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Needs Assessment—Railroad Test Track Siding Options for High Speed Testing

Office of Research, Development, and Technology
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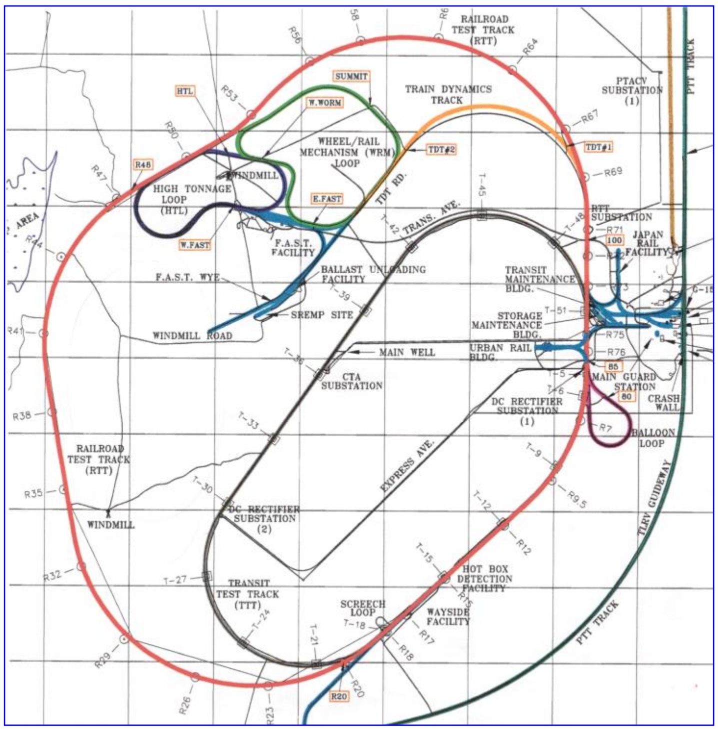

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13. ABSTRACT (Maximum 200 words)
This report presents the results and findings from a study titled "Needs Assessment—Railroad Test Track (RTT) Siding Options for High Speed Testing." This study was conducted to (1) determine potential capabilities that the proposed siding test track for the Transportation Technology Center, Inc. (TTCI) RTT can offer, (2) develop requirement specifications for a siding test track for high speed rail (HSR) testing and track geometry car qualification, and (3) develop and analyze various options to achieve the specified requirements and provide rough order of magnitude (ROM) design and construction costs.

Based on a literature review that will include a survey of FRA regulations, a siding test track to RTT can be built to offer a number of essential HSR testing capabilities for research and development, vehicle performance testing, endurance testing, and communication and train control testing. Eight options for a siding test track have been developed. Each option was evaluated on its ability to meet testing requirements, particularly the requirements for a perturbed track section and high speed turnouts, its limitations and merits, and associated ROM design and construction costs.

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1 yard (yd)	=	0.9 meter (m)	1 meter (m)	=	3.3 feet (ft)
1 mile (mi)	=	1.6 kilometers (km)	1 meter (m)	=	1.1 yards (yd)
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1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)	1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
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				=	1.1 short tons

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1 fluid ounce (fl oz)	=	30 milliliters (ml)	1 liter (l)	=	1.06 quarts (qt)
1 cup (c)	=	0.24 liter (l)	1 liter (l)	=	0.26 gallon (gal)
1 pint (pt)	=	0.47 liter (l)			
1 quart (qt)	=	0.96 liter (l)			
1 gallon (gal)	=	3.8 liters (l)			
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)	1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)	1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

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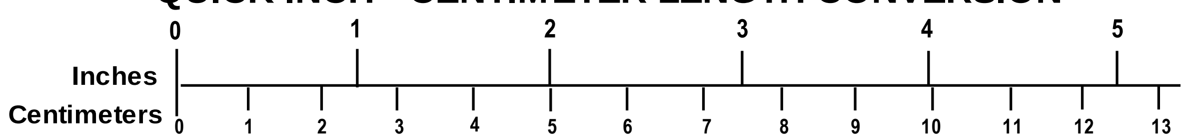

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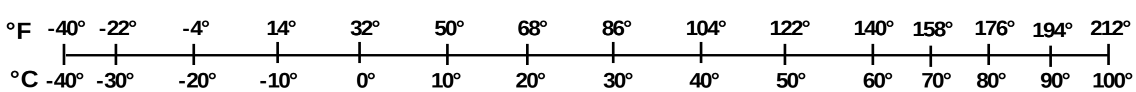

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Executive Summary

The Transportation Technology Center (TTC) in Pueblo, CO, owned by the Federal Railroad Administration (FRA), currently has a 13.5-mile test loop named the Railroad Test Track (RTT), which has speed capabilities of up to 165 mph. Under contract with FRA, the Transportation Technology Center, Inc. (TTCI) conducted two studies on high speed rail (HSR) testing requirements. One of the studies under a separate task order, “High Speed Rail Testing Strategies,” investigated the general requirements for high speed (HS) testing, and evaluated how testing at laboratories, specialized test tracks, and facilities such as TTC, as well as testing on revenue service routes, can meet those needs.

This report presents the results from the study titled “Needs Assessment—RTT Siding Options for High Speed Testing” and focuses on options for building a siding test track along the RTT to meet the needs of particular test requirements. The study was conducted to (1) determine potential capabilities that the proposed RTT siding test track can offer, (2) develop requirement specifications for a siding test track for HSR testing and track geometry car qualification, and (3) develop and analyze various options to achieve the specified requirements and provide rough order of magnitude (ROM) design and construction costs.

Based on a literature review that included a survey of FRA regulations, TTCI determined that a siding test track to RTT can be built to offer a number of essential HSR testing capabilities for research and development purposes, vehicle performance testing, endurance testing, and communication and train control testing. Specifications were devised for two major requirements: a section of track containing a desired set of track geometry deviations (e.g., Minimally Compliant Analytical Track or MCAT) and locations for testing HS turnouts. Other elements of this siding test track, such as catenary configurations, track structures (including ballasted track versus slab track), signal, and train control devices, were also discussed.

Eight options for the proposed siding test track were developed. Each option was evaluated on its ability to meet testing requirements, particularly those for perturbed track segments and HS turnouts, its limitations and merits, and its ROM design and construction costs. Table 1 summarizes siding lengths, number of perturbation test segments, estimated maximum tests speeds, and ROM costs.

Because of the acceleration and braking considerations required to negotiate the diverging routes of the proposed HS turnouts and provide a sufficient braking distance between adjacent perturbations, all the siding options have limitations on maximum speed and number of perturbed track segments if the perturbations are not easily removable or adjustable. To avoid these limitations, adjustable perturbations (Option 6) could be installed either in the siding or on the RTT mainline, which would provide much greater flexibility in the placement, number, and shapes of perturbation segments, and correspondingly increase the maximum test speeds.

Options 4 and 5 individually offer the most inexpensive and quickest solutions to meet some of the desired test requirement capabilities. Option 1 provides the most inexpensive and quickest solution to constructing a completed siding, albeit with the lowest maximum test speed and limited scope for flexibility and future expansion.

Options 2, 3, 7, and 8 offer increased testing capabilities and better possibilities for future expansion compared with Option 1, but they also come with increased construction costs. All four options could be constructed in multiple phases with installation of just the HS turnouts

(Option 4) being considered the first phase. Overall, option 8 offers the most flexibility and broadest scope for future expansion of HS train testing capabilities at TTC.

Note that any option developed under this study will not affect potential expansion of the RTT to enable a higher speed (e.g., 250 mph) test loop.

Table 1. Summary of RTT Siding Options

Option and Length	Number of MCAT Segments	Estimated Maximum Speed	Estimated Cost (in millions)
Option 1—0.59-mile siding to west tangent	1	110 mph	$8.8
Option 2—2.7-mile siding to west tangent and northwest curve	2	120 mph	$16.8
Option 3—3.8-mile siding to west tangent and adjacent south curve	3	120 mph	$23.7
Option 4—HS turnouts on RTT mainline (early phase of any option)	NA	NA	$6.1
Option 5—Adjustable perturbation on RTT mainline	NA	165 mph	$0.3
Option 6—Crossover between RTT and HTL	NA	NA	Cost not estimated
Option 7—5.33-mile siding on outside of RTT R50 to R17	4	120 mph	Cost not estimated
Option 8—Make the inside track the siding and the outside track the HS track (6.8 miles or 9.3 miles)	4 or more	Between 120 and 130 mph	Cost not estimated

1. Introduction

This report fulfills the deliverable requirement for Task Order 259, "High Speed Performance Test Track Needs Assessment," conducted by TTCI for FRA.

1.1 Background

With the planned increase in intercity passenger HSR corridors in the United States, there is a growing need for suitable locations to test new equipment and technology prior to their introduction into revenue service. FRA's TTC currently has a 13.5-mile test loop called the RTT. Figure 1 shows this test track, which has speed capabilities of up to 165 mph in tangent sections and a limiting speed in a $1^{o}15'$ reverse curve that depends on a railcar's ability to operate safely at cant deficiency (CD). FRA contracted TTCI to conduct two studies regarding potential upgrades of the RTT for various HSR testing requirements. One of the studies, under Task Order 261 "High Speed Rail Testing Strategies," presents potential options for upgrading the entire RTT. The study reported here was under Task Order 259, and it investigates the option of building a siding attached to the RTT for various test requirements discussed in this report.

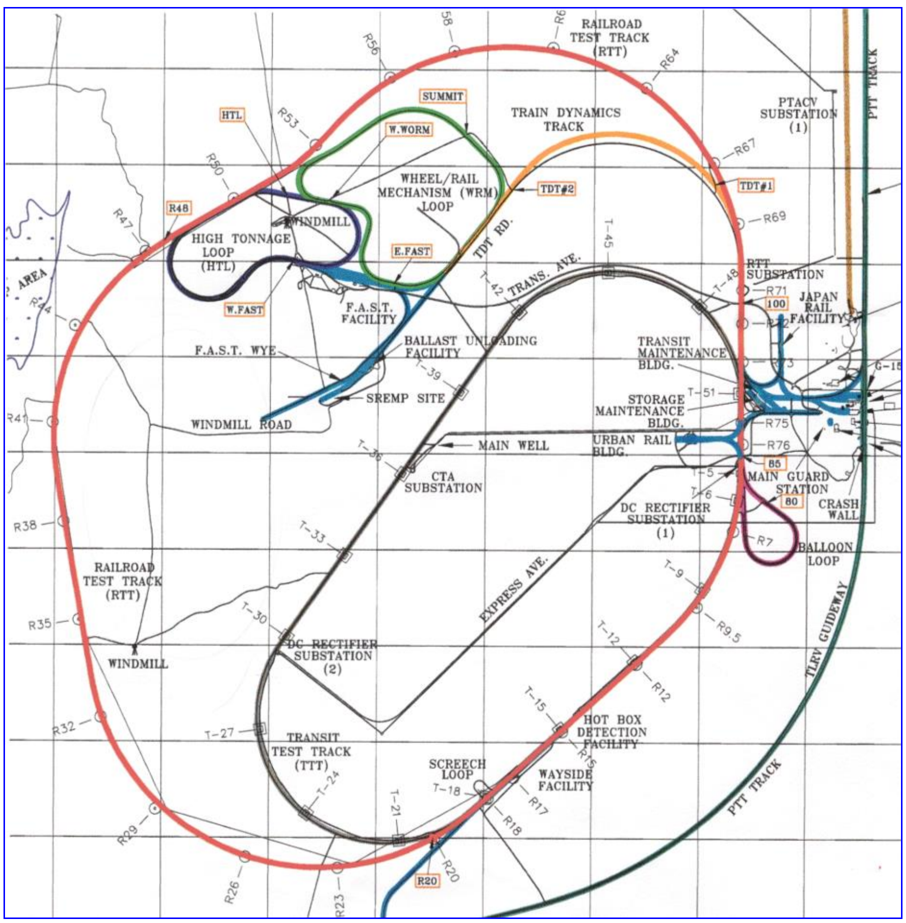

Figure 1. RTT Loop

1.2 Objectives

The objectives of this study were as follows:

- Perform a needs assessment to determine the potential operational capabilities that the proposed facility (siding to the RTT) should offer based on the literature survey of global HSR systems and FRA regulations;
- Develop design requirement specifications for the addition of a siding test track to the RTT for HSR testing and geometry car qualification testing; and
- Develop siding options and ROM cost estimates.

