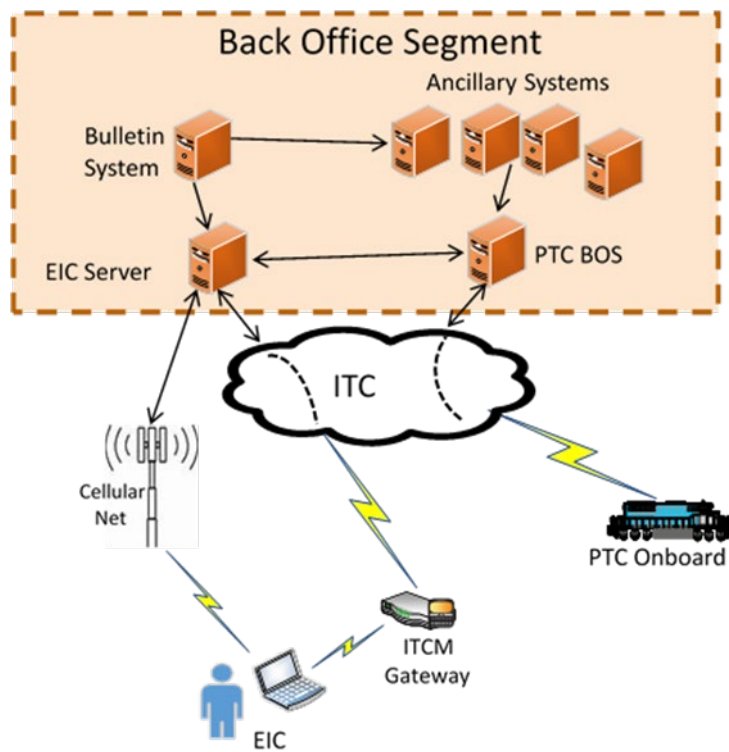




Interoperable Employee-In-Charge Portable Remote Terminal (EIC PRT) Summary Report



NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. Any opinions, findings and conclusions, or recommendations expressed in this material do not necessarily reflect the views or policies of the United States Government, nor does mention of trade names, commercial products, or organizations imply endorsement by the United States Government. The United States Government assumes no liability for the content or use of the material contained in this document.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

**REPORT DOCUMENTATION
PAGE**

*Form Approved
OMB No. 0704-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 21/12/2021		2. REPORT TYPE Technical Report		3. DATES COVERED (From - To) 5/23/2016 – 12/31/2021	
4. TITLE AND SUBTITLE Interoperable Employee-In-Charge Portable Remote Terminal (EIC-PRT) Summary Report				5a. CONTRACT NUMBER DTFR5311D00008L	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Joel Kindt – ORCiD: 0000-0002-8065-763X Thomas Nast – ORCiD: 0000-0003-1534-3519				5d. PROJECT NUMBER	
				5e. TASK NUMBER 0028	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Transportation Technology Center, Inc. 55500 DOT Road PO BOX 11130 Pueblo, CO 81001-0130				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Railroad Administration Office of Railroad Policy and Development Office of Research, Development, and Technology (RD&T) Washington, DC 20590				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) DOT/FRA/ORD-24-08	
12. DISTRIBUTION/AVAILABILITY STATEMENT This document is available to the public through the FRA Web site at http://www.fra.dot.gov					
13. SUPPLEMENTARY NOTES COR: Francesco Bedini					
14. ABSTRACT The Federal Railroad Administration (FRA) sponsored Transportation Technology Center, Inc. (TTCI) to define the requirements for Interoperable Employee-In-Charge (EIC) Portable Remote Terminal (PRT) functionality for use with Positive Train Control (PTC) systems. The Interoperable EIC-PRT is a safety overlay system that integrates with PTC to protect maintenance-of-way (MOW) workers by placing the entry of trains into work zones (WZ) under the control of the EIC. This research was conducted between 2016 and 2021. Collaborating with the North American railroad industry, the team developed systems engineering documents defining the EIC PRT system, including the interoperable requirements for the EIC PRT, EIC Server and Onboard segments. Additionally, the team developed a prototype Roadway Worker Terminal (RWT) application following the interoperable requirements and tested the application to demonstrate requirement compliance.					
15. SUBJECT TERMS Positive Train Control (PTC), Employee-in-Charge Portable Remote Terminal (EIC-PRT), work zone, electronic instructions					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Thomas Nast, Principal Investigator II
Unclassified	Unclassified	Unclassified		18	19b. TELEPHONE NUMBER (Include area code) 719-584-0658

