FTA RESEARCH

FEDERAL TRANSIT ADMINISTRATION

Transit Track Worker Safety Protection Demonstration Project

APRIL 2013

FTA Report No. 0046
Federal Transit Administration

PREPARED BY

Mark Willer
Bombardier Transportation

U.S. Department of Transportation
Federal Transit Administration

COVER PHOTO

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Federal Transit Administration
Office of Research, Demonstration and Innovation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

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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	liters	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)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

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13. ABSTRACT

This report describes the demonstration of an innovative system to reduce the hazards of working in the track environment. It describes the deployment of the system, provides a summary of developments to further enhance the system for transit agencies and railroads, describes the testing of the system, and summarizes user feedback.

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- Federal Transit Administration, particularly Mr. Roy Chen
- Metropolitan Atlanta Rapid Transit Authority, particularly the members of the Project Steering Committee

ABSTRACT

This report describes the demonstration of an innovative system to reduce the hazards of working in the track environment. It describes the deployment of the system, provides a summary of developments to further enhance the system for transit agencies and railroads, describes the testing of the system, and summarizes user feedback.

EXECUTIVE SUMMARY

The Federal Transit Administration (FTA) has as one of its top priorities the safety of those engaged in repair, maintenance, and other activities within or close to the envelope of trains. Tragically, there have been a number of fatal accidents in recent years that have contributed to a worsening trend.

In 2011, FTA, through the Office of Technology, issued an RFP seeking to demonstrate new technologies that could be employed to reduce the risks of working in the track environment.

Bombardier Mass Transit Corporation and the Metropolitan Atlanta Rapid Transit Authority (MARTA) partnered to propose a demonstration of Bombardier's TrackSafe technology on a section of MARTA's operational rail transit system. The proposal was selected by FTA, and TrackSafe equipment was manufactured and installed between Bankhead station and Ashby station on MARTA's Green Line.

During the initial project phases, a number of opportunities were jointly identified and implemented to enhance the functionality of the system. These included:

- A sophisticated display of track worker locations for the Rail Service Control Center
- Improved data management through record automation
- Radio-Frequency Identification (RFID) tag incorporated in existing Wayside Access Pass
- Vandal-resistant design

During commissioning, some logic issues were discovered within the system; however, with minor software updates, these discrepancies were overcome so that the system was able to function satisfactorily.

MARTA train operators and track workers provided ad-hoc feedback during various stages of deployment, which were taken into account by Bombardier's Project Team. In many cases, this helped with final configuration of customized solutions.

SECTION 1

Background

Between October 2005 and April 2007, Federal Transit Administration (FTA) and Federal Railroad Administration (FRA)[1] data show a three-fold increase in the number of rail transit worker fatalities and a significant increase in injuries. Of the 19 worker fatalities reported to the National Transit Database (NTD) from 2003–2008, 17 were reported for heavy rail service and 2 for light rail service. Over half of those fatalities reported occurred on the right-of-way. This is in addition to the track worker injuries and close calls that occurred on the right-of-way during the period.

As a consequence of this disturbing trend, FTA, through its Transit Safety Research Program, issued FTA-2011-010-TRI in February 2011 requesting proposals to demonstrate new and innovative technologies to mitigate the hazards associated with rail track work in revenue and non-revenue operation. In response to this RFP, Bombardier, in partnership with the Metropolitan Atlanta Rapid Transportation Authority (MARTA), proposed demonstrating its TrackSafe technology along a section of MARTA's right-of-way.

Bombardier Mass Transit Corporation

Bombardier Mass Transit Corporation is a U.S. subsidiary of Bombardier, Inc., a world-leading manufacturer of innovative transportation solutions, from regional aircraft and business jets to rail transportation equipment and services. With more than 29,000 employees worldwide, Bombardier Transportation is the global leader in the rail equipment manufacturing and servicing industry. Products includes passenger rail vehicles, total transit systems, operations and maintenance services, overhauls, material solutions, and technology solutions. It also manufactures locomotives, bogies, propulsion, and controls and provides rail control solutions.

MARTA

The Metropolitan Atlanta Rapid Transit Authority (MARTA) is the ninth largest transit system in the United States and has provided combined bus and rail service to DeKalb and Fulton counties and the city of Atlanta for more than 30 years. MARTA transit service serves as the backbone of the greater-Atlanta regional transit network, including 91 fixed bus routes with 38 rail stations and 48 miles route-miles of rail service.

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[1]"Dear Colleague" letter issued by FTA Administrator, May 8, 2007. Available at http://www.fta.dot.gov/news/colleague/news_events_6836.html.

The MARTA service area includes the jurisdictions of Fulton and DeKalb counties and the city of Atlanta, with a total estimated population of 1,612,500 in 805 square miles. The estimated population for the entire metropolitan Atlanta area is 5,269,000; this area is also served by the MARTA transit system. Other cities within the MARTA service area include College Park, East Point, Decatur, Sandy Springs, Dunwoody, Roswell, Alpharetta, and Stone Mountain. Rail service also is provided to Clayton County (Airport Station) and limited bus service to Cobb County, both of which are outside the MARTA service area as defined by the MARTA Act. Additionally, bus service from the surrounding counties of Cobb and Gwinnett as well as the Georgia Regional Transportation Authority (GRTA) Express terminate/originate nearby or at seven MARTA rail stations during peak service hours. The MARTA service area includes the Georgia World Congress Center, the Centers for Disease Control (CDC), the Georgia Dome, Hartsfield-Jackson International Airport, the Buckhead Financial District, the GA400 Corridor, major colleges and universities, and key regional medical facilities.

Many of MARTA's transit stations serve as the connecting hub for three other fixed-route transit operators and various shuttle services. A 2010 Atlanta Regional Commission on-board bus transit survey estimated that of the total weekday boardings for the three other fixed-route transit operators in the region, 32 percent of these riders transferred to and from the MARTA system.

MARTA provides heavy rail, fixed-route bus, and complementary paratransit service. Fixed-route bus service began operating in 1972 and heavy rail service in 1979. FY 2013 weekday boardings averaged 0.4 million and annual passenger trips 129.9 million, with FY 2014 estimates of 0.4 million average weekday boardings and 130.3 million annual passenger trips. FY 2014 operating estimates are 25.9 million bus miles and 18.0million rail miles. Paratransit annual ridership for FY 2013 was 0.6 million, with FY 2014 estimates to remain constant. MARTA currently operates 318 railcars, 531 transit buses (CNG/diesel), 187 paratransit vehicles, 3 rail maintenance facilities, 4 bus maintenance facilities, and 1 paratransit vehicle maintenance facility.

Figure 1-1

MARTA trains

SECTION 2

TrackSafe Overview

Since the advent of rail transit operations, the task of inspecting and repairing track, signals, and related wayside infrastructure has been essential to safely moving millions of people every day. It has also been one of the most hazardous jobs in the transit industry.

