



U.S. Department of Transportation
Federal Railroad Administration

PTC Testing

Field Testing, Revenue Service Demonstration, and
Interoperability Testing

Federal Railroad Administration – Positive Train Control (PTC) Symposium #2

July 16, 2018

Outline

1. Test Objectives and Phases
2. Test Plans, Requests, Procedures, and Test Cases
3. Test Types and Test Sequence (Laboratory Through RSD)
4. Questions and Discussion



Section 1: Test Objectives and Phases

Brief Overview of the PTC System Certification Process

Phase 1 – Implementation Planning

- Identify the main lines on which a PTC system shall be implemented, establish implementation schedule, and request FRA's approval of any applicable exceptions
- **Submittals:** *PTC Implementation Plan (PTCIP) and any Requests for Amendment*

Phase 2 – System Development

- Describe the specific technology and how it will comply with regulations
- **Submittals:** *PTC Development Plan (PTCDP), Notice of Product Intent (NPI), and/or Type Approval Identification & Variance*

Phase 3 – System Deployment & Testing

- Finalize designs, install PTC system, & conduct testing
- **Submittals:** *Field Test Request, Test Plans, and RSD Request*

Phase 4 – Certification & Full Deployment

- System functionality is verified and deployment continues until the PTC system is fully implemented
- **Submittals:** *PTC Safety Plan (PTCSP)*

TODAY

Testing Objectives

Ensure the Safety of Personnel, Equipment, and the Public

- Pre-certification
- Post-certification

Validate and Verify the PTC System Implementation Meets Functional Requirements

- Reliably and Functionally
 - Prevent Train-to-train Collisions
 - Prevent Overspeed Derailments
 - Prevent Movements Through Misaligned Switches
 - Prevent Incursions into Work Zones

Ensure the As Built/As Deployed System Safety Is Not Compromised

Utilize Industry Best Practices and Standards

Obtain Data to Support PTC System Certification (for Host Railroads)

Test Phases

Laboratory Testing

- Unit (Supplier)
- Segment
- Integration
- Track Database Validation

Field Testing

- Wayside Interface Unit (WIU) Validation
- Critical Feature Validation
- Locomotive Post-installation
- Locomotive Class/Interface Testing
- Brake Testing
- “Field Integration Testing (FIT)”
- “Field Qualification Testing (FQT)”
- Interoperability

FIT & FQT
are railroad acronyms
with varying definitions.

Revenue Service Demonstration (RSD)

Advanced stage of field testing of an uncertified PTC system, when FRA permits a railroad to operate PTC-equipped trains in revenue service under specific test conditions.



Initial & Regression
Office
Wayside
Locomotive
Communications



Section 2:

Test Plans, Requests, Procedures, and Test Cases

Overview of When FRA Approval Is Required

Rule – Before a railroad may field test (including RSD) an **uncertified PTC system** on the general rail system, the railroad must submit a formal request to FRA and obtain FRA’s written approval. 49 CFR § 236.1035; *see also* 49 U.S.C. § 20157(h).

If the host railroad has not obtained at least conditional PTC System Certification, FRA approval* is required before a railroad may do *any* field testing or RSD of the PTC system.

*Reminder: All FRA approvals referred to in this presentation are written FRA approvals.

Limited Circumstances When FRA Approval Is Required *After* Host Railroad Has Obtained PTC System Certification

- A host railroad that has obtained at least conditional PTC System Certification must obtain FRA approval for a tenant railroad to conduct field testing, RSD, or interoperability testing on the host railroad’s property ONLY IF:
 - The tenant railroad will be testing a categorically different **type** of PTC system (i.e., I-ETMS, ACSES II, ASES II, or ITCS) on the host railroad’s territory than is covered by the host railroad’s PTC System Certification.

Test Requests

Required Contents of a Field Test Request Under 49 CFR § 236.1035:

- A complete description of the PTC system
- An operational concepts document
- A complete description of the specific test procedures and safety precautions (including the measures the railroad will take to protect trains and on-track equipment)
- An analysis of the applicability of the 49 CFR 236 subpart A through G requirements to the PTC system that will not apply during testing
- The date the proposed testing will begin
- The test locations
 - *Best practice:* Include the exact milepost and/or control point limits and a description of the track characteristics. Explain whether this is an entire track segment outlined in PTC Implementation Plan or a portion of a track segment.
- The effect on the current method(s) of operation the PTC system will or may have under test

