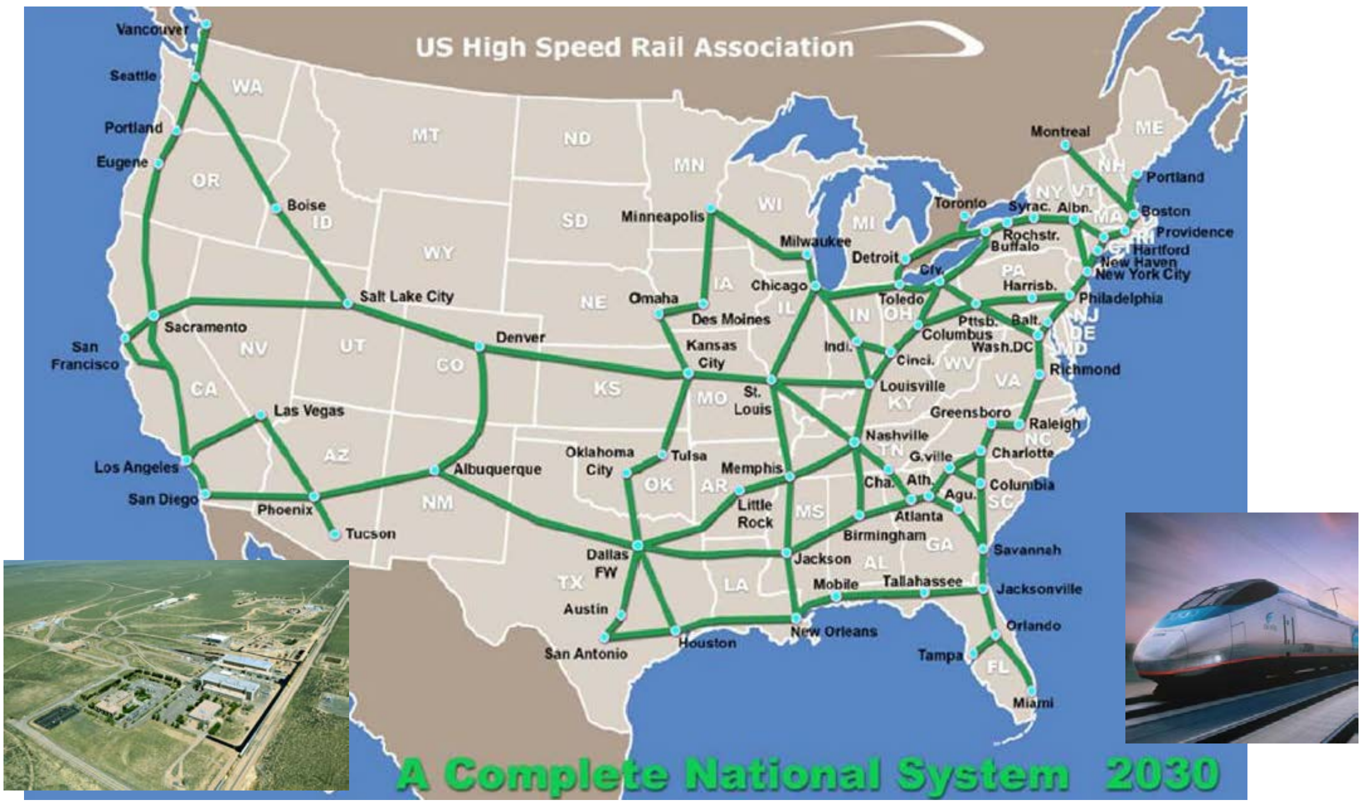
U.S. Department of Transportation

Federal Railroad Administration

High-Speed and Intercity Passenger Rail Testing Strategy

Office of Research
and Development
Washington, DC 20590



DOT/FRA/ORD-13/26

Final Report
May 2013

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 2013	Technical Report

4. TITLE AND SUBTITLE
High-Speed and Intercity Passenger Rail Testing Strategy

5. FUNDING NUMBERS
DTFR53-00-C-00012
Task Order 261

6. AUTHOR(S)
Matthew Witte, Robert Swearingen, Nicholas Wilson, and Robert Fries

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Transportation Technology Center, Inc., a subsidiary of Association of American Railroads
55500 DOT Road
Pueblo, Colorado

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
Office of Research and Development
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FRA/ORD-13/26

11. SUPPLEMENTARY NOTES
Program Manager: Luis Maal

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the FRA Web site at http://www.fra.dot.gov.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This high-speed and intercity passenger rail (HSIPR) testing strategy addresses the requirements for testing of high-speed train sets and technology before introduction to the North American railroad system. The report documents the results of a survey of industry stakeholders on the requirements for testing HSIPR technologies worldwide. The report identifies all testing required for development of new technologies, assurance of existing technologies, characterization of new designs, and qualification of equipment. The report identifies the potential locations for each type of testing and evaluates the shortcomings, if any, of those test locations. The report includes rough order of magnitude (ROM) estimates of investment and operational test costs. It also provides ROM estimates of investment costs necessary to improve resources at Transportation Technology Center (TTC) so that researchers can test very high-speed rail (HSR) equipment. At a minimum, a high-speed siding and a body structural test facility should be added at TTC to meet the testing requirements of HSR for the United States.

14. SUBJECT TERMS
high-speed passenger rail, very high speed passenger rail, qualification testing, acceptance testing, vehicle track interaction, vehicle dynamics, characterization testing, durability testing, reliability testing

15. NUMBER OF PAGES
81

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

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, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

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, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °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 (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	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

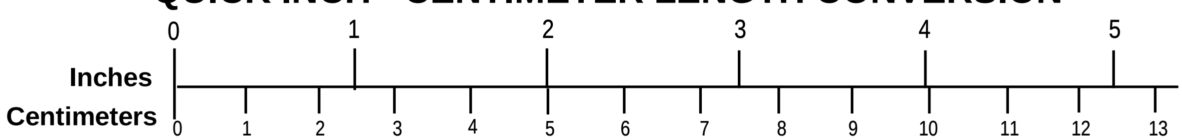
VOLUME (APPROXIMATE)

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 (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

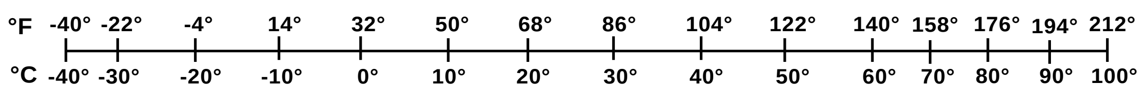
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO



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

Contents

Illustrations

Tables

Executive Summary

The Passenger Rail Investment and Improvement Act of 2008 (PRIIA) tasks Amtrak and the Department of Transportation, the Federal Railroad Administration (FRA), States, and other stakeholders to improve the U.S. passenger rail network. The vision for this network includes high-speed and intercity passenger rail (HSIPR) service throughout the country. Safe, reliable HSIPR networks exist around the world, and the United States is poised to benefit from these established technologies. International HSIPR systems can be adapted to work with and enhance the U.S. railroad network, but foreign technologies must be assessed before introduction to the North American rail network. A well planned testing strategy will ensure safety and reliability. This report outlines such a testing strategy.

A well-designed testing strategy meets the technological and regulatory requirements at the lowest cost. The Transportation Technology Center, Inc. (TTCI), addressed those requirements by surveying industry, regulatory agencies, government, and other stakeholders to ascertain what is essential to a good strategy. The survey revealed testing requirements to characterize components, to qualify vehicles and infrastructure for service, to research and develop new technologies, and to ensure durability and reliability of railway operations. TTCI also assessed the locations for testing. Generally, testing will be conducted on existing/updated revenue service routes at an engineering test facility such as FRA's Transportation Technology Center (TTC) in Pueblo, CO, as the new corridors are built or at dedicated test laboratories. Recommendations and comments on where to perform each test are included in this report. It also provides rough order of magnitude (ROM) cost estimates such as investment costs and day-to-day costs for the various testing options. The report also addresses upgrading the TTC facility to include a body structural test facility and a high-speed siding on the Railroad Test Track (RTT) as outlined in a companion report, *Needs Assessment – Railroad Test Track Siding Options for High-Speed Testing*.

1. Introduction

The need to test new rail equipment and infrastructure components increased dramatically after Congress awarded $8 billion to fund HSIPR projects under the American Recovery and Reinvestment Act (or the economic stimulus package) of 2009. Such testing will ensure new and improved HSIPR operations are safe, efficient, and reliable. This report proposes a strategy for HSIPR testing.

1.1 Background

The PRIIA expands the U.S. passenger rail network by tasking the U.S. Department of Transportation, FRA, and other stakeholders to improve service, operations, and facilities for high-speed rail (HSR) in the United States. Safe, reliable HSR networks exist in countries around the world, and the United States is poised to benefit from these established technologies. However, these technologies will need to be assessed before they are introduced into the country's existing railroad infrastructure. This report proposes a testing strategy to perform this assessment.

The investment required to bring HSR to the United States is substantial. The network will start with localized services that will grow to connect larger regions. Figure 1 shows the emerging megaregions that will ultimately make up the HSR network in the United States. It may ultimately take decades to complete the network. Planning, testing, and careful execution are required for success.

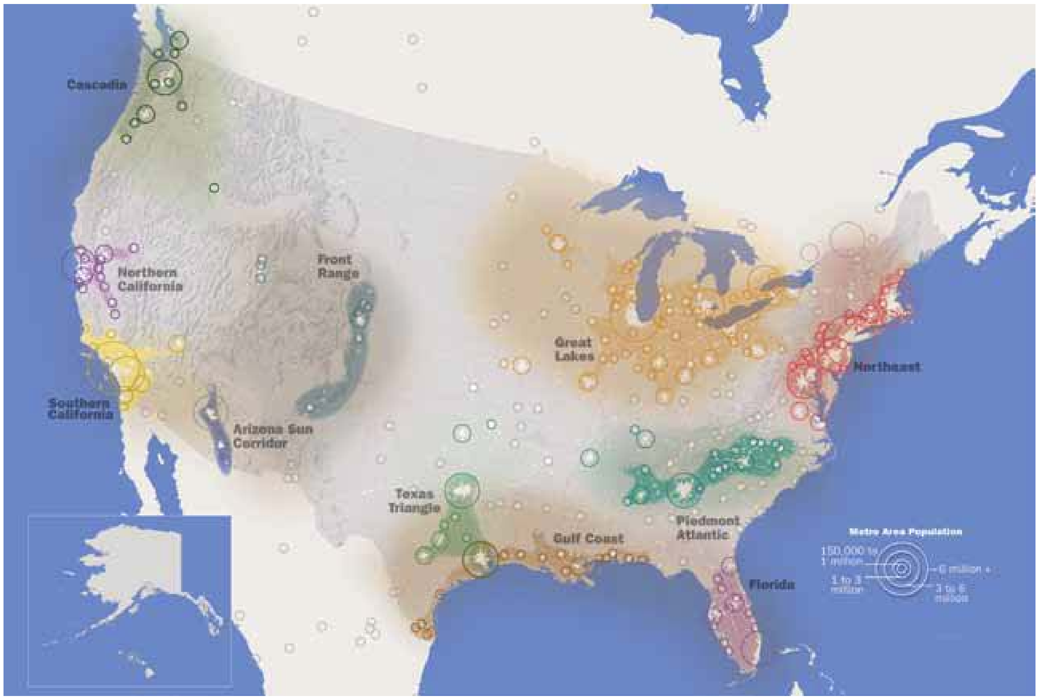


Figure 1. Emerging Megaregions (Source: *National Rail Plan*) (1)

1.2 Objectives

The objective of this report is to propose a strategy for HSIPR testing in the United States. The intention is to describe the types of testing that are required and the most cost-effective location for performing those tests.

1.3 Overall Approach

The HSIPR testing strategy has been developed by consultation with the U.S. railroad industry. Input was solicited from Class I freight railroads, Amtrak, HSR authorities, and equipment and component suppliers. Detailed questionnaires were circulated, and test plan documentation was shared by the stakeholders. TTCI also conducted a review and comparison of FRA and international HSR railroad standards under separate contract (1). The standards review and comparison helps to ensure that all of the testing requirements were met (2).

1.4 Scope

The testing strategy covers equipment and infrastructure including the following:

- Rolling stock
- Inspection equipment
- Track and structures
- Overhead electrification
- Signaling and train control
- Noise and vibration
- Aerodynamics

Testing for crashworthiness is considered only briefly; specifications for crashworthiness are still being developed. Likewise, laboratory testing of materials and components is not considered because it is not unique to HSR. The test locations suggested are limited to those within the United States.

This strategy report does not authorize any new FRA regulations or authorize changes to any existing ones. Although this summary of information was gathered on behalf of FRA, it is not a regulatory document. Where possible, the strategy does look ahead to accommodate regulatory changes anticipated for HSIPR.

1.5 Organization of the Report

Appendix A shows spreadsheets that summarize the details of the tests typically required for characterization and qualification of HSIPR equipment. Research testing and durability testing are also considered because of their vital role in HSR operations. This appendix provides a foundation to understanding the breadth and scope of the individual tests.

Section 2 describes the testing requirements and identifies the features required of the testing facilities. The main subsections of Section 2 cover equipment and infrastructure.

Section 3 describes the testing strategy. Subsections give details about the different types of testing: developing standards, research and development, technology demonstration, and qualification.

The rest of the report is organized as follows: Section 4, ROM cost estimates for the different types of testing; Section 5, an analysis that prioritizes the testing based on the cost and economic/ technical impact; and Section 6, conclusions that can be drawn from this work.