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
 1 foot (ft) = 30 centimeters (cm)
 1 yard (yd) = 0.9 meter (m)
 1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in²) = 6.5 square centimeters (cm²)
 1 square foot (sq ft, ft²) = 0.09 square meter (m²)
 1 square yard (sq yd, yd²) = 0.8 square meter (m²)
 1 square mile (sq mi, mi²) = 2.6 square kilometers (km²)
 1 acre = 0.4 hectare (he) = 4,000 square meters (m²)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
 1 pound (lb) = 0.45 kilogram (kg)
 1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
 1 tablespoon (tbsp) = 15 milliliters (ml)
 1 fluid ounce (fl oz) = 30 milliliters (ml)
 1 cup (c) = 0.24 liter (l)
 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, ft³) = 0.03 cubic meter (m³)
 1 cubic yard (cu yd, yd³) = 0.76 cubic meter (m³)

TEMPERATURE (EXACT)

$$[(x-32)(5/9)] \text{ } ^\circ\text{F} = y \text{ } ^\circ\text{C}$$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
 1 centimeter (cm) = 0.4 inch (in)
 1 meter (m) = 3.3 feet (ft)
 1 meter (m) = 1.1 yards (yd)
 1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm²) = 0.16 square inch (sq in, in²)
 1 square meter (m²) = 1.2 square yards (sq yd, yd²)
 1 square kilometer (km²) = 0.4 square mile (sq mi, mi²)
 10,000 square meters (m²) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
 1 kilogram (kg) = 2.2 pounds (lb)
 1 tonne (t) = 1,000 kilograms (kg)
 = 1.1 short tons

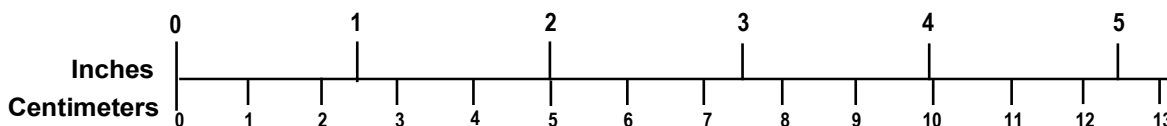
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
 1 liter (l) = 2.1 pints (pt)
 1 liter (l) = 1.06 quarts (qt)
 1 liter (l) = 0.26 gallon (gal)
 1 cubic meter (m³) = 36 cubic feet (cu ft, ft³)
 1 cubic meter (m³) = 1.3 cubic yards (cu yd, yd³)

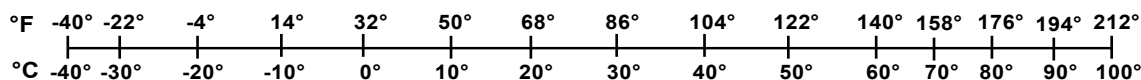
TEMPERATURE (EXACT)

$$[(9/5) y + 32] \text{ } ^\circ\text{C} = x \text{ } ^\circ\text{F}$$

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



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

Updated 6/17/98

Acknowledgements

Transportation Technology Center, Inc. recognizes the substantial technical and resource contributions to this project by BNSF Railway and the collaborative efforts and assistance provided by the railroad advisory group.

Contents

Executive Summary 1

1. Introduction 2

 1.1 Objectives 4

 1.2 Overall Approach 5

 1.3 Scope 5

 1.4 Organization of the Report 6

2. Project Accomplishments 7

3. Conclusion and Recommended Next Steps 8

4. References 9

Appendices 10

Abbreviations and Acronyms 11

Illustrations

Figure 1. EIC PRT Architecture (from EIC-PRT CONOPS 1.5).....	3
Figure 2. EIC Instructions to Trains (from EIC PRT CONOPS 1.5)	4

Executive Summary

The Federal Railroad Administration (FRA) sponsored Transportation Technology Center, Inc. (TTCI) to define the requirements for Interoperable Employee-In-Charge (EIC) Portable Remote Terminal (PRT) functionality for use with Positive Train Control (PTC) systems. The Interoperable EIC-PRT is a safety overlay system that integrates with PTC to protect maintenance-of-way (MOW) workers by placing the entry of trains into work zones (WZ) under the control of the EIC. This research was conducted between 2016 and 2021.

Collaborating with the North American railroad industry, the team developed systems engineering documents defining the EIC PRT system, including the interoperable requirements for the EIC PRT, EIC Server and Onboard segments. Additionally, the team developed a prototype Roadway Worker Terminal (RWT) application following the interoperable requirements and tested the application to demonstrate requirement compliance.