TrackSafe Concept

TrackSafe provides improved location awareness and highly-relevant alerts to train operators and roadway workers. It provides this enhanced level of safety through the use of proven Radio-Frequency Identification (RFID) technology and use of the existing transit infrastructure as much as possible so that the system can be installed quickly and inexpensively.

Roadway workers are equipped with an RFID tag, typically embedded in a wristband, which they use to "tag in" at a unit at their point of entry to track level. No other equipment is required for the roadway workers, allowing them to carry necessary work equipment and enhance their safety with minimal effort.

As the roadway work crew proceeds at track level, they tag in at various check points. This creates an Alert Warning Zone (AWZ) by automatically illuminating LED lights that warn train operators of the location of roadway workers as the train approaches the AWZ. The AWZ is 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.

Figure 2-1
TrackSafe concept

Track Worker Awareness

As a train enters the AWZ, it is detected by the TrackSafe system. Roadway workers are alerted to the presence of the approaching train through audible and visual signals, thus providing adequate time for them to proceed to a safe location as the train approaches.

Train Operator Awareness

Train operators are notified of the presence of roadway workers in two ways. First, a warning light is illuminated at the edge of the station platform where roadway workers are present. In this way, the train operator will beware that he will encounter roadway workers between this station and the next station. Second, as the train operator gets closer to the area in which he will encounter roadway workers, wayside lights will be activated on both sides of the roadway workers (and dark in other areas of the track).

Central Control Awareness

There are various ways in which the Central Control operators can be made aware of the location of roadway workers using TrackSafe. For the purpose of this FTA Demonstration, a laptop computer was used to monitor the location of the roadway. For a full-scale implementation, roadway worker location can be conveyed to Central Control using a stand-alone system or integrated into the transit agency's signal or Supervisory Control and Data Acquisition (SCADA) system.

SECTION
3

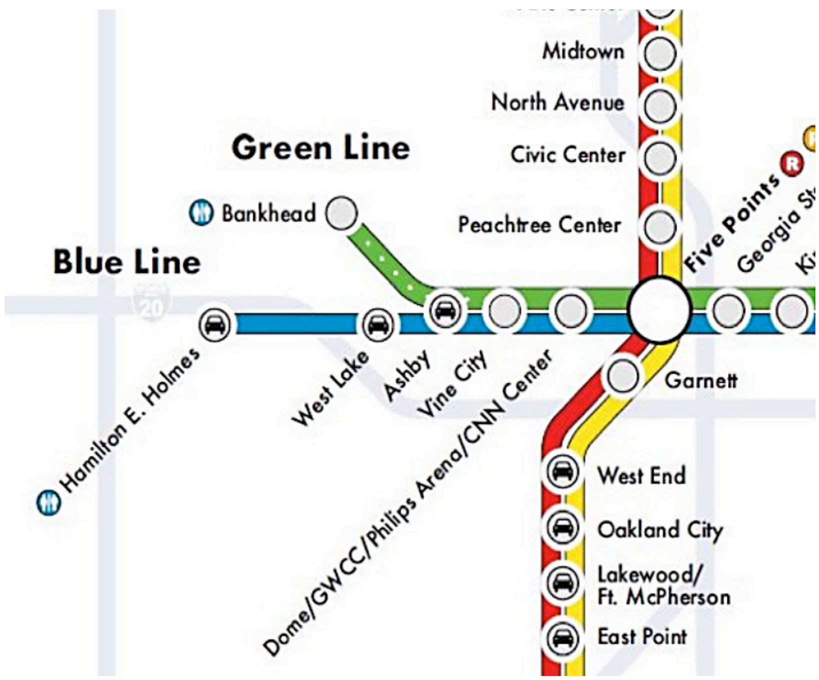
Demonstration Envelope

In consultation with MARTA and FTA, the section of track selected for the demonstration was between Ashby Station and Bankhead Station on MARTAs Green Line. This section which is approximately 1.5 miles in length and features:

- 1,500 feet of tunnel in a tight curve
- Changes in gradient
- Road and rail bridges over the track
- A bridge featuring limited clearance that carries the MARTA track over a creek

All of these factors combine to compromise the perception of the approach of a train and also provide challenges in terms of places of safety where track workers can stand while a train passes.

Figure 3-1
MARTA rail map



Implementation

The system was implemented in accordance with the plan submitted with Bombardier's proposal as adjusted for the date that the agreement was executed. A Project Steering Committee was formed comprising senior management from MARTA and Bombardier. Steering group meetings were held as required. In addition, more frequent meetings were held with key stakeholders. Detailed planning commenced in Spring 2012 along with the manufacture of the equipment.

Following manufacture and factory acceptance tests, the equipment was installed and commissioned in November 2012. A demonstration of the functioning system was provided to MARTA senior management and APTA's Safety Committee on December 6, 2012. Bombardier obtained extremely valuable feedback from MARTA professional staff (Engineering, Safety, and Operations), as well as staff in Track and the Rail Services Control Center.

Bombardier provided the equipment shown in Table 3-1, which was installed by MARTA (and supervised by Bombardier) along the selected section of track together with the associated power and communications infrastructure:

Table 3-1
Equipment Provided

Equipment Description	Qty	Notes
Track Level Unit	8	Programmable controller located along track
Station Level Unit	2	Programmable controller located at Peachtree Centre and Five Points
Train Detectors	20	Train detectors integrated with Track Level Units (TLUs)
RFID Tags	20	RFID tags embedded in suitable form factors (e.g., wristbands) for TLU activation
Laptop computer to display track worker locations	1	Provided for duration of demonstration when Bombardier personnel were on-site

Installation

The system was deployed and commissioned over two weekends of "track time." Figure 3-2 shows the TrackSafe equipment mounted to a wall.

Figure 3-2
Track Level Unit (TLU)

In the tunnel section, a secondary reader unit was placed at a height that enabled a track worker to tag in without climbing onto the catwalk, as shown in Figure 3-3.