1.3 Scope

1.3.1 Task 1—Needs Assessment

Task 1 established the capability requirements of a siding test track to the RTT. The global industry was surveyed and FRA regulations were reviewed. The following factors were considered:

- FRA minimum track geometry limits and standards for proposed HS track classes
- FRA vehicle-track interaction safety standards for HS and High CD Operations
- International geometry and performance standards for established HS services
- Development of a means to calibrate and test track geometry measuring systems
- Development of the capability to effectively measure vehicle performance for the purpose of theoretical model validation
- Development of the capability to measure vehicle performance during negotiation of special trackwork applicable to HS service
- Development of the capability to assess HS equipment and infrastructure performance issues related to various catenary designs and catenary/pantograph systems
- Development of the capability to support the development and evaluation of Positive Train Control technology

1.3.2 Task 2—Requirements Specification

Task 2 developed design requirements for the siding test track to the RTT, based on the needs assessment established in Task 1. The following factors were considered in the design requirements:

- Testing speed
- Length of facility or portions of the facility
- Tangents and curves
- Amplitude, wavelength, tolerance, and capability to control or modify track geometry and track geometry deviations

- Track types and stiffness
- Turnout specifications
- Ability to vary rail profile and gage as needed

1.3.3 Task 3—Analysis of Options

Task 3 developed and analyzed various options to achieve the specified design and operational requirements. Various design options were evaluated on their ability to meet each of the stated requirements, the limitations and merits associated with each option, and the ROM design and construction costs, including the cost to construct a track containing a desired set of track geometry deviations.

1.4 Organization of the report

The report is organized in terms of the three major tasks conducted under this study.

Task 1—Needs Assessment

Task 2—Requirements Specification

Task 3—Analysis of Options

1.5 Acknowledgements

Authors of this report acknowledge the contributions of the following people to the study presented in this report: Dr. John Tunna, FRA's Director of Research and Development, for initiating and providing guidance on the study; Blaine Peterson, formerly of Nortrak, for providing input on HS turnout designs and construction costs of siding options; Mark White, TTCI, for helping to develop siding options and prepare ROM cost estimates; and other TTCI personnel, including Curt Urban, David Davis, Richard Morgan, and Mike Sherer, for their overall input to this study.

2. Needs Assessment

Based on a literature review that included a survey of FRA regulations, TTCI determined that a potential siding test track to the RTT can offer a number of capabilities that are essential for HSR testing. These capabilities are grouped into four categories: research and development, vehicle performance testing, endurance testing, and communication and train control (C&TC) testing.

2.1 Research and Development

One of the main purposes of this potential siding on the RTT is to provide a test track for HSR research and development. More specifically, this siding can offer the following testing capabilities:

- Assessment of accuracy, repeatability, and calibration of track geometry measuring vehicles
- Track components and materials developed for HSR
- HSR special trackwork, including HS turnouts
- Range of track stiffness with different track structures
- HSR track maintenance standards
- Vehicle suspension development
- Vehicle-track interaction and rolling contact fatigue
- Shared track issues between freight and HSR, if the siding is connected to the High Tonnage Loop (HTL) at TTC (see Figure 1)
- Pantograph and catenary system performance
- Noise attenuation technologies
- Wayside detectors for HSR operations

2.2 Vehicle Performance Testing

Many additional testing opportunities will be possible if the siding test track built on the RTT includes a section of perturbed test track, such as any of those segments in the Minimally Compliant Analytical Track (MCAT). This siding could then be used for performance testing of new and improved equipment and technologies intended for HS operations prior to revenue service testing. More specifically, this siding can offer the following capabilities:

- Test new HSR equipment to meet the performance criteria, including
  - Vehicle-track interaction safety criteria
    - Track perturbations
  - Hunting stability
  - Ride comfort

        - Curve and spiral
        - Track perturbations
    - Track stability (such as panel shift)
- Validate simulation models for further HSR equipment qualification
    - Track perturbations and features
- Test overhead contact force to meet the performance criteria
    - Catenary perturbations

2.3 Endurance Testing

An endurance test requires repeated operations of test tracks on the RTT.

This potential siding test track may be used as part of the RTT test loop for endurance testing to determine the reliability, availability, and maintainability of HSR trains. Perturbations on the siding can offer unfavorable track inputs to train operations and thereby help identify issues related to reliability of new equipment intended for HS operations. Track components developed for HS operations can also be installed on this siding to test the components' endurance, reliability, and maintainability.

In addition, wayside fault reporting systems and performance detectors can be installed on the siding to monitor the performance and operating conditions of the new equipment to be tested.

2.4 C&TC

This potential siding test track can be of great value to test train control and signal systems developed for passenger train operations. C&TC examples include radio communications, conditions of failure (such as in manual control), shunting operations, and signaling configurations.

2.5 Other Highlights from Literature Review

Sections 2.1–2.4 provide a summary, based on a literature review, of a number of needs or capabilities that a potential siding test track to the RTT can offer to meet some of the requirements for HSR testing. Additional literature review results can also be found in TTCI reports to be published for the three task orders listed below:

- Task Order 258—HSR Standards Comparison
- Task Order 260—HSR Dynamic Vehicle Modeling
- Task Order 261—HSR Testing Strategy

In Europe and Asia, HSR is generally defined as passenger train operations at speeds of 125 mph (200 km/h) or higher. In the United States, FRA's National Rail Plan [1] has defined HSR corridors as follows:

- Core Express Corridors: These routes would connect large urban areas up to 500 miles apart with 2–3 hour travel time, and train speeds would be between 125 and 250 mph

(200 and 400 km/h). Service would be frequent and the trains would operate on electrified, dedicated, publicly owned track. Based on their operation in and between large, dense metropolitan regions, the Core Express corridors would form the "backbone" of the national passenger rail system.

- Regional Corridors: This network would connect mid-sized urban areas, and smaller communities in between, with convenient, frequent 90–125 mph (144–200 km/h) 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 (144 km/h) 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.

In addition, FRA Track Safety Standards [2] has defined track classes as follows (Table 2).

Table 2. FRA HS Track Classes [2]

Track Classes	Maximum Allowable Speed (mph)
Class 6	110
Class 7	125
Class 8	160
Class 9	220

HSR track can be built on either ballasted track or ballastless track (slab track). Some requirements may vary, depending on which track form is used. For example, Chinese Railways have minimum radius requirements that are dependent on track form and maximum operating speed, as Table 3 shows [3].

Table 3. Minimum Radius Requirement for HSR [3]

Ballasted Track	Slab Track	Maximum Speed (mph)
6,000 m (0.29^{o})	5,500 m (0.32^{o})	156–219
4,500 m (0.39^{o})	4,000 m (0.44^{o})	125–188
3,000 m (0.58^{o})	2,800 m (0.62^{o})	125–156

Several test tracks have been built around the world for HSR testing. For example, in Valenciennes, France, three test tracks were opened in 2000, with a maximum test speed of 75 mph (120 km/h) and a curvature of 5.4 degrees (325 m in radius). A plan was subsequently proposed for an upgrade of the test track for partial certification for HS trains with test speeds well in excess of 124 mph (200 km/h). In Germany, the Wegberg-Wildenrath Test and Validation Center has 17 miles (28 km) of test track, including two test loops, which were opened in 1997: Test oval T1, 3.7 miles (6 km), curvature of 2.5 degrees (700 m in radius), test speed of 100 mph (160) km/h, and Test oval T2, 1.6 miles (2.5 km), curvature of 5.8 degrees (300 m in radius), test speed of 62 mph (100 km/h). In the United Kingdom, the Asfordby Test Track was upgraded in 1999 to test Pendolino tilting trains at speeds up to 125 mph (200 km/h). In China, tests can be conducted for HSR equipment on the test loop operated by the China Academy of Railway Sciences (CARS), with a maximum test speed of 106 mph (170 km/h).

In general, tests were conducted first on the test tracks to demonstrate compliance with a certain number of performance and safety criteria prior to testing in revenue service. For example, in China, tests were conducted first in the test loop of CARS at the maximum test speed of 106 mph (170 km/h), and then tests were conducted in revenue service line with maximum test speed exceeding maximum running speed by 10 percent.

There are a number of on-track tests required for HS equipment compliance and qualification. The following two paragraphs, however, offers a general discussion of vehicle-track interaction tests that have been developed to certify safety and ride quality performance.

Although specifics may be different in terms of the developed criteria, most countries require that the vehicle-track system meet established performance limits. In most cases, compliance is demonstrated through tests and simulations. For example, European HSR Standards [4] state that in order to ensure safety against derailment and running safety, and avoid overloading of the track, an acceptance test procedure shall be carried out for vehicles that are newly developed, have had relevant design modifications that could affect safety against derailment, running safety or track loading, or have had changes in their operating regimes that could affect safety against derailment, running safety, or track loading. In addition, vehicles shall be designed to be stable on track meeting the requirements of the HS infrastructure at the maximum vehicle design speed plus 10 percent.

A number of vehicle-track interaction criteria have been developed to prevent rail accidents due to poor vehicle-track interaction and minimize the likelihood of unsafe ride and passenger injury, derailment, failure of track structure, and vehicle rollover. The following are several common criteria for testing and simulations [2–4]:

- Vehicle Running Stability
    - Derailment coefficient (single wheel L/V ratio)
    - Single wheel vertical load ratio
    - Panel shift (net axle L/V ratio)
    - Truck side L/V ratio
    - Truck lateral stability (truck lateral acceleration)
- Ride Quality
    - Carbody lateral and vertical accelerations
    - Riding comfort, riding index

3. Requirement Specifications

For the RTT siding options developed and analyzed under this study, the two most important goals are use of a perturbed track for model validation and for evaluation of track geometry cars. Therefore, major consideration was first given to a section of track containing a desired set of track geometry deviations. In addition, consideration was given to locations for testing HS turnouts. With these considerations in mind, there are specifics that need to be achieved in terms of section length, testing speed, etc. Other requirements, such as catenary configurations, track structures (including ballasted track versus slab track and ranges of track stiffness), signal, and train control devices, are dependent on the specifications of the perturbed track sections and the locations for HS turnouts.

