DEPLOYING DRONE-ENABLED SENSING FOR AUTOMATED HIGHWAY RAIL GRADE CROSSING ASSESSMENT WITH THE CROSSING-I SYSTEM

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MTRI, Inc.

Crossing-i R R System

Rail Transportation Program
Michigan Tech Transportation Institute • Michigan Technological University

Michigan Technological University
1885

PROBLEM BEING SOLVED

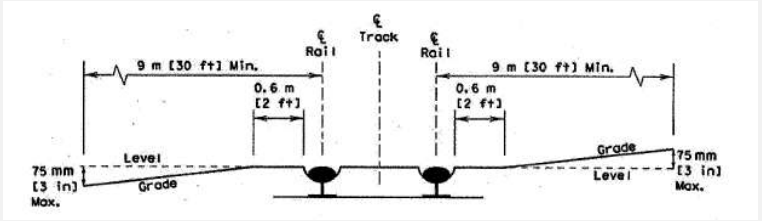
- Loss of life and of property occur too frequently at rail crossings
- 130,000 public and 209,000 total crossings in the U.S.
  - 200+ annual fatalities
  - 2000+ annual injuries

3/7/2017 Biloxi, 4 deaths, 38 injuries (50 total onboard, retirees)

10/16/21 Thackerville, OK: Amtrak train strikes semi-truck car hauler stuck on tracks; 5 injured

BEFORE MEASUREMENTS: DEFINE REQUIREMENTS

- Defined the requirements to measure grade crossings
  - Crossing profile measurement requirements: Based on AASHTO's "A Policy on Geometric Design and Streets" (Green Book) – 0.89% max grade for 30ft from ends of ties (3 inches over 28 ft; 75mm over 8.4m)
    - Rate of change critical to find locally problematic areas
  - Sight line requirements: Railroad-Highway Grade Crossing Handbook by the FHWA



Critical areas for 3D measurement of vertical highway profiles at grade crossings – 0.89% grade over 30' (9.1m) – AASHTO Green Book

	Case B: Departure from stop	Case A: Moving vehicle							
	Vehicle speed (mph)								
Train speed (mph)	0	10	20	30	40	50	60	70	80
	Distance along railroad from crossing, d_r (feet)								
10	240	146	106	99	100	105	111	118	126
20	480	293	212	198	200	209	222	236	252
30	721	439	318	297	300	314	333	355	378
40	961	585	424	396	401	419	444	473	504
50	1201	732	530	494	501	524	555	591	630
60	1441	878	636	593	601	628	666	709	756
70	1681	1024	742	692	701	733	777	828	882
80	1921	1171	848	791	801	838	888	946	1008
90	2162	1317	954	890	901	943	999	1064	1134
	Distance along highway from crossing, d_h (feet)								
		69	135	220	324	447	589	751	931

Table 32 Railroad-Highway Grade Crossing Handbook – helps determine distances needed for data collection along highways & railways

HANG-UP DETECTION VEHICLE STANDARDS

- Eck and Kang, 1991, update Clawson 2002, checked against current standards
- They also state that vehicles with ground clearance down to 2 inches have been observed
- Recommend use of 40 foot wheel base with 4 inch clearance (12.2m x 0.10m)
- We produce school bus, motorcoach, & low-boy trailer by default; can do any other, with alternative clearances & wheelbases

Table 4.1 – Design Vehicle Dimensions

Design Vehicles	Wheelbase (ft)	Overhang (ft)		Ground clearance (in)		
		Front	Rear	Wheelbase	Front	Rear
Single Unit Trucks –						
Single Unit Beverage Truck	24	--	10	6	--	8
Articulated Beverage Truck	30	--	--	10	--	--
Rear-Load Garbage Truck	20	--	12.5	12	--	14
Aerial Fire Truck	20	7	12	9	11	10
Pumper Fire Truck	22	8	10	7	8	10
Buses -						
Mini-Bus	15	--	16	10	--	8
School Bus	23	--	13	7	--	11
Single Unit Transit Bus	25	18	--	8	6	--
Articulated Transit Bus	22 / 26	--	10	10 / 10	--	9
Motorcoach	27	7.6	10	7	10	8
Trucks -						
Low-Boy Trailers < 53 ft	38	--	--	5	--	--
Double-Drop Trailer	40	--	--	6	--	--
Car Carrier Trailer	40	--	14	4	--	6
Belly Dump Trailer	40	--	--	11	--	--
Recreational Vehicles -						
Passenger Vehicle and Trailer – Private Use	20	--	13	5	--	5
Passenger Vehicle and Trailer – Commercial Use	27 (24 to hitch)	--	13	7	--	7
Recreation Vehicle	27	7.8	16	7	6	8

Clawson, Amy Lorraine, "Establishing design vehicles for the hang-up problem" (2002)

SIGHT DISTANCE

- Requirements from the 2018 Green Book are the same as 2011.

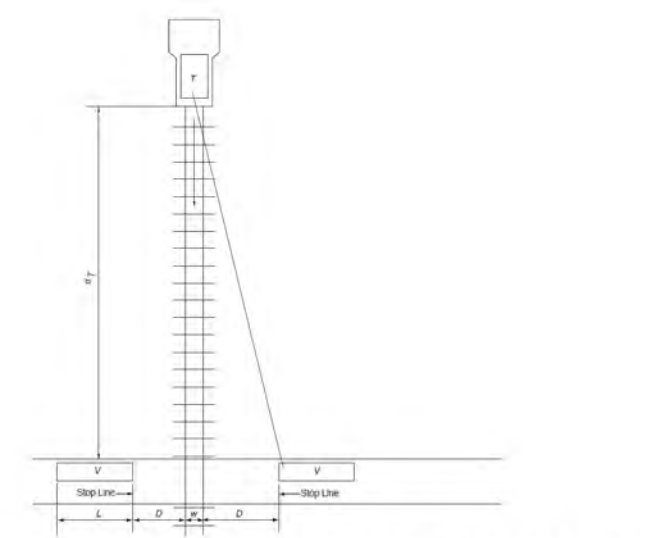


Figure 9-77. Case B: Departure of Vehicle from Stopped Position to Cross Single Railroad Track

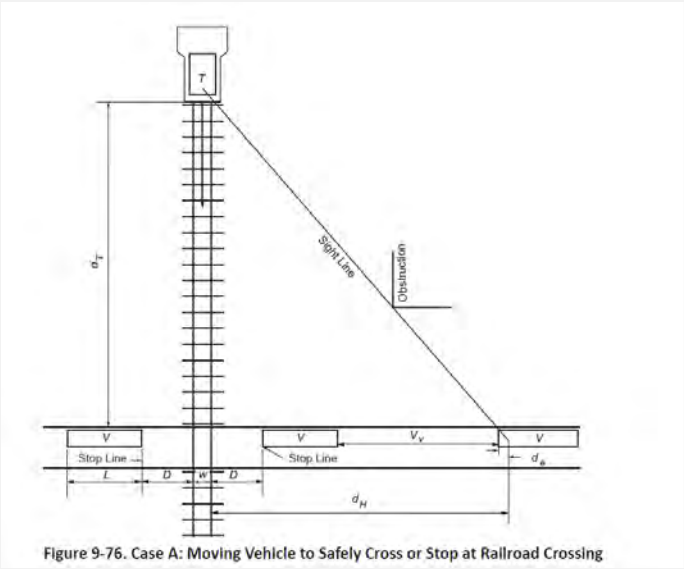
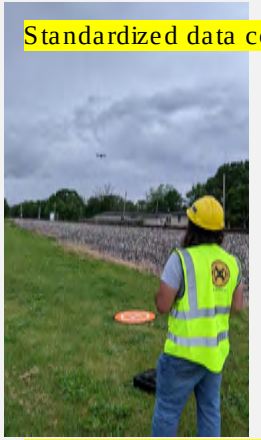


Figure 9-76. Case A: Moving Vehicle to Safely Cross or Stop at Railroad Crossing

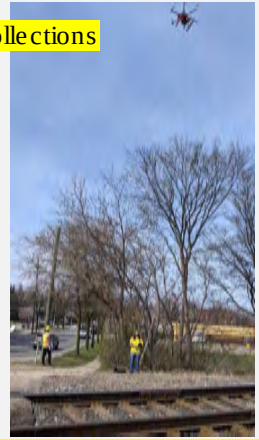
Need to consider vehicles starting from stopped position (left) or already moving vehicles (right)

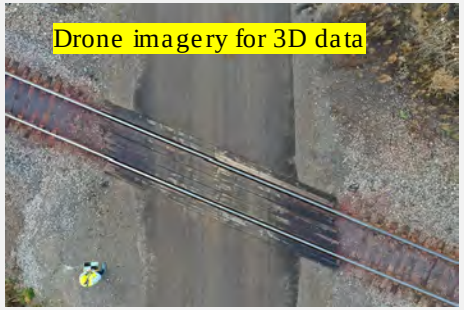
* We calculate site line adequacy for approaching vehicles *