2. Testing Requirements

Testing of HSIPR equipment is performed to ensure safe and reliable operation during revenue service. Such testing requires replicating the service environment conditions for the component in question. This service environment may be the actual service setting, or it may be represented by surrogates, depending on the component and the objectives of the test. For example, testing of rolling stock can take place on the intended corridor, or it may take place at an engineered test facility such as FRA's TTC in Pueblo, CO. Likewise, testing of infrastructure components can take place in existing service corridors, or components can be tested at a dedicated engineered test facility such as the test tracks at TTC. Section 2 will investigate the specific requirements for testing of all elements of the HSR system from rolling stock to the track and infrastructure it rides.

2.1 Rolling Stock

Rolling stock types vary with the intended service. Speed, passenger comfort, and capacity all affect design, as well as regulatory guidelines and operating environment (maximum speed of operation). Thus, testing requirements will vary with the specific rolling stock under test and the type of test. For example, segments of track suitable to test a train at 150 mph may not be suitable for testing at 220 mph because of cant limits. In addition, the intent of each test affects the way it is performed and what data is required. For example, component characterization tests have different objectives than qualification testing of the same component and thus may require different facilities to perform them. The following sections consider the testing of rolling stock and the requirements specific to each test type and each equipment type.

2.1.1 Developing Standards and Specifications

The Code of Federal Regulations (CFR) is FRA's published safety standards for Tier I (125 mph maximum) and Tier II (150 mph maximum) equipment (49 CFR 238). These standards have been used to specify and procure equipment operating up to 150 mph in the United States. They continue to be developed under the Railway Safety Advisory Committee (RSAC) process.

The current notice of proposed rulemaking for vehicle-track interaction safety has new limits for equipment performance (3). These limits have been derived from testing at speeds up to 150 mph. Extrapolation to higher speeds is accomplished with computer modeling up to the maximum speeds of interest. There is a need to validate the modeling at high cant deficiencies and at speeds above 150 mph.

The safety margin allows for variations in track quality and suspension condition, and uncertainties in modeling. Quantifying the margin of safety becomes more important as train speeds increase. The safety margin can be quantified by testing.

The Association of American Railroads' (AAR) *Manual of Standards of Recommended Practices* Chapter XI tests define acceptable limits for vehicle dynamic behavior of freight trains negotiating a series of prescribed inputs (4). Similarly, FRA's minimally compliant analytical track (MCAT) specifies the track irregularities high-speed trains must be able to safely negotiate. Testing on track segments that include precise track irregularities is required for validating computer simulation models.

2.1.2 Research and Development

Suppliers have indicated a need to perform tests as they develop new equipment for the U.S. HSIPR market. Assessing equipment development is usually best done at a test facility that is not in service operation. For example, the Acela train underwent extensive testing at TTC prior to its introduction for service on the Northeast Corridor. Access to a test track allows cycles of modification and testing to be repeated without having to wait for slots in the service timetable. Car builders reported on their questionnaires a shortage of time (opportunity) to test vehicles during the development cycle. It may be advantageous to require by regulation a minimum amount of testing of new HSR equipment before using it in revenue service.

2.1.3 Vehicle Qualification

Rolling stock that has no previous U.S. service history may be specified for use on very high-speed corridors such as those proposed in California (220 mph). This new equipment is likely to be modified from existing high-speed equipment operating elsewhere in the world. Whether the equipment is a modification to existing designs or an entirely new design, FRA regulations will require qualification testing before introduction to revenue service.

Rolling stock for States that are planning operating speed upgrades to 125 mph could be all new or be based on equipment with an existing qualification. For example, a Spanish Talgo model that is certified to 124 mph internationally is qualified to operate only at 79 mph in Washington State, although this limitation is due to train control issues rather than dynamic performance. In any case, FRA will require qualification tests whenever speed is to exceed 90 mph for operation in the United States.

The PRIIA Section 305 Committee is currently developing specifications for the next generation of passenger equipment. The specifications require testing of any equipment designed to meet these requirements.

Table 1 shows estimates for the number of different types of high-speed equipment that are expected from 2010 to 2020. These numbers were interpolated from data received from the American Public Transportation/International Union of Railways (APTA/UIC) HSR Practicum of May 3–5, 2011, in Baltimore, MD. The order in which these are delivered and the speeds at which they are expected to run will significantly affect the overall testing strategy. The testing strategy needs to regard the importance and order of equipment introductions.

Table 1. Estimates of New Equipment Requiring Qualification Testing – 2010 to 2020

Type	Maximum Speed (mph)	Low	High
Very High Speed (train sets)	220	1	20
High Speed (train sets)	186	1	60
Next-Generation Bilevel Car (cars)	125	1	80
Next-Generation Single-Level Car (cars)	125	1	100
Next-Generation Train Set (train sets)	125	1	50
Next-Generation Nonelectric Locomotive (cars)	125	1	50
Next-Generation Multiple Unit (train sets)	125	1	50

*NOTE: High estimates based on data from APTA/UIC HSR Practicum; estimates will depend on projects approved.

The qualification process requires a combination of full-scale testing and computer modeling. The computer models are validated by comparing analytical results with test results. Validation requires accurate knowledge of the track geometry inputs and vehicle parameters, and these measurements are also part of the testing strategy.

2.1.4 Technology Demonstration

Equipment suppliers with products in high-speed operation elsewhere in the world may be required to demonstrate performance in the U.S. revenue service environment. The operating conditions may be worse than those for which the equipment was originally designed. Demonstration testing would provide data to either ensure safe operation or make modifications to ensure safe operation.

2.2 Infrastructure

2.2.1 Developing Standards and Specifications

FRA has published safety standards for track in several classes up to a maximum train operating speed of 220 mph (49 CFR 213) (5). The RSAC process continues to develop these standards.

The current Federal notice of proposed rulemaking for vehicle-track interaction safety has new limits for track geometry irregularities for Class 6 and above (3). These limits were derived from testing up to 150 mph and through computer modeling above 150 mph up to the maximum speed. There is a need to validate the modeling at high cant deficiencies and at speeds above 150 mph.

Also, standards are required for the alignment of the catenary in corridors with overhead electrification. In addition to limits on the size of geometric defects in the wire alignment, standards cover the registration between the track and the catenary. High-speed testing will be required to ensure dynamic performance of the catenary and current collection systems.

2.2.2 Research and Development

Existing infrastructure components used in low speed operation need to be developed for higher speed operations. Table 2 lists infrastructure components and the types of development that are required.

Table 2. Infrastructure Development Needs

Component	Development
Rail	Improved resistence to surface damage including wear and rolling contact fatigue
Fasteners and rail pads	Reduction in rail seat abrasion
Crossties	Test to demonstrate improved durability
Turnouts	Reduction in impact forces and improved geometry durability
Bridge transitions	Reduction in vertical acceleration
Slab track	Tests to develop and evaluate specialized new structures such as floating slabs for sound and vibration attenuation

Maintaining the right-of-way requires frequent inspection and specialized equipment, including that for rail defect detection, rail stress measurement, gage widening, and automated inspection of roadbeds. Demonstration of these technologies will require testing concurrent with the deployment of the new HSR networks in the United States.

2.2.3 Track Component Qualification

Track components that have no U.S. service history may be specified for the very high-speed corridors such as those proposed in California (220 mph). These new components are likely to be modifications of existing designs rather than completely new designs. Testing will demonstrate that they would function safely in the new environment.

New and existing types of track components may be required for shared freight and passenger corridors to permit efficient operation of both types of trains. For example, higher speed turnouts designed for passenger service may be specified that have not yet been proven to perform satisfactorily under heavy-haul freight trains. A demonstration of these technologies could be efficiently accomplished at TTC, with modifications to the Facility for Accelerated Service Testing (FAST) and the RTT. Appendix B shows several alternatives and the ROM cost estimates to upgrade the RTT to combine heavy axle load and HSR testing.

2.2.4 Track Inspection Equipment Qualification

New higher speed track geometry inspection systems and other types of track structure inspection systems are under development. Some of this equipment is intended to operate at line speed so that inspections can be performed with minimal impact to normal train operations. There is a need for a dedicated test facility that provides verifiable and repeatable tests for calibrating such equipment and verifying that flaws and exceptions can be reliably detected and reported. If such vehicles are to operate at passenger train speeds, they will also need to undergo safety performance qualification tests according to their intended operating speeds.

2.2.5 Technology Demonstration

Suppliers of high-speed infrastructure components expressed a need to demonstrate the performance of their products in the United States. For example, suppliers want to demonstrate high-speed turnouts for use in the United States and may desire the demonstration of turnout components at TTC.

3. Testing Strategy

Four distinct possibilities exist for meeting the test requirements identified in Section 2.

1. Test at a dedicated test facility such as the TTC.
2. Test in current revenue service corridors.
3. Test on new HSR corridors as they are constructed and before they go into service.
4. Test at a factory (or component test facility).

The following subsections describe the testing strategy. Several broad categories of testing are described. This is followed by a discussion of the requirements and optimal locations for performing the different types of tests.

3.1 Developing Standards and Specifications

Developing standards and specifications is best done at a dedicated test facility for the following reasons:

- Testing to determine safety limits may have higher safety risks to other track users and neighbors.
- Testing in revenue service disrupts other traffic.
- Standards and specifications need to be developed before corridors are built and available to be used for testing.

3.2 Research and Development

A fundamental purpose of a dedicated test facility is research and development testing. There is no revenue service interruption, and new technologies can be safely tried in a controlled setting. Table 3 shows the current FRA Track Research Division major programs. Many of these projects could be supported at TTC.

Table 3. FRA Track Research Division's Major Programs and Projects

Track and Components	Track-Train Interaction	Operation/Facilities	Broad Agency Announcement
Inspection Techniques • Rail Defect • Geometry • Gage Widening • Vertical Track support • Review • Ground Penetrating Radar (GPR) • Phased Array • Internal Mapping Flaw System • Portable Track Loading Fixture • Stress Measurement in Continuous Welded Rail **Materials/Components** • Rail Steels • Ties/Fastenings **Track/Structure Design & Performance** • Alternate Track Design • Longitudinal Stress • Bridges	**Derailment Mechanism & Prevention** • Track Geometry • Wheel/Rail Interaction • Wheel/Rail Profile Lubrication • Forces in Special Track Work **Vehicle-Track Performance** • Vehicle-Track Interaction Safety Standards • Modeling, Simulation, and Testing of Vehicle-Track Interaction and Validation • High-Speed Test Track Needs Assessment	**Operation, Maintenance, and Enhancements of R&D Research Cars** • Joint Bar Inspection System (T-18) • GPR System (T19) **Government Furnished Equipment** **Facilities** • TTC	**HSR Research and Development** • Crosstie & Fastener Research • Automated Inspection Technologies • Mixed-Mode Operation Challenges • Track/Train Dynamics

3.3 Technology Demonstration

Infrastructure components, such as high-speed turnouts that are in use overseas, must be demonstrated for use in the United States. HSR operations at the FRA Tier I (80–125 mph) and Tier II (126–150 mph) levels are likely to be intermixed with freight. Testing would demonstrate technologies in this environment. Testing at a dedicated facility would provide an initial demonstration, but revenue service testing may be required to achieve the frequent high loadings required for a full demonstration.

3.4 Vehicle and Component Qualification

Vehicle qualification testing is required to bring any particular model into revenue service. As specified in 49 CFR 213.345: "All rolling stock types which operate at Class 6 speeds and above shall be qualified for operation for their intended track classes in order to demonstrate that the vehicle dynamic response to track alignment and geometry variations are within acceptable limits to assure safe operation" (5). This testing can happen on a test track, but according to the current FRA rules, final qualification will not be granted by FRA until the train has been operated over its entire operating route at the intended full speed plus 5 mph.

New components such as car parts, wheel and rail steels, or ties and fasteners must be qualified before they enter revenue service. Survivability testing under controlled conditions (i.e., extreme loads, environmental conditions, or fatigue) would best be done at either a laboratory or a dedicated test facility.

3.5 Model Validation

In recent years, computer simulation modeling has improved to the point that certain certifications are possible without the expense of testing, but this requires a model that has been validated with test data. Testing over prescribed track geometries with prescribed perturbations is essential to validate models. Measurements of wheel/rail forces may be required, either with strain gaged rails and/or with instrumented wheel sets. A dedicated test facility with representative infrastructure and track segments would provide this environment. An ability to easily change perturbation amplitudes and wavelengths would be beneficial.

3.6 Speed Ranges

In the *National Rail Plan*, FRA identifies rail corridors that take into account the different markets and geographic contexts found throughout the United States (1). This vision includes the following tiers (taken directly from the *National Rail Plan*):

- **Core Express Corridors**: These routes would connect large urban areas up to 500 miles apart with 2- to 3-hour travel time, and train speeds would be between 125 and 250 mph. Service will be frequent and will operate on an electrified, dedicated track that is publicly owned. On the basis of their operation in and between large, dense metropolitan regions, the Core Express corridors will form the "backbone" of the national passenger rail system.
- **Regional Corridors**: This network would connect midsized urban areas and smaller communities in between, with convenient, frequent 90- to 125-mile per hour service on a mix of dedicated and shared track, depending on the particular corridor. In some areas, these corridors could connect to Core Express corridors, with many potential passenger services operating over both the Core Express and Regional routes.
- **Emerging/Feeder Routes**: Emerging routes would connect regional urban areas at speeds up to 90 mph on shared track. In some areas, the Emerging/Feeder routes could connect to the Core Express or Regional corridors, allowing residents of these smaller or more distant areas to have efficient access to the national system.
- **Community Connections**: For this vision of 21st century passenger rail to be successful, it must be integrated with existing and future policies and investments in public transportation, airports, and other modes to provide convenient options for accessing the passenger rail network. This access is critical to ensuring that passenger rail is a viable alternative to other methods of intercity travel.