3.1 Perturbation Test Track

A major requirement for this potential siding test track to the RTT is that a section of the track contain a desired set of track geometry deviations, which can be used for the following purposes:

- Test HSR equipment to meet performance and safety criteria
- Validate simulation models for HSR equipment qualification
- Test and calibrate track geometry measuring systems

Although the actual perturbations for a proposed RTT siding are to be determined, this report uses the specifications of the MCAT as the basis for study [2]. Figure 2 shows the general configurations of the MCAT, which contains segments of various track geometry perturbations in alignment and surface. Their wavelengths and amplitudes depend on track class, curvature, and CD.

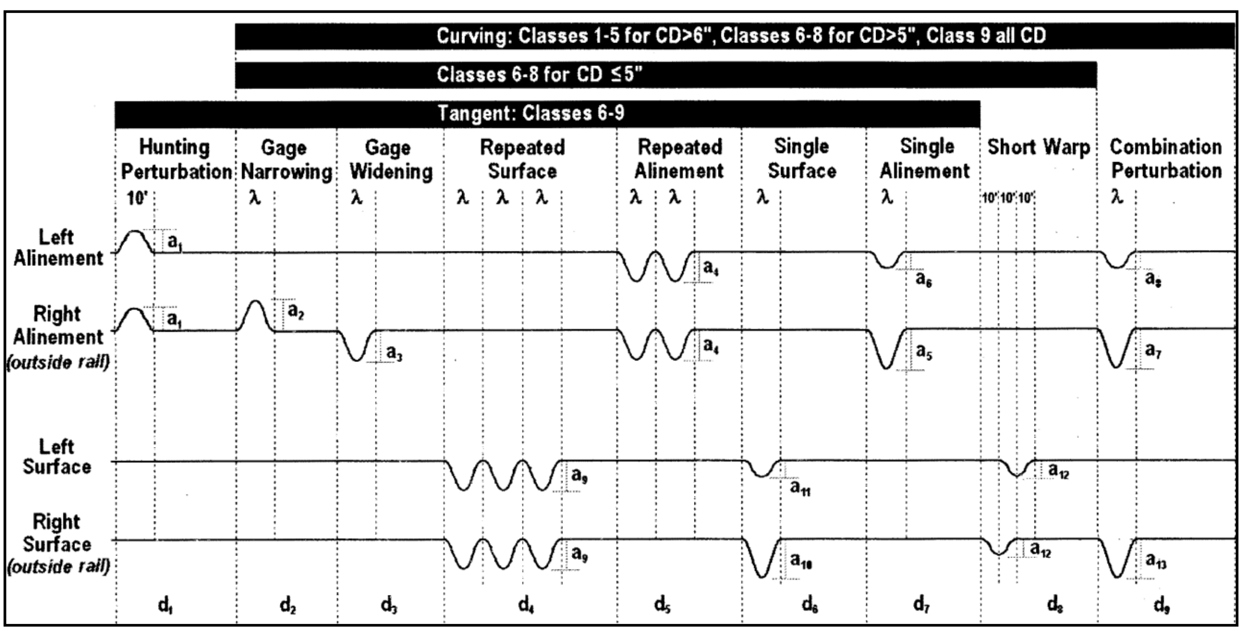

Figure 2. MCAT

As Figure 2 shows, the MCAT has 7 segments for tangent track of classes 6–9 and curve track of classes 6–8 for CD<=5 in. The MCAT has 8 segments for curve track of classes 6–8 for CD>5 in or class 9.

Table 4 gives the length of each segment in the MCAT. The total length of MCAT is as follows:

- Tangent MCAT = 7,500 ft, 7 segments
- Curve MCAT (classes 6–8, CD<=5 in) = 7,500 ft, 7 segments
- Curve MCAT (classes 6–8 for CD>5 in or class 9) = 8,500 ft, 8 segments

Table 4. Minimum Lengths (in feet) of MCAT Segments [2]

d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9
1000	1000	1000	1500	1000	1000	1000	1000	1000

The dimensions in Table 4 are the requirements for performing simulations. However, when conducting on-track tests, the individual perturbation segments will probably need to be placed farther apart to permit testing at a variety of speeds. A vehicle may be capable of running at full speed over one type of track perturbation, but require a speed restriction over another one. Therefore, space must be allowed between the perturbation types to allow the test train to slow down to a safe speed, or accelerate up from a speed restriction. A long enough space will also be required after each perturbation type to ensure that dynamic response from a preceding zone has damped out. Section 4.1 includes a more complete discussion of these issues.

For the purposes of performing the analyses in Section 4, the most important MCAT length parameter to consider is therefore the length of the longest single perturbation type. The longest MCAT perturbation type is 372 ft long: three 124-foot long repeated surface deviations.

For simulations, three wavelengths (31 ft, 62 ft, and 124 ft) are required for the MCAT. It is desirable that the perturbed test track be adjustable to achieve any of these three wavelengths. Section 3.3 discusses one possible method for adjusting MCAT amplitudes and wavelengths. To illustrate the importance of different wavelengths, Figure 3 shows the various speeds it takes to reach typical vehicle rigid body resonance frequencies for three different wavelengths.

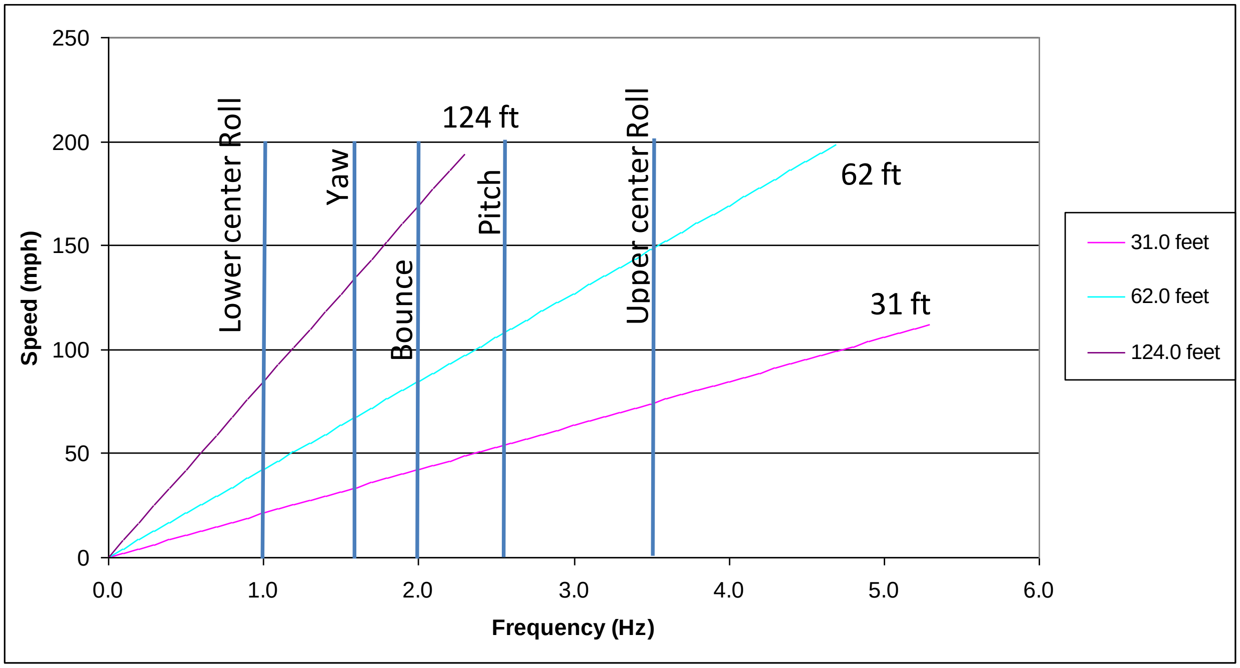

Figure 3. Speed versus Frequency for Three Different Wavelengths

Tables 5 and 6 give the amplitude for each perturbation (versine) of the MCAT shown in Figure 2, using the wavelength of 62 ft for track class of 6 (maximum speed of 110 mph) as the example. For other wavelengths and track classes, values of amplitudes can be found in 49 CFR Parts 213 and 238 [2]. A test track may not be required to reproduce perturbations with amplitudes as large as those in the MCAT specification.

Table 5. Amplitude (in inches) of MCAT, Tangent, Gage 56.5 in [2]

a_1	a_2	a_3	a_4	a_5	a_6	a_9	a_{10}	a_{11}
0.5	0.5	0.5	0.5	0.75	0.25	0.75	1.0	0.0

Table 6. Amplitude (in inches) of MCAT, Curve, CD<=5 in, Gage 56.5 in [2]

a_2	a_3	a_4	a_5	a_6	a_9	a_{10}	a_{11}	a_{12}
0.5	0.5	0.5	0.625	0.125	0.75	1.0	0.0	0.625

3.2 HS Turnouts

Another major requirement of a potential siding test track is that it be able to test HS turnouts. In this study, each option considered will include two prototype turnouts that permit diverging route speeds of up to 110 mph and mainline speeds of up to 220 mph (but limited to the RTT maximum speed of 165 mph).

The HS turnout is to be constructed on a section of tangent track. To maximize siding length, it should be installed with the points as close as possible to the beginning of the tangent section.

For analysis, such a HS turnout will need a minimum length of 570 ft, plus 100 ft prior to the point of switch to allow for cars to straighten out after the preceding curve. In addition, to bring the siding parallel to the main track on 16.5 ft centers, a reverse curve of the same length must follow the frog, which results in a total turnout length of 1,240 ft. Normal operating practice would not allow trains to exceed the 110 mph turnout speed until the end of the train has cleared the end of the reverse curve.

For each siding option considered, there is no overlap between the MCAT test section and a HS turnout section.

3.3 Track Structures

As discussed earlier, both ballasted track and slab track can be used for HSR. A siding test track to the RTT could include two types of track forms: ballasted track and slab track. With each track form, variation in other track components, such as rail and fastening, can be considered. The researchers have also considered designing and building one HS turnout on slab track and the other HS turnout on ballasted track. To accommodate a HS turnout (570 ft) on slab track and two adjacent transitions, a minimum slab track length for a HS turnout (770 ft) is required.

To allow for possible adjustment, the perturbed track section could be built on either ballasted track or slab track. TTCI recently developed a method for building perturbations needed for a special vehicle-track interaction test. This method uses adjustable tie plates installed between rails and ties to facilitate varying vertical and lateral track geometry adjustments. Figure 4 shows two pictures of a perturbation track built at TTC in 2010 for a special test.

Note that the adjustable tie plate system currently being tested at TTC requires the use of wood ties and has accuracies of $^{1}/_{8}$ in lateral and $^{1}/_{16}$ in vertical. To use this system for the MCAT on ballasted track would require either using wood ties or modifying the design to work with concrete ties.