1. Introduction

In the Rail Safety Improvement Act of 2008 (RSIA 2008), Congress mandated that each Class I freight railroad or other entity providing regularly scheduled intercity or commuter rail passenger transportation must implement a Positive Train Control (PTC) system on designated main lines with regularly scheduled passenger service or over which designated hazardous materials are transported. PTC systems, as defined by RSIA 2008, are designed to prevent:

- Train-to-train collisions
- Over-speed derailments
- Incursions into established work zone (WZ) limits
- Movement of a train through a switch left in the wrong position

Since 2008, the U.S. railroad industry has devoted a significant amount of financial and human resources to develop safe and functional PTC systems, and railroads have encountered an array of technical and nontechnical challenges in its design and deployment. Early PTC development demonstrated the need for WZ boundaries to be enforced by the PTC system until the Employee In Charge (EIC) of a maintenance-of-way (MOW) work gang provides permission for an approaching train to enter the WZ.

The EIC Portable Remote Terminal (EIC PRT) system provides the EIC with a PTC system interface that allows them to control train entry and movement through the EIC's WZ. Using the EIC PRT system, the EIC can issue PTC-enforceable instructions to a train, including permission for a train to enter a WZ and speed limits for a train while operating within a WZ.

The EIC PRT system can increase protection of MOW personnel by providing the PTC onboard segment with enforceable EIC instructions equivalent to those issued by voice to the train crew. The first build addresses the following EIC PRT project safety objectives:

- Prevent failure of train from stopping at WZ boundary, as could occur when the locomotive engineer incorrectly indicates permission received to travel through the WZ
- Prevent train over-speed within WZ limits
- Mitigate train/gang collisions within WZ limits
- Mitigate EIC working outside of WZ protected time, by providing warnings when a WZ is about to expire (configurable option)
- Prevent instructions to the Onboard by unauthorized third party

The Interoperable EIC-PRT system architecture is illustrated in [Figure 1](#). The EIC PRT application is independent of the communication network used to transport messages between the EIC PRT and the EIC Server.