The rolling equipment on each corridor will be certified to its particular speed range. The testing strategy must take into account the intended operational speed for the equipment under test. Equipment operating on the core express corridors at speeds up to 250 mph will require special facilities. Currently, the maximum continuous curving speed on the RTT at TTC is 165 mph. Additional capital investment is required at TTC to update the high-speed testing track to achieve higher testing speeds. Appendix B shows several alternatives and their estimated costs for improving the RTT at TTC.

3.7 Recommended Testing Locations

The following two subsections categorize the testing strategy in two ways: first, by vehicle, track, or system being tested, and second, by the four different classes of testing locations:

1. Engineered testing facility
2. Existing revenue service corridor
3. New HSR corridor
4. Factory (or component test facility)

A wide array of tests was identified in this survey. In general, only the railroad-specific types of testing are listed here. Tests such as material certification, which are not unique to railroad technology, are omitted, because they can be accomplished at nonrailroad facilities. Priority is given to the tests that will provide the best return specific to development of the HSR system.

3.7.1 Test Strategy Locations Categorized by System or Component Being Tested

Tables 4 though 9 summarize the proposed location classes above for testing different systems and components:

- Table 4: Locomotive/Power Car Characterization Testing
- Table 5: Locomotive/Power Car Qualification Testing
- Table 6: Passenger Vehicle Characteristic Testing
- Table 7: Passenger Vehicle Qualification Testing
- Table 8: Track and Infrastructure Testing
- Table 9: Systems Testing

Table 4. Testing Locations – Locomotive/Power Car Characterization Testing

Test Type/Name	Location	Comment
Couplers and Draft Gear	4	
Coupler Carrier	4	
Body Structural Tests	4 or 1	
Air Brake Tests	4	
Parking Brake Tests	1 or 2 or 3	
Headlight	4	
Horn Test	4	
Wheel Slip/Slide System Test	1 or 2	
Electrical System Tests	4	
Locomotive Sequencing	4	
Acceleration and Deceleration Rates	1 or 2 or 3	Location determined by maximum speed
Traction Motor Current	1 or 4	
Locomotive/Power Car Integral Brake Component (BCP, P-Wire Control System)	1 or 4	
Speed/Distance/Time	1 or 2	
Ride Quality Indices	1 or 2	

(1) Test Facility; (2) Revenue Corridor; (3) New HSR Corridor; (4) Factory or Laboratory.

Table 5. Testing Locations – Locomotive/Power Car Qualification Testing

Test Type/Name	Location	Comment
Water Tightness	4	
Cab Pressure Tightness	4	
Air-Conditioning Functional Test	4	
Heating Functional Test	4	
Body Compressive or Squeeze Test	1 or 4	
Collision Post	1 or 4	
Corner Post	1 or 4	
Miscellaneous Tests and Adjustments	4	
Clearance Test	1 , 2, or 3	
Weighing – Load Weigh System	4	
Horn Test	1, 2, 3, or 4	
Wheel Slip/Slide System Test	1	
Locomotive Electrical Tests	1 or 3	
Locomotive Brake Tests	1 or 3	
Locomotive Sequence Tests	1, 2, 3, or 4	
Sound Level Test	1 or 3	
Head-End Power (HEP) Test	1, 2, 3, or 4	
Locomotive Track Test	1 or 3	
Train Speed Control Test	3	
Electromagnetic Interface (EMI) and Radio Frequency Interference (RFI) (Onboard)	1 or 3	
Vehicle Track Interaction (VTI)	1, 2, or 3	

(1) Test Facility; (2) Revenue Corridor; (3) New HSR Corridor; (4) Factory or Laboratory.

Table 6. Testing Locations – Passenger Vehicle Characteristic Testing

Test Type/Name	Location	Comment
Trucks	4	
Couplers	4	
Brakes	4	
Door System	1 or 4	
Heating, Ventilating, and Air-Conditioning (HVAC)	4	
Lighting	4	
Communications/Online Tracking Information System (OTIS)	4	
Electrical	4	
Food Service	4	
Water and Waste	4	
Cab and Controls	1 or 4	
First Prototype Car and First Prototype Train Testing	1 or 2	

(1) Test Facility; (2) Revenue Corridor; (3) New HSR Corridor; (4) Factory or Laboratory.

Table 7. Testing Locations – Passenger Vehicle Qualification Testing

Test Type/Name	Location	Comment
Carbody	1 or 4	
Truck Tests	1 or 4	
Couplers	1 or 4	
Brakes	1 or 4	
Door System Tests	1 or 4	
HVAC	1 or 4	
Lighting	1 or 4	
Communications/OTIS	1 or 3	
Electrical	1 or 4	
Food Service	4	
Water and Waste	4	
Cab and Controls	1 or 4	
Completed Car	1 or 3	
Acceptance Tests	1	
Functional Tests	1 or 3	
Car Acceptance Tests	1 or 3	
Functional Tests	1 or 3	
Testing of Trains with Other Equipment	2 or 3	

(1) Test Facility; (2) Revenue Corridor; (3) New HSR Corridor; (4) Factory or Laboratory.

Table 8. Testing Locations – Track and Infrastructure Testing

Test Type/Name	Location	Comment
Track Geometry Measurement Car Calibration and Qualification	1	Requires controlled geometry defects
Rail Fastening Systems	1, 2	Accelerated possible at TTC
Improved Rail Steel	1, 2	Accelerated possible at TTC
Catenary Registration	1 or 3	Qualification on corridor
Pantograph and Catenary System Performance Testing	1 or 3	Initial testing at TTC
Signal System	1 or 3	European Train Control System (ETCS) level 2 assumed
Automated Track Inspection Equipment	1	Controlled flaws at TTC
Wayside Noise	1, 2, or 3	Sensitive to surroundings
Ground Borne Vibration Testing	1, 2, or 3	Qualification on corridor
Special Track work and HSR Components	1	Accelerated possible at TTC
EMI and RFI Vehicle Induced	1, 2, or 3	Controlled environment at TTC
EMI and RFI Ambient	1, 2, or 3	Sensitive to surroundings
Range of Track Stiffness	1	Qualify at TTC
HSR Track Maintenance Standards	1, 3	Develop at TTC, qualify on corridor
Rolling Contact Fatigue	1	Accelerated possible at TTC
Wayside Detectors for HSR Operations	1, 3	Develop at TTC, qualify on corridor
Accuracy of Track Geometry Vehicles for High-Speed Operations	1	Controlled conditions at TTC
Slab/Ballasted Track Testing	1	Accelerated possible at TTC
Rail Profile and Gage Testing	1	Accelerated possible at TTC
Aerodynamic Testing	3, 4	Modeling primarily

(1) Test Facility; (2) Revenue Corridor; (3) New HSR Corridor; (4) Factory or Laboratory.

Table 9. Testing Locations – Systems Testing

Test Type/Name	Location	Comment
Suspension System		
Wheel Load Equalization	1 or 3	Known perturbations at TTC
Static Lean	1 or 2 or 4	No service interrupt at TTC
Track Dynamic Maximum P2 Forces	1	Controlled conditions at TTC
Dynamic Response on FRA Class 1 through 5 Track	1 or 2	Controlled conditions at TTC
Dynamic Response on FRA Class 6 and 7 Track	1 or 2	Controlled conditions at TTC
VTI Safety Limits	1	Controlled conditions at TTC
Wheel Slip-slide Control System Maximum Jerk Rate	1	Controlled conditions at TTC
Brake System		
Braking Rates	1 or 3	No service interrupt at TTC
Parking Brake on 3% Grade	1 or 2	Location with track grade
Road Brake Test (full consist)	1 or 3	No service interrupt at TTC
Blended Brake Tests	1 or 3	No service interrupt at TTC
Complete Train	1, 2, 3	
Dimensions with Bogie	4	Static test
Axle Load	4	Static test
External Lighting	4	
Electrical Resistance between Wheels	4	
Pantograph Contact Force	1	Controlled conditions at TTC
Air Circuit	4	
Pneumatic Circuit	4	
Compressed Air and Brake via Brake Pipe	4	
Automatic Train Protection	3	
Internal Sockets 120 VAC	4	
Dead Man	4	

Test Type/Name	Location	Comment
HVAC and Cab Air-Conditioning	4	
Electrical Interface Test	1 or 3	No service interrupt at TTC
Safety Systems	1	No service interrupt at TTC
Train Composition Visual Inspection	4	
Reliability and Post Delivery Tests	1 or 3 or 4	
Shared Track Issues	1	No service interrupt at TTC
Test Train Control and Signal Systems	1 or 3	Controlled conditions at TTC
Radio Communications	1 and 3	Controlled conditions at TTC

(1) Test Facility; (2) Revenue Corridor; (3) New HSR Corridor; (4) Factory or Laboratory.

3.7.2 Testing Strategy Categorized by Four Different Test Location Types

Tables 10 through 13 provide a different view of the testing strategy. Each table represents a testing location and lists what testing may best be performed there.

- Table 10: Engineered Railroad Testing Facility
- Table 11: Existing Revenue Service Corridors
- Table 12: New HSR Corridor
- Table 13: Factory (or component test laboratory/facility)

Table 10. Testing That Can Be Performed at an Engineered Railroad Testing Facility (TTC)

Test Type	Test Name	Comment
Track Geometry Measurement Car	Calibration Qualification Acceptance	Requires controlled geometry defects
Locomotive Power Car Characteristic Testing	Body Structural Tests	Structural Test Facility
	Parking Brake Tests	Requires 3% grade
	Acceleration/Deceleration Rates	
	Speed/Distance/Time	
	Ride Quality Indices	
	Wheel Slip/Slide System Test	
	Energy Consumption	
	EMI	
	Traction Motor Current	
	Locomotive/Power Car Integral Brake Component (BCP. P-Wire Control System)	
Locomotive/Power Car Qualification Testing	Collision Post	Structural Test Facility
	Corner Post	Structural Test Facility
	Longitudinal Squeeze	Structural Test Facility
	Wheel Slip/Slide	
	Brakes Systems	
	Sound-Level Interior/Exterior	
	Locomotive Track Test	
Passenger Vehicle Characteristic Tests	First Prototype Car Testing	
Passenger Vehicle Qualification Tests	Carbody	
	Truck Tests	
	Couplers	
	Brakes	

Test Type	Test Name	Comment
	Electrical	
	Cab and Controls	
	Acceptance Tests	
Infrastructure Research	Rail Fastening Systems	
	Improved Rail Steel	
	Catenary Registration	
	Signal System	
	Automated Track Inspection Equipment	
	Ground Vibration	
	Wayside Noise	
	EMI - Wayside	
Vehicle Suspension System	Wheel Load Equalization	
	Static Lean	
	Track Dynamic Max P2 Forces	Maximum 165 mph at TTC
	Dynamic Response on FRA Class 1 through 5 Track	
	Dynamic Response on FRA Class 6 and 7 Track	Maximum 165 mph at TTC
	VTI Safety Limits	Maximum 165 mph at TTC
	Wheel Slip-Slide Control System Maximum Jerk Rate	
Brake System Testing	Braking Rates	
	Road Brake Test (full consist)	
	Blended Brake Tests	
Complete Train Testing	Pantograph Contact Force	
	Electrical Interface Testing	
	Safety Systems	
	Reliability and Post Delivery Testing	

Table 11. Testing That Can Be Performed on Existing Revenue Service Corridors

Test Type	Test Name	Comment
Locomotive/Power Car Characteristic Testing	Parking Brake Tests	
	Acceleration and Deceleration Rates	Maximum speed limited
	Speed/Distance/Time	
	Ride Quality Indices	
	Wheel Slip/Slide System Test	
Passenger Vehicle Characteristic Testing	Pilot Car and Pilot Train Testing	
Passenger Vehicle Qualification Testing	Testing of Trains with Other Equipment	
	Completed Car	
Infrastructure Research Testing	Rail Fastening Systems	
	Improved Rail Steel	
Systems Testing	Static Lean	
	Dynamic Response on FRA Class 1 through 5 Track	
	Dynamic Response on FRA Class 6 and 7 Track	
	Parking Brake on 3% Grade	

Table 12. Testing That Can Be Performed on the New HSR Corridor

Test Type	Test Name	Comment
Locomotive/Power Car Characteristic Testing	Acceleration and Deceleration	Final qualification on corridor
	Locomotive Electrical Tests	
	Interface with Train Signaling System(s)	Final qualification on corridor
	Locomotive Brake Tests	
	Sound Level	Final qualification on corridor
Locomotive/Power Car Qualification	Locomotive Track Test	Final qualification on corridor
	Train Speed Control Test	Final qualification on corridor
Passenger Vehicle Qualification	Communications/OTIS	Final qualification on corridor
	Completed Car	
	Functional Tests	
	Car Acceptance Tests	
	Testing of Trains with Other Equipment	
Infrastructure Qualification	Catenary Registration	Final qualification on corridor
	Signal System	Final qualification on corridor
Suspension System	Wheel Load Equalization	Final qualification on corridor
	Road Brake Test (full consist)	Final qualification on corridor
	Blended Brake Tests	
Brake System	Braking Rates	
	Road Brake Test (full consist)	Final qualification on corridor
	Blended Brake Tests	
	Parking Brake on 3% Grade	
Complete Train Tests	Electrical Interface Test	
	Automatic Train Protection	
	Reliability and Post Delivery Tests	

