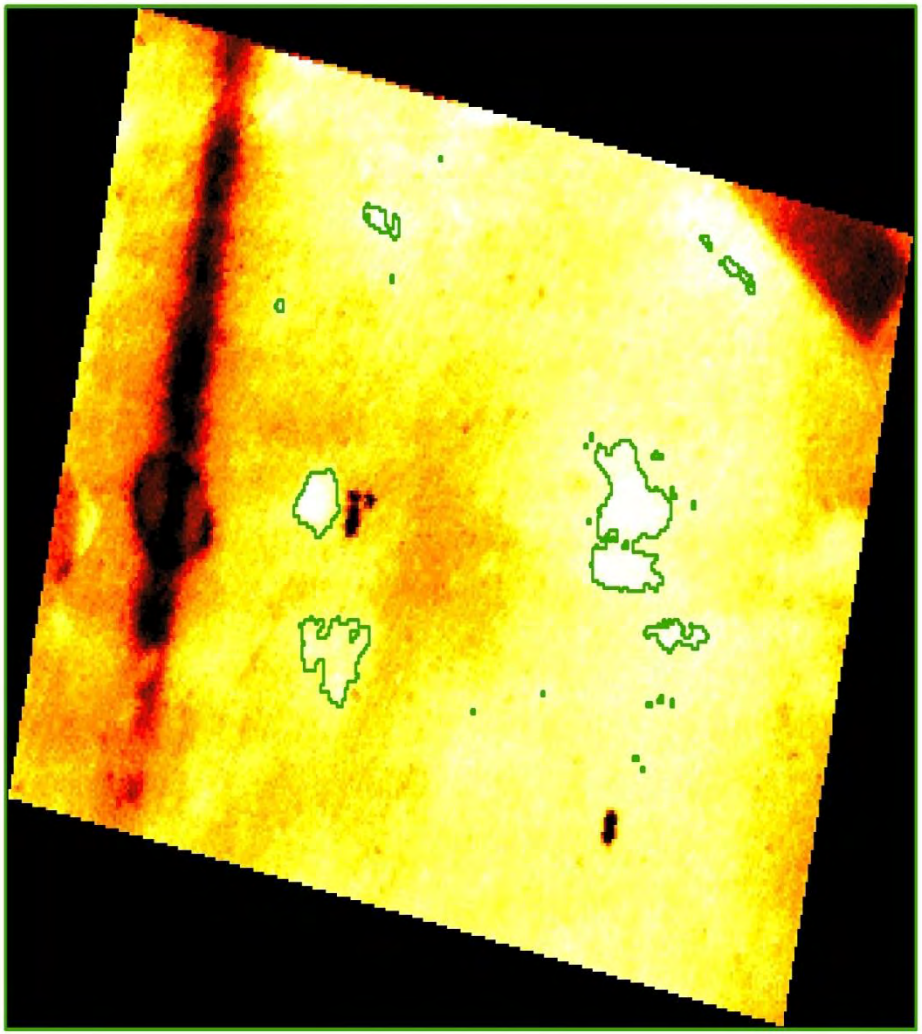


Merrim
an

Stark

Automated delamination detection

Delamination should be evident in thermal but not in visible!



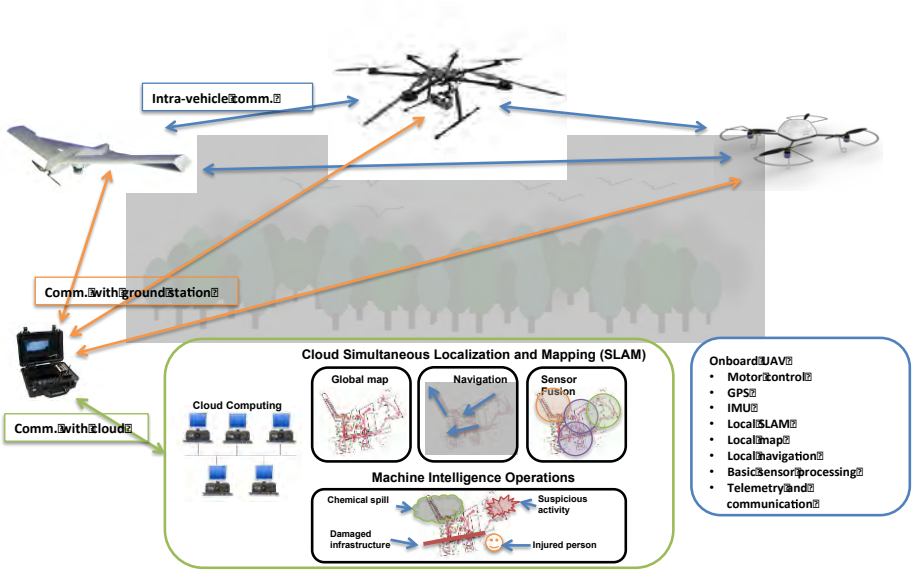
Criteria can be added: eliminate small areas (e. g. single pixels, pixels with low number of neighbors, etc.), look at individual bands, etc.

