**NATIONAL RAILROAD PASSENGER CORPORATION**
60 Massachusetts Avenue, NE, Washington, DC 20002

AMTRAK

November 18, 2014

Docket Clerk, Office of Chief Counsel
Federal Railroad Administration
1200 New Jersey Avenue, SE.
Mail Stop 10
Washington, DC 20590

To the Docket Clerk:

The National Railroad Passenger Corporation (Amtrak) requests the waiver of certain limitations on or associated with train speeds contained in Federal Railroad Administration (FRA) safety regulations and in the FRA Final Order of Particular Applicability published on July 22, 1998 (63 FR 39342; July 22, 1998) [Docket No. FRA 2001-9972; Formerly FRA Docket No. 87-2]. Granting this relief would enable Amtrak to achieve optimum trip times on the Northeast Corridor (NEC) consistent with the capabilities of existing Acela trainsets, where conditions otherwise permit. Relief is also requested to permit the use of "Tier III" trainsets built to designs that are already service-proven internationally, which, as adapted to meet specific U.S. requirements and respond to NEC conditions, would initially supplement and later replace the existing Acela equipment as it reaches the end of its useful life. Again, this relief would be utilized where conditions otherwise permit. Use of Tier III equipment would provide the potential for further improvements in trip times while also potentially offering increased seating capacity.

Amtrak respectfully submits that the relief sought herein is in the public interest and consistent with railroad safety.

Please contact me if further discussion concerning technical details is required.

Sincerely,

DJ Stadtler
*Executive Vice President and Chief Operations Officer*

Enclosure

cc: M. Yachmetz
S. Gardner
M. DeCataldo
M. Bergeron
S. Naparstek

**Before the Federal Railroad Administration**
**United States Department of Transportation**

# Petition for Relief from Certain Regulatory Limitations to Permit Operation of Acela Trainsets and "Tier III" Trainsets On the Northeast Corridor At up to the Maximum Speed for Class 8 Track

## Preface

The National Railroad Passenger Corporation (Amtrak) requests the waiver of certain limitations on or associated with train speeds contained in Federal Railroad Administration (FRA) safety regulations and in the FRA Final Order of Particular Applicability published on July 22, 1998 (63 FR 39342; July 22, 1998) [Docket No. FRA 2001-9972; Formerly FRA Docket No. 87-2]. Granting this relief would enable Amtrak to achieve optimum trip times on the Northeast Corridor (NEC) consistent with the capabilities of existing Acela trainsets, where conditions otherwise permit. Relief is also requested to permit the use of "Tier III" trainsets built to designs that are already service-proven internationally, which, as adapted to meet specific U.S. requirements and respond to NEC conditions, would initially supplement and later replace the existing Acela equipment as it reaches the end of its useful life. Again, this relief would be utilized where conditions otherwise permit. Use of Tier III equipment would provide the potential for further improvements in trip times while also potentially offering increased seating capacity.

The proposed path for achieving the proposed enhancements in Amtrak's premium NEC service would then proceed as follows:

- First, FRA would process and—if deemed warranted—approve this petition, providing a framework for subsequent handling.
- Second, Amtrak would complete necessary improvements to support enhanced speeds (for the Acela service and Tier III equipment service, respectively, in the several high speed zones).
- Third, Amtrak and FRA would work to complete all necessary special approvals.

The FRA exercises its authority regarding qualification of high-speed trainsets, train control systems, and other safety-relevant subject matter through special approvals that are based on close review of program documentation, engineering analysis, and testing. Nothing in this waiver request is intended to diminish that oversight in any way.

At the present time it is anticipated that Acela service could be increased in designated speed zones on an incremental basis within the next one to three years. Introduction of the Tier III-compliant equipment would be founded on a Notice to Proceed issued only after a grant of approval in this proceeding and would occur only after (i) necessary risk mitigations had been completed in the subject speed zone(s) and all (ii) necessary qualification testing is satisfactorily completed.

If this petition is approved, Amtrak would expect to issue a Notice to Proceed to the successful Tier III equipment vendor shortly after the anticipated selection of that vendor in April of 2015. Delivery and testing of new trainsets would require approximately 3 to 4 years from the Notice to Proceed, during which a variety of additional safety mitigations would be implemented.

