FTA RESEARCH

FEDERAL TRANSIT ADMINISTRATION

Wayside Worker Protection Technology—TrackSafe Phase II

Research & Demonstration Report

MAY 2021

FTA Report No. 0194
Federal Transit Administration

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Federal Transit Administration

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Metric Conversion Table

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liter	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

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14. ABSTRACT
This report outlines research and demonstration of a roadway worker protection (RWP) warning technology developed by Bombardier Rail called TrackSafe. The system was installed at the Metropolitan Atlanta Rapid Transit Authority (MARTA) and was designed to reduce the hazards of working within a transit rail right-of-way (ROW). The report details the proof of concept, design, construction, commissioning, and operation of the technology, shares issues experienced during the project, and provides a qualitative assessment supported by lessons learned. Sharing these experiences should further enhance RWP technologies for more reliable systems in the future, ultimately creating a safer work environment for ROW workers at rail transit agencies.

15. SUBJECT TERMS Transit safety, rail safety, roadway worker protection, RWP, right-of-way, ROW, wayside, roadway worker, work zone safety, secondary warning devices, redundant protection, radio frequency identification, RFID, sensor network, train detection, operator warning, track worker warning, MARTA, Bombardier

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Abstract

This report outlines research and demonstration of a roadway worker protection (RWP) warning technology developed by Bombardier Rail called TrackSafe. The system was installed at the Metropolitan Atlanta Rapid Transit Authority (MARTA) and was designed to reduce the hazards of working within a transit rail right-of-way (ROW). The report details the proof of concept, design, construction, commissioning, and operation of the technology, shares issues experienced during the project, and provides a qualitative assessment supported by lessons learned. Sharing these experiences should further enhance RWP technologies for more reliable systems in the future, ultimately creating a safer work environment for ROW workers at rail transit agencies.

EXECUTIVE SUMMARY

Transit authorities across the U.S. are responsible for transporting millions of people daily. To ensure safe travel for their patrons, transit teams are responsible for inspection, maintenance, and construction of transit railways on a regular basis. These activities require workers to expose themselves to the inherent hazards of the rail right-of-way (ROW). In many cases, these activities occur while trains are in service traversing at significant speeds. Sadly, fatal accidents have occurred in the ROW due to workers and train operators not being locationally aware of each other's presence.

In 2015, the Federal Transit Administration (FTA) Office of Research, Demonstration and Innovation sought to advance research to develop technology in areas such as track worker safety to reduce transit injuries and fatalities.

To pursue this endeavor, the Metropolitan Atlanta Rapid Transit Authority (MARTA) partnered with Bombardier Rail to perform a demonstration of Bombardier's TrackSafe technology on a section of MARTA's operational rail transit system. This project also expanded the Phase I demonstration to assess the feasibility and benefits of a system-wide deployment of TrackSafe. As part of Phase II, TrackSafe was designed, manufactured, installed, and commissioned along a three-mile section of MARTA's Red Line between the Dunwoody and North Springs stations. Subsequently, the system was placed into operation to allow a team of ROW inspectors, rail controllers, and others to use the system and provide feedback from their experience.

This report introduces TrackSafe technology, provides MARTA's observations, and shares lessons learned acquired during multiple phases of the program. This report documents and informs the following aspects of the project:

- Program background
- TrackSafe concept and technology overview
- Program summary
- Highlights from operational period
- MARTA's observations during the project
- Lessons learned and recommendations for future deployments and technology improvements
- Conclusions
- Third-party assessment report by TRA with observations by MARTA operations

SECTION

1

Background

Since the advent of rail transit operations, the task of inspecting and repairing track, signals, and infrastructure located in the wayside or right-of-way (ROW) has been essential to safely moving millions of people every day. It has also been one of the most hazardous jobs in the rail transit industry.

Public rail transit agencies have seen an increase in worker fatalities in recent years. According to the U.S. Bureau of Transportation Statistics, between 2010 and 2019, 59% of reported transit worker fatalities were rail-related incidents.

To address this issue, the Federal Transit Administration (FTA) provided support for research and demonstration of advanced ROW warning system technologies that mitigate the risks and accidents for ROW workers of transit systems in the U.S.

In 2011, Bombardier Transportation was awarded a competitive grant from FTA to develop a prototype for a secondary advanced ROW warning system, named TrackSafe. TrackSafe is Bombardier's solution to create location awareness for ROW workers, rail controllers, and train operators. As part of this effort, Bombardier partnered with the Metropolitan Atlanta Rapid Transit Authority (MARTA) to test its system along MARTA's Green line during normal revenue service operations. Their collaborative efforts resulted in a successful proof of concept demonstration and a modified prototype of TrackSafe.

In 2015, FTA and MARTA entered into a cooperative agreement under a competitive safety program, the Innovative Safety, Resiliency, and All-Hazard Emergency Response and Recovery Program, to further develop, deploy, and evaluate TrackSafe in an operating transit environment.

FTA's implementation plan for this project included the formation of a collaborative team made up of the following:

- MARTA, the eighth largest heavy rail transit agency in the U.S. with a deep bench of technical and operational expertise in rail and bus transit. MARTA has experience implementing a robust wayside access program since its inception in 1979 and desired to promote research for new safety technologies that can enhance its current practices and improve safety for ROW workers throughout the industry.
- Bombardier, a global leader in the transportation industry that provides trains, rail equipment, and systems to transit and airport authorities. Bombardier creates innovative technology systems and solutions and provides a broad range of aftermarket services in the industry, including operations, maintenance, vehicle, and component refurbishment.

- TRA, a nationally-recognized consulting firm reputed for its expertise on safety and security for transit operations. TRA served as an independent evaluator of the project and provided in-depth rail subject matter expertise and an overall assessment of the results from the demonstration.

Some goals of this demonstration included the following:

- Improve the safety of transit workers through use of new and advanced roadway worker protection (RWP) technologies.
- Improve visibility of ROW workers to both train operators and rail control center staff responsible for permitting access to the wayside.
- Demonstrate the reliability of new technologies deployed in an operating transit environment.
- Gain feedback and an assessment from those that interacted with the technology during a finite demonstration period.
- Provide an evaluation and lessons learned from various phases of deployment.

The scope included the design, fabrication, installation, commissioning, and demonstration of TrackSafe along approximately three track miles of MARTA's rail corridor from Dunwoody Station to North Springs Station. MARTA selected this track segment because it contained several attributes conducive to a favorable testing environment such as aerial, underground, curved, and at-grade track configurations. After commissioning the system, MARTA selected a team of ROW workers that used TrackSafe for 180 days during both revenue and non-revenue operations. Subsequently, this group was interviewed by a third-party observation team and shared their experience with the technology. Their observations are documented in the report in Appendix A.

SECTION

2

TrackSafe Overview

Concept

As the adage goes, the first rule of being on the railroad is "expect a train at any time, from any direction." With this in mind, the investigation began on a journey to solve the problem of reducing the inherent hazards that come with the essential duty of inspecting, maintaining, and repairing rail infrastructure located within the ROW.

Currently, MARTA requires anyone who needs to enter its ROW to adhere to rules and procedures set forth in its Wayside Access Procedures (WAP), the established primary set of procedures and protocol that must be followed when entering the ROW. MARTA personnel and outside contractors are required to attend and pass a wayside certification course on an annual basis before entering its ROW. After being certified, MARTA dedicated lookouts are issued a radio that becomes the primary means of communication with rail controllers located at the Integrated Operations Center (IOC).

When a dedicated lookout enters the ROW, they communicate their intention to foul the track by providing a radio transmission, and the rail controllers at the IOC send out general radio calls to train operators that ROW worker teams are now entering the wayside. This is effective when ROW work is limited to a dedicated work zone for the duration of the work restriction. Train operators are made aware of the presence workers by the implementation of speed restrictions, flagging implementations, lanterns, shunt-straps, and other means. However, when ROW workers are performing mobile inspection services, train operators and workers are aware of each other's presence only by listening to radio transmissions and by line of sight. There are several track configurations such as curved track sections where both train operators and ROW workers may find themselves in a dangerous situation if ROW workers have not cleared the track in time. Conditions such as these created the need for technologies that enable more situational awareness between rail controllers, train operators, and ROW workers.

TrackSafe enables ROW workers to be aware of oncoming trains and on-track equipment (OTE). It serves as a secondary ROW worker warning system that supplements MARTA's WAP and provides ROW workers with audible and visual alerts when a train and/or OTE are approaching them from either direction. Concurrently, vehicle operators are provided flashing visual alerts as they approach individuals or work crews in the ROW. In parallel, rail controllers are provided a graphical depiction of the location of ROW workers on a dedicated computer screen at the IOC, allowing them to better plan train movements and respond to emergency situations in the ROW.

How TrackSafe Works

"Check In" at WAU

Prior to entering the wayside, personnel and/or crews confirm their track activities by "checking in" at a Wayside Access Unit (WAU) typically found at the end of station platforms or at entry-gates adjacent to the ROW. At the WAU, the following steps were customized to follow MARTA Wayside Entry Procedures (the system can be customized to fit other Rail Transit Authority protocols):

- The dedicated lookout for the team selects the relevant wayside restriction from a pre-populated menu that pulls from MARTA's track allocation schedule system. They also enter attributes such as crew size, radio ID call number, confirmation of proper personal protective equipment (PPE) and others.
- All remaining team members swipe their MARTA-issued RFID cards.
- At the IOC, information populates a graphical user interface (GUI) for the rail controller on a dedicated screen for TrackSafe.
- After the check-in at the WAU, the dedicated lookout follows regular WAP procedures and calls the rail controller to confirm they have all the relevant information. Subsequently, they provide a radio transmission to enter the ROW.

Tag in at TIU

Once provided authorization to enter the wayside by the rail controller, the dedicated lookout activates the TrackSafe system by "tagging in" at a Tag-In Unit (TIU) located near their point-of-entry using their RFID-card. Once activated, the system creates a Safety Zone (SZ) around the work crew. Additionally, an Operator Warning Zone (OWZ) is created by automatically illuminating LED lights that warn train operators of the location of roadway workers as the train approaches the SZ. No other equipment or wearable devices are required for ROW personnel, allowing them to carry necessary work equipment and enhance their safety with minimal effort.

As the work crew proceeds along the wayside, they continue to tag in at each TIU they encounter. This action updates their position within the system, which automatically updates the SZ and OWZ around the work crew. The SZ and OWZ are configurable so that varying combinations of maximum train approach speed, stopping distance, and time for track workers to reach a place of safety can be accommodated.

Look and Listen for OWL

After the ROW workers tag into a TIU, they should expect to see Operator Warning Lights (OWL) light up with a solid color (based on the chosen RTA color scheme). In addition, the OWL provides an audible alert when a train enters the SZ from either normal or reverse directions. The OWL also serves to warn train operators that they have entered an SZ and can expect to see workers ahead.

"Check Out" at WAU

Upon exiting the wayside, the dedicated lookout confirms the completion of track activities for that session and "checks out" at a WAU. This requires them to first follow the WAP and provide radio confirmation to the rail controller that work is complete and the entire crew has exited the ROW. Thereafter, the dedicated lookout has all crew members swipe their RFID cards to complete the check-out process and deactivates the TrackSafe system.

Figure 2-1 shows the OWZ and SZ zones and the need for a 15-second warning notice on either side of the workers. This is configurable based on track conditions on individual transit property requirements.

Figure 2-1

TrackSafe concept

Technology

TrackSafe is an integrated safety system composed of three primary components deployed in the field that report to a central "head-end" computer that can report data to either cloud-based or local servers. As part of this project, these components were installed on multiple transit station platforms, OTE vehicle access points, and within the ROW between the North Springs and Dunwoody stations. The following provides a description of each field-installed component.

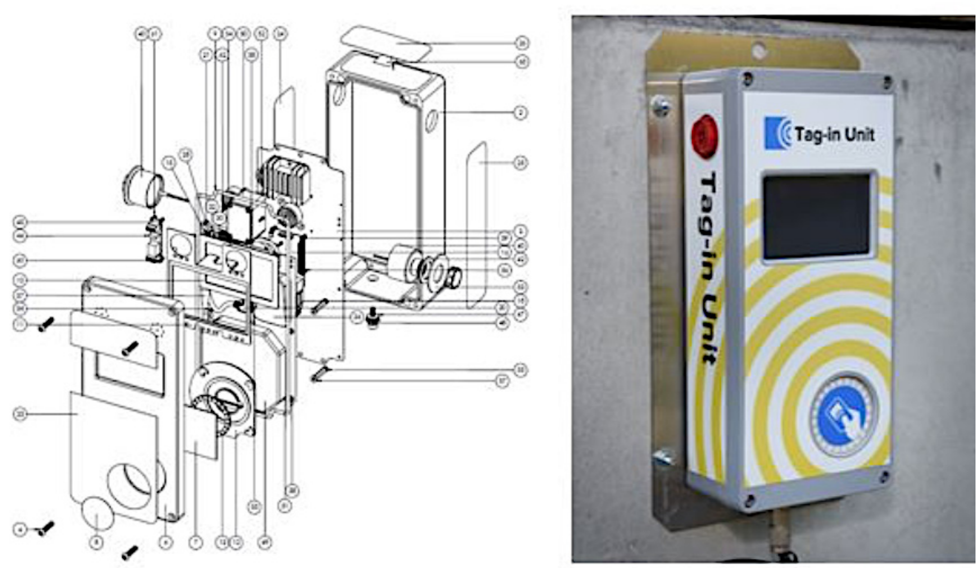
Tag-In Unit (TIU)

The primary function of the TIU is to allow personnel to report their position by interacting with the device using an assigned Radio Frequency Identification (RFID) card. Each TIU is equipped with both a short-range and/or a long-range RFID reader with which ROW workers interact by using their pre-programmed personal RFID card. The secondary function of the TIU is to function as part of an integrated network of TIUs to provide both visual and audible alerts to ROW personnel warning them of an incoming train, thus providing adequate time for them to proceed to a safe location as the train approaches. Finally, a tertiary function of the TIU is to detect the presence of a train or OTE using the integrated radar-based detector.

In general, TIUs are installed every 500–1,000 feet depending on factors such as the configuration of the track, ROW worker and train operator line of sight, allowable train speeds, and environmental noise conditions. For example, TIUs are installed closer together in curved track sections where the line of sight is shortened when compared to straight track.

Figure 2-2

TIU exploded view and installed unit



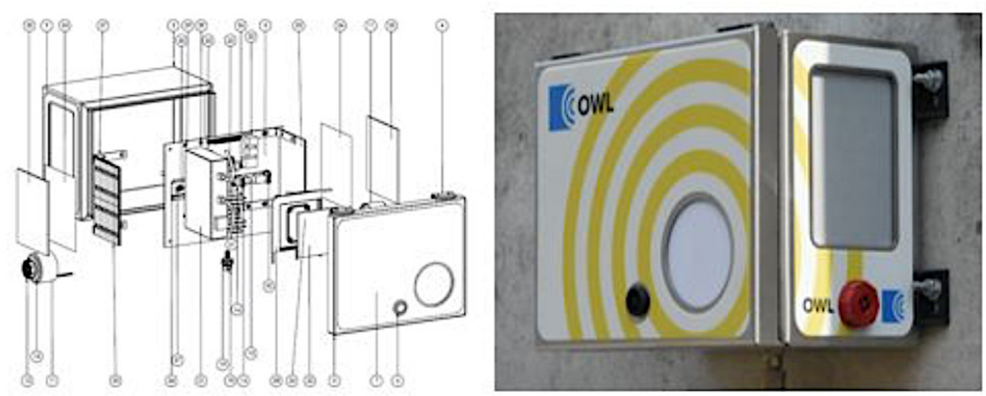
Operator Warning Light (OWL)

The primary purpose of the OWL is to provide train operators with a visual cue as they approach personnel on the ROW. OWLs become activated when ROW personnel activate a TIU with their RFID, thereby creating an OWZ and SZ. OWLs located within the OWZ will provide a flashing light to the train operator in both directions and on both tracks, mitigating any risks that may result from trains approaching in the reverse direction. After a train or OTE enters an activated OWZ, operators will be alerted by flashing lights that increase in frequency the closer their vehicle gets to ROW personnel. The secondary function of the OWL is to provide both visual and audible alerts to ROW personnel warning them of an incoming train. The OWL lights flash at the same frequency in both forward and reverse directions, and light colors are customizable based on the established signal color schematics for individual agencies. Finally, a tertiary function of the OWL is to detect the presence of a train or OTE using an integrated radar-based detector. This eliminates the need to install any equipment on OTE vehicles to be detected by TrackSafe.

Like TIUs, OWLs are also installed every 500–1,000 feet depending on factors such as track configuration, ROW personnel and train operator line of sight, allowable train speeds, and environmental noise conditions.

Figure 2-3

OWL exploded view and installed unit

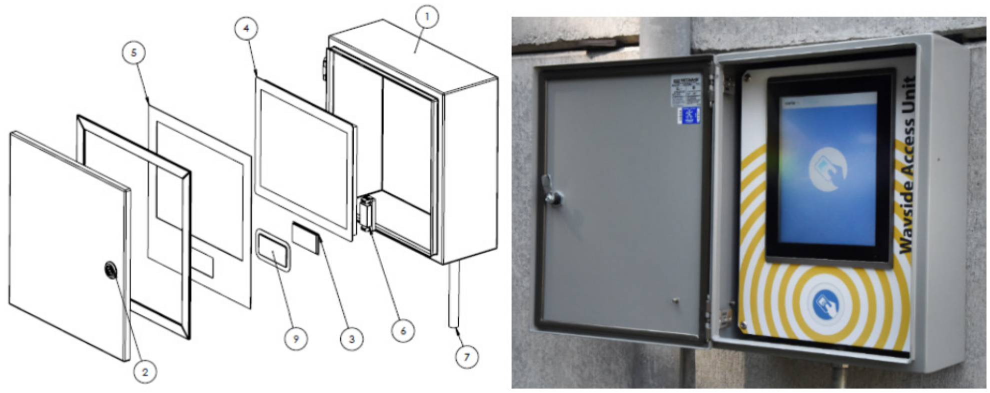


Wayside Access Unit (WAU)

The primary purpose of the WAU is to organize and communicate key information between ROW personnel and rail controllers prior to accessing the ROW for any reason. WAUs are installed at station platforms, high-rail access points, and other designated ROW entrance areas. At MARTA, WAUs were installed within a non-descript NEMA-rated lockable cabinet enclosure that housed a touchscreen computer that functions like a tablet. The WAU is activated by swiping an authorized TrackSafe RFID card. Once a WAU is accessed, the dedicated lookout for a ROW crew enters relevant information such as crew size, radio-identification number, confirmation that crew members have adequate PPE, validation of adequate wayside certification, and other track work scheduling information. This information then pre-populates a table found on a GUI located in the rail control theater. For this proof-of-concept pilot, a tablet computer was housed in MARTA's IOC to monitor the location of ROW workers. The GUI shows where crews are located by overlaying icons on top of MARTA's track system map. For a full-scale implementation, crew location could be conveyed to the rail controller using either a stand-alone system or integrating TrackSafe's GUI into the transit agency's primary system track map, which would require additional software development and integration effort.

Figure 2-4

WAU exploded view and installed unit



SECTION

3

Program Summary

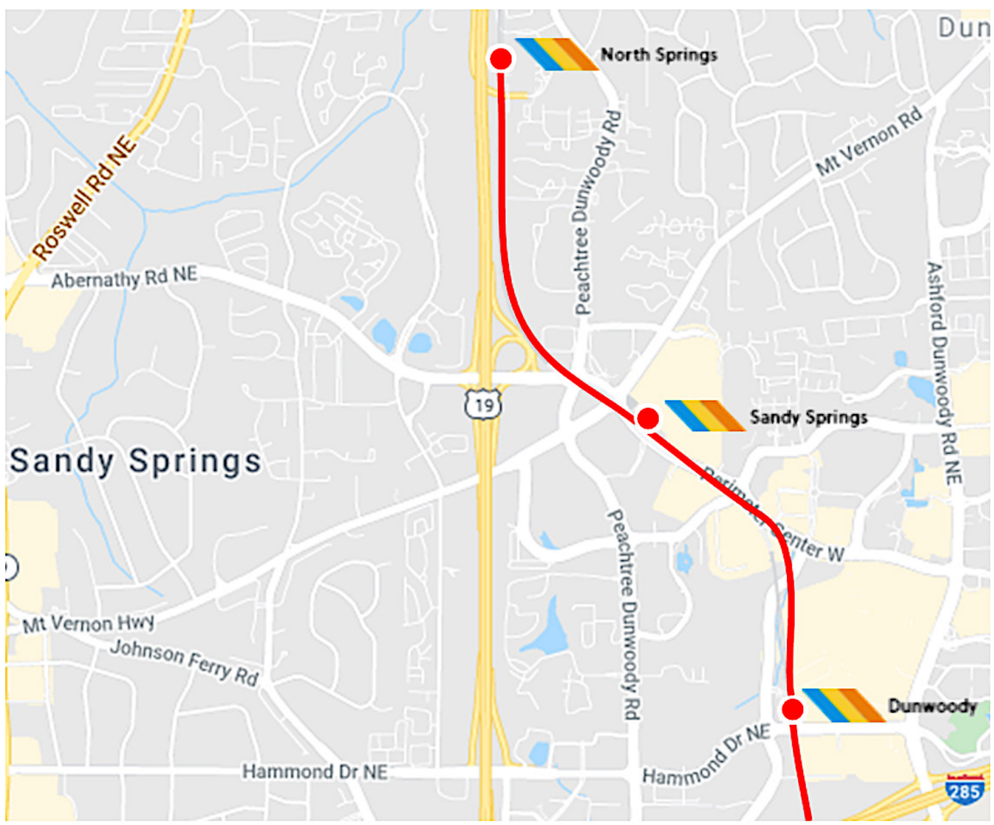
Demonstration Envelope

For this demonstration, TrackSafe was installed along MARTA's Red Line from the south end of the North Springs Station platform to the north end of Dunwoody Station. This section of the Red Line is approximately three miles of bi-directional tracks and features multiple track configurations such as:

- Curved and tangent track
- Track at-grade
- Track in tunnels
- Track on elevated structures
- Areas of high background noise (parallel to highway)
- Multiple high-rail vehicle access points

Figure 3-1

Map of MARTA Red Line



Design Process, Prototype, and Manufacturing

As part of a collaborative design process, the design team engaged track inspectors, train operators, rail controllers, and management personnel through a series of interviews, work groups, and design charrettes to gain perspectives of each business unit. The objectives of the interviews and design sessions included the following:

- Understanding track inspector perspectives on current procedures to gain access to the ROW, determining how to streamline the sign in process with Rail Control, determining the needs of maintenance teams responsible for keeping TrackSafe in a state of good repair, understanding how to optimize interaction with TrackSafe, and determining the level of system feedback needed while they performed on-track activities.
- Understanding train operator experiences when approaching work crews without the benefit of a secondary warning systems and determining how to better position OWLs in the ROW to minimize visual disruption and still be provided relevant visual alerts when ROW personnel are present.
- Understanding the environment and process in which rail controllers functions as they monitor the system and communicate with personnel including train operators and ROW work crews and determining what metadata are captured manually in current paper-driven processes and how to create an electronic process to streamline access to ROW, especially during peak ROW access times during shift-changes.