Table 13. Testing That Can Be Performed at the Factory or a Component Testing Facility

Test Type	Test Name	Comment
Materials Certification	Glazing Strength	
	Flammability	
Locomotive/Power Car Characteristic Testing	Couplers and Draft Gear	
	Coupler Carrier	
	Body Structural Tests	
	Air Brake Tests	
	Parking Brake Tests	
	Headlight	
	Horn Test	
	Traction Motor Current	
	Electrical System Tests	
	Subsystem EMI/RFI	
Locomotive/Power Car Qualification Testing	Miscellaneous Tests and Adjustments	
	Weighing	
	Horn Test	
	Water Tightness	
	Cab Pressure Tightness	
	Air-Conditioning Functional Test	
	Heating Functional Test	
	Body Compressive or Squeeze Test	
Passenger Vehicle Characteristic Testing	Trucks	
	Couplers	
	Brakes	
	Door System	
	HVAC	
	Lighting	
	Communications/OTIS	
	Electrical	

Test Type	Test Name	Comment
	Food Service	
	Water and Waste	
	Cab and Controls	
Passenger Vehicle Qualification	Truck Tests	
	Couplers	
	Brakes	
	Carbody	
	Door System	
	HVAC	
	Lighting	
	Electrical	
	Food Service	
	Water and Waste	
	Cab and Controls	
Complete Train	Dimensions with Bogie	
	Axle Load	
	External Lighting	
	Electrical Resistance between Wheels	
	Air Circuit	
	Pneumatic Circuit	
	Compressed Air and Brake via Brake Pipe	
	Internal Sockets 230 Volts AC	
	Dead Man	
	HVAC and Cab Air-Conditioning	
	Train Composition Visual Inspection	
	Reliability and Post Delivery Tests	

4. Costs

TTCI has made ROM cost estimates for the testing to be performed at TTC. These cost estimates include both investment and operation costs for performing the testing. ROM estimates for vehicle tests are on a per vehicle basis. A per car multiplier is required for multiple vehicle sets. The investment numbers include updates required at TTC facilities for operation at 150 mph maximum (Tier II). Costs for testing at a factory or dedicated laboratory facility are not included. Facilities that are not railroad specific are readily available, and costs are borne by the manufacturers. Test-by-test cost estimates are provided in the spreadsheets in Appendix A.

5. Analysis – Testing Priorities

This section prioritizes the testing based on investment cost and technical considerations.

The testing listed in Appendix A reflects all of the procedures reported to TTCI through the industry survey. Many of the tests are not railroad specific. For example, the material certification tests are best performed by dedicated materials testing laboratories. This sort of testing is not considered in this section. The railroad-specific tests, for example, vehicle dynamic qualification, are essential qualities of the HSR system and require dedicated railroad facilities. This is the sort of testing that is prioritized and summarized here. For simplicity, only the testing that is best performed at TTC is considered. Testing on-corridor is required in some instances, and ROM costs would be considered equivalent to TTC levels in these cases. Generally, research and development testing and demonstration testing can be accomplished on the same track segments at TTC as the characterization tests.

Facilities at TTC are currently configured for testing Tier II level rolling stock and equipment with a maximum speed of approximately 165 mph, depending on allowable cant deficiency for the equipment under test. The ROM cost estimates in Appendix A assume testing only within this speed range. Major facility upgrades will be required to test at higher speeds, and such estimates are not included in these investment costs.

5.1 Raising Maximum Test Speed

Cant deficiency limits the maximum continuous speed on the RTT to approximately 150 mph for nontilting equipment. To raise the maximum testing speed, the track must be modified by increasing the loop size. Investment numbers rise dramatically with such improvements. Appendix B shows cost estimates associated with several proposals to increase testing speed. The acreage at TTC is sufficient to contain a closed oval with curvature suitable for 220 mph, but the investment for such a track would approach $150 million. In addition, this track would have tangent sections capable of a useful peak speed of approximately 250 mph. If the track is extended beyond the current northern boundary, an additional $50 million investment would yield a tangent section capable of testing at speeds above 270 mph. Construction time is approximately 3 years.

5.2 High-Speed Siding

A new siding with HSR test sections is proposed for the RTT. The siding would be used to support HSR and positive train control (PTC) performance testing.

Safety of new high-speed equipment may be ensured by testing it on track that has geometry defects matching those in FRA safety standards. Building a new siding would provide such a performance test track capable of testing at speeds up to 130 mph. Measurements made on this performance test track may be used to validate computer models of equipment, and the models may then be used to evaluate performance with different track geometry, speed, wheel profiles, and other parameters. The new test track can also be used to validate high-speed track geometry recording equipment.

Adding an HSR siding to the RTT for $21 million will provide a location for track geometry perturbations and will facilitate many of the required tests (6). This 3-mile siding would include both tangent and curved track. Multiple track forms can be tested. The curve in this siding can be used for cant deficiency studies. Timing for this project would be 18–24 months.

5.2.1 Communication and Train Control

A siding test track to the RTT would facilitate communication and train control (C&TC) tests for passenger train operations more efficiently than the current C&TC test bed on the RTT can provide. For example, when configured properly, this siding would allow the following tests: conditions of failure (such as in manual control), shunting operations, and various signaling configurations.

Figure 2 shows the proposed configuration for the high-speed siding track. It includes a conventional C&TC configuration, track circuits, vital interlocking, wayside interface unit (WIU), batteries, antennas, bungalow, radio communication, and interface at both ends of the siding.

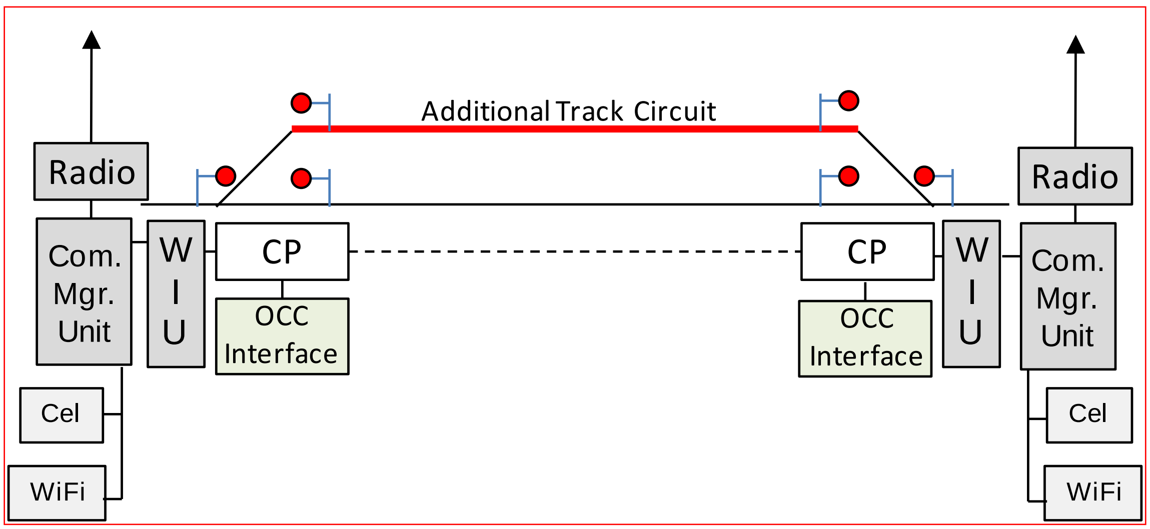


Figure 2. C&TC Configuration on High-Speed Siding Track to RTT

5.3 Shared Track Facility

Another potential benefit of the high-speed siding is its proximity to the High Tonnage Loop (HTL). As such, it can potentially be extended for research and testing for shared heavy freight and high-speed operations. The existing RTT and HTL run parallel for approximately 0.5 mile. The HTL and the Wheel Rail Mechanism (WRM) track are close to the RTT over a length of approximately 1.5 miles that includes the reverse curve on the RTT. In these areas, it would be possible to arrange a section of shared track on which either:

a) The train at FAST runs over part of the RTT, or
b) A train on the RTT runs over part or all of the HTL and WRM.

Investment for such a loop would add between $1 million and $10 million, depending on the siding configuration, and would take 18–24 months to complete. This option would have an effect on operations at FAST. This investment and a shared track testing plan would have to be discussed and agreed upon with the AAR's Railway Technology Working Committee.

5.4 Catenary Upgrade

Figure 3 shows the RTT catenary system, which is a compound catenary design that typically performs well at speeds up to 125 mph. This catenary design allows speeds in the 150-mile per hour range; however, overall system performance declines to marginal levels as speed increases.

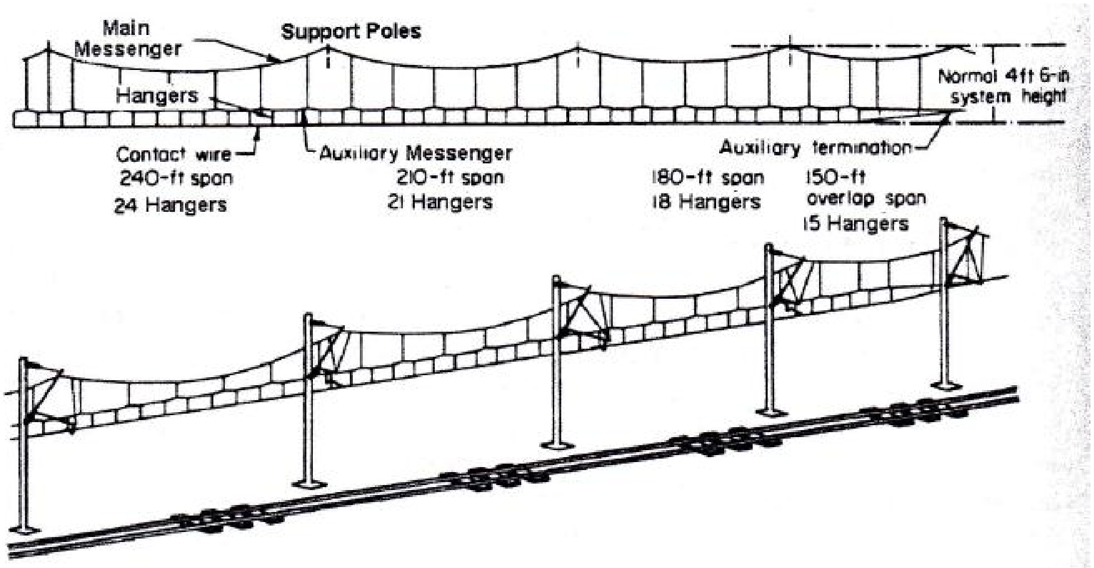


Figure 3. Existing Compound Catenary at TTC

The RTT catenary has extensive wear in the existing hanger supports and contact wires as a result of operating and environmental factors. The Colorado climate has contributed heavily to the deterioration of the system components; for example, high winds and other factors have accelerated mechanical wear and corrosive damage.

The estimate below for refurbishment of the existing compound catenary system is based on a 1994 overall assessment of the RTT. Although some investments have been made to correct deficiencies found at that time (and as recently as 2009), it can be assumed that mechanical wear and failures with this design have continued. A more thorough analysis is needed to quantify the required work.

The preferred option is to convert the current RTT compound catenary system to a simple catenary system. Figure 4 shows the simple catenary system, which has become the system of choice for high-speed applications in Europe and has been installed on the New Haven-to-Boston section of the Northeast Corridor.

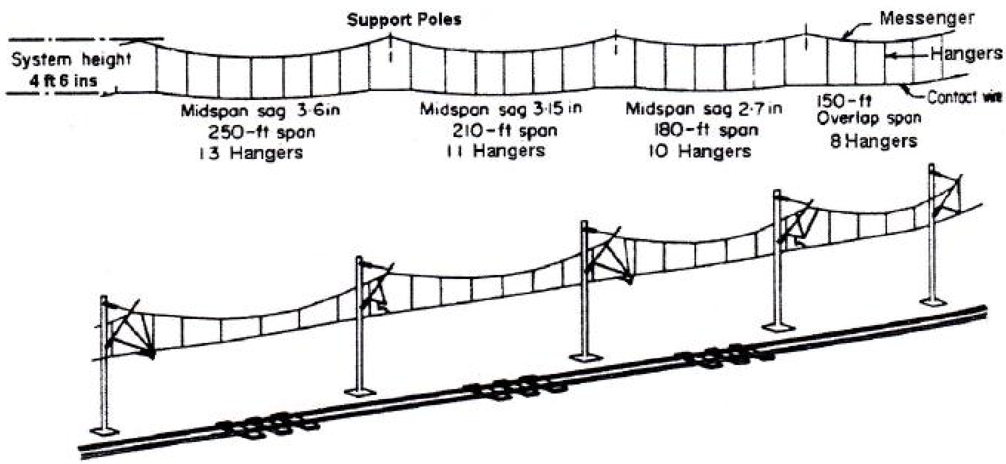


Figure 4. Simple Catenary System

The following are primary advantages of the simple catenary system:

1. It allows speeds in excess of 200 mph. It has been tested in France at speeds up to 350 mph.
2. It reduces the number of system components, which reduces component wear, maintenance, and longer term capital restoration costs.
3. It can be installed in a staged approach (if required) with the current compound catenary system.

The estimated cost to replace and convert the existing compound catenary system to a simple catenary system is $2 million and would take approximately 12 months.