This petition is organized as follows:

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B. Need for flexibility to meet service needs

C. History of regulatory provisions

D. Developments since existing regulations were issued

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III. Acela 160 miles per hour (mph) request

A. Previous waiver request for speed zone in Rhode Island

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## I. Background and Introduction

The NEC constitutes a vital national asset that is utilized for intercity, commuter, and freight rail service along its length of 457 miles from Washington, D.C.'s Union Station to Boston's South Station.[1] Although most of the daily trains on the NEC are operated by commuter authorities serving discrete areas, and although use of the NEC is necessary to serve local customers at a number of locations on NEC tracks and on freight lines that can only be accessed via the NEC, Amtrak is the only entity that provides service using trains that traverse the entire length of the NEC; and every segment of the NEC is also used by Amtrak trains that originate or terminate off the spine of the Corridor.

FRA enjoys a very long and intimate acquaintance with the NEC, having managed the original Northeast Corridor Improvement Project in the 1970s, and having funded electrification and upgrading of the "North End" in the late 1990's. FRA continues to provide assistance to a number of parties working on coordinated improvements to the NEC, and FRA funds Amtrak capital and operating needs as provided by law.

Amtrak wishes to emphasize that, even though the current petition focuses on achievement of shorter trip times and enhanced capacity for Amtrak customers, the measures that are being implemented to

[1] For purposes of this filing, the "NEC" is defined as the "spine" of the electrified NEC not including auxiliary branches such as the Keystone Corridor and Springfield line.

facilitate this enhanced service will also benefit all users of the NEC in a variety of ways, including improved safety and reliability for all operators, their passengers, and citizens of the region.[2]

## A. Amtrak's role on the NEC

Amtrak dispatches and maintains the NEC, on its own behalf or for another public authority, from Washington to Boston, with the exception of one interlocking with the MTA Long Island Rail Road and the portion of the NEC controlled by the MTA Metro-North Railroad (Mileposts MN 16.3 near New Rochelle to AB 72.9 near New Haven). All of the high speed zones discussed in this petition are located on portions of the NEC dispatched and maintained by Amtrak. Although dispatched and maintained by Amtrak, the portion of the NEC located in Massachusetts (MP AB 190-229) is owned by the State.

Amtrak also provides leadership for improvements to the NEC that will benefit all users, both in the short term and in the future. The current petition is an important step in a series of actions that have been identified as necessary and useful to the future of the NEC and the region, as discussed under "Public Interest Considerations," below. *See*, also, ***The Amtrak Vision for the Northeast Corridor*** (2012 Update Report).

## B. Need for flexibility to meet service needs

Amtrak is requesting relief in this proceeding in order to provide enhanced high-speed rail service on the NEC, consistent with regional needs and Federal policy. Service would be "enhanced" in two respects. First, higher maximum train speeds within designated "speed zones" would contribute trip time savings that would be combined with other savings being planned at bridges, terminals and similar locations to make rail travel even more attractive and useful to current and potential Amtrak riders.

Second, introduction of additional high-speed trainsets—trainsets with more passenger seats—will provide essential capacity in a growing intercity transportation market. Thus far, Amtrak's Acela service has been extremely successful in claiming market share and thereby providing an environmentally beneficial alternative to air travel, while helping to reduce pressure on highly constrained airports in the region. However, in recent years Acela ridership has been running at or near capacity during the most heavily-traveled periods. Additional seats will facilitate growth in Amtrak's premium service while also relieving pressure on regional service capacity.

Moving toward lighter-weight international technology, as contemplated in the proposed Tier III standards, may offer the additional benefit of better acceleration while maintaining braking characteristics equivalent to the existing Acela fleet, further aiding trip times.

Providing approval of the Tier III request would also permit Amtrak, over time, to retire the existing Acela fleet without being wed to an existing set of requirements that far exceed any in place elsewhere internationally. Building new trainsets (or additional coaches for existing trains) under existing Tier II requirements could limit passenger capacity, result in higher energy consumption, and could be much more costly per unit, given the unique requirements. Amtrak's performance-based specifications do not eliminate Tier II equipment from consideration; however, Amtrak submits that continued use of Tier II equipment should not be required, given—

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[2] For a succinct summary of the importance of the NEC to region and the Nation, see ***The Northeast Corridor and the American Economy*** (Northeast Corridor Infrastructure and Operations Advisory Commission April 2014).

- The specific characteristics of the NEC, which is primarily configured and operated as a passenger railroad;
- Safety experience since the onset of Acela service in 2000;
- The deployment and successful demonstration of positive train control technologies;
- Advances in crash energy management (CEM) technology in railroading internationally;
- The development of system safety and safety management processes, soon to be embodied in FRA risk reduction regulations; and
- Specific additional mitigations called out in this petition.