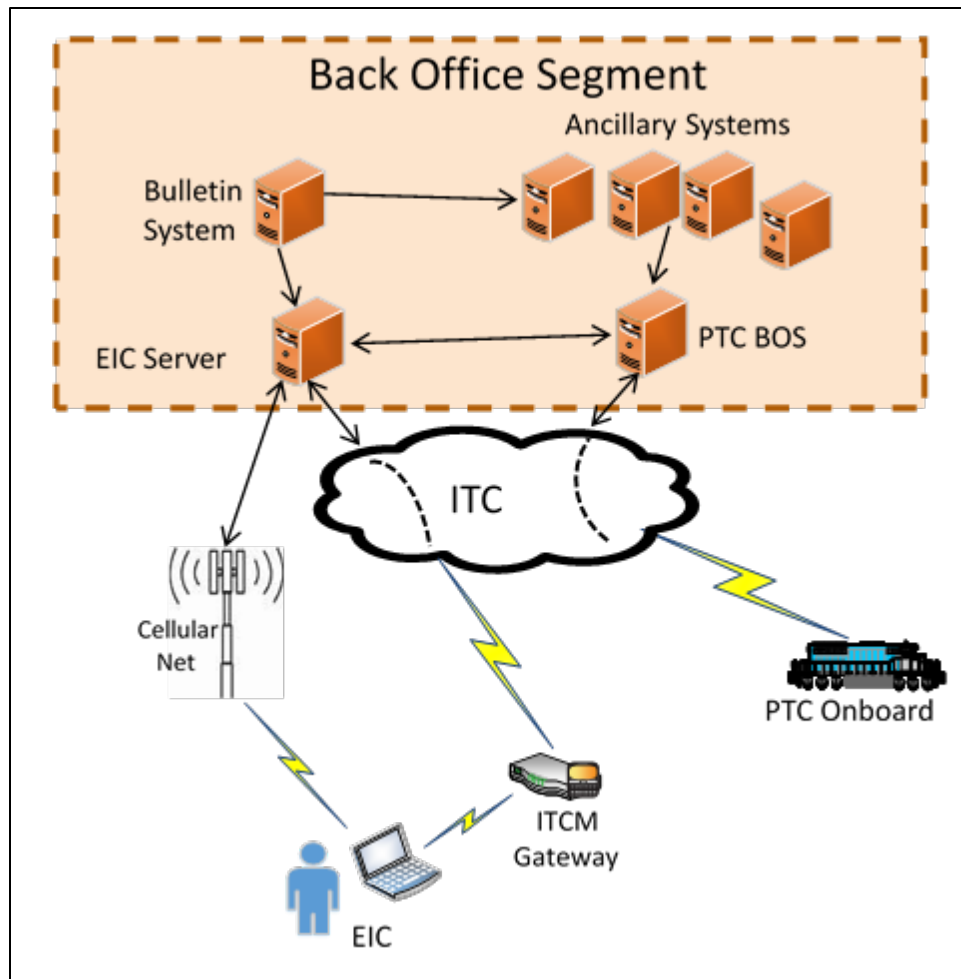


Figure 1. EIC PRT Architecture (from EIC-PRT CONOPS 1.5)

Figure 2 illustrates how an EIC uses the EIC PRT system to provide instructions to a PTC-equipped train as it approaches a WZ. Note that, as illustrated, the EIC PRT is an overlay to existing operating practices, therefore voice communication between an EIC and a train crew is maintained.

FRA has previously funded projects supporting the development and integration of EIC PRT functionality with BNSF Railway’s PTC system. Under these prior efforts, researchers developed and tested EIC PRT functionality, but variations in operating rules and railroad-specific features of Interoperable Train Control (ITC)-compliant PTC systems required modification of the EIC PRT functional definition and implementation to support industry-wide interoperability.

In this research, conducted between 2016 and 2021, the team modified the EIC PRT system engineering documentation and prototype application to satisfy the interoperability requirements of the North American freight railroad industry and other ITC users.

