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From May 1, 2016, through August 31, 2016, the Transportation Technology Center (TTC) assessed Class I Positive Train Control (PTC) test facilities, and held discussions with commuter and short line railroad representatives to recommend a project approach to implement an industry test laboratory for Interoperable Train Control (ITC) at TTC.

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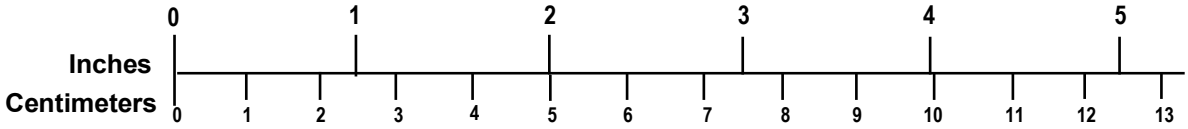

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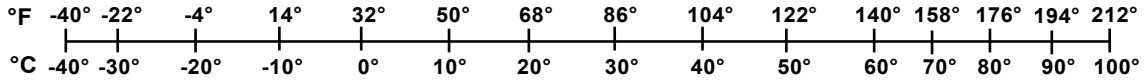

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Executive Summary

The Federal Railroad Administration (FRA) provided funding to Transportation Technology Center, Inc. (TTCI) to visit and assess multiple railroad developed Positive Train Control (PTC) test facilities. TTCI reviewed these railroad test methodologies to develop recommendations for a PTC industry test laboratory located at the Transportation Technology Center (TTC) in Pueblo, CO. The research was conducted from May 1, 2016, through August 31, 2016.

TTCI organized the assessment into three categories: test methodology, test case management, and laboratory architecture. In addition to reviewing existing railroad test facilities, discussions were held with various representatives of the railroad industry to determine the industry's PTC test needs and whether it could potentially benefit from an industry PTC test laboratory at TTC.

TTCI used the railroad test facility assessment and additional discussions to recommend a project approach to meet short line and commuter railroad PTC deployment testing and ongoing industry PTC testing objectives.

Short line and commuter railroad objectives include:

- Develop a common test outline for initial PTC deployment testing.
- Develop test cases derived from operating practices and rules to test PTC behavior.
- Assess and develop test capabilities/facilities to support short line and commuter PTC testing.

Ongoing industry PTC testing objectives include:

- Determine the scope and scale of test facilities at TTC.
- Develop a TTC test laboratory implementation plan based on the defined test laboratory scope and scale.
- Execute TTC test laboratory implementation plan.

From these overall objectives, it is recommended that TTCI continue working with Class I, short line, and commuter railroads, and coordinate with FRA's Office of Research, Development and Technology and Office of Railroad Safety to accomplish the objectives in future phases of this program detailed in the recommended project approach section of this report. A coordinated approach that considers the needs and expectations of both the railroad industry and FRA could help to ensure that the developed outline and test facilities are used as industry tools to support PTC testing now and in the future as this technology evolves.

1. Introduction

This document describes the PTC test facility project's Phase I findings and Transportation Technology Center, Inc.'s (TTCI) recommended approach for future phases, including the next phase of research, which started on May 18, 2017. This information was developed by reviewing railroads' current Positive Train Control (PTC) test methodologies, test facilities, and needs, and expectations for an industry PTC test facility.

1.1 Background

To assist the North American railroad industry with both initial implementation and the ongoing development of PTC, the Federal Railroad Administration (FRA) and TTCI have been dedicating efforts towards building a PTC Test Bed at the Transportation Technology Center (TTC) in Pueblo, Colorado. Initially, the PTC Test Bed was developed for field testing PTC-related systems, equipment, and technologies at a site that was free of the challenges associated with revenue service test activities. The current Test Bed at TTC includes operational production of Interoperable Train Control (ITC)/Interoperable Electronic Train Management System (I-ETMS®[1]) and Advanced Civil Speed Enforcement System (ACSES) PTC systems, including locomotive, wayside, and back office segments. More recently, the industry discussed using the PTC Test Bed, with additional capabilities, to support ongoing regression testing of changes to components and software releases of PTC systems as they evolve throughout their lifecycles.