In short, Amtrak submits that, within the framework of this specific set of facts, a transition to fuller reliance on "active safety" (preventing mishaps)," rather than "passive safety" (reducing mishap consequences) will best serve safety performance and the public interest.

### C. History of regulatory provisions

Regulatory requirements grow inexorably out of the needs pertinent to the time of their initial development and issuance. Although regulatory agencies maintain regulatory review programs and endeavor to introduce flexibility through incremental changes over time, inevitably the demands of the present limit the agency's ability to remain "current" across a broad range of subject matters. Even maintaining full consistency among the regulatory provisions issued recently, vs. some time ago, is an understandable and inevitable challenge. For instance, high-speed rail issues have been addressed very recently in amendments related to track-vehicle interaction; and these amendments sought to reconcile provisions in the track and passenger equipment regulations, simplifying requirements. But a subset of these issues remains unreconciled in the positive train control regulations—some of which are referenced in this filing.

In addition, regulations are often structured to address situations categorically. Yet it is not always easy to separate categories neatly. For instance, a railroad that hosts light to moderate freight traffic subject to full train control and with mitigations in place to address the relevant hazards is different in degree, at least, from a railroad devoted predominately to freight traffic where a sponsoring organization might want to operate a few high-speed passenger trains.

Amtrak requests that FRA take these considerations into account when evaluating the present request for relief. Amtrak does not seek to contravene the purpose or intent of any existing (or proposed) regulations. However, Amtrak does ask that current, specific circumstances be taken into account as they are applied.

Amtrak submits that this kind of flexibility is especially appropriate in light of the history of several of the regulatory provisions in question.

For instance, the Advanced Civil Speed Enforcement System Order was issued to facilitate safe, higher speed passenger service on the NEC. Recognizing the varying conditions on the "North" (timetable east) End of the NEC vs. the "South" (timetable west) End of the corridor as the decade of the 1990s was unfolding, Amtrak specifically requested flexibility to operate up to 150 mph on the North End, with all movements ACSES-equipped, under new constant-tension catenary. By contrast, Amtrak requested authority to operate up to 135 mph on portions of the South End, with flanking protection provided by the traffic control system but with the anticipation that improvements to the catenary would be required before speeds could be raised further. FRA found these conditions to be reasonable at the time, and issued the order as requested.

Meanwhile, negotiations between Amtrak and FRA had described crashworthiness requirements for what would become the Tier II standards (with FRA clearly in the deciding capacity at the end of the negotiations),[3] and Amtrak ordered the Acela trainsets well before the Passenger Equipment Safety Standards were in development within the Railroad Safety Advisory Committee.

Although the 150-mph cap on Tier II train speeds (and NEC train speeds) was based largely on what seemed reasonable to attain on the NEC or under similar circumstances at the time, the crashworthiness requirements were influenced by very serious events on the NEC within the memory of those working on what would become the basis for the Acela specifications and the Tier II regulatory requirements.

The major events of then-recent memory on the NEC illustrate the urgent concerns underlying FRA's actions during the 1990s.

> **Chase, MD.** On January 4, 1987, the accident at Gunpow interlocking killed 16 and injured 174. The Conrail crew responsible for passing the home signal at this busy junction had been using marijuana, likely while on duty. The cab signal system was designed to warn crew members of a signal downgrade, but the warning that might have been provided by the cab signal whistle had been silenced with duct tape.
>
> **Chester, PA.** On January 29, 1988, just over one year after Chase, the block operator at Hook routed the Night Owl into a track containing heavy MOW equipment. The collision and derailment resulted in injury to 143 persons, including 66 injuries characterized by the NTSB as serious.
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> **Back Bay, MA.** On December 12, 1990, the student engineer and supervising engineer on board Amtrak Train 66 failed to obey civil speed restrictions approaching and entering the station. The train derailed at an estimated 76 to 80 mph and collided with an MBTA commuter train, resulting in 453 injured, and $12.7 million in damages (in part from a diesel fuel fire).

The technical basis for what would become the Tier II crashworthiness requirements were based upon the best engineering judgment of equipment performance post-collision available at the time. Numerous analyses were conducted using 1-dimensional collision dynamic lumped-mass models. These simplified analytical models assumed large deformation crush characteristics to define desired levels of crashworthiness performance for train-to-train collisions. Based upon these assumptions and the desire to protect occupants within the high-speed trainsets for other types of incidents up to the average speed along the corridor, a combination of non-passenger occupied power cars at the trainsets leading and trailing positions with significantly increased buff strength requirements as well as significant energy absorption levels were required as part of the technical specification for the Acela trainsets.