Design Criteria & Attributes

Based on the ideas, suggestions, and feedback from MARTA's operations team, industrial designers, engineers and other subject matter experts, Bombardier's Engineering Team began the design process and focused on form, function, and interaction with ROW personnel with audible and visual alerts, train operators, and rail control with visibility of ROW worker locations along the system. The team designed and manufactured in accordance with good engineering and industry practices including adherence to environmental ratings (NEMA 4X), fire protection (NFPA 130), and other standards.

Design attributes for TIU:

- Use of multi-sensory (audible and visual) indicators to reliably enable workers to tag-in under diverse rail conditions.
- Ergonomics enabled by easy operation with minimal distraction from oncoming trains and work being done, enhancing use and not changing current WAP procedure and being easy to use and understand.
- Right size"—compact and easy to integrate the overall size of unit and associated signage into wayside environment.

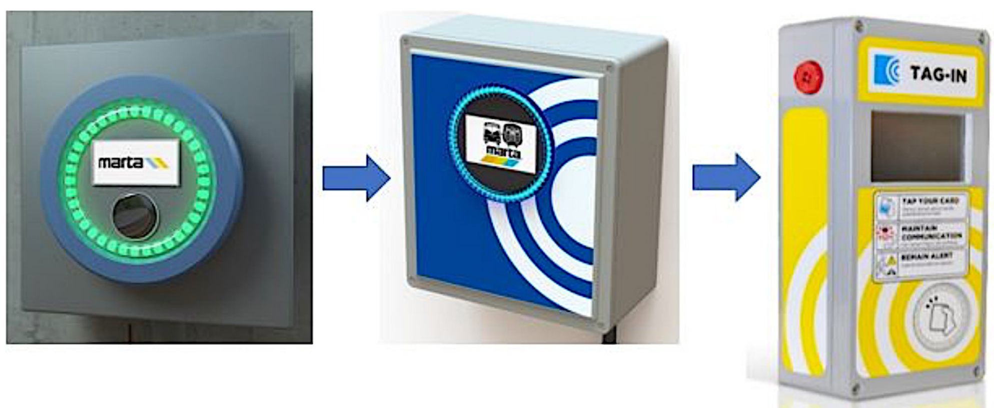
- Easy use and maintenance—"railroad proof" to suit every condition, "plug and play" installation with limited hand tools needed for maintenance, remote monitoring and self-health diagnostics, vandal-resistant.

Design details for TIU:

- Clearly recognizable as a TrackSafe component via TrackSafe logo on front of display and associated signage.
- Installed at waist height where possible for ease of tagging in with an RFID-enabled card.
- Form factor that includes maximum depth of 3.25 inches including mounting; rugged, water-resistant, extended temperature range to minimize obstruction on tunnel catwalks.
- Multi-color ring LED ring illumination to help indicate location, draw wayside personnel to device as they conduct track activity; LED also illuminates when RFID card detected to indicate system was activated.
- Directional audible alert with decibel rating that would draw attention over background noise of 76 db at 150 ft.
- Integrated radar-based sensing capabilities of trains and on-track equipment.
- Display to provide feedback about state of the system and confirmation of tag-in.
- Short- and long-range RFID sensors to provide better card sensing capability.

Figure 3-2

Evolution of TIU from concept to final design



Design attributes for OWL:

- Use of multi-sensory (audible and visual) indicators to provide alerts and notifications under diverse rail conditions. Reliably notify workers that trains and/or on-track equipment is approaching from either normal or reverse traffic directions. These same alerts also notify train operators that they are approaching personnel in the ROW.
- Provide easy to hear, see and understand notifications. Visual stimuli should have associated colors. All notifications must differentiate themselves from the other signals and sounds on wayside. Usage enhances but does not modify existing WAP procedure.

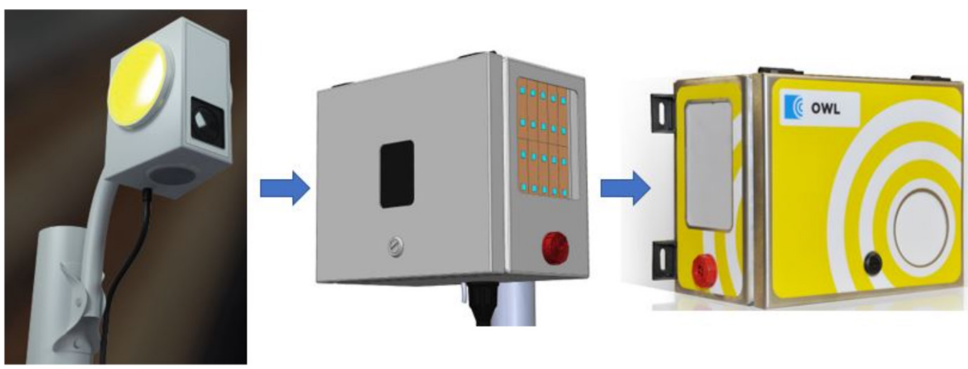
- The "right size": Compact and easy to integrate the overall size of unit and associated signage into wayside environment.
- Ease of use and maintenance: "railroad proof" to suit every condition, "plug and play" installation with limited hand tools needed for maintenance. Remote monitoring and self-health diagnostics. Vandal resistant.

Design details for OWL:

- Recognizable as a TrackSafe component via TrackSafe logo on front of display and on associated signage.
- Form factor to include bi-directional LED lights that allows operators to observe from both track directions; rugged, water-resistant, extended temperature range; LED lights can be programmed to change colors aligning with transit authority's signal light preference.
- Directional audible alert with decibel rating that would draw attention over background noise of 76 db at 150 ft.
- Integrated radar-based sensing capabilities of trains and on-track equipment.

Figure 3-3

Evolution of OWL from concept to final design



Design attributes for WAU:

- Securable vandal-resistant enclosure located at end of station platforms and selected ROW entry points.
- Enclosure indistinguishable from other cabinets on station platform to not attract unwarranted attention from vandals.
- WAU GUI to provide large, easy-to-read instructions.
- WAU RFID card reader to provide positive feedback when swiped.

Design details for WAU:

- Heavy-gauge steel NEMA 4X-certified enclosure with pre-determined knockouts for communication conduit entry point.

- Integrated WAU touchscreen adequately designed for industrial use and heat exposure.
- Enclosure able to receive MARTA-issued key lock body or cylinder to simplify WAU access.
- RFID card reader designed to light up when scanned, providing positive response to user.

Design attributes for IOC computer and GUI:

- GUI mimicks rail signal chart as opposed to matching crew locations to engineering station locations; altered from Phase I to allow rail controllers to better compare locations of workers with larger IOC theater screen.
- For pilot demonstration, stand-alone tablet used to minimize space in theater because MARTA was undergoing transition between two rail control spaces concurrent with project.
- Tablet was portable and transferrable if needed to go to a backup rail control center.
- For purposes of pilot, tablet provided access to a guest internet service provider to prevent cybersecurity issues during the project.

Manufacturing and Factory Acceptance Testing

Phases in the manufacturing process included the following:

- Bombardier fabricated two first-article prototypes of the TIU, OWL, and WAU in preparation for factory acceptance testing procedures at a fabricating facility in the greater metro Atlanta region. Bombardier would perform quality control inspections of individual components and subcomponents in the factory along with selecting products such as adhesives, cable organization within housing enclosures, etc. Once final assembly of the prototypes was complete, MARTA was invited to the factory to conduct an on-site visit to validate prototype completion and set up for factory acceptance testing conducted by Bombardier.
- Upon first article inspection approval, factory acceptance testing and configuration for each device were conducted separately at the fabrication facility for hardware configuration tests and software configuration tests.. However, for the combined hardware and software configuration test, Bombardier performed the factory acceptance test at the North Springs Station platform rather than in the factory, thus excluding the ability to simulate some scenarios as originally outlined in the test plan. Testing activities included the following:
  - Hardware configuration testing focused on the same attributes for the TIU, OWL, and WAU and included the following:
    - Measurement of physical attributes and comparison to approved design
    - Confirmation of inclusion of components and subcomponents

- Environmental testing included in the original test plan, which included hose-down test to confirm compliance with NEMA 4x standards and temperature test from -20F to +120F for 24 hours with a rate of change of ambient temperature to maximum/minimum for over 3 hours; these tests were not conducted due to scheduling issues but are highly recommended for final prototype assemblies.

– Software configuration testing for the TIU, OWL, and WAU were the same and included the following:

  - Power-on testing
  - Functional self-testing
  - Communication testing
  - Digital documentation records of equipment including serial number, unique identifying number, software, and firmware revision number

– Hardware and software configuration testing for the entire system included the following:

  - Bombardier's test plan intended to use a mini system to simulate scenario-based testing of the system; instead, an on-site test was conducted at the North Springs Station that was able to conduct a live test with revenue service trains. Test plan included the following tests:
    - Confirmation of standby mode
    - Tagging a TIU to activate a zone
    - Tagging a TIU within an active zone
    - Train detection by system once in an active zone

Construction

The system was installed using a phased approach beginning with installation of power and communication infrastructure followed by installation of TrackSafe system components.

Power and Communication – Installation & Testing

The installation of power and communication infrastructure spanned approximately five months. The deployment was divided into 12 sections between North Springs and Dunwoody. Intermittent wire and cable testing was conducted as each section was installed. High voltage electrical testing and certification was performed according to local and State laws. Testing and certification of the fiber communication link was performed using an optical loss test set (OLTS). Testing and certification of the Category 5e cables was based on the EIA/TIA-568 standard.

System Components – Installation & Testing

Installation of the TIUs, OWLs, and WAUs was completed in two phases. During the first phase, 40% of the devices were installed; the remaining devices were installed during the second phase.

Individual testing of the equipment included a field power-on test followed by verification of communication between the device and the backend TrackSafe applications and services that were running on servers deployed off the wayside. Upon completion of installation of equipment in a predetermined section, a system hardware and software integration test was conducted that involved verifying the expected behavior of the devices when operated as a contiguous SZ (activation of SZ, relevant audible and visual alerts, train detection activity).

Commissioning

The commissioning effort was completed using a phased approach beginning with testing network infrastructure first. The next phase included commissioning of independent components of TrackSafe (TIUs, OWLs, WAUs) and concluded with integration testing of the system.

Phase 1 – Network Infrastructure

At the core of the network is the TrackSafe fiber backbone, where all devices on the network communicate between each other using the backbone. The backbone is deployed using a ring topology to allow for redundancy and act as a backup in case of single link failure.

The effort in this phase included the installation of base software, firmware upgrades, and configuration of each device as required by design requirements. This phase concluded upon successful integration testing and establishing end-to-end communication across the entire ring network backbone.

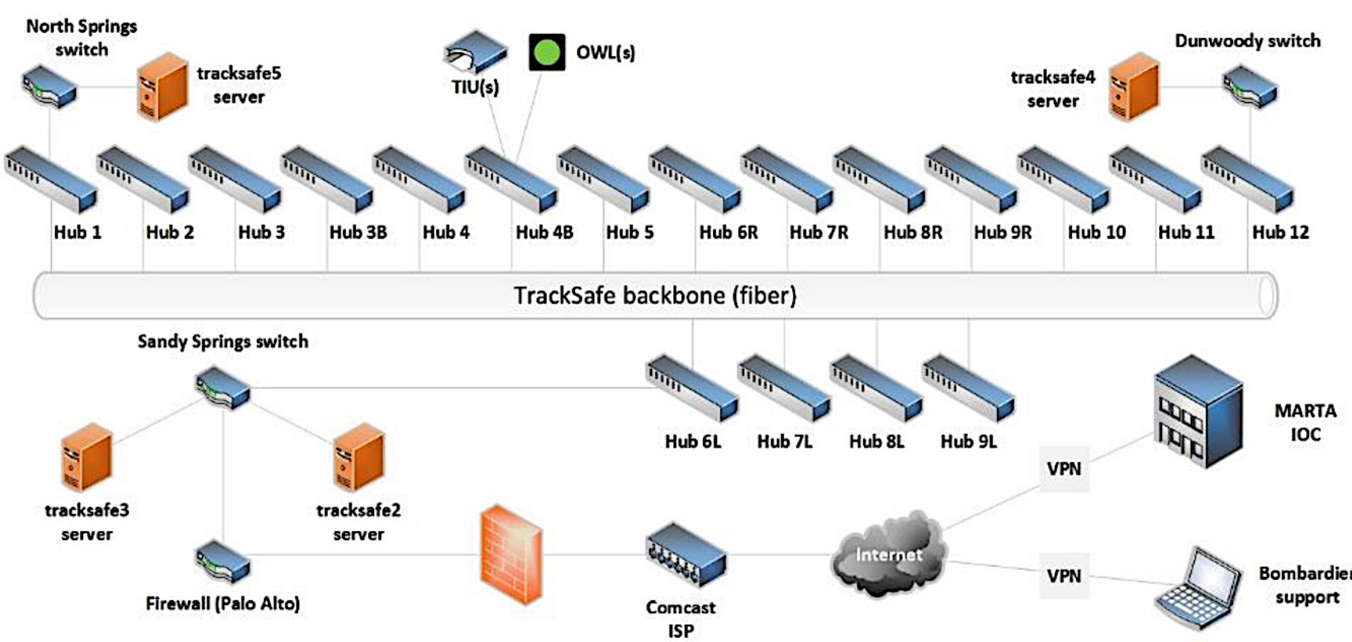


Figure 3-4

Overview of network topology

Table 3-1 summarizes the network infrastructure that was commissioned.

Table 3-1

Network Infrastructure Commissioned

Equipment Description	Quantity	Location
Servers	4	Train Control Room(s)
Switches	3	Train Control Room(s)
Communication hubs	18	Along wayside with 1–2 in each section
Comcast ISP	1	Train Control Room

Phase 2 – Equipment

The effort in this phase included the upgrade of base software and configuration of each device as required by design requirements. This phase concluded upon successful integration testing and establishing end-to-end communication between each device and TrackSafe applications and services that were hosted on the servers.

Table 3-2

Equipment Commissioned

Equipment Description	Quantity	Location
TIU	41	Along wayside, tunnel catwalks, aerial structure handrails
OWL	48	Along wayside at height of 6–7 ft
WAU	9	Entry points to wayside (station platforms, hi-rail access points, wayside entrance gates)

Phase 3 – Integration Testing

The integration testing phase was split into two sub-phases. The first sub-phase included testing independent system functionality and overall system functionality. The following tests were performed:

- Verification of operability of TIUs, OWLs, WAUs
- Verification of visual and audible alerts from each device
- Sound pressure level testing using a calibrated sound level meter
- Verification of remote access to system using VPN connection via Comcast internet service provider
- Verification of IOC tablet screen update when interacting with any components in field

In the second and final phase of integration testing, seven use-case scenarios were tested:

- Single crew member tag progression – authorized user(s)
- Single crew member tag progression – unauthorized user(s)
- Multiple crew member tag progression
- Overlapping crews
- Train approaching crew – single train
- Train approaching crew – multiple trains (same track/adjacent tracks)
- Train inside safety zone

Following is a sample of the procedures followed during the testing of the scenarios:

1. Standby mode verified, crew checked in at starting WAU.
2. WAU operation verified by swiping RFID card and checking crew status. Action checked against Rail Control map.
3. Crew tagged into first TIU verifying crew profile on TIU screen and activation of SZ.
4. TIUs and OWLs that are part of SZ verified to be demonstrating expected behavior. Action checked against Rail Control map.
5. Crew continued to proceed tagging TIUs based on scenario path. At each tagging location, crew profile on TIU screen and update of SZ verified.
6. TIUs and OWLs that are part of the SZ verified to be demonstrating expected behavior. Action checked against Rail Control map.
7. As trains were coming through SZ, activation of long-range audible devices within SZ verified to be accurate and warning time before train arrival recorded.
8. Crew checkout completed, verification that zone deactivated.

Training

Bombardier developed a training plan as part of its deliverables for the project. Included were training modules for track inspectors, rail controllers, and maintainers.

As part of this demonstration, training was provided to track inspectors and rail control operators only. An e-training module developed for system maintainers, however, was not implemented because MARTA decided to not fully implement the system after completion of the demonstration. Bombardier was responsible for maintenance of the system during this demonstration.

Track Inspection Training

The Track Inspection group selected to interact with TrackSafe during the operational period initially comprised six track inspectors who were provided in-class training that introduced them to the following:

- Introduction to overall system layout along Red Line
- Explanation of TrackSafe components and features
- Explanation of how to interact with TrackSafe

Thereafter, on-site training was provided on the wayside to show the team how to use the system and allow for a live demonstration. Upon completion of training, each track inspector was issued a personal RFID-enabled card pre-loaded with information specific to each individual. Thereafter, they were tasked with interacting with TrackSafe during the operational period whenever inspection activities were along the demonstration site.

The limited size of the team enabled completing training exercises with relatively few classes. With a full roll-out of TrackSafe, it is recommended to combine TrackSafe operational training into the regular Wayside Certification Training Course as a supplemental section and to investigate converting the existing MARTA Wayside Certification Card into a TrackSafe-compatible RFID card to eliminate the need for carrying additional equipment to interact with the system.

Rail Control Training

The Rail Control group comprised 25 IOC rail controllers and 7 IOC rail superintendents. Training was provided in class only with an overview of the system and its functionality. Each classroom session concluded with hands-on training on a Bombardier-furnished tablet configured to connect to the TrackSafe system and provide access to the rail control terminal. Each member of the Rail Control group was assigned login credentials to the rail control terminal.

Maintenance Training

For a future system-wide rollout, Bombardier created a system maintainer training module to allow owners to diagnose and maintain the system without the need for Bombardier to be on-site. In addition, Bombardier prepared a full e-learning suite to supplement its live training program. This training would be vital for owners that fully implemented TrackSafe at their property.

Schedule

The project was on-schedule during procurement, design, and fabrication but began to slip during the construction phase, primarily due to discovery of manufacturing defects during initial deployment of devices. Afterwards, the project experienced an extended testing and commissioning phase due to system instability and calibration issues related to the radar. Fortunately, Bombardier was able to determine root cause in each instance and continued to refine and improve the system during this period. These issues are outlined later in this report.

ID	Task Name	Start	Finish
1	Project Kickoff	01/09/2015	01/09/2015
2	Procurement	01/09/2015	30/11/2015
3	Design and Engineering	01/12/2015	29/04/2016
4	Prototype Fabrication	02/05/2016	23/06/2017
5	Construction	26/06/2017	05/04/2018
6	Commissioning	11/10/2017	20/09/2019
7	Training	04/11/2019	12/11/2019
8	Operational Period	13/11/2019	11/05/2020

Figure 3-5

As-built project schedule

SECTION

4

Operational Period Observations

The operational period began on November 13, 2019, and concluded on May 10, 2020, for a duration of 180 consecutive days operating during both revenue and non-revenue service. During this period, six ROW personnel and 32 rail controllers had the opportunity to use the system; Unfortunately, the actual test group that interacted with the system was limited to 3 ROW personnel and 1 rail controller. Due to the track inspection schedule being limited to one day-shift per week, if the track inspector and rail controller were not explicitly notifying each other to participate in the study, the rail controller might not have been using the IOC TrackSafe tablet while the inspector was interacting with the system.

However, events and system performance were recorded and gathered during this operational period (see KPI report in Appendix C). The following summarizes the findings from the data:

- System availability (time in which the system was online and operational) was predominately at 100%. There was a span of 12 days when the system was offline that contributed to an overall system availability of 94% during the 180-day operational period. MARTA observed that the TrackSafe software was properly sending instructions to on-site hardware per Bombardier's Key Performance Indicator reports (see Appendix B).
- Hardware component (TIU, OWL, WAU) health was monitored and, when properly functioning, performed within the expected design parameters. However, when components were exposed to environmental elements such as excessive heat and water intrusion, the system became unstable and would frequently come offline. For instance, components sheltered within a tunnel segment fared much better than components exposed to solar radiation, wind, and rain on aerial and at-grade track. Table 4-1 shows component availability within various track configurations.

