MichiganTech Research Institute

An update on transportation infrastructure assessment with Unmanned Aerial Vehicles

Colin N. Brooks, Michigan Tech Research Institute
cnbrooks@mtu.edu 734-604-4196

30th Annual Regional Local Road Conference,
Rapid City, South Dakota
October 21, 2015



Center for Technology & Training · igd · WOOLPERT · MichiganTech Research Institute www.mtri.org · Transportation Asset Management Council · ROAD COMMISSION for OAKLAND COUNTY · SEMCOG Southeast Michigan Council of Governments

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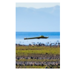
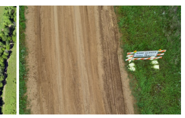
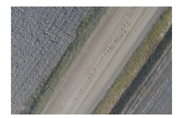
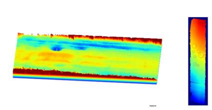
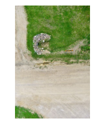
Project team

- Michigan Tech Research Institute (MTRI team – Colin Brooks, Rick Dobson, David Dean)
- 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



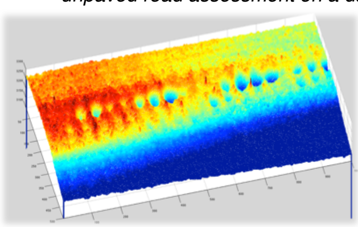






AURA
Aerial Unpaved Road Assessment system

Project Goal: develop an unpaved road assessment system

Phase 1: *Extend available Commercial Remote Sensing and Spatial Information (CRS&SI) tools to enhance and develop an unpaved road assessment system by developing a sensor for, and demonstrating the utility of remote sensing platform(s) for unpaved road assessment.*

Phase 2: *Take our working prototype technologies from a useful, successfully demonstrated research-level tool to a commercially-available, implemented system available to transportation agencies for objective unpaved road assessment on a day-to-day, as needed basis.*



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

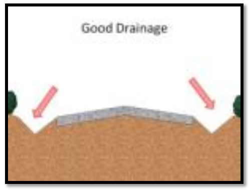
Road Characteristic Analysis Detail

- **Surface Width**
  - Collected every 10', with a precision of +/- 4"
- **Cross Section (Loss of Crown)**
  - Facilitates drainage, typically 2% - 4% (up to 6%) vertical change, sloping away from the centerline to the edge
  - Measure the profile every 10' along the road direction, able to detect a 1% change across a 9'-wide lane
- **Potholes**
  - <1', 1'-2', 2'-3', >3' width bins
  - <2", 2"-4", >4" depth bins
- **Ruts**
  - Detect features >5", >10' in length, precision +/-2"

Road Characteristic Analysis Detail Cont.

- **Corrugations (Washboarding)**
  - Classify by depth to a precision of +/-1"
    - <1", 1"-3", >3"
  - Report total area of the reporting segment affected

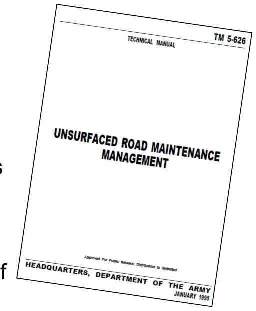
- **Roadside Drainage**
  - System should be able to measure ditch bottom relative to road surface within +/-2", if >6"
  - Detect the presence of water, elevation +/-2", width +/-4"



- **Float Aggregate (Berms)**

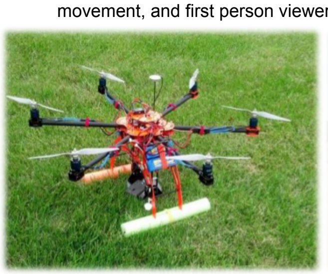
Combined Methods: Dept. Army Unsurfaced Road Condition Index (URCI)

- 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
  - Includes autopilot system, stabilized mount that is independent of platform movement, and first person viewer system (altitude, speed, battery life, etc.)



Selected Sensor: Nikon D800

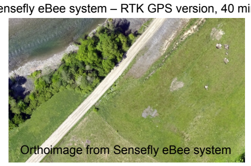
- Nikon D800 – Full-Sized (FX) Sensor
- 36.3 Megapixels
- 4 Frames per Second
- Cost: $3,000
- Evaluating Sony A7R Mirrorless camera
  - Same cost/resolution, half the weight.