5.5 Passenger Car Structural Test Facility

Quasi-static structural strength validation testing of vehicles requires presses and loading frame equipment capable of:

- Vertical load test (with approximately 200,000 ft-lb distributed over the floor)
- End load tests (with loads up to 800,000 ft-lb applied at different heights)
- Side load test
- Corner post energy absorption test (120,000 ft-lb at 30 inches above the floor)
- Principal energy absorption mechanism test (900,000–1,400,000 ft-lb with 38-inch stroke)

Currently, there is not a facility in North America set up to conduct these tests in a cost-effective, efficient manner. As a result, car builders either secure waivers to avoid testing or ship the cars overseas to conduct the tests in facilities in Europe or Asia. Establishing a state-of-the-art fully automated testing facility at TTC will ensure that safety-related testing can be conducted in a cost-effective, efficient manner for cars built in North America. The estimated cost for this facility improvement is $1.5 million and would require approximately 12 months to construct.

Table 14 shows a prioritized list of the proposed upgrade at TTC to conduct HSR testing.

Table 14. Prioritized Testing and Investment Cost Schedule

Description	Cost	Timing (months)	Comment
High-Speed Turnouts on RTT	$7.4 million	8	Preliminary for High-Speed Siding
RTT High-Speed Siding	$21.6 million	18–24	Vehicle dynamic characterization up to 130 mph
Passenger Car Structural test facility	$1.5 million	12	Quasi-static vehicle structural testing
Catenary Upgrade	$2 million	2	All on track testing
Shared Track Facility	$10 million	24	Durability testing of track components
Raise Maximum Test Speed	$21–205 million	36	CFR Tier III speeds up to 220 mph

6. Conclusions

This report identifies the magnitude of the testing requirements for HSR. It lists all typically required tests and suggests locations where this testing may be performed, identifies shortcomings in the test facilities, and suggests alternatives while providing ROM cost and timing for these improvements. Also, the report prioritizes testing, tabulates shortcomings of the test facilities, identifies timing for correcting these shortcomings, and estimates investment costs for doing so.

7. References

1. Witte, M., Wilson, N., Fries, R., and Wu, H. (2011 April). *Comparison of FRA Regulations to International High Speed Rail Standards,* DOT/FRA/ORD report, Federal Railroad Administration, Washington, D.C.
2. *Federal Register*/Vol. 75, No. 89 May 10, 2010. "Notice of Proposed Rulemaking for Vehicle-Track Interaction Safety."
3. Association of American Railroads. (2007). *Manual of Standards and Recommended Practices*. Section C-II Specifications for Design, Fabrication, and Construction of Freight Cars, M-1001, "Chapter XI Service Worthiness Tests and Analyses for Freight Cars." Washington, D.C.
4. Federal Railroad Administration. (2010 Sept.). *National Rail Plan - Moving Forward – A Progress Report*, Washington, D.C.
5. Federal Railroad Administration. *Code of Federal Regulations.* "49CFR Part 213 Track Safety Standards," Washington, D.C.
6. Dingqing, L., Wilson, N., and Tajiddini, A. (2011 March). *Needs Assessment – Railroad Test Track Siding Options for High-Speed Testing,* DOT/FRA/ORD report, Federal Railroad Administration, Washington, D.C.

Bibliography

American Public Transportation Association and the International Union of Railways. May 3-5, 2011. *2nd International Practicum on Implementing High-Speed Rail in the United States*, Baltimore, MD

Carr, Gary, Presentation to TRB, Track Research Division, Federal Railroad Administration Office of Research and Development, Washington, DC

Chinese Ministry of Railways, Code for Design of HSR, December 1, 2009

Christener of Bombardier, Questionnaire Infrastructure RP003-01

Christener of Bombardier, Questionnaire Equipment RP002-01

EN 12663-1:2010 Railway Applications – Structural requirements of railway vehicle bodies. Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons.)

EN 13146-8:2002 Railway Applications – Track – Test methods for fastening systems

EN 14363:2005 Railway Applications – Testing for the acceptance of running characteristics of railway vehicles – Testing of running behavior and stationary tests

Federal Railroad Administration. *Code of Federal Regulations*. “49CFR Part 210 Railroad Noise Emission Compliance Regulations,” Washington, DC

Federal Railroad Administration. *Code of Federal Regulations.* “49CFR Part 223 Safety Glazing Standards – Locomotives, passenger Cars, and Cabooses,” Washington, DC

Federal Railroad Administration. *Code of Federal Regulations.* “49CFR Part 229 Railroad Locomotive Safety Standards,” Washington, DC

Federal Railroad Administration. *Code of Federal Regulations.* “49CFR Part 238 Passenger Equipment Safety,” Washington, DC

Johnson of Siemens, Infrastructure Questionnaire RP003_01-V01

Johnson of Siemens Equipment Questionnaire_LT_HDA

Krause, Tammy Lee, originator, PRIIA Specification No. 305-001, Amtrak Specification No. 962, Initial Release August 31, 2010

S130 TT and RT per vehicle, Spanish test planning document

TSI Infrastructure. Commission decision of 20 December, 2007, concerning a technical specification for interoperability relating to the “infrastructure” sub-system of the trans-European HSR system. Document number L071 (2008/217/EC).

TSI Rolling Stock. Commission Decision of 21 February, 2008 concerning a technical specification for interoperability relating to the “rolling stock” sub-system of the trans-European HSR system. Document L084 (2008/232/CE).

Appendix A.
HSR Tests by Type for Testing Strategy

See electronic spreadsheet file: Testing requirements with ROM costs for HSR Testing Strategy_April 2011.xlsx

Appendix A1. Vehicle Tests.pdf

Vehicle Tests

Test Type/Name	Specification	Facility Requirements	Proposed Location	Comments	Source/Reference	Test ROM	Investment ROM
Locomotives							
Characterization Tests							
Couplers and Draft Gear							
Compressive Load without Permanent Deflection	800,000 lb	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$50,000	$90,000
Coupler Carrier							
Compliant with	FRA Rule 229.141 (a) (3)	Passenger car structural test facility	TTC	100K lb vertical	Locomotive spec PRIIA 305	$20,000	$80,000
Push-Back Coupler							
Initiation Load	600,000-pound minimum	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$30,000	$30,000
Pounds of Draft Load during Push-Back Sequence	Capable of transferring 250,000		TTC		Locomotive spec PRIIA 305	$30,000	$30,000
Locomotive Body Structural							
Static End Load at Draft Stops	800,000 lb	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$30,000

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Collision Posts	Per 49CFR 229 Subpart D	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$200,000
Corner Posts	Per 49CFR 229 Subpart D	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$10,000
End Nose Plate	Per AAR S580-08	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$10,000
250K Pounds Applied in any Direction on the Truck Attachments	Per AAR S480-08	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$25,000
Safety Appliances	Per FRA 49CFR 231		Builder		Locomotive spec PRIIA 305		
ROM Totals						**$330,000**	**$505,000**
<u>Locomotives</u>							
Qualification Tests							
Water Tightness Test	Locomotive spec PRIIA 305 Section 21.1.5		Builder		Locomotive spec PRIIA 305		
Cab Pressure Tightness	IT-1601-96		Builder		S130 TT and RT per vehicle		
HVAC Functional Test	Locomotive spec PRIIA 305 Sections 21.1.6, 21.1.7		Builder		Locomotive spec PRIIA 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Locomotive Body Compressive End Load Test	APTA SS-C&S-0034	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$50,000	$90,000
Collision Post Test	APTA SS-C&S-0034	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$200,000
Corner Post Test	APTA SS-C&S-0034	Passenger car structural test facility	TTC		Locomotive spec PRIIA 305	$40,000	$10,000
Truck Coupler and Cable Clearance Test	Locomotive spec PRIIA 305 Section 21.1.11.1	(315-ft radius curve, No. 7 crossover at 12-ft centers)	Builder		Locomotive spec PRIIA 305		
Locomotive Headlight	49CFR 229.125		Builder		Locomotive spec PRIIA 305		
Clearance Test	Locomotive spec PRIIA 305 Section 21.1.12	(roll angle at 6 inches of superelevation with fully worn wheels and broken springs)	Builder		Locomotive spec PRIIA 305	$80,000	$50,000
Locomotive Weight	Locomotive spec PRIIA 305 Section 21.1.13	Scale	Builder		Locomotive spec PRIIA 305		
Horn Test	Per FRA requirements	Sound measurement	Builder		Locomotive spec PRIIA 305	$15,000	

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Wheel Slip/Slide System Test	Locomotive spec PRIIA 305 Section 21.1.15		Builder		Locomotive spec PRIIA 305	$60,000	$20,000
Locomotive Electrical System Tests	Locomotive spec PRIIA 305 Section 21.1.16		Builder		Locomotive spec PRIIA 305		
Air Brake Tests	Per FRA and AAR requirements		Builder		Locomotive spec PRIIA 305	$20,000	
Parking Brake Test (New and Fully Worn Shoes)	Locomotive spec PRIIA 305 Section 21.1.17	3% grade	Builder		Locomotive spec PRIIA 305	$20,000	
Locomotive Sequencing Test	Locomotive spec PRIIA 305 Section 21.1.18		Builder		Locomotive spec PRIIA 305	$25,000	
Sound Level Test	Per 49CFR 229.121 (Static and dynamic)	Sound measurement	Builder		Locomotive spec PRIIA 305	$50,000	
HEP Test	Locomotive spec PRIIA 305 Section 21.1.20		Builder		Locomotive spec PRIIA 305	$50,000	$200,000
Locomotive On-Track Test	Locomotive spec PRIIA 305 section 21.1.21		TTC	TTC test track capable to 160 mph	Locomotive spec PRIIA 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
500 Miles of Nonrevenue Service Operation	Locomotive spec PRIIA 305 section 21.1.21	(1 locomotive + 4 PRIIA compliant cars) IWS, 125 mph	Final corridor	Acceleration/ deceleration rates, traction motor current, brake pipe pressure, locomotive BCP, dynamic brake current, speed, distance, time, ride quality indices, wheel slip/slide system performance	Locomotive spec PRIIA 305	$400,000	$700,000
Fuel Fill Tests	Locomotive spec PRIIA 305 section 21.1		Builder		Locomotive spec PRIIA 305		
Twisted Track	PF-0102	Precision track segment	TTC	Speed limitation may apply	S130 TT and RT per vehicle	$50,000	$30,000
Suspension Coefficient	PF-0105		Full Train		S130 TT and RT per vehicle		
Electrical Interface Test	tbd		Full Train		S130 TT and RT per vehicle		
External Door Type Tests	PF-0087		TTC		S130 TT and RT per vehicle		
ASFA Interferences by Return Current in Rail	3EH-213455-0001		TTC		S130 TT and RT per vehicle		
Noise Dynamic	PF-0127		TTC		S130 TT and RT per vehicle	$50,000	

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Running Dynamics	PF-0102		TTC	Speed limitation may apply	S130 TT and RT per vehicle		
Interferences with the Signaling System AC	3EH-214246-0001		TTC		S130 TT and RT per vehicle		
Interferences with the Signaling System DC and Maximum Voltage	3EH-214247-0001		TTC		S130 TT and RT per vehicle		
Overvoltage Due to Harmonics AC	3EH-214246-0001		TTC		S130 TT and RT per vehicle		
Track Effect (Pressure Wave Effect on Platform)	tbd		Destination Corridor	No platform at TTC	S130 TT and RT per vehicle		
Wipers	tbd		Builder		S130 TT and RT per vehicle		
Aerodynamic Effects, Tunnels	tbd		Laboratory		S130 TT and RT per vehicle		
Axial Displacement of Wheels	tbd		Builder		S130 TT and RT per vehicle	$25,000	$15,000
Cab Voice Recorder	3EH-212847-0001		Builder		S130 TT and RT per vehicle		
ROM Totals						**$975,000**	**$1,315,000**
Coaches							
Characterization Tests							

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
<u>Carbody Structural</u>						Performed at TTC	Performed at TTC
Vertical Load Test	19.5.1.6 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder	100K pound vertical	PRIIA BiLevel spec 305	$100,000	$400,000
End Sill Compression Load Test	19.5.1.7 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$50,000	$100,000
Compression Load at the Draft Stop	19.5.8 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$50,000	$50,000
Diagonal Jacking Test	19.5.1.9 per APTA SS-C&S-034-99		Builder		PRIIA BiLevel spec 305	$30,000	$10,000
Collision Post Elastic Test	19.5.1.10 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$40,000	$200,000
Corner Post Longitudinal Load	19.5.1.11 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$40,000	$10,000
Corner Post Transverse Load	19.5.1.12 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$40,000	$10,000
Collision Post Elastic–Plastic Test	19.5.1.13 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$40,000	$10,000

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Corner Post Elastic–Plastic Test	19.5.1.14 per APTA SS-C&S-034-99	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305	$40,000	$10,000
Crash Energy Management (CEM)	19.5.1.15 per APTA SS-C&S-034-99		Builder	Builder does component testing. System testing at TTC.	PRIIA BiLevel spec 305		
Wheelchair Lift	ADA requirements		Builder		PRIIA BiLevel spec 305		
<u>Trucks</u>							
Allowable Stresses	19.5.2.1		Builder		PRIIA BiLevel spec 305		
Equalization Test	Per APTA SS-M-0140-06 for car type G		Builder		PRIIA BiLevel spec 305	$40,000	$25,000
Truck Frame and Bolster Maximum Load Test	19.5.2.3		Builder		PRIIA BiLevel spec 305	$50,000	$100,000
Truck Frame Overload Test	19.5.2.4	Strain gages	Builder		PRIIA BiLevel spec 305		
Truck Frame Fatigue Test	Per APTA RP-M-009-98		Builder		PRIIA BiLevel spec 305	$50,000	$100,000
Primary Suspension Test (Load Deflection and Creep Tests)	19.5.2.6		Builder		PRIIA BiLevel spec 305	$50,000	$100,000
<u>Couplers</u>							