SBIR PHASE I, II, & FOLLOW-ON RESULTS FOR CROSSING SAFETY ASSESSMENT



Standardized data collections

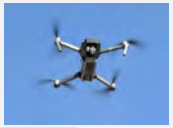


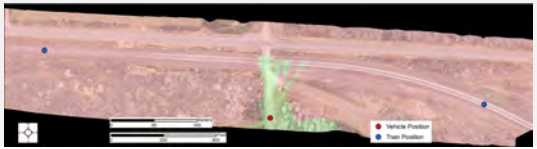


Drone imagery for 3D data

6 states, 51 crossings

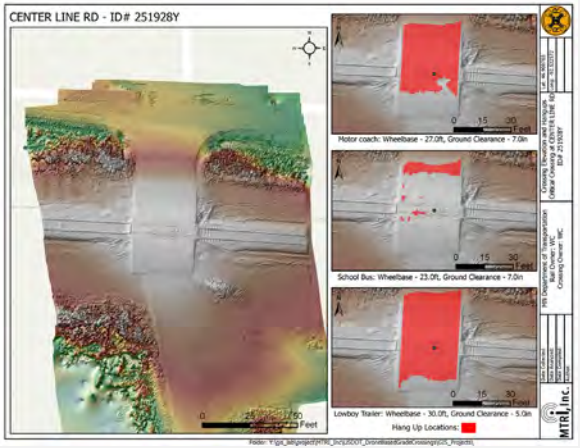
Automated sign ID

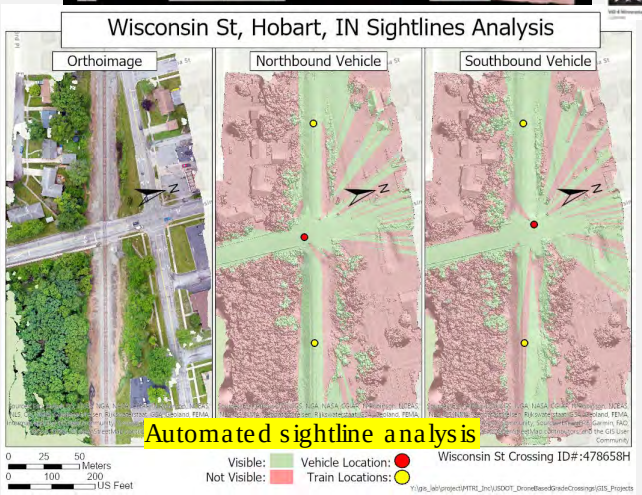




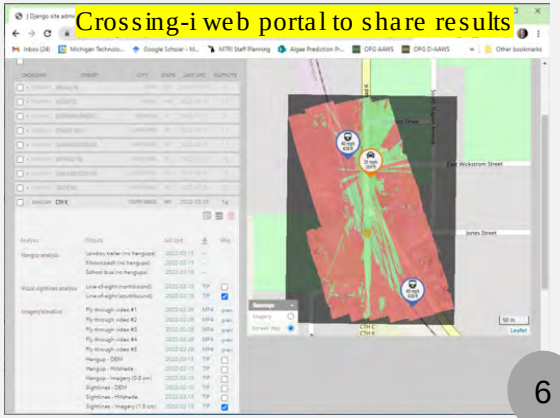
Drone & 360° ground videos

Automated humped crossing detection by vehicle type & Crossing-i reports





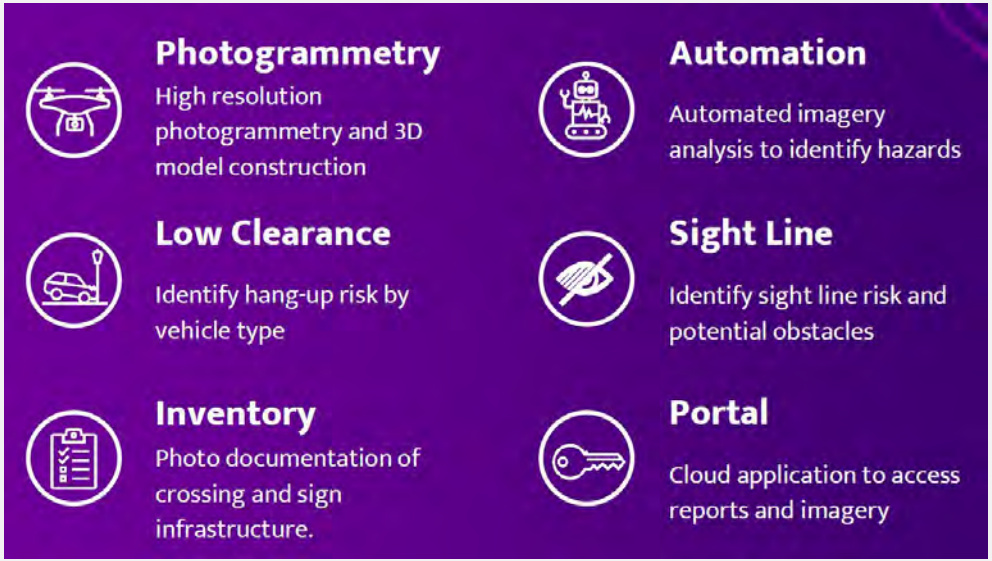
Automated sightline analysis



Crossing-i web portal to share results

TECHNOLOGY SOLUTION: CROSSING-I

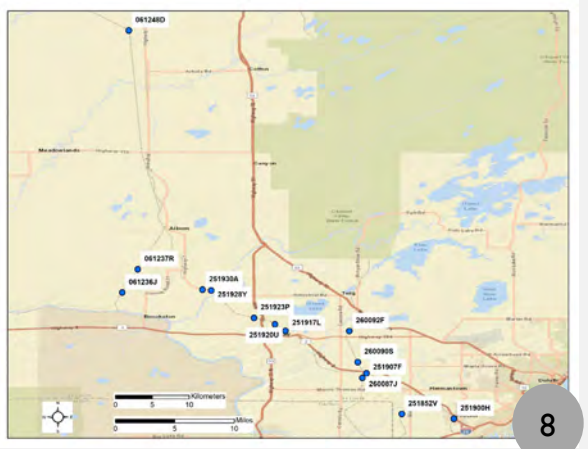
- We have developed an advanced, practical, and available drone based technology to reduce life threatening accidents at railroad crossings.
- Developed under USDOT SBIR Phase I & II funding - partnership between MTU and MTRI Inc.
- Now being made commercially available



https://mtriinc.com/rail-crossing-assessment/

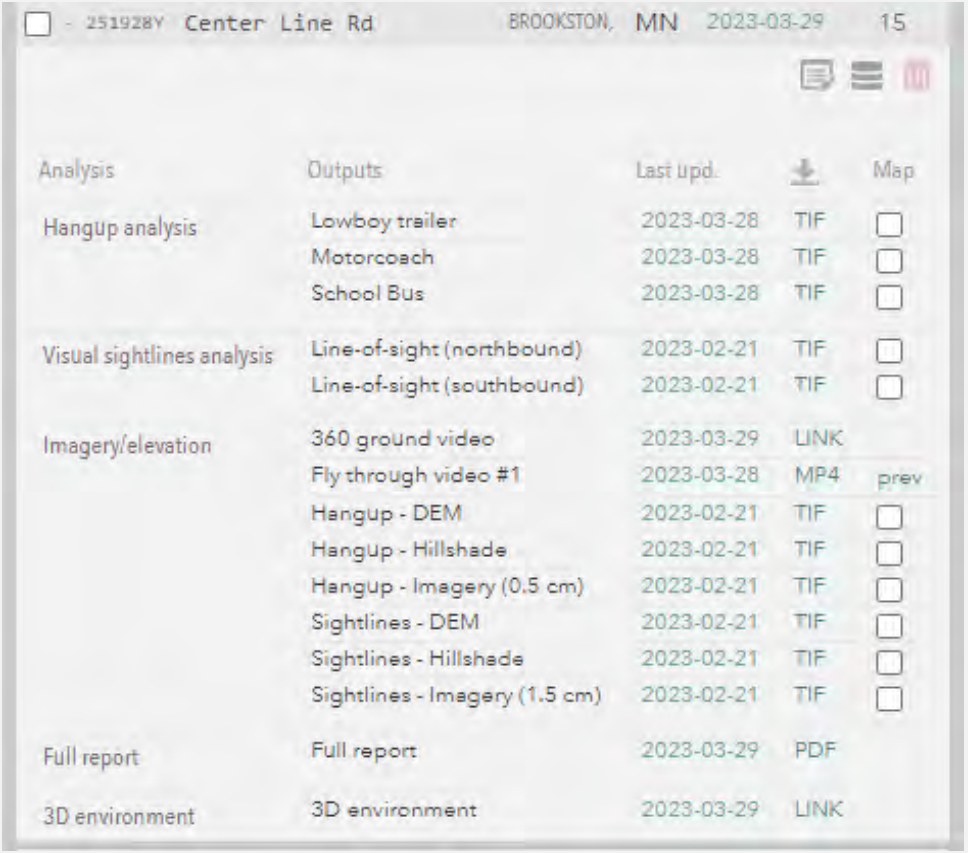
TECHNOLOGY SOLUTION: CROSSING-I

- Crossing-i demonstrated in 34 crossings (five states), 2019-2021 (SBIR I & II funding)
  - MnDOT, WISDOT, MDOT, INDOT, ICC
  - Crossing survey planning & execution methods are well established & efficient
- MnDOT, St. Louis County (MN), Ohio Rail Development Commission (ORDC) partners for 2022-2023 projects
  - Collected 12 crossings near Duluth last week, Oct. 2022
  - 5 Ohio crossings, May 2023
- 30 crossings in MI – working with ENSCO to compare to train lidar system (DOTX 218)



