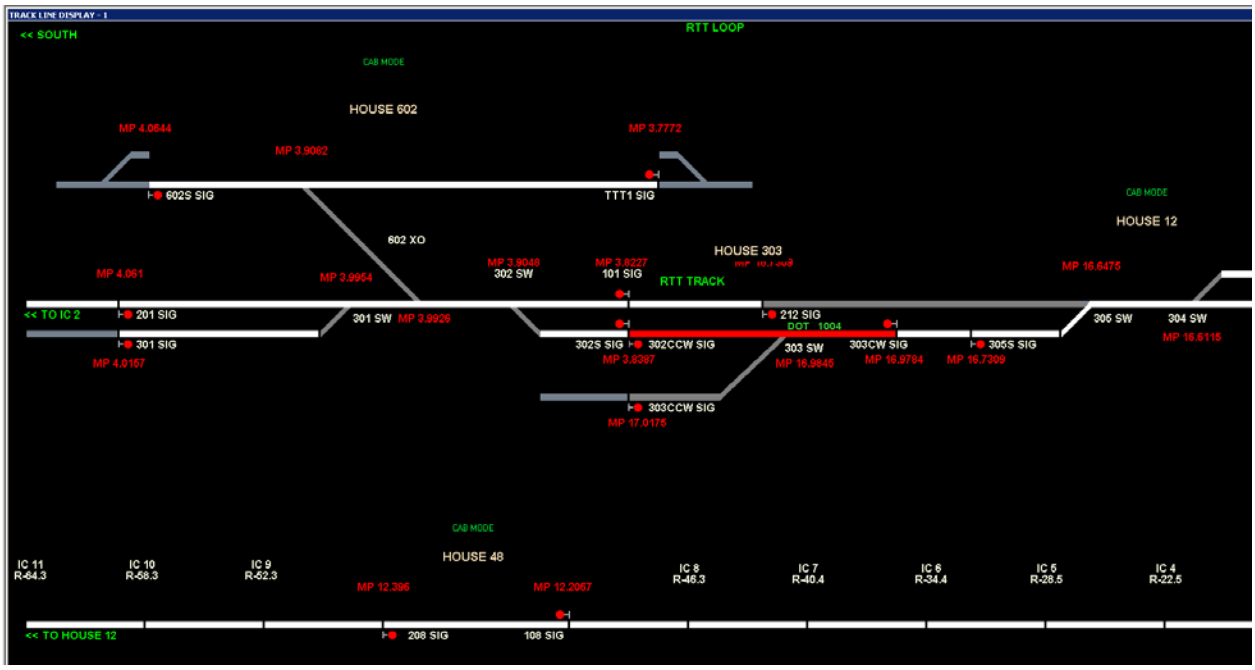
U.S. Department of Transportation

Federal Railroad Administration

PTC Test Bed Upgrades to Back Office and Computer-Aided Dispatch Systems

Office of Research,
Development
and Technology
Washington, DC 20590



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May 2018

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13. ABSTRACT (Maximum 200 words)
Transportation Technology Center, Inc. (TTCI) performed work sponsored by The Federal Railroad Administration (FRA) to complete updates to the Positive Train Control (PTC) Test Bed at the Transportation Technology Center (TTC). The updates also included the PTC back office (BOS) and computer-aided dispatch (CAD) systems, PTC track database, PTC wayside interface units (WIUs), and the PTC messaging system. Functional tests were completed to demonstrate that the PTC system operated as expected after updates were completed, resulting in a fully functional PTC system capable of supporting a broad range of PTC-related test programs.

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Positive Train Control, PTC, Train Management Dispatching System, TMDS®, PTC Test Bed, computer-aided dispatch system, CAD, Railroad Test Track, RTT

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1 inch (in) = 2.5 centimeters (cm)	1 millimeter (mm) = 0.04 inch (in)
1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
	1 kilometer (km) = 0.6 mile (mi)
AREA (APPROXIMATE)	**AREA (APPROXIMATE)**
1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)	1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)	1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
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1 ounce (oz) = 28 grams (gm)	1 gram (gm) = 0.036 ounce (oz)
1 pound (lb) = 0.45 kilogram (kg)	1 kilogram (kg) = 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg)
	= 1.1 short tons
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1 teaspoon (tsp) = 5 milliliters (ml)	1 milliliter (ml) = 0.03 fluid ounce (fl oz)
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1 cup (c) = 0.24 liter (l)	1 liter (l) = 0.26 gallon (gal)
1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)	1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
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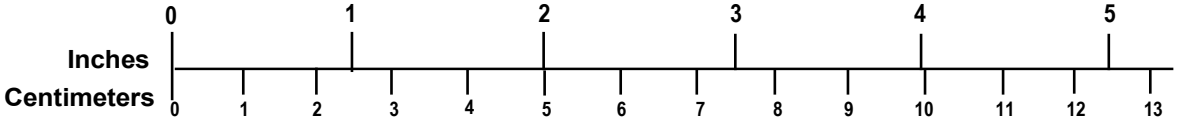

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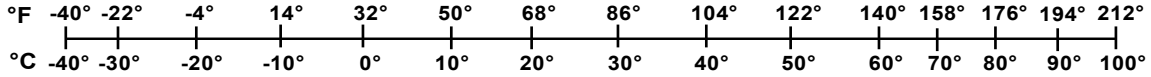

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Contents

Illustrations

Executive Summary

Transportation Technology Center, Inc. (TTCI) conducted work sponsored by the Federal Railroad Administration (FRA) to update and perform functional testing to the Positive Train Control (PTC) back office system (BOS). Upgrades to the PTC Test Bed included updating the PTC BOS, computer-aided dispatching (CAD) system, PTC track database, PTC wayside interface units (WIUs), and the PTC messaging system.

The updates to these components, which are part of the Wabtec Train Management Dispatching System (TMDS®), took place between July 21, 2015, and January 31, 2016, at the Transportation Technology Center (TTC) where TMDS® was updated to reflect the current configuration of the PTC Test Bed. Updates to the PTC track database were performed, as well as updates to the PTC WIUs and messaging system to show current wayside signaling logic and reflect all changes made in this project. Functional testing of the PTC Test Bed showed the system operated as expected after the updates were completed to each of these areas.

1. Introduction

1.1 Background

The Federal Railroad Administration (FRA) and Transportation Technology Center, Inc. (TTCI) developed a Positive Train Control (PTC) Test Bed at the Transportation Technology Center (TTC) through a series of FRA funded projects, which included a signaling system and Interoperable Train Control (ITC) compliant PTC system components on the Railroad Test Track (RTT). During the early stages of this research, TTCI acquired a Wabtec Train Management Dispatching System (TMDS®[1]), which included the PTC back office system (BOS) and computer-aided dispatching (CAD) system for the test bed. Over time, to support railroad PTC development and testing, additional features and capabilities were added to the PTC Test Bed on the RTT, resulting in the configuration and setup of the PTC BOS and CAD becoming outdated.