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Complete Coupler, Draft Gear, Radial Connector, Yoke, Coupler Carrier, and Uncoupling Mechanism	19.5.3 Per FRA & APTA regs	Passenger car structural test facility	Builder		PRIIA BiLevel spec 305		
<u>Brakes</u>							
Brake Pad and Shoe Force Tests	19.5.4.1		Builder		PRIIA BiLevel spec 305		
Brake Component Fatigue Tests	19.5.4.2	(1M cycles at AW2)	Builder		PRIIA BiLevel spec 305		
Friction Brake System Endurance Tests	19.5.4.3	(1M cycles)	Builder		PRIIA BiLevel spec 305		
Brake Capacity Tests on a Full-scale Dynamometer	19.5.4.4 Amtrak 80-276	125 mph	Builder		PRIIA BiLevel spec 305		
Handbrake Tests	19.5.4.5 per APTA SS-M-006-98		Builder		PRIIA BiLevel spec 305		
<u>Door System</u>							
System Integrity	19.5.5.1	500K cycles	Builder		PRIIA BiLevel spec 305		
Side Door Safety	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Functionality and Operation	19.5.5.2		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Opening and Closing Times and Speeds	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Train Line Controls, Indicators and Interlocks	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Compliance with Applicable Regulations	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Reliability	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Maintainability	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Sustained and Compliant Performance under all Specified Operational and Environmental Conditions	19.5.5.2		Builder		PRIIA BiLevel spec 305		
Side Door Reliability Test	19.5.5.1	(500K cycles)	Builder		PRIIA BiLevel spec 305		
End Door Reliability Test	19.5.5.3	(100K cycles)	Builder		PRIIA BiLevel spec 305		
Interior							
Overhead Luggage Bins	19.5.6.1	(Strength Test, 8/4/4g crashworthiness requirement, 50K cycle endurance	Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
		test					
Seats	per APTA SS-C&S-016-99		Builder		PRIIA BiLevel spec 305		
Seat Tests	19.5.6.3		Builder				
HVAC							
HVAC Unit Tests	19.5.7.1 ANSI/ASHRAE Std 37 ASHRAE Standard 41.1		Builder		PRIIA BiLevel spec 305		
Air Balance Test	19.5.7.3		Builder		PRIIA BiLevel spec 305		
Temperature Control Test	19.5.7.4 Amtrak specification963		Builder		PRIIA BiLevel spec 305		
Refrigerant Charge Test	19.5.7.5		Builder		PRIIA BiLevel spec 305		
HVAC System Tests	19.5.7.6 ARI Standard 700		Builder		PRIIA BiLevel spec 305		
Control Scan Test (Thermostat Operations)	19.5.7.7		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Vehicle Heat Transfer Test (Carbody Insulation Effectiveness)	19.5.7.8		Builder		PRIIA BiLevel spec 305		
Cooling System Tests	19.5.7.9	High ambient hot room	Builder		PRIIA BiLevel spec 305		
Pull Down and Steady State	19.5.7.9.1		Builder		PRIIA BiLevel spec 305		
Door Cycling Test (Cooling)	19.5.7.9.2		Builder		PRIIA BiLevel spec 305		
High Ambient Test	19.5.7.9.3		Builder		PRIIA BiLevel spec 305		
High Pressure Cutout Test	19.5.7.9.4		Builder		PRIIA BiLevel spec 305		
Condensate Carryover Test	19.5.7.9.5		Builder		PRIIA BiLevel spec 305		
Low Ambient Temperature Test	19.5.7.9.6		Builder		PRIIA BiLevel spec 305		
Low Ambient Temp Test with High Internal Load	19.5.7.9.7		Builder		PRIIA BiLevel spec 305		
Heating System Tests	19.5.7.10		Builder		PRIIA BiLevel spec 305		
Layover Verification Test	19.5.7.10.1		Builder		PRIIA BiLevel spec 305		
Steady State Heating at Design Conditions Test	19.5.7.10.2		Builder		PRIIA BiLevel spec 305		
Steady State Heating (Minimum Voltage)	19.5.7.10.3		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Door Cycling Test (Heating)	19.5.7.10.4		Builder		PRIIA BiLevel spec 305		
Steady State Heating Tests	19.5.7.10.5		Builder		PRIIA BiLevel spec 305		
Overhead Heater Safety Tests	19.5.7.10.6		Builder		PRIIA BiLevel spec 305		
Freeze Protection Tests	19.5.7.10.7		Builder		PRIIA BiLevel spec 305		
Cab Heating Tests	19.5.7.10.8		Builder		PRIIA BiLevel spec 305		
Equipment Room Heater Test	19.5.7.10.9		Builder		PRIIA BiLevel spec 305		
Lighting							
Lighting Fixture Performance Test	19.5.8.1		Builder		PRIIA BiLevel spec 305		
Ballast Qualification	19.5.8.2		Builder		PRIIA BiLevel spec 305		
Independent Power Sources (Emergency Lighting)	19.5.8.3		Builder		PRIIA BiLevel spec 305		
Marker Light Certification	Per FRA 49CFR 221		Builder		PRIIA BiLevel spec 305		
Lighting Intensity–Interior	Per APTA RP-E-012-99		Builder		PRIIA BiLevel spec 305		
Lighting Intensity–Exterior	Per FRA 49CFR 229.125 and 229.133		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Emergency Lighting Intensity and Duration	Per APTA SS-E-013-99 and FRA 49CFR 238.115		Builder		PRIIA BiLevel spec 305		
Communications/ OTIS							
PA/IC System Performance	19.5.9.1		Builder		PRIIA BiLevel spec 305		
Destination Sign System Performance	19.5.9.2		Builder		PRIIA BiLevel spec 305		
EMI/EMC	Per APTA SS-E-010-98		Builder		PRIIA BiLevel spec 305		
Wayside Equipment Tests (GPS, Radio Systems, LAN, AVL, CDT)	19.5.9.4		Builder		PRIIA BiLevel spec 305		
Electrical							
Electrical Load/Phase Balance/Power Factor	19.5.10.1		Builder		PRIIA BiLevel spec 305		
Trainline Tests	19.5.10.2		Builder		PRIIA BiLevel spec 305		
Battery and Battery Charger Tests	19.5.10.3		Builder		PRIIA BiLevel spec 305		
Battery Capacity Tests	19.5.10.3.1		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Battery/Charger Performance	19.5.10.3.2		Builder		PRIIA BiLevel spec 305		
Battery Tilt and Shock at 45-degree tilt and 8/4/4g acceleration	Per FRA 49CFR 238.115		Builder		PRIIA BiLevel spec 305		
Dielectric Strength	3EH-213366-0001		Builder		S130 TT and RT per vehicle		
Insulation Impedance	3EH-213366-0001		Builder		S130 TT and RT per vehicle		
Safety and Earthing Connections	3EH-213366-0001		Builder		S130 TT and RT per vehicle		
110VDC Circuit	3EH-212788-0001		Builder		S130 TT and RT per vehicle		
Auxiliary Supply 3x400v AC and Distribution	3EH-212788-0001		Builder		S130 TT and RT per vehicle		
Food Service							
Crashworthiness Structural Requirements for Carts, Chillers, and Appliances	19.5.11.1		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Elevator Performance	19.5.11.2		Builder		PRIIA BiLevel spec 305		
Refrigeration System Performance	19.5.11.3		Builder		PRIIA BiLevel spec 305		
Water and Waste							
Water and Waste System Performance	19.5.12.1		Builder		PRIIA BiLevel Passenger Rail Car Specification		
ROM Totals						**$620,000**	**$1,125,000**
ROM Totals for Cab and Controls							
Train Control, Event Recorder, Train Data System and Video Equipment Qualification Tests	19.5.13.1		Builder	Subject to review and approval by the customer, FRA, Amtrak, and host railroads	PRIIA BiLevel spec 305		
Operation of PTC System	19.5.13.2		Builder		PRIIA BiLevel spec 305		
Cab Audio Alarm Levels Performance	19.5.13.3		Builder		PRIIA BiLevel spec 305		
Event Recorder/Video System Performance	19.5.13.1		Builder		PRIIA BiLevel spec 305		
Horn and Bell Performance	per FRA 49CFR 229		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Pilot Car and Pilot Train Testing							
Roll Angle Tests	19.5.14.1 49CFR 213.57	(AW0, AW1, & AW3, 7 inches of superelevation, meets clearance diagram)	Builder		PRIIA BiLevel spec 305	$100,000	$50,000
Door Controls	19.5.14.2.1		Builder		PRIIA BiLevel spec 305		
End of Train Identification	19.5.14.2.1		Builder		PRIIA BiLevel spec 305		
Locomotive Control	19.5.14.2.1		Builder		PRIIA BiLevel spec 305		
PA, IC and PIS Communications and Data Transfer	19.5.14.2.1		Builder		PRIIA BiLevel spec 305		
HEP and Power Distribution	19.5.14.2.1		Builder		PRIIA BiLevel spec 305		
Air Brake Application and Release	19.5.14.2.1		Builder		PRIIA BiLevel spec 305		
Compliance with Track Geometry Requirements Including Curve and Crossover Negotiation	19.5.14.2.2		Builder		PRIIA BiLevel spec 305	$200,000	$450,000
Carbody Clearance	19.5.14.2.2		Builder				
Truck Swing	19.5.14.2.2		Builder				

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Coupler Swing	19.5.14.2.2		Builder				
MU, COMM, and HEP Cables	19.5.14.2.2		Builder				
Brake Pipe and Main Reservoir Air Hoses	19.5.14.2.2		Builder				
Diaphragms, Buffer Plates and Diaphragm Curtains	19.5.14.2.2		Builder				
Pilot Train Compatibility with Existing Amtrak Bilevel Cars	19.5.14.2.2	(California Car, Superliner, Surfliner)	Builder		PRIIA BiLevel spec 305		
High-Speed Testing	Per 49CFR 213.345	125 mph, instrumented car, IWS	TTC	TTC test track capable to 165 mph	PRIIA BiLevel spec 305	$200,000	$450,000
Interior and Exterior Noise and Vibration Tests	ANSI Standard S1.4 Type2, A weighted slow		Builder		PRIIA BiLevel spec 305	$85,000	$50,000
Friction Brake Performance Test	19.5.14.2.8		Builder		PRIIA BiLevel spec 305	$150,000	
Ride Quality Tests (AW1)	19.5.14.2.9	MCAT track segment	TTC		PRIIA BiLevel spec 305	$150,000	
ROM Totals						**$885,000**	**$1,000,000**
Production Tests (All cars including Pilot Cars)							

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Carbody Watertightness Tests	19.6.1.1	Water spray nozzles	Builder		PRIIA BiLevel spec 305		
Water Spray–Bare Shell Watertightness Test	19.6.1.1.1		Builder		PRIIA BiLevel spec 305		
Water Spray–Completed Car	19.6.1.1.2		Builder		PRIIA BiLevel spec 305		
Wheelchair Lift Functionality Check	19.6.1.2		Builder		PRIIA BiLevel spec 305		
AEI Tag Functionality and Data Integrity Check	19.6.1.3		Builder		PRIIA BiLevel spec 305		
NDE Inspection of all Truck Components (Frames, Bolsters, and other Primary Structural Members)	19.6.2.1	NDE technology—preferably radiographic for inspecting welds and castings	Builder		PRIIA BiLevel spec 305		
Truck Weight	19.6.2.2		Builder		PRIIA BiLevel spec 305		
Carbody Leveling and Floor Height	19.6.2.3		Builder		PRIIA BiLevel spec 305		
Truck Attachment, Leveling and Coupler Heights (AW0)	19.6.2.3.1		Builder		PRIIA BiLevel spec 305		
Coupler Height and Operation	19.6.3		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Single Car Air Brake Test and Pneumatic System Operation	Per APTA SS-M-005-98 and AAR S471		Builder		PRIIA BiLevel spec 305		
Hand Brake Operation	19.6.4.2		Builder		PRIIA BiLevel spec 305		
Wheelslide Control System Operation	19.6.4.3		Builder		PRIIA BiLevel spec 305		
Door System/Door Safety Tests	19.6.5	800 cycles	Builder		PRIIA BiLevel spec 305		
Interior Doors/Hardware Functionality Tests	19.6.6		Builder		PRIIA BiLevel spec 305		
Seat Functionality Tests	19.6.6.2		Builder		PRIIA BiLevel spec 305		
Overhead Luggage Storage Bins Functionality Tests	19.6.6.3		Builder		PRIIA BiLevel spec 305		
HVAC System Functionality Tests	19.6.7		Builder		PRIIA BiLevel spec 305		
Lighting System Functionality Tests	19.6.8		Builder		PRIIA BiLevel spec 305		
Communications/ OTIS Functionality Tests	19.6.9		Builder		PRIIA BiLevel spec 305		
Electrical System Functionality Tests	19.6.10 APTA RP-E-007-98R1 APTA SS-E-001-98		Builder		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Food Service Equipment Functionality Tests	19.6.11		Builder		PRIIA BiLevel spec 305		
Water and Waste Systems Functionality Tests	19.6.12		Builder		PRIIA BiLevel spec 305		
Cab and Controls Functionality Tests	19.6.13 APTA SS-M-011-99 49CFR 229.125		Builder		PRIIA BiLevel spec 305		
Car Weight	19.6.14		Builder		PRIIA BiLevel spec 305		
Clearance Diagram Compliance Tests	19.6.14.1.2		Builder		PRIIA BiLevel spec 305		
<u>Coaches</u>							
Qualification Tests							
<u>Carbody Structural</u>							
Vertical Load Test	APTA SS-C&S-034-99	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$50,000	$200,000
End Sill Compression Load Test	APTA SS-C&S-034-99	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$50,000	$50,000
Compression Load Test at the Draft Stops	APTA SS-C&S-034-99	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Diagonal Jacking Test	APTA SS-C&S-034-99	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$40,000	$10,000
Collision Post Elastic Test	APTA SS-C&S-034-99 & APTA SS-C&S-034-99 Rev 2	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$40,000	$200,000
Corner Post Longitudinal Load Test	APTA SS-C&S-034-99	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$40,000	$10,000
Corner Post Transverse Load Test	APTA SS-C&S-034-99	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$40,000	$10,000
Collision Post Elastic–Plastic Test	APTA SS-C&S-034-99 & APTA SS-C&S-034-99 Rev 2	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$40,000	$10,000
Corner Post Elastic–Plastic Test	APTA SS-C&S-034-99 & APTA SS-C&S-034-99 Rev 2	Passenger car structural test facility	TTC		PRIIA BiLevel spec 305	$40,000	$10,000
CEM Test	APTA SS-C&S-034-99		TTC		PRIIA BiLevel spec 305	$300,000	$100,000
Wheelchair Lift Test	per applicable ADA requirements		Builder		PRIIA BiLevel spec 305		
Acceptance Tests							