Installing the perturbations on slab track would probably have higher initial cost, but would likely be easier and less costly to maintain at the desired amplitudes and wavelengths; the perturbations on slab track would also be easier to adjust to a new shape, or to remove completely. However, installation on a slab track would result in considerably different track stiffness characteristics than installation on ballasted track.

Figure 4. Adjustable Plates for Vertical and Lateral Track Geometry Perturbations

Depending on the length of the potential siding test track (see Section 4), other track features that can be installed on the siding may include the following:

- A section of track that allows adjustment of track stiffness
- A section of track that has a different rail profile from the rest of the siding

In general, the desirable minimum length is 1,000 ft for a section of test track with a specific feature (such as slab track versus ballasted track) and for a testing objective related to vehicle-track interaction. However, when a test is designed to evaluate the performance of track components such as rail and fastening, the minimum test section length can be as short as 250 ft [5].

3.4 Testing Speeds

Testing speeds for a proposed RTT siding track will depend on a number of factors including:

- Maximum turnout diverging route speed (110 mph)
- RTT maximum test speed (165 mph)
- Length of siding
- Train acceleration and braking rates
- Train length
- Number and distance between perturbations and other test sections installed
- Testing purpose and objectives

Several siding options are presented in Section 4. The effects and interrelationships of the factors listed above on the siding length and potential testing speeds will be analyzed for each siding option.

The objectives of the testing will significantly affect the siding speed analyses. The siding was originally expected to perform repeatability and accuracy testing of HS track geometry measuring vehicles. This option, however, is likely to require testing at full speed, possibly as high as 165 mph, over known track perturbations similar to MCAT perturbations.

However, if the main objective for the siding is to validate vehicle dynamic models and evaluate new vehicle performance with the use of instrumented wheelsets, according to the requirements of the recent FRA NPRM [2], then a maximum speed of 110 mph or 120 mph may be acceptable.

3.5 Catenary

As part of the construction of a siding test track to the RTT, a catenary will need to be built to provide power to HS trains operating on the siding. The proposed system will be the simple catenary system used in Europe and in Amtrak Northeast Corridor and under design for the California HSR corridor. Figure 5 shows this system.

Currently, however, the existing catenary system on the RTT is a compound system, which needs to be upgraded to the simple system in the future. The existing catenary system on RTT is looped, with the substation and primary feed located on the east side of the RTT at Station R70.8 (Figure 1). A return wire runs along the top of the pole line for grounding purposes, but the primary return follows the track structure back to the primary feed in both directions. The typical tension section is approximately 1 mile long. However, there are 17 tension sections in the 13.5-mile loop. Contact wire height is set at 22 ft 6 in above top of rail to allow for all vehicle heights to clear with an adequate air gap in a 50 KVAC operating system environment. This overhead catenary system (OCS) is capable of operating at 12.5, 25, and 50 KVAC. A phase break exists in Option 3 (See Section 4) to allow for dual voltage operation around the RTT, and this break would have to be duplicated on the wayside track.

In addition to providing motive power, this siding can be used to test pantograph and catenary system performance such as maximum overhead contact force.

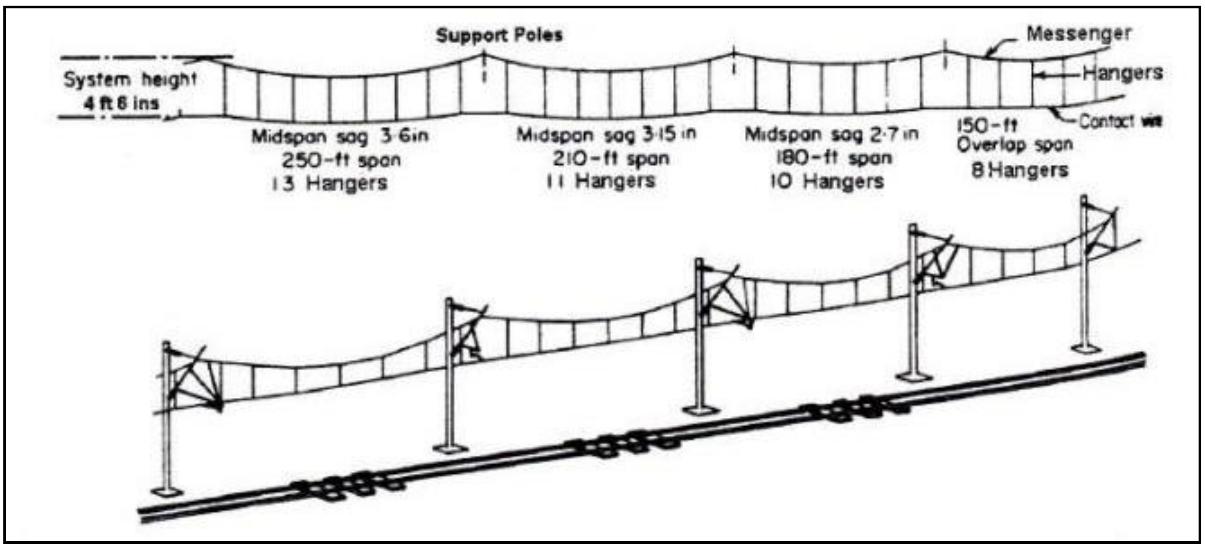

Figure 5. Catenary System Proposed for Siding Test Track to RTT

3.6 C&TC

A siding test track to the RTT will permit C&TC tests for passenger train operations to be carried out more efficiently than the current C&TC test bed on RTT allows. For example, when configured properly, this siding will permit researchers to test conditions of failure (such as in manual control), shunting operations, and various signaling configurations.

Figure 6 shows the configuration that is being considered for the RTT siding. 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.

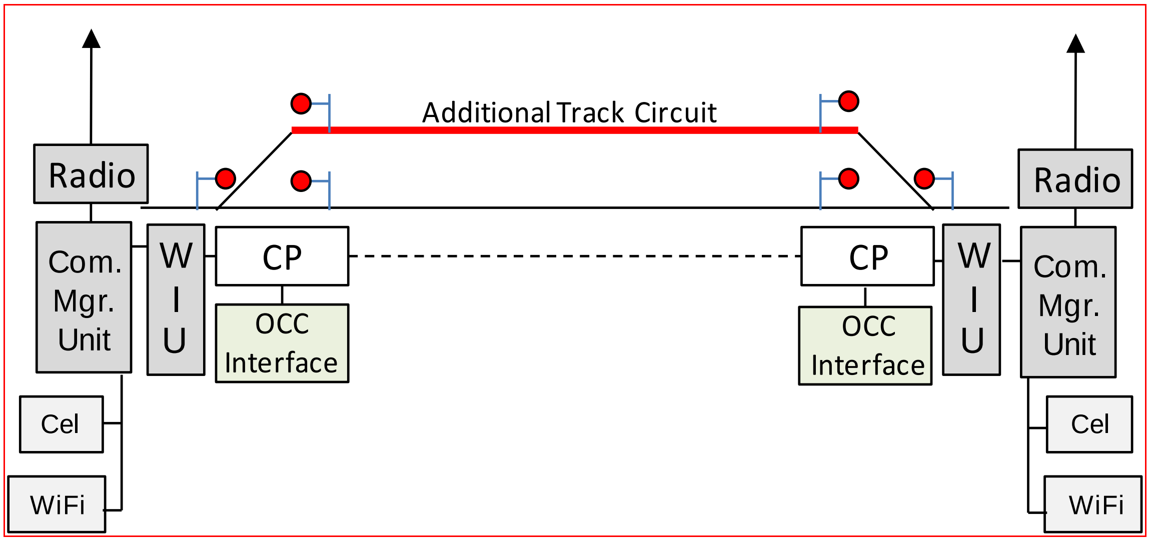

Figure 6. C&TC Configuration on Siding Test Track to RTT

3.7 Siding Specifications versus Test Requirements

In Section 2, a number of testing requirements are established for a siding test track that can offer the following HSR testing capabilities: research and development, vehicle performance testing, endurance testing, and C&TC. In Section 3, various specifications are developed to meet proposed test requirements. Table 7 gives a summary of the siding features/specifications and corresponding test requirements that these features can accomplish.

Table 7. Siding Specifications versus Test Requirements

Siding Features/Specifications	Research and Development	Performance Testing	Endurance Testing	C&TC Testing
Perturbations	X	X	X	
HS Turnout	X		X	
Track Forms	X		X	
Track Components	X		X	X
Catenary	X	X	X	
Wayside Technologies	X	X		X

4. Analysis of Options

To meet testing requirements and specifications discussed in Sections 2 and 3, TTCI has developed the following eight options for a siding test track:

- Option 1—Siding to the west tangent of the RTT (Figure 8)
- Option 2—Siding to the west tangent and adjacent northwest curve of the RTT (Figure 9)
- Option 3—Siding to the west tangent and adjacent south curve of the RTT (Figure 10)
- Option 4—Two HS turnouts on the RTT mainline. This option is considered as the early phase of the other siding options and is shown as one in the west tangent near Post R32, and the other one is in the north tangent near R50 (Figure 11).
- Option 5—Adjustable perturbations on RTT mainline
- Option 6—Crossover between RTT and HTL
- Option 7—Very long siding on the outside of RTT Station 50 to RTT Station 17
- Option 8—Making the inside track the siding and the outside track the mainline

The following subsections provide detailed analyses of the first four options. Each of the four options was evaluated on its ability to meet each of the specification requirements of each option, in particular the requirements of a perturbation test track segment and two locations for HS turnouts, its limitations and associated merits, and the ROM design and construction costs. A limited discussion and analysis is also provided for options 5 through 8.

4.1 Siding Length and Maximum Test Speed Analysis

Each of the options was analyzed to determine the maximum possible testing speeds and maximum number of perturbation track segments (using MCAT as the example for analysis) that can be installed within the available siding length. The analysis is based on the following assumptions:

- 110 mph maximum speed through turnouts and adjacent reverse curve
- 165 mph maximum speed
- Reaction time required to start accelerating after a train clears any speed restriction such as a turnout or perturbation is 2 seconds.
- Reaction time required to start braking after negotiating a track feature such as a turnout or speed restriction is 10 seconds (5 seconds for engineer to react; 5 seconds for brakes to fully apply).
- Time required to ensure a train reaches a steady speed prior to entering a test zone such as a perturbation is 5 seconds.
- Single turnout length with 110 mph speed restriction including adjacent reverse curve is 1,240 ft.

- Typical single MCAT segment of 1,400 ft, including maximum perturbation length of 372 ft, plus length afterwards to allow the vehicle dynamic response to damp out
- Typical multi-unit passenger train length to be tested is 800 ft (2 power units and 8 coaches).
- Typical 2-unit test train length is 170 ft (locomotive plus coach).
- Perturbations and other test zones must be spaced far enough apart to allow a test train to slow to 90 mph before reaching the next test zone in case the train cannot travel over the next test zone safely at a higher speed.

The final assumption is based on TTCI's many years of experience performing tests over the track perturbations on TTC test track. A vehicle may be capable of running at full speed over one type of track perturbation, but require a speed restriction over another one. Because the siding is for HS testing, the basic assumption is that any train running on the siding must be able to safely negotiate the installed test zones at speeds of 90 mph or less.