Table 4-1

Hardware Availability in Various Track Configurations

TrackSafe Component	Total Commissioned	Installed on At-Grade Track	Installed on Aerial Track	Installed in Tunnel Track
	Hardware Availability (%)	*Hardware Availability (%)*	*Hardware Availability (%)*	*Hardware Availability (%)*
WAU	90.00%	66.67%	100.00%	100.00%
TIU	50.00%	14.29%	9.09%	81.82%
OWL	41.67%	40.00%	0.00%	51.43%
Total	*57.02%*	*44.44%*	*25.00%*	*70.83%*

- Hardware connectivity issues and the resulting communications loss were observed for approximately 42% of the OWLs, with 10% of them taken offline due to the inability to resolve connectivity issues.
- WAUs performed very well, confirming that NEMA 4X-rated enclosures can adequately protect internal components. One WAU experienced connectivity issues due to a communications line issue. Overall, the WAU hardware performed per design, and components were robust enough to remain stable through the demonstration period. Track inspectors noted the following issues with the WAU during the operational period:
  - Screen contents were difficult to read due to glare caused by sunlight.
  - The WAU check-in process took several minutes to process prior to allowing entry; this may have been due to communications or network-related issues.
- TIUs experienced a significant loss of connectivity, with only 50% of the units being available for use. As with the OWLs, TIUs located within a tunnel and away from direct exposure to rainfall and solar radiation fared much better than components that did not. This clearly pointed to the need for more robust industrial-grade hardware.
- In total, 211 successful tag events were recorded using viable contiguous parts of the system during 31 sessions.

Given that the system was operational during both revenue and non-revenue service provided an opportunity to test and demonstrate the following use cases:

- Crew member tag progression:
  - Demonstrated both single and multiple ROW crew tag progression through the system as authorized users.
  - Scenarios with multiple ROW crews demonstrated the ability of the system to merge and unmerge the SZ and OWZ of each crew (overlapping zones).
- Train approaching crew:
  - Demonstrated single train approaching the crew either on the same track or adjacent track.
  - Demonstrated multiple trains approaching the crew on both the same track and adjacent track as the crew.
  - Train inside the OWZ demonstrated as a feature where the system was activated at a point where the train was already within the OWZ of the crew and adequate warning could not be provided. The outcome for such a case was that the crew was alerted to the presence of a train immediately and was given a warning.

Outreach Efforts

The MARTA and Bombardier project management teams conducted several outreach efforts throughout the duration of the program. Presentations and live demonstrations garnered much interest from several transit properties, both domestically and internationally. One notable event was during the 2017 APTA EXPO in Atlanta at which MARTA served as host transit property. During the expo, a live demonstration was conducted in front of an audience with several transit property owners in attendance.

Table 4-2 summarizes industry-facing events at which the project team shared knowledge using various methods.

Table 4-2

Outreach Effort

Evaluation Category	Evaluation Objective	Measures of Evaluation	Events
Technology/ Knowledge Transfer	Demonstrations, presentations, webinars, other	Number of outreach events; number and agency/institution of attendees	• 2015, APTA Rail Seminar, Salt Lake City, UT, presentation • 2015, International Rail Safety Symposium, Orlando, FL, presentation • 2016, Transportation Research Board Annual Conference, Rail Transit Infrastructure Committee AR055, Washington, DC, presentation • 2016, Tri-Met Transit Visit, Atlanta, GA, live demonstration • 2017, APTA EXPO Conference, Atlanta, GA, live demonstration • 2017, International Rail Safety Symposium, Orlando, FL, presentation • 2017, APTA Mid-Year Safety Conference, Houston, TX, presentation • 2017, *Mass Transit Magazine*, interview leading to published article on June 17, 2017 • 2018, Transportation Research Board Annual Conference, Transit Safety and Security Task Force AP0180T, Washington, DC, presentation • 2018, Center for Urban Transportation Research, Transit Standards Working Group, presentation

Figure 4-1
2017 APTA EXPO demonstration

Figure 4-2
2017 APTA EXPO demonstration

SECTION

5

MARTA Project Observations

The following outlines some of MARTA's observations during the project.

- **Sound concept and design** – MARTA was impressed with Bombardier's TrackSafe System during the conceptual and design phases. MOW teams appreciated that TrackSafe did not require the use of wearable devices on their person, except for an RFID card. Based on the proof-of-concept prototype from Phase I, MARTA also validated that TrackSafe adequately produced unique audio and visual alerts to allow workers to clear the wayside when a train was approaching from either direction. In addition, the system also provided a GUI to rail controllers so they were locationally aware of wayside teams along the system. In addition, the WAU converted a paper-driven wayside check-in process to an automated electronic check-in system that would make it more efficient for teams to access the trackway and audit historic data. After the design was complete, the first prototypes were aesthetically pleasing, and incorporated design features allowed for easy removal and self-health monitoring.
- **Need for more robust hardware and improved self-health diagnostics** – When TrackSafe was fully functional, the team discovered that several hardware components failed when exposed to the harsh environment of a revenue operating transit system. More specifically, when the system was exposed to environmental-based rigors, the system would frequently go offline. The self-health monitoring features notified Bombardier of some of the failures, but not comprehensively. The team found that to bring system components back online, Bombardier would have to go on-site to conduct activities in the wayside rather than remotely, which would require transit owners significant resources to maintain TrackSafe if a system-wide deployment were to occur. MARTA would also encourage further development of TrackSafe components into lighter industrial-grade products that are more reliable, durable, and transportable. The current prototype was constantly plagued by water infiltration issues and disruptions due to excessive heat during the summer months.
- **Leverage dedicated fiber network to substantiate increased cost or go wireless** – MARTA noted that a system-wide deployment of TrackSafe would require installation of a dedicated fiber loop network backbone, which would require a significant investment of cost and installation time. If MARTA were to make an investment in a new fiber loop, this infrastructure would be leveraged by tying in other features such as closed circuit TV (CCTV) enabled with video analytics and microphones to aid with remotely diagnosing

TrackSafe. Alternatively, if the system could be further developed to become a completely wireless solution, then deployment costs and resources could also be significantly decreased.

- **Support radar technology with other vehicle detection technologies for better accuracy** – MARTA observed that the radar technology selected to detect trains required frequent on-site adjustment and recalibration by Bombardier. It was noted that if Bombardier was able to supplement radar technology with features such as vibration detection or LIDAR, that could potentially minimize false positives experienced by the system. It could also serve to better detect OTE and allow TrackSafe to discern other vehicle types and better isolate what track the vehicle is on.
- **Software works as per design** – Despite hardware-related issues, Bombardier's software algorithms functioned as intended. Bombardier noted that the system was working as designed and reported clearly when hardware components were on-line. The on-line performance of the software logic is shown in the Key Performance Indicator Report in Appendix B.
- **WAU check-in/check-out process was innovative** – Another feature of the system that was very well received was the check-in and check-out process created by use of the WAUs. This concept proved to be very helpful to confirm if team members had the appropriate wayside certification credentials to perform scheduled track work along with electronic validation of proper PPE.

SECTION

6

Lessons Learned and Recommendations

Environmental Factors

TrackSafe was installed in both tunnel and open-air track environments, exposing the system to several environmental elements such as changes in temperature, humidity, solar radiation, vibration, and events of mild to heavy rainfall.

- **Water infiltration** – Repeated exposure to rain events (mild to heavy) caused water infiltration to occur in equipment installed along aerial and open cut track segments. One root cause of water infiltration was a combination of poor adhesive selection and imperfections created during the manufacturing process. In most cases, water infiltration issues were resolved by applying a better adhesive in the cut-out portions of equipment enclosures. Another feature of TrackSafe devices often disrupted due to water infiltration was the "quick-disconnect" cable at the end of all Power over Ethernet (POE) cables. These connection points initially failed due to water infiltration, which brought system components off-line. To address this issue, Bombardier created a looped "pigtail" with the POE cable prior to connecting with the TrackSafe Device to allow water to draw away from the connection point. It is recommended that first-article system assemblies include connected cables and undergo a spray test, described in more detail below.

  For prevention of water ingress, it is recommended that any enclosures used are certified as NEMA 4X-rated and that any cut-outs be pre-cut at the manufacturing facility. If field cut-outs are required, proper adhesives should be selected that perform well under repeated exposure to both water and changes in temperature (heating and cooling of adhesives over time will cause them to deteriorate). It is also recommended that any first-article components undergo extensive environment testing such as temperature humidity testing. The test plan should include ASTM B117 or equivalent "salt spray testing" of ROW installed component assemblies and should be conducted at both coastal and inland transit authorities.

- **Extreme temperature and humidity** – Ambient air temperature above 90°F combined with the effects of humidity in the Atlanta area impacted the operation of the electronics, primarily power circuits and processing boards. The impacts observed ranged from temporary disruption of operation to complete premature failure (in which case the component had to be replaced or decommissioned). For future designs, it is recommended that electronic components have an industrial operating temperature range from -40°F to 185°F (– 40°C to 85°C), with sufficient air flow inside the enclosure and adequate heat sinking for components that are expected to operate at higher temperatures.

- **Sound ordinance considerations** – During the design process, transit authorities should be aware of daytime and nighttime sound ordinances adjacent to their right of way. These ordinances and sound pressure levels should be considered during design and selection of horns. TrackSafe would benefit from having remotely-adjustable audible devices within their OWL and TIU units to allow sound pressure levels to be adjustable during certain time periods to comply with local ordinances and minimize noise complaints from surrounding neighbors.

Infrastructure Improvements

To aid system maintenance activities, quick-disconnect M12 connectors were used as part of the design. The benefits of using quick-disconnect connectors was observed during the commissioning period when devices had to be disconnected for diagnostics or troubleshooting and in use-case testing (simulating loss of power or communications).

POE cables were used to reduce the amount of cabling infrastructure required to be installed in the ROW. Although maximum power delivery by the sourcing equipment is limited to 30 W based on the IEEE 802.3at standard, this limitation was not observed during equipment operation, as the equipment was designed to a theoretical limit of 21 W. Another ancillary reason to use POE cables is that they are not as prone to theft as regular power cables.

It is important to note that any devices supported by a POW line must be within 300 ft of the hub. If there is a need for additional distance, then a POE extender must be used to allow for an additional 100 ft.

The network infrastructure backbone included fiber optic and twisted pair (Category 5e) POE cabling. Fiber optic cables were outdoor-rated with Low Smoke Zero Halogen (LSZH) sheathing to comply with NFPA130 standards. During the infrastructure installation phase, each cable run was tested and successfully passed. However, during the commissioning phase, intermittent communication interruptions where experienced, both as temporary loss of communication and performance loss (latency). It was determined that the root cause could have been due to Cat 5e cable being exposed to water for a prolonged period due to water ingress into supporting conduit infrastructure, resulting in degraded dielectric performance of the cable. This could result in disruption of cable impedance, attenuation, and return loss causing disruption to the communication backbone.

Both quick-disconnect connectors and POE are recommended in future designs. In addition, if MARTA was to invest in creating a dedicated fiber network specifically for TrackSafe, it is recommended that Bombardier supplement ROW technologies with solutions such as CCTV cameras overlaid with intrusion detection technologies to better justify initial deployment costs.

Industrial-Grade Hardware

Several components used in the design can be categorized as consumer-grade, with some prone to premature failure due to the impact of environmental factors as described above. For example, the initial design used microSD flash memory technology to support the operating system and logging; however, this technology failed prematurely and was determined to be inadequate for such an application. The final design replaced the microSD memory with solid-state drives optimized to run an operating system partition, which performed more reliably (no failures reported). It is recommended that future designs use storage devices that are appropriate for the application (including durable on-board memory controllers).

Other components initially prone to failure were the LED ring bracket and LCD window lens on the TIUs. Initially, both were failing due to water infiltration on earlier prototypes. Bombardier discovered the issue early and subsequently recalled and replaced TIUs with a more robust screens to mitigate future issues. DC power convertors also were a source of failure on both TIUs and OWLs.

It is highly recommended that industrial-grade hardware be used and fully constructed assemblies of TrackSafe components be environmentally tested before deployment.

Cybersecurity and Dark Fiber Availability

During design, MARTA and Bombardier chose to create a local dedicated fiber optic network exclusively for TrackSafe. A dedicated fiber loop architecture was selected to isolate TrackSafe from MARTA's Enterprise Network and avoid any potential cybersecurity threats or create any cybersecurity infiltration points. In addition, a firewall was placed at internet service connection points along the system.

Creating a dedicated fiber loop required building more supporting infrastructure. During constructability reviews, it became apparent that existing dark fiber strands were available from legacy SCADA and network systems that could be used by TrackSafe to create a redundant network.

It is recommended that transit agencies take inventory of their dark fiber prior to installation to seek opportunities to use existing fiber networks to build a dedicated network. Network security engineers need to be cognizant of where to place firewalls to prevent cybersecurity related issues.

Power Requirements

To power TrackSafe Hubs, MARTA used the same emergency light circuit that powers its emergency trip station lights. This power circuit was selected because it is tied to an Uninterrupted Power Supply (UPS) battery backup system along with a redundant power circuit source, providing for multiple back-up power sources for this safety system. In addition, it created both cost and time savings during construction as there was no longer a need to install additional conduits and cable infrastructure within the train envelope.

Self-Health Monitoring Feature

TrackSafe is designed with limited self-health monitoring features to help diagnose issues prior to entering the wayside for maintenance efforts. Unfortunately, the limited information gathered remotely led to multiple on-site trips by Bombardier to remedy issues as they occurred. If MARTA was to pursue a system-wide deployment of a dispersed network solution such as TrackSafe, it would be necessary to fully diagnose system components remotely. Self-health diagnostics should be defined at a level at which maintenance teams can determine what tools to bring prior to entering the wayside and what type of track restrictions are necessary to make the repairs. Maintenance training should be provided at a level at which transit agencies can make their own repairs or adequately swap-out parts when necessary for repair by the vendor.

Hardware Maintenance

During the conceptual design phase, MARTA maintenance teams realized that TrackSafe was made up of many individual components dispersed over the entire rail system within the wayside. The need to service these components could require scheduling track restrictions and disrupting revenue service if the components were difficult to remove, service, and replace. With this in mind, TrackSafe was designed to be able to swap out faulty system components with the use of hand tools and to carry components by hand off the wayside in a Maintenance Restriction area at MARTA. This type of restriction does not disrupt revenue service making TrackSafe easier to access and maintain. One recommended improvement is an adjustable bracket that can be lowered to access the OWL component for maintenance. Currently, a stepladder is necessary to access OWL devices, which impacts revenue operations.

Software Maintenance and Updates

TrackSafe is a proprietary system created by Bombardier, and future software updates would need to be provided by the vendor. MARTA recommends anyone entering into a contract with vendors confirm that software updates will be provided by the vendor as they become available. MARTA also recommends Bombardier include a feature that allows software updates to be pushed remotely to on-site devices to avoid the need to physically access components in the wayside.

TrackSafe Data Access

Bombardier houses all diagnostic data on its own servers. These data were presented to MARTA after being sanitized by Bombardier within Key Performance Indicator reports (see Appendix B). It is recommended that Bombardier provide transit property end-users with access rights to all available data in addition to formatted reports for full transparency. Establishing base contract terms and licenses can reduce the ambiguity of data accessibility.

Warranty Terms and Replacement Unit Costs

Base contracts should include warranty terms based on end-of-useful-life estimates provided by the manufacturer. Manufacturers should also provide a recommended spare parts list with established unit costs. Owners should require adherence to mean-time-between-failure criteria established by the manufacturer.

If a system is proprietary and requires vendor response to remedy malfunctioning equipment, response time criteria should be established in the contract along with late fees for missing contractually-accepted response times.

SECTION

7

Conclusions

MARTA and Bombardier successfully completed this research and demonstration with several takeaways that will help inform and improve RWP technologies for transit industry peers. During the initial phase of this program, the TrackSafe concept was well-received by MARTA Operations, and Bombardier was empowered with feedback directly from ROW workers. During Phase II, Bombardier incorporated some of the insights gained from Phase I to successfully design, fabricate, and deploy an improved version of TrackSafe onto three miles of track along the MARTA Red Line.

FTA's vision of deploying RWP solutions into an operating transit environment proved to be very relevant for Phase II. TrackSafe hardware components were put to the test, and the team was able to glean information that could not be simulated in a manufacturing facility or laboratory. The resulting lessons learned were, in some cases, specific to TrackSafe and in others universal to all RWP technology platforms.

The following summarizes perspectives of various end-users of TrackSafe:

- ROW workers appreciated the audio/visual alerts and not having to carry additional equipment on their person. They also liked that the SZ of protection would alert them in case of a train moving in the reverse direction. During the operational period, they reported that hardware such as the WAU process was cumbersome due to the long wait times for response. They also reported that TIUs did not always provide positive feedback, which made them question the reliability of the system. The key takeaway was that the hardware and communications network need to be made more robust. The test plan should include additional network testing criteria as well as rigorous environmental testing of components ensuring reliability prior to deployment.
- Train operators liked having advanced visual warning when approaching a track worker, especially in curved sections. Although feedback was not obtained from train operators during this demonstration period, this feature was well-received during design charrette discussions.
- Rail control supervisors were keen on gaining location awareness of wayside personnel distributed across the system on one central GUI. They also liked the ability to convert existing paper processes to electronic. However, they stated they would prefer to see a GUI incorporated as an overlay screen to their existing train control GUI in the IOC theater as opposed to a standalone computer that requires monitoring. They noted that the electronic check-in process seems to be a more efficient process for allowing personnel on the track during peak rush hours for wayside activity.

- MARTA trainers valued having the system authorize personnel to enter the wayside only if they had a current wayside certification and the correct certification for the selected track restriction.
- MARTA safety personnel appreciated that ROW workers had to confirm proper PPE before entering the wayside.
- MARTA ROW maintainers were apprehensive about the volume of devices that would need to be maintained in the wayside if a full system-wide deployment were to occur. However, they appreciated the ability to quickly disconnect, remove, and replace components. There was no first-hand training during this demonstration due to MARTA's decision to not pursue a full system-wide deployment of TrackSafe. During interviews, MARTA maintenance noted the need for self-health monitoring features to be readily available remotely. The project team observed that due to communications network instability, any intrinsic intelligence features could not be used.

Given the reliability issues associated with TrackSafe, MARTA did not pursue deployment of this version of TrackSafe technology based on the position that RWP technologies should serve to supplement wayside access procedures and be used only as a secondary warning system rather than as a primary means of protection. Transit agencies are encouraged to investigate RWP technology solutions to modify their existing standard operating procedures to incorporate these technologies on a robust wayside access training program. It is not recommended that agencies rely on these solutions exclusively.

The project team believes that this was a very successful demonstration despite the instability of hardware components that provided for a limited data set. The exposure of TrackSafe to the rigors of an operating transit environment provided a significant amount of information to aid in the development of an improved future version. The software, electrical infrastructure, and network design were thoughtfully designed and effective. There were many lessons learned during construction and implementation that Bombardier can use towards development of a new and improved version of TrackSafe.

Although MARTA did not pursue system-wide deployment of this version of TrackSafe technology, Bombardier is encouraged to continue to refine the system. One point of emphasis is the need to better leverage and overlay the TrackSafe dedicated fiber infrastructure with other synergistic products, such as intrusion detection, to substantiate and reduce initial costs of deployment.

This report should serve to help other transit agencies investing in RWP technologies and RWP technology innovators to better refine solutions as the path towards providing a reliable solution to this very vital need to the transit industry continues.

APPENDIX

A

TRA Third-Party Oversight Observations

TRA Safety Assessment of TrackSafe

Performed by Transportation Resource Associates, Inc. (TRA)
In Collaboration with Metropolitan Atlanta Rapid Transit
and Bombardier Transportation

April 15, 2021

Contents

Executive Summary

The Federal Transit Administration (FTA) commissioned a demonstration of Bombardier Transportation's (Bombardier) TrackSafe system, a secondary roadway worker protection (RWP) warning system. The Metropolitan Atlanta Rapid Transit Authority (MARTA) hosted the demonstration at its rail system; after installation, testing, and commissioning, the field demonstration of TrackSafe took place between December 2019 and May 2020. MARTA retained Transportation Resource Associates, Inc. (TRA) to serve as an independent safety assessor of the demonstration, and this report represents TRA's safety assessment of the TrackSafe system. TRA evaluated how well the TrackSafe system provides an extra layer of RWP safety for wayside workers, as well as what safety gaps in the TrackSafe system must be addressed for it to effectively provide secondary protection to wayside workers. The on-site portion of TRA's safety assessment took place at MARTA from March 9 – 12, 2020. (Since the time of the on-site portion of the assessment, MARTA has issued an update to its Wayside Access Procedure, dated April 2020.)

Overall, the TrackSafe system shows promise for being a viable secondary RWP warning system at rail transit agencies (RTAs). The feedback from MARTA employee focus groups was that in principle, a secondary RWP warning system would enhance wayside workers' safety on the right-of-way. However, employees who worked under the TrackSafe system in this demonstration also provided valuable feedback on the system, such as comments about tag-in units (TIUs) being slow to read the specialized TrackSafe identification (ID) cards; false positive and negative visual and audible alarms of approaching trains; and placement of system hardware relative to wayside workers' ergonomic and safety concerns. Due to TrackSafe demonstration system hardware component failures, MARTA and Bombardier opted to take the failed components out of service for the demonstration period. The Key Performance Indicators (KPIs) of TrackSafe system reliability indicate that the remaining components of the TrackSafe system are reliable; however, the need to take so many failed components offline reinforces the importance of a robust RWP program as a fallback to a secondary warning system.

The observations from this safety assessment also identified several gaps in the implementation of the demonstration system that should be addressed in future improvements and testing of an updated TrackSafe prototype. First, while the TrackSafe system is designed to involve interactions with wayside workers, rail controllers, and train operators, the demonstration at MARTA was effectively limited to wayside workers, and only those from the Track Department. While MARTA rail controllers were trained on the TrackSafe system, MARTA did not require them to work using TrackSafe in the execution of their duties during the demonstration. MARTA train operators did not participate in the demonstration at all. As such, this demonstration was missing valuable feedback from rail controllers and train operators. Future pilots of an updated TrackSafe demonstration system also include the full participation of rail controllers and train operators, along with wayside workers. The participation of these RTA constituencies in the next demonstration is crucial for Bombardier to observe how well the TrackSafe system works.