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Functionality Tests of all Equipment	19.7.2	Diagnostic test equipment	Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Compatibility Tests with other Amtrak Rolling Stock	19.8.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Door Control, Door System Status and Traction Inhibit	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Locomotive control	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
PA, IC and PIS Communications and Data Transfer	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
HEP and Power Distribution	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Air Brake Application and Release	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Carbody Clearance	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Truck Swing	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		

Vehicle Tests							
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**Comments**	**Source/Reference**	**Test ROM**	**Investment ROM**
Coupler Swing	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
MU, COMM and HEP Cables	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Brake Pipe and Main Reservoir Air Hoses	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Diaphragms and Diaphragm Curtains	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Reliability and Post-Delivery Tests (MTBF Monitoring for a Period of 365 Days)	19.7.		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
Software Files	19.7.2		Destination Corridor		PRIIA BiLevel Passenger Rail Car Specification		
ROM Totals						**$640,000**	**$600,000**

Appendix A2. Track Tests.pdf

Track Tests					
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**
Characterization Tests					
Test Methods for Fastening Systems—In Service Testing	BS EN 13146-8:2002	RTT at TTC	TTC/HS Corridor	$100,000	In situ testing at TTC
Improved Rail Steel		Shared Track Facility	TTC/HS Corridor	$100,000	Metallurgical Tests lab & field
Automated Track Inspection Equipment			TTC/HS Corridor	$75,000	Evaluation of existing onboard inspection systems
Special Trackwork and HSR Components		Shared Track Facility	TTC		Requires installation of test articles—speed capable to 160 mph
Range of Track Stiffness		RTT at TTC	TTC	$150,000	Use of TLV type of test system
HSR Track Maintenance Standards		RTT at TTC	TTC	$200,000	Development of process—time
Rolling Contact Fatigue		RTT at TTC	TTC/HS Corridor	$200,000	
Accuracy of Track Geometry Vehicles for HS Operations			TTC/HS Corridor	$75,000	Evaluation of existing onboard systems
Slab/Ballasted Track Testing		RTT at TTC	TTC	$100,000	
Rail Profile and Gage Testing		RTT at TTC	TTC	$75,000	Evaluation of existing systems—non contacting onboard systems
Rom Totals				**$1,075,000**	
Qualification Tests					
Ground Borne Vibration Testing			HS Corridor	**$100,000**	Location sensitive test

Appendix A3. Signal Tests.pdf

Signal Tests					
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**
Characterization Tests					
Signaling Equipment	ETCS Level 2 assumed		TTC/ Destination Corridor		Research and development testing at TTC requires installation of equipment
Signal System	ETCS Level 2 assumed		TTC/ Destination Corridor		Research and development testing at TTC requires installation of equipment
Continuous Test Track with Two Radio Stations for Speed		250 mph capable	TTC/ Destination Corridor		TTC max speed 165 mph
Interface Testing with New Vehicles	ETCS Level 2		TTC/ Destination Corridor		Research and development testing at TTC requires installation of equipment
EMI and RFI Tolerance			TTC/ Destination Corridor	$100,000	Use of subcontractor—Retlif Labs development of EMI/RFI to then test system tolerances
Software Testing			TTC	$100,000	
Electrical Resistance	EN 13146-5		TTC/ Destination Corridor	$100,000	
Qualification Tests					
Software Qualification					
ROM Totals				**$300,000**	

Appendix A4. Catenary Tests.pdf

Catenary Tests					
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**
Characterization Tests					
Catenary Registration	TSI Infrastructure L071 2008-217-EC sec. 4.2.3		TTC/ Destination Location		Updates may be required to TTC catenary
Pantograph and Catenary System Performance Testing	BS EN 50206-1:2010		TTC/ Destination Location		Updates may be required to TTC catenary
EMI and RFI Vehicle Induced and Ambient			TTC/ Destination Location		
Pantograph Contact Force	BS EN 50206-1:2010		TTC/ Destination Location	$25,000	Static
Automatic Train Protection			TTC/ Destination Location		Train Control
Electrical Interface Test			TTC/ Destination Location		
Qualification Tests					

Appendix A5. Materials Tests.pdf

Materials Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
Materials Certification Tests						
Exterior Glazing	49 CFR 223 requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305
Interior Materials	Per smoke, flame & toxicity requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305
Subfloor Panels	Per strength & impact resistance requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305
Stainless and Carbon Steel used in Car Shell	Per strength, composition & performance standards		Factory/ Laboratory			PRIIA BiLevel Spec 305
Components used in the Truck, Suspension and Couplers	Per strength composition & performance standards		Factory/ Laboratory			PRIIA BiLevel Spec 305
Insulation Materials	Per applicable insulation performance standards		Factory/ Laboratory			PRIIA BiLevel Spec 305
Materials used in Food Prep Areas, Portable Water Systems, Trash Storage	Per applicable public health standards		Factory/ Laboratory			PRIIA BiLevel Spec 305
Interior and Exterior Emergency Signage Materials	Per FRA emergency exit signage requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305
Emergency Power Sources	Per FRA emergency exit pathway requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305
Emergency Equipment	Per FRA regulations and other applicable requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305
Exterior Graphics	Per applicable performance requirements		Factory/ Laboratory			PRIIA BiLevel Spec 305

Appendix A6. System Tests.pdf

System Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
Characterization Tests						
<u>Suspension System</u>						
Wheel Load Equalization	Per APTA SS-M-014-06 Class G	RTT High-Speed Siding	TTC	$100,000	*TTC capable only to 160 mph	Locomotive spec PRIIA 305
Static Lean	Per FRA 49CFR 213.57 and FRA 49CFR 213.329		TTC	$60,000	Separate multiple car tests—e.g., power car, coach car ROM is per car	Locomotive spec PRIIA 305
Track Dynamic Maximum P2 Forces	82,000 lb for a 0.5-degree dip angle at all speeds up to 125 mph	RTT High-Speed Siding with MCAT segments	TTC	$150,000	Installation of "bump(s)" and testing	Locomotive spec PRIIA 305
Dynamic Response on FRA Class 1 through 5 Track (Constant Curving, Spiral Negotiation, Twist & Roll (90 mph), Pitch & Bounce (90 mph), Yaw & Sway (90 mph), Dynamic Curving)	Per Chapter XI of AAR M-1001		TTC	$625,000	Provision of test facility and instrumentation IWS inclusive. IWS estimated at $450,000. Testing estimated at $15,000 per day × 5 days	Locomotive spec PRIIA 305
Dynamic Response on FRA Class 6 and 7 Track, MCAT Simulations,	Per 49CFR 213.345		TTC	$200,000		Locomotive spec PRIIA 305

System Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
VTI Safety Limits	Per 49CFR 213.333 and APTA SS-M-017-06 using a minimum conicity of 0.3, IWS testing required.	RTT High-Speed Siding	TTC	$200,000		Locomotive spec PRIIA 305
Brake System						
Wheel Slip-Slide Control System—Maximum jerk rate of 1.5 mph/s/s			Builder	$150,000	Can be performed at TTC. Spray system installed and full instrumentation of multiple tachometers and reference speeds.	Locomotive spec PRIIA 305
Braking Rates	21.1.3		TTC	$100,000	Concurrent with locomotive testing at various vehicle weights.	Locomotive spec PRIIA 305
Parking Brake must hold Locomotive on a 3% grade		3% grade	Corridor		TTC does not have a 3% grade	Locomotive spec PRIIA 305
Road Brake Test (loco + 4 cars)—deceleration rates, stopping distance, wheel temperatures, spin/slide control			TTC	$100,000		Locomotive spec PRIIA 305
Blended brake test—deceleration rates, stopping distance			TTC	$100,000		Locomotive spec PRIIA 305
Complete Train						

System Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
Dimensions with Bogie	PC-TC036-B01.00	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Axle Load	PF-0086	Static Test—catenary required	Builder			S130 TT and RT per vehicle
External Lighting	3EH-213062-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Internal Illumination	3EH-212868-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Cab Voice Recorder	3EH-212847-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
ASFA Stand Alone	3NGG509459.PRS	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Electrical Resistance between Wheels	PF-0084	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Pantograph Contact Force, Current Flow, and Control AC	3EH-213327-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Pantograph Contact Force, Current Flow and Control DC	3EH-214180-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Air Circuit	PE:775.00.00	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Pneumatic Circuit	PE:775.00.00	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Compressed Air and Brake Via Brake Pipe	PF-0120	Static Test—catenary required	Builder			S130 TT and RT per vehicle

System Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
Automatic Train Protection ETCS + STM LZB, EBICAB (900+ASFA)	3NGM004183D000	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Parking Brake	PE:775.00.00	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Internal Sockets 230VAC	3EH-212988-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Dead Man	3EH-212988-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Heating, Ventilation, Cab Air-Conditioning	PF-0131 / PF-0124	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Dynamic Gauge	PF-0113	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Electrical Interface Test	PTIR08-93	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Electrical Interface Test	PTIS08-30	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Speaker System	3EH-213443-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Rearview Mirror Video System	3EH-212949-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Safety Systems	PTIS08-29	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Train Composition Visual Inspection	PC-TC036-L20.00	Static Test—catenary required	Builder			S130 TT and RT per vehicle

System Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
Sanding	PTIR08-85	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Wheel Flange Lubrication	PTIR08-84	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Analog Radio (Artexo)	TR-100E/2	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Alarm Handle	EN50215:2009 8.14.7	Static Test—catenary required	Builder			S130 TT and RT per vehicle
External Lighting	3EH-213062-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
All Control Functions from Control Device, Switch, Press Button	3EH-213815-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Wheel Seizure Detection	PF-0121	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Basic Functions Vehicle Operation	3EH-213127-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Bug Nose, Front-, Back- and Emergency Coupling Semi Static	tbd	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Doors and their Respective Activation Control	PTIR08-91	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Rearview Mirror Video System	3EH-212949-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle

System Tests						
Test Type/Name	**Specification**	**Facility Requirements**	**Proposed Location**	**ROM Cost**	**Comments**	**Source/Reference**
Basic Functions Vehicle Operation	3EH-213127-0001	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Bug Nose, Front-, Back- and Emergency Coupling	PTIR08-88	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Train Composition Visual Inspection	PC-TC036-L20.00	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Digital Radio (GSM-R)	4449.001.00001.IV	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Suspension Coefficient	PF-0105	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Noise Static	PF-0127	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Horn Static	PF-0106	Static Test—catenary required	Builder			S130 TT and RT per vehicle
Aerodynamic Testing		Wind tunnel	Laboratory		Mostly CFD modeling validation	
Signal System					See Signal tab on worksheet	
Wayside Detectors for HSR Operations		RTT at TTC	TTC		Research and development testing at TTC requires installation of equipment	
ROM Total				**$1,785,000**		
Qualification Tests						
Vehicle Dynamic Qualification	49CFR 213.345	RTT High Speed Turnout with MCAT segment	TTC	$7,426,000	Test track segment required. Add price of IWS at $450,000; Speed limited to 130 mph	
ROM Totals				**$9,211,000**		

Appendix B. Proposals to Upgrade RTT at TTC including ROM Cost Estimates

#	Description	Max. Curve Speed (mph)	Est. Max. Speed (mph)	Cost ($M)	Time (months)
1	By-pass RTT reverse curve	162	180	33	28
2	Extend RTT 6.8 miles to eliminate reverse curve	162	200	53	32
3	Extend RTT 14.4 miles to northern property limit	187	235	88	36
4	Extend RTT 17.3 miles using LIMRV alignment	187	230	95	36
5	New Ultra High Speed Loop within property limits	225	270	146	36
6	New Ultra High Speed Loop extending north of property limit	225	305	205	36