Below is a timeline of the PTC Test Bed's evolution on the RTT, starting with the original project.

2011

The existing broken rail detection system on the RTT was transitioned into six 12,000-foot intermediate signal blocks with 4-aspect block signaling that was PTC capable. A PTC wayside interface unit (WIU) was installed at each of the six signaling blocks along with equipment to support PTC communications over cellular and Wi-Fi networks. Two locomotives were equipped with Wabtec's Interoperable Electronic Train Management (I-ETMS®[2]) onboard systems. Wabtec's TMDS® system was also installed, which included the PTC BOS and CAD systems.

2011

During another 2011 project, the test bed was modified from six 12,000-foot intermediate signaling blocks to twelve 6,000-foot intermediate signaling blocks while still maintaining 4-aspect block signaling that was PTC capable. PTC WIUs and communication hardware were installed at the six new signaling locations to support PTC operations. Switches on the RTT were integrated into the signaling system for the signal blocks that were located in and monitored by the PTC WIUs. A total of five powered switches and one hand throw switch were configured to be monitored and controlled in this configuration of the PTC Test Bed.

2012

Two of the intermediate blocks were transitioned to absolute blocks, creating two control points (CP), one at Post 100 and the other at Post 85, on the PTC Test Bed. Figure 1 is a map of the RTT that shows the location of these two CPs. This transition included adding more signaling

[1] TMDS® is a registered trademark of Wabtec Corporation.

[2] I-ETMS® is a registered trademark of Wabtec Corporation.

equipment at these locations, as well as installing new entrance and exit signals to the RTT Test Bed. The signaling logic was upgraded at the CP locations to add the capability of requesting authority through the signals at these locations. During this project, PTC 220 MHz radios and the interoperable train control messaging (ITCM) system were installed at the base station, locomotives, and waysides.

2013

The 4,000-foot siding on the RTT was transitioned from a non-signaled siding to a signaled siding. The transition included installing new signaling equipment at each end of the siding, as well as installing a new equipment house (House 303), a powered switch machine, signal masts, and signaling equipment approximately in the middle of the siding, which runs from the CP at Post 85 to the CP at Post 100. Figure 1 is a map of the RTT that shows the location of the siding and the new CP at House 303. Signaling logic was upgraded at the CP locations, as well as the two intermediate locations entering the CPs, to reflect the new routes available, from the addition of the signaled siding to the PTC Test Bed.

2015

A new CP location was installed on the RTT, between R-48 and R-49, where a future proposed main line extension could be located. With the addition of this CP, new signaling equipment was installed in an existing bungalow at R-48 along with the addition of a signal mast on the RTT at that location, and a new bungalow with signaling equipment was installed at R-49 with the addition of a signal mast on the RTT at that location. Figure 1 is a map of the RTT that shows the location of this CP.

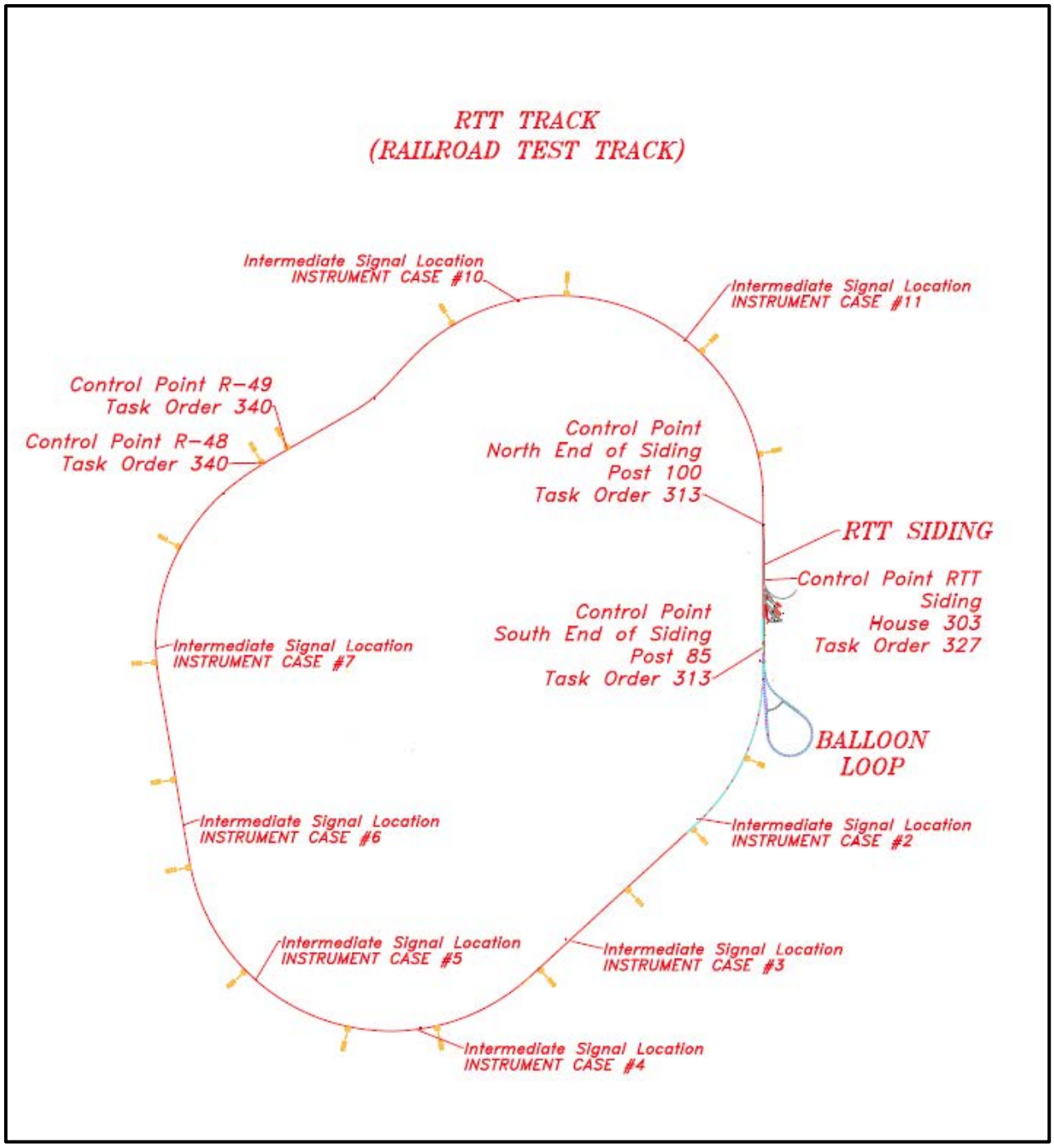


Figure 1. Map of the RTT with CPs and Intermediate Signal Locations

1.2 Objectives

The objectives of this project were to upgrade the PTC Test Bed BOS, which is a Wabtec TMDS®, to the latest software versions, and to update the configuration of the PTC system to reflect all the test bed modifications conducted on the previous FRA projects outlined in Section 1.1. This project also included a high-level system check of the PTC BOS and CAD system.

