Protecting Railway Workers with an Electronic Overlay – a Demonstration

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ABSTRACT

Miller Ingenuity is committed to preventing near-misses and fatalities for railway workers. The NTSB Safety Alert (SA-066) released in July 2017, discusses the problem with Train Approach Warning protection, provided by a watchman/lookout, not restricting either trains or equipment from entering a work location. Essentially, these factors all point to human error, whether that is fatigue, distraction, incomplete job briefings, side effects of performing a repetitive routine, and more.

Miller Ingenuity entered an agreement with Maryland Transit Administration to install ZoneGuard™, an electronic roadway worker protection (eRWP) system, on 30 miles of their light rail line through a FTA Safety Research and Demonstration (SRD) Program grant. The program includes research, implementation, and testing of a fixed (permanently mounted) eRWP system capable of detecting, locating and tracking trains and other track vehicles, alerting train operators who are approaching work crews, and alerting work crews of approaching trains within safe clearing times.

In addition to presenting an update of data taken from the research program, Miller will discuss the importance of adopting innovative electronic RWP systems to use in conjunction with existing railway worker safety rules and the important role these systems play on worker safety and efficiency.

Key Takeaways:
1. The problem: Insufficient TAW protection
2. A solution: Electronic RWP system safety overlay
3. eRWP Performance Update: data review

Learning Objectives

Why are existing safety rules and procedures failing to protect railway workers?
Existing safety procedures can only work to a certain extent. An electronic solution that coincides with current safety rules protects workers from common human error factors that are frequent contributors to accidents and close-calls, such as distraction, complacency, miscommunication, and inexperience.

What is electronic roadway worker protection and how is it used to protect railway workers?
Electronic roadway worker protection is typically a system that detects trains entering a work zone and alerts workers of the approaching track vehicle to help prevent tragic accidents or close-calls.

The ZoneGuard™ eRWP system uses a unique and redundant combination of four different sensor technologies - LIDAR, RADAR, infrared camera, and accelerometer – to accurately detect oncoming track vehicles entering a work zone and alert the roadway workers via a wearable device with an audible and physical alarm.

ZoneGuard's™ flexibility allows it to perform within high-noise urban environments, under high power lines, and across multiple tracks. While also not requiring on-board installation to operate, the system's on-board component is compatible and able to integrate with PTC implementation.

The system's cloud-based web portal can provide customers with real-time worker/work zone information, as well as, many key efficiency and safety performance reports to ensure that workers are working in compliance with federal and customer specific safety rules.

In addition to a permanent installation, ZoneGuard™ is also available in a light-weight portable solution.

How does the system perform in various unique operating environments and circumstances?
(example – multiple tracks, lone worker, within urban settings)
This answer will be present through data that is currently being collected at the Maryland Transit Authority's Light Rail Line. The data will show accuracy of the system in various scenarios and additional data points that present themselves.

How can eRWP improve the efficiency and accuracy of railway workers?
ZoneGuard™ automatically detects a train entering an established work zone and sends an audible and physical alarm to each individual worker via a wearable device. This gives the workers ample time to quickly and safety clear the work zone. The train operators are then able to move through the work zone without disruption to service. This results in improved train velocity and operating ratios and improved work zone efficiency.

INTRODUCTION

For years, roadway workers have experienced inconsistent protection while working in active work zones. Traditional roadway worker protection (RWP) rules and procedures were created to prevent costly accidents and personal injuries to work crews, however, there are still frequent close calls and tragic accidents that occur every year. According to the Fatality Analysis of Maintenance-of-way Employees and Signalmen Committee (FAMES), there have been an estimated total of 52 fatal RWP accidents in which 55 roadway workers have perished, between 1997 and February 1, 2017. *(1)*