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

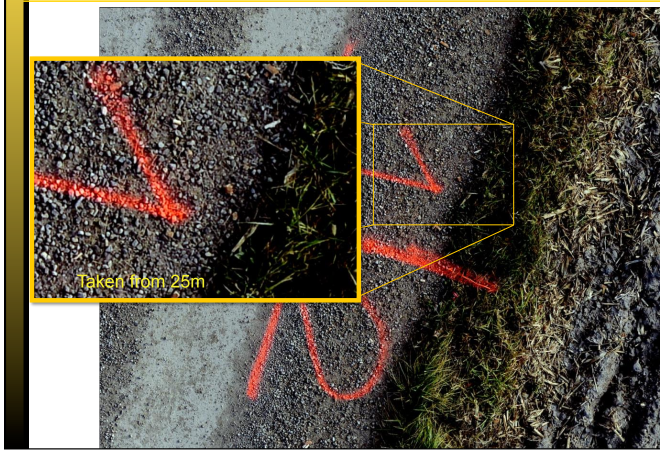
Sensefly eBee system – RTK GPS version, 40 min flight time - $51k

MTRI fixed wing tests, Oct. 2014



Orthoimage from Sensefly eBee system

Performance – Collected Imagery



Ground Truth

3D Reconstruction – Surface

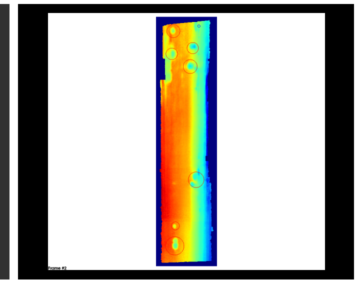
3D Model of Rutting

Distress Detection – Potholes

- Canny Edge Detection Used to Locate Edges
- Hough Circle Transform is Used to Locate Potholes

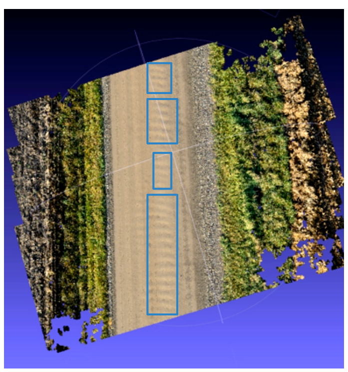
Edge Detection

Identified Circles

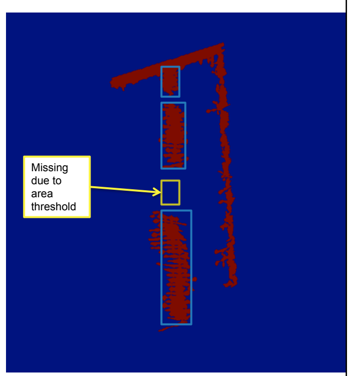


Note: circles near edges ignored.

Distress Detection – Washboarding

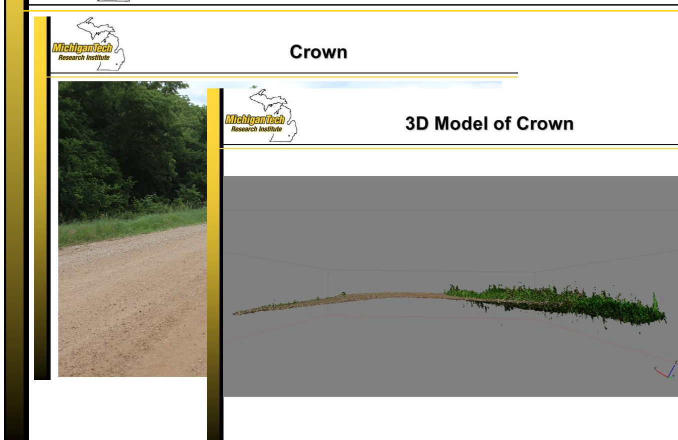


Ground Truth Corrugation Area: 19.6 sq. m



Computed Corrugation Area: 17.2 sq. m

Crown estimation – better than 1%



Algorithm Performance Summary

- Pothole Detection: 96% accuracy

Potholes	Detected Potholes	Potholes misidentified	Probability of Detection	Probability of False Alarm	Probability of Correct Classification
101	96	4	95%	4%	96%