Figure 3-3
Extra Reader Unit

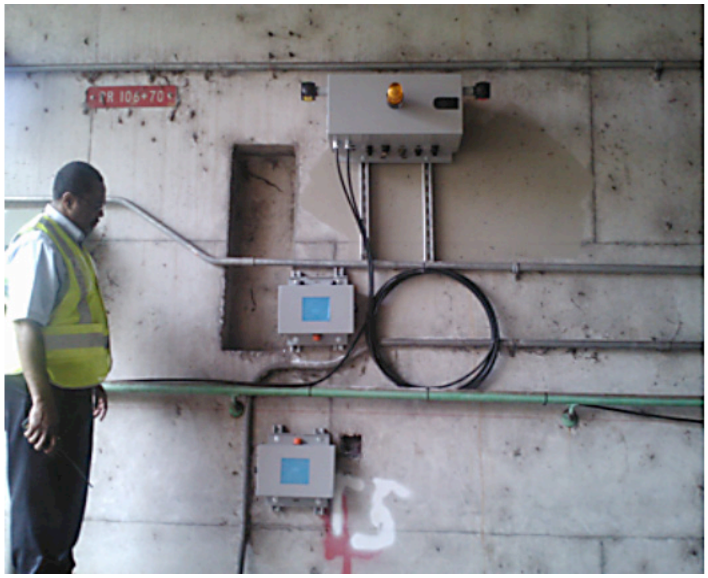


Figure 3-4
Bankhead Station installation

Audible and Visual Alert Selection

MARTA initially had some concerns that it might receive complaints from residents about the level of noise generated by the system. Two strategies were developed to address this: a variable output horn and incorporation within the design of the TLUs the ability to connect multiple strobe lights. In this way, strobe lights could be used instead of horns at noise-sensitive locations. The TLU alert light color was customized to match existing MARTA train approach lighting systems to better integrate with existing operations.

SECTION 4

Testing

Testing was conducted to determine the reliability of the system as well as expose opportunities for improvement. Multiple aspects of the system were tested. These included:

- Alert Warning Zone
- Train Detection
- Track Level Units
- Station Level Units
- Transit Control Interface
- RFID Tag Format

Testing was conducted during deployment and during scheduled revenue service. Some of the testing required the team to access equipment such as TLUs that were deployed within the wayside. MARTA facilitated this testing by providing appropriate resources; for example, track workers provided safe access for Bombardier's team whenever servicing TLUs within the wayside. Following a robust pre-determined testing plan, multiple iterations of testing were conducted for all aspects of the system. The initial testing, during deployment, was used to identify challenges that needed to be addressed. System software was updated and follow-on testing was performed to ensure the system operated in a reliable manner. Details of the test scenarios are contained within the appendices of this report.

Alert Warning Zone Testing

AWZs were thoroughly tested. Multiple scenarios were investigated and simulated, including the following:

- Checking in as a single worker and walking along the track
- Checking in as a group and walking along the track
- Checking in multiple groups and walking along the track
- Checking in as a group and then splitting the group during the walk
- Have a workers enter the wayside without checking in

Results from the final tests included the following:

- The AWZ was set up properly and the zone updated as the worker moved along the track. The information was also promptly updated at the transit control interface, and no warnings were noticed on the transit control interface.

- The AWZ was set up properly and the zone updated as the group of workers moved along the track. The information was promptly updated at the transit control interface, along with the proper group size, and no warnings were noticed on the transit control interface.
- Multiple AWZs were set up properly as the groups moved along the tracks. Information was promptly updated at the transit control interface, and no warnings were noticed on the transit control interface
- One AWZ was set up after check-in. This remained a single warning group system and updated the warning zones and enabled two warning zones. The transit control interface showed the split-off worker's radio ID in red, and a warning was provided to alert the RCSS staff.
- AWZs were set up based on the TLU where the worker tagged in. The transit control interface displayed the worker with the radio ID in red, and a warning was provided to the RCSS staff.

The team was able to test some other permutations of these scenarios. The team also was able to test the proper behavior of worker protection zones with forward and reverse direction trains as well as with non-revenue, non-train equipment on the tracks.

During the initial commissioning and testing, the team discovered a few issues with the logic that processes the AWZs. Multiple groups posed some challenges, and zones were not optimally configured. As a result, the system architecture and algorithms were updated, and thorough testing was conducted to ensure that the current version of the server software could reliably respond to multiple groups at the track level with multiple workers being present at different sections of the track. Testing was conducted by observing the execution of commands in real time by the server as well as by team members observing the behavior of the system at the wayside.

Train Detection Testing

Each track level unit is outfitted with two RADAR sensors. This ensures that even if one of the sensors stops functioning, the train gets detected and the appropriate actions are taken by the system in terms of setting up the AWZ and sounding the proper alerts. (Note: A Ford F350 hi-rail was used for testing. This is the smallest on-track vehicle that MARTA uses.)

A key issue related to train detection was observed during the initial testing. The impact of multiple train detection messages in a very short period of time led to challenges in the communication between the server and the TL units. This was overwhelming the server and causing it to behave in an erratic manner. The team was able to fix this by implementing logic to filter out multiple train detection messages. This was done at the TL units (as a first measure) and also at the server level (to provide a second level of filtering) to enhance the robustness and reliability of the system's response to train detection messages. The system was thoroughly tested after this update, and the system behaved as expected.

Track Level Unit Testing

TLUs provide track workers with an interface to communicate their location with the rest of the system. This is enabled through the workers swiping their tags at the TLUs. They communicate with the server to send event-based information and receive commands from the server to turn on lights or horns based on their location in the AWZ.

TLUs were also tested as part of the rest of system testing. Initial challenges with multiple reads from sensors required the firmware for TLUs to be updated. Any erratic behavior observed in initial testing (such as not sounding horns properly or TLUs becoming non-responsive for a few minutes) were fixed through firmware updates. The units were tested based on firmware updates, and the final testing results are provided above.

Station Level Unit Testing

SLUs are used by workers to check in and check out. The testing conducted on SLUs is discussed below. Challenges were experienced with the SLUs during initial testing. These challenges were due to the changing architecture of the server. Once the server architecture was updated, these challenges were resolved and the results from final testing are provided above.

Transit Control Interface Testing

The transit control interface provides the Railway Services Control Center (RSCC) staff with a view of who is on the track as well as their location and contact information. This information would be helpful for MARTA to enhance emergency response operations.

The transit control interface was pretty stable throughout the testing. This is a key way to format and present information that MARTA (and other transit agencies) would find useful. It takes the useful information and provides it in a visual and timely manner for Control Center employees to document and make better decisions during events requiring emergency response. The transit control interface was demonstrated and tested locally using a laptop on the SLU. However, further testing needs to be conducted by installing and testing the system remotely within the RSCC. This would provide an opportunity to test the transit control interface for any issues that might arise due to latency introduced by communication networks.

RFID Tag Format Testing

The format for RFID tags depends on the needs of the transit agency. MARTA was interested in exploring RFID tags that are embedded in employee badges. Three formats of RFID tags were tested: a form factor of a wristband, a tag embedded in a credit card form (to emulate tags embedded in employee badges), and a tag embedded in a track certification card.

It was noticed that regardless of the form factor, the tags were read by the reader at close proximity. Once the tags were placed a few centimeters from the reader, they were not read. This should address any false detection as workers walk by readers, and it also confirms that transit agencies should be able to choose a form factor that suits their needs.