15+ CROSSING-I PRODUCTS AVAILABLE FOR EACH CROSSING:

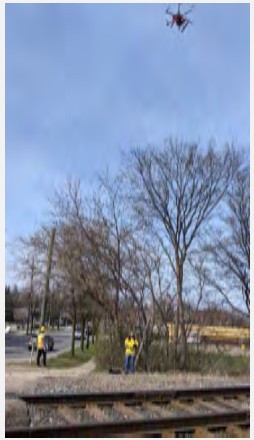
- Hang-up analysis (low ground clearance)
  - Lowboy trailer
  - Motorcoach
  - School Bus
  - Customizable to other vehicles
- Visual sight lines - are there sightline issues for vehicles approaching the crossing?
  - Active vs. passive crossings
  - Able to create dynamic (animated) sight lines
- GIS results
- Drone video
- 360˚ camera video (driver's point of view)
- Crossing-i report
- 3D environment

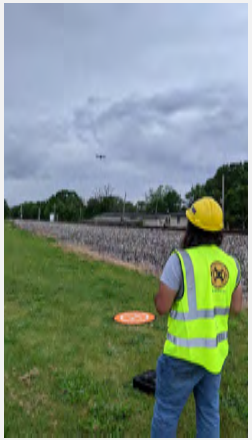


DRONE-ENABLED DATA COLLECTIONS

- Completed data collections for crossing assessments for SBIR funding
  - Completing up to 8 crossings per day, more possible (depends on proximity of crossings, FAA rules for flight operations)
    - Submitted whitepaper to FAA to enable Beyond Visual Line of Sight (BVLOS) operations for grade crossing assessment via drone
  - Crossing data typically collected within 45 minutes.
- Data collection workflow

1. Place ground control targets (now with Aeropoints)
   - 4 at the crossing for humped crossing
   - 2 further away from crossing for visual sight lines
     - Specific distance from crossing is determined by AASHTO Green Book calculations for sight line triangles
2. Fly larger UAS with high-res imaging for humped crossing analysis
3. Fly smaller DJI Mavic 2 Pro for visual sight lines analysis; can do all with larger UAS
4. Retrieve ground control targets

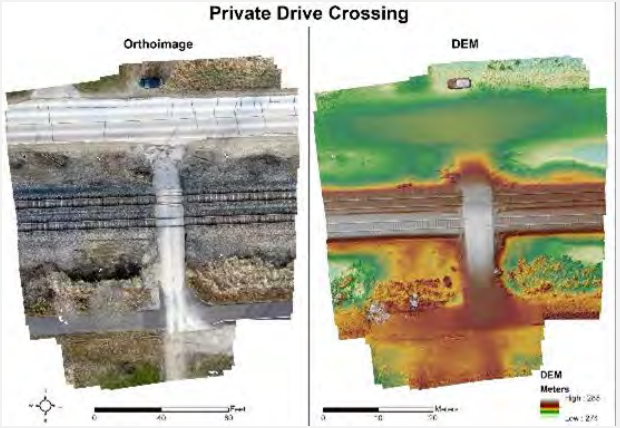


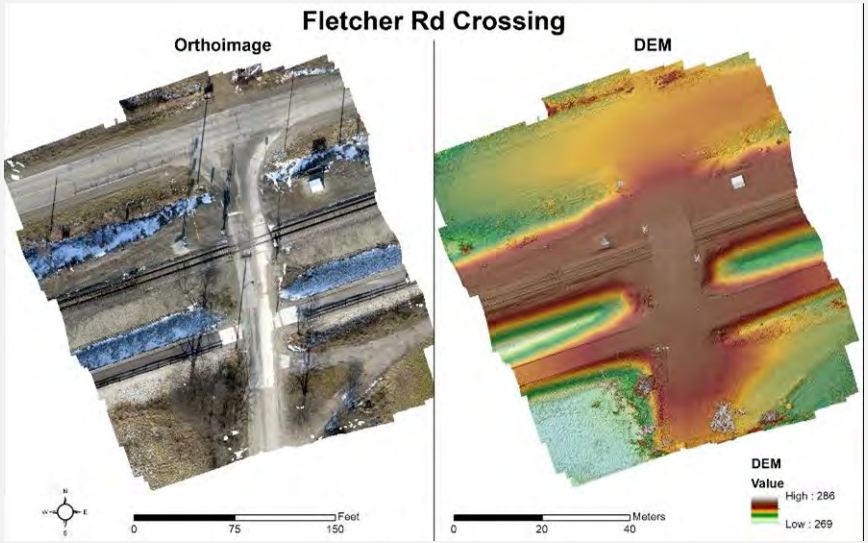


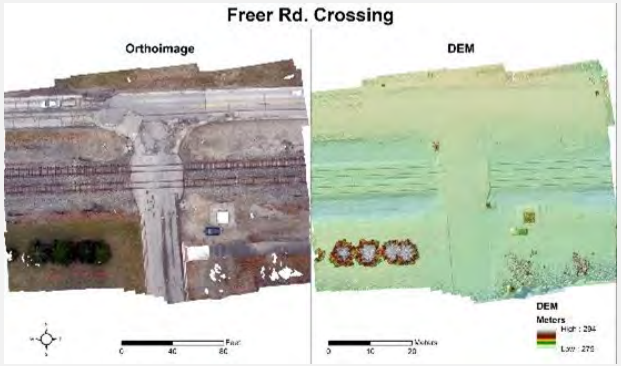
HIGH RESOLUTION IMAGES:
USED FOR 3D DATA GENERATION WITH PHOTOGRAMMETRY

- Collected via drone, with flight plans
  - Higher-resolution for crossing profiles
  - Moderate resolution for larger site line analysis areas

HIGH RESOLUTION IMAGES & ORTHO OUTPUTS, INCLUDING DEMS







442ND ST, HARRIS, MN – 082750K

U. S. DOT CROSSING INVENTORY FORM

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

OMB No. 2130-0017

Instructions for the initial reporting of the following types of new or previously unreported crossings: For public highway-rail grade crossings, complete the entire inventory form. For private highway-rail grade crossings, complete the Header, Parts I and II, and the Submission Information section. For public pathway grade crossings (including pedestrian station grade crossings), complete the Header, Parts I and II, and the Submission Information section. For private pathway grade crossings, complete the Header, Parts I and II, and the Submission Information section. For grade-separated highway-rail or pathway crossings (including pedestrian station crossings), complete the Header, Part I, and the Submission Information section. For changes to existing data, complete the Header, Part I Items 1-3, and the Submission Information section, in addition to the updated data fields. Note: For private crossings only, Part I Item 20 and Part III Item 2.K. are required unless otherwise noted. An asterisk * denotes an optional field.

A. Revision Date (MM/DD/YYYY)	B. Reporting Agency	C. Reason for Update (Select only one)	D. DOT Crossing Inventory Number
02 / 20 / 2018	☒ Railroad ☐ Transit ☐ State ☐ Other	☒ Change in Data ☐ New Crossing ☐ Closed ☐ No Train Traffic ☐ Quiet Zone Update ☐ Re-Open ☐ Date Change Only ☐ Change in Primary Operating RR ☐ Admin. Correction	082750K

Part I: Location and Classification Information

1. Primary Operating Railroad	2. State	3. County
St. Croix Valley Railroad Company (SCXY)	MINNESOTA	CHISAGO

4. City / Municipality	5. Street/Road Name & Block Number	6. Highway Type & No.
☐ In ☒ Near HARRIS	442ND ST (Street/Road Name) / * (Block Number)	MUN 13

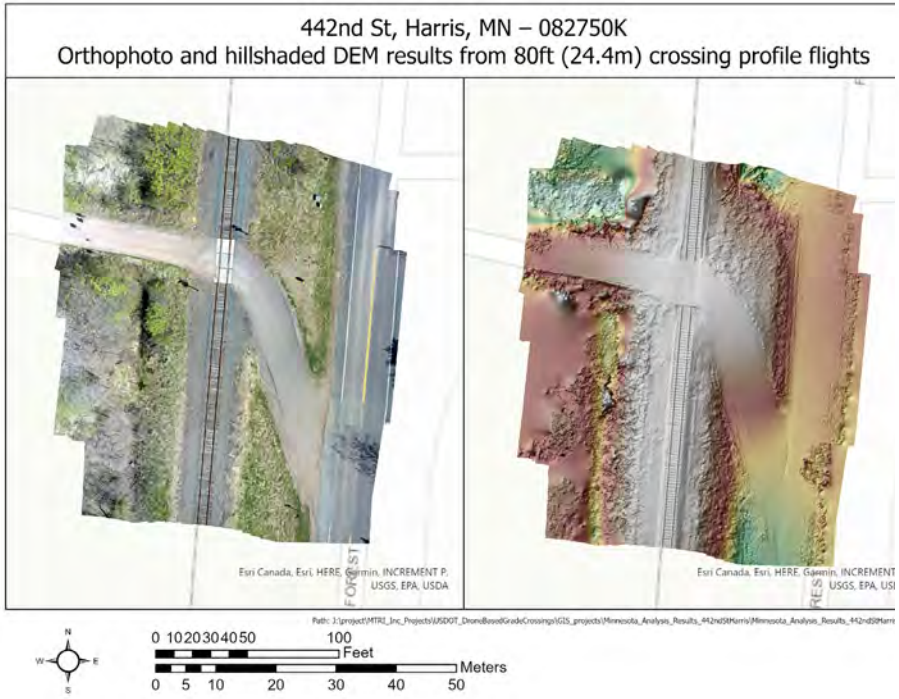
7. Do Other Railroads Operate a Separate Track at Crossing?	8. Do Other Railroads Operate Over Your Track at Crossing?
☐ Yes ☒ No If Yes, Specify RR	☐ Yes ☒ No If Yes, Specify RR