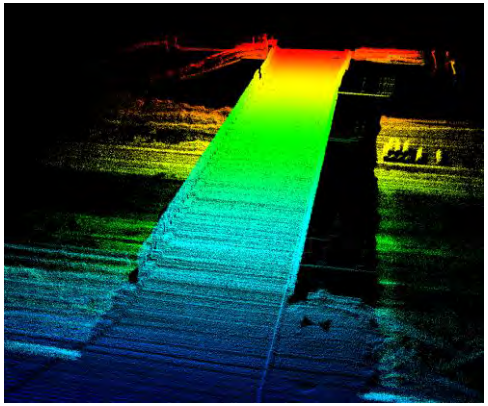
Only pixels with more than 6 neighbors.

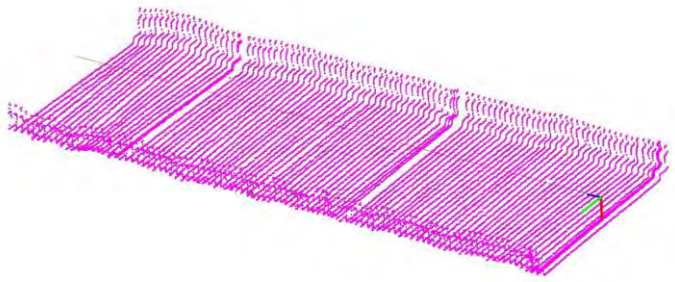
Area = 0.18 m^2

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





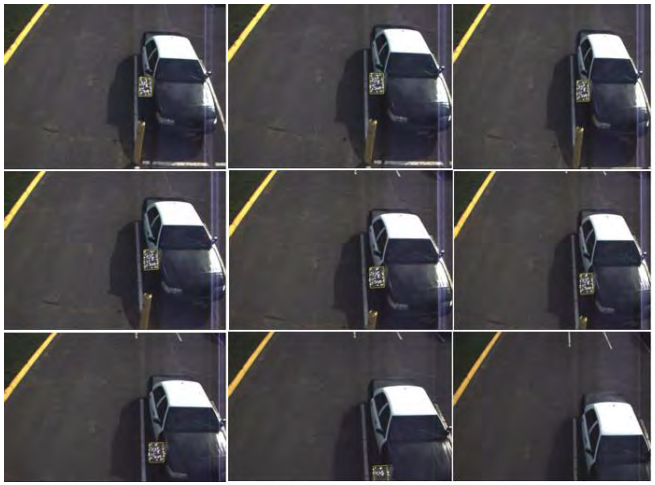


Bridge with linear interpolation assumption

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

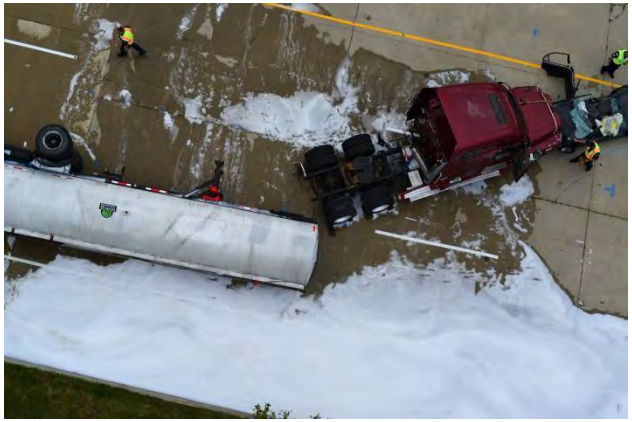


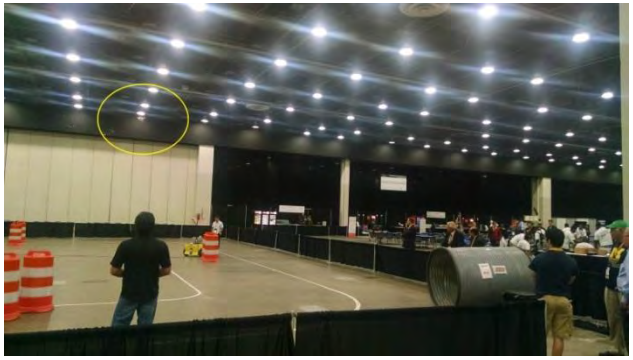
No Parking sign detected & tracked from UAV imagery

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





Where next?

- 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

Colin Brooks cnbrooks@mtu.edu
Desk: 734-913-6858, Mobile: 734-604-4196
Michigan Tech Research Institute, MTRI
3600 Green Court, Suite 100
Ann Arbor, MI 48105
www.mtri.org
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