This safety assessment also identified several planning needs that prospective RTA customers of the TrackSafe system should consider. These needs include usage decisions, such as whether to use TrackSafe on all levels of wayside access/RWP, versus just some levels; whether to use TrackSafe in all weather conditions; which department will be responsible for maintaining the TrackSafe system; and other such considerations. A prospective RTA customer also needs to modify its operating rules and procedures to account for proper use of the TrackSafe system in order to ensure that the system functions as designed.

This safety assessment was a beneficial use of federal grant funding in that it was able to demonstrate that a secondary RWP system is feasible. The assessment identified gaps in the demonstration system that Bombardier should address in an updated prototype prior to putting the product into production. The assessment also identified implementation gaps that the host RTA of the next demonstration should address to ensure that the TrackSafe system's capabilities are fully tested. Overall, the findings and observations of this safety assessment highlight the need for future TrackSafe system customers from the RTA to coordinate closely with Bombardier. This coordination, in turn, is crucial for the need to configure the TrackSafe system to match the RTA's existing rules, procedures, and practices, as well as for the RTA to adjust or add to its rules, procedures, and practices to ensure that its personnel use the TrackSafe system as designed in order to ensure their own safety.

1 Introduction

The Federal Transit Administration (FTA) commissioned the TrackSafe Phase II study for the purpose of demonstrating a prototype of TrackSafe, a secondary roadway worker protection (RWP) warning system developed by Bombardier Transportation. The Metropolitan Atlanta Rapid Transit Authority (MARTA) hosted Phase II of the study. Transportation Resource Associates, Inc. (TRA) performed the independent safety assessment. This report appendix documents the findings, observations, and recommendations from TRA's assessment of the TrackSafe Phase II demonstration system installed at MARTA.

This appendix discusses an overview of the independent safety assessment; includes TRA's methodology for this safety assessment; presents a brief overview of MARTA's current wayside access/RWP program; discusses results and observations from TRA's on-site observations of the TrackSafe demonstration system and MARTA employees' interaction with the system; and details recommendations developed from the results and observations from on-site activities. Finally, this appendix identifies the implications of the safety assessment for future development of TrackSafe.

1.1 RWP Definition

RWP is a concept in the rail transit industry in which a coordinated set of operating rules, procedures, and training are designed and implemented by a rail transit agency (RTA) for the purpose of protecting workers working on the RTA's right-of-way. Such workers may be employed by the RTA directly, by the RTA's contractors, by the RTA's safety regulators and/or their contractors, or by any other organization whose personnel the RTA has allowed onto its right-of-way. At MARTA, the Wayside Access Program (WAP) serves the purpose of an RWP program at the RTA. As defined by MARTA, WAP rules are in effect for activities occurring "wayside":

> "The Wayside is defined as the track right-of-way including the track and supporting structures enclosed by the first fence line, wall, barrier, handrail, or platform encountered when proceeding away from the track center line."[1]

In this report, the MARTA term "wayside worker" is used to refer to all individuals working on the right-of-way. Other RTAs may refer to such workers as "roadway workers," "track workers," or other similar terminology. Similarly, this report refers to all activities completed by wayside workers on the track right-of-way as "wayside" activities.

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[1]Wayside Access and Safety: Level 1 Wayside Access Training Course Manual, Revision 4, October 2019; MARTA Office of Training, Infrastructure Training

1.2 Overview of TrackSafe Pilot Program – Phase II

1.2.1 TrackSafe system purpose

TrackSafe is an RWP secondary warning system. TrackSafe is intended for use at RTAs, including on both heavy rail and light rail systems, as inspection and maintenance work requiring wayside workers is required at rail transit systems of both types. The TrackSafe system provides additional warning to wayside workers of approaching trains and to train operators of the presence of upcoming wayside workers on the right-of-way. The TrackSafe system also enables rail controllers to visualize where on the right-of-way wayside workers are located in real-time, as well as their movements along the right-of-way. The TrackSafe system is not, however, intended to serve as the primary means of providing RWP. To that end, wayside workers, train and on-track equipment operators, rail controllers, and other personnel involved with wayside work must strictly follow the RTA's RWP rules and procedures. Wayside workers must be aware of their surroundings and alert for oncoming trains or on-track equipment. Conversely, train and on-track equipment operators must also be alert for the presence of wayside workers along the right-of-way as they operate their vehicles.

1.2.2 Study Purpose

The purpose of the independent safety assessment by TRA is two-fold: 1) to evaluate how well TrackSafe provides an extra layer of RWP safety for wayside workers and 2) to evaluate what safety gaps in the TrackSafe system must be addressed in order for it to effectively provide secondary protection to wayside workers. Additionally, this assessment yielded many observations, lessons learned, and recommendations from the demonstration TrackSafe system that can be applied to future iterations of the TrackSafe product. RTAs can also apply the observations, lessons learned, and recommendations from this assessment to future evaluation of secondary RWP warning systems.

1.2.3 TrackSafe Phase II Demonstration Period Implementation at MARTA

For the Phase II of this study, Bombardier installed the TrackSafe demonstration system on the MARTA Red Line between North Springs and Dunwoody Stations. Hardware for the TrackSafe demonstration system was initially installed on the entire alignment between North Springs and Dunwoody Stations, both along open-air and tunnel portions of the Red Line alignment. However, TrackSafe components, namely Tag-in Units (TIUs), that were installed along the open-air portions of the Red Line alignment failed due to water intrusion and other environmental elements. Due to these component failures, MARTA and Bombardier decided to have the demonstration period proceed with use of the hardware that was installed only in the tunnel portions of the Red Line alignment between Sandy Springs and Dunwoody Stations, as well as the outdoor TIUs between the North Springs Station platform and the portal to the tunnel to the south of North Springs Station. Bombardier decommissioned the remaining outdoor TIUs in the demonstration zone and physically labeled the units as such.

1.3 Safety Assessment Methodology

TRA's independent safety assessment of the TrackSafe Phase II demonstration system began in February 2018. In the two years between February 2018 and the conclusion of the assessment, TRA completed the activities described below to execute this safety assessment. TRA participated in weekly calls with MARTA and Bombardier and also attended an initial field demonstration of TrackSafe at North Springs Station in February 2018. Throughout the course of 2018, TRA reviewed and commented on draft TrackSafe supporting documentation, including the training plan, operations and maintenance manuals, and the alpha and beta versions of the TrackSafe eLearning video training modules. In November 2018, TRA collaborated with MARTA and Bombardier to develop a set of key performance indicators (KPIs) for TrackSafe that measure system availability, component health, successful tag-ins, and authorized/unauthorized/unregistered wayside worker entries.

1.3.1 On-Site/Field Activities

In March 2020, three members of the TRA team conducted a site visit to MARTA to receive wayside access training, conduct focus groups of MARTA personnel participating in the TrackSafe demonstration, and to make field observations of MARTA track inspectors and rail controllers interacting with the TrackSafe system both on the right-of-way and in the Integrated Operations Center (IOC) – Rail Control.

On March 9, 2020, three TRA team members successfully completed MARTA's wayside access training class in order to receive certification to walk under MARTA escort on the right-of-way in order to conduct field observations.

On March 10, 2020, the TRA team administered a survey to a focus group of MARTA rail controllers to garner feedback on the usefulness of a secondary RWP warning system, what additional training and mitigations could enhance RWP safety at MARTA, the quality of the TrackSafe training, and the quality and ease of use of the TrackSafe system.

On the morning of March 11, 2020, the TRA team split into two subsets for field observations of MARTA personnel working under TrackSafe. At North Springs Station, three TRA team members who were certified for MARTA wayside access surveyed a focus group of MARTA track inspectors who had worked under TrackSafe in the course of their day-to-day duties. After the conclusion of the focus group, the three TRA members, plus one representative from Bombardier, joined the MARTA track inspectors on a track walk from North Springs to Dunwoody Stations, with the MARTA track inspectors interacting with the TrackSafe system. The TRA team observed the MARTA track inspectors' interactions with TrackSafe and also noted observations about the configuration and functionality of the system. TRA team personnel also asked questions of the MARTA track inspectors on their experiences in interacting with TrackSafe and also posed questions to the Bombardier representative about TrackSafe's design, configuration, and functionality.

Figure 1: Entry to Right-of-Way at North Springs Station

Concurrently, two TRA team members observed rail operations control at the IOC to understand the interface between MARTA's typical train management systems and the dedicated TrackSafe tablet. TRA team members observed train control communication with wayside work crews and manual recording of crew information and also observed the TrackSafe interface to determine how it fit into MARTA practices. The MARTA resident engineer for TrackSafe Phase II project and a second Bombardier representative were also present to demonstrate TrackSafe and answer questions.

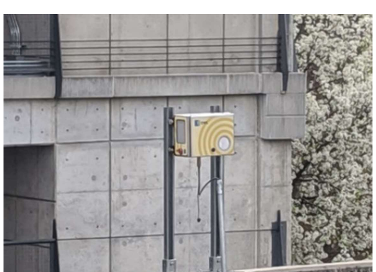

Figure 2: Operator Warning Light (OWL) at North Springs Station

On the afternoon of March 11, 2020, three TRA team members administered the same track inspector focus group survey to the larger group of all MARTA track inspectors at Avondale Yard. This focus group included both track inspectors who had worked under TrackSafe in the execution of their daily duties, as well as those who did not.

On the morning of March 12, 2020, the entire TRA team debriefed the MARTA project manager and resident engineer and the two Bombardier representatives on the site visit activities, concluding the site visit.

The criteria that TRA used to evaluate the TrackSafe demonstration system were MARTA's own WAP rules and procedures; the American Public Transportation Association (APTA) Standard for Roadway Worker Protection Program Requirements; FTA safety bulletins advisories, and guidance on RWP; and comparison with industry RWP best practices.

2 Brief Overview of Current State of Wayside Access Program

2.1 Current Governing Procedures, Policies, and Materials

The TRA team reviewed MARTA's Wayside Access Procedure (standard operating procedure [SOP] Number 10.3.51, dated February 20, 2013), Wayside Access and Safety Level 1 Wayside Access Manual (Revision 4, October 2019), Wayside Access and Safety Dedicated Lookout Manual (Revision 3, March 2014), and Wayside Access and Safety Flagperson Wayside Access Manual (Revision 3, March 2014) as part of the TrackSafe assessment; these were the respective document versions in effect at the time of the on-site component of this assessment (since the time of the on-site portion of the audit, MARTA had issued an update to its Wayside Access Procedure, dated April, 2020). The team compared these MARTA procedures with those recommended by the National Transportation Safety Board (NTSB), FTA Safety Directive 14-01 Right-of-Way Worker Protection (December 2013), the APTA Standard for Roadway Worker Protection Program Requirements (APTA RT-OP-S -016-11 Rev 1), as well as with RWP practices at other similar rail transit systems. This review is not intended to be an exhaustive review of MARTA's wayside access procedures. It is a high-level review of some of MARTA's practices and provides some observations and recommendations that may help improve the procedures.

MARTA permits workers on its tracks under four types wayside access classifications: **Clearances, Maintenance Restrictions, Track(s) Out of Service**, and **Yards**.

- During **Clearances**, workers are on the track with active train traffic with no speed restrictions and with the third rail energized.
- During **Maintenance Restrictions**, MARTA automatic train control personnel restrict train operations in the maintenance area: train speed is limited, with MARTA automatic train control personnel setting speed commands from Train Control Room, and the third rail remains energized.
- In accordance with MARTA's Track Allocation System Procedure, SOP 25.1.3, Rail Transportation authorizes requests for work zones with the **Track(s) Out of Service restriction**. Under this restriction, Rail Transportation removes one or more track from service, grants control of the work zone to the requesting work crew, and directs all train traffic into single-tracking around the work zone.

- **Yards** are the final type of restriction, governing work zones and train and on-track equipment movements around wayside workers in yard limits.

See the MARTA Wayside Access Procedures, SOP 10.3.51, Revision February 2013, for detailed descriptions of the wayside access clearances and restrictions at MARTA.

2.2 Current Training

MARTA has three levels of Wayside Access certification for persons who need to work on the right-of-way:

- Level 1: Individual is allowed to access the right-of-way but must be escorted by a MARTA Level 2- or Level 3-certified employee while on the right-of-way. Persons with Level 1 Wayside Access certification are prohibited from entering the MARTA right-of-way without a Level 2 or 3 escort except in the event of an emergency, which is defined as "a condition that endangers personnel, property, or a delay of schedule."[2]
- Level 2: Individual is allowed to access the right-of-way to set up Clearances, as well as escort Level 1-certified personnel accessing the right-of-way under a Clearance.
- Level 3: Individual is allowed to access the right-of-way to set up Clearances and Restrictions, and to supervise personnel accessing the right-of-way and working under Clearances and Restrictions.

In order to achieve Level 1 Wayside Access certification, an individual (MARTA employee, contractor, or visitor) must take a two-hour in-person class delivered by MARTA Office of Training personnel and successfully pass a written exam. Level 1 Wayside Access certification is valid for one calendar year from the date of the class, and persons with Level 1 certification must successfully pass the certification class each year thereafter in order to maintain their certifications. MARTA permits a grace period of no earlier than 30 days before and no later than 30 days after the certification anniversary for employees to recertify.

In order to achieve Level 2 Wayside Access certification, a MARTA employee must have a valid Level 1 certification as a prerequisite. Level 2 certifications are not available to non-MARTA employees. Similar to Level 1 certification, a MARTA employee achieves Level 2 certification by attending a four-hour in-person class delivered by MARTA Office of Training personnel and successfully passing a written exam. Level 2 Wayside Access certification is valid for one calendar year from the date of the class, and persons with Level 2 certification must successfully pass the certification class each year thereafter in order to maintain their certifications. MARTA permits a grace period of no earlier than 30 days before and no later than 30 days after the certification anniversary for employees to recertify.

In order to achieve Level 3 Wayside Access certification, a MARTA employee must have a valid Level 2 certification. Level 3 certifications are not available to non-MARTA employees. Similar to Level 1 and 2 certifications, a MARTA employee achieves Level 3 certification by attending a four-hour in-person class delivered by MARTA Office of Training personnel and successfully passing a written exam. Level 3 Wayside Access certification is valid for one calendar year from the date of the class, and persons with Level 3 certification must successfully pass the certification class each year thereafter in order to maintain their

[2] Wayside Access and Safety: Level 1 Wayside Access Training Course Manual, Revision 4, October 2019; MARTA Office of Training, Infrastructure Training

certifications. MARTA permits a grace period of no earlier than 30 days before and no later than 30 days after the certification anniversary for employees to recertify.

3 Results and Observations from TrackSafe Demonstration Period

3.1 Results of and Observations from Focus Groups

For its assessment, TRA convened focus groups with personnel from the two MARTA functional areas whose employees received training on the TrackSafe system: track inspectors and rail controllers. Bombardier delivered TrackSafe demonstration system training to these two groups of MARTA personnel in November 2019. Of these employees, only a pair of MARTA track inspectors executed their duties regularly under the TrackSafe system. The remaining track inspectors did not perform their duties under the TrackSafe system during the demonstration period. While rail controllers received TrackSafe system training, MARTA did not require rail controllers to use the TrackSafe system in the execution of their duties during the demonstration period, and none did. Thus, the entire demonstration period in effect did not yield any observations from rail controllers' perspectives.

3.1.1 Track Inspectors

TRA conducted a focus group with MARTA track inspectors to collect their feedback about TrackSafe system training and, if applicable, their experiences in interacting with the TrackSafe system during their work. While all MARTA track inspectors received training on the TrackSafe system in November 2019, only two track inspectors interacted with the system during their regular work responsibilities throughout the demonstration period, from December 2019 through May 2020.

TRA interviewed the track inspectors concerning the training they received concerning their wayside work. The track inspectors stated they receive MARTA Level 3 Wayside Access training and receive refresher training when needed. If track inspectors have any questions, they contact the MARTA Office of Training. The track inspectors reported that they received the necessary training for TrackSafe.

TRA also interviewed the track inspectors concerning safeguards that are put in place while they work in the right-of-way. The track inspectors stated that safety huddles are completed in the morning before work commences. They also reported that MARTA supervision conducts compliance checks of their adherence WAP rules, using a safety checklist. Any violations are reported to the IOC, which houses the rail control function. The track inspectors also described communications procedures for informing IOC of their work; communications are managed through flagpersons, with one primary flagperson responsible for communicating with IOC via radio. The track inspectors also stated that every individual is ultimately responsible for their own safety.

Figure 3 - Operator Warning Light (OWL)

The track inspectors stated that they felt that TrackSafe could potentially provide an extra level of protection and notify the workers of oncoming trains, although they noted that the audible alarms can be bothersome, and too many false alarms could cause workers to ignore the irritating sound. However, the inspectors noted that TrackSafe could only provide this level of protection if the system was working as designed. The track inspectors estimated that system components are inoperable 70 percent of the time, and as such, they were unable to see the system function as designed. The track inspectors stated that they react to operator warning lights (OWLs) alarms by stopping work and looking for oncoming trains. However, the inspectors reported that alarms sometimes do not sound until the train is very close to the workers. They stated that the TrackSafe system components did not work in sequence as they should, i.e. there were delays to visual and audible alarms emitted by OWLs and TIUs relative to trains approaching. The track inspectors were unsure if the system is able to follow the workers on both tracks, if they work on more than one track.

Other issues that the focus group reported about the system are as follows:

- Each TIU must be logged into and tagged into. This means, if inspectors forget to tag into a TIU, they must return to that TIU before continuing
- Some TIUs take up to 20 seconds to tag into, prolonging and distracting the workers from their primary work task(s)
- The TrackSafe system often sounds false alarms when there is no train approaching
- Other times, even if there is a train in the area, no alarms will sound

Ultimately, during the demonstration period, the system did not function as intended and never functioned at full capacity.

The track inspectors reported that the training they received on TrackSafe was helpful and complete. However, they also reported that, except for the two inspectors who regularly utilized TrackSafe, they did not retain the information gained through the training due to lack of exposure to the system. The inspectors reported that the training included field demonstrations and videos; no written training materials were provided.

TRA also discussed with the track inspectors their processes to enhance MARTA WAP requirements and how MARTA could improve worker safety while on the right-of-way. One main piece of feedback was for IOC to better communicate to train operators where track inspectors are located on the right-of-way; the track inspectors reported hearing feedback from train operators that train operators were unaware of the presence of track inspectors in the right-of-way until the train was in close proximity to their location. TrackSafe, through its visual OWL alerts, could alert operators to the location(s) of wayside workers when the train is farther out.

3.1.2 Rail Control

As part of this assessment, the TRA team conducted a focus group with MARTA rail controllers concerning MARTA wayside access and TrackSafe. During this focus group, the TRA team interviewed the controllers concerning WAP training, Wayside Access Procedure implementation and enforcement, intra- and interdepartmental communications related to wayside access, training on the TrackSafe system, and the impact of the TrackSafe system at MARTA.

During the interview, the rail controllers explained MARTA's communications and documentation processes for workers entering the wayside as well as their ability to ask questions or provide suggestions concerning MARTA wayside access processes. The TRA team also discussed with the controllers the processes in place for ensuring wayside worker compliance with MARTA procedures and how observed violations are addressed.

Overall, MARTA's controllers reported, and demonstrated through their responses to the interview questions, that they had had little interaction with the TrackSafe system since its installation. The interviewed controllers reported that they had received training on the TrackSafe system in 2019 and that the training was informative. However, since that training, very few of the controllers, possibly as few as one, had utilized the system during the demonstration period. The majority of the focus group participants reported that they no longer had access to, or knowledge of, their TrackSafe tablet credentials. Therefore, it was impossible for the controllers to provide information concerning the functionality of the TrackSafe system or its actual impact on the safety of operations and wayside workers.

Therefore, through the focus group, the TRA team solicited insight from the controllers about the potential implications of the TrackSafe system on their tasks, MARTA's WAP, and safety. Overall, the MARTA rail controllers reported that they believe that TrackSafe has the potential to make MARTA safer. The controllers noted the importance of full integration of TrackSafe into an RTA's existing IOC infrastructure. During the demonstration phase, access to the TrackSafe system was limited to a tablet through which controllers could visualize wayside workers as a graphic on a track diagram; controllers were not able to access this information via existing IOC consoles. The controllers reported the potential issues an added screen could pose in the IOC and to the completion of control activities.

The TRA team has concluded that additional rail controller use of the TrackSafe system is necessary to fully assess the functionality and safety impact of TrackSafe from a control center perspective. Additional use would allow for the identification of system challenges and needed improvements to implement TrackSafe effectively and optimally.

3.2 Results of and Observations from Track Walk

On March 11, 2020, TRA made its field observations for this assessment during a regularly-scheduled MARTA track inspection in the demonstration zone, i.e. between North Springs and Dunwoody Stations. One team of TRA team members made observations of the TrackSafe system while accompanying MARTA track inspectors, and a second TRA team made concurrent observations of the TrackSafe system from IOC to observe rail controllers' actions with the TrackSafe system activated.

3.2.1 Track walk on alignment – TRA and Bombardier with MARTA Track Inspectors

Three members of the TRA team accompanied two MARTA track inspectors and one representative of Bombardier during a routine MARTA track inspection of track FR from North Springs Station to Dunwoody Station to assess the operation of the TrackSafe equipment and the interactions of the inspection team with the TrackSafe system. MARTA inspectors are assigned an Inspection Clearance when completing a routine track inspection with a dedicated lookout and an inspector. The Inspection Clearance process is described in Appendix 1 of MARTA's Wayside Access Procedure SOP 10.3.51.