### D. Developments since existing regulations were issued

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[3] FRA had clear and decisive leverage in the negotiation based, from a formal perspective, on its control over relief from the existing speed cap in the Track Safety Standards, and more practically, on Amtrak's status as a publicly-assisted passenger operator with the Department of Transportation serving on its board of directors.

Each of the serious accidents that occurred in the 1980's and early 1990's spurred actions by FRA and industry, the efficacy of which would have to be proven over an extended period of time as programs were conceived, training and technology were deployed, and compliance and results were verified.

For instance, the Chase MD accident led to enactment of the Rail Safety Improvement Act of 1988, establishment of the Locomotive Engineer Certification Program, installation of automatic train control (ATC) on all freight locomotives operating on the NEC, and implementation of random drug testing (on top of other forms of testing FRA had already required). With the benefit of history, most railroad officers and employees would likely judge that this tragedy led to significant and lasting change.

In the years after the Chester PA accident, block operator positions were abolished and a computer-aided dispatching system and new procedures were implemented on the NEC that have been highly successful in providing protection for trains and maintenance-of-way equipment within the limits of their authority.

Very shortly after the Back Bay accident, at FRA's request, Amtrak surveyed the NEC for locations where the permitted signal speed might exceed the overturning speed. In 1991, signal code change points were installed at 6 relevant locations, including Back Bay, providing enforcement of civil speeds at those critical locations. Subsequently, where ACSES has been put in place, enforcement of all civil speed limitations has been provided. ACSES is complete from New Haven to Boston and has been in effect for Amtrak trains on Tracks 2 and 3 on the South End for a number of years. Extension of ACSES to all NEC tracks is nearing completion.

Scores of additional initiatives have unfolded since the mid-1990's, as FRA and industry have addressed a broad range of concerns related to track, equipment, signals and human factors. For instance, as part of the Northeast High-Speed Rail Improvement Program (NHRIP) project, several grade crossings were closed, and other crossings were enhanced with four-quadrant gates with presence detection, tied into the cab signal system to automatically downgrade the signal speed if gates descend and a vehicle is detected. No grade crossings remain in any of the high-speed zones specifically addressed in this petition.

FRA's recent updates to the Track Safety Standards have tightened the track geometry limits (e.g. implemented requirements for short warp and combined defects) and expanded requirements for ensuring rail integrity. FRA has conducted exhaustive simulations using a validated model of the Acela equipment to verify safe operations of the Acela at speeds of at least 160 mph with track maintained to the minimum requirements contained in the new rule. Additionally, Amtrak currently meets or exceeds the minimum requirements for track class 8 in the current Track Safety Standards

Significant research efforts sponsored by the FRA and led by the Volpe National Transportation Systems Center have advanced the state-of-the-art in vehicle structural design and dynamic crash testing to better define the post-collision performance of passenger equipment involved in a variety of collision conditions. The post-impact performance of equipment is now better understood. This work in conjunction with international experience in advanced trainset designs have led to the development of highly crashworthy but light trainset designs that provide a high level of system safety when combined with advanced signal systems such as Positive Train Control (PTC). The current effort to demonstrate appropriate safety within this Waiver Petition from a systems perspective leverages this information.

Together with the unfolding PTC roll-out, these developments, and further mitigations undertaken by Amtrak on its own initiatives (as described below), have to a large degree obviated the need for the very ambitious crashworthiness requirements embodied in the Tier II standards.

## II. NEC safety performance

### A. Accident/incident review

In determining whether to file this request and considering its scope, Amtrak initially reviewed reported train accident data for the NEC spine over the period 2000-2012. The year 2000 was selected because it was the initial year for Acela service. The year 2012 was selected because it was the last full year for which data were available at the time the review commenced. Any incident that was FRA reportable in this timeframe on the spine of the NEC was examined with special emphasis on passenger train incidents. Where multiple reports were filed for an individual accident, all of the reports were retrieved and examined for insight into the causal factors and circumstances. Reports bearing on risk in high-speed zones in the NEC were further categorized in support of the Quantitative Risk Analysis (QRA) model (or "risk model") described below.

The review was conducted using two methodologies.