9. Railroad Division or Region	10. Railroad Subdivision or District	11. Branch or Line Name	12. RR Milepost (prefix) (mmm.mm) (suffix)
☐ None MINNESOTA	☐ None SCXY RR	☐ None HINCK-FOREST LK.	0046.09

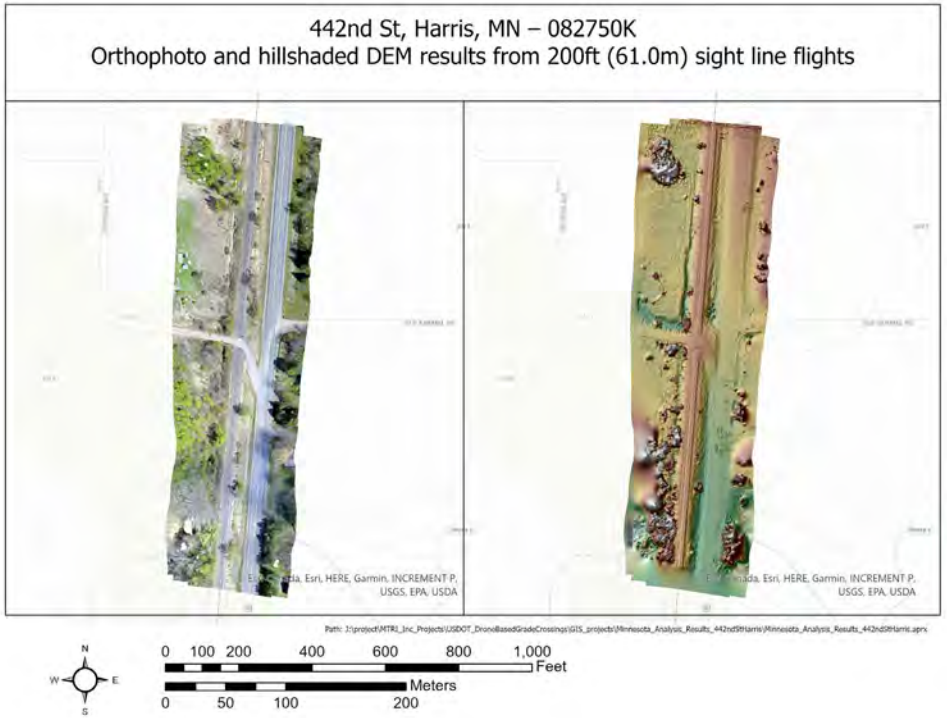
13. Line Segment *	14. Nearest RR Timetable Station *	15. Parent RR (If applicable)	16. Crossing Owner (If applicable)
0214	NORTH BRANCH	☐ N/A SCXY	☐ N/A SCXY

17. Crossing Type	18. Crossing Purpose	19. Crossing Position	20. Public Access (If Private Crossing)	21. Type of Train		22. Average Passenger Train Count Per Day
☒ Public ☐ Private	☒ Highway ☐ Pathway, Ped. ☐ Station, Ped.	☒ At Grade ☐ RR Under ☐ RR Over	☐ Yes ☐ No	☒ Freight ☐ Intercity Passenger ☐ Commuter	☐ Transit ☐ Shared Use Transit ☐ Tourist/Other	☐ Less Than One Per Day ☐ Number Per Day 0

442ND ST. ORTHOS & DEMS



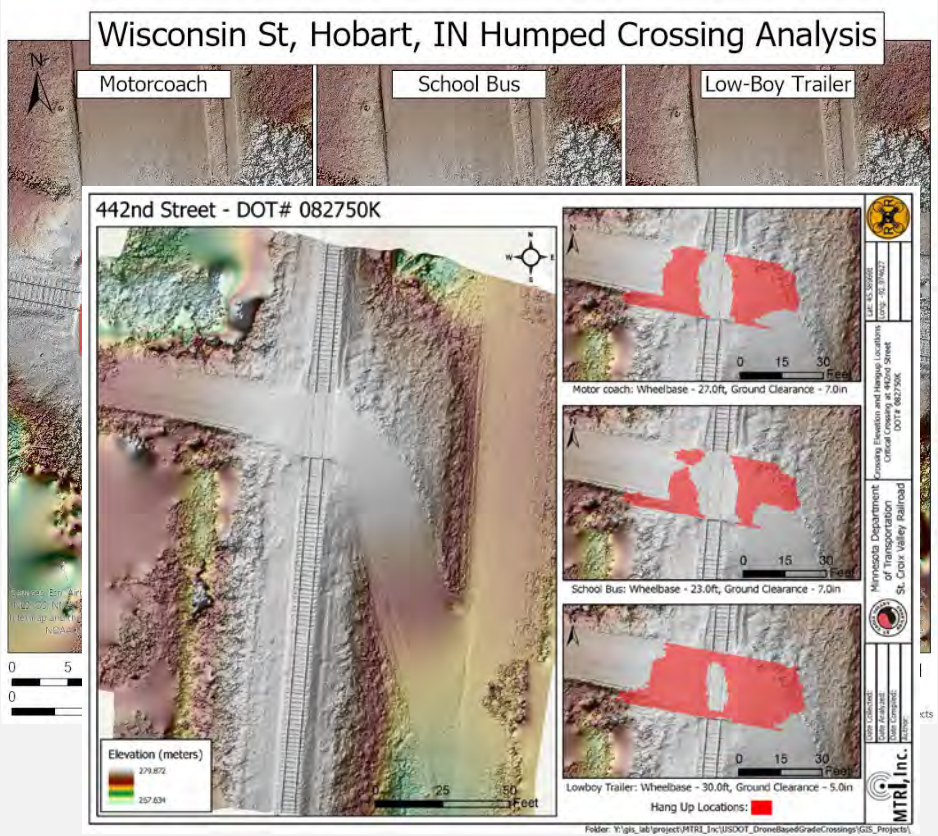
Crossing profile ortho resolution = 4.9mm pixel GSD (0.19”),