1.3 Overall Approach

The approach to updating the PTC BOS and CAD included the following major tasks:

- Create several virtual machines that work together to comprise Wabtec's TMDS®
- Connect CPs on the PTC Test Bed to TMDS® to gain the ability to monitor and control signals and switches at each of the locations
- Update the dispatching system to the current software release and modify the dispatching map to reflect the current PTC Test Bed track configuration
- Update the PTC WIU mapping and configuration files to reflect the current PTC Test Bed setup
- Modify PTC messaging system at waysides, locomotives, and the back office
- Update the RTT PTC track database to reflect the current PTC Test Bed setup

1.4 Scope

The scope of this project included the following:

- Updating the PTC BOS
- Updating the CAD system
- Configuring the PTC WIUs and PTC messaging system
- Updating the PTC track database for the RTT Test Bed
- Performing a high-level system check of the PTC BOS and CAD

1.5 Organization of the Report

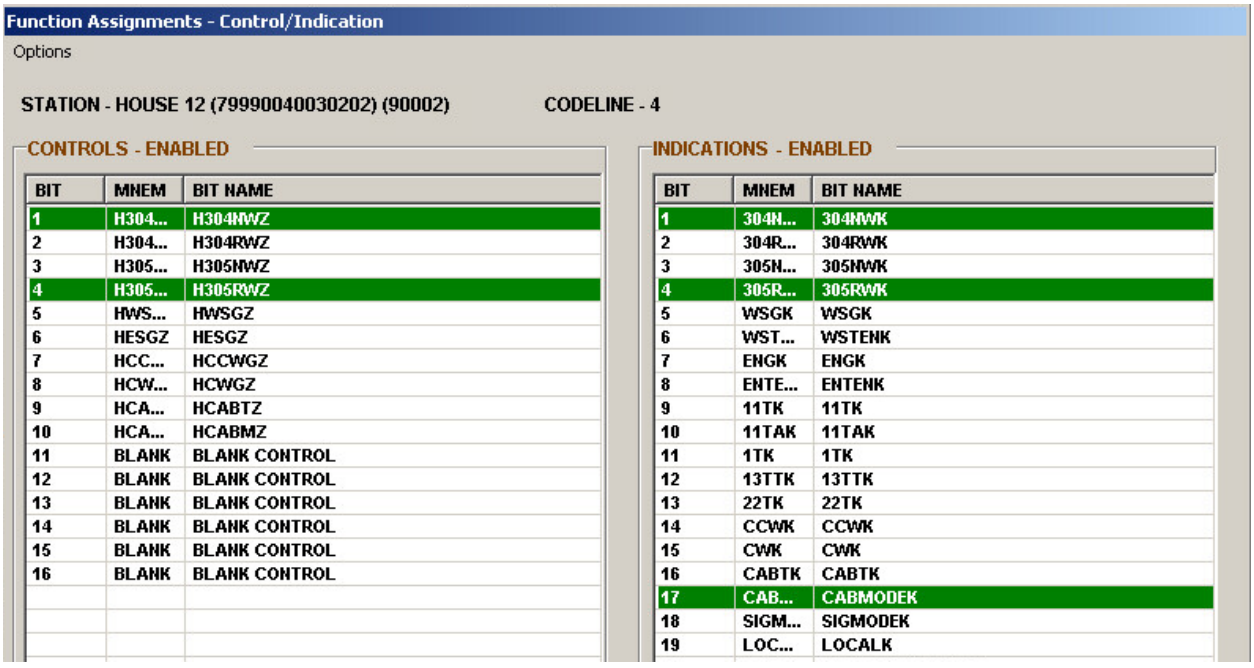
This report is organized in three major sections. Section 1 is the introduction, which presents the background and history of the PTC Test Bed. Section 2 describes the details of the PTC Test Bed BOS upgrades. Section 3 provides a summary-level conclusion.

2. Wabtec's Train Management Dispatching System

The PTC Test Bed BOS uses Wabtec's TMDS. At TTC, TMDS® is set up through several virtual machines that perform individual functions and work together to form the PTC Test Bed BOS. The following subsections describe several of the virtual machines in more detail.

2.1.1 TMDS-Code

TMDS-Code is the interface between the BOS and the CPs on the PTC Test Bed. Indications (signal status, switch position, local control state, signaling mode, track occupancy) and controls (signal authority requests and switch alignment requests, signal mode requests) are routed to and from the TMDS-Code machine to be processed. Indications coming from the CPs get routed through the TMDS office communication manager (TMDS-OCM), described in Section 2.1.3 , to TMDS-Code, where they are processed and then forwarded to other back office segments (for example the dispatching system uses indications to populate the dispatching display). Controls come from the dispatching system to TMDS-Code, where they are processed and a message is created in TMDS-Code and routed to the CP through TMDS-OCM. The CP receives the control request and the local signaling logic processes the request. Figure 2 shows the controls and indications for signal House 12. Controls that are highlighted in green are active control requests from the back office and are also active indications from the CP.



BIT	MNEM	BIT NAME
1	H304...	H304NWZ
2	H304...	H304RWZ
3	H305...	H305NWZ
4	H305...	H305RWZ
5	HWS...	HWSGZ
6	HESGZ	HESGZ
7	HCC...	HCCWGZ
8	HCW...	HCWGZ
9	HCA...	HCABTZ
10	HCA...	HCABMZ
11	BLANK	BLANK CONTROL
12	BLANK	BLANK CONTROL
13	BLANK	BLANK CONTROL
14	BLANK	BLANK CONTROL
15	BLANK	BLANK CONTROL
16	BLANK	BLANK CONTROL

BIT	MNEM	BIT NAME
1	304N...	304NWK
2	304R...	304RWK
3	305N...	305NWK
4	305R...	305RWK
5	WSGK	WSGK
6	WST...	WSTENK
7	ENGK	ENGK
8	ENTE...	ENTENK
9	11TK	11TK
10	11TAK	11TAK
11	1TK	1TK
12	13TTK	13TTK
13	22TK	22TK
14	CCWK	CCWK
15	CWK	CWK
16	CABTK	CABTK
17	CAB...	CABMODEK
18	SIGM...	SIGMODEK
19	LOC...	LOCALK

Figure 2. Controls and Indications from Signaling House 12

With support from Wabtec, all the indications and controls from the four CPs on the PTC Test Bed were confirmed to be mapped correctly in TMDS-Code.