The NTSB has taken notice. The FTA received an urgent safety advisory from the NTSB in December of 2013 (SA-14-01) recommending that they "issue a directive to all rail transit properties requiring redundant protection for roadway workers, such as positive train control, secondary warning devices, or shunting. (R-13-39)" *(2)* Additionally, this safety advisory concluded "that lone workers, moving crews, and workers moving point-to-point who access the right-of-way (ROW) solely under their own protection are at significant risk of being struck by trains." *(2)* "Under their own protection, track workers may not be aware of the presence of a train" *(2)* so they recommended that "redundant protection be used when workers are on the ROW under their own protection"*(2)* such as "secondary warning devices and alert systems." *(2)*

A NTSB Safety Alert (SA-066) released in July 2017 outlined an issue with Train Approach Warning (TAW) protection provided by watchman/lookouts "not restrict[ing] either trains or equipment from entering a work location." *(3)* The alert stated that there are many issues that can cause a watchman/lookout to provide insufficient TAW protection, including:

- If a watchman/lookout does not devote his full attention to detecting approaching trains, he may not provide warning in sufficient time for the work group to clear to a safe location. *(3)*
- When a watchman/lookout does not consider variables such as train speed, track characteristics, sight distance, noise, environmental conditions, and whether the train carries freight or passengers, TAW does not provide adequate safety for the work group. *(3)*
- If a watchman/lookout does not provide a clear and distinct warning of approaching trains, roadway workers are unlikely to clear the track before a train arrives. *(3)*
- If a job briefing for on-track safety is incomplete, roadway workers may not be aware of vital information, such as the location of a previously arranged place of safety, the required sight distance to detect an approaching train, or the means the watchman/lookout will use to communicate an approaching train. *(3)*

On October 4, 2018, the NTSB issued Safety Recommendation R-18-025 in response to a fatal April 2016 roadway worker accident involving an Amtrak train striking a backhoe in an active work zone. The conclusion of the investigation led the NTSB to recommend to the FRA that they "study available technologies that automatically alert maintenance-of-way workers fouling tracks of approaching trains, then require that such technology be implemented as a redundant protective measure." *(4)*

It is observed that throughout the years, the NTSB has issued many safety alerts, advisories and recommendations to transit railroads for the adoption of a redundant form of technology that provides roadway workers with additional protection. The recommendations have also essentially lead to one conclusion for the root cause of these accidents: human error. Fatigue, distractions, miscommunication within a job briefing or with the train operators, failure to warn with a clear and distinct manner or in enough time to allow the crew to clear the track, inexperience or even the side effects of performing a repetitive routine have all lead to these reported tragic accidents or close calls.

With this information, Miller Ingenuity developed an electronic roadway worker protection (eRWP) system that uses redundant train detection sensors to identify track vehicles entering an active work zone. This system operates as a safety overlay to work with and enhance existing safety procedures to eliminate the human error factor of roadway worker safety.

ELECTRONIC ROADWAY WORKER PROTECTION SYSTEM – HOW DOES IT WORK?

ZoneGuard™, Miller Ingenuity's eRWP system, is comprised of Train Detection Modules (TDMs), Train Alert Modules (TAMs), and worker wearable devices. The system can be used portably, or it can be permanently installed. ZoneGuard™ uses a unique combination of redundant sensor technologies to capture motion entering a work zone. The LIDAR, radar, accelerometer, and infrared cameras work together to ensure that a track vehicle will be detected consistently and accurately every time and in all conditions.

ZoneGuard™ Fixed System

Workers are outfitted with wearable devices that are connected to the ZoneGuard™ network and provide the system with updated worker location information. Each TDM and TAM is configured with a customer and location specific track profile, which includes the Maximum Allowable Speed of every track segment and a configurable alert time for when trains are approaching connected on-track workers. Alerts are configured to a minimum of 15 seconds to meet federal regulations but can be configured to provide greater warning times to meet customer specific rules or to increase the overall safety of the worker.

As trains and workers are detected, the system continuously monitors their locations and calculates intercept times between trains and connected workers in order to generate alerts at the configured time. This setup allows for workers and trains to receive alerts when trains are approaching workers despite track curves, tunnels, bridges, and when workers are working in multiple track territories.