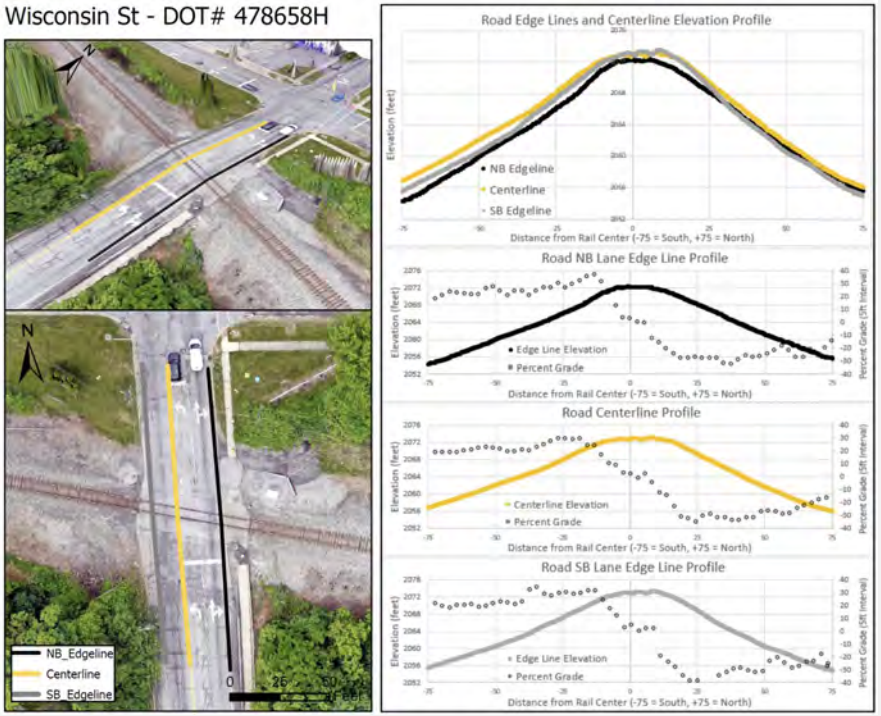


Crossing profile ortho resolution = 14.4mm pixel GSD (0.57”),

TECHNOLOGY SOLUTION – "HUMPED" CROSSINGS

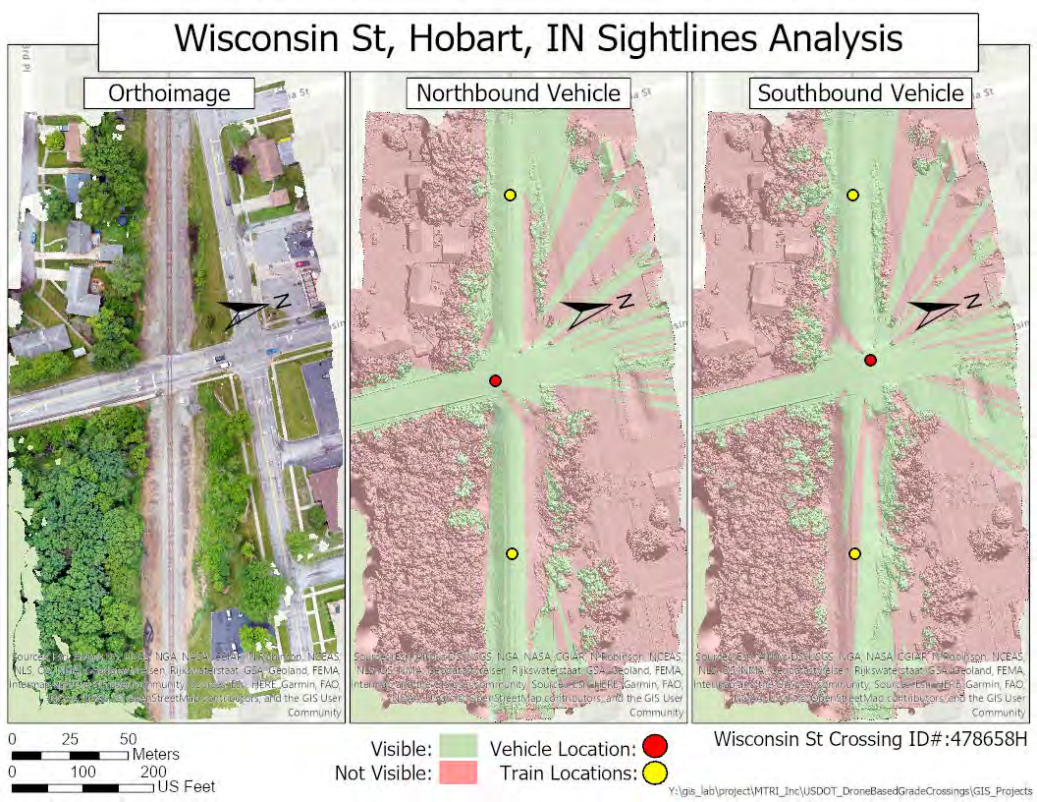
Automated Profile Assessment Tool – specifies specific hangup locations for multiple vehicle types

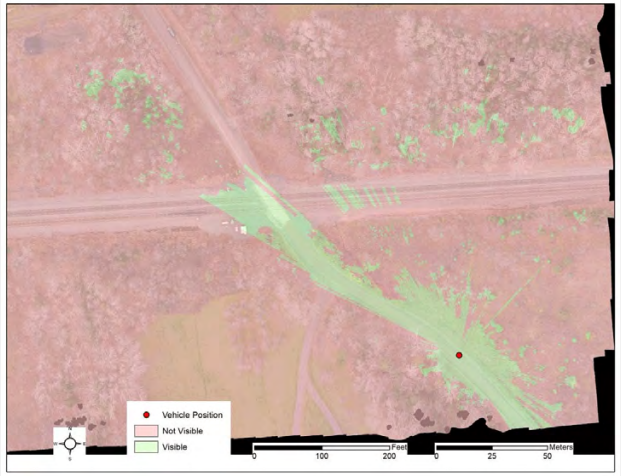




TECHNOLOGY SOLUTION – VISUAL SIGHT LINES

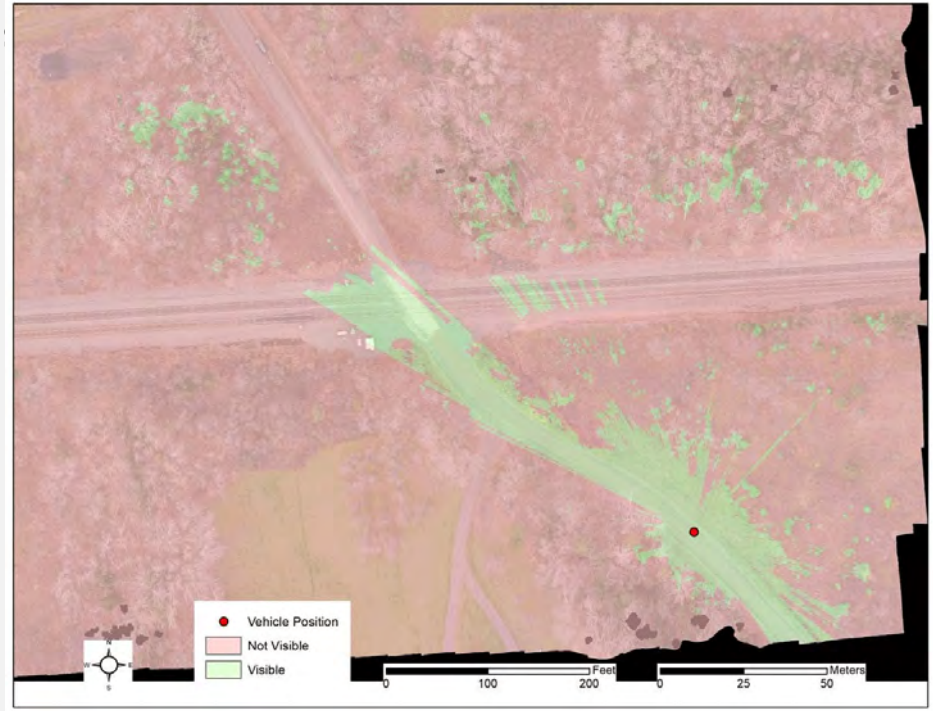
Railroad Grade Crossing Viewshed Tool Results – with dynamic results available