Outcomes

Although prior testing of TrackSafe has been conducted in controlled environments, this was the first substantial testing of TrackSafe in a live transit environment. The team was able to work with MARTA employees to identify areas of improvement for TrackSafe. This section provides a summary of the outcomes as well as identified areas of improvement from this project.

Outcomes – TrackSafe

Transit Control Interface

Bombardier had proposed demonstrating how track worker locations could be displayed at the RSCC on a graphical user interface (GUI). Members of the RSCC were interviewed and observed during operations to determine what information would benefit a rail controller during operations. Existing forms and data gathered during operations were analyzed and input into a customized GUI that was presented to MARTA's Rail Control Team. The result of this effort can be seen in Figure 5-1. The Control Center interface displays the radio ID of the flag person on the map next to the last RFID tagged location on the display map. Additional information including the name, restriction ID, certification level, and group size are provided in a tabular format. This information is displayed for all active worker groups at the track at any given time. The transit control interface was tested thoroughly, and the location ID and display were updated without any noticeable time delay. The interface also has a column to alert RSCC staff to any system errors or any workers that get to the track level without checking in (at all or properly).

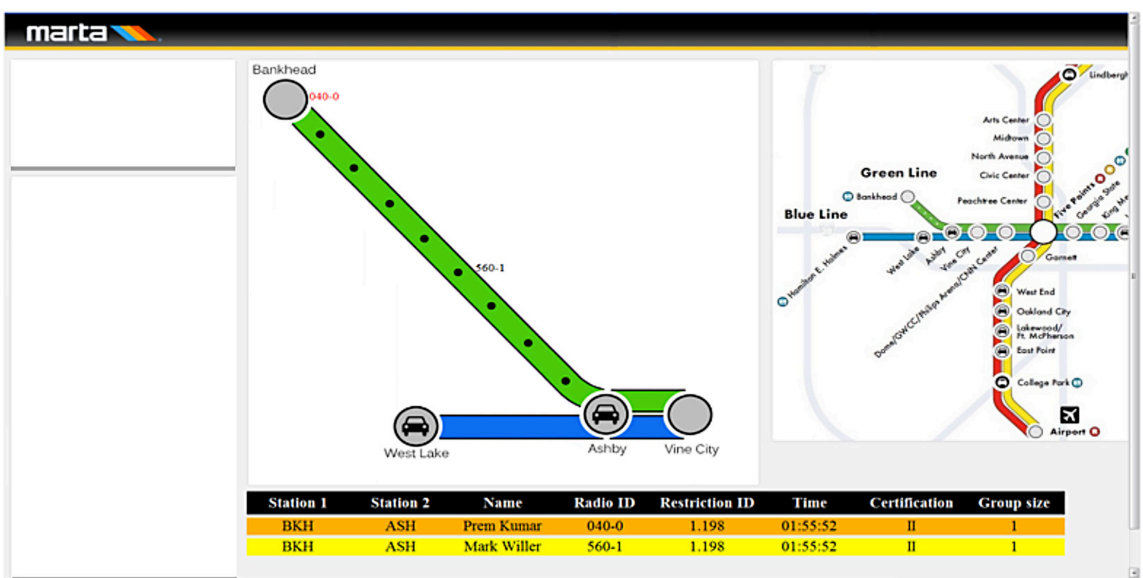


Figure 5-1

Transit Control User Interface

The development of the transit control interface is a significant outcome from this project. The need was identified through the activities undertaken in this project, and the Bombardier team was able to develop the interface and demonstrate it during the project.

Vandal-Resistant Design

All equipment was designed taking into account the environment in which it was to be installed. Following a process review with MARTA, it became apparent that the SLUs would need to be placed on the station platforms in a location accessible to the public.

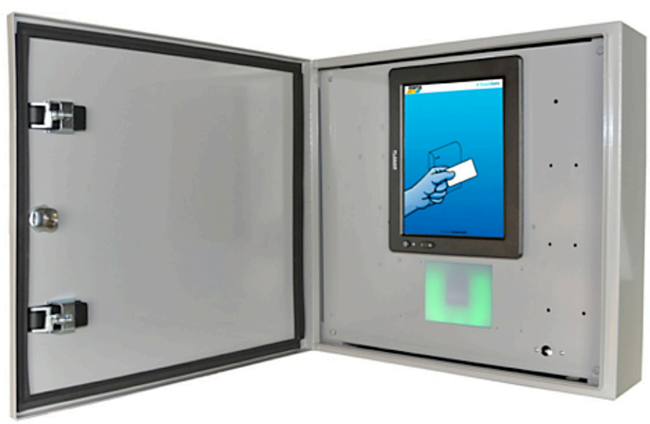
In response to this change in circumstance, the SLUs were redesigned to include additional anti-vandal properties. This included a fully-locking door, opened with a "standard issue" MARTA key. The design was also modified to look as inconspicuous as possible. Heavier-gauge steel was also selected for manufacturing the enclosures to provide an extra layer of anti-tampering.

This enclosure design will be helpful during deployments for units that need to be placed on platforms or in areas that are accessible to travelers.

SLUs were installed at the Bankhead and Ashby stations.

Figure 5-2

Station Level Unit (SLU)



Audible Alert Selection

MARTA initially had some concerns that it might receive complaints from residents about the level of noise generated by the system. This led the team to modify the design to accommodate variable output horns where the volume of the horn and the type of output can be modified based on the location of the horn. This can be done without impacting the rest of the system.

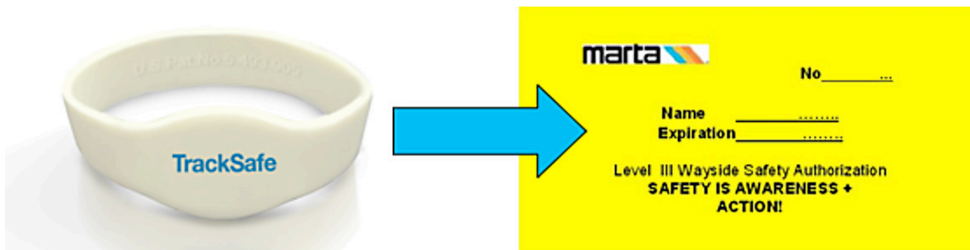
The TLUs were also redesigned to work with multiple strobe lights. This mechanism provides more flexibility for the transit agencies as, instead of horns, it can be used to alert track workers in sensitive locations. The system design also was updated to change the alert mechanism between strobes and horns, depending on the time of day. This was deployed at two locations, and tests were conducted to ensure reliable operations on units with multiple strobe lights.

RFID Tag Format

During the project, in consultation with various MARTA personnel, it was established that the initial design of an RFID wristband could be replaced with an RFID "chip" inserted into the existing MARTA Wayside Access Pass, in an effort to integrate with current MARTA Operational Procedures. This had the benefit of requiring no additional items to be carried or remembered (since MARTA rules specify that the Wayside Access Pass is required to be carried at all times when wayside.)