To understand the potential benefits and necessary capabilities of an industry PTC test facility, TTCI conducted an initial assessment of the railroads' current PTC test methodologies. Although a more detailed assessment is necessary to develop the requirements and architecture for the PTC Test Facility, it is recognized that more efficient and effective PTC testing is possible with laboratory testing in conjunction with field testing. A laboratory with simulators and PTC hardware in-the-loop, combined with existing on-track test capabilities of the PTC Test Bed at TTC can provide the desired test facilities for railroads to perform regression testing with new components and software releases, as well as incremental system enhancements. This could help to ensure that railroads are operating compatible and fully tested PTC releases, which is essential for PTC's safe and efficient ongoing operations.

1.2 Objectives

The PTC Test Facility Assessment and Laboratory Development project was divided into multiple phases. The following are the objectives of Phase I:

1. Conduct an initial assessment of railroad PTC test cases.
2. Perform a high-level analysis to determine recommendations for developing and executing a plan to implement an industry standard PTC test laboratory.
3. Gather information for the PTC test laboratory that will be needed to develop cost and schedule estimates for Phase II.

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

1.3 Overall Approach

TTCI began the PTC Test Facility Assessment by reviewing existing railroad PTC test facilities and engaging representatives from Class I, short line and commuter railroads to identify:

- The objectives and scope of current individual railroad PTC laboratory testing activities
- The architecture and elements currently used by Class I railroads in their individual test laboratories
- The needs and expectations for an industry test facility from the perspectives of Class I, short line, and commuter railroads

This information was used to develop recommendations that would be used to create an implementation plan for an industry test laboratory.

1.4 Scope

Phase I of this project was organized into four tasks:

- Task 1 provided the project management and application of resources necessary to complete the objectives of the project on time and within budget.
- Task 2 included the railroad PTC Test Facility Assessment used to understand existing PTC test methodologies and laboratory deployments.
- Task 3 performed a review of existing and required industry ITC test capabilities.
- Task 4 provided a summary report describing the research and findings that included recommendations on a way forward.

1.5 Organization of the Report

The report is organized into three sections: Phase I findings, recommended ITC test facility strategy, and TTCI's recommended project approach.

2. Phase I Findings

This section describes the information gathered while assessing railroad PTC test cases in order to recommend an implementation plan for an ITC PTC test laboratory at TTC. A review of two Class I railroad test facilities was conducted in conjunction with conversations including commuter and short line representatives to determine PTC testing needs. The findings were categorized into three segments:

- Test Methodology
- Test Case Management
- Laboratory Architecture

2.1 Test Methodology

The test methodology section provides an overview of the PTC test approach and test case implementation methods utilized by the railroads.

2.1.1 Test Approach Overview

In 2012, the Association of American Railroads (AAR) adopted the PTC Interoperable I-ETMS® Master Test Strategy (MTS) defined in the Recommended Practice RP-9457.V1.0 [1]. The MTS provides a recommended test approach for the I-ETMS® system that incorporates laboratory and field testing for the deployment of a PTC system. Tests are defined to be conducted at different system levels and range from verifying lower level system requirements to overall system testing for revenue service operations approval from the FRA. Table 1 shows a portion of the MTS test levels. The table provides a description and an indication if the collection of test artifacts (i.e., data to support test results) for FRA submittal is required for each test level.

Table 1. Master Test Strategy Test Levels

Test Level	Description	Environment	Test Artifacts
Unit Test	Ensures code meets design of components	Laboratory	Optional
Segment Test	Tests the system segment by including input and outputs from each segment (onboard, wayside, back office, and communications) through simulators	Laboratory	Optional
Nearest Neighbor Testing	Tests two or more system segments to verify messages properly communicate	Laboratory	Optional
End-to-End Testing	Tests the entire system to verify functionality as a whole	Laboratory	Optional
Field Integration Testing	Full system testing that could not be completed in the laboratory	Field	Optional
Field Qualification Testing	Field testing with the goal of obtaining PTC system approval from the FRA	Field	Required
Interoperable Field Qualification Testing	Field testing with the goal of obtaining PTC system approval across railroads from the FRA	Field	Required

One objective of the MTS is to provide railroads with an outline and approach that could be used to satisfy the PTC Safety Plan (PTCSP) requirements defined in Title 49 Code of Federal Regulations Section 236.1015 [2]. Within the PTCSP, a railroad can define the amount of testing to be completed within each test level of the MTS based upon their railroad-specific implementation needs. Before a railroad can receive a PTC System Certification for revenue service operations, the PTCSP must be submitted and approved by the FRA. The PTCSP must include a description of all initial implementation testing procedures, as well as all post-implementation testing and monitoring procedures.