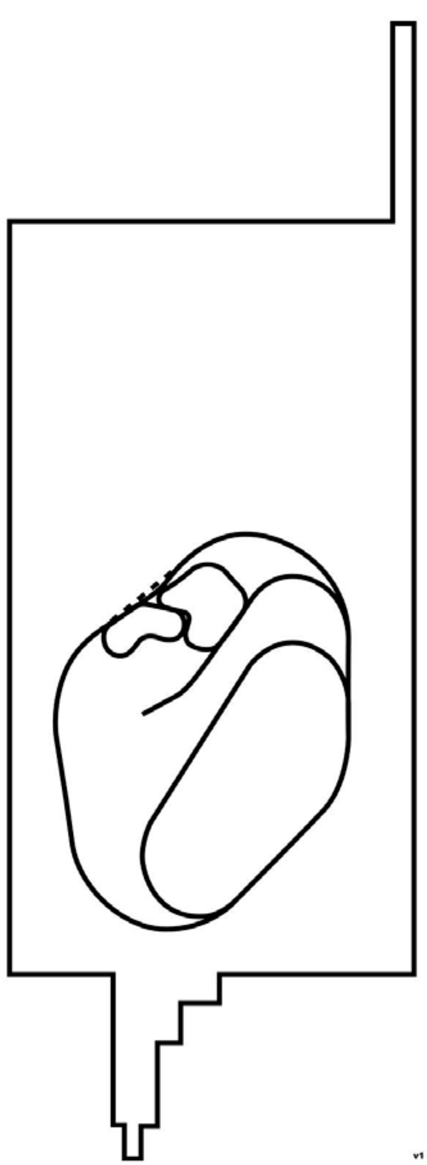


Figure B1. RTT Proposal No. 1

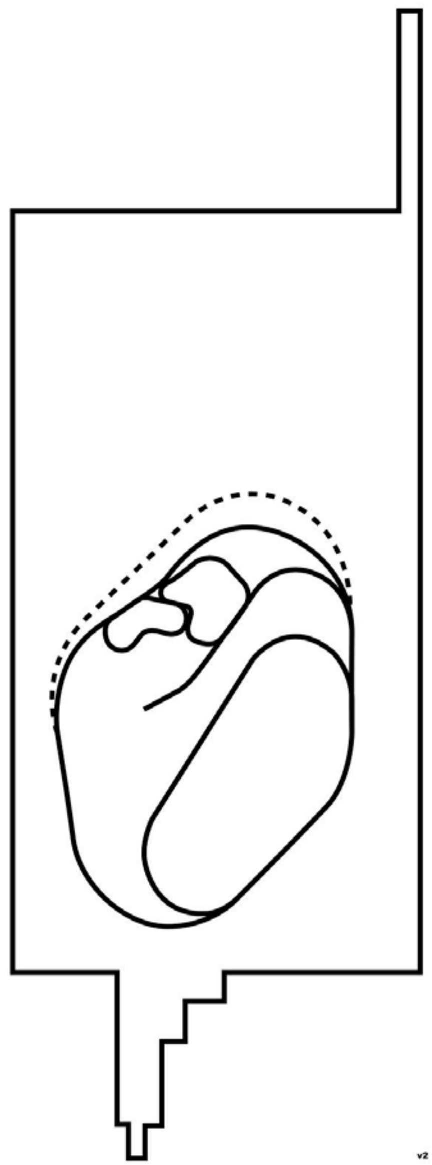


Figure B2. RTT Proposal No. 2

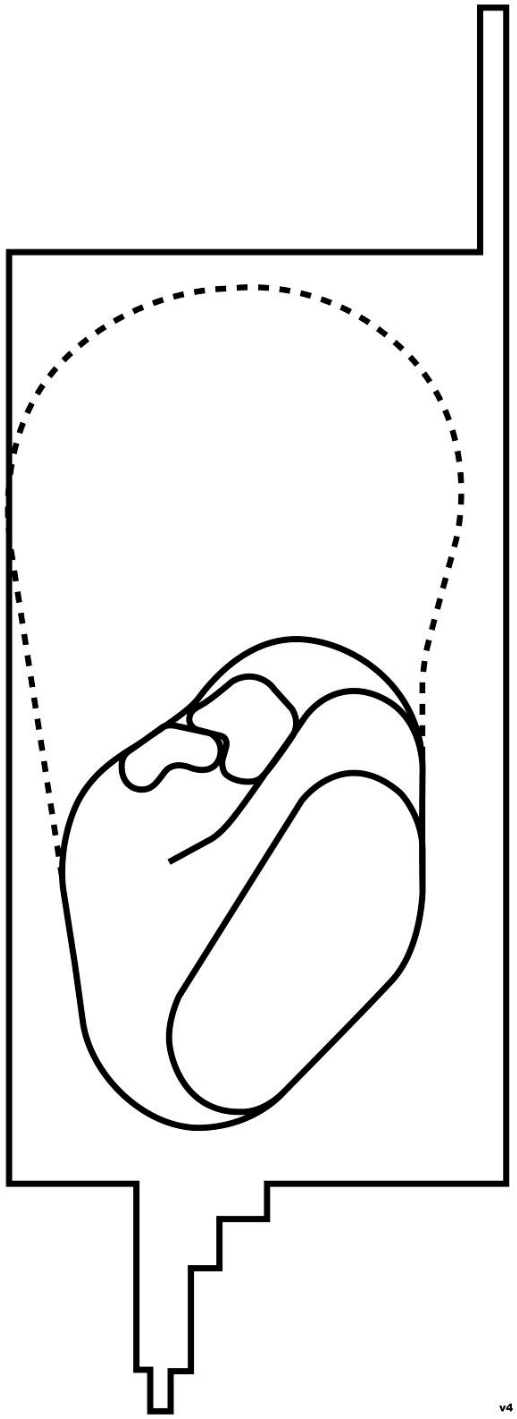


Figure B3. RTT Proposal No. 3

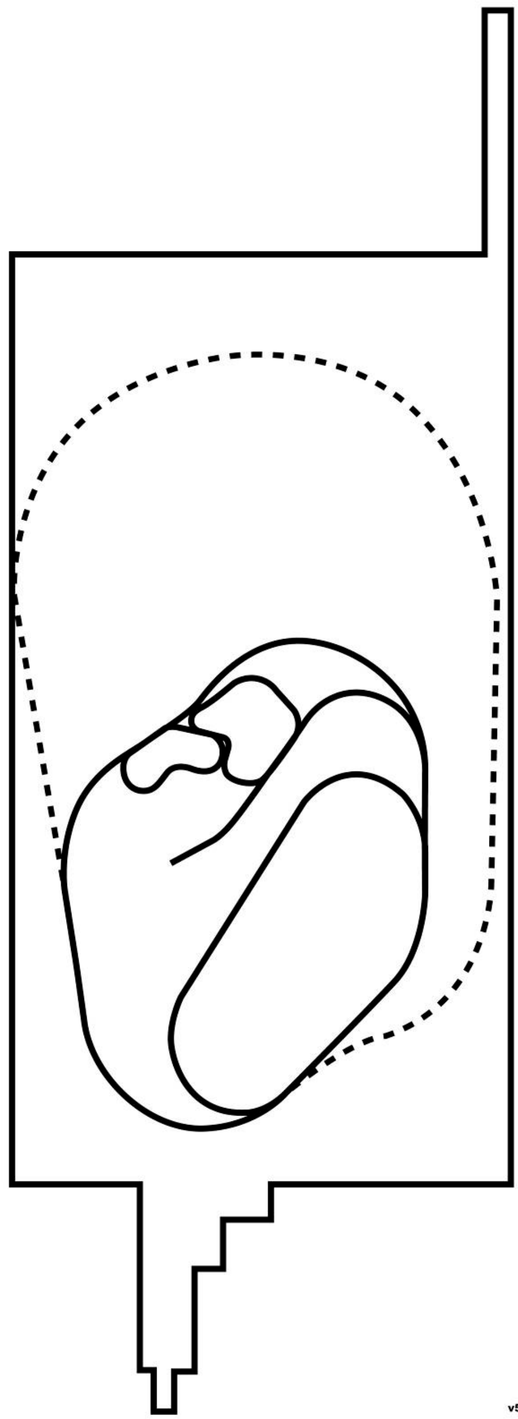


Figure B4. RTT Proposal No. 4

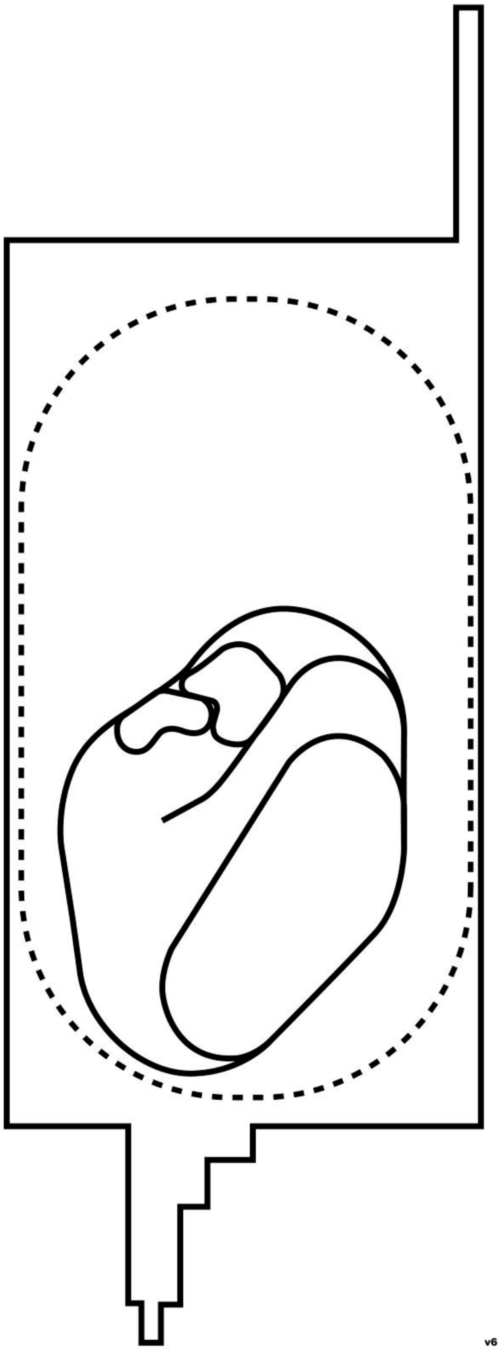


Figure B5. RTT Proposal No. 5

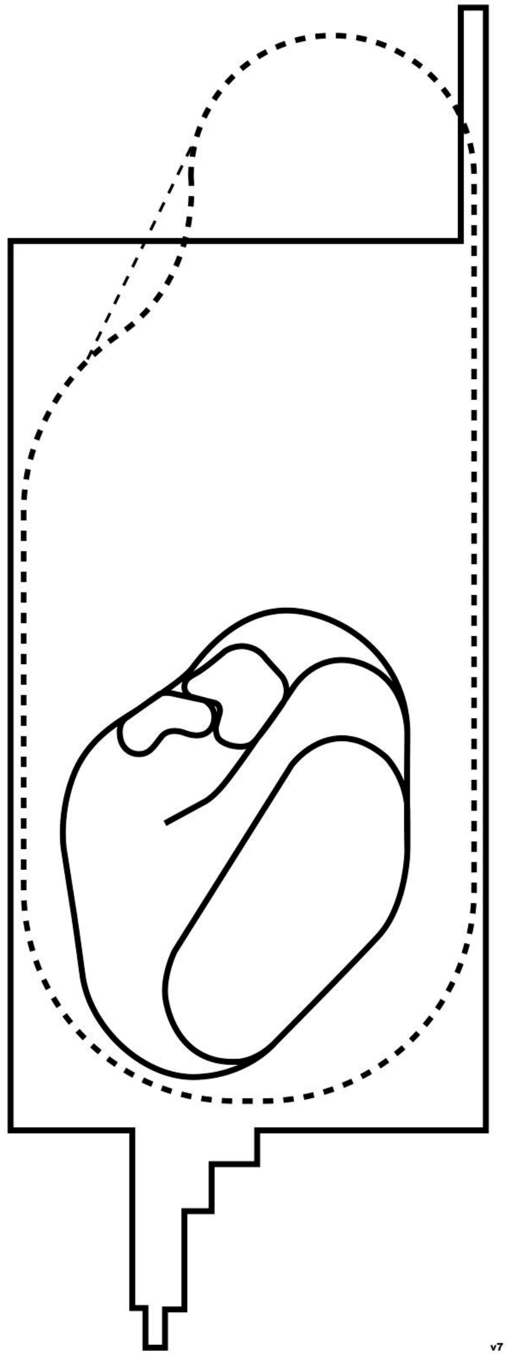


Figure B6. RTT Proposal No. 6

Abbreviations and Acronyms

AAR	Association of American Railroads
APTA	American Public Transportation Association
C&TC	communication and train control
CFR	Code of Federal Regulations
EMI	electromagnetic interface
ETCS	European Train Control System
FAST	Facility for Accelerated Service Testing
FRA	Federal Railroad Administration
GPR	ground penetrating radar
GRMS	gage restraint measurement system
HEP	head-end power
HSIPR	high-speed and intercity passenger rail
HSR	high-speed rail
HTL	High Tonnage Loop (track at TTC)
HVAC	heating, ventilating, and air-conditioning
MCAT	minimally compliant analytical track
OTIS	Online Tracking Information System
PRIIA	Passenger Rail Investment and Improvement Act
PTC	positive train control
RDTF	Rail Defect Test Facility (at TTC)
RFI	radio frequency interference
ROM	rough order of magnitude
RSAC	Railway Safety Advisory Committee
RTT	Railroad Test Track (at TTC)
TTC	Transportation Technology Center (the site)
TTCI	Transportation Technology Center, Inc. (the company)
UIC	International Union of Railways
VTI	vehicle track interaction
WIU	wayside interface unit
WRM	Wheel Rail Mechanism (track at TTC)