Figure 5-3

RFID form factors



Testing was conducted with RFID tags in credit card (employee badge) format, Wayside Certification format, and wristband format. No difference was noted in the performance of the system regardless of the tag format that was used for testing.

Areas of Improvement – TrackSafe

Data Management – Records and Reporting

Existing MARTA processes dictate that rail controllers must manually-document information during the entry of personnel within MARTA's wayside, resulting in a very paper-intensive process. These same records must then be maintained and archived. Bombardier saw this as an opportunity to convert this paper-driven process into an e-documented process.

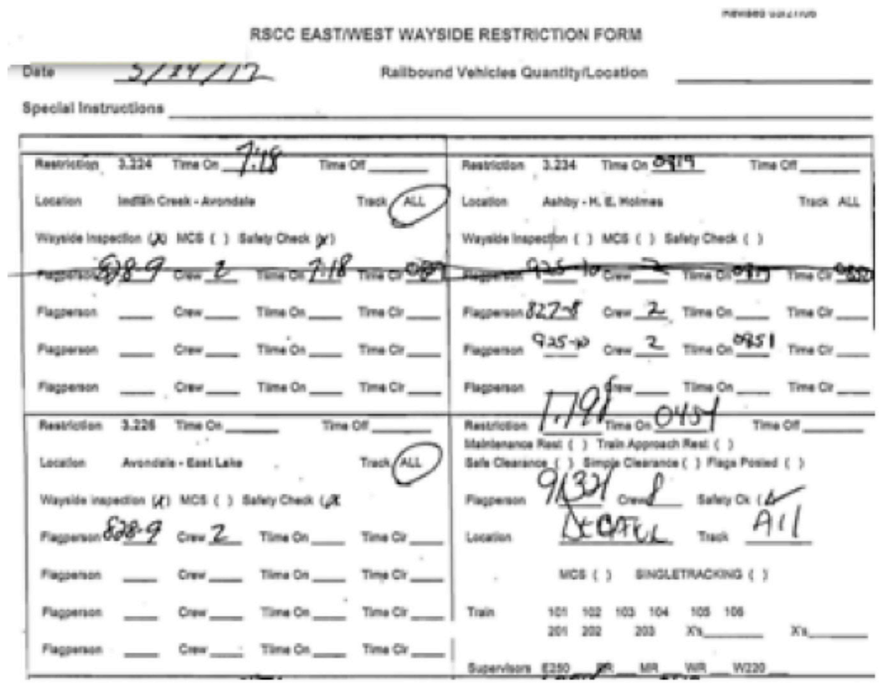
With TrackSafe, Bombardier was able to demonstrate how these records could be automated through a simple user interface. The worker check-in process requires less time, as less information is communicated, and business rules are used to determine if the track worker can get access to the track. This results in minimizing errors, frees up staff time, and enables MARTA to run reports for management when required.

The paper form (Figure 5-4) was replaced with screens at the track walk entry point (Figure 5-5). The restriction IDs are pre-programmed. New restriction

IDs can be added as and when necessary. The restriction IDs are used to fill out the activity information (including check-in point, proposed check-out point, restriction type, if the power needs to be turned off, etc.).

Figure 5-4

Manual Rail Service Control Center (RSCC) record



RSCC EAST/WEST WAYSIDE RESTRICTION FORM

Date 5/24/12 Railbound Vehicles Quantity/Location

Special Instructions

Restriction 3.224 Time On 7:18 Time Off

Location Indian Creek - Avondale Track ALL

Wayside Inspection (X) MCS ( ) Safety Check (X)

Flagperson 989 Crew 2 Time On 7:18 Time Clr

Flagperson Crew Time On Time Clr

Flagperson Crew Time On Time Clr

Flagperson Crew Time On Time Clr

Restriction 3.226 Time On Time Off

Location Avondale - East Lake Track ALL

Wayside Inspection (X) MCS ( ) Safety Check (X)

Flagperson 828-9 Crew 2 Time On Time Clr

Flagperson Crew Time On Time Clr

Flagperson Crew Time On Time Clr

Flagperson Crew Time On Time Clr

Restriction 3.234 Time On 0919 Time Off

Location Ashby - H. E. Holmes Track ALL

Wayside Inspection ( ) MCS ( ) Safety Check ( )

Flagperson 925-10 Crew Time On 0919 Time Clr

Flagperson 827-8 Crew 2 Time On Time Clr

Flagperson 925-10 Crew 2 Time On 0951 Time Clr

Flagperson Crew Time On Time Clr

Restriction 1.191 Time On 0454 Time Off

Maintenance Rest ( ) Train Approach Rest ( )

Safe Clearance ( ) Simple Clearance ( ) Flags Posted ( )

Flagperson 9/321 Crew 2 Safety Ck ( )

Location Decatur Track All

MCS ( ) SINGLETRACKING ( )

Train 101 102 103 104 105 106 201 202 203 X's X's

Supervisors E250 ER MR WR W220

Figure 5-5

Check-in screen

Upon MARTA's request, Bombardier was able to deploy and demonstrate the application of MARTA's wayside access control procedure by only allowing users to select "restrictions" that are appropriate for the level of their wayside access training and by not allowing those with expired Wayside Access Passes to proceed through the system.

The importance of the data management aspect of the system, as it pertains to automating processes and enabling better recordkeeping and reporting, was highlighted through feedback from MARTA employees. Bombardier was able to implement some of this functionality during the pilot project and is currently working on enhancing this to meet MARTA's evolving needs as well as the needs of other transit agencies.

Enclosure Design

The vandal-resistant design of enclosures worked very well. No units were tampered with or vandalized during deployment or testing. However, the team was able to identify a few areas where the design can be improved:

- Make SLUs more tamper-proof by extending the enclosure to protect cables connected to the unit.
- Modify the mounting plates to make it easier to access internal components. This will have an impact on reducing maintenance effort in the long term.

SECTION 6

MARTA Feedback

The evaluation team from MARTA included representation from the following groups:

- Track workers
- Train operators
- Wayside Certification trainers
- RSCC supervisors
- Management and supervision

Bombardier is pleased to report very encouraging feedback from MARTA personnel.

During the installation and commissioning phase, there was a great amount of interest in the project from train operators and track workers. More than 70 MARTA personnel requested information/demonstrations from the Bombardier Team. This level of interest and engagement was very encouraging. The train operators were particularly interested in receiving timely and relevant alerts, and the track workers were interested in the additional layer of safety TrackSafe enables for them. In particular the following feedback was received:

- Track workers stated that audible and visual alerts were effective in alerting them of approaching trains.
- Track workers appreciated not having to carry additional equipment.
- Rail operators stated that visual indicators were effective, especially in curve sections.
- RSCC supervisors liked the concept of being able to locate trackside personnel on a centrally-located GUI for the entire system. Envisaged benefits to this are:
  - Improve visibility of track worker locations, leading to better safety
  - Improved train service management and emergency response
  - Improved planning/conflict avoidance
- MARTA Wayside Certification trainers liked the concept of having an additional check-point to confirm certification training prior to entry onto the trackway.