Figure 4 - Wayside Access Unit (WAU) at North Springs Station platform

The inspectors, one of whom acted as the lookout throughout the inspection, provided a job safety briefing before entering the track area. The inspection team walked south on track FR throughout the entire inspection, except when approaching the Dunwoody Station platform. The inspector walked in the track area except when he cleared the track area for passing trains. Whenever possible, the lookout, the TRA team, and the Bombardier representative walked in places of safety, including on safety walkways within system portals. The inspected segment of the system included open, at-grade track; elevated track; and track within portals.

The inspectors, prior to entering the track area, demonstrated the TrackSafe login procedures at the Wayside Access Unit (WAU) at the south end of the North Springs Station platform. The login process ultimately was successful, registering the two inspectors for their entry onto the right-of-way at the location of the WAU. However, the TRA team noted delays in the response from the WAU; it took several minutes to complete the login process for two inspectors.

MARTA permits its trains to operate at full operating speed, up to 70 miles per hour (mph), when passing personnel on the right-of-way with Inspection Clearances. Therefore, at MARTA, advanced warning of approaching trains is vital, especially on segments of track such as where the demonstration was conducted. The inspectors' sight distances are too short to provide them adequate time to observe an oncoming train and clear the right-of-way. Most similar RTAs require all trains to slow to a restricted speed such as 10 mph, when the operator observes wayside workers. Some similar transit systems position a lookout on the preceding station platform to notify the train operators of the mobile wayside workers on the upcoming segment of track and to notify the mobile wayside workers of the imminent train arrival. Conceptually, TrackSafe would provide a similar level of safety without the extra lookout positioned on the preceding station platform.

During the inspection, the inspectors tagged into all passed, operable TrackSafe TIUs. The TRA team noted delayed TIU responses when the inspectors tagged in at some of the TIUs along the right-of-way. While some TIUs immediately recognized wayside worker identification (ID) cards, others took several attempts or longer periods of time to register the cards. The Bombardier representative that accompanied the TRA team track inspection observation reported that the delays in TIU recognition were likely due to communications fiber or power issues rather than unit failures.

Figure 5 - Tag-In Unit (TIU) at North Springs Hi-Rail Access point

Additionally, the TIUs were often installed in locations that were difficult for the inspection team to access. For example, in the portals, TIUs were installed just above the walking surface of the safety walkways, so that personnel in the track area could reach them. However, in most, if not all, cases, the lookout engaged the TIUs from the walkway. This resulted in the lookout taking both inspectors' cards and bending down to utilize the TIU at foot level. It is vital that all TIUs are installed in locations that do not pose additional hazards for users, such as losing sight of oncoming trains, fouling the dynamic envelope of the train, or crossing the third rail when otherwise unnecessary.

Throughout the inspection, the TRA team noted inconsistencies in the performance of the TrackSafe OWLs in alerting the inspection team to the presence of oncoming trains. For several trains, the OWLs sounded with ample time for the inspector to safely clear the track area before the arrival of the train. In other cases, there were delays in the response of the OWLs to oncoming trains; the train would be passing or would even have passed the inspection team before the OWLs would alarm. There were also occasions during the inspection when the OWLs would alarm, sometimes for up to 30 seconds, and no train would arrive. These false alarms are disconcerting for the inspectors and led to an inability for them to rely on the system. The Bombardier representative participating in the observation of the inspection reported that a number of these irregularities were due to malfunctioning TrackSafe system units. False positive alarms on this system could have the potential to make users less reactive to actual alarms while false negatives could put users at risk of contact with oncoming trains.

Overall, the TRA team noted that the TrackSafe system alarms that sounded were sufficiently loud, giving the user a clear indication that a train was approaching. However, in certain locations on the system, there was significant ambient noise, including from the nearby highway just south of North Springs Station, that interfered with the inspectors' ability to hear oncoming trains, hear TrackSafe alarms, and communicate with other members of the inspection team. A prospective RTA customer needs to consider the implications of local noise ordinances and complaints on the implementation of the TrackSafe system. During the demonstration, for example, MARTA had to restrict the TrackSafe system alarm volume in areas such as the North Springs location due to the presence of nearby residential zones and associated complaints, as well as compliance with local noise ordinances. MARTA would have to apply the same volume restrictions in any future application of the system. In addition to limitations imposed by local noise ordinances and complaints on the system's audible features, a prospective RTA customer should also analyze how effective the TrackSafe system is as serving as a secondary RWP warning device with day-to-day environmental elements. These elements include background noise from an adjacent highway, as was the case along the MARTA demonstration alignment, and other noisy environments. A prospective RTA customer will need to consider whether background noise would compromise the effectiveness of the TrackSafe system's audible features, and if so, how to proceed with providing secondary RWP for its wayside workers.

The inspector and lookout relied on existing MARTA methods of train identification to supplement the protections supplied by the TrackSafe system. The inspectors monitored radio communications to determine when a northbound train was approaching and would clear the track area if a train arrival was imminent. The lookout would monitor the number of northbound trains that passed versus the number of southbound trains to anticipate oncoming trains. Additionally, MARTA has train alert lights installed in certain segments of the system, separate from the TrackSafe system, that flash when a train is approaching. The inspectors utilized these MARTA lights during the observed inspection; when the lights would flash, the inspector would clear the track area. Redundancy in wayside worker protections is vital, particularly in areas where lines of sight are shorter than those needed to safely identify an approaching train and clear the right-of-way prior to the train's arrival. However, the existing MARTA train alert lights and the TrackSafe system were not integrated and could possibly give conflicting information about the status of approaching trains. Two unlinked systems can cause a discrepancy that may lead to major confusion.

3.2.2 IOC Rail Control

Two members of the TRA team observed IOC rail controllers during the March 11, 2020 track inspection. One Bombardier representative and one MARTA representative accompanied the TRA team members in the IOC. During this inspection, the rail controllers' only means of interacting with the TrackSafe system was via the dedicated TrackSafe tablet, which was not integrated with MARTA's existing train control infrastructure. The tablet interface provides information about crew members requesting access, certification status of the crew, work request information, and the location of the wayside workers. The interface includes a visual depiction of a "bubble" representing the location of the wayside work crew signed into the TrackSafe system; the bubble is superimposed on a track map and moves down the track as the wayside work crew moves and tags into TIUs in real-time, thereby providing rail controllers a visual representation of the crew's location wayside. The TRA team observed general train location on the IOC's display boards. Train location was noted on a track diagram that also indicated track block occupancy. The TRA team observed MARTA's process for manually recording the clearance of wayside workers to enter the right-of-way, which included written confirmation of locations for the inspection and the inspectors involved. The TRA team was able to observe the track inspectors tag into the system from the TrackSafe tablet, but then noted that the TrackSafe interface did not clearly display when the inspectors both accessed the right-of-way. The controllers were able to provide this information due to communications with the track inspectors, but this information was not provided through the TrackSafe interface.

Although the TrackSafe system was activated, controllers in IOC were not asked to use the tablet and TrackSafe information. Controllers did not know how to fully utilize TrackSafe; the TRA team was not present during the training of the controllers on TrackSafe. The tablet graphic displaying the location of the workers on the wayside is not to scale and since MARTA does not require controllers and train operators to actively communicate with each other each time a train enters a block or area in which workers will be present, the rail controllers' knowledge of the location of the workers within the block may be limited. The lack of to-scale information and an unclearly defined color-coded strip showing a zone of safety around the worker' last point of check-in resulted in only a general knowledge that a work crew was between the two stations and moving either north or south.

4 Gaps in the TrackSafe Demonstration System and Recommendations to Address

The TrackSafe Phase II demonstration was valuable in that it was an opportunity to demonstrate the proof of concept of the TrackSafe system. The TRA team was able to observe MARTA's use of the system in a real-world operating environment and their track inspectors' interaction with it. The demonstration yielded several gaps that Bombardier and the RTA that hosts the next demonstration should address so that Bombardier can make refinements to the TrackSafe system prior to making a production version of the system. These gaps are discussed below.

4.1.1 No Train Operator Participation in Demonstration

MARTA train operators did not participate in the TrackSafe system demonstration. While MARTA train operators were able to see the warning lights emitted by the TrackSafe system's OWLs during the demonstration period, MARTA did not train its train operators on what OWL lights meant. Additionally, since train operators did not participate in this demonstration, they did not have a focus group for this assessment in which to provide their feedback on TrackSafe system training or functionality, nor did they formally have a forum to provide such feedback. A pilot test of a future iteration of the TrackSafe prototype system should include full participation of the test RTA's train operators. Train operators' feedback on both the functionality of TrackSafe system itself as well as whether such a system enhances their ability to detect and avoid wayside workers will be valuable to Bombardier.

4.1.2 Rail Controllers Not Required to Use TrackSafe System During Demonstration

In order to be successful, the TrackSafe system requires a clear concept of operations for the use of its various components. While the TrackSafe Phase II demonstration included the participation of rail controllers, training was provided to the controllers, and a tablet was made available at IOC, it is not clear that a concept of operations for controller use of the tablet or for the TrackSafe system was fully developed. As noted in the results of the observations from the focus group, rail controllers recalled being trained on the system and learning about its functionality, but their use of the TrackSafe system and expectations for reporting on its use were not clearly identified by MARTA or Bombardier. As such, rail controllers subsequently managed wayside work activity through the existing MARTA protocols involving radio communication and hand recording of information at IOC; they did not use the TrackSafe tablet.

In a future demonstration of the system, a clear concept of operations for the TrackSafe system tablet should be established with protocols for how the rail controller should use it. This should be integrated with the existing recording protocols so that it can be better determined if TrackSafe could reasonably replace the existing recording of information about wayside work activities, granting permission, tracking and monitoring wayside access, and confirming clearance from the right-of-way.

The tablet interface included potentially useful, detailed information about crew members requesting wayside access; the certification status of the crew, in terms of permission to enter the right-of-way; the status of the work request; and the location of the wayside workers. However, controllers were not asked to use these features and determine what may or may not be helpful in the real-world environment.

Had controllers been provided clearer expectations of participation, they may have identified challenges associated with times when workers logged into TrackSafe versus when they entered the right-of-way, inconsistent displays of information concerning the location of the wayside crews, including the color-coded strip to indicate the safe zone around wayside workers, or other challenges with what the controller is supposed to do with the information presented.

Additionally, it is unclear how the TrackSafe system fully integrates with MARTA's own operating rules and procedures and the rail controllers' work. As noted above, TrackSafe has the functionality to record crew information, work assignments, and locations of the crews, which is beneficial and a potential enhancement to the existing manual methods used. However, the graphic displaying the location of the workers on the wayside is not to scale and since MARTA does not require controllers and train operators to actively communicate with each other each time a train enters a block or area in which workers will be present, the rail controller's knowledge of the specific location of the workers may be limited. A major benefit to the system would be if the location could be presented on the large train control board and individual screens that show train locations – either for general quick visual reference or possibly as part of a different type of operating and communications protocol. Future demonstrations should provide better integration of the TrackSafe system with an RTA's control center policies and procedures in order to best understand all of its capabilities and functionalities.

4.1.3 TrackSafe Hardware Reliability in Demonstration

The TRA team noted through this assessment that various TrackSafe system unit failures during the demonstration period at MARTA made it difficult for both the team and MARTA employees to properly assess the impact of the TrackSafe system. The TRA team observed such failures directly through its observation of a MARTA track inspection as detailed in Section 4.2.1 and was informed of the failures through interviews with the MARTA track inspectors who regularly utilized TrackSafe during the demonstration period.

Figure 6 - Tag-In Unit (TIU)

A number of TrackSafe TIU and OWL units, including all units in an open track segment, were not functional at the time of the on-site portion of the assessment conducted by the TRA team. Some units had failed due to exposure to the elements and direct water intrusion. Some of the failed units had been replaced and still did not function, suggesting that the units in question were not compromised, but instead that the unit's cabling or communications hardware had failed. The conduits for the cables at each of the TIUs and OWLs ended with a vertical segment with only the unit itself to prevent rainwater from entering the conduit. Failed units had been marked as inoperable by Bombardier.

Additionally, the interviewed track inspectors reported that during the demonstration period there were always a number of units that did not function and that this made it challenging for them to assess the functionality of the system and its impact on their safety. They reported that due to unit failures, the functioning OWLs did not alarm in a manner that provided accurate and timely alert of oncoming trains. The high number of unit failures inhibited the inspectors' ability to fully assess how the TrackSafe OWLs would function if the system was fully operable. The TRA team experienced these conditions during the observed track walk. As alarm false positives and negatives can lower user trust in and responsiveness to alarms and put wayside workers at risk of being struck by trains or on-track equipment respectively, proper system functionality is key to evaluating the level of safety provided by TrackSafe.

4.1.4 TrackSafe Demonstrated Under Limited Number of Scenarios

In order for the TrackSafe system to be ready for purchase and use by RTAs, the system needs to be tested under all types of work conditions. During the demonstration period, MARTA personnel participating in the demonstration worked under the TrackSafe system only during Inspection Clearances. Additionally, the scope of the participating MARTA departments was limited to Track and Structures, and thus, the experiences of and feedback from other possible TrackSafe system end users, namely rail controllers and train operators, were not fully addressed in this demonstration. In order for the TrackSafe system to be a robust enough product to serve the differing needs of RTAs across the industry, the next iteration of a TrackSafe pilot system should include use in other conditions, such as under levels of protection other than Inspection Clearances. A future pilot system should also be tested with all possible TrackSafe end users, i.e. wayside work groups from other maintenance departments, as well as rail controllers and train operators, in order to test the system's full capabilities. Finally, the next demonstration of an updated TrackSafe system should test how the system works with small (four to five) versus large (ten or more) groups of wayside workers. The observations from these scenarios may yield future considerations by potential RTA customers on whether to impose a limit on the number of employees in wayside work groups working under the TrackSafe system.

Once the TrackSafe system's full capabilities and limitations are confirmed, then potential RTA customers should make the following decisions on how to integrate the TrackSafe system into their own RTA's use.

5 Recommendations on TrackSafe Integration Needs

5.1 Evaluation of Existing RWP Program

Before determining whether and how to use the TrackSafe system, an RTA needs to do a full evaluation of their existing RWP program. As noted throughout this report, the TrackSafe system is designed to be supplementary to an RTA's already existing RWP program and must integrate smoothly into it. As a part of this evaluation, an RTA should examine how it conducts RWP, how it meets the best practices and guidance of the industry, and how it could use the technology to further enhance it. A full evaluation of the RTA's existing RWP program will ensure that the TrackSafe system is not simply overlaid on top of the current program but is integrated for effectiveness and efficiency.

5.2 TrackSafe Use Decisions

When deciding whether to acquire and implement a secondary RWP warning system, an RTA will evaluate how well such a system integrates into its existing systems and infrastructure, including, but not limited to, train control/signals, supervisory control and data acquisition systems, communications and telephony, and other systems vital to rail transit operations and maintenance. The RTA also evaluates how well such a system can be integrated into its existing operating and maintenance rules and procedures. As such, the design and configuration of any secondary RWP warning system that an RTA will acquire, such as TrackSafe, must take the following factors into account, discussed below in this section.

5.3 Identification of Clearances and Restrictions Under Which TrackSafe will be Used

One of the first decisions that an RTA needs to make when evaluating whether to acquire the TrackSafe system is when to use such a product. An RTA will need to decide whether to have all personnel working on the right-of-way work under the TrackSafe system, as well as when personnel who are designated to work under the system will do so. An RTA should decide whether its employees should work under the TrackSafe system during all wayside work scenarios, versus just selected scenarios, such as when there is active train and/or on-track equipment movement concurrent with wayside work taking place. Discussed below are decisions that an RTA will have to make regarding TrackSafe system use on its property.

As stated above, MARTA used the demonstration TrackSafe system only under Inspection Clearances, which offers a lower level of protection than Maintenance Restrictions. Under Inspection Clearances at MARTA, trains are permitted to operate at the maximum speed permitted on the alignment and third rail power is energized. The work crew must assign an individual as the designated lookout to watch for oncoming train traffic who is not permitted to do any other work. The Inspection Clearance is intended for a work crew to gain access to the right-of-way in order to perform an inspection or light maintenance, such as a visual track inspection or tightening or replacing track bolts.

In evaluating whether to acquire the TrackSafe system, RTAs will need to determine the levels of protection under which the system would be used. For example, an RTA could decide to require that all of its wayside workers work under the TrackSafe system, regardless of the level of clearance, restriction, or protection, as appropriate. Alternatively, an RTA could determine that work taking place under a level of protection similar or equivalent to Track Out-of-Service need not do so under the TrackSafe system, since the train traffic is by definition prohibited from the track out-of-service; as such, the track being out of service is a strong enough safeguard in itself to protect the wayside workers from train and on-track equipment traffic. These are considerations that an RTA must take when deciding whether to acquire a secondary on-track warning system and when to use it.

5.4 Designating Personnel to Troubleshoot and Maintain TrackSafe

As with any other piece of equipment that an RTA uses, the TrackSafe system may encounter situations in which it does not function properly. Also, the TrackSafe system and its components will require preventive and corrective maintenance, just as other RTA infrastructure and equipment do, as well. An RTA that purchases the TrackSafe system will need to decide who should handle system troubleshooting. For example, an RTA could decide to train all personnel from departments that work under the TrackSafe system to perform basic troubleshooting, or it could designate specific individuals as dedicated troubleshooters and instruct remaining personnel to report system malfunctions to rail control and revert to the base RWP/WAP rules and procedures.

An RTA should also designate a specific department to perform preventive and corrective maintenance on the TrackSafe system. By assigning an "owner" department, the RTA can ensure that the system is part of a regular maintenance program and thus can function properly, as with any other piece of equipment or infrastructure. Some possible candidate departments that could have primary responsibility for TrackSafe system maintenance are signals/train control, radio communications, or information technology (IT), given the TrackSafe system's functions. What is most important, however, is that a specific department is responsible for managing the maintenance of the TrackSafe system so that required preventive and corrective maintenance is not overlooked and that maintenance records are kept.

5.4.1 Inspection/Maintenance of TrackSafe

An RTA should consider any potential burden in the form of labor and parts of the inspection and maintenance of the TrackSafe system. The potential burden will depend partly on the decisions the RTA makes around designating personnel and/or a department to maintain the TrackSafe system. An RTA should consider whether the maintenance of the system would limit available track time or require extra equipment, or if the maintenance burden could be mitigated through integration and shared use with MARTA's existing maintenance protocols and equipment.

5.5 Other Considerations for TrackSafe System Use

In addition to TrackSafe system use scenarios, RTAs should also consider environmental factors when deciding if and when to use the TrackSafe system. RTAs that implement the TrackSafe system must comply with noise ordinances for each jurisdiction in which the RTA intends to use the system. In the event that the applicable noise ordinances render the TrackSafe system's audible alarms insufficiently loud to warn wayside workers as intended, the RTA should consider whether to proceed with working with the TrackSafe system operating under the limits of the noise ordinances or explore alternatives. Bombardier may also wish to see if development of a wearable alarm device for wayside workers is a feasible alternative to the audible alarms.

An RTA that is evaluating whether to acquire the TrackSafe system should also consider whether the system's effectiveness, particularly from the audible and visual cues emitting from TIUs and OWLs, are compromised during inclement weather or other environmental elements during use along outdoor portions of the right-of-way. The next iteration of the pilot TrackSafe system should demonstrate how the system performs during inclement weather of all varieties, including rain; snow events; high winds; and other weather conditions. North American RTAs operate in a wide range of climates, and the production version of the TrackSafe system will need to be able to operate successfully in all of them.

5.5.1 Failsafe Design of TrackSafe System

Based on the demonstration period, the TrackSafe system did not function as a failsafe system for RWP due to false negative alarms. As stated above, the TrackSafe demonstration system experienced hardware component failures, and MARTA and Bombardier opted to take the failed components out of service for the demonstration period. The Key Performance Indicators (KPIs) of TrackSafe system reliability indicate that the remaining components of the TrackSafe system are reliable; however, the need to take so many failed components offline reinforces the importance of a robust RWP program as a fallback to a secondary warning system. Potential RTA customers should implement a system demonstrated to be vital and failsafe.

5.6 Recommendations on Additional/Revised Policies and Procedures Required

5.6.1 Overview

During the demonstration period, MARTA track inspectors received training on how to interact with the TrackSafe system. An RTA that purchases the TrackSafe system will need to codify the procedures into the RTA's operating rules, SOPs, WAP/RWP manuals, and into employee training. This codification will ensure that employees complete the proper steps to activate the system to provide the employees protection while on the right-of-way. Such protection includes the important elements of the TrackSafe system depicting to rail controllers the real-time locations of wayside work crews, as well as alerting oncoming train and on-track-equipment operators to the presence of wayside work crews.

5.6.2 Wayside Access/Roadway Worker Protection Rules

The TrackSafe system is designed to supplement an RTA's RWP program by providing an additional layer of protection for wayside workers above the foundational RWP rules, procedures, and equipment. The steps required to effectively use the TrackSafe system as designed that an RTA must codify are:

- Employees and contractors working under the TrackSafe system must use an RTA-issued TrackSafe system ID card that is compatible with the system.
- The department planning to do wayside work must designate a crew leader for the job. The crew leader then must enter the time, date, and location of work being done, and the work crew roster into the TrackSafe system prior to work being done.
- Upon arrival near the work site, the designated crew leader must sign into the closest WAU, confirm to the TrackSafe system the work being done, and sign each crew member in.
- The crew leader should note any worker's expired track certification flagged by the TrackSafe system and ensure only those with current certifications perform work. The notification of an expired certification should trigger a plan to recertify the appropriate crew member.
- While walking along the right-of-way, work crew members must tap their TrackSafe system ID cards at each TIU so that rail controllers can see the "bubble" that depicts the current location of the work crew.
- Upon exiting the right-of-way, the crew leader must sign each crew member out of the TrackSafe system so that the system and rail controllers recognize that the crew is clear of the right-of-way.
- The crew leader should collect reports of TrackSafe system defects and/or malfunctions while in the field and report these issues to the TrackSafe system's owner department at the RTA. That department can then troubleshoot and perform corrective maintenance on the TrackSafe system as appropriate.