Test Plans

Master Test Plan

- Describes the technical and management approach to be followed for testing a component, subsystem, or system
- Contents
 - Items to be tested
 - Tasks to be performed
 - Responsibilities
 - Schedules
 - Required resources
 - Defines test cases and procedures

Test Procedures

Test Procedures

- Detailed instructions for the setup, execution, and evaluation of results for a given set of test cases
- Contents
 - Test objectives
 - Relationships to other procedures
 - Test inputs and preconditions, outputs and post conditions, entry and exit criteria
 - Ordered description of steps
 - Required resources
 - Requirements being tested
 - Safety requirements

Test Cases

Test Cases

- Set of test inputs, execution conditions, and expected results developed for a particular objective
- Clearly written, with NO ambiguity
 - Correct sequence
 - Clearly mapped to requirements and results
 - Indicate inter-dependencies
- Contents
 - Unique Identification
 - Name
 - Purpose and Scope
 - Associated Requirements
 - Assumptions/Prerequisites
 - Specific Setup or Configuration
 - Test Steps to be Executed
 - Success Results and Expected Results
 - Specific Safety Requirements and Warnings

Section 3:

Test Types and Test Sequence

Test Types

System: Testing an integrated system to verify that it meets specified requirements.

User: Testing to evaluate a system, component, or feature with real users.

Functional: Testing software to ensure that it has all the required functionality that is specified within its functional requirements.

Performance: Testing to determine how a system performs in terms of responsiveness and stability under a particular workload.

Interoperability: Testing to check whether software can interoperate with other software component, software types or versions, or systems.

Regression: Testing that ensures that previously developed and tested software still performs the same way after it is changed or interfaced with other software.

Conformance: Testing to see if an implementation meets the requirements of a standard or specification.

Critical Anomalies

Critical Anomalies: Anomalies that may affect the safety of train operations, including, but not necessarily limited to, the following:

- **Failure to enforce brakes.** A failure of a PTC system to generate a brake application command when the train was supposed to be stopped or slowed down.
- **Overrun of authority boundaries.** A failure of a PTC system to display the correct authority at the appropriate time (the train did not receive authority sent by the dispatcher, or received the correct authority too late), or to record the discrepancies associated with authority transmission.
- **Unintended enforcement.** This is an erroneous generation of the brake application command without warning or when not required.
- **Category 1 or 2 Software Issue** (as defined on the next slide).

Note: FRA requires that a railroad report any critical anomalies immediately to the FRA test monitor or to his or her designated representative during RSD.

Software Issues

Category 1 Software Issue: Any deficiency that, if uncorrected, has no known and acceptable workaround (i.e., repair necessitates taking the system offline until repairs are completed, and the system is tested and returned to normal functionality), and may:

- 1) cause death, severe injury, or severe occupational illness;
- 2) cause major loss or damage to equipment or a system;
- 3) prevent the accomplishment of an essential capability or required interaction with other mission-critical functions; or
- 4) adversely affect an essential capability or negatively impact operational safety, suitability, or effectiveness.

Category 2 Software Issue: Any deficiency that adversely affects an essential capability or negatively impacts operational safety, suitability, or effectiveness, but where adequate performance may be achieved through significant compensation or an acceptable workaround.

Section 3a:

Test Types and Test Sequence

Laboratory Testing

Laboratory Segment Testing

Objective:

- Verify that individual Office, Onboard, Wayside, and Communications Subsystems meet requirements

Test Types: Functional, Performance, Conformance, and Regression

Minimum Entry Criteria:

- Unit and integration tests for segment are complete
- All previously detected Category 1 and 2 defects are fixed and retested successfully
- Test cases created, approved, and ready for execution

Exit Criteria:

- All pertinent Category 1, 2, and 3 defects discovered are fixed and retested successfully
- All Category 4 defects discovered are addressed
- All test cases are successfully completed with documented results

FRA Participation: None

Laboratory Integration Testing

Objective:

- Verify Integration of Office, Onboard, Wayside, and Communications Subsystems

Test Types: System, Functional, Performance, Conformance, and Regression

Minimum Entry Criteria:

- All laboratory segment testing successfully are completed and approved
- All previously detected Category 1, 2, and 3 defects are fixed and retested successfully
- Test cases created, approved, and ready for execution

Exit Criteria:

- All Category 1, 2, and select critical Category 3 defects discovered are fixed and retested successfully
- Remaining Category 3 and all Category 4 defects discovered are addressed
- All test cases are successfully completed with documented results

FRA Participation: None

Laboratory Track Database Validation

Objective:

Validate every production track database in a laboratory environment

- Verify critical features
- Verify proper navigation for all possible routes
- Verify non-locational attributes of critical features

Test Types: Functional, Conformance, and Regression

Minimum Entry Criteria: Production database approved and under configuration management

Exit Criteria: All features have been successfully validated with no errors

FRA Role: Notification of Validation to FRA (in Railroad's Field Test Request Submission)

Section 3b:

Test Types and Test Sequence

Field Testing

Field Wayside Interface Unit Validation

Objective:

- Validate ALL wayside signal and switch assets are properly identified and mapped in the track database

Test Type: Conformance

Minimum Entry Criteria:

- Production database approved and maintained under FRA-approved configuration management plan
- Territory to be validated completely installed and maintained under FRA-approved configuration management plan
- Test plan approved by FRA
- Notification to FRA of planned testing dates and locations

Exit Criteria: All WIU data have been successfully validated with no errors

FRA Participation (Applies Throughout Field Testing):

- FRA approval of test plan in advance of field testing
- FRA may witness and audit field testing

Field Critical Feature Validation

Objective:

- Validate that ALL critical features (including mileposts, crossings, switches, clearance points, signals, and speed restrictions) are properly identified and precisely located in the track database

Test Type: Conformance

Minimum Entry Criteria:

- Production database approved and maintained under FRA-approved configuration management plan
- Territory to be validated completely installed and maintained under FRA-approved configuration management plan
- Test plan approved by FRA
- Notification to FRA of planned testing dates and locations

Exit Criteria: All critical features have been successfully validated with no errors

FRA Participation (Applies Throughout Field Testing):

- FRA approval of test plan in advance of field testing
- FRA may witness and audit field testing

Field Locomotive Post-Installation Testing

Objective:

- Verify individual locomotive would be ready for safety-critical service

Test Types: Conformance, Functional, and Regression

Minimum Entry Criteria: All onboard equipment installed in accordance with railroad and vendor requirements

Exit Criteria:

- Test results reported and exceptions noted
- Once successfully validated, locomotive maintained under configuration management plan and monitored for serviceability
- Locomotive removed from testing and flagged for repair when system faults detected

FRA Participation: FRA may witness and audit field testing

Field Locomotive Class/Interface testing

Objective:

- Verify PTC functions related to interfaces to the locomotive control and braking systems for each railroad locomotive class

Test Types: Conformance and Functional

Minimum Entry Criteria:

- Equipment Installation Checkout Complete
- All Category 1 and 2 defects from previous tests resolved or deferral approved
- Test plan approved by FRA
- Notification to FRA of planned testing dates and locations
- All tenant railroads notified of planned testing dates, locations, and any requirements

Exit Criteria: All functions have been successfully validated with no errors

FRA Participation (Applies Throughout Field Testing):

- FRA approval of test plan in advance of field testing
- FRA may witness and audit field testing

Field Brake Testing

Objective: Validate Braking Algorithm

Test Types: System, Conformance, Functional, and Performance

Minimum Entry Criteria:

- All Category 1 and 2 defects from previous tests are resolved or deferral is approved
- Test plan approved by FRA
- Notification to FRA of planned testing dates and locations
- All tenant railroads notified of planned testing dates, locations, and any requirements
- Production versions of communications network and onboard system

Exit Criteria:

- Prescribed number of ascending, descending, and level grade tests complete
- No overruns

FRA Participation (Applies Throughout Field Testing):

- FRA approval of test plan in advance of field brake testing
- FRA may witness and audit field brake testing

Section 3c:

Test Types and Test Sequence

FIT and FQT

Field Integration Testing vs. Field Qualification Testing

FIT =>

- Testing of the components, subsystems, and entire end-to-end PTC system, using production-version PTC components to the extent possible, to validate system operation in the field environment and to dry run FQT tests
- May be done in test track facility and/or general rail system
- May be done with hi-rails and/or locomotives and locomotive consists

FQT =>

- Formal testing of the entire end-to-end PTC system using ALL production-version PTC components to demonstrate PTC system meets:
 1. Regulatory requirements under 49 CFR part 236, subpart I, and
 2. Railroad-specific vendor and operational requirements.
- Will be done on general rail system in an operational environment with locomotives and locomotive consists

Each railroad has different definitions based on its master test strategy and organizational structure, requirements, resources, and capabilities.

Each railroad **MUST** clearly define what it means by FIT and FQT.