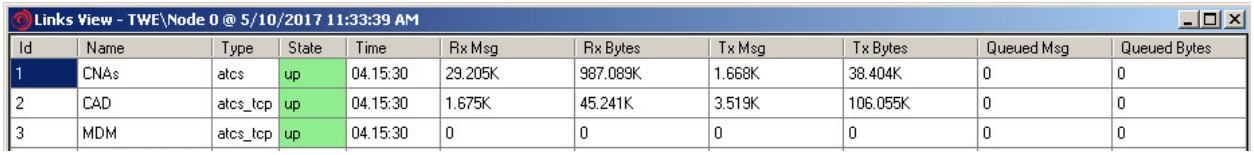
2.1.2 TMDS-Back Office Server (TMDS-BOS)

TMDS-BOS performs the main PTC back office functions in TMDS®. This machine is used to load the back office version of the PTC track database, to add PTC locomotives to the back office, as well as adding PTC-authorized employees into the system. TMDS-BOS also maintains a list of PTC locomotives initialized with the back office and processes all PTC messaging to and from the locomotives. TMDS-BOS has several connections to other back office segments including:

- TMDS-OCM – Connects TMDS-BOS with CAD, enabling TMDS-BOS to obtain information about consists, bulletins, and authorities created by the dispatcher.
- TMDS-SQL – TMDS-BOS uses TMDS-SQL to get detailed information on PTC locomotives, bulletins, PTC-authorized employee information, PTC consist data, and other information needed to create or process PTC messages to and from locomotives.
- PTC Back Office Messaging Server – TMDS-BOS interfaces with the PTC BO messaging server to route PTC messages in and out of the back office to and from locomotives.

2.1.3 TMDS-Office Communication Manager (TMDS-OCM)

TMDS-OCM functions as a router of messages between the TMDS® components and the field CP components. Connections are made from the CPs to TMDS-OCM and from the dispatching system to TMDS-OCM allowing TMDS-OCM to route messages to and from these connections to other TMDS components. The connection between TMDS-OCM and the CPs on the PTC Test Bed required an external communications network adapter (CNA) because the TMDS-OCM could not talk directly to the CPs with the protocol currently used. For messages coming from the CPs, the CNA translates the protocol used by the CPs to a protocol usable by TMDS-OCM. For messages coming from TMDS-OCM, the CNA translates the protocol used by TMDS-OCM to the protocol used by the CPs. Figure 3 shows the links that are set up with TMDS-OCM and the state of these links.



Id	Name	Type	State	Time	Rx Msg	Rx Bytes	Tx Msg	Tx Bytes	Queued Msg	Queued Bytes
1	CNAs	atcs	up	04.15:30	29.205K	987.089K	1.668K	38.404K	0	0
2	CAD	atcs_tcp	up	04.15:30	1.675K	45.241K	3.519K	106.055K	0	0
3	MDM	atcs_tcp	up	04.15:30	0	0	0	0	0	0

Figure 3. Links Setup with TMDS-OCM

TMDS-OCM includes a presence view that indicates which connections are made under what link. Figure 4 shows the presence of the four CPs on the PTC Test Bed, under the link CNAs, and one dispatching system, under the link CAD.

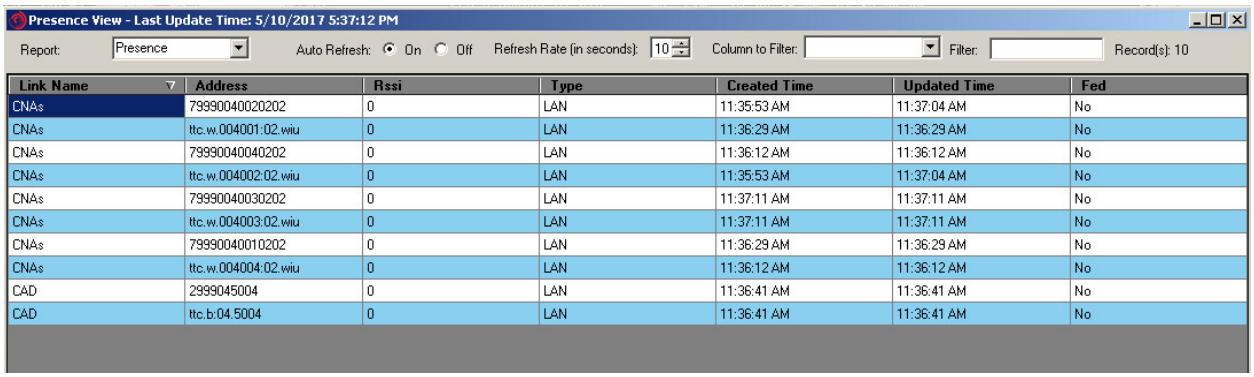


Figure 4. Presence View from TMDS-OCM

2.1.4 TMDS-Mobile Device Manager (TMDS-MDM)

The TMDS-MDM is used to push file sets to PTC-equipped locomotives for use by the onboard PTC system. These file sets could contain onboard configuration files, PTC track databases, and/or updated software releases. File sets are used by the onboard system to update onboard components as requested by the TMDS-MDM. The TMDS-MDM connects to the PTC locomotives through the PTC back office messaging server.

2.1.5 TMDS-SQL 1 and 2

The TMDS-SQL machines house a database that contains information for the PTC BOS, which can be written to and/or queried by individual segments within the BOS. PTC information stored in TMDS-SQL includes:

- Employee authentication data
- Locomotive data
- Subdivision data includes information on CPs, signals, switches, tracks, and crossings
- Consist information
- TMDS® computer information
- Bulletin information

TMDS-SQL2 is a copy of TMDS-SQL1 and is only used if TMDS-SQL1 becomes unavailable.

2.2 CAD System

The same physical workstation used for the original CAD installation was used for this upgrade. TTCI contracted Wabtec to provide technical support during the update of the CAD software to the latest release and to modify the CAD display to represent the current PTC Test Bed layout. This update provides the dispatcher with the ability to send switch and signal requests to the four CPs on the PTC Test Bed and the display provides indications for everything monitored at these four CP locations. Figure 5 shows the display from the CAD system. The display in Figure 4 is populated based on the indications from the CPs, which are sent to TMDS® and then to the CAD system. The white track indicates that switches are lined for movement on that track, and the

dispatcher can send signal requests on those tracks. The grey track indicates switches are not lined for movement on those tracks or they are tracks located in non-signaled territory. The red track indicates that there is a track occupancy in that block.