- Crown Damage: within 0.1%

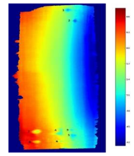
	Width (cm)	Crown A (cm)	Crown B (cm)	Grade A	Grade B	Min Grade	Damage
1	535	-8.1	10.9	-3.02%	4.07%	-3.02%	H
2	537	-7.4	11.5	-2.75%	4.28%	-2.75%	H
3	545	-7.5	12	-2.75%	4.40%	-2.75%	H
4	519	-7.1	13.1	-2.73%	5.04%	-2.73%	H
5	550	-7.3	12.9	-2.65%	4.69%	-2.65%	H
6	539	-7.5	13	-2.78%	4.82%	-2.78%	H
7	537	-6.4	13	-2.38%	4.84%	-2.38%	H
8	530	-6.1	12.6	-2.30%	4.75%	-2.30%	H
9	525	-5.2	12.6	-1.98%	4.80%	-1.98%	M
10	520	-7.2	11.7	-2.76%	4.50%	-2.76%	H

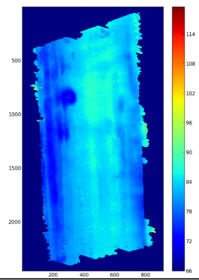
- Rut Detection: (*being updated*)

Probability of Detection	Probability of False Alarm
67%	19%

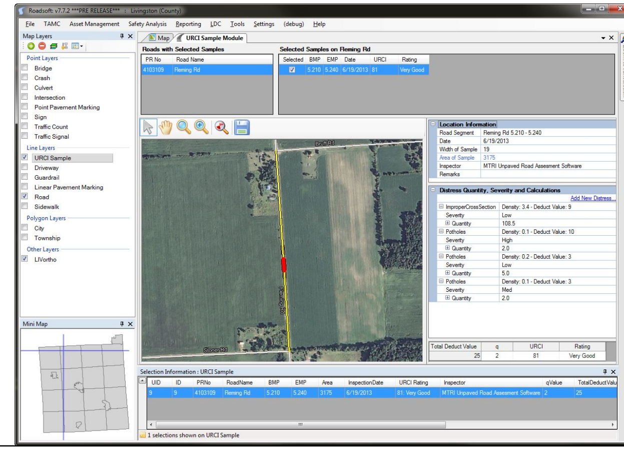
- Corrugation Detection: (*being updated*)

Probability of Detection	Probability of False Alarm
100%	38.5%





Analyzed Data Integrated into RoadSoft GIS Decision Support System



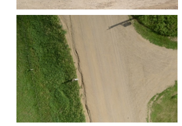
All of these together – components of the AURA system!

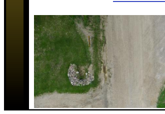
- Aerial Unpaved Road Assessment (AURA) system

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

June, 2014 technical demo in Sioux Falls, SD

- Successful demonstration to South Dakota DOT & local transportation agencies in Sioux Falls, June 26, 2014
  - 36 attendees, 15 groups (state & local agencies) – SDDOT, SDLTAP, 3 local counties, Nebraska LTAP, ND LTAP
  - Overview, live field demo, quick data processing, round table discussion
  - Feedback:
    - Definite improvement over "windshield surveys"
    - A practical system – "see tremendous use"
    - Strong interest in accessing as a third-party service
  - Other interests expressed: **Haul road inventories, road geometry evaluations, encroachment issues, natural disaster documentation**
- Partnered with outreach specialist (Valerie Lefler, Integrated Global Dimensions - IGD) – organized June demonstration workshop
  - www.mtriaura.com (updated)





July, 2015 technical demo in Salina, KS

October, 2015 Rapid City area demo

Commercialization of AURA for Day-to-Day Usage

- **Outputs**
  - Inclusion of private sector inputs on the best practices for third-party commercialization of AURA
  - Working with **Woolpert, Inc.** of Dayton, Ohio
    - Provide expertise on commercialization potential form a business perspective
    - Expertise in commercial UAV deployment
- Woolpert writing "Commercialization Report on AURA for Day-to-Day Operations"
- Make these methods available across the country – inc. working with local partners