The TrackSafe system can only fully perform as designed when users follow all of the steps above, as well as any others required by TrackSafe system original equipment manufacturer (OEM) procedures. An expedient way to foster correct usage of the system is to codify these steps in the WAP/RWP program and/or operating rules. Making these steps rules makes them compulsory and thus improves wayside workers' compliance with TrackSafe use procedures, and in so doing, enhances the protection provided to wayside workers.

5.6.2.1 Rules for TrackSafe System Malfunction or Failure

An RTA that implements the TrackSafe system should also develop contingencies for employees to follow in the event that the system fails or malfunctions. Should the system fail, malfunction, or otherwise be rendered unreliable in providing secondary RWP, the RTA should have in its WAP/RWP rules and procedures requirements for wayside workers to fall back on foundational WAP/RWP rules. Additionally, the RTA should codify the procedure for employees to report system malfunctions to rail control and onto the RTA's owner department of the TrackSafe system for system troubleshooting and repair.

5.6.2.2 Implications for Personal Protective Equipment (PPE) Requirements

A central feature of the TrackSafe system's designed functionality is wayside workers' use of special TrackSafe system ID cards to tell the system their locations on the right-of-way. RTAs that use the TrackSafe system should designate such TrackSafe system ID cards as a required piece of personal protective equipment (PPE) for on-track work. Just as wayside workers are required to wear or possess PPE such as safety vests, flashlights, safety shoes, and other pieces of equipment for on-track work, making the TrackSafe system ID card a PPE requirement for wayside work will enable the system to function correctly and protect the wayside workers, just as the other pieces of PPE are intended to do.

5.6.3 IOC Rules and Procedures

Rail controllers play an important role in the proper functioning of the TrackSafe system as designed. They ensure that all personnel who are authorized to enter the right-of-way are safe to do so and know the locations of trains and other on-track equipment on the rail system. Rail controllers are in radio communication with a designated member of the wayside work crew, which provides a critical conduit of information between the two parties. While on-track crews are working wayside, rail controllers' duties include monitoring their locations in order to protect them from oncoming train and on-track equipment traffic and vice versa. To that end, the TrackSafe system displays a visual bubble superimposed on a graphic of the right-of-way to depict the work crews' location(s). Just as codifying TrackSafe system procedures into an RTA's rules and procedures improves compliance with such procedures in order enable the TrackSafe system to function correctly, the same should be done with rail control rules for the same reason.

A central feature of the TrackSafe system is the visual display of wayside workers' locations on a graphic of the rail system for rail controllers to monitor. This display works only when wayside work crews sign into the TrackSafe system in accordance with the system's designed procedures and when rail controllers correctly use the system as well. As such, an RTA that uses the TrackSafe system should codify the following steps for rail controllers to use the system correctly:

- Procedure for rail controllers to sign into and out of the TrackSafe system. Once the TrackSafe system is installed at a customer RTA, the procedure for how the rail controller signs into the TrackSafe system should be codified so that rail controllers will have full use of the TrackSafe system.
- Procedure for the scenario in which an unauthorized user gains access to the right-of-way but signs into the TrackSafe system. The TrackSafe system will still generate a protection "bubble" that will also appear on the Rail Controllers' interface; the RTA should memorialize the exact procedure that rail controllers are to follow in order to ensure the protection of the unauthorized entrant to the right-of-way and to get that individual to clear the right-of-way as soon as possible.
- Procedures for forcing TrackSafe system user sign-outs. The TrackSafe system has encountered situations in which a user attempts to sign out from the system, but the system fails to recognize that the user signed out. In such a scenario, a rail controller is able to force the system to sign out the user in question from the TrackSafe system so that the system no longer indicates that the user is still wayside.
- Procedures for when a member or members of the work crew break(s) away from the larger group. Occasionally, a member or members of the larger work group may break away and leave the right-of-way for any number of reasons. An RTA should codify the rules and procedures that a rail controller must follow in this scenario to ensure the continued safety of the wayside worker(s) who has/have broken away from the larger work group. Alternatively, an RTA could prohibit such behavior by rule as well.

Each of these rules and procedures, and others as applicable to use of the TrackSafe system, exists in addition to the RTA's existing wayside access/RWP rules and procedures.

5.6.4 Operating Rules and Procedures

The TrackSafe system is designed to also be beneficial to an RTA's train and on-track equipment operators. As wayside workers tag TIUs as they walk along the right-of-way during their jobs, the TrackSafe system components will emit strobe lights in the wayside workers' current location(s) for the primary purpose of warning train and on-track equipment operators of the wayside workers' presence. RTAs generally already have operating rules that address train and equipment operators' required actions in a variety of scenarios; an RTA that uses the TrackSafe system should enact operating rules that address scenarios specific to train and equipment operators' interactions with the TrackSafe system.

5.6.4.1 Rules for Train Operators

The TrackSafe system is designed to so that train operators do not need to directly manipulate the system in order to benefit from the information that the system is giving, i.e. that wayside workers are in the vicinity. Even so, an RTA that purchases the TrackSafe system should codify in operating rules the desired behaviors of train operators in response to outputs from the system. Most RTAs already have existing rules that require train and on-track equipment operators to slow their vehicles to a restricted speed (e.g. 10 mph, 15 mph, etc.) when approaching and passing wayside workers. Rail transit systems that use the TrackSafe system could augment their existing operating rules by issuing new rules requiring train and equipment operators to slow their vehicles to a restricted speed upon recognition of a TrackSafe system strobe light. Such new rules that are tied to the TrackSafe system should be in addition to, and not replace, existing rules requiring train and on-track equipment operators to slow their vehicles to restricted speed upon visual recognition of wayside workers. In the event that the TrackSafe system is not functional for whatever reason, the existing rules requiring slowing down to restricted speed upon visual recognition of wayside workers must be preserved for the wayside workers' safety.

5.6.4.2 Track Allocation

A key feature of the TrackSafe system is that the sign-in/sign-out process permits only authorized RTA work crews to access the right-of-way at assigned times. Typically, RTAs assign which departments and/or contractors can access what parts of the right-of-way and when through the track allocation process. Since the TrackSafe system by design grants access to wayside work crews through the sign-in process, RTAs should incorporate programming wayside access assignments into the track allocation process. In addition to RTA departments and contractors requesting dates, times, and locations to access the ROW, these requestors must also confirm their track allocation assignment in the TrackSafe system to ensure that the system recognizes each crew at its designated time and authorizes those crews to enter the right-of-way. The RTA department or group that manages the track allocation process can then enter wayside access requests into the TrackSafe system to ensure that the system permits work crews to enter the right-of-way at their designated times. Incorporating the entry of work requests into the track allocation process ensures that this key process takes places as required for the system to function as designed.

5.6.5 Compliance Program

RTAs that acquire the TrackSafe system will also need to incorporate monitoring of TrackSafe system-specific operating rules into their rules compliance program. The purpose of rules compliance programs is to ensure that employees are properly following operating rules and procedures to ensure that their actions are safe and that they use tools and equipment properly. Monitoring employee compliance with TrackSafe system-specific rules helps ensure that employees are using the TrackSafe system as instructed so that the system can offer the maximum level of protection to which it was designed. As with any robust rail transit rules compliance program, the RTA can have multiple departments administering compliance checks for TrackSafe system-specific rules. Possible departments administering these checks can include TrackSafe system end-user departments, such as Track, Structures, Traction Power, Signals/Train Control, or any other functional department that works wayside. Rail Transportation departments can also incorporate TrackSafe system rules compliance checks into their programs to ensure that train operators are properly slowing down upon encountering TrackSafe system strobe lights, which indicate the presence of wayside workers in the vicinity. RTA safety departments should also administer their own rules compliance checks in their capacity as the independent monitors of safety within the RTA.

5.7 Additional Training

5.7.1 Overview

Any RTA that purchases the TrackSafe system will need to integrate TrackSafe's features and functionality into its operating and maintenance rules and procedures so that employees will be able to properly use the system. Doing so will enable employees to do their jobs safely and enable the TrackSafe system to deliver the secondary RWP warnings that it is designed to provide. The following are key areas in which additional training specific to TrackSafe will need to be provided.

5.7.2 Integration of TrackSafe into Wayside Access/RWP Training

At the time of this study, MARTA had not integrated training on wayside workers' interactions with the TrackSafe system into its WAP training, since the TrackSafe system was only being used on a demonstration basis. However, any RTA that purchases TrackSafe should include in its planning integration of TrackSafe system functionality into its WAP/RWP training curriculum. Important details to cover are who in a work crew has responsibility for signing work crews in and out of the TrackSafe system at the WAUs; the requirement for all personnel in work crews to tag into TIUs as they move through a work zone, so that TrackSafe can properly function as designed; and what personnel should do in the event that parts of or the entire TrackSafe system fails to function as intended. An RTA that purchases the TrackSafe system should integrate the product into its WAP/RWP training, just as it would for any other piece of equipment purchased so that employees can properly do their jobs with the purchased product, as intended.

5.7.3 TrackSafe-Specific Training

After an RTA has purchased the TrackSafe system, it must also train its employees on how to properly use and interact with the system as part of their job duties. Employees being properly trained on and using the TrackSafe system will enable the system to offer the maximum designed protection possible for wayside workers. Below are descriptions of some job classifications that will require TrackSafe-specific training in order for the system to function as intended.

5.7.3.1 IOC Rail Controllers

Any new system requires comprehensive training on two key elements – the technology itself and the concept and purpose of the system in the current operating environment. Rail controllers received training on the TrackSafe system itself and learned about its features. However, MARTA did not require controllers to use the system on an ongoing basis as part of their day-to-day work involving existing MARTA rules and procedures. For example, controllers manually write down information about work crews when the crews radio into IOC to request wayside access. While TrackSafe logins by wayside crews would provide this information to the controllers, it was not evident that the controllers had been trained on how to use that information specifically in the MARTA operating environment or for the purposes of gathering information for this demonstration.

Controllers should be provided additional training that incorporates the RTA's requirements for each stage of the use of the TrackSafe system. For controllers, this training would focus on steps related to reviewing the day's upcoming work assignments, which would be in a fully implemented TrackSafe, granting permission to wayside crews using TrackSafe system features and radio communications, managing train and wayside crew activities based on the information presented by TrackSafe, and ensuring that when work is completed, TrackSafe appropriately records and indicates the completion of the work and crew's exiting from the system. Similarly, other features of the TrackSafe system should be taught to the controllers, as is appropriate for their use.

5.7.3.2 Contractors

The universe of personnel who work on the right-of-way is not limited to RTA employees. RTAs often retain contractors to perform specialized work on the right-of-way or to augment their own personnel. Regulators, including safety regulators, may also need to work wayside for such activities as inspections, investigations, or observations. An RTA that purchases the TrackSafe system should include in its WAP/RWP training for contractors and visitors on how to interact with the system to maximize their protection. The RTA's training for contractors and visitors should specify whether contractors and visitors will be issued TrackSafe ID cards in order to tag into TIUs along the right-of-way, or if contractors and visitors will not be issued such ID cards and only the RTA's own employees will use their own TrackSafe ID cards to interact with the system.

5.7.3.3 Train and On-Track Equipment Operators

As discussed above, the TrackSafe system is designed so that train and on-track equipment operators' interactions with the system are limited to responses to the audible and visual alarms that the system emits to announce the presence of wayside workers. The RTA would need to conduct TrackSafe training with its rail and on-track equipment operators concerning the procedures and desired actions that such operators must take upon receiving the TrackSafe system audible or visual alarm, such as slowing the train or on-track equipment to a restricted speed before passing the on-track crew at that speed. The training should also cover what actions the train and on-track equipment operators must take if they see an on-track crew approaching and the TrackSafe system does not alarm (e.g. due to the system not being activated, malfunctioning, or down for maintenance, etc.). In such instances, the expected action should be slowing to a restricted speed as defined in the operations rulebook and passing the on-track crew at the restricted speed until the train or on-track equipment is clear of the crew. The operators should be trained on how and when to report failures such as these.

5.8 TrackSafe Planning Needs

TRA repeatedly observed throughout the study that TrackSafe offers great potential to provide useful information to different rail transit workers who interface with the system. This information can help employees, contractors, and other parties work on the wayside and manage rail service more safely. In order to assure the success of the TrackSafe product, the RTA will require a comprehensive document that identifies all of the functions and features of the product including all of Bombardier's assumptions for those functions and features. This is critical so that the RTA is able to evaluate if all of the features align with the procedures and operating practices of the RTA. Features of TrackSafe that are not helpful to MARTA may be helpful to another RTA, and vice versa. The RTA must have the full list of features so that it can then develop a crosswalk and eventual operating plan which fully integrates the use of TrackSafe into its existing rules, procedures, and operating practices. Gathering all of this information, including an overview of all of the controller tablet displays, is critical to understanding how the system can be integrated with or complement existing train control display and other train communications equipment. The RTA must be able to understand what features are optional or could be turned off, if they are not expected to be used.

6 Conclusion

The TrackSafe system offers promise for providing a secondary warning technology that helps wayside workers. This safety assessment has been helpful in identifying gaps in the TrackSafe concept of operations as applied in the real world at MARTA. By taking the lessons learned from this demonstration, the TrackSafe product can be modified to account for the challenges of operating in the dynamic transit environment. If Bombardier were able to incorporate the recommendations in this report into the TrackSafe product development, further testing of an updated TrackSafe system would be beneficial.

This study was a beneficial use of federal grant funding in that it was able to demonstrate that a secondary RWP warning system is feasible. This study also identified potential improvements that must be made to the product itself, as well as the planning for integration of such a product into an RTA's operating practices and procedures. Such planning would need to take place anew at each RTA purchasing the TrackSafe system, due to the unique operating characteristics of each RTA. Such lessons learned will be beneficial in the future towards the protection of wayside workers at FTA-funded and -regulated RTAs.

TRA thanks MARTA, Bombardier, and FTA for the opportunity to participate in this study and to conduct this safety assessment. TRA appreciates the opportunity to be able to collaborate with MARTA, Bombardier, and FTA in furthering transit worker safety.

APPENDIX

B Project Artifacts

- Submittal Log – deliverables provided by vendor
- Request for Information Log – inquiries from vendor
- MARTA Test Readiness Key Performance Indicator Report

marta

2424 Piedmont Rd. NE
Atlanta, GA 30324-3330
404-848-5000

SUBMITTAL LOG
PROJECT No: PN#32108 RFP36027
PROJECT TITLE: TrackSafeII Red Line Deployment (North Line)

Contractor Drawing No.	Type	Description	Tracking No.				Transmittal Dates				Review Code	Design Review Time	Total Review Time	Inspector Copy	Comments
			Transmittal Number	Spec. Section	Print No.	Rev. No.	Received from Contractor	Sent to Design	Received from Design	Sent to Contractor					
	C/D	High Level Design Presentation	T-01	2.1	HL	0	12/11/2015	12/11/2015	1/8/2016	1/8/2016	A	28	28	n/a	
	C/D	Preliminary Design	T-02	2.1	PD	0	5/19/2016	6/21/2016	8/1/2016	8/2/2016	B	41	75	n/a	received eng on 6/28/2016
	C/D	Project Management Plan	T-03	1.1	PMP	0	5/18/2017	5/18/2017	5/18/2017	5/18/2017	A	0	0		
	C/D	Configuration Management Plan	T-04	3.1	CMP	0	11/11/2016	11/11/2016	11/22/2016	11/22/2016	A	11	11	n/a	
	C/D	Test Plan	T-05	5.1	TP	0	12/1/2016	12/1/2016	1/3/2017	1/10/2017	C	33	40	n/a	
	C/D	Test Plan	T-05A	5.1	TP	1	2/6/2017	2/6/2017	2/7/2017	2/7/2017	B	1	1	n/a	
		Test Plan	T-5 B	5.1	TP	2	5/5/2017	5/8/2017	5/30/2017	5/30/2017	A	22	25		
	C/D	Final Design	T-06	2.1	FD	0	12/19/2016	12/22/2016	12/22/2016	1/10/2017	E	0	22	n/a	submittal incomplete
	C/D	Final Design	T-06A	2.1	FD	1	2/10/2017	2/20/2017	5/11/2017	5/11/2017	B	80	90	Yes	
	P/R	Installation Draft Plan	T-07	4.1	DIP	0	1/25/2017	1/26/2017	2/21/2017	2/21/2017	C	26	27	n/a	Began receiving comments on 2/7/17 from reviewers
	P/R	Installation Draft Plan	T-07A	4.1	DIP	1	3/10/2017	3/20/2017	4/7/2017	4/13/2017	B	18	34	Yes	Came in on Compressed day.
	C/D	W/C Procedures	T-8	5.2	W/C	0	3/6/2017	3/8/2017	3/24/2017	4/13/2017	B/C	16	38	n/a	Resent on 3/20
		W/C Procedures	T-8A	5.2	W/C	1	4/25/2018	5/3/2018	5/17/2018	5/24/2018	B	14	29		
		Hardware Configuration	T-9	3.2	HC	0	5/31/2017	6/1/2017	6/22/2017	6/22/2017	A	21	22		
		Hardware Configuration Witnessed	T-9A	4.2	HC	1	6/23/2017	6/23/2017	6/23/2017	6/23/2017	A	0	0		
		Software Configuration	T-10	3.3	SC	0	7/20/2017	7/26/2017	8/17/2017	8/17/2017	A	22	28		
		Hardware/Software Configuration	T-11	5.4	HSC	0	8/10/2017	8/13/2017	8/13/2017	8/13/2017	A	0	3		
		Hardware/Software Configuration Witnessed	T-11A	5.4	HSC	1	6/15/2018	6/15/2018	6/15/2018	6/15/2018	A	0	0		
		Software Configuration Witnessed	T-12	3.2	SC	0	10/31/2017	11/1/2017	11/3/2017	11/3/2017	B	2	3		
		Software Configuration Witnessed	T-12A	3.2	SC	1	11/21/2017	11/27/2017	11/30/2017	11/30/2017	A	3	9		Thanksgiving Break
		not used	T-13				n/a	n/a	n/a	n/a		n/a	n/a		
		Field & Commissioning Testing - Test Procedure& Data	T-14	5.2	FT	0	4/3/2018	4/3/2018	7/23/2018	7/23/2018	D	111	111		
		Field & Commissioning Testing - Test Procedure& Data	T-14A	5.2	FT	1	8/31/2018	9/6/2018	9/18/2018	9/18/2018	D	12	18		
		Field & Commissioning Testing - Test Procedure& Data	T-14B	5.2	FT	2	9/28/2018	10/4/2018	10/10/2018	10/10/2018	A	6	12		
		Training	T-15	6.1	TP	0	4/17/2018	4/17/2018	7/23/2018	7/23/2018	D	97	97		
		Training	T-15A	6.1	TP	1	9/18/2018	9/18/2018	10/25/2018	10/25/2018	C	37	37		
		Training	T-15B	6.1	TP	2	2/11/2019	2/11/2019	3/10/2019	3/11/2019	C	27	28		
		Training	T-15C	6.1	TP	3	11/18/2019	11/18/2019	11/18/2019	11/18/2019	A	0	0		
		As Builts	T-16	2.3	AB	0	10/11/2018	10/11/2018	10/11/2018	10/11/2018	D	0	0		
		Test Readiness Report	T-17	5.3	RR	0	5/2/2019	5/2/2019	5/3/2019	5/3/2019	A	1	1		
		Fiel& Commissioning Results	T-18	5.2	FT	0	9/26/2019	9/26/2019	10/4/2019	9/27/2019	A	8	1		
		O&M Manuals	T-19	7.1	OM	0	2/3/2020	2/3/2020	2/3/2020	2/3/2020	A	0	0		
		As-Built/Final Configuration	T-20	2.3	AB	1	2/3/2020	2/3/2020	2/3/2020	2/3/2020	A	0	0		Close Out Design and Asbuilt

2424 Piedmont Rd. NE
Atlanta, GA 30324-3330
404-848-5000

PROJECT TITLE: TrackSafeII Red Line Deployment

PN32108 P36027 **REQUEST FOR INFORMATION LOG**

RFI No.	SUBJECT	Date Created by Contractor	Date Received By MARTA	Date Required By Field	Date Returned to Contractor	Reviewing Discipline	Days From Original Created To Field Required	Days From MARTA Rec'd To Returned To Contractor	Comments
001	Cat 5/6 Cable	11/23/2015	11/23/2015	12/7/2015	1/26/2017	Systems	14	430	
002	Network Architecture	3/1/2016	3/1/2016	3/10/2016	1/26/2017	IT	9	331	
003	Network Architecture	2/17/2016	2/17/2016	2/24/2016	1/26/2017	IT	7	344	
004	Equipment Placement/Distribution	10/20/2016	10/20/2016	10/27/2016	1/26/2017	RE, Sys Eng	7	98	
005	Rail Control and WorkShop displays	10/20/2016	10/20/2016	10/27/2016	1/26/2017	RSCC, IT	7	98	
006	Sound Restrictions	12/21/2016	12/22/2016	1/15/2017	1/26/2017	ARCH	25	35	
007	POE Runs	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
008	Conduit Runs Over Tunnel Mouth	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
009	POE Extender Placement	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
010	Hub 1 - Tapping Into Pull Box	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
011	Drilling Through TCR Wall	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
012	Conduit Under Hi Rail Access	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
013	Sound Proofing	12/21/2016	12/22/2016	1/15/2017	2/16/2017	Structural	25	56	
014	TCR Power for Hubs	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
015	TCR Power for Hub 6	12/21/2016	12/22/2016	1/15/2017	1/26/2017	Systems	25	35	
016	2 Hubs at Sandy Springs	12/21/2016	12/22/2016	1/15/2017	1/26/2017	Syst Eng, ATC	25	35	ATC
017	UPS AC40 Panel	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
018	EMT Inside TCRs	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
019	Tapping Into 277 Volts	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
020	Working Over Road	12/21/2016	12/22/2016	1/15/2017	1/26/2017	Utilities	25	35	
021	Mounting to Aerial Structure	12/21/2016	12/22/2016	1/15/2017	2/16/2017	Structural	25	56	
022	Power Routing to Hub 11	12/21/2016	12/22/2016	1/15/2017	1/25/2017	Systems	25	34	
023	<NOT USED>	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Not USED
024	Radio Display Format	1/24/2017	1/24/2017	2/3/2017	2/7/2017	Track	10	14	
025	Minimum training level to be a person in charge	1/24/2017	1/24/2017	2/3/2017	2/2/2017	Training	10	9	
026	Learning Management Systems	2/16/2017	2/16/2017	2/26/2017	3/9/2017	Training	10	21	
027	Rail Control Display Format	2/16/2017	2/16/2017	2/26/2017	4/13/2017	RSCC	10	56	
028	Checking Out from Rail Control	2/16/2017	2/16/2017	2/26/2017	3/9/2017	RSCC	10	21	
029	Dark Fiber	3/3/2017	3/3/2017	3/10/2017	7/27/2017	IT Infrastructure	7	146	
030	Firewall	3/9/2017	3/9/2017	3/16/2017	4/13/2017	IT	7	35	
031	Pigtail	4/10/2017	4/24/2017	4/18/2017	4/27/2017	Eng	8	3	
032	Splice Box	5/11/2017	5/11/2017	5/18/2017	7/10/2017	Sys Eng	7	60	
033	Cat 6 (#1)	5/11/2017	5/11/2017	5/18/2017	7/10/2017	Sys Eng	7	60	
034	Cat 6 (#2)	5/23/2017	5/23/2017	5/26/2017	7/10/2017	Eng	3	48	
035	Dunwoody Conduit Routing	5/24/2017	5/24/2017	5/26/2017	7/10/2017	Eng	2	47	
036	Fiber Cable	6/26/2017	6/26/2017	6/28/2017	7/6/2017	Sys Eng	2	10	
037	Fibre Routing	7/17/2017	7/18/2017	n/a	n/a	n/a	n/a	n/a	RFI wthdrawn. Splice box eliminated in asbuilts.
038	Firewall	8/9/2017	8/10/2017	8/11/2017	9/7/2017	IT	2	28	
039	Firewall	3/30/2018	4/2/2018	4/10/2018	4/26/2018	IT	11	24	

MARTA

Test Readiness

Key Performance Indicator Reports

Phase II

Report No.