Quantification. First, accident counts by type and cause were determined for main lines, sidings and industry tracks. Yard accidents were excluded for this purpose, because the types of events and infrastructure conditions were not considered typical of risks present in high-speed zones. Accidents involving all NEC operators, passenger and freight, were included. Accidents were included whether or not they occurred within candidate high-speed zones, because it was felt that in some cases underlying causes might reflect on accident risk in high-speed zones. Events involving the overhead contact system and locomotive pantographs were excluded, since it was felt that the events reviewed were not apparently speed dependent; and the events, although numerous, typically did not result in harm to persons.[4] Fires were also excluded, because the events were not found to be speed dependent; and in most cases there was no harm to persons. As a further refinement, accidents that occurred within track segments with higher speeds (>80 mph) were captured to help inform the Quantitative Risk Analysis. The results of this review are described more particularly in the Risk Analysis Report appended as Exhibit 1.

Individual review for topicality. Independently, 2000-2012 NEC train accidents involving a report by Amtrak (because an Amtrak train was involved or the event occurred on Amtrak's line) were reviewed for relevance and for indications of specific mitigations that might be useful going forward. This review was somewhat broader, in that yard and terminal accidents, not on the main line, were also reviewed to verify that the risk profile associated with those occurrences. No attempt was made to sort or quantify these events; rather, those deemed of interest were separately listed on a Table of Exemplary Events, which includes the narrative description(s) of the accidents and any other information available in National Transportation Safety Board or FRA reports (where available). Exhibit 2A.

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[4] The only pantograph/catenary event which involved an injury during the period was RAIRS # 060546, February 23, 2000, at Odenton, MD. An associated 6180.55a report indicated one employee injury for one day's lost time, due to a bruise or contusion to the elbow, account unexpected movement.

The two data sets were compared to verify that application of filters to the database had not resulted in omissions or inappropriate inclusion (e.g., because the event was not on the NEC spine), and corrections were made as necessary.

As accident reports became available for 2013 and a portion of 2014, these events were reviewed individually to ensure consideration of the circumstances with respect to risk mitigation going forward; and notable events were placed on a second Table of Exemplary Events, as warranted. Exhibit 2B. They were not included in the Quantitative Risk Assessment, because work had already begun on that assessment; and results for the more recent periods were so favorable that reliance on them might have been considered less than fully conservative.

As is true with any review of train accident data, there were a number of relevant observations that suggested the need for specific actions going forward. As more fully explained in the Risk Analysis Report, these observations have been documented by track segment and considered for risk mitigation, either in the short term or in specific support of the Tier III request contained herein. However, the following over-arching observations appear to be relevant to the state of safety on the spine of the NEC:

- Given the extensive operations conducted by Amtrak, commuter railroads, and freight operators over the period examined, train accidents were relatively few in number.

- Although the small number of events makes determination of trend lines difficult, train accidents on the NEC appeared to decline in frequency over the period. (The results vary depending upon the filters applied to derive relevant sets, but the overall trends appear to at least mirror the progress nationally.)

- The events examined provide one window into remaining risk to train occupants on the NEC. Most of that risk appears to stem primarily from obstruction events (vehicles and other large objects that end up on the right-of-way due to the negligence of others, or vandalism) and derailments caused by a variety of causes, the vast majority at low speeds. Events involving only maintenance of way equipment (impacts, derailments) were also a concern. At least two events were recorded where MOW equipment was not within limits of authority.

- Only one serious train-to-train collision was recorded during the period. It occurred in the Baltimore terminal area and involved improper use of air brakes on a diesel-hauled train. Although this event warrants concern, it does not appear to suggest a systemic issue that would be likely to arise in a high-speed zone.

- There was a serious collision involving an MBTA train and freight car that rolled out from the MBCR Stoughton Branch, striking the MBTA train at Canton Junction, MA. The accident was caused by the failure to apply the hand brake on the freight car, or because someone subsequently released it. FRA cited an improperly installed and adjusted derail, which was integrated into the MBCR signal system, as a factor in the accident. FRA HQ-2008-33.

- Acela trains, like others operating on the NEC, were involved during the study period in a few incidents, including an impact with a boulder, impact with snow from an overhead bridge, etc. However, importantly, Acela trains have been involved in no events, such as serious collisions or derailments, which challenged the crashworthiness features of the trainsets in a way that we would expect to present different outcomes for conventional or Tier III-type equipment . This is a very encouraging record. Acela trains have logged more than 40.6 million train miles since their introduction in late 2000.[5]

### B. Existing safety measures

The very good state of safety on the NEC is not a matter of happenstance. Both Federally-mandated safety programs and technology, on the one hand, and aggressive voluntary actions, on the other, have contributed to the increasingly strong safety record.