WOOLPERT
DESIGN | GEOSPATIAL | INFRASTRUCTURE

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

Costs – Remote Sensing

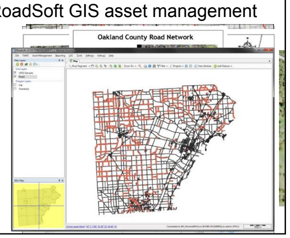
- **UAV, high-resolution camera, and good-quality lens:**
  - Cost per mile rated $30,590/yr/1575 mi/yr = $19.42/mi rated.
  - HOWEVER…two 100-foot measured segments represent one mile of road, so 5,280 ft/200ft is 26.4. Therefore each mile of measured road represents a road network 26 times larger.
  - 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
- Caution must be made for cost comparisons between remote sensing and manual characterization of road conditions due to the resolutions of the outputs; centimeter-by-centimeter analysis of entire road segments is essentially impossible via manual inspection.

Next steps in light of changing FAA regulations

- **FAA Section 333 program** has enabled over 1,700 commercial exemptions for use of small UAVs since Dec. 2014 (3-4 months for initial approval) – up from 548 in July, 2015!
- **New "Small UAS" (sUAS) rules** proposed by FAA Feb. 2015, comment period closed Apr. 2015, implementation in 2016/2017 – $300 operators permit instead of pilot's license, line of sight, rapid deployment – more practical, 55 lbs max gross weight, no manned aircraft certificate
- **Beyond line of sight testing** efforts under FAA Pathfinder program (BNSF – railroads, CNN – newsgathering, PrecisionHawk - agriculture)
- **Continued need for R&D efforts** – integrating multiple sensors, testing capabilities of new platforms (fixed wing), automated feature detection, converting data into useful information (algorithm development)
  - Applied research services – MTRI interested in partnering
  - Commercializing MTRI efforts – looking for partners in all parts of the country (road condition assessment, bridge condition evaluation)

Inventory: Surface Type

- How many miles of unpaved road are there? Not all counties have this.
- Need to able to determine inventory
- c. 43,000 (1984 estimate) – but no up-to-date, accurate state inventory exists
- c. 800 miles in Oakland County estimate
- We are extracting this from recent, high-resolution aerial imagery, focusing on unincorporated areas – attribute existing state Framework roads layer
- Completed Oakland, Monroe, Livingston, St. Clair, Macomb, Washtenaw, Counties; shared with SEMCOG, adding to RoadSoft GIS asset management tool
- 87%-94% accuracy
- Ex: Livingston Co.: 894 miles unpaved
  - 1289 miles unpaved



Contact Info

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
Tim Colling, Ph.D., P.E. tkcollin@mtu.edu
Chris Roussi croussi@mtu.edu
Rick Dobson rjdobson@mtu.edu
Ben Hart behart@mtu.edu
Joe Garbarino jgarb@mtu.edu
David Dean dbdean@mtu.edu
Valerie Lefler, M.P.A. valerie.lefler@integratedglobaldimensions.com

www.mtri.org/unpaved

Project #: RITARS-11-H-MTU1

Michigan Tech Research Institute

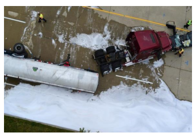
Evaluating the Use of Unmanned Aerial Vehicles for Transportation Purposes

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

www.mtri.org

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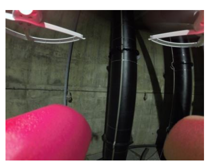
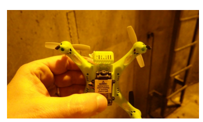
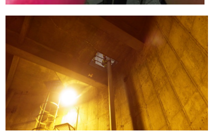
http://www.mtri.org/mdot_uav.html