2.1.2 Test Case Implementation Method

Although the railroads have a similar test approach as described in the MTS, test cases were independently developed by each railroad. The railroads created the test cases to best fit their needs to demonstrate PTC functionality on their territory and locomotives. The primary difference found was the degree to which the test cases reveal the lower level (L2) system requirements in each method. The L2 requirements specify the lower-level functionality of the individual PTC segments (e.g., the locomotive onboard component). The two methods are described as explicit and implicit test cases:

- Explicit test cases directly reveal an L2 system requirement through the test procedure and its expected result.
- Implicit test cases can contain multiple L2 system requirements and do not directly reveal L2 requirements through test procedures and expected results.

In either case, explicit and implicit test cases both trace back to L2 requirements within the test case management program. This is vital to properly conduct regression testing caused by software and/or hardware changes to the system. Additionally, both methods provide sufficient coverage to test the functionality of the PTC system. However, industry agreement on the test case implementation method is necessary to develop a 'common' set of test cases.

2.2 Test Case Management

A key component of PTC deployment and regression testing is a test case management tool. The primary purpose of this tool is to organize and maintain the large number of test cases and their traceability to system requirements. Railroads currently use commercially available software as their test case management tool. During regression testing, the test case management tool allows a railroad to select or modify test cases to re-verify system functionality on their railroad after they receive the component release notes describing the software and/or hardware changes to system requirements.

The test case management tool contains a database that allows a test team to efficiently navigate through test plans, test cases, test artifacts, and defect tickets. Table 2 provides a description for each of the categories.

Table 2. Test Case Management Information

Database Category	Description
Test Plans	Documents objectives and test work flow
Test Cases	Includes test name, description, system requirement, required equipment, preconditions, comments, expected results, and test procedures
Test Artifacts	Contains test data that could include signed test books, screen shots, Wireshark data, and system debugger information
Defect Tickets	Maintains and tracks system defects found while testing

2.3 Laboratory Architecture

The components and simulators required for laboratory testing are dependent upon the test level being performed. For the purpose of this report, laboratory designs will be referenced to the AAR Recommended Practice RP-9457.V1.0 MTS [1]. Figure 1 and Figure 2 illustrate the laboratory architecture used for segment testing and end-to-end testing, respectively.