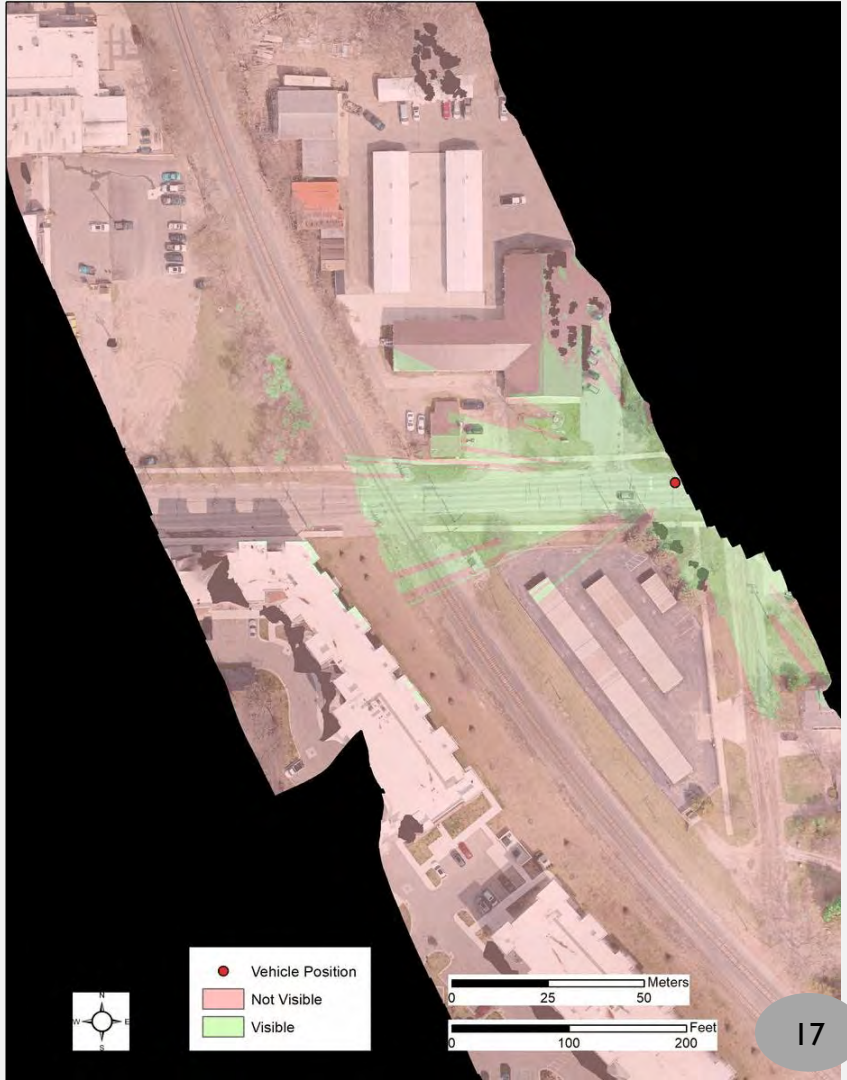




TECHNOLOGY SOLUTION

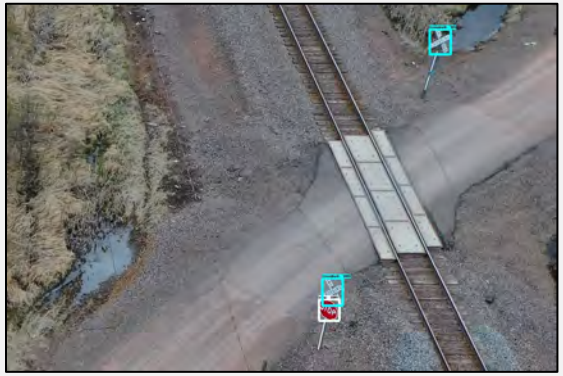
Dynamic Viewshed Tool Results

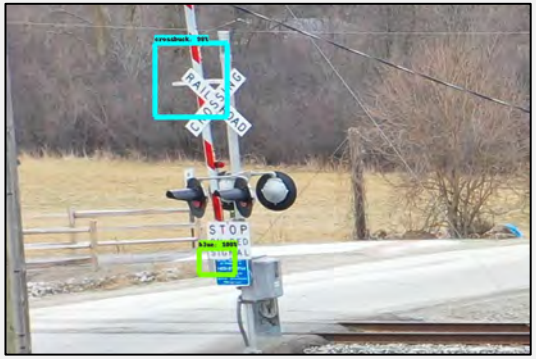




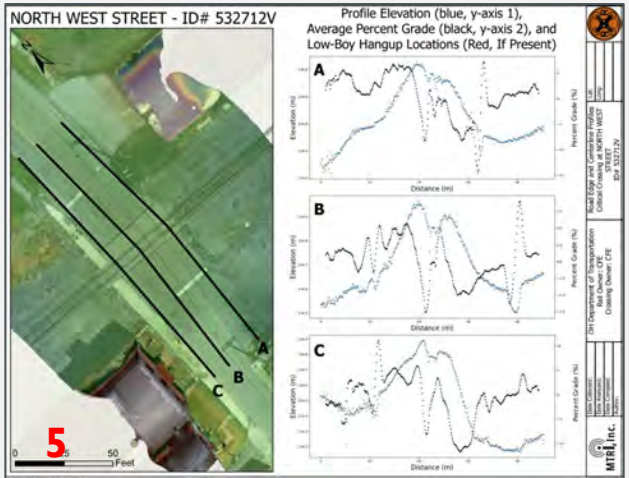
AUTOMATED SIGN IDENTIFICATION

Automated Sign Identification Using Machine Learning Tool Results





CROSSING-I REPORTS – 5-PAGE PDF FOR EACH SITE



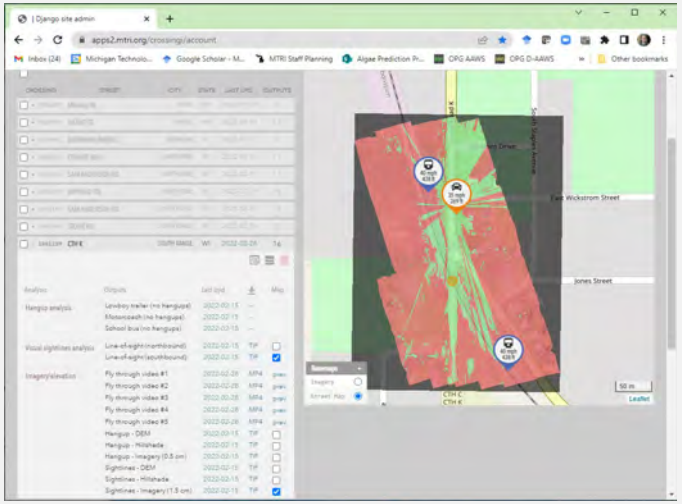
CROSSING-I PORTAL

- Customer Access Point
- Crossing-i Analytics Reports
- Fly-Through Videos
- 360˚ ground videos
- Crossing-i GIS Outputs
- Recording of standard crossing survey data

Added examples of 3D panoramic viewing of results to help with <u>Virtual Diagnostic surveys</u>

* Upgrades completed under Michigan Economic Development Corporation MTRAC program

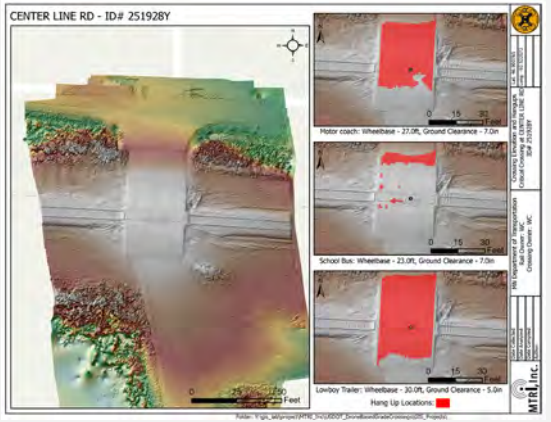
- Helpful for virtual diagnostics



GIS data viewing

Standard FRA report updating

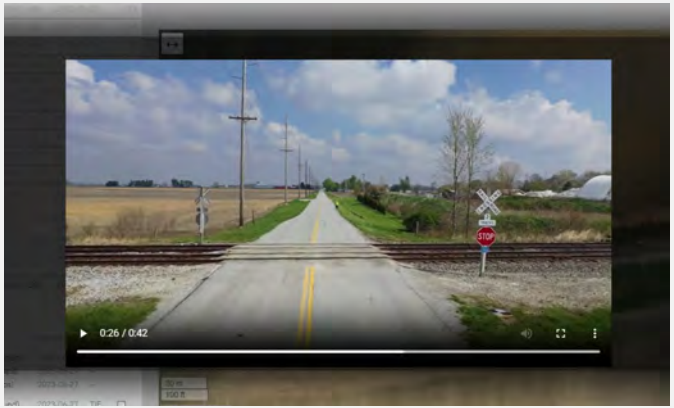
Video viewing

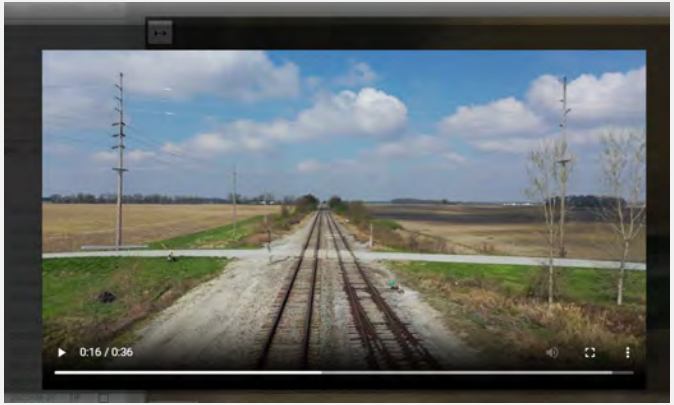


Access Crossing-i PDF reports

DRONE FLY-THROUGH VIDEOS AND 360° GROUND VIDEOS

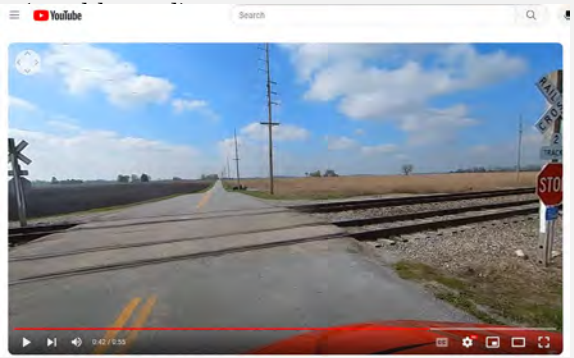
CR-110B (532625S) - Upper Sandusky, OH





Drone videos - road, track; can be viewed on site & downloaded

https://www.youtube.com/watch?v=K9VPWWRtWgE



https://www.youtube.com/watch?v=f_ir3JpkE4E (southbound)

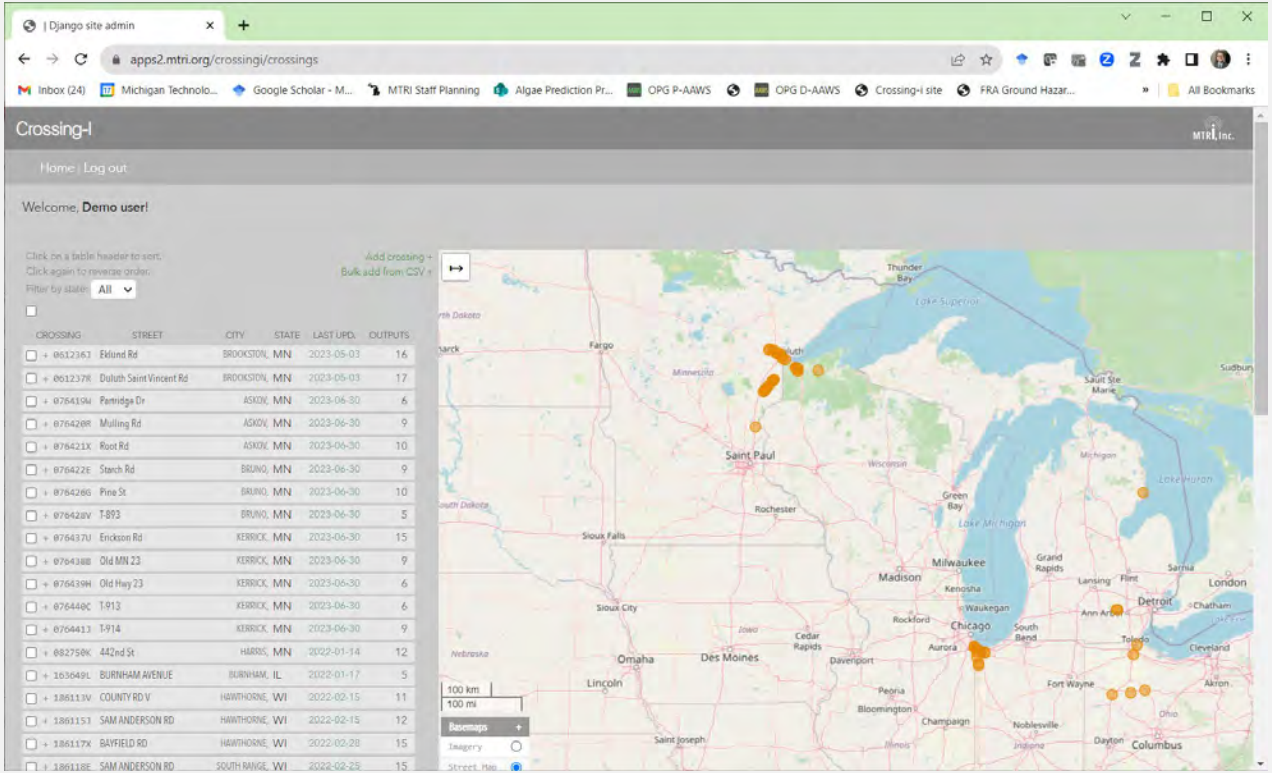
Insta360 ground videos from moving car - can be rotated, paused