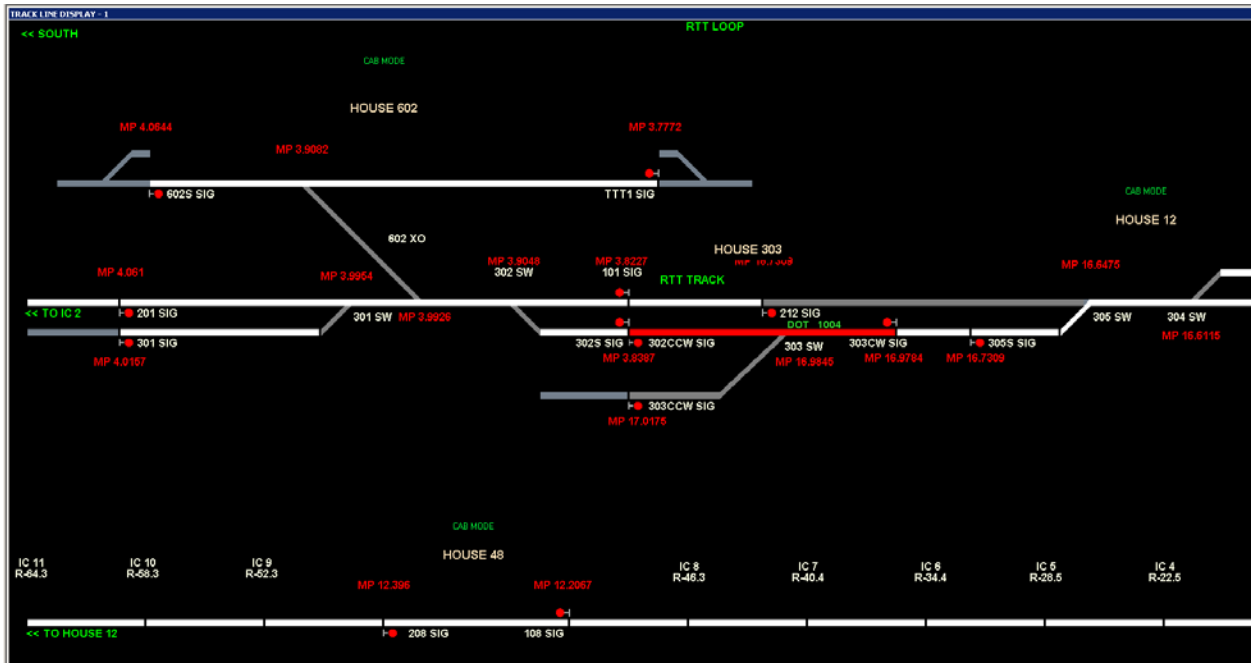


Figure 5. Dispatching Screen from TTCI's CAD

The dispatcher can request switch movement or signal authority through the dispatching screen by using the mouse and left clicking on the location where the request is being made. The left click will highlight the result of the request and a right click will confirm the request. Figure 6 shows an example of the display with a left click on a signal. In this example, the request colors the track that will be cleared yellow. Figure 7 shows the display once the request is confirmed. Once the request is confirmed and indication that the signal has cleared is received from the CP, the display shows the track as green.