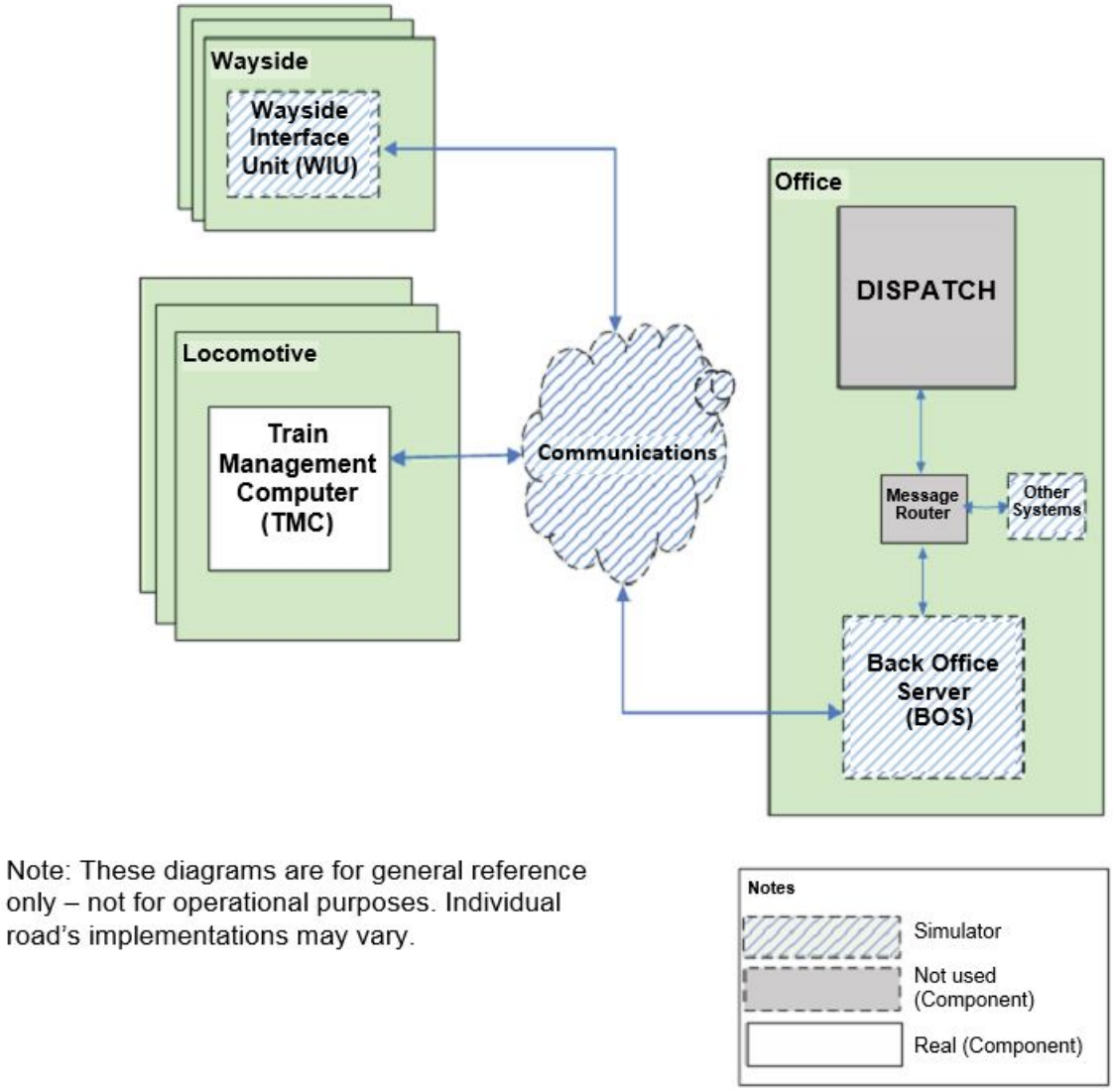

Figure 1. Onboard Segment Test Laboratory

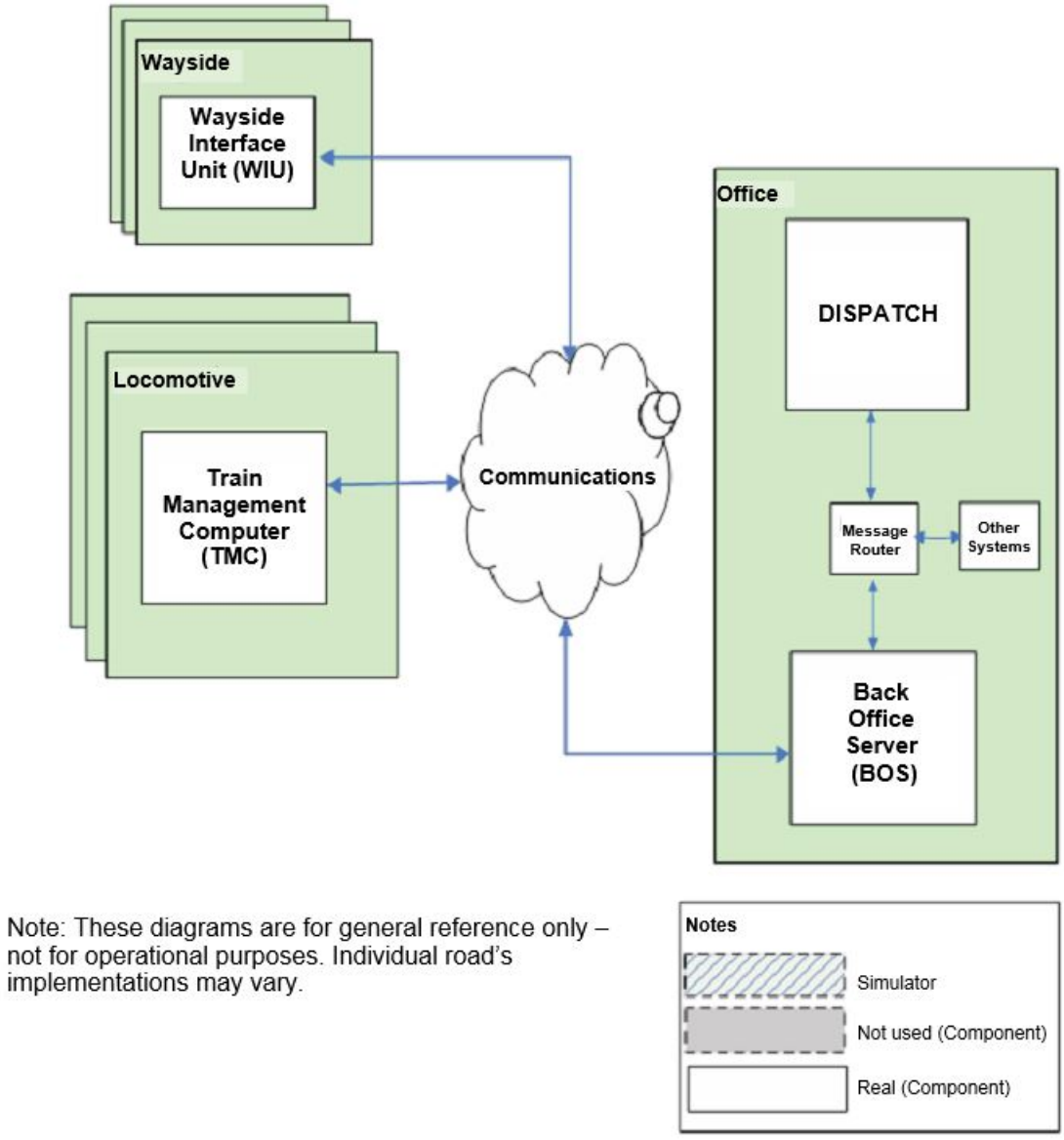

Figure 2. End-to-End Test Laboratory

The onboard segment test laboratory, shown in Figure 1, illustrates an architecture centralized around the Train Management Computer (TMC) with simulated inputs from the wayside, communications, and back office segments.

The end-to-end test laboratory, shown in Figure 2, illustrates an architecture designed to test all PTC components to verify the system functions as a whole before field testing. In this instance, the laboratory must be built with PTC components used by the testing railroad in order to verify the system functions in their territory.

Additional components needed to support laboratory testing are described in Table 3.

Table 3. Test Laboratory Components

Component	Description
PTC Hardware/Software	PTC components necessary to support level-of-testing, e.g., TMC, Back Office Server (BOS)
Train Motion Simulator	Provides tachometer and Global Positioning System information to simulate train movement on track
Onboard Interface Simulator	Provides discrete input/output to the TMC
Wayside Simulator	Provides Wayside Status Messages to the TMC
Back Office Simulator	Simulates BOS messages including movement authorities, initialization, and bulletins
Data Acquisition Tools	Wireshark and debugger software to record test data
PTC Communication Network	Interoperable Train Control Messaging compatible network to route all PTC message between components and simulators
Test Team Network	Network for operators to conduct test cases and gather test artifacts