POTENTIAL IMMEDIATE ROI - "VIRTUAL DIAGNOSTICS"

- Based on inquiry/suggestion from DOTs
- To reduce complexities and resources needed for diagnostics meetings
- Use resources demonstrated today
- Quantifying the true value/benefits

Parameter	Virtual Diagnostics	Traditional Diagnostics
Time Commitment	Low and consistent	High and variable
Coordination Complexity	Medium (no travel)	High (travel and meeting time)
Meeting Cost	Low (only time cost)	High (travel, lodging, time)
Stakeholder absence	Later review of recordings	Requires new time
Documentation	Reports (Crossing-i) & Recording	Create after meeting
Safety	High (office)	Low (live traffic)
Access to data	Any time (portal)	Meeting only (marked)

CROSSING-I PORTAL DEMO (TIME PERMITTING)

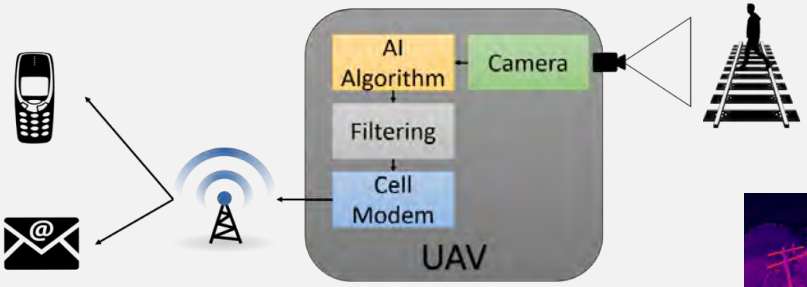


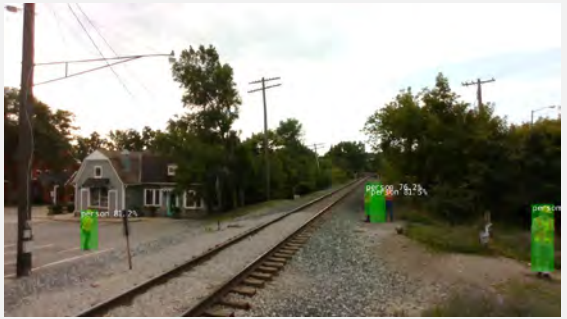
- https://apps2.mtri.org/crossingi/account

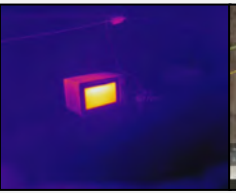
RAILROAD ARTIFICIAL INTELLIGENCE INTRUDER LEARNING SYSTEM (RAIILS)

Colin Brooks, Ph.D.
cnbrooks@mtu.edu
734-604-4196 (mobile)
with Eric Vega (PI)

- Drone-based automated detection of trespassers at sites of interest
- Detection can take place in real-time w/ onboard AI/ML detection algorithm
- System can automatically send email or text message to interested party
- Report on RAIILS prototype available - FRA
- Next steps: demonstrate with tethered & longer-duration drones



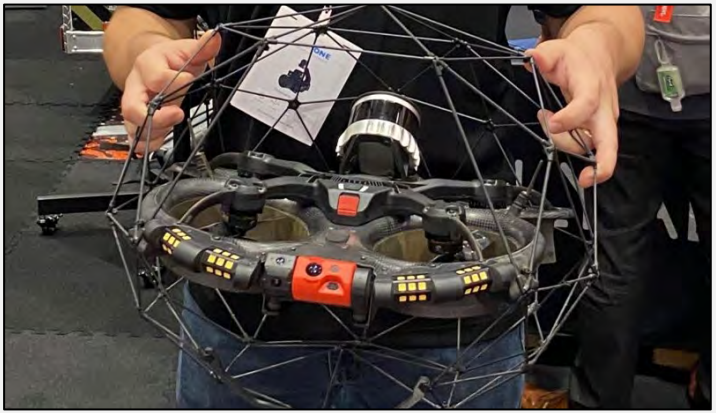




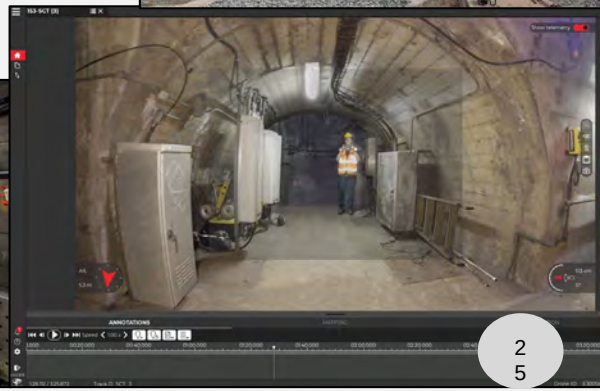
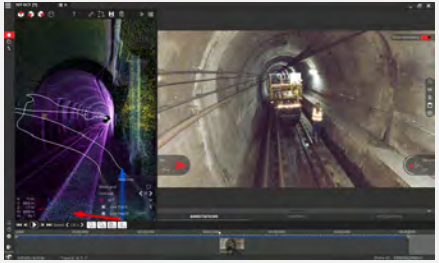
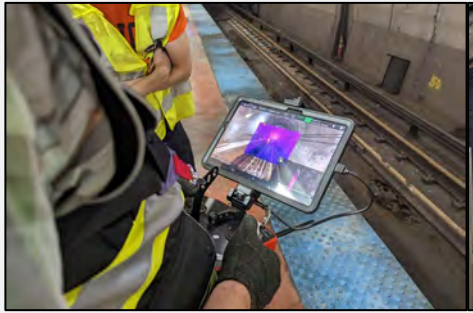




PHASE III CROSSING-I SBIR: DATA COLLECTION RELATED TO THE STRUCTURAL INTEGRITY AND SAFETY OF TRANSIT TRACKS

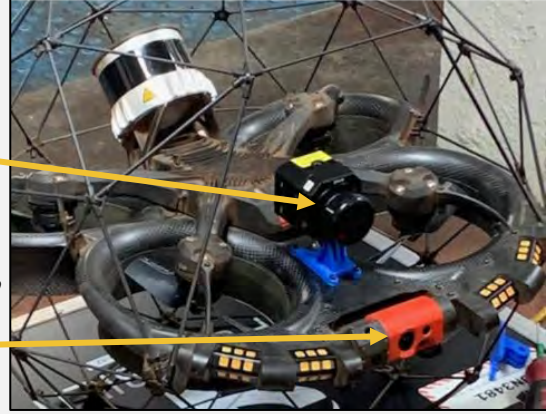


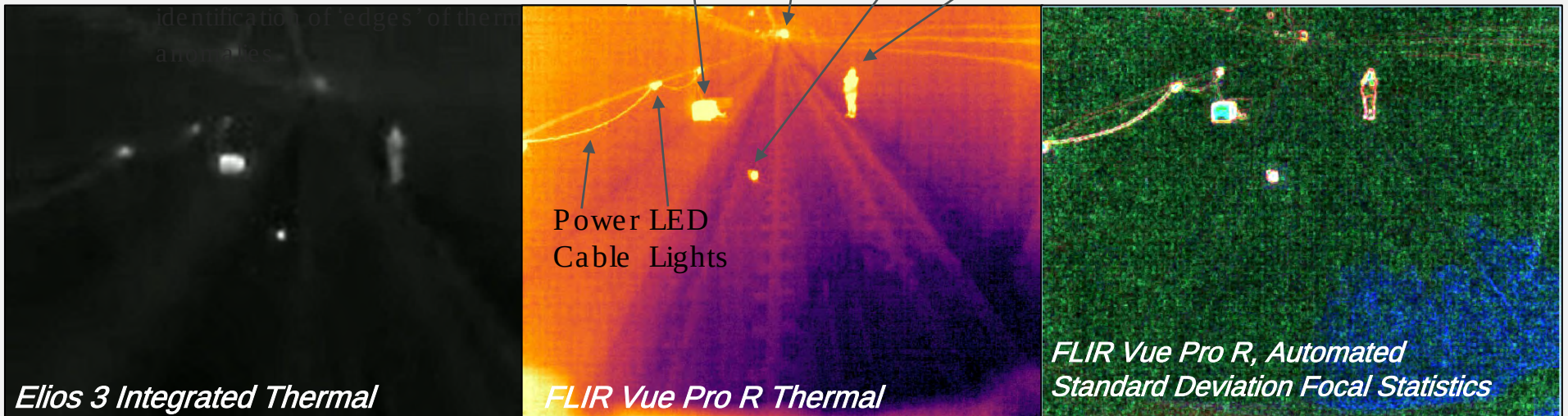
- FTA funding through USDOT Volpe
- Demonstrating Flyability Elios 3
- Working with Enspect Engineering
- Demonstrating at Chicago Transit Authority tunnel
- Plans for TTC demo (ENSCO) in CO