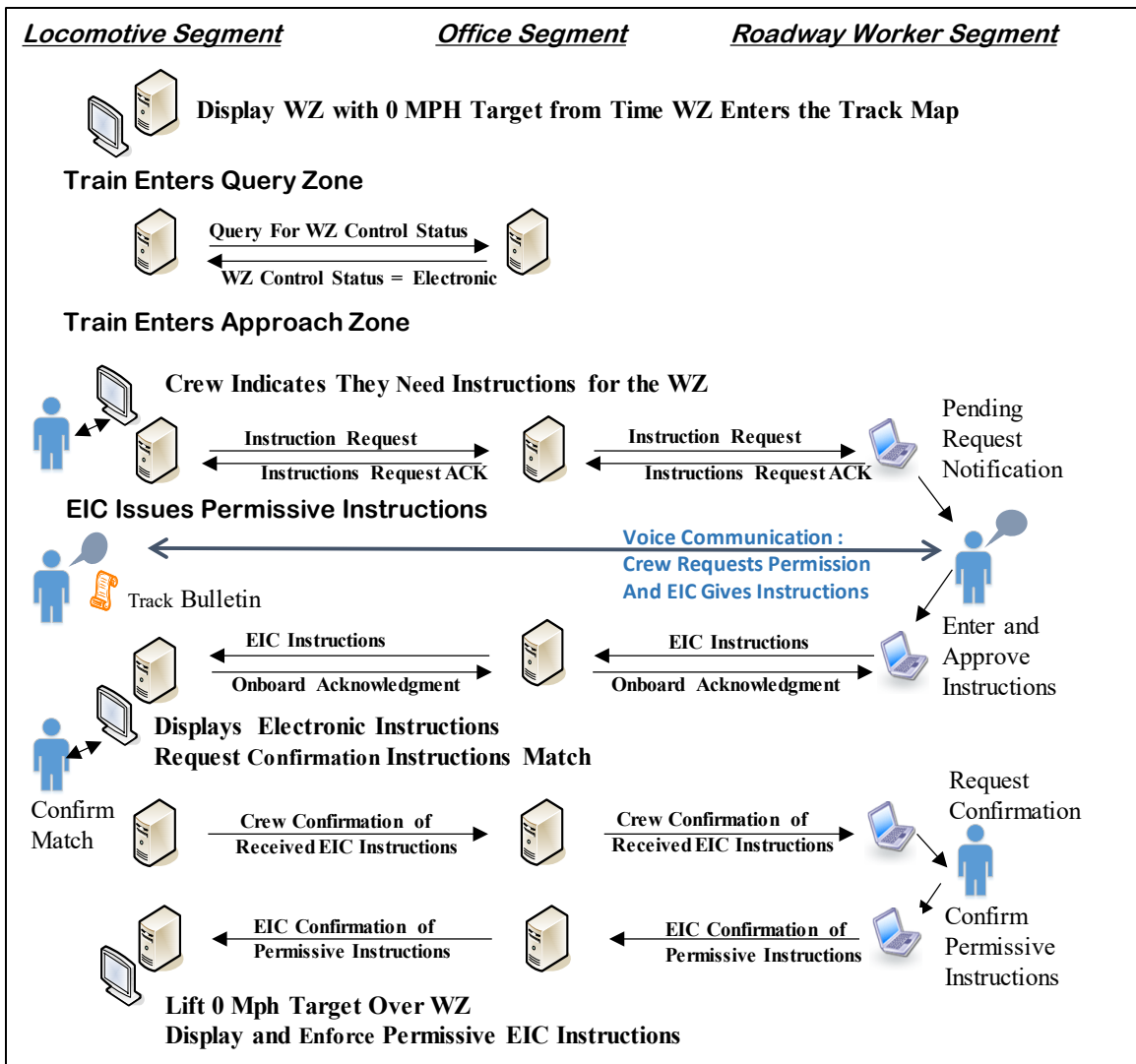


Figure 2. EIC Instructions to Trains (from EIC PRT CONOPS 1.5)

1.1 Objectives

The key objectives of this project were:

- Preparation of Interoperable EIC PRT engineering documents
- Submission of documents to the Association of American Railroads (AAR) for consideration for the *Manual of Standards and Recommended Practices* (MSRP) publication
- Implementation of EIC PRT test tools
- Implementation of the Roadway Worker Terminal (RWT) application
- Unit testing of the RWT application
- Laboratory Integration Nearest Neighbor (LINN) testing of the interoperable EIC PRT

- Revision of EIC PRT safety documentation (e.g., critical assumptions, hazard log, risk assessment, etc.)

1.2 Overall Approach

Researchers worked with a technical advisory group (TAG) comprised of representatives from Class I freight railroads and FRA to revise the EIC PRT requirements to satisfy the interoperability requirements of the railroad industry and ITC principles. The TAG members participated in weekly EIC PRT development teleconferences and design review meetings. Team efforts focused on the overall system definition and development of the EIC PRT RWT application. The TAG approved all Interoperable EIC PRT documents before they were submitted to AAR for possible inclusion in the MSRP.

1.3 Scope

The Interoperable EIC PRT project effort included:

- Development of Interoperable EIC PRT system definition documentation
- Development of Interoperable EIC PRT RWT application software
- Testing on the EIC PRT RWT application software
- Continuation of the EIC PRT safety assessment effort, limited by dependencies on the design within the back office and onboard

Interoperable EIC PRT definition documentation produced in this project included:

- Interoperable EIC PRT Concept of Operations (CONOPS)
- Interoperable EIC PRT RWT – Back Office System interface control document
- Interoperable EIC PRT Locomotive Onboard – Back Office System interface control document
- Interoperable EIC PRT RWT Requirements
- Interoperable EIC PRT Back Office Segment Requirements
- Interoperable EIC PRT Locomotive Onboard Segment Requirements

The publication of EIC PRT design documentation and materials produced in this project in the AAR MSRP is out of the scope of this effort and is at the discretion of the AAR.

Additional documentation produced in this project includes:

- EIC PRT RWT software requirements
- EIC Server Simulator requirements
- EIC PRT RWT unit test cases and test artifacts
- Preliminary Hazard Analysis (PHA)
- Configurable parameter safety assessment

[All documentation is available upon request from FRA.](#)

1.4 Organization of the Report

This is a summary report that highlights the results of the Interoperable EIC PRT project. This report is organized as follows:

- [Section 2](#) provides an overview of the interoperable EIC PRT deliverables.
- [Section 3](#) provides project conclusions and recommendations for next steps.
- Appendices A through F contain a set of draft interoperable EIC PRT systems engineering documents. Appendices G through H contain the results and artifacts of the interoperable EIC PRT unit testing. Appendix I contains current drafts of the EIC PRT safety documentation. [All appendices are available upon request.](#)

2. Project Accomplishments

The team collaborated with the railroad industry for this research. Researchers conducted working sessions to address technical details as they arose. The team held formal design review meetings, including a Preliminary Design Review (PDR) and a Critical Design Review (CDR), hosted by BNSF Railway. The participants in these design review meetings included representatives from the research team, FRA, Class I freight railroads, an onboard supplier, the developer for the EIC PRT application, and a safety consultant.