15

Reporting period

April 27 to May 10

Version Reference	Author(s)	Date	Comments
Version 0.9	Pawel Waszczur	11/30/2018	Pre-release first draft
Version 1.0	Pawel Waszczur	12/10/2018	First draft
Version 1.1	Pawel Waszczur	01/04/2019	First revision based on feedback - updated tab 1.0
Version 1.2	AJ Joshi	16/04/2019	Second revision based on MARTA PM feedback
Version 1.3	Pawel Waszczur	02/05/2019	Third revision based on comments from v1.2

No.	1.0			*Legend*	0-74% of actual availability	
Title	*System Availability*				75%-99% of actual availability	
					100% of actual availability	
Review period	Start date	13/11/2019		No. of days	180	
	End date	10/05/2020				
Expected System Availability	4320 hrs	4320 hrs	4320 hrs	4320 hrs	4320 hrs	4320 hrs
Actual System Availability	4032 hrs	4032 hrs	4320 hrs	4320 hrs	4320 hrs	4224 hrs
Daily Availability	***System Availability***	***Wayside Access Unit***	***Tag In Unit***	***Operator Warning Lights***	***Integrated Operations Center Interface***	***Train Control Room Equipment***
13/11/2019	100%	100%	100%	100%	100%	100%
14/11/2019	100%	100%	100%	100%	100%	100%
15/11/2019	100%	100%	100%	100%	100%	100%
16/11/2019	100%	100%	100%	100%	100%	100%
17/11/2019	100%	100%	100%	100%	100%	100%
18/11/2019	100%	100%	100%	100%	100%	100%
19/11/2019	100%	100%	100%	100%	100%	100%
20/11/2019	100%	100%	100%	100%	100%	100%
21/11/2019	100%	100%	100%	100%	100%	100%
22/11/2019	100%	100%	100%	100%	100%	100%
23/11/2019	100%	100%	100%	100%	100%	100%
24/11/2019	100%	100%	100%	100%	100%	100%
25/11/2019	100%	100%	100%	100%	100%	100%
26/11/2019	100%	100%	100%	100%	100%	100%
27/11/2019	100%	100%	100%	100%	100%	100%
28/11/2019	100%	100%	100%	100%	100%	100%
29/11/2019	100%	100%	100%	100%	100%	100%
30/11/2019	100%	100%	100%	100%	100%	100%
01/12/2019	100%	100%	100%	100%	100%	100%
02/12/2019	100%	100%	100%	100%	100%	100%

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03/12/2019	100%	100%	100%	100%	100%	100%
04/12/2019	100%	100%	100%	100%	100%	100%
05/12/2019	100%	100%	100%	100%	100%	100%
06/12/2019	100%	100%	100%	100%	100%	100%
07/12/2019	100%	100%	100%	100%	100%	100%
08/12/2019	100%	100%	100%	100%	100%	100%
09/12/2019	100%	100%	100%	100%	100%	100%
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13/12/2019	100%	100%	100%	100%	100%	100%
14/12/2019	100%	100%	100%	100%	100%	100%
15/12/2019	100%	100%	100%	100%	100%	100%
16/12/2019	100%	100%	100%	100%	100%	100%
17/12/2019	100%	100%	100%	100%	100%	100%
18/12/2019	100%	100%	100%	100%	100%	100%
19/12/2019	100%	100%	100%	100%	100%	100%
20/12/2019	100%	100%	100%	100%	100%	100%
21/12/2019	100%	100%	100%	100%	100%	100%
22/12/2019	100%	100%	100%	100%	100%	100%
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24/12/2019	100%	100%	100%	100%	100%	100%
25/12/2019	100%	100%	100%	100%	100%	100%
26/12/2019	100%	100%	100%	100%	100%	100%
27/12/2019	100%	100%	100%	100%	100%	100%
28/12/2019	100%	100%	100%	100%	100%	100%
29/12/2019	100%	100%	100%	100%	100%	100%
30/12/2019	100%	100%	100%	100%	100%	100%
31/12/2019	100%	100%	100%	100%	100%	100%
01/01/2020	100%	100%	100%	100%	100%	100%
02/01/2020	100%	100%	100%	100%	100%	100%
03/01/2020	100%	100%	100%	100%	100%	100%
04/01/2020	100%	100%	100%	100%	100%	100%
05/01/2020	100%	100%	100%	100%	100%	100%

Contract Number P36027

06/01/2020	100%	100%	100%	100%	100%	100%
07/01/2020	100%	100%	100%	100%	100%	100%
08/01/2020	100%	100%	100%	100%	100%	100%
09/01/2020	100%	100%	100%	100%	100%	100%
10/01/2020	100%	100%	100%	100%	100%	100%
11/01/2020	100%	100%	100%	100%	100%	100%
12/01/2020	100%	100%	100%	100%	100%	100%
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14/01/2020	100%	100%	100%	100%	100%	100%
15/01/2020	100%	100%	100%	100%	100%	100%
16/01/2020	100%	100%	100%	100%	100%	100%
17/01/2020	100%	100%	100%	100%	100%	100%
18/01/2020	100%	100%	100%	100%	100%	100%
19/01/2020	100%	100%	100%	100%	100%	100%
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24/01/2020	100%	100%	100%	100%	100%	100%
25/01/2020	100%	100%	100%	100%	100%	100%
26/01/2020	100%	100%	100%	100%	100%	100%
27/01/2020	100%	100%	100%	100%	100%	100%
28/01/2020	100%	100%	100%	100%	100%	100%
29/01/2020	100%	100%	100%	100%	100%	100%
30/01/2020	100%	100%	100%	100%	100%	100%
31/01/2020	100%	100%	100%	100%	100%	100%
01/02/2020	100%	100%	100%	100%	100%	100%
02/02/2020	100%	100%	100%	100%	100%	100%
03/02/2020	100%	100%	100%	100%	100%	100%
04/02/2020	100%	100%	100%	100%	100%	100%
05/02/2020	100%	88%	100%	100%	100%	100%
06/02/2020	100%	88%	100%	100%	100%	100%
07/02/2020	100%	88%	100%	100%	100%	100%
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09/02/2020	100%	88%	100%	100%	100%	100%
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13/02/2020	100%	88%	100%	100%	100%	100%
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15/02/2020	100%	88%	100%	100%	100%	100%
16/02/2020	100%	88%	100%	100%	100%	100%
17/02/2020	100%	88%	100%	100%	100%	100%
18/02/2020	100%	88%	100%	100%	100%	100%
19/02/2020	0%	88%	100%	100%	100%	67%
20/02/2020	0%	88%	100%	100%	100%	67%
21/02/2020	0%	88%	100%	100%	100%	67%
22/02/2020	0%	88%	100%	100%	100%	67%
23/02/2020	0%	88%	100%	100%	100%	67%
24/02/2020	0%	88%	100%	100%	100%	67%
25/02/2020	0%	88%	100%	100%	100%	67%
26/02/2020	0%	88%	100%	100%	100%	67%
27/02/2020	0%	88%	100%	100%	100%	67%
28/02/2020	0%	88%	100%	100%	100%	67%
29/02/2020	0%	88%	100%	100%	100%	67%
01/03/2020	0%	88%	100%	100%	100%	67%
02/03/2020	100%	88%	100%	100%	100%	100%
03/03/2020	100%	88%	100%	100%	100%	100%
04/03/2020	100%	88%	100%	100%	100%	100%
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14/03/2020	100%	88%	100%	100%	100%	100%
15/03/2020	100%	88%	100%	100%	100%	100%
16/03/2020	100%	88%	100%	100%	100%	100%
17/03/2020	100%	88%	100%	100%	100%	100%
18/03/2020	100%	88%	100%	100%	100%	100%
19/03/2020	100%	88%	100%	100%	100%	100%
20/03/2020	100%	88%	100%	100%	100%	100%
21/03/2020	100%	88%	100%	100%	100%	100%
22/03/2020	100%	88%	100%	100%	100%	100%
23/03/2020	100%	88%	100%	100%	100%	100%
24/03/2020	100%	88%	100%	100%	100%	100%
25/03/2020	100%	88%	100%	100%	100%	100%
26/03/2020	100%	88%	100%	100%	100%	100%
27/03/2020	100%	88%	100%	100%	100%	100%
28/03/2020	100%	88%	100%	100%	100%	100%
29/03/2020	100%	88%	100%	100%	100%	100%
30/03/2020	100%	88%	100%	100%	100%	100%
31/03/2020	100%	88%	100%	100%	100%	100%
01/04/2020	100%	88%	100%	100%	100%	100%
02/04/2020	100%	88%	100%	100%	100%	100%
03/04/2020	100%	88%	100%	100%	100%	100%
04/04/2020	100%	88%	100%	100%	100%	100%
05/04/2020	100%	88%	100%	100%	100%	100%
06/04/2020	100%	88%	100%	100%	100%	100%
07/04/2020	100%	88%	100%	100%	100%	100%
08/04/2020	100%	88%	100%	100%	100%	100%
09/04/2020	100%	88%	100%	100%	100%	100%
10/04/2020	100%	88%	100%	100%	100%	100%
11/04/2020	100%	88%	100%	100%	100%	100%
12/04/2020	100%	88%	100%	100%	100%	100%
13/04/2020	100%	88%	100%	100%	100%	100%
14/04/2020	100%	88%	100%	100%	100%	100%
15/04/2020	100%	88%	100%	100%	100%	100%
16/04/2020	100%	88%	100%	100%	100%	100%

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17/04/2020	100%	88%	100%	100%	100%	100%
18/04/2020	100%	88%	100%	100%	100%	100%
19/04/2020	100%	88%	100%	100%	100%	100%
20/04/2020	100%	88%	100%	100%	100%	100%
21/04/2020	100%	88%	100%	100%	100%	100%
22/04/2020	100%	88%	100%	100%	100%	100%
23/04/2020	100%	88%	100%	100%	100%	100%
24/04/2020	100%	88%	100%	100%	100%	100%
25/04/2020	100%	88%	100%	100%	100%	100%
26/04/2020	100%	88%	100%	100%	100%	100%
27/04/2020	100%	88%	100%	100%	100%	100%
28/04/2020	100%	88%	100%	100%	100%	100%
29/04/2020	100%	88%	100%	100%	100%	100%
30/04/2020	100%	88%	100%	100%	100%	100%
01/05/2020	100%	88%	100%	100%	100%	100%
02/05/2020	100%	88%	100%	100%	100%	100%
03/05/2020	100%	88%	100%	100%	100%	100%
04/05/2020	100%	88%	100%	100%	100%	100%
05/05/2020	100%	88%	100%	100%	100%	100%
06/05/2020	100%	88%	100%	100%	100%	100%
07/05/2020	100%	88%	100%	100%	100%	100%
08/05/2020	100%	88%	100%	100%	100%	100%
09/05/2020	100%	88%	100%	100%	100%	100%
10/05/2020	100%	88%	100%	100%	100%	100%

Weekly Availability	***System Availability***	***Wayside Access Unit***	***Tag In Unit***	***Operator Warning Lights***	***Integrated Operations Center Interface***	***Train Control Room Equipment***
November 13-20	100%	100%	100%	100%	100%	100%
November 21-27	100%	100%	100%	100%	100%	100%
November 28 - December 4	100%	100%	100%	100%	100%	100%
December 5 - December 11	100%	100%	100%	100%	100%	100%
December 12 - December 22	100%	100%	100%	100%	100%	100%
December 23 - January 5	100%	100%	100%	100%	100%	100%

January 6 - January 19	100%	100%	100%	100%	100%	100%
January 20 - February 2	100%	100%	100%	100%	100%	100%
February 3 - February 16	100%	89%	100%	100%	100%	100%
February 17 - March 1	14%	88%	100%	100%	100%	71%
March 2 - March 15	100%	88%	100%	100%	100%	100%
March 16 - March 29	100%	88%	100%	100%	100%	100%
March 30 - April 12	100%	88%	100%	100%	100%	100%
April 13 - April 26	100%	88%	100%	100%	100%	100%
April 27 - May 10	100%	88%	100%	100%	100%	100%
Monthly Availability	***System Availability***	***Wayside Access Unit***	***Tag In Unit***	***Operator Warning Lights***	***Integrated Operations Center Interface***	***Train Control Room Equipment***
Month of November	100%	100%	100%	100%	100%	100%
Month of December	100%	100%	100%	100%	100%	100%
Month of January	100%	100%	100%	100%	100%	100%
Month of February	62%	89%	100%	100%	100%	87%
Month of March	97%	88%	100%	100%	100%	99%
Month of April	100%	88%	100%	100%	100%	100%
Month of May	100%	88%	100%	100%	100%	100%
Quarterly Availability	***System Availability***	***Wayside Access Unit***	***Tag In Unit***	***Operator Warning Lights***	***Integrated Operations Center Interface***	***Train Control Room Equipment***
Q4 2019	100%	100%	100%	100%	100%	100%
Q1 2020	87%	92%	100%	100%	100%	96%
Q2 2020	100%	88%	100%	100%	100%	100%
Yearly Availability	***System Availability***	***Wayside Access Unit***	***Tag In Unit***	***Operator Warning Lights***	***Integrated Operations Center Interface***	***Train Control Room Equipment***
Year-to-date	91%	91%	100%	100%	100%	97%

No.	2.0								
Title	*Component Health Status Report*								
Review period	Start date		13/11/2019		No. of days	180			
	End date		10/05/2020						
Hardware (# of Units)	***# of Failures This Period***	**(%)**	***# of Failures Year to Date***	**(%)**					
WAU (8)	0	0%	1	13%					
TIU (19)	0	0%	0	0%					
OWL (20)	1	5%	9	45%					

No	*Equipment type*	*Last Date in Service*	*Date of Failure*	*Location (Engineering Marker)*	*Component Serial no.*	*Track Environment*	*Weather*	*Reason for failure (if known)*	If reason for failure is *other,* list explaination below
1	OWL	17/01/2020	17/01/2020	FL 780+00	020	Tunnel	Unknown	Other	Appears to be experiencing intermittent power issues
2	WAU	05/02/2020	N/A	FR 739+80	017	Platform	Unknown	Other	Equipment failure has NOT occured. Device is not accessible due to communication issue at Dunwoody TCR. Cause of issue is unkown.
3	System	19/02/2020	19/02/2020	N/A	N/A	TCR	Unknown	Loss of Communication	Refer to note 1
4	OWL	06/03/2020	06/03/2020	FR 759+50	045	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues

5	OWL	09/03/2020	09/03/2020	FL 807+00	025	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues
6	OWL	20/03/2020	20/03/2020	FL 769+10	060	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues
7	OWL	25/03/2020	25/03/2020	FL 773+30	042	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues
8	OWL	25/03/2020	25/03/2020	FL 766+14	046	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues
9	OWL	08/04/2020	08/04/2020	FR 799+00	023	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues
10	OWL	17/04/2020	17/04/2020	FR 790+50	031	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues
11	OWL	04/05/2020	04/05/2020	FL 799+00	005	Tunnel	Unknown	Other	Appears to be experiencing power/connectivity issues

Note 1 - Communication issue between Sandy Springs and North Springs caused the networking backbone to experience an outage, which impacted the system availability. Since the failure occured where there is a combination of Bombardier and MARTA infrastructure, the source of the issue is unknown. A mitigation plan was put into place and system availability was restored on March 2, 2020.

No.		3.0				
Title		*TrackSafe Badge Tag-In Report*				
Review period		Start date	13/11/2019		No. of days	180
		End date	10/05/2020			
		This period	**(%)**	**YTD**	**(%)**	
Total tag-ins		10	N/A	128	N/A	
Total successful tag-ins		10	100%	128	100%	
Total unsuccessful tag-ins		0	0%	0	0%	
No	*Access type*	*Date*	*Created on*	*Successful*	*Unsuccessful*	*Unit Location*
1	successful_tag	13/11/2019	9:49:47	TRUE	FALSE	FR 832+50
2	successful_tag	13/11/2019	9:53:38	TRUE	FALSE	FR 832+50
3	successful_tag	13/11/2019	10:01:32	TRUE	FALSE	FR 822+50
4	successful_tag	13/11/2019	10:05:41	TRUE	FALSE	FL 812+90
5	successful_tag	13/11/2019	10:05:44	TRUE	FALSE	FR 812+90
6	successful_tag	13/11/2019	10:11:47	TRUE	FALSE	FR 799+00
7	successful_tag	13/11/2019	10:12:04	TRUE	FALSE	FL 799+00
8	successful_tag	13/11/2019	10:13:59	TRUE	FALSE	FR 795+50
9	successful_tag	13/11/2019	10:15:22	TRUE	FALSE	FR 793+20
10	successful_tag	13/11/2019	10:15:33	TRUE	FALSE	FL 793+20
11	successful_tag	13/11/2019	10:16:47	TRUE	FALSE	FR 790+50
12	successful_tag	13/11/2019	10:16:56	TRUE	FALSE	FL 790+50
13	successful_tag	13/11/2019	10:19:52	TRUE	FALSE	FR 784+27
14	successful_tag	13/11/2019	10:20:03	TRUE	FALSE	FL 784+27
15	successful_tag	13/11/2019	10:21:21	TRUE	FALSE	FL 780+00
16	successful_tag	13/11/2019	10:24:45	TRUE	FALSE	FR 773+30
17	successful_tag	13/11/2019	10:28:04	TRUE	FALSE	FL 769+10
18	successful_tag	13/11/2019	10:27:57	TRUE	FALSE	FR 769+10
19	successful_tag	13/11/2019	10:30:59	TRUE	FALSE	FL 763+00
20	successful_tag	13/11/2019	10:31:42	TRUE	FALSE	FR 763+00
21	successful_tag	29/11/2019	9:15:19	TRUE	FALSE	FR 763+00
22	successful_tag	29/11/2019	9:18:38	TRUE	FALSE	FL 769+10