The ZoneGuard™ fixed system provides 24/7 train tracking capability and is online ready to be used by any number of roadway workers, at any time, with no configuration or setup required. Roadway workers simply need to enter within radio range of the outfitted track alignment, connect to the ZoneGuard™ network, and will begin receiving alerts for all approaching on-track vehicles that are within a specific time of arrival to roadway workers, based on customer specific On-Track Protection rules.

While not requiring on-board installation to operate, an optional on-board component can provide real-time vehicle location information to provide precise warnings to train operators and workers when approaching an active work crew and can allow for PTC integration through future updates.

Figure 1: Installation of fixed ZoneGuard™ eRWP system on MTA Baltimore Light Rail Line.

ZoneGuard™ Portable System

The portable eRWP kit is used as a standalone system and does not rely on any outside on-board or signaling systems in order to operate. The train detection modules define the outermost limits of the detection and alerting zone and are temporarily placed at the limits of a work zone, which is typically defined by a customer's sight-distance rules for watchman or are placed alongside approach and stop boards. TAMs are placed in between the outermost TDMs to act as radio network repeaters for TDMs and workers that are connected to the network through their wearable devices. As an additional alert to workers, TAMs also include a siren and bright side LED warning lights that are enabled when a train detection alert has been generated by TDMs.

The TDMs that are placed at the outermost limits of the temporary work zone will detect approaching on-track vehicles as they reach TDM locations and will generate alerts to all worker wearables and train alert modules that are in use.

Once the alert has been received, workers have cleared to their place of safety, and it has been determined that it is safe to resume work, the ZoneGuard™ alerts are reset using working wearables or at any TDM/TAM location in order to receive an alert for the next approaching on-track vehicle.

Figure 2: Portable ZoneGuard™ eRWP TDM

MARYLAND MTA SAFETY RESEARCH AND DEMONSTRATION PROGRAM

Project Description
Miller Ingenuity entered an agreement with Maryland Transit Administration to install, study, and test ZoneGuard on 30 miles of their light rail line through a FTA Safety Research and Demonstration (SRD) Program grant. The Proof-of-Concept (POC) project explores and demonstrates a fixed-mounted Train Detection and Worker Warning system.

The purpose of the project is to demonstrate the ability to detect on-track vehicles using wayside mounted detection sensors, to share this information across a linear communication network, and to warn workers of approaching trains through personal wearable devices that are connected to the communication network. This POC project is being demonstrated by developing a fixed-infrastructure deployment of the ZoneGuard™ Roadway Worker Protection system. The system employs the use of TDMs, TAMs and personal wearable devices for workers. Train Detection modules are installed at key locations along the Baltimore Light Rail line and are responsible for detecting trains as they move throughout the Light Rail system. TAMs are installed in between TDM locations where needed, to act as radio network repeaters in locations where TDM to TDM wireless communication cannot be achieved either due to distance or line-of-sight constraints. Once the complete linear communication network has been formed, TDMs will share train detection location information along the radio network. When a worker or work group joins the communication network through their personal wearables, the network will take note of the location of these workers and will notify roadway workers of approaching trains in advance of a train arrival, in conjunction with federal regulations and MTA specific on-track worker requirements.

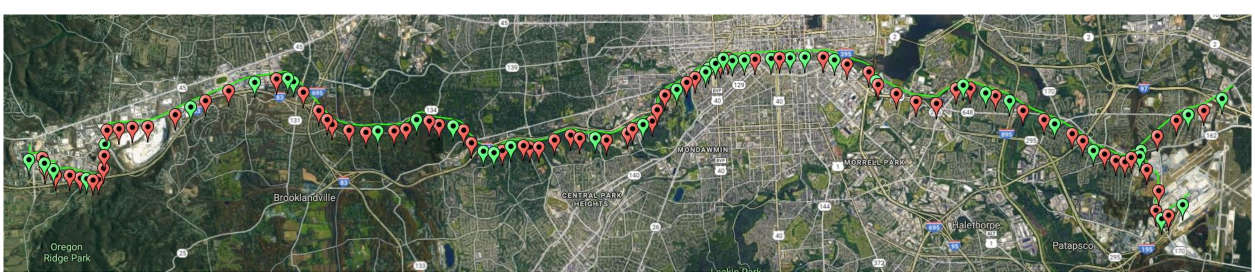

Figure 3: Installed TDMs and TAMs on MTA Baltimore Light Rail Line

Project Results

Test 1 Light Rail 3rd Party Camera Detection Verification (TDM000015)