Note that if the adjustable tie plate system shown in Figure 4 is used, the requirement to allow room to slow down between perturbation test zones might be reduced or eliminated. If a particular perturbation proved troublesome, its amplitude could be quickly reduced to remove the need for a speed restriction, which might in turn allow more test zones to be fitted within a particular siding length. In that case, the distance between zones would be set to a distance (such as 500 ft) long enough to ensure that dynamic response from a preceding zone damped out.

Figure 7 shows two samples of speed-distance curves from acceleration and deceleration tests for two HS trains. The acceleration and braking rates used in the analyses have been derived from curve B. The actual acceleration rates and speeds that can be achieved will be dependent on the specific trains tested because each type of HS train will have different acceleration rates, although maximum deceleration rates are likely to be similar. Braking rates, however, will be similar for all trains because the maximum service braking rate is normally limited to approximately 2.2 mph/second. The actual braking rate at a particular speed is usually somewhat lower.

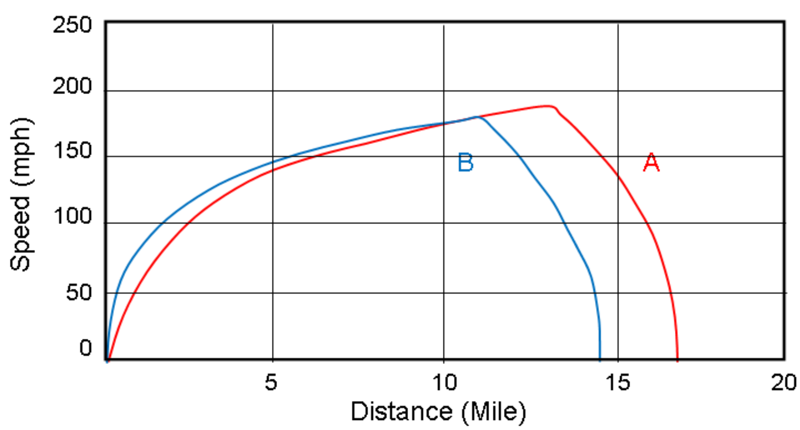

Figure 7. Example Speed-Distance Curves from Acceleration and Deceleration

The acceleration data from Figure 7 was used to calculate the distance required to accelerate from 90 mph and 110 mph to a desired test speed prior to entering a test zone. Table 8 provides the results, which include the 5-second "settle" distance (column 2) to ensure the train speed stabilizes before entering the test zone. The 110 mph start speed corresponds to the speed restriction due to the turnouts. The 90 mph start speed is calculated to show how much distance would be required to accelerate following a speed restriction.

Table 8. Approximate Distances Needed to Accelerate to Desired Test Speed

Desired Test Speed (mph)	5-second "settle" distance (ft)	Acceleration Distances (ft)	
		90 mph starting speed (after possible speed restriction)	110 mph starting speed (after HS turnout)
110	810	5,500	0
120	880	8,500	4,100
130	950	12,100	7,700
140	1,030	17,000	12,700
150	1,100	23,000	18,600
160	1,170	30, 600	26,200
165	1,210	34,600	30,200

The data from Figure 7 was used to calculate the distance required to brake from a given test speed to 90 mph and 110 mph. Table 9 provides the results, which include the 10-second reaction distance (column 2) to account for driver reaction time and time for the brakes to fully apply. To be conservative, it was assumed that no braking occurred during the 10-second delay period. The 110 mph final speed corresponds to the speed restriction due to the turnouts. The 90 mph final speed corresponds to the possibility of a train being speed restricted over a particular perturbation.

Table 9. Approximate Distances Needed to Brake from Given Test Speed

Start Speed (mph)	10-second initial delay distance (ft)	Braking Distances (ft)	
		90 mph final speed (between perturbations)	110 mph final speed (before turnout)
110	1,610	3,800	0
120	1,760	5,100	1,200
130	1,910	6,700	4,600
140	2,050	8,300	6,200
150	2,200	10,000	7,900
160	2,350	12,000	9,900
165	2,420	13,100	10,900

The acceleration and braking distances shown in Tables 8 and 9 can be used to estimate the minimum siding lengths required to achieve a given test speed over perturbations installed in the siding. Table 10 shows some examples of siding length calculations for up to four individual MCAT segments using the previously listed assumptions, plus the following:

- Multi-unit train length of 800 ft

- End of train must fully clear the turnout or a MCAT segment before starting to brake or accelerating to the desired speed.
- Distance between adjacent MCAT segments allows for braking to a possible speed restriction of 90 mph, but might not permit acceleration from a 90 mph speed restriction up to the target test speed.

Note that the minimum lengths shown in Table 10 may not result in a siding that can be used bi-directionally at all speeds. The braking zone at one end required to slow down to 110 mph is much shorter than the zone required at the beginning to accelerate from 110 mph to the desired test speed. To make the siding bidirectional, the braking zones at the ends need to be lengthened to be the same length as the acceleration zones. Similarly, to accommodate testing at full speed over a perturbation that follows a 90 mph speed restriction, the braking zone between adjacent perturbations needs to be lengthened to accommodate accelerating the train to the desired test speed.

Table 10. Minimum Siding Lengths Required for Different Numbers of MCAT Segments

Test Speed (mph)	Minimum Siding Length (ft) for Different Numbers of MCAT Segments			
	1	2	3	4
110	2,400	8,400	14,300	20,300
120	8,300	15,700	23,000	30,300
130	15,300	24,200	33,200	42,100
140	21,800	32,300	42,900	53,400
150	29,500	41,700	53,900	66,000
160	39,100	53,300	67,500	81,700
165	44,200	59,400	74,700	90,000

If a method for easily adjusting and/or removing the perturbations is used (as discussed in Section 3.3), then the requirement to allow for braking between test sections can be dropped. Table 11 shows some example siding length calculations without the braking section. In this case, the total MCAT test zone length is increased to 2,400 ft from 1,400 ft to ensure that dynamic responses in adjacent zones do not influence each other.

Table 11. Minimum Siding Lengths Required for Different Numbers of MCAT Test Segments with No Braking Section in Between

Test Speed (mph)	Minimum Siding Length (ft) for Different Numbers of MCAT Test Sections				
	1	**2**	**3**	**4**	**5**
110	2,400	4,800	7,200	9,600	12,000
120	8,300	10,700	13,100	15,500	17,000
130	15,300	17,700	20,100	22,500	24,000
140	21,800	24,200	26,600	29,000	30,400
150	29,500	31,900	34,300	36,700	38,100
160	39,100	41,500	43,900	46,300	47,700
165	44,200	46,600	49,000	51,400	52,800

4.2 Option 1—Siding to West Tangent

Figure 8 shows Option 1, a siding to be located to the west of the existing tangent (5,628 ft design length). This is the shortest siding option to the RTT considered in this study. The two proposed turnouts with reverse curves result in a combined length of 2,480 ft. The RTT west tangent is 5,628 ft long. Therefore, the estimated tangent track between the two turnouts would be approximately 3,100 ft long. According to Tables 8 and 9, this would allow installation of only one MCAT test segment, with a maximum test speed of 110 mph. A short consist train (one or two units) might be able to reach a slightly higher maximum speed.

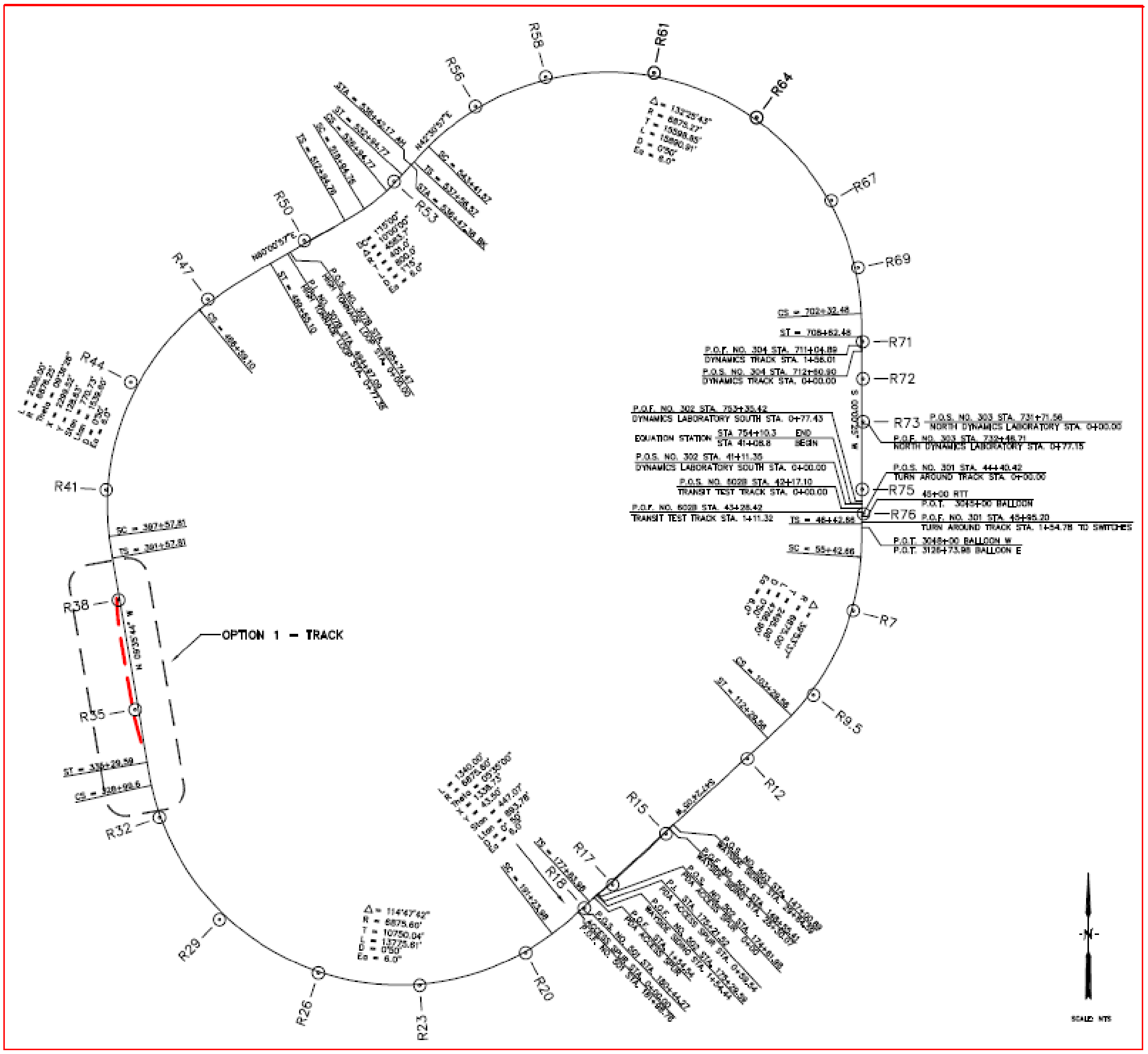

Figure 8. Option 1—Siding to West Tangent

Table 12 gives a possible arrangement of this siding for various test requirements. In this arrangement, the siding would be capable of testing two HS turnouts with a diverging route speed up to 110 mph. It could include at least two track forms (slab track and ballasted track) and one MCAT segment. Note that distance is counted clockwise (CW) in this table.