Benefits of Pilot in Operational Environment

Input from an Operations group is invaluable when determining a customized solution that integrates with existing operational procedures. System exposure to MARTA's operating transit environment provided data for individual components that helped with determining product selection. Collaborative discussions led to development of a GUI at both the RSCC and SLU that conceptually integrates existing operations for gaining access and performing work on the track way.

The team expressed the need for intelligent self-diagnostic capabilities down to a component level to significantly help with maintenance efforts over the life of each component.

SECTION 7

APTA Demonstration

One of the objectives that FTA conveyed to Bombardier was the need to ensure that the outcome of the project was shared within the transit industry. To this end, Bombardier took the opportunity to demonstrate the system to the assembled safety professionals from across the U.S. at a meeting of APTA's Safety Committee in Atlanta on December 6, 2012. More than 30 people attended the demonstration; 15 percent were from industry groups concerned with railway transportation and workers safety, 20 percent were consultants and suppliers to transit agencies, and 65 percent were employees from transit agencies across North America. The majority of these attendees are responsible for ensuring the safety of workers in transit agencies.

The purpose of the demonstration was to provide the attendees with an overview of TrackSafe and a live demonstration of all aspects of the system, AWZ, transit control interface, etc., and feedback was received from the attendees in an ad hoc manner. The feedback received pointed to the interest that safety managers have in exploring systems that can be used to enhance worker safety while either enhancing worker productivity or at least minimizing any negative impact on worker productivity.

More feedback needs to be gathered from track workers, train operators, and safety professionals to determine the real impact that technologies such as TrackSafe can have on the urban transit industry. This needs to be done in a scientifically rigorous manner. The team has had the opportunity to learn from this project and will be including those activities as a key part for any follow on projects.

Figure 7-1
APTA demonstration attendees

SECTION

8

Future Development

This demonstration project proved invaluable from the point of view of testing the TrackSafe technology to ensure that it functions as intended in an operational environment. The Bombardier and MARTA team identified a number of areas for future research and development:

- **Installation Facilitation** – The present design of the equipment at the track level involves a number of separate units that interconnect. This makes the installation more complex and take longer than necessary. To simplify installation, research should be conducted into simplifying the design and reducing the number of individual components at track level.
- **Vandal Resistance** – During the course of the project, some cabling was removed (presumably for its copper value) and a fiber cable was cut. Future design should reduce make the equipment and installation more vandal-resistant.
- **Self-Health Monitoring** – Although the present design provides a check on connectivity every few seconds along with an alert if units do not respond, there is significant opportunity to increase the scope of self-health monitoring. This will be key to ensuring maximum system availability, reducing down time, and maintenance costs.
- **Ease of Maintenance** – Although all of the equipment during the demonstrations worked without any failures, further research should be targeted at facilitation of easy maintenance. A philosophy of unit change will minimize the impact of any equipment problems on the operation of transit systems.
- **Multiple Station-to-Station Sections** – Further development should target the functionality across a larger deployment zone to address software configuration, deployment, and use policy issues (multiple sections of track with one of more SLU check-ins).
- **Multi-Direction Traffic** – This demonstration was carried out on one side of the dual track between the Ashby and Bankhead stations. The configuration of the alerts in multi-track deployments is another further area for research. It will be important that track workers are able to perceive from which track and direction a train is approaching.
- **Operational Procedures** – Further research is needed in the area of transit system policies for the use of a system such as TrackSafe as well as the formal procedures for use as part of the overall operation.

SECTION

9

IET Innovation Award

Due, in part, to this project, Bombardier was awarded the Institution of Engineering and Technologies (IET) Innovation Award for 2012 in the category of "Embedded and Critical Systems" out of 420 entries in 15 categories. IET is one of the world's leading professional societies for the engineering and technology community, with more than 150,000 members in 127 countries and offices in Europe, North America, and Asia-Pacific. IET represents the engineering profession in matters of public concern and assists governments to make the public aware of engineering and technology.

Figure 9-1

IET Innovation Award

APPENDIX A

Project Organization

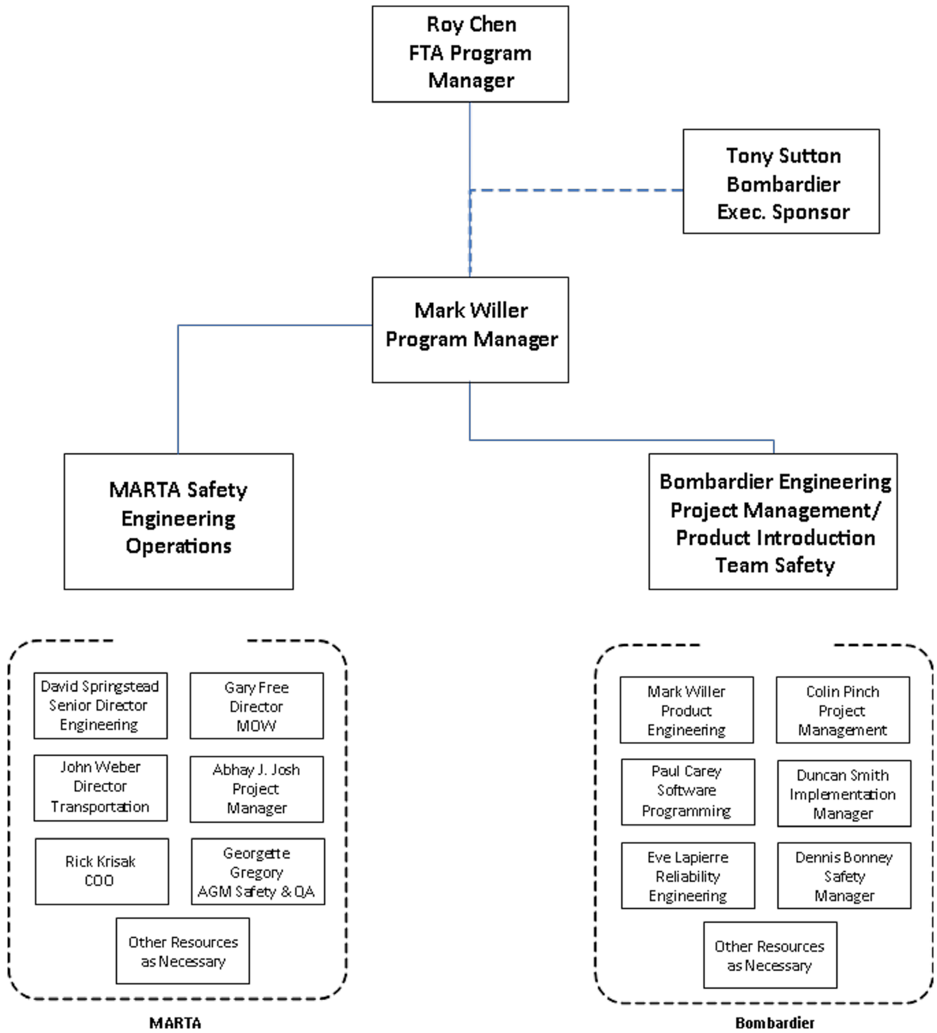


Figure A-1

Project Organization Chart

APPENDIX

B

Project Schedule

Table B-1 indicates the planned project dates and their actual completion date.