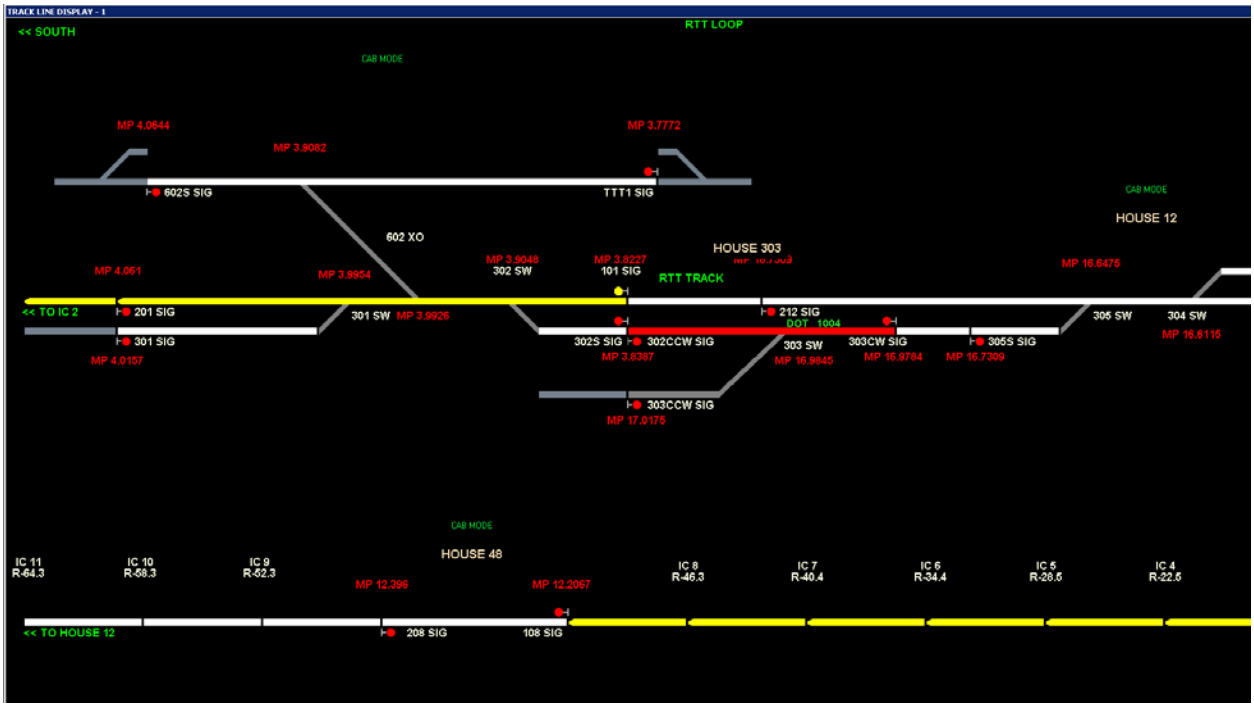


Figure 6. Example of Dispatcher Preview of Signal Request

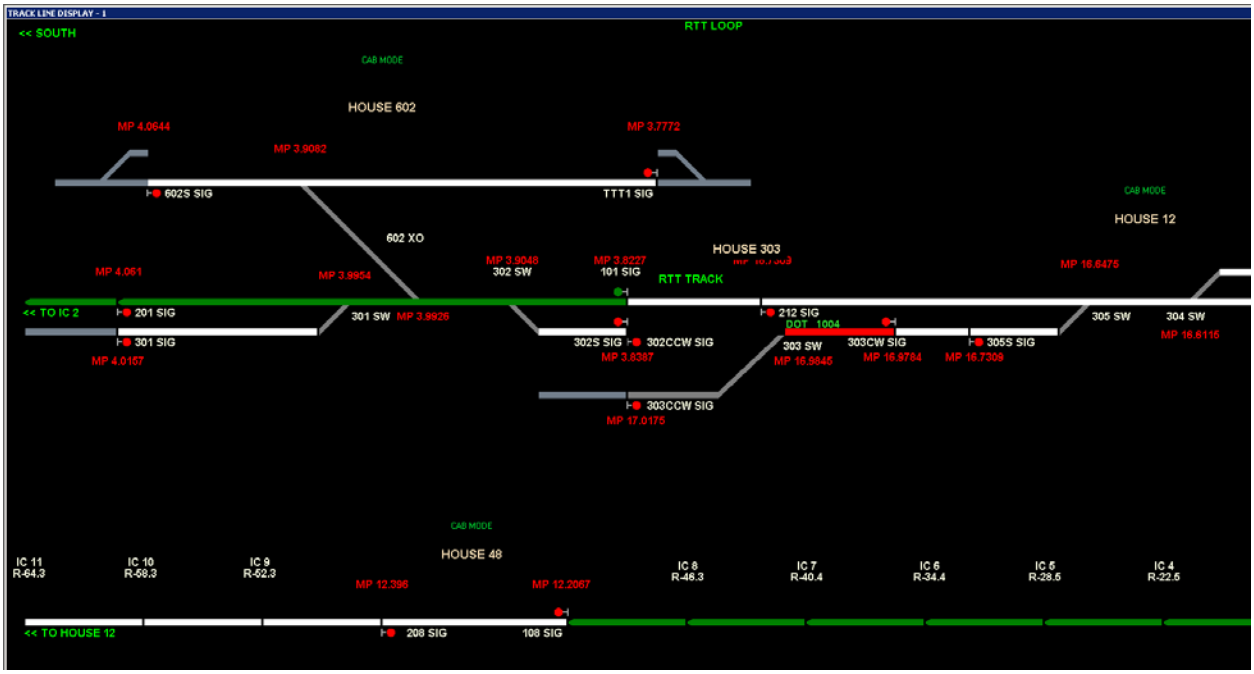


Figure 7. Example of Dispatcher Confirming Request and CP Indicates Signal has Cleared

The dispatcher from the CAD system can also setup and issue track bulletins by filling out the electronic form for the specific bulletin to be issued. The CAD system has the ability to issue the following track bulletins:

- Form A – Speed Restriction
- Form B – Work Zone
- Form C – Free Form
- Form O – Out of Service
- Form X – Crossing Protection
- TCM – Track Condition Message

Figure 8 shows an example of a work zone bulletin that can be created by the dispatcher.

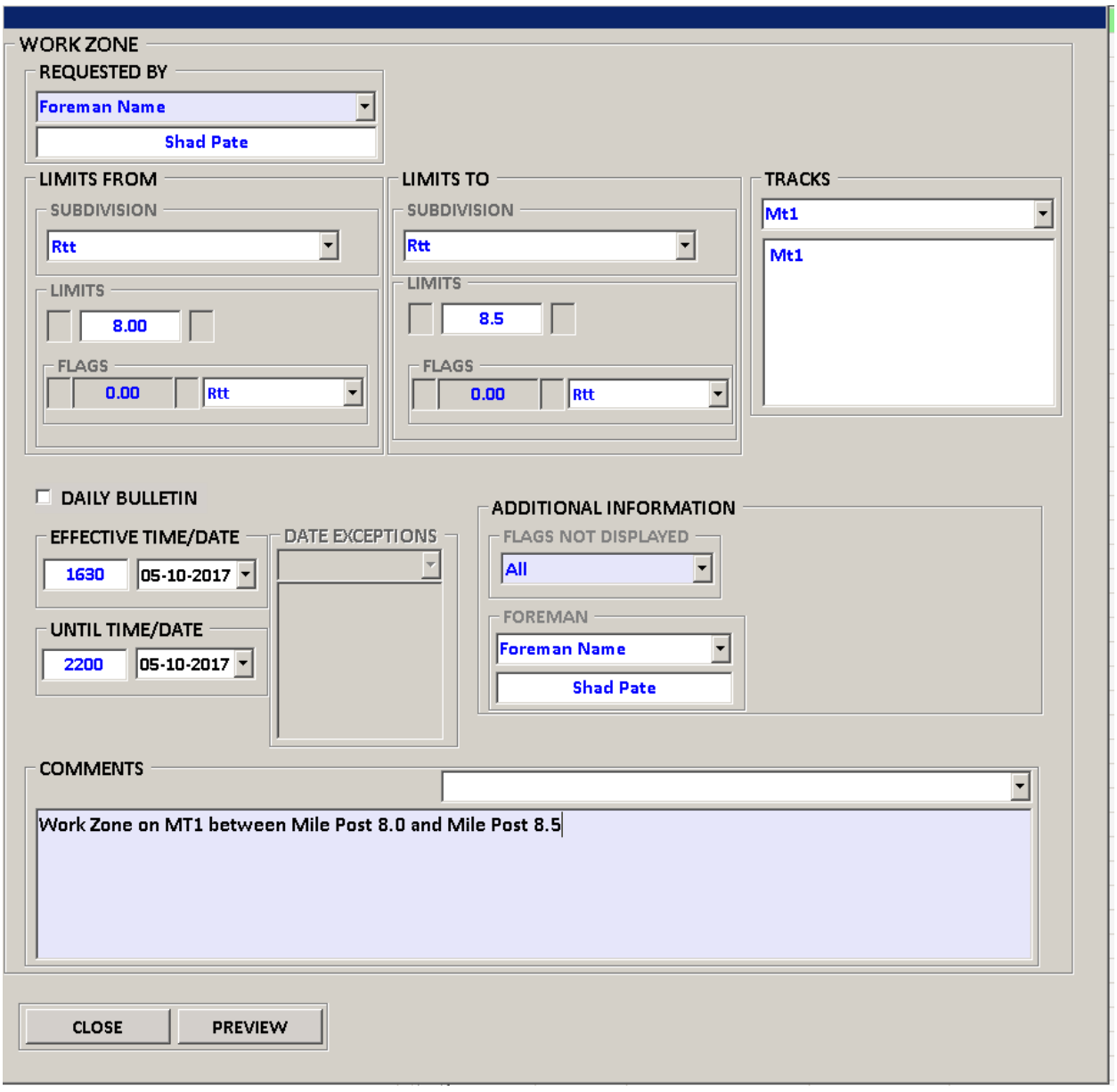


Figure 8. Example Work Zone Bulletin

Once the dispatcher creates a work zone, they are required by rule to repeat it back to the employee in charge, selecting each line as it is read and then reselecting each line as the employee in charge recites it back. The dispatcher can then confirm and activate the bulletin.

For active trains in the area, the dispatcher will repeat the process of reading the bulletin to the engineer and have the engineer repeat it back before the bulletin can be activated for that train. If the train is running PTC, a prompt will also show on the onboard display to indicate that a new bulletin was received. Figure 9 shows an example of the display the dispatcher uses to read bulletins to employees. As the dispatcher clicks on each line that is read, the line turns blue. Figure 10 shows the display the dispatcher uses when employees repeat the bulletins back to the dispatcher. As the dispatcher clicks on each line that has been read, the line turns green.