Table 12. Track Configuration under Option 1

Track Segment (ft)	Track Configuration	Test Speed (mph)
0–1240	HS turnout and reverse curve	110
0–1,240	Slab track under HS turnout	110
1,240–2,600	Possible space for alternate track structure or fastener tests	110
2,600–3,000	1 MCAT segments: ballasted or slab track	110
3,000–4,388	Possible space for alternate track structure or fastener tests	110
4,388–5,628	HS turnout and reverse curve	110

If adjustable perturbations were used and some compromises were made in spacing between turnouts and the adjacent perturbations, it might be possible to fit two MCAT segments and still achieve 110 mph test speeds.

The RTT west tangent section was constructed with a future siding track in mind; the siding would have a maximum track centerline spacing of 18 ft. The OCS constructed in the tangent section is an A-frame style support structure (portal section) that allows for an adjustable location for the cross arm assembly over the siding track. The siding subgrade is currently the service road adjacent to the tangent track. Subgrade work and OCS for Option 1 would be minimal because of current conditions. Concrete ties removed from the main track for installation of the turnouts and transition sections are in good condition and can be used again in the siding track. An existing overhead pole line adjacent to the track provides power for the broken rail-signal system along the west tangent section. Additional conductors would have to be added to the pole line to feed sufficient power for the electric switch operators in the turnouts.

4.3 Option 2—Siding to West Tangent and Adjacent Northwest Curve

Figure 9 shows Option 2, which would be a siding located on the west tangent and its adjacent northwest curve. Compared with Option 1, this siding option has a longer tangent as open test track because of the elimination of the space needed for one HS turnout in the west tangent. In addition, this option includes a curve, which can be used for CD studies.

The total length of this siding would be approximately14,190 ft between the reverse curves at the end of each HS turnout, which would provide approximately 4,350 ft of tangent track paralleling the existing RTT tangent track, with approximately 6,900 ft in a 0° 50’ degree of curve. The rest of the siding track would be taken by the curve spirals.

Because of the longer track segment, more MCAT segments could be installed for testing at 110 mph. Because 4,083 ft is required to accelerate from 110 mph to 120 mph, there is only room for two MCATs for testing at 120 mph in a counterclockwise (CCW) direction, with a small compromise on the length of the braking zone between them. This arrangement does not leave much margin for braking after the end of the tangent MCAT. Testing could not be performed at 120 mph in the CW direction over the MCAT in the tangent because there is not enough acceleration length.

For testing at 130 mph, it might be possible to install one MCAT segment near the end of the curve with some compromises on the location relative to the spirals and the location of the starting point for braking. Different track forms (ballasted track versus slab track) could be installed in the tangent track and curve.

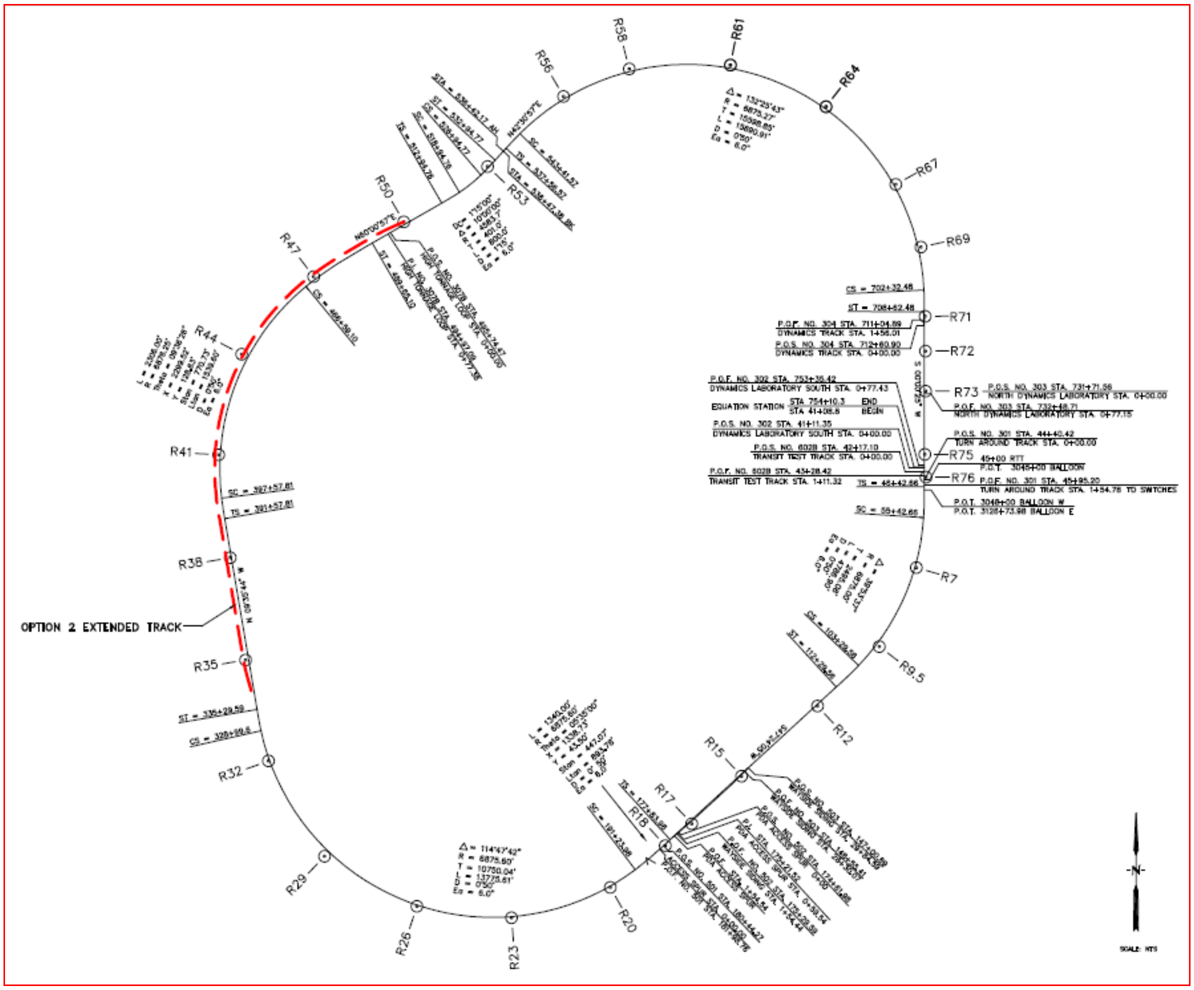

Figure 9. Option 2—Siding to West Tangent and Adjacent Northwest Curve

Table 13 gives a possible arrangement of this siding for testing at the 120 mph test requirement discussed above. As a minimum, this siding would be capable of testing two HS turnouts with a diverging route speed up to 120 mph. It could include at least two track forms (slab track and ballasted track) and two MCAT segments. Distance is counted CW in this table.

Table 13. 120 mph Track Configuration under Option 2

Track Segment (ft)	Track Configuration	Test Speed (mph)
0–1,240	HS turnout and reverse curve	110
0–1,240	Slab track under HS turnout	110
1,240–6,120	Possible space for alternate track structure or fastener tests	110–120
6,120–6,520	Curved MCAT segment: ballasted or slab track	120
6,520–12,720	Braking safety zone. Possible space for alternate track structure or fastener tests	120
12,720–13,120	Tangent MCAT segment: ballasted or slab track	120
13,120–15,430	Possible space for alternate track structure or fastener tests	120–110
15,430–16,670	HS turnout and reverse curve	110

If adjustable perturbations were used and some compromises were made in spacing between turnouts and the adjacent perturbations and the locations relative to the spirals, it would probably be possible to fit four MCAT segments (two in the tangent and two in the curve) and still achieve 120 mph test speeds.

A service road was constructed as an extension of the track subgrade that could be used as the subgrade for the siding track under this option. The existing service road would then have to be relocated adjacent to the siding track. Subgrade work for Option 2 would be minimal because of current conditions. The OCS line would be constructed adjacent to the siding track, with crossover tension sections at the turnout point of switches. OCS in the tangent section would take advantage of the existing portal section (see Option 1). As with Option 1, an existing overhead pole line adjacent to the track would provide power for the broken rail-signal system along the west and north tangent sections. Additional conductors would have to be added to the pole line to feed sufficient power for the electric switch operators in the turnouts.

4.4 Option 3—Siding to West Tangent and Adjacent South Curve

Figure 10 shows Option 3, which would be a siding adjacent to the west RTT tangent and its adjacent south curve. The siding track would connect to the north end of the tangent section on the southeast side of RTT, at the same location as Option 1, and rejoin the RTT located near the current turnout in the RTT (No. 501) that is part of a crossover track to the existing wayside track and Pueblo Chemical Depot (PCD) access track. The crossover track and turnout No. 501 would have to be removed and relocated to the east end of the existing wayside track, connecting to the RTT at the east end of the RTT south tangent section (near Station R 14.7). A section of the PCD access track would also have to be relined to clear for the new siding.