Test Automation Tools	Programs to conduct test cases and gather test artifacts without operator interaction

3. Recommended ITC Test Facility Strategy

This section describes TTCI's recommended strategy based upon the findings and discussions held with railroads in Phase I. The strategy focuses on two primary areas: (1) PTC deployment testing support for short line and commuter railroads and (2) ongoing industry PTC test support. The strategy described in the following subsections is to be executed in future project phases.

3.1 Short Line and Commuter Railroad PTC Testing Support Approach

The project's first focus is to assist short line and commuter railroad PTC testing before the mandated deployment deadline in 2018. TTCI has developed the following recommended objectives and approach:

1. Work with railroads to develop a common test outline for commuter and short line railroad PTC testing.
    a. Focus on initial PTC deployment testing.
    b. Coordinate with FRA Office of Safety.
2. Define test cases derived from railroad operating practices and rules to test required PTC behavior in consideration of both host and tenant railroads.
    a. Host railroad testing to include:
        i. Office-related PTC testing
        ii. Track database attribute testing
        iii. Field end-to-end PTC testing
    b. Tenant railroad testing to include:
        i. Locomotive class testing
        ii. Coordination with host railroads
3. Implement test case management software to maintain test cases in support of short line and commuter PTC testing.
4. Assess and develop test capabilities and facilities to support identified short line and commuter PTC testing.