Table B-1

Project Schedule

Milestone	Planned (TEAM)	Actual
Project Mobilization	3/15/2012	03/19/2012
Installation Plan	4/15/2012	05/25/2012
Configuration Requirements	5/15/2012	05/25/2012
Software Development	10/01/2012	10/01/2012
Install Infrastructure	10/01/2012	10/08/2012
System Configuration	10/15/2012	10/15/2012
System Test	11/01/2012	10/24/2012
System Documentation	1/01/2013	3/15/2013
System Setup/Test	2/01/2013	11/26/2012
Demonstration	2/15/2013	12/6/2012 (APTA)
Final Report	6/15/2013	7/2013

APPENDIX

C

Use Case Scenarios

Table C-1

Alert Warning Zone Testing Results

Use Case Scenario	Expected Results	Actual Results
Single group of workers – Check-in.	AWZ set up in forward and reverse directions (alerts operational for train operators but no alerts for workers).	AWZ set up in forward and reverse directions (alerts operational for train operators but no alerts for workers).
Single group of workers – Check in, train enters AWZ in forward (normal) direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of forward zone trigger worker alerts.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of forward zone trigger worker alerts.
Single group of workers – Check in, train exits AWZ in forward direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.
Single group of workers – Check in, train enters AWZ in reverse direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of reverse zone trigger worker alerts.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of reverse zone trigger worker alerts.
Single group of workers – Check in, train exits AWZ in normal direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.
Single group of workers – Tag in at subsequent TL units (test repeated 8 times for 8 TL units).	AWZ updated for forward and reverse directions based on last tagged TL unit (alerts operational for train operators but no alerts for workers).	AWZ updated for the forward and reverse directions based on last tagged TL unit (alerts operational for train operators but no alerts for workers).

Table C-1 (cont.)

Alert Warning Zone Testing Results

Use Case Scenario	Expected Results	Actual Results
Single group of workers – Tag in at subsequent TL units (test repeated 8 times for 8 TL units), train enters – forward direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (Audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of forward zone trigger worker alerts.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of forward zone trigger worker alerts.
Single group of workers – Tag in at subsequent TL units (test repeated 8 times for 8 TL units), train exits – forward direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.
Single group of workers – Tag in at subsequent TL units (test repeated 8 times for 8 TL units), train enters – reverse direction	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of reverse zone trigger worker alerts.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of reverse zone trigger worker alerts.
Single group of workers – Tag in at subsequent TL units (test repeated 8 times for 8 TL units), train exits – reverse direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.
Single group of workers – Skip a TL unit and tag in at a subsequent TL unit (test repeated in an ad hoc manner).	AWZ updated for forward and reverse directions based on last tagged TL unit (alerts operational for train operators but no alerts for workers).	AWZ updated for forward and reverse directions based on last tagged TL unit (alerts operational for train operators but no alerts for workers).
Single group of workers – Skip a TL unit and tag in at a subsequent TL unit (test repeated in an ad hoc manner), train enters – forward direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of forward zone trigger worker alerts.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of forward zone trigger worker alerts.
Single group of workers – Skip a TL unit and tag in at a subsequent TL unit (test repeated in an ad hoc manner), train exits – forward direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.

Table C-1 (cont.)

Alert Warning Zone Testing Results

Use Case Scenario	Expected Results	Actual Results
Single group of workers – Skip a TL unit and tag in at a subsequent TL unit (test repeated in an ad hoc manner), train enters – reverse direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of reverse zone trigger worker alerts.	AWZ set up in forward and reverse directions. Train operator alerts operational. Horn (audio alert on units in AWZ zone sounds three times) and worker strobe lights turn on for workers and stay on. Only units that are a part of reverse zone trigger worker alerts.
Single group of workers – Skip a TL unit and tag in at a subsequent TL unit (test repeated in an ad hoc manner), train exits – reverse direction.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.	AWZ set up in forward and reverse directions. Train operator alerts operational. Worker strobe lights in AWZ turn off for workers.
Single group of workers – Check out.	AWZ set up in forward and reverse directions turned off.	AWZ set up in forward and reverse directions turned off.
All above tests repeated for multiple groups checked in.	AWZ set up based on location of multiple groups of workers. Train operator alerts always on.in AWZ. Worker alerts turned on based on trains entering forward or reverse zones and stopping when train exits active AWZ.	AWZ set up based on location of multiple groups of workers. Train operator alerts always on in the AWZ. Worker alerts turned on based on trains entering forward or reverse zones and stopping when train exits active AWZ.
All above tests repeated for groups that spilt up once they are already at wayside.	AWZ set up based on all locations where workers have actively tagged in with different tags. Train operator alerts always on in AWZ. Worker alerts turned on based on trains entering forward or reverse zones and stopping when train exits active AWZ.	AWZ set up based on all locations where workers have actively tagged in with different tags. Train operator alerts always on in AWZ. Worker alerts turned on based on trains entering forward or reverse zones and stopping when train exits active AWZ.

Table C-2

Train Detection Testing Results

Use Case Scenario	Expected Results	Actual Results
Both sensors working – Worker standing in front of TLU or walking past sensors.	No detection on either sensor.	No detection on either sensor.
Both sensors working – Train passing.	Train detected on both sensors.	Train detected on both sensors. Time stamp on detection message validates which sensor detected train first. Train detected multiple time by sensors.
One sensor working – Worker passing by (simulated by unplugging a sensor).	No detection on either sensor.	No detection on either sensor.
One sensor working – Worker passing by (simulated by unplugging a sensor).	Train detected by live sensor.	Train detected by live sensor. Validated through timestamp and port with which detection message was associated.
Both sensors working – Hi-Rail vehicle passing by.	Hi-Rail detected on both sensors.	Hi-Rail detected on both sensors. Time stamp on detection message validates which sensor detected Hi-Rail first. Number of detections depended on speed of Hi-Rail vehicle as it passed TL unit.