Thermal Data Comparison & Analysis

- Detection of thermal anomalies - equipment & people
  - Oven, space heater, researcher, and warm electrical infrastructure clearly visible
  - FLIR Vue Pro R (640x512 pixels) has much greater pixel resolution relative to Integrated FLIR Lepton 3.5 (160x120 pixels)
  - Focal Statistics useful for automated identification of edges of thermal anomalies





An Integrated and Automated Decision Support System for Ground Hazard Risk Mitigation for Railways using Remote Sensing and Traditional Condition Monitoring Data

PIs: Thomas Oommen (now at OleMiss), Pasi Lautala, Colin Brooks

Program Manager: Hugh Thompson, FRA

Michigan Tech Research Institute

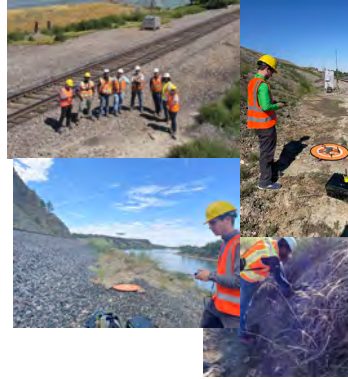
Rail Transportation Program
Michigan Tech Transportation Institute • Michigan Technological University

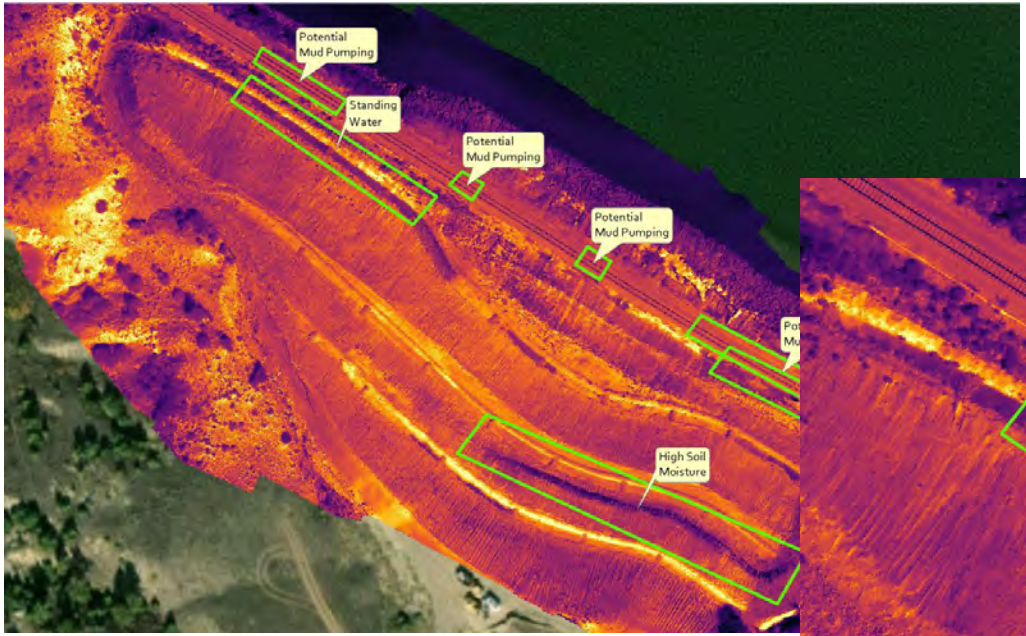
Michigan Technological University

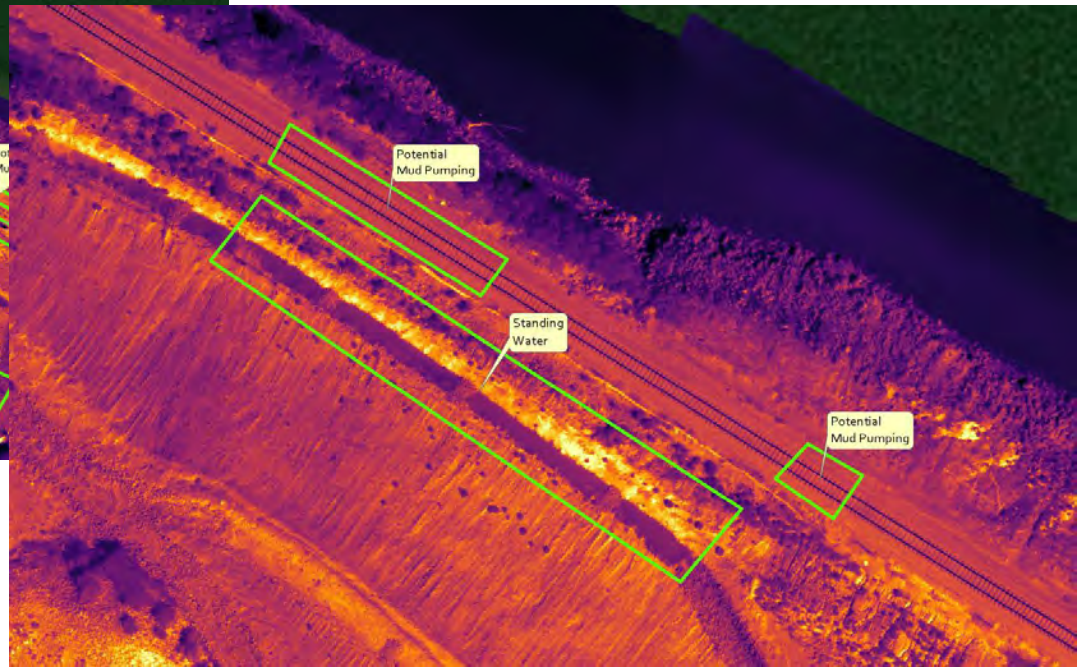
LORAM Technologies

LORAM Finland

Analysis of Field Data Collected

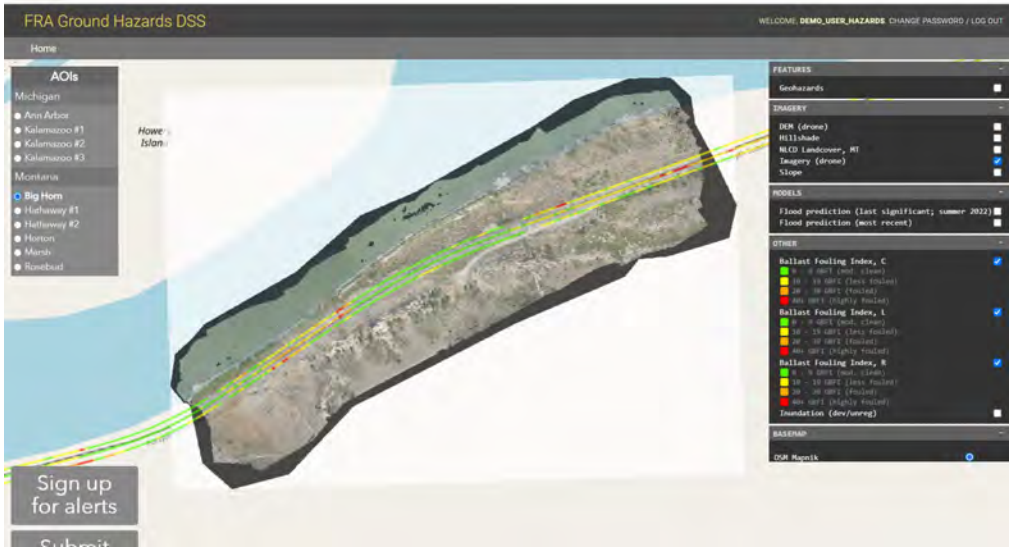






Decision Support System

- The decision support system is being built for this project to provide a database structure to manage all the data acquisitions and serve as a platform for deploying all machine learning models.



Decision Support System

NEXT STEPS FOR DRONE-ENABLED RAIL GRADE CROSSING ASSESSMENT WITH CROSSING-I:

- Technology exists to assess all or nearly all crossings in the U.S. that might have low-ground clearance / humped problems – airborne (Crossing-i), complements train-mounted LiDAR systems as well (DOTX 218)
  - Crossing-i is useful for crossings that train-mounted LiDAR systems cannot easily be deployed at
  - Can be deployed at will unless near towered airports
- Technology is now available & ready for use
  - Currently for line-of-sight high resolution 3D assessment
  - Improved for 360° virtual crossing diagnostics, newest data for MN, OH, & MI
  - Can work with local drone data collection teams (rail companies, transportation agencies, drone services & engineering firms)
  - Able to create cost estimates for end-users

Crossing-i ready for commercial use

Interested in working with engineering & drone firms as well

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