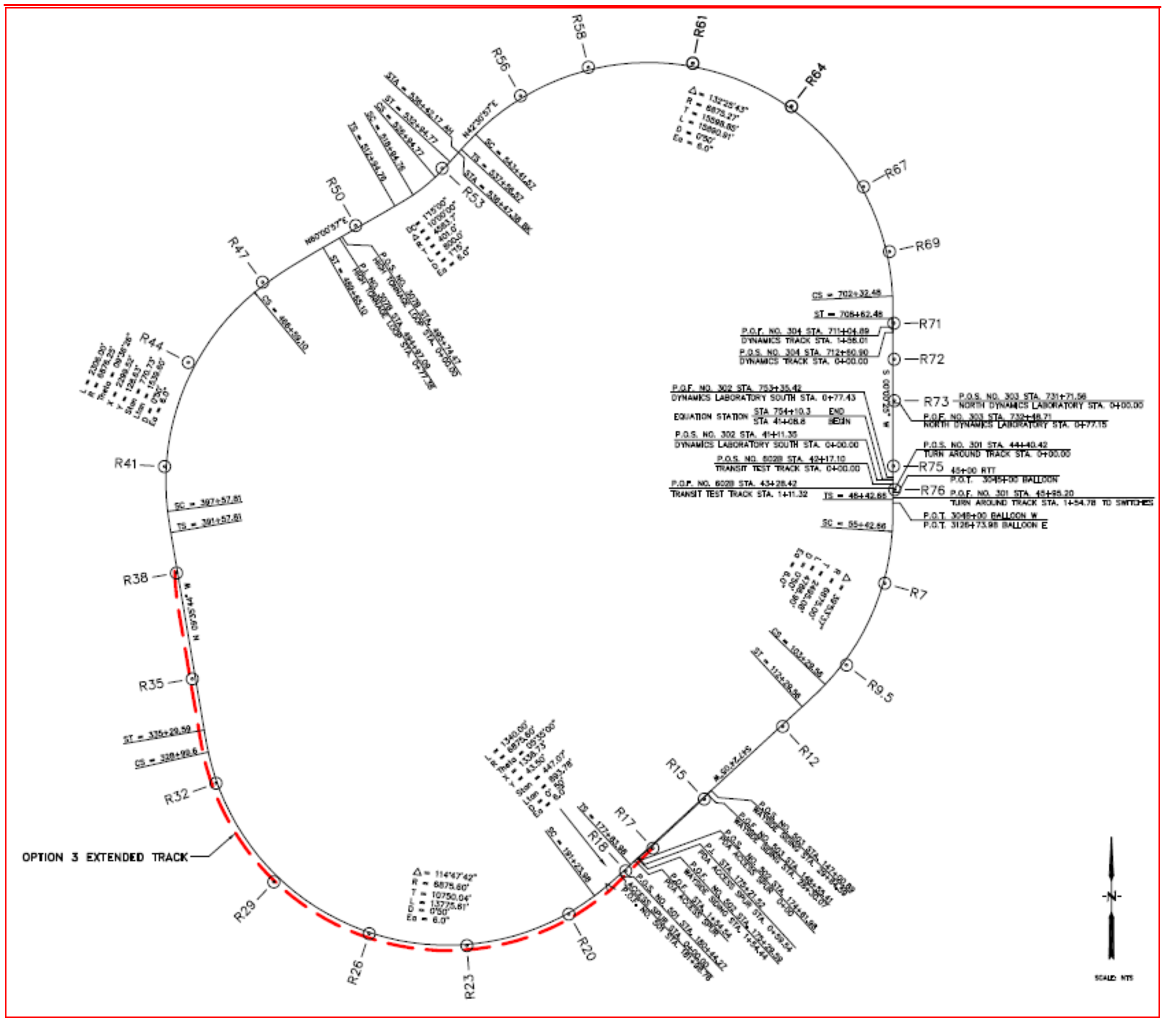

Figure 10. Option 3—Siding to West Tangent and Adjacent South Curve

Compared with Option 1, Option 3 has a longer tangent section of track because of the elimination of the space needed for one HS turnout in the west tangent. In addition, Option 3 includes a curve, which can be used for CD studies. Compared with Option 2, Option 3 has a longer curve, but the same length of tangent.

The total length of this siding is approximately 20,130 ft between the reverse curves at the end of each HS turnout. This length would provide approximately 4,350 ft of tangent track paralleling the existing RTT tangent track, with approximately 13,800 ft in a 0° 50’ degree of curve. The rest of the siding track would be taken by the curve spirals.

Because of the longer track segment, more MCAT segments could be installed for testing. Because 4,083 ft is required to accelerate from 110 mph to 120 mph, there is only room for three MCAT segments for testing at 120 mph in a CW direction, with small compromises on the length of the braking zone between them. This arrangement does not leave much margin for braking after the end of the tangent MCAT. Testing could not be performed at 120 mph in the CCW direction over the MCAT in the tangent because there was not enough acceleration length.

For testing at 130 and 140 mph, it would be possible to install only one MCAT segment in the curve and none in the tangent. There is room for a variety of different track forms (ballasted track versus slab track) to be installed in the tangent track and curve.

Table 14 gives a possible arrangement of this siding for the 120 mph CCW test condition. As a minimum, this siding would be capable of testing two HS turnouts with a diverging route speed up to 110 mph. It could include at least two track forms and two MCAT segments in the body of the curve and one segment in the tangent. Distance is counted CCW in this table.

Table 14. 120 mph CCW Track Configuration under Option 3

Track Segment (ft)	Track Configuration	Test Speed (mph)
0–1,240	HS turnout and reverse curve	110
0–1,240	Slab track under HS turnout	110
1,240–6,120	Possible space for alternate track structure or fastener tests	110–120
6,120–6,520	Curved MCAT segment: ballasted or slab track	120
6,520–12,720	Braking safety zone. Possible space for alternate track structure or fastener tests	120
12,720–13,120	Curved MCAT segment: ballasted or slab track	120
13,120–18,730	Braking safety zone. Possible space for alternate track structure or fastener tests	120
18,730–19,130	Tangent MCAT segment: ballasted or slab track	120
19,130–21,370	Possible space for alternate track structure or fastener tests	120–110
21,370–22,610	HS turnout and reverse curve	110

If adjustable perturbations were used, and some compromises were made in spacing between turnouts and the adjacent perturbations and the locations relative to the spirals, it would possibly fit at least five MCAT segments (two in the tangent and three in the curve) and still achieve 120 mph test speeds.

The south RTT curve has two long sections of high subgrade fill areas, most likely resulting in more compacted fill work for this option. Sufficient power is available adjacent to the south HS turnout location, but additional conductors would have to be added to the existing pole line for sufficient power at the north turnout.

4.5 Option 4—HS Turnouts on RTT Mainline

Figure 11 shows Option 4, which actually does not represent a siding option, but is an option that would allow some HS turnout testing prior to any of the three siding options previously described being designed and built. Option 4 can be considered the first phase of other siding options.

Although Figure 11 shows the turnout installed for Option 2, the turnouts could be installed in any of the required locations for the different siding options. The two HS turnouts would be installed with the main route on the RTT mainline and the diverging route directed towards the future siding track. Installation of the turnouts would not impact the current RTT allowable test speed, which is 165 mph. Modifications would have to be made to the current broken rail detection signal system at the turnouts to compensate for the change in rail conditions and in the position of the switch operators.

Compared with any of the other five siding options (1, 2, 3, 7, and 8), Option 4 would require lower costs for the initial construction effort and would take less time to complete. However, this option alone would not offer other track, catenary, signal, and train control features that are essential for HSR research and testing, unless this option were installed as the early phase of other options. Initial testing would be limited to operations through the tangent side of the turnouts.

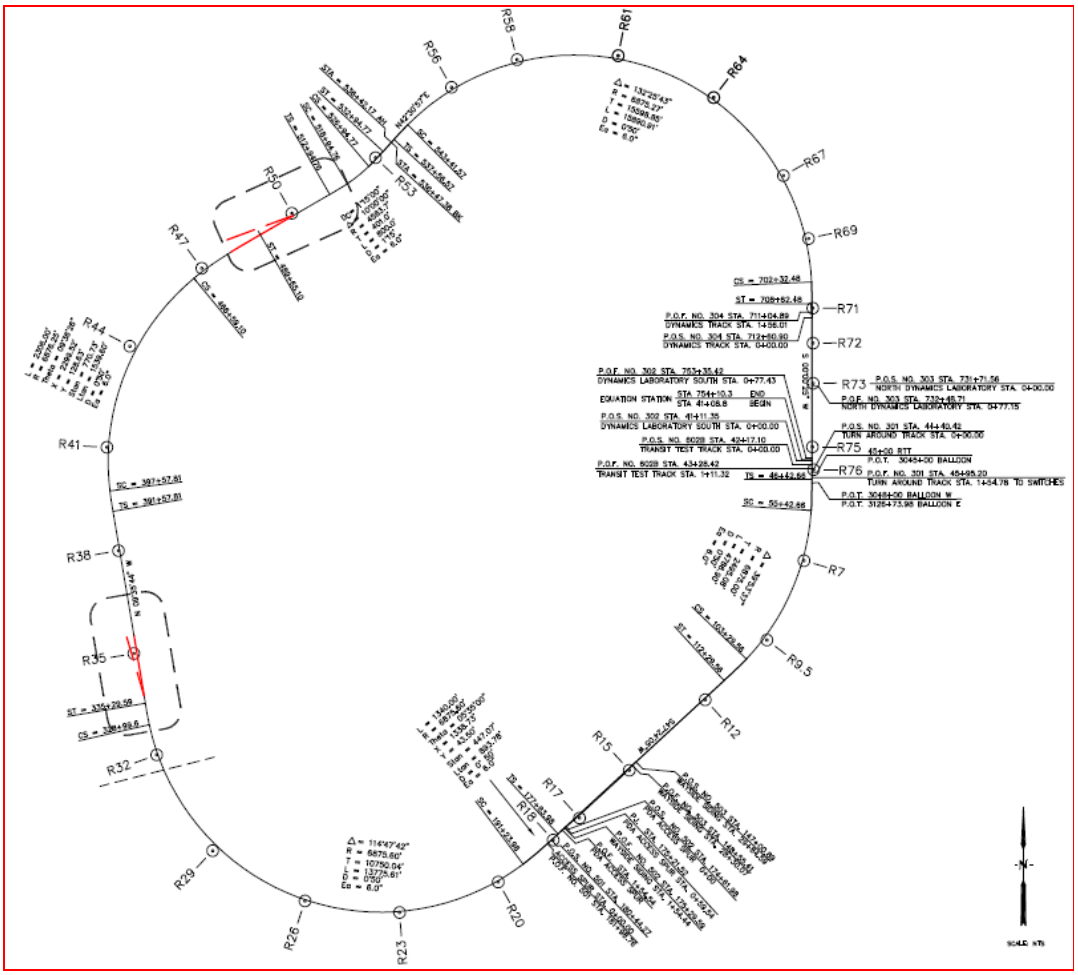

Figure 11. Option 4—HS Turnouts on RTT Mainline

4.6 Option 5—Adjustable/Removable Perturbation on RTT Mainline

Due to the acceleration and braking considerations required to negotiate the diverging routes of the HS turnouts and provide a braking distance between adjacent perturbations, the three siding options discussed have limitations on maximum speeds and number of MCAT segments:

- Option 1 is limited to 110 mph.
- Option 2 with two MCAT segments is limited to 120 mph.
- Option 3 with three MCAT segments is limited to 120 mph.
- Option 3 with one MCAT segment is limited to 130 mph.

To avoid these limitations, adjustable perturbations described in Section 3.3 could be installed on the RTT mainline, which would allow testing without the need to construct a siding. The perturbations would be "dialed in" when needed and then removed after testing was completed. This option would allow testing over perturbations to proceed before completion of siding construction. The perturbations could be placed in various locations around the RTT. Because they would be adjustable, spacing between them would only need to be sufficient (perhaps only 2,000 ft) to ensure that dynamic response over one location did not affect response in another.

A significant advantage of installing adjustable perturbations is that the maximum possible test speeds could be raised to 165 mph.

4.7 Option 6—Crossover between RTT and HTL

If a crossover were installed between the RTT and the HTL (see Figure 1), it would facilitate easy movement of the heavy axle load freight train from the HTL onto any of the above siding options. The turnout installed on the RTT would need to accommodate HS traffic in its normal (tangent) direction. The turnout on the HTL could be a normal freight service turnout.

Note that current track arrangements do not preclude moving the HTL train onto the RTT and the proposed sidings. This new crossover would just make the operational logistics a little simpler and easier.

A potential advantage of the crossover would be to permit research and testing of shared heavy freight and HS operations. Experiments can be installed on the siding to address heavy freight and HS passenger train operations.