Field Integration Testing (FIT)

Objective: Test the actual integration of each PTC system component and verify the integrated PTC system is functioning safely and as designed on the general rail system

Test Types: System, Functional, Performance, and Regression

Minimum Entry Criteria:

- Test plan approved by FRA
- Notification to FRA of planned testing dates and locations for FIT

Exit Criteria: Determined by railroad

FRA Participation (Applies Throughout Field Testing):

- FRA approval of test plan in advance of field testing
- FRA may witness and audit FIT

Field Qualification Testing (FQT)

Objective: Prove ALL PTC system functionality described in the applicable PTC Development Plan through execution of scenario-based test cases involving all methods of operations and track characteristics

Test Types: System, Conformance, User, Functional, and Performance

Minimum Entry Criteria:

- All Category 1 and 2 defects from previous tests resolved or deferral approved
- Test plan approved by FRA
- Notification to FRA of planned testing dates and locations
- All tenant railroads notified of planned testing dates, locations, and any requirements
- All production hardware and software (for the back office, wayside, communication, and onboard subsystems)
- All FIT complete

Exit Criteria: All functions have been successfully tested for the method of operation

FRA Participation (Applies Throughout Field Testing):

- FRA approval of test plan in advance of field testing
- FRA may witness and audit FQT

Request to Conduct Field Testing

Contents (49 CFR § 236.1035 Field Test Requirements): Before any field testing of an uncertified PTC system, or a product of an uncertified PTC system or any regression testing of a certified PTC system, on the general rail system, the railroad must provide:

- Complete description of the PTC system
- Operational concepts document
- Complete description of the specific test procedures, including measures that will be taken to protect trains and on-track equipment
- Analysis of the applicability of the requirements of subparts A through G to the PTC system that will not apply during testing
- Date the proposed testing will begin
- Test locations
 - *Best practice:* Include the exact milepost and/or control point limits and a description of the track characteristics. Explain whether this is an entire track segment outlined in PTCIP or a portion of a track segment.
- Effect on the current method of operation the PTC system will or may have under test

Other Information to Support a Field Test Request:

- System configuration (including software versions)
- Identification of the types of locomotives and/or other power units to be tested
- Description of the timetable and governing operating rules

Field Testing Typical Conditions (Slide 1 of 2)

Overview of Typical Conditions Imposed in FRA's Written Approval Letter:

- Test plan must be submitted for approval 10 days prior to the commencement of the testing, and testing cannot commence until written approval is received.
- Acceptable configuration management plan for critical features submitted, as well as written instructions and procedures for V&V testing (lab and field)
- Verification of the position of each critical feature against the track database
- Verification of equipment inputs and outputs
- Written notification to all tenant railroads that operate on the applicable track segments
- Before testing using a locomotive or cab car, provide:
 - Complete description of the system deployed, including software versions
 - Operating rules and special instructions
 - Training and qualification program
 - Documentation of job training for train and engine crew

Field Testing Typical Conditions (Slide 2 of 2)

Overview of Typical Conditions Imposed in FRA's Written Approval Letter:

- Provide training to train and engine crew members
- Conduct brake testing, providing records of results (upon request)
- Test trains must operate under absolute block conditions under any circumstances where block signal indications will not be observed or where block limits may be overrun
- No tests involving PTC brake applications will be performed on trains in revenue service
- Locomotive engineer must retain the ability to initiate and immediately terminate operation of the horn
- Mandatory directives must be provided in writing to the crew and/or in accordance with 49 CFR part 220

Section 3d:

Test Types and Test Sequence

Revenue Service Demonstration

Revenue Service Demonstration (RSD) (Slide 1 of 2)

Objectives:

- Validate the performance of the system as a whole (including the human element);
- Test the system under “full load” (i.e., normal, real-world operations);
- Ensure training, processes, and system configurations are sufficient to support safe and normal revenue service operations; and
- Support the railroad’s safety case it will make in its PTC Safety Plan (if it is a host railroad).