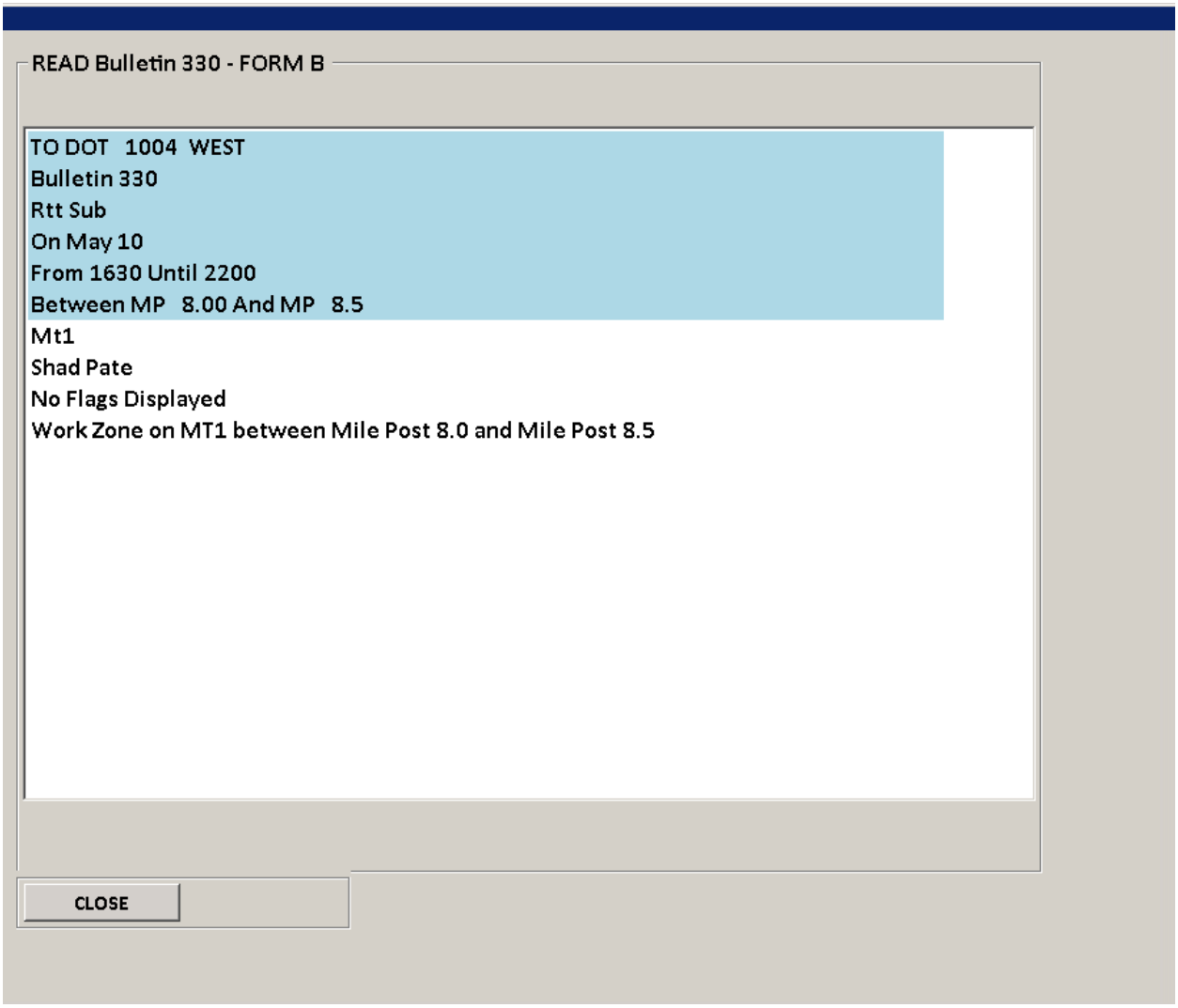


Figure 9. Dispatchers Screen to Read Bulletins to Employees

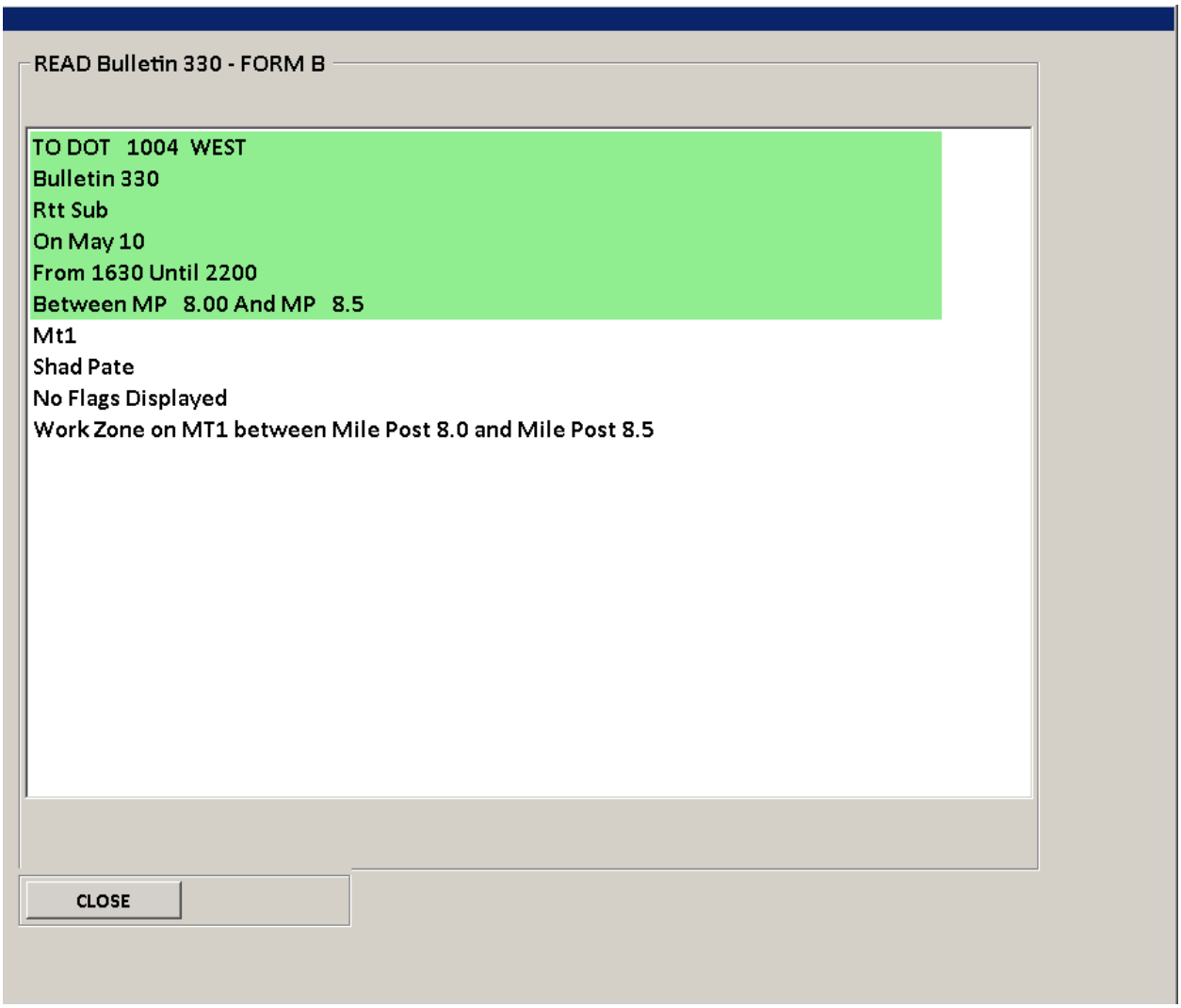


Figure 10. Dispatchers Screen When Bulletins are Read Back to Them

Bulletins will show on the dispatcher's screen as hashed track in the blocks over which the bulletins are active. The dispatcher can move the mouse to those blocks to get information about the bulletin and can also pull up a bulletin summary page to view the bulletins.

2.3 PTC WIU and PTC Track Database Updates

This section will show that the PTC WIU upgrades were created to setup communication links, while the PTC track database updates were performed to reflect the current status of the PTC Test Bed.

2.3.1 PTC WIU Updates

The current signaling logic at each wayside location was used to create PTC mapping and PTC configuration files. These files were created using software from the signaling manufacturer and are loaded onto the WIUs. The PTC configuration file is used to setup communication links to the WIU, security key and CRC information, wayside status message (WSM) beacon status, PTC

WIU address, and PTC time data. The PTC mapping file is used with the PTC configuration file on the WIU to create PTC WSMs that are broadcast from the wayside locations.

2.3.2 PTC Track Database Updates

TTCI contracted Xorail to provide support in updating the PTC track database to reflect the current status of the PTC Test Bed. Updates to the PTC track database included:

- Removing signal locations where signals were physically removed
- Adding signal locations for new signals that were added
  - Includes signal name, Global Positioning System data for signal location, subdivision data, track name signal is associated with, signal type, and PTC WIU info that reports signal status
- Updating WIU information based on WIU updates
  - Includes the PTC WIU address, security key and CRC data, and WIU beacon status
- Updating communication links to include PTC messaging routes for TMDS-BOS and TMDS-MDM
- Updating track centerline data, track rules, and PTC limits to reflect the current PTC Test Bed physical layout
- Adding the railroad grade crossing at Post 100, located just north of the RTT siding

TTCI worked with Wabtec and Xorail to load the PTC track database onto the onboard PTC system and onto the PTC BOS, as well as ran through system checks to verify that the database was working properly in both locations.

2.4 PTC Messaging System

Updates were completed for the PTC messaging system at waysides, locomotives, and the back office. Updates were performed to reflect changes that were made at each of these locations to ensure the messaging routes for PTC were available and working properly. For the back office and locomotive segments, an additional PTC messaging route was created to support messages from the TMDS-MDM.

2.5 System Checkout

As part of this project, TTCI was able to complete a high-level checkout of the updates to the PTC Test Bed completed during this project. The following checkout tasks were completed:

- CP indication and control of switches and signals through the TMDS® and CAD system
- PTC locomotive and PTC-authorized employee creation in TMDS® through the BOS
  - Included the creation of locomotive security keys and employee PIN and ID numbers