Dates: September 20, 2018 to September 22, 2018

Location: This survey report covers TDM000015 detections during this timeframe.

Setup: Miller Ingenuity has installed a series of 3rd Party Cameras in order to verify the TDM's detection algorithm. This algorithm has been fine-tuned through several firmware revisions, and this verification process is integral to proving the integrity of the system's detection capabilities.

A camera is installed in close proximity to the TDM that will be under observation. A Miller Ingenuity employee navigates all 24 hours of video and manually records all instances of a train passing by. This collected data is then compared to the detection logs of the associated TDM, and an accuracy calculation is derived from this comparison.

The accuracy calculation is based off of False Positives (when a TDM records that a train was detected, when in reality no train or something else passed in front of it) and False Negatives (when a TDM fails to record that a train passed in front of it).

Test 1 Results:

1. During the observation period from September 20 to September 22, a total of 132 detection events were recorded from observing the recorded video footage.
2. The weather was moderately overcast. There were no extreme weather circumstances (strong thunderstorm, blizzard, etc.) to report.
3. From those 132 detection events:
    a. 132 detections were properly recorded by the TDM.
    b. 0 False Positives were found.
    c. 0 False Negative was found
    d. The detection algorithm accuracy calculation over these five days is 100.0%.

Test 1 Light Rail 3rd Party Camera Detection Verification (TDM000019)

Test 2 Dates: August 9, 2018 - August 12, 2018; September 20, 2018 - September 23, 2018

Test 2 Location: This survey report covers TDM000019 detections during this timeframe.

Test 2 Setup: Miller Ingenuity has installed a series of 3rd Party Cameras in order to verify the TDM's detection algorithm. This algorithm has been fine-tuned through several firmware revisions, and this verification process is integral to proving the integrity of the system's detection capabilities.
A camera is installed in close proximity to the TDM that will be under observation. A Miller Ingenuity employee navigates all 24 hours of video and manually records all instances of a train passing by. This collected data is then compared to the detection logs of the associated TDM, and an accuracy calculation is derived from this comparison.

The accuracy calculation is based off of False Positives (when a TDM records that a train was detected, when in reality no train or something else passed in front of it) and False Negatives (when a TDM fails to record that a train passed in front of it).

Test 2 Results:

1. During the observation period from August 9 to August 12 and September 20 to September 23, a total of 605 detection events were recorded from observing the recorded video footage.
2. The weather was moderately overcast. There were no extreme weather circumstances (strong thunderstorm, blizzard, etc.) to report.

3. From those 605 detection events:
    - a. 605 detections were properly recorded by the TDM.
    - b. 0 False Positives were found.
    - c. 0 False Negative was found
    - d. The detection algorithm accuracy calculation over these five days is 100.0%

Detection Data – October 22, 2018 - October 28, 2018

This data is taken from five detectors installed at MTA over a seven-day period. Over a one-week time period there were roughly 950 trains that passed each of these detectors. Not all sensors detected the exact same number of trains, which is expected of the system.

TDM/TAM ID	10-22-2018 to 10-28-2018							
	Individual Sensors Detection					Application Detections		
	Accelerometer Moderate Detections	Accelerometer Strong Detections	RADAR Detections	LeddarOne Detections Near Track	LeddarOne Detections Far Track	Near Track Trains	Far Track Trains	Total
TDM000007	7723	1187	994	634	398	597	397	994
TDM000014	6550	410	1106	1140	0	999	0	999
TDM000003	9239	1693	1300	1233	0	1008	0	1008
TDM000028	2715	949	975	502	491	501	491	992
TDM000010	5593	1047	988	497	494	497	494	991

Figure 4. TDM and TAM detection data for October 22-28, 2018.