Table C-3

Track Level Unit Testing Results

Use Case Scenario	Expected Results	Actual Results
TL unit turned on, not connected to network.	TL unit turns on and waits for communication with server.	TL unit turned on and went through self-testing. This was observed through lights turning on and off once. Also, worker swipe area turns purple and stays purple.
TL unit turned on, not connected to network, train passing by.	TL unit turns on and detects train.	TL unit tuned on. Worker swipe area goes from purple to green when a train is detected and turns back to purple once train detection is processed. Light in worker swipe area changes multiple times if train is detected multiple times.
TL unit connected to server.	TL unit connected to server and ready to receive commands from server.	Worker swipe area of TL unit turns blue. TL unit settings file communicated from server to TL unit.
TL unit connected to server, train passing by.	TL unit communicates train detection messages to server.	Worker swipe area turns from blue to green and back to blue. This was observed multiple times for multiple train detection messages. Train detection messages communicated to server.
TL unit connected to server, worker tag in.	Worker tagged in.	Worker tag information captured. Worker swipe area turns from blue to green and then back to blue once reader has read tag ID. Multiple tag reads are filtered. Even communicated to server. TL unit acts on commands issued by server in response to worker tagging event.
TL unit disconnected from network.	TL unit goes in high alert state.	TL unit detects loss of access to communication network in a timely manner (less than a minute) and goes into a high alert state (train operator lights on, worker strobe light on).
TL unit reconnected to network.	TL unit goes to normal operational mode.	TL unit detects communication network, reconnects with server, and goes back to normal operational mode. Train operator lights and worker strobe lights turn off and TL unit waits for server to send further commands.

Table C-4

Track Level Unit Testing Results

Use Case Scenario	Expected Results	Actual Results
Station level unit turned on, not connected to server.	Station level unit turned on but not connected to server.	Station level unit turned on. Worker swipe are stays purple. Train detection messages observed through worker swipe area color changing from purple to green and back to purple.
Station level unit turned on, not connected to server, worker tag in.	Station level unit turned on but not connected to server.	Station level unit turned on. Worker swipe are stays purple. Worker tag in observed through worker swipe area color changing from purple to green and back to purple. No alert warning zone setup.
Station level unit turned on, connected to server.	Station level unit turned on and connected to server.	SLU turned on. Worker swipe area turned blue.
Station level unit turned on, single worker check in.	Worker checked in and appropriate information communicated with server and transit control interface.	Worker check-in based on process discussed with MARTA. SLU lets worker change radio ID but provides rest of information for worker. Worker is able to select a restriction. Only restrictions that worker is allowed to select (based on certification level) are provided. Worker asked to provide information about flag person. Worker asked about possession of PPE. Once these steps are completed, worker authorized to access wayside. Information communicated to server, which leads to setup of appropriate alert worker zone. Information also provided to transit control interface.
Station level unit turned on, multiple workers (group) check in.	Group checked in and appropriate information communicated with server and transit control interface.	Group checked in based on process discussed with MARTA. SLU lets lead worker change radio ID but provides rest of information for worker. Worker is able to select a restriction. Only restrictions that worker is allowed to select (based on certification level) are provided. All workers in group have to tag in using their worker tags. Group asked to provide information about flag person. Flag person asked about possession of PPE. Once these steps are completed, the group is authorized to access wayside. Information communicated to server, which leads to setup of appropriate alert worker zone. Information also provided to transit control interface.
Station level unit, checkout single worker.	Worker checked out, information communicated with server and transit control interface.	Worker goes through checkout process as defined by MARTA. Information about checkout is communicated with server (alert worker zone is either turned off or updated based on other worker activity at track level). Information also communicated with transit control interface.
Station level unit, checkout multiple workers (group).	Group checked out, information communicated with server and transit control interface.	Group goes through checkout process as defined by MARTA. Information about checkout is communicated with server (alert worker zone is either turned off or updated based on other worker activity at track level). Information also communicated with transit control interface.

Table C-5

Transit Control Interface Testing Results

Use Case Scenario	Expected Results	Actual Results
Single worker starts checking in.	Information communicated to transit control interface.	Radio ID associated with worker shows up on transit control interface in red and corresponding entry for detailed information is listed as Unknown as information has not yet been communicated by worker.
Single worker concludes check in.	Information communicated to transit control interface.	Radio ID associated with worker shows up next to check-in station. Display color for ID changes from red to black. Detailed information about worker including radio ID, name, certification level, restriction ID, track access station, and track exit station listed in bottom section of transit control interface. Group size displays 1.
Single worker tags in at a TL unit (multiple tests)	Information communicated to transit control interface.	Radio ID moves to TL unit where worker last tagged.
Single worker checks out.	Information communicated to transit control interface.	Radio ID disappears from transit control interface, along with detailed information about worker.
Group starts checking in.	Information communicated to transit control interface.	Radio ID associated with worker that initiates check-in shows up on transit control interface in red and corresponding entry for detailed information listed as Unknown as information has not yet been communicated by worker.
Group concludes checking.	Information communicated to transit control interface.	Radio ID associated with flag person shows up next to check-in station. Display color for ID changes from red to black. Detailed information about worker including radio ID, name, certification level, restriction ID, track access station and track exit station listed in bottom section of transit control interface. Group size displays number of workers in group.
Group tags in at a TL unit (multiple tests).	Information communicated to transit control interface.	Radio ID of flag person moves to TL unit where worker last tagged.
Group splits during track walk and a non-flag person tags in at a TL unit.	Information communicated to transit control interface.	Radio ID for group stays at location last tagged by flag person. New Radio ID for person that split from group shows up on transit control interface. ID listed next to unit where worker tagged in and is displayed in red.
Group checkout.	Information communicated to transit control interface.	Radio ID disappears from transit control interface, along with detailed information about group of workers.

Table C-6

RFID Tag Format Testing Results

Use Case Scenario	Expected Results	Actual Results
Wrist band – tagging at TLU – tag touching reader.	Tag read.	Tag read. Worker scan area turned green to acknowledge tag read. Tag ID processed and communicated to server. Multiple tag reads filtered out.
Wrist band – tagging at TLU – tag 3 cm from reader.	Tag not read.	Tag not read by TLU.
Tag embedded in a credit card form - tagging at TLU – tag touching reader.	Tag read.	Tag read. Worker scan area turned green to acknowledge tag read. Tag ID processed and communicated to server. Multiple tag reads filtered out.
Tag embedded in a credit card form - tagging at TLU – tag 3 cm from reader.	Tag not read.	Tag not read by TLU.
Tag embedded in track certification card - tagging at TLU – tag touching reader.	Tag read.	Tag read. Worker scan area turned green to acknowledge tag read. Tag ID processed and communicated to server. Multiple tag reads filtered out.
Tag embedded in track certification card - tagging at TLU – tag 3 cm from reader.	Tag not read.	Tag not read by TLU.

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