- The loading of PTC track database on PTC equipped locomotives, on the PTC BOS, and on the CAD system.

- Transitioning from PTC CUT OUT state on the locomotive to PTC ACTIVE state.
  - Included creating the consist from the dispatching system
  - Assigned PTC employees to the consist
  - PTC employees logged into the PTC system using employee PIN, ID, and general track bulletin numbers
  - Verified PTC messages between locomotive and BOS over the 220 MHz radio
  - Engineer received and accepted the consist message
  - Conducted and passed the departure test
- Creation of bulletins from the dispatching system included:
  - Work zone, speed restriction, grade crossing protection, and track out of service bulletins
  - Verified bulletins were transmitted to onboard PTC system with a prompt for the engineer to review and accept
  - Verified bulletins appeared on the onboard display once they were accepted by the engineer and verified the proper PTC response during train operations over sections of track with active bulletins
    - Conducted tests on tracks with an active bulletin when the operation did not violate the bulletin (for example, for a speed restriction, the engineer approached the restriction at a speed below that required by the restriction) and verified that the onboard system operated as expected
    - Conducted tests on tracks with an active bulletin when the operation violated the bulletin, and observed that the onboard system provided warnings and prompts associated with the bulletin, followed by initiating a penalty brake enforcement, bringing the locomotive to a stop.
- Transmission of peer-to-peer messages from a wayside location and receiving the messages on the locomotive, as well as confirming the PTC onboard display, which showed the correct wayside aspects
  - Included tests approaching clear signals and tests approaching signals at stop
    - For clear signals, the engineer was allowed to proceed at track speed without any interruptions from the PTC system.
    - For stop signals, the engineer received a warning upon approaching the signal, and a penalty brake enforcement was initiated when the system predicted the train would overrun the signal location.

3. Conclusion

TTCI was successful in updating the PTC BOS and CAD components of the PTC Test Bed to reflect the current track layout and configuration of the PTC Test Bed. These update efforts to the TMDS® included the CAD, the PTC track database, the PTC messaging system, and the PTC WIUs. With support from Wabtec and Xorail, TTCI was able to complete high-level system check of the PTC Test Bed to demonstrate that the updates implemented under this project resulted in a fully functional PTC system capable of supporting a broad range of PTC-related test programs.

Abbreviations and Acronyms

BOS	Back Office System
CAD	Computer-Aided Dispatch
CNA	Communication Network Adapter
CP	Control Point
FRA	Federal Railroad Administration
I-ETMS®	Interoperable Electronic Train Management System
ITC	Interoperable Train Control
ITCM	Interoperable Train Control Messaging
MDM	Mobil Device Manager
OCM	Office Communication Manager
PTC	Positive Train Control
RTT	Railroad Test Track
TCM	Track Condition Message
TMDS®	Train Management Dispatching System
TTC	Transportation Technology Center (the site)
TTCI	Transportation Technology Center, Inc. (the company)
WIU	Wayside Interface Unit
WSM	Wayside Status Message