4.8 Option 7—Siding Adjacent to Northwest Curve, West Tangent, and South Curve

Option 7 is a siding adjacent to the RTT northwest curve, the west RTT tangent, and the RTT south curve. It is essentially a combination of Options 2 and 3, and it provides a 28,180 ft siding length with a greater number of possibilities for perturbed track segments (e.g., MCAT segments) and other experiments and the highest possible testing speeds. The siding would start at the north side of the RTT near station 50 as in Option 2 and would end on the southeast side near station 17 as in Option 3. Because of its length, the siding should be able to accommodate four MCAT segments and still allow testing at speeds up to 120 mph.

4.9 Option 8—Make Inside Track the Siding and Outside Track the Mainline

Option 8 has as its ultimate goal the conversion of a portion of the existing RTT track on the north, west, and south sides of the RTT into a long siding and the construction of a new HS track on the outside of the existing RTT loop, possibly parallel to the existing RTT track. Option 8 could be applied as a variation to any of the options, depending on where the turnouts are installed. The best locations for the turnouts would be near R70 or R56 on the north side and near R18 on the south side. These placements would result in a siding that runs CCW along the same alignment of the current RTT loop from RTT station R70 or R56 to RTT station R18. The new mainline route would be on the outside of the siding.

A siding from R56 to R18 would be approximately 36,000 ft long and would accommodate at least four MCAT segments with maximum testing speeds between 120 and 130 mph. A siding from R70 to R18 would be approximately 49,000 ft long and would accommodate more MCAT segments and/or higher maximum testing speeds. For greatest flexibility, Option 8 should be constructed with adjustable perturbations.

Construction and operation of Option 8 is envisaged to be accomplished in three phases:

Phase 1 Construction (see Options 4 and 5 ROM costs):

- Temporarily install two HS turnouts in a straight section of the RTT (Option 4)
- Install adjustable perturbations at various locations on RTT curves and tangents (Option 5)

Phase 1 testing would consist of:

- Operation at up to 165 mph over the revised loop
- Performance testing on perturbations
- HS turnout testing through tangent legs of both HS turnouts

Phase 2 Construction to be performed simultaneously with Phase 1 testing:

- Construct new HS (165+ mph) track alignment on outside of RTT loop from R69 or R55 on the north side to R19 on the south side
- Construction could make use of existing side road subgrade or run on any other alignment that is desired
- New track to be connected into the existing RTT loop in Phase 3

Phase 3 Construction:

- Move the HS turnouts to R70 or R56 on the north side and R18 on the south side (or install new turnouts).
- Connect north and south ends of the new HS track (Phase 2) to the tangent parts of the relocated turnouts, which would form the new HS track alignment.
- Realign existing RTT track to connect to the curved portions of the moved turnouts, which would form the new siding. Realignments designed for at least 110 mph operation.
- Install additional adjustable perturbations as needed.

The new HS track (Phase 2 construction) could run mostly parallel to the existing RTT track, or it could run outside the existing RTT loop to allow a much longer route, a variety of curves, and a possible run at test speeds above 165 mph. Some advantages of Option 8 include:

- Phased construction to minimize initial cost and allow testing at an intermediate phase (Note: phased construction is possible for some of the other options)
- Possibility of raising maximum speed limit on new HS track above 165 mph because of new track alignments
- Possibility of connecting RTT directly to HS siding through a crossover without affecting the final (Phase 3) HS track alignment

4.10 ROM Costs

Table 15 gives a summary of estimated ROM costs for Options 1, 2, 3, 4, and 5. Estimates include the design and construction of track (including perturbed track segments), signal and train control equipment, and overhead catenary.

Table 15. ROM Costs for Various Siding Options

Option	Estimated Cost (in millions)
Option 1 – Siding to West Tangent	$8.8
Option 2 – Siding to West Tangent and Adjacent Northwest Curve	$16.8
Option 3 – Siding to West Tangent and Adjacent South Curve	$23.7
Option 4 – HS Turnout on RTT Mainline (Early phase of other options)	$6.1
Option 5 – Adjustable Perturbation in RTT or Siding (cost of a single MCAT segment)	$0.3

Table 16 gives a further cost breakdown. Note that no donations from suppliers and railroads (which are possible) are considered in the estimate. Estimates for additional perturbations (MCAT segments) in either the siding or the RTT under any option can be derived from the information in Table 16. The cost for Phase 1 of Option 8 (just the turnouts and the perturbations in the RTT) can also be derived from Table 16.

Table 16. Cost Breakdown for Each Option

DESCRIPTION	Option 1 1 MCAT	Option 2 2 MCATs	Option 3 3 MCATs	Option 4 2 Turnouts	Option 5 1 Adjustable MCAT
Environmental Assessment-National Environmental Policy Act/Air Emissions	$70,000	$80,000	$80,000		
Electrical Power Modifications	$100,000	$200,000	$200,000	$75,000	
TRACK under TURNOUTS					
Subgrade	$169,000	$169,000	$169,000	$169,000	
Turnout	$1,520,000	$1,520,000	$1,520,000	$1,520,000	
Subgrade	$201,000	$201,000	$201,000	$201,000	
Turnout with slab track	$2,900,000	$2,900,000	$2,900,000	$2,900,000	
BALLASTED TRACK					
Subgrade	$180,000	$1,290,000	$1,915,000		
Track Construction	$974,000	$4,420,000	$8,254,000		
Overhead Catenary System	$687,000	$2,294,000	$3,431,000		
Perturbations in new track	$125,000	$250,000	$375,000		
Perturbations in existing track					$250,000
Broken Rail/Signal Protection	$500,000	$803,000	$935,000	$250,000	
SUBTOTAL	**$7,426,000**	**$14,127,000**	**$19,980,000**	**$5,115,000**	**$250,000**
Engineering Design (4%)	$297,000	$565,000	$799,000	$205,000	$10,000
Construction Management (3%)	$223,000	$424,000	$599,000	$153,000	$8,000
Government G&A (14.5%)	$1,152,000	$2,192,000	$3,100,000	$794,000	$39,000
SUBTOTAL	**$8,578,000**	**$16,319,000**	**$23,080,000**	**$5,909,000**	**$289,000**
Government Oversight (10%)	$115,000	$219,000	$310,000	$79,000	$4,000
Contingency (10%)	$115,000	$219,000	$310,000	$79,000	$4,000
TOTAL	**$8,808,000**	**$16,757,000**	**$23,700,000**	**$6,067,000**	**$297,000**

5. Conclusions

This report presents the results and findings from the study "Needs Assessment—RTT Siding Options for High Speed Testing." It was conducted to (1) determine potential capabilities that the addition of a proposed siding test track to the RTT can offer, (2) develop requirement specifications for a siding test track for HSR testing and geometry car qualification, and (3) develop and analyze various options to achieve the specified requirements and provide ROM design and construction costs.

Based on a literature review that included a survey of FRA regulations, TTCI determined that a siding test track to RTT could be built to offer a number of essential HSR testing capabilities for research and development, vehicle performance testing, endurance testing, and C&TC testing.

Consideration was given to two major requirements: a section of track containing a desired set of track geometry deviations and locations for testing HS turnouts. Specifications were established for these two requirements. Other elements of the proposed siding test track, such as catenary configurations, track structures (including ballasted track versus slab track), signal, and train control devices, were also discussed in this study.

Eight options for a siding test track were developed and evaluated on their ability to meet testing requirements, in particular the requirements for perturbed track and HS turnouts, the limitations and associated merits of each, and ROM design and construction costs. Table 17 summarizes siding lengths, number of perturbed track segments, estimated maximum tests speeds, and ROM costs.

Because of the acceleration and braking considerations required to negotiate the diverging routes of the HS turnouts and provide sufficient braking distance between adjacent perturbations, all the siding options discussed will have limitations on maximum speed and number of perturbed track segments (e.g., MCAT segments), if the perturbations could not be easily removed or adjusted. To avoid these limitations, adjustable perturbations could be installed either in the siding or on the RTT mainline, which would provide much greater flexibility in the placement, numbers and shapes of perturbations, and maximum test speeds.

Options 4 and 5 taken individually offer the most inexpensive and quickest solutions to meet some of the desired test requirements. Option 1 offers the most inexpensive and quickest solution to achieve a completed siding, albeit with the lowest maximum test speed and limited scope for flexibility and future expansion.

Options 2, 3, 7, and 8 offer increased testing capabilities and better possibilities for future expansion compared with Option 1, but with corresponding increased costs for construction. All four options could be constructed in multiple phases with installation of just the HS turnouts (Option 4) being considered in the first phase. Option 8 probably offers the most flexibility and broadest scope for future expansion of HS train testing capabilities at TTC.

Table 17. Summary of RTT Siding Options

Option and Length	Number of MCAT Segments	Estimated Maximum Speed	Estimated Cost (in millions)
Option 1—0.59-mile siding to west tangent (Figure 8)	1	110 mph	$8.8
Option 2—2.7-mile siding to west tangent and northwest curve (Figure 9)	2	120 mph	$16.8
Option 3—3.8-mile siding to west tangent and adjacent south curve (Figure 10)	3	120 mph	$23.7
Option 4—HS turnouts on RTT mainline (Figure 11) (Early phase of any option)	NA	NA	$6.1
Option 5—Adjustable perturbations on RTT mainline	NA	165 mph	$0.3
Option 6—Crossover between RTT and HTL	NA	NA	Cost not estimated
Option 7—Very long siding on outside of RTT R50 to R17 (5.33 miles)	4	120 mph	Cost not estimated
Option 8—Make the inside track the siding and the outside track the HS track (6.8 miles or 9.3 miles)	4 or more	Between 120 and 130 mph	Cost not estimated

6. References

[1] Federal Railroad Administration, *National Rail Plan*, Washington, DC, Sept. 2010.

[2] Federal Railroad Administration, 49 CFR Parts 213 and 238, Vehicle/Track Interaction Safety Standards; High Speed and High Cant Deficiency Operations; Final Rule, Washington, DC, M, 2013.

[3] Ministry of Railways of People's Republic of China, *Code for Design of High Speed Railway (Trial)*, December 1, 2009.

[4] European Union, technical specification for interoperability (TSI) relating to the 'rolling stock' sub-system of the trans-European high-speed rail system, February 21, 2008.

[5] Li, D. "Slab Track Field Test and Demonstration Program for Shared Freight and High-Speed Passenger Service," DOT/FRA/ORD-10/10, Final Report, U.S. Department of Transportation, Federal Railroad Administration, Office of Research and Development, Washington, DC, August 2010.

Abbreviations and Acronyms

CARS	China Academy of Railway Sciences
C&TC	Communication and Train Control
CD	Cant Deficiency
CCW	counterclockwise
CW	clockwise
FRA	Federal Railroad Administration
HS	high speed
HSR	high speed rail
HTL	High Tonnage Loop
MCAT	Minimally Compliant Analytical Track (in this document also refers to individual track perturbations)
NPRM	notice of proposed rulemaking
OCS	Overhead Catenary System
PCD	Pueblo Chemical Depot
ROM	rough order of magnitude
RTT	Railroad Test Track
TTC	Transportation Technology Center (the Site)
TTCI	Transportation Technology Center, Inc. (the Company)
WIU	wayside interface unit