23	successful_tag	29/11/2019	9:37:44	TRUE	FALSE	FL 799+00
24	successful_tag	29/11/2019	9:44:12	TRUE	FALSE	FL 812+90
25	successful_tag	29/11/2019	9:48:49	TRUE	FALSE	FR 822+50
26	successful_tag	29/11/2019	9:53:58	TRUE	FALSE	FR 832+50
27	successful_tag	04/12/2019	9:21:38	TRUE	FALSE	FR 763+00
28	successful_tag	04/12/2019	9:24:55	TRUE	FALSE	FL 769+10
29	successful_tag	04/12/2019	9:27:38	TRUE	FALSE	FR 773+30
30	successful_tag	04/12/2019	9:31:47	TRUE	FALSE	FL 780+00
31	successful_tag	04/12/2019	9:33:14	TRUE	FALSE	FL 784+27
32	successful_tag	04/12/2019	9:33:39	TRUE	FALSE	FR 784+27
33	successful_tag	04/12/2019	9:37:08	TRUE	FALSE	FR 790+50
34	successful_tag	04/12/2019	9:37:10	TRUE	FALSE	FL 790+50
35	successful_tag	04/12/2019	9:38:42	TRUE	FALSE	FR 793+20
36	successful_tag	04/12/2019	9:38:56	TRUE	FALSE	FL 793+20
37	successful_tag	04/12/2019	9:40:02	TRUE	FALSE	FR 795+50
38	successful_tag	04/12/2019	9:41:29	TRUE	FALSE	FL 799+00
39	successful_tag	04/12/2019	9:41:47	TRUE	FALSE	FR 799+00
40	successful_tag	04/12/2019	9:47:35	TRUE	FALSE	FL 812+90
41	successful_tag	04/12/2019	9:48:02	TRUE	FALSE	FR 812+90
42	successful_tag	04/12/2019	9:52:16	TRUE	FALSE	FR 822+50
43	successful_tag	04/12/2019	9:56:51	TRUE	FALSE	FR 832+50
44	successful_tag	06/12/2019	9:54:34	TRUE	FALSE	FR 784+27
45	successful_tag	06/12/2019	9:55:00	TRUE	FALSE	FL 784+27
46	successful_tag	06/12/2019	10:24:40	TRUE	FALSE	FR 832+50
47	successful_tag	06/12/2019	10:25:06	TRUE	FALSE	FR 832+50
48	successful_tag	11/12/2019	9:14:07	TRUE	FALSE	FR 832+50
49	successful_tag	11/12/2019	9:14:22	TRUE	FALSE	FR 832+50
50	successful_tag	11/12/2019	9:22:08	TRUE	FALSE	FR 822+50
51	successful_tag	11/12/2019	9:26:46	TRUE	FALSE	FR 812+90
52	successful_tag	11/12/2019	9:27:05	TRUE	FALSE	FL 812+90
53	successful_tag	11/12/2019	9:33:06	TRUE	FALSE	FR 799+00
54	successful_tag	11/12/2019	9:33:07	TRUE	FALSE	FL 799+00
55	successful_tag	11/12/2019	9:34:40	TRUE	FALSE	FR 795+50
56	successful_tag	11/12/2019	9:35:53	TRUE	FALSE	FL 793+20

57	successful_tag	11/12/2019	9:35:54	TRUE	FALSE	FR 793+20
58	successful_tag	11/12/2019	9:37:18	TRUE	FALSE	FL 790+50
59	successful_tag	11/12/2019	9:37:24	TRUE	FALSE	FR 790+50
60	successful_tag	11/12/2019	9:40:16	TRUE	FALSE	FR 784+27
61	successful_tag	11/12/2019	9:40:16	TRUE	FALSE	FL 784+27
62	successful_tag	11/12/2019	9:41:53	TRUE	FALSE	FL 780+00
63	successful_tag	11/12/2019	9:45:20	TRUE	FALSE	FR 773+30
64	successful_tag	11/12/2019	9:47:27	TRUE	FALSE	FL 769+10
65	successful_tag	11/12/2019	9:47:52	TRUE	FALSE	FR 769+10
66	successful_tag	11/12/2019	9:50:32	TRUE	FALSE	FL 763+00
67	successful_tag	11/12/2019	9:50:52	TRUE	FALSE	FR 763+00
68	successful_tag	13/12/2019	9:43:38	TRUE	FALSE	FR 832+50
69	successful_tag	13/12/2019	9:43:39	TRUE	FALSE	FR 832+50
70	successful_tag	13/12/2019	10:02:36	TRUE	FALSE	FR 784+27
71	successful_tag	13/12/2019	10:03:22	TRUE	FALSE	FL 790+50
72	successful_tag	13/12/2019	10:06:24	TRUE	FALSE	FL 784+27
73	successful_tag	18/12/2019	9:17:17	TRUE	FALSE	FR 812+90
74	successful_tag	18/12/2019	9:23:10	TRUE	FALSE	FR 799+00
75	successful_tag	18/12/2019	9:26:19	TRUE	FALSE	FL 793+20
76	successful_tag	18/12/2019	9:26:19	TRUE	FALSE	FL 793+20
77	successful_tag	18/12/2019	9:27:37	TRUE	FALSE	FR 790+50
78	successful_tag	18/12/2019	9:30:24	TRUE	FALSE	FR 784+27
79	successful_tag	18/12/2019	9:31:52	TRUE	FALSE	FL 780+00
80	successful_tag	18/12/2019	9:37:14	TRUE	FALSE	FR 769+10
81	successful_tag	18/12/2019	9:37:39	TRUE	FALSE	FL 769+10
82	successful_tag	18/12/2019	9:40:31	TRUE	FALSE	FL 763+00
83	successful_tag	18/12/2019	9:41:08	TRUE	FALSE	FR 763+00
84	successful_tag	17/01/2020	9:41:06	TRUE	FALSE	FR 832+50
85	successful_tag	17/01/2020	9:46:53	TRUE	FALSE	FR 822+50
86	successful_tag	17/01/2020	9:51:51	TRUE	FALSE	FR 812+90
87	successful_tag	17/01/2020	9:52:07	TRUE	FALSE	FL 812+90
88	successful_tag	17/01/2020	9:58:30	TRUE	FALSE	FR 799+00
89	successful_tag	17/01/2020	9:58:32	TRUE	FALSE	FL 799+00
90	successful_tag	17/01/2020	10:00:03	TRUE	FALSE	FR 795+50

91	successful_tag	17/01/2020	10:01:05	TRUE	FALSE	FR 793+20
92	successful_tag	17/01/2020	10:01:32	TRUE	FALSE	FL 793+20
93	successful_tag	17/01/2020	10:02:42	TRUE	FALSE	FR 790+50
94	successful_tag	17/01/2020	10:03:08	TRUE	FALSE	FL 790+50
95	successful_tag	17/01/2020	10:08:44	TRUE	FALSE	FR 784+27
96	successful_tag	17/01/2020	10:19:18	TRUE	FALSE	FL 784+27
97	successful_tag	22/01/2020	9:19:15	TRUE	FALSE	FR 832+50
98	successful_tag	22/01/2020	9:19:33	TRUE	FALSE	FR 832+50
99	successful_tag	22/01/2020	9:25:34	TRUE	FALSE	FR 822+50
100	successful_tag	22/01/2020	9:29:45	TRUE	FALSE	FR 812+90
101	successful_tag	22/01/2020	9:30:04	TRUE	FALSE	FL 812+90
102	successful_tag	22/01/2020	9:35:48	TRUE	FALSE	FR 799+00
103	successful_tag	22/01/2020	9:36:03	TRUE	FALSE	FL 799+00
104	successful_tag	22/01/2020	9:37:32	TRUE	FALSE	FR 795+50
105	successful_tag	22/01/2020	9:38:35	TRUE	FALSE	FR 793+20
106	successful_tag	22/01/2020	9:38:55	TRUE	FALSE	FL 793+20
107	successful_tag	22/01/2020	9:40:10	TRUE	FALSE	FL 790+50
108	successful_tag	22/01/2020	9:43:40	TRUE	FALSE	FL 784+27
109	successful_tag	22/01/2020	9:44:15	TRUE	FALSE	FR 784+27
110	successful_tag	22/01/2020	9:45:42	TRUE	FALSE	FL 780+00
111	successful_tag	22/01/2020	9:49:39	TRUE	FALSE	FR 773+30
112	successful_tag	22/01/2020	9:50:57	TRUE	FALSE	FL 769+10
113	successful_tag	22/01/2020	9:54:29	TRUE	FALSE	FR 763+00
114	successful_tag	22/01/2020	9:54:42	TRUE	FALSE	FL 763+00
115	successful_tag	24/01/2020	9:16:39	TRUE	FALSE	FR 832+50
116	successful_tag	24/01/2020	9:16:57	TRUE	FALSE	FR 832+50
117	successful_tag	24/01/2020	9:54:02	TRUE	FALSE	FL 790+50
118	successful_tag	24/01/2020	9:54:18	TRUE	FALSE	FR 790+50
119	successful_tag	24/01/2020	9:54:13	TRUE	FALSE	FR 790+50
120	successful_tag	24/01/2020	9:53:19	TRUE	FALSE	FL 784+27
121	successful_tag	29/01/2020	9:20:56	TRUE	FALSE	FR 832+50
122	successful_tag	29/01/2020	9:21:22	TRUE	FALSE	FR 832+50
123	successful_tag	29/01/2020	9:27:05	TRUE	FALSE	FR 822+50
124	successful_tag	29/01/2020	9:31:52	TRUE	FALSE	FR 812+90

125	successful_tag	29/01/2020	9:31:52	TRUE	FALSE	FL 812+90
126	successful_tag	29/01/2020	9:37:58	TRUE	FALSE	FR 799+00
127	successful_tag	29/01/2020	9:37:59	TRUE	FALSE	FL 799+00
128	successful_tag	29/01/2020	9:39:37	TRUE	FALSE	FR 795+50
129	successful_tag	29/01/2020	9:40:35	TRUE	FALSE	FR 793+20
130	successful_tag	29/01/2020	9:41:01	TRUE	FALSE	FL 793+20
131	successful_tag	29/01/2020	9:42:23	TRUE	FALSE	FL 790+50
132	successful_tag	29/01/2020	9:45:12	TRUE	FALSE	FL 784+27
133	successful_tag	29/01/2020	9:46:19	TRUE	FALSE	FL 780+00
134	successful_tag	29/01/2020	9:50:26	TRUE	FALSE	FR 773+30
135	successful_tag	29/01/2020	9:52:11	TRUE	FALSE	FR 769+10
136	successful_tag	29/01/2020	9:52:28	TRUE	FALSE	FL 769+10
137	successful_tag	29/01/2020	9:55:06	TRUE	FALSE	FR 763+00
138	successful_tag	29/01/2020	9:55:06	TRUE	FALSE	FL 763+00
139	successful_tag	31/01/2020	9:52:49	TRUE	FALSE	FL 790+50
140	successful_tag	31/01/2020	9:53:36	TRUE	FALSE	FR 790+50
141	successful_tag	31/01/2020	9:56:34	TRUE	FALSE	FR 784+27
142	successful_tag	31/01/2020	9:56:36	TRUE	FALSE	FL 784+27
143	successful_tag	05/02/2020	9:05:59	TRUE	FALSE	FR 832+50
144	successful_tag	05/02/2020	9:06:25	TRUE	FALSE	FR 832+50
145	successful_tag	05/02/2020	9:15:59	TRUE	FALSE	FR 822+50
146	successful_tag	05/02/2020	9:20:37	TRUE	FALSE	FL 812+90
147	successful_tag	05/02/2020	9:21:03	TRUE	FALSE	FR 812+90
148	successful_tag	05/02/2020	9:27:15	TRUE	FALSE	FL 799+00
149	successful_tag	05/02/2020	9:27:16	TRUE	FALSE	FR 799+00
150	successful_tag	05/02/2020	9:28:55	TRUE	FALSE	FR 795+50
151	successful_tag	05/02/2020	9:30:00	TRUE	FALSE	FL 793+20
152	successful_tag	05/02/2020	9:31:36	TRUE	FALSE	FR 790+50
153	successful_tag	05/02/2020	9:31:52	TRUE	FALSE	FL 790+50
154	successful_tag	05/02/2020	9:34:44	TRUE	FALSE	FL 784+27
155	successful_tag	05/02/2020	9:35:02	TRUE	FALSE	FR 784+27
156	successful_tag	05/02/2020	9:36:30	TRUE	FALSE	FL 780+00
157	successful_tag	05/02/2020	9:42:27	TRUE	FALSE	FR 769+10
158	successful_tag	05/02/2020	9:42:28	TRUE	FALSE	FL 769+10

159	successful_tag	05/02/2020	9:45:17	TRUE	FALSE	FR 763+00
160	successful_tag	12/02/2020	9:15:51	TRUE	FALSE	FR 832+50
161	successful_tag	12/02/2020	9:16:10	TRUE	FALSE	FR 832+50
162	successful_tag	12/02/2020	9:22:18	TRUE	FALSE	FR 822+50
163	successful_tag	12/02/2020	9:27:10	TRUE	FALSE	FR 812+90
164	successful_tag	12/02/2020	9:27:11	TRUE	FALSE	FL 812+90
165	successful_tag	12/02/2020	9:33:49	TRUE	FALSE	FR 799+00
166	successful_tag	12/02/2020	9:34:02	TRUE	FALSE	FL 799+00
167	successful_tag	12/02/2020	9:35:40	TRUE	FALSE	FR 795+50
168	successful_tag	12/02/2020	9:36:43	TRUE	FALSE	FL 793+20
169	successful_tag	12/02/2020	9:36:45	TRUE	FALSE	FR 793+20
170	successful_tag	12/02/2020	9:38:27	TRUE	FALSE	FR 790+50
171	successful_tag	12/02/2020	9:38:52	TRUE	FALSE	FL 790+50
172	successful_tag	12/02/2020	9:42:41	TRUE	FALSE	FR 784+27
173	successful_tag	12/02/2020	9:42:59	TRUE	FALSE	FL 784+27
174	successful_tag	12/02/2020	9:44:28	TRUE	FALSE	FL 780+00
175	successful_tag	12/02/2020	9:48:08	TRUE	FALSE	FR 773+30
176	successful_tag	12/02/2020	9:49:53	TRUE	FALSE	FL 769+10
177	successful_tag	12/02/2020	9:50:10	TRUE	FALSE	FR 769+10
178	successful_tag	12/02/2020	9:52:58	TRUE	FALSE	FL 763+00
179	successful_tag	12/02/2020	9:53:11	TRUE	FALSE	FR 763+00
180	successful_tag	11/03/2020	10:28:32	TRUE	FALSE	FR 832+50
181	successful_tag	11/03/2020	10:28:58	TRUE	FALSE	FR 832+50
182	successful_tag	11/03/2020	10:37:53	TRUE	FALSE	FR 822+50
183	successful_tag	11/03/2020	10:38:10	TRUE	FALSE	FR 822+50
184	successful_tag	11/03/2020	10:43:45	TRUE	FALSE	FR 812+90
185	successful_tag	11/03/2020	10:44:26	TRUE	FALSE	FR 812+90
186	successful_tag	11/03/2020	10:52:49	TRUE	FALSE	FR 799+00
187	successful_tag	11/03/2020	10:53:09	TRUE	FALSE	FR 799+00
188	successful_tag	11/03/2020	10:54:54	TRUE	FALSE	FR 795+50
189	successful_tag	11/03/2020	10:55:20	TRUE	FALSE	FR 795+50
190	successful_tag	11/03/2020	10:56:39	TRUE	FALSE	FR 793+20
191	successful_tag	11/03/2020	10:56:59	TRUE	FALSE	FR 793+20
192	successful_tag	11/03/2020	10:58:55	TRUE	FALSE	FR 790+50

193	successful_tag	11/03/2020	10:59:28	TRUE	FALSE	FR 790+50
194	successful_tag	11/03/2020	11:04:59	TRUE	FALSE	FR 784+27
195	successful_tag	11/03/2020	11:04:59	TRUE	FALSE	FR 784+27
196	successful_tag	11/03/2020	11:12:34	TRUE	FALSE	FR 773+30
197	successful_tag	11/03/2020	11:13:00	TRUE	FALSE	FR 773+30
198	successful_tag	11/03/2020	11:16:12	TRUE	FALSE	FR 769+10
199	successful_tag	11/03/2020	11:16:28	TRUE	FALSE	FR 769+10
200	successful_tag	11/03/2020	11:19:44	TRUE	FALSE	FR 763+00
201	successful_tag	11/03/2020	11:19:55	TRUE	FALSE	FR 763+00
202	successful_tag	06/05/2020	8:20:36	TRUE	FALSE	FR 832+50
203	successful_tag	06/05/2020	8:48:01	TRUE	FALSE	FR 822+50
204	successful_tag	06/05/2020	8:52:35	TRUE	FALSE	FL 812+90
205	successful_tag	06/05/2020	8:58:13	TRUE	FALSE	FL 799+00
206	successful_tag	06/05/2020	9:00:39	TRUE	FALSE	FL 793+20
207	successful_tag	06/05/2020	9:04:40	TRUE	FALSE	FL 784+27
208	successful_tag	06/05/2020	9:06:19	TRUE	FALSE	FL 780+00
209	successful_tag	06/05/2020	9:11:41	TRUE	FALSE	FL 769+10
210	successful_tag	06/05/2020	9:14:29	TRUE	FALSE	FL 763+00
211	successful_tag	08/05/2020	8:24:07	TRUE	FALSE	FR 832+50

No.		4.0				
Title		*Authorized/Unauthorized/Unregistered Wayside Worker Entry Report*				
Review period		Start date	13/11/2019		No. of days	180
		End date	10/05/2020			
		This period	**(%)**	**YTD**	**(%)**	
Total users		2	N/A	18	N/A	
Total authorized users		2	100%	18	100%	
Total unauthorized users		0	0%	0	0%	
Total unregistered users		0	0%	0	0%	
No	*Access type*	*Date*	*Created on*	*Authorized type*	*Unauthorized Type*	*Entry Location*
1015	crew_entering_wayside	13/11/2019	9:49:47	TRUE	FALSE	FR 832+50
1016	crew_entering_wayside	13/11/2019	9:53:38	TRUE	FALSE	FR 832+50
1026	crew_entering_wayside	29/11/2019	9:15:19	TRUE	FALSE	FR 763+00
1028	crew_entering_wayside	04/12/2019	9:21:38	TRUE	FALSE	FR 763+00
1029	crew_entering_wayside	04/12/2019	9:24:55	TRUE	FALSE	FL 769+10
1031	crew_entering_wayside	06/12/2019	9:54:34	TRUE	FALSE	FR 784+27
1032	crew_entering_wayside	06/12/2019	9:55:00	TRUE	FALSE	FL 784+27
1033	crew_entering_wayside	11/12/2019	9:14:07	TRUE	FALSE	FR 832+50
1034	crew_entering_wayside	11/12/2019	9:14:22	TRUE	FALSE	FR 832+50
1035	crew_entering_wayside	13/12/2019	9:43:38	TRUE	FALSE	FR 832+50
1036	crew_entering_wayside	13/12/2019	9:43:39	TRUE	FALSE	FR 832+50
1037	crew_entering_wayside	18/12/2019	9:17:17	TRUE	FALSE	FR 812+90
1038	crew_entering_wayside	18/12/2019	9:26:20	TRUE	FALSE	FL 793+20
1043	crew_entering_wayside	17/01/2020	9:41:16	TRUE	FALSE	FR 832+50
1044	crew_entering_wayside	17/01/2020	9:52:07	TRUE	FALSE	FL 812+90
1045	crew_entering_wayside	22/01/2020	9:19:15	TRUE	FALSE	FR 832+50
1046	crew_entering_wayside	22/01/2020	9:19:33	TRUE	FALSE	FR 832+50
1048	crew_entering_wayside	24/01/2020	9:16:39	TRUE	FALSE	FR 832+50
1049	crew_entering_wayside	24/01/2020	9:16:57	TRUE	FALSE	FR 832+50
1050	crew_entering_wayside	29/01/2020	9:20:56	TRUE	FALSE	FR 832+50
1051	crew_entering_wayside	29/01/2020	9:21:22	TRUE	FALSE	FR 832+50

1053	crew_entering_wayside	31/01/2020	9:52:49	TRUE	FALSE	FL 790+50
1054	crew_entering_wayside	31/01/2020	9:53:36	TRUE	FALSE	FR 790+50
1055	crew_entering_wayside	05/02/2020	9:05:59	TRUE	FALSE	FR 832+50
1056	crew_entering_wayside	05/02/2020	9:06:25	TRUE	FALSE	FR 832+50
1057	crew_entering_wayside	12/02/2020	9:15:51	TRUE	FALSE	FR 832+50
1058	crew_entering_wayside	12/02/2020	9:16:10	TRUE	FALSE	FR 832+50
1060	crew_entering_wayside	11/03/2020	10:28:32	TRUE	FALSE	FR 832+50
1061	crew_entering_wayside	11/03/2020	10:28:58	TRUE	FALSE	FR 832+50
1063	crew_entering_wayside	06/05/2020	8:20:36	TRUE	FALSE	FR 832+50
1064	crew_entering_wayside	08/05/2020	8:24:07	TRUE	FALSE	FR 832+50

No.	5.0
Title	Definitions
Authorized user	User that has a valid TrackSafe profile and RFID card and follows the WAU check-in procedure prior to accessing the wayside.
Unauthorized user	User that has a valid TrackSafe profile and RFID card and does not follow the WAU check-in procedure prior to accessing the wayside. User accesses the wayside equipment without checking into a WAU.
Unregistered user	User that does not have a valid RFID card (either inactive TrackSafe RFID card, or same frequency third party card. User may or may not have a valid TrackSafe profile.
TIU	Tag-In Unit - Used by track workers to update their positions and to alert them of approaching trains
OWL	Operator Warning Unit - Used to warn train operators that they are approaching workers at the wayside
WAU	Wayside Access Unit - Used by track workers to initiate access to the wayside
TCR	Train Control Room

ACRONYMS AND ABBREVIATIONS

APTA	American Public Transportation Association
ASTM	ASTM International, formerly American Society for Testing and Materials
EIA	Electronic Industries Alliance
FTA	Federal Transit Administration
GUI	Graphical user interface
IEEE	Institute of Electric and Electronics Engineers (Standards Association)
IOC	Integrated Operations Center
ISP	Internet service provider
LED	Light emitting diode
LSZH	Low smoke, zero halogen
MARTA	Metropolitan Atlanta Rapid Transit Authority
NEMA	National Electric Manufacturers Association
NFPA	National Fire Protection Association
OLTS	Optical loss test set
OTE	On-track equipment
OWL	Operator warning light
OWZ	Operator warning zone
POE	Power over Ethernet
PPE	Personal protective equipment
RFID	Radio frequency identification
ROW	Right of way
RTA	Rail Transit Authority
RWP	Roadway worker protection
SCADA	Supervisory Control and Data Acquisition
SZ	Safety zone
TIA	Telecommunication Industry Association
TIU	Tag-in unit
UPS	Uninterrupted power supply
VPN	Virtual private network
WAP	Wayside access procedure
WAU	Wayside access unit

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