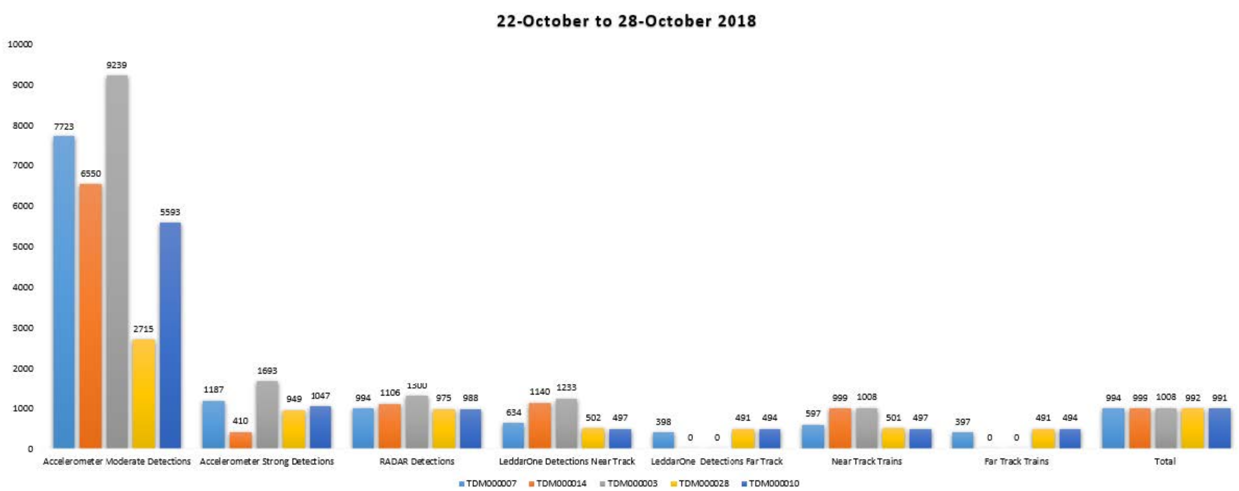

Figure 5. TDM and TAM detection data for October 22-28, 2018.

Sample Detection Results: All sensors have the same settings with the exception of sensing distance, which is set based on the distance each detector is installed relative to the track(s) it is monitoring. Despite this fact, some detectors have a radar that is sensing far more objects than its neighbors and some detectors have a LIDAR that is sensing far more objects than its neighbors. This tells us that each unique location where a detector is installed has differing environments and surroundings that cause different types of sensors to detect at different rates from one location to another.

In this data, if we were to use only one type of sensor in our system to detect trains and generate alerts, we would be extremely inconsistent. Using only one type of sensor to detect trains would cause a system to have high number of false alerts, meaning workers would become complacent with the system and begin ignoring alerts. By using an algorithm that uses multiple types of sensors, and not just multiple sensors, we are able to virtually eliminate false detections and/or alerts and missed detections.

Once all sensors are detecting an object at the same time, the Train Detector determines that a train has been detected and takes a picture using the infrared camera. This allows development teams to go back through every instance of a train detection and look at the picture evidence to determine every instance in which a false detection occurred. If we are able to find such an instance, the data leading up to and during that time is used to refine the algorithm so that particular false detection is removed from the algorithm in the future.