The information, services, and facilities to be developed within this project are to be used as tools by commuter and short line railroads (e.g., as a hosted service). The intent is that TTCI will perform tests per the agreed upon test procedures and will provide reports on the results and artifacts for each individual test case, but will not provide PTC system certification with the capabilities developed under this project as each railroad is responsible for their own PTC system certification.

3.2 Ongoing Industry PTC Test Support Approach

The second project focus is to support ongoing industry PTC testing following PTC implementation (e.g., for the maintenance phase). TTCI has developed the following recommended objectives and approach:

1. Use railroad input to determine the scope and scale of TTC test laboratory facilities.
    a. Define how the scope of testing will be supported for different test levels (e.g., segment, Laboratory Integration Nearest-Neighbor, Laboratory Integration End-to-End). When the scope of testing is defined, it will consider:
        i. Common ITC PTC testing
        ii. Railroad-specific ITC PTC testing
        iii. Other testing that can be executed at TTC test laboratory
    b. Determine resources required to fulfill the defined scope of test laboratory testing. Resources include:
        i. Test personnel
        ii. Equipment/architecture
        iii. Infrastructure to support railroad PTC test teams (e.g., remote access)
    c. Identify testing that can be performed at industry test facility.
2. Develop TTC test laboratory implementation plan on the basis of defined test laboratory scope and scale.
3. Execute TTC test laboratory implementation plan, including:
    a. Install test facility components.
    b. Develop simulators.
    c. Implement test management tools.
    d. Implement instrumentation, data acquisition, and analysis tools.
    e. Develop and implement test automation tools.

The recommended objectives and approach assume the following:

- Railroad industry agrees on common scope and scale for the TTC test facility.
- TTCI establishes access to vendor-specific requirements for supporting the test scope.
- TTCI obtains railroads' test cases pertaining to identified test scope.
- TTCI obtains railroads' test tools (i.e., software) to the extent possible and relevant to the scope of testing.

If any of the above assumptions are proven to be invalid, the recommended project approach will have to be redefined.

4. TTCI's Recommended Project Approach

This section describes the proposed phases for executing the project's strategy defined in Section 3.

4.1 Project Phase II

Phase II began May 18, 2017, and includes the following tasks:

1. Support short line and commuter PTC testing.
    a. Work with railroads to develop a test outline for short line and commuter PTC testing.
    b. Develop test cases derived from railroad operating practices and rules to test PTC behavior in consideration of host and tenant railroads.
    c. Implement a test case management system. Software potentially exists within the railroads, as noted in Section 2.2.
    d. Determine test capabilities and facilities needed to support short line and commuter PTC testing.
2. Support ongoing industry PTC testing.
    a. Work with railroads to define the scope and scale of test laboratory facilities to support ongoing PTC test needs.
3. Develop test laboratory implementation plan for TTC based on the defined test laboratory scope and scale.

4.2 Future Phases

A breakdown of future phases will be defined in the test laboratory implementation plan, which will be developed in Phase II. This phase's research began on May 18, 2017. The future phases will include execution of the TTC test laboratory implementation plan developed in Phase II:

1. Implement test capabilities and/or facilities identified in Phase II to support short line and commuter PTC testing needs.
2. Expand test laboratory facilities' scope and scale identified in Phase II to support ongoing industry PTC test needs.

5. References

1. Association of American Railroads. (2014, August). *Manual of Standards and Recommended Practices.* Section K-V. Electronics Environmental Requirements and System Management. RP-9457.V1.0. "Positive Train Control Interoperable Electronic Train Management System (I-ETMS®) Master Test Strategy (MTS)."
2. Code of Federal Regulations—Title 49: Transportation. § 236.1015. "PTC Safety Plan content requirements and PTC System Certification." Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=6ea0ade3271cf9dea9e69cce9228080b&mc=true&node=pt49.4.236&rgn=div5#se49.4.236_11015.

Abbreviations and Acronyms

AAR	Association of American Railroads
BOS	Back Office Server
CFR	Code of Federal Regulation
FRA	Federal Railroad Administration
I-ETMS®	Interoperable Electronic Train Control Management System
ITC	Interoperable Train Control
MTS	Master Test Strategy
PTC	Positive Train Control
PTCSP	Positive Train Control Safety Plan
RP	Recommended Practice
TMC	Train Management Computer
TTC	Transportation Technology Center
TTCI	Transportation Technology Center, Inc.