Through this collaborative work, the research team produced EIC PRT systems engineering documents which were submitted to the TAG for final review and approval. After iterative review, the TAG approved the systems engineering documents and the research team then submitted the documents to AAR for possible inclusion in the MSRP.

The team also modified the EIC PRT roadway worker application to satisfy industry-approved interoperability requirements and testing. Researchers developed unit test cases using a requirements verification and criteria matrix (RVCCM) and performed unit testing of the EIC PRT RWT application.

The following Interoperable EIC PRT systems engineering and requirements documents were produced:

- Interoperable EIC PRT CONOPS
- Interoperable EIC PRT Roadway Worker Segment Requirements
- Interoperable EIC PRT Back Office Segment Requirements
- Interoperable EIC PRT Locomotive Onboard Segment Requirements
- Interoperable EIC PRT RWT – Back Office System Interface Control Document
- Interoperable EIC PRT Locomotive Onboard Segment – Back Office System Interface Control Document¹
- EIC PRT RWT Application Software Requirements Document

[All documentation is available by request from FRA.](#)

LINN tests are usually conducted between adjacent system segments, such as the EIC PRT RWT application and the EIC server. However, development of EIC PRT functions within PTC back office and PTC locomotive onboard equipment was delayed, impacting the LINN testing schedule. As a result, LINN tests were not completed as part of this project.

The finalization of the EIC PRT Fault Tree Analysis (FTA) and integration of the EIC PRT fault tree with the PTC onboard fault tree has not yet been completed due to similar delays.

¹ This document was produced by Wabtec with the input/guidance of the TAG and the research team, and was included in the documentation provided to AAR.

3. Conclusion and Recommended Next Steps

The research team worked with representatives from the rail industry to define and develop the Interoperable EIC PRT system to enhance the safety benefit of PTC.

The team recommends several steps to facilitate the integration of the EIC PRT system into current railroad operations with PTC. These tasks can help the industry deploy the EIC PRT system in interoperable operations.

1. LINN testing between the RWT and back office (once the back-office segment EIC PRT function support is implemented)
2. LINN testing between the onboard and back-office segments (once the back office and onboard EIC PRT function support is implemented)
3. Field integration testing
4. Field service testing with user experience feedback
5. Complete safety assessment

The research team also recommends further revision of the EIC PRT documents developed in this research when integrating the EIC PRT system into high automation train operation, including high automation addenda for the EIC PRT systems engineering documents. These addenda should describe how the previously developed concepts and the EIC PRT requirements should be modified to minimize required crew prompts during high automation of the EIC PRT.

4. References

1. Rail Safety Improvement Act of 2008. Pub. L. No. 110-432, 122 stat. 4848.

Appendices

[The following appendices are available by request from FRA.](#)

Appendix A: Interoperable EIC PRT Concept of Operations

Appendix B: Interoperable EIC PRT Roadway Worker Application Requirements

Appendix C: Interoperable EIC PRT Back Office Segment Requirements

Appendix D: Interoperable EIC PRT Locomotive Onboard Segment Requirements

Appendix E: Interoperable EIC PRT Roadway Worker Terminal – Back Office System Interface Control Document

Appendix F: EIC PRT RWT Application Software Requirements Document

Appendix G: EIC PRT Roadway Worker Terminal Application Unit Test Plans and Test Cases

Appendix H: Summary of EIC PRT Roadway Worker Terminal Application Unit Test Results

Appendix I: EIC PRT Safety Assessment Documents

Abbreviations and Acronyms

ACRONYM	DEFINITION
AAR	Association of American Railroads
BNSF	Burlington Northern Santa Fe Railway Company
BOS	Back Office Server
CDR	Critical Design Review
CFR	Code of Federal Regulations
CONOPS	Concept of Operations
EIC	Employee-in-Charge
FRA	Federal Railroad Administration
FTA	Fault Tree Analysis
ITC	Interoperable Train Control
LINN	Laboratory Integration Nearest Neighbor
MOW	Maintenance of Way
MSRP	Manual of Standards and Recommended Practices
PDR	Preliminary Design Review
PHA	Preliminary Hazard Analysis
PRT	Portable Remote Terminal
PTC	Positive Train Control
RSIA '08	Rail Safety Improvement Act of 2008
RVCCM	Requirements Verification Conditions and Criteria Matrix
RWT	Roadway Worker Terminal
SRS	Software Requirements Specification
SSPP	System Safety Program Plan
TAG	Technical Advisory Group
TBD	To Be Determined
WZ	Work Zone