CONCLUSION

It is obvious that there is a problem with how maintenance-of-way rail safety procedures are currently operating. These procedures rely heavily on human judgement and more often than not, those human decisions are contributing factors in numerous close-calls and tragic accidents. The NTSB has made it clear that they fully recommend transit rail to invest in "redundant protection" *(2)* such as "secondary warning devices and alert systems." *(2)*

The data shown from Miller Ingenuity's eRWP technology currently being tested at MTA Baltimore's Light Rail Line, proves that the patented multiple sensor technologies being used in the ZoneGuard™ system creates a consistently accurate and reliable train detection solution. Because of the accurate detections, maintenance crews are able to work with an extra layer of safety and they are also able to clear the tracks quickly allowing train operators to move through the work zones without disruption to service. This results in improved train velocity and operating ratios and improved work zone efficiency.

Electronic roadway worker protection is a proven technology that can help innovate rail safety.

ACKNOWLEDGEMENTS

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FIGURES

Biographical Sketch:
Christine Nestor is the Marketing and Digital Communications Specialist at Miller Ingenuity, a position she has held over the past 2.5 years. Christine joined Miller Ingenuity from 20/10 Solutions, a marketing agency right outside of Philadelphia, PA.

Protecting Railway Workers With an Electronic Overlay

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Key Presentation Take-aways

- The Problem: Insufficient TAW Protection
- A Solution: Electronic RWP Safety Overlay
- eRWP Performance Update: Data Review

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The Problem: Insufficient TAW Protection

- 1997 - Feb.2017 = 52 fatal RWP accidents (55 perished) [*Source: FAMES*]
- Human Error
- NTSB Safety Alert (SA-14-01) & (SA-066)
- NTSB Safety Recommendation (R-18-025)

The Solution: eRWP System Safety Overlay

- What is eRWP?
- What does it do?

ZONEGUARD

Safety in your own hands

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The Solution: eRWP System Safety Overlay

ZoneGuard Components:

- Train Detection Modules (TDMs) & Train Alert Modules (TAMs)

The Solution: eRWP System Safety Overlay

ZoneGuard Components:

- Worker Wearable Devices

The Solution: eRWP System Safety Overlay

ZoneGuard Components:

- Onboard Unit (optional)

The Solution: eRWP System Safety Overlay

ZoneGuard Components:

- Web Dashboard

The Solution: eRWP System Safety Overlay

- ZoneGuard Fixed System

The Solution: eRWP System Safety Overlay

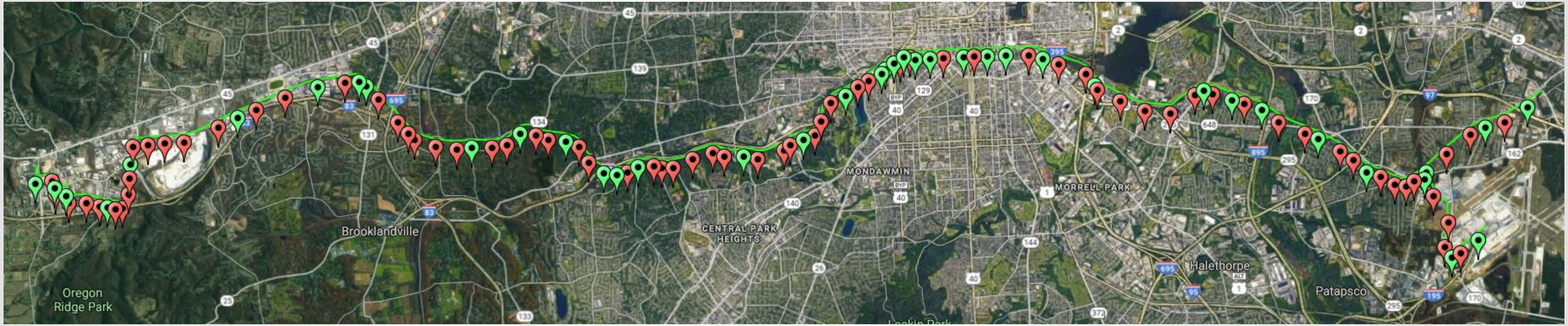
- ZoneGuard Portable System

eRWP Performance Update: Data Review

- Maryland MTA Safety Research & Demonstration Program
- 30 Miles Light Rail Line
- Fixed Mounted Train Detection & Worker Warning System

eRWP Performance Update: Data Review

- TDMs = GREEN, TAMs = RED



eRWP Performance Update: Data Review

MTA Configuration:

- 43 TDMs, 56 TAMs = 99 total devices
- Wearables = 180 total devices
  - 140 Worker Wearables
  - 20 Watchman/Lookout Wearables
  - 20 RWIC Wearables

eRWP Performance Update: Data Review

MTA Configuration:

- 43 TDMs, 56 TAMs = 99 total devices
- Wearables = 180 total devices
    - 140 Worker Wearables
    - 20 Watchman/Lookout Wearables
    - 20 RWIC Wearables

eRWP Performance Update: Data Review

- Obstacles with installation
- What were our solutions?

eRWP Performance Update: Project Results

Test #1

- September 20, 2018 – September 22, 2018
- Location: TDM000015
- Setup
- Results

eRWP Performance Update: Project Results

Test #2

- Aug. 9, 2018 – Aug. 12, 2018; Set 20, 2018 – Sept. 23, 2018
- Location: TDM000019
- Setup
- Results

eRWP Performance Update: Project Results

Test #3

- October 22, 2018 – October 28, 2018
- Location: 5 Detectors
- Setup
- Results

eRWP Performance Update: Project Results

TDM/TAM ID	10-22-2018 to 10-28-2018							
	Individual Sensors Detection					Application Detections		
	Accelerometer Moderate Detections	Accelerometer Strong Detections	RADAR Detections	LeddarOne Detections Near Track	LeddarOne Detections Far Track	Near Track Trains	Far Track Trains	Total
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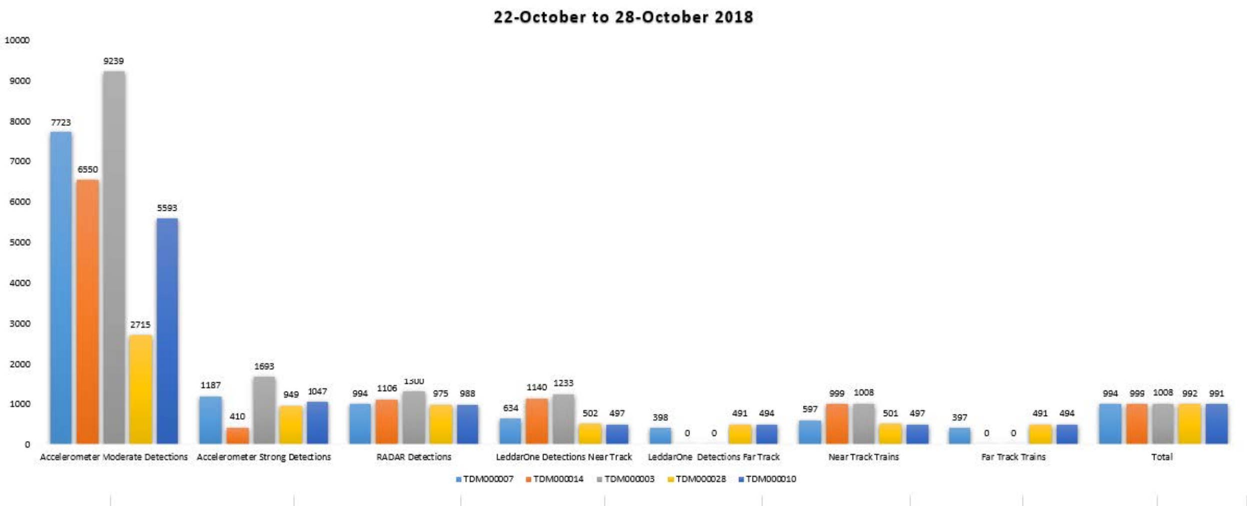

eRWP Performance Update: Project Results

Conclusion

- Existing safety rules fail to protect
- Multiple sensor technology provides accurate & consistent detections
- eRWP is a proven technology

Questions?

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