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



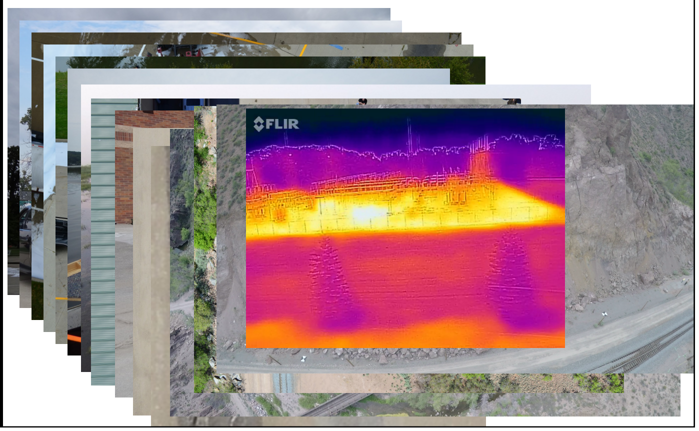
Tethered Blimps for Traffic Monitoring



- 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

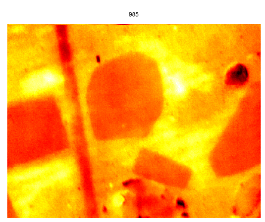

Support for emergency response

Post-spill response; post-flooding evaluation, crash scene reconstruction, landslide mapping, thermal mapping



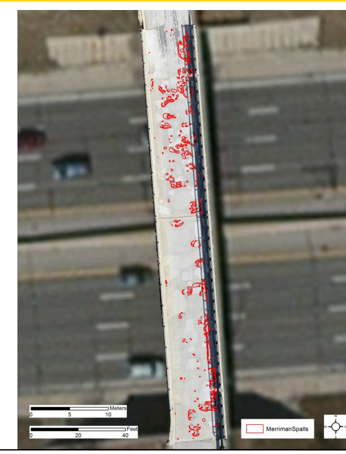
Bridge asset management & condition assessment imagery: collecting data

Bridge asset management & condition assessment imagery: examples

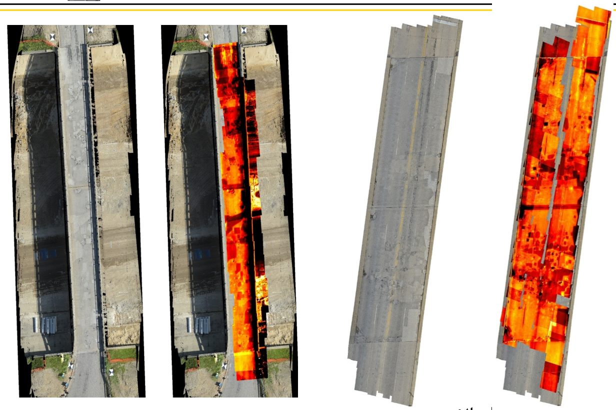


Automated spall detection

- 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

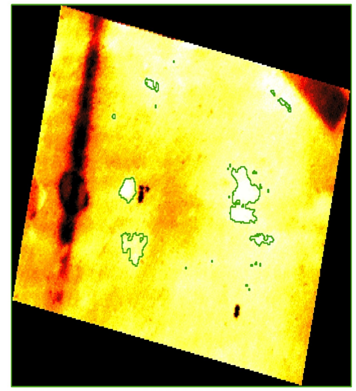


Merriman

Stark

Automated delamination detection

Delamination should be evident in thermal but not in visible!



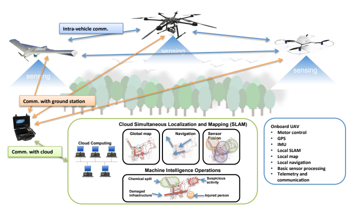
Criteria can be added: eliminate small areas (e. g. single pixels, pixels with low number of neighbors, etc.), look at individual bands, etc.

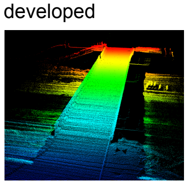
Only pixels with more than 6 neighbors.

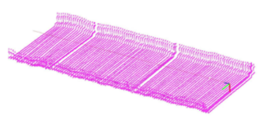
Area = 0.18 m^2

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



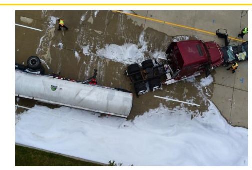


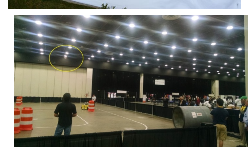


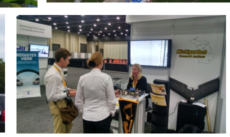
Bridge with linear interpolation assumption

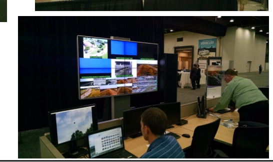
ITS World Congress 2014 demonstrations

- 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









Contact Info

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
www.mtri.org/mdot_uav.html