Test Types: System, User, and Performance

Minimum Entry Criteria:

- FRA approval of RSD request
- Configuration management plan is approved and in place
- Training program developed and sufficient employees have been trained under 49 CFR §§ 236.1041 to 236.1049 to support RSD
- All relevant field testing has been completed:
 - Onboard testing/commissioning complete
 - Critical features V&V complete (for at least the RSD territory)
 - Wayside I/O, BOS, COMMS, and CAD testing complete (including regression testing)
 - End-to-end testing complete (on RSD territory)
- Proof that open “unacceptable/undesirable” hazard risk items are remediated/justified

RSD (Slide 2 of 2)

Exit Criteria: FRA Approval of Host Railroad's PTCSP and Issuance of PTC System Certification

FRA Participation:

- FRA approval in advance of initiation of RSD
- FRA may witness and audit RSD

Request to Initiate RSD (Slide 1 of 2)

Contents: RSD is an advanced form of field testing, and the contents of an RSD request must include the following, consistent with 49 CFR § 236.1035:

- Complete description of the PTC system
- Operational concepts document
- Complete description of the specific test procedures, including measures that will be taken to protect trains and on-track equipment
- Analysis of the applicability of the requirements of subparts A through G to the PTC system that will not apply during testing
- Date the proposed testing will begin
- Test locations
 - *Best practice:* Include the exact milepost and/or control point limits and a description of the track characteristics. Explain whether this is an entire track segment outlined in PTCIP or a portion of a track segment.
- Effect on the current method of operation the PTC system will or may have under test

Request to Initiate RSD (Slide 2 of 2)

Other Information to Support an RSD Request:

- System configuration (including software versions);
- Identification of the types of trains, locomotives, and/or other power units, train volume and frequency, and approximate number of passengers;
- Description of the effect RSD will have on the applicable timetable and governing operating rules;
- Proof that regression testing is completed;
- Pointers to test evidence, including V&V, I/O, critical features, functional testing, etc.;
- Hazard/risk index and results; and
- Plan for RSD data collection, analysis, and reporting.

RSD Typical Conditions

Overview of Prerequisite Conditions FRA Imposes in Conditional Approval Letter

- Verification of the position of each critical feature against the track database
- Verification of equipment inputs and outputs
- Complete all functional feature testing
- No outstanding open Category 1 or 2 software issues
- Written identification of all outstanding software issues (and associated mitigations)
- Proof of satisfactory closure of all Hazard Risk Index issues
- Complete defined number of consecutive end-to-end runs without any system anomalies or failures
- Written verification that all appropriate personnel have received PTC training
- Written notification to all tenant railroads that operate on the applicable track segment
- Approved RSD data collection, analysis, and reporting plan

Other Typical RSD Testing Conditions (Apply Once RSD Testing Has Been Initiated)

- Complete a minimum number of consecutive runs without a critical anomaly
- Minimum level of training required and job briefings before operation of an equipped train
- Compliance with PTC regulations and railroad operating rules
- Immediately report any critical anomalies or violations of conditions or rules
- Monthly summary report (penalty brake applications, anomalies or system failures, failures to enforce when PTC system should have enforced, departure test failures, and cuts outs)
- Unless otherwise noted, RSD approval is only for the host railroad's equipment (separate approval is required for a tenant railroad to initiate RSD before the host railroad receives PTC System Certification)

Section 3e:

Test Types and Test Sequence

Interoperability Testing

Interoperability Requirements

General Rule: Consistent with the applicable PTC Implementation Plan (PTCIP) and PTC Safety Plan, any train—including trains operated by foreign power and tenant railroads—that operates on a main line subject to the mandate must be governed by a PTC system.

Practical Steps:

Comply with the host railroad's PTCIP, which, as required, currently:

- Provides the **written agreement** between each host railroad and tenant railroad to achieve interoperability, and
- Outlines the **specific methods** the railroads will utilize to achieve interoperability.

Testing defined by host railroad, subject to FRA approval:

- Test types include system level, functional, and performance, and
- FRA may witness and audit interoperability testing.

Although not specifically required, host railroads and tenant railroads should consider documenting any interoperability testing agreements in writing to ensure mutual understanding of roles and responsibilities and scope of the testing (e.g., testing approach and strategy, testing processes and procedures, and obligations and responsibilities of the parties for safety).

Interoperability Testing

Objective: Validate interoperability between one or more railroads

Test Types: System, Functional, Performance, and Interoperability

Minimum Entry Criteria (Assuming Testing an Uncertified PTC System – See Slide 8):

- All Category 1 and 2 defects from previous tests resolved or deferral approved
- Joint railroad test plan approved by FRA
- Notification to FRA of planned testing dates and locations
- All affected tenant railroads notified of planned testing dates, locations, and requirements
- WIU and critical feature validation complete on territory where testing will be performed
- All railroads' FQT testing complete
- Production systems

Exit Criteria: All interoperability tests successfully completed

FRA Participation:

- FRA approval of test plan in advance of interoperability testing on general rail system*
- FRA may witness and audit interoperability testing

**Please see Slide 8 for when FRA approval is or is not required for interoperability testing*

Questions and Discussion