Amtrak seeks to comply very rigorously with FRA-administered statutes and regulations pertaining to railroad safety. This attention to compliance is sustained and supported at the highest levels of the Corporation.

As a result of prior Interstate Commerce Commission and FRA orders, the NEC is the principal territory within the United States that is equipped with cab signals (providing a continuous indication to the locomotive engineer regarding the permitted signal speed), and speed control (providing warning and, if necessary, intervention if the cab signal speed is not observed). As noted above, key locations have been protected against civil overspeed conditions. All train movements on the North End of the NEC are subject to full PTC (ACSES plus ACS/ATC), and Amtrak has equipped its locomotives operating on the NEC with ACSES, which is operative on all Amtrak trains traversing South End tracks that are ACSES-equipped.

Amtrak recognizes that its responsibility for safety on a passenger railroad goes beyond compliance with minimum safety standards. Accordingly, Amtrak has been an early adopter of system safety planning, hazard analysis, and proactive safety management. These efforts continue to unfold and will gain further impetus as FRA rolls out its new regulations for risk reduction and as passenger railroads share lessons learned. In the meantime, Amtrak continues to undertake very specific risk mitigation steps across its departments that help to explain the robust safety record achieved in the 2000-2012 period and today.

**Leveraging technology.** Amtrak's efforts to leverage technology including the following:

- Technology to reduce track-related derailment risk, including the risk of derailment fouling high-speed tracks, is employed at a level exceeding Federal requirements:
    - A crewed Track Recording car is operated over the high-speed route every two weeks. (The FRA requirement is once per month.) The success rate for the two week operation over a year is about 80%. The issues for not attaining 100% are weather (particularly in winter when snow prevents the effective operation of the track geometry car), failure of the track geometry car systems during a test, failure of the train to complete the journey, and reroute of the train off of the high speed route for various reasons.

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[5] Acela trains, like other trains operating on the NEC have been involved in train incidents resulting in fatalities to occupants of a motor vehicle at a grade crossing, as well as persons on the tracks. However, as noted elsewhere in this petition, speed is strictly limited over the few remaining grade crossings. Fatalities to individuals occupying the track structure typically do not involve sufficient damage to equipment to endanger train occupants. Generally speaking, then, these events are not implicated in the discussion regarding use of Tier II vs. Tier III standards.

  - A crewed Track Recording car is operated over the Alternate Main tracks on the NEC every two months. (The FRA requirement is once every two months for Class 7 track, once per year, for class 6 track, and no requirement for Class 1 thru 5 track.)

  - A crewed Track Recording car with Gage Restraint Measurement System technology is operated over every track in the NEC, including crossovers, yard and terminal trackage once per year. (The FRA requirement is that all Class 8 and 9 track is tested once per calendar year. There is no requirement for class 1 thru 7 track.)

  - Autonomous Ride Meters (ARM) deriving data from accelerometers are used every day on 18 of the 20 Acela Trainsets, three Amfleet cars, and a Cab Car. (The FRA requires carbody acceleration measurements be taken on one vehicle operating at class 8 and 9 speeds four times within any 7 day period.)

- FRA's January 2014 final rule on rail integrity is strengthening internal rail flaw detection and rail management practices across the industry.[6] Amtrak measures to further reduce the chance of derailment and secondary collisions caused by rail failures include the following:

  - Rail testing of the route of oil trains is performed at twice the federally mandated frequency, from twice annually to four times annually.

  - In addition to the federally mandated twice a year "walking stick" rail test on the high speed turnouts and crossovers, all turnouts and crossovers are tested once a year with the walking stick.

  - Although not mandated, use of hot bearing and dragging equipment detectors is common across the national rail system. Amtrak has been particularly aggressive in utilizing these arrangements. In the most recent inventory, the following fully active detector locations were catalogued:

    - Between New York and Washington, 41 dragging equipment and 8 hot bearing locations; and

    - Between New Haven and Boston, 7 dragging equipment and 8 hot bearing locations.

    In general, detectors south of New York are tied directly into the signal system, while detectors between New Haven and Boston are "talkers."

  - FRA research and development has hastened the introduction of advanced inspection technologies that can monitor the health of the freight car fleet and target interventions, often at an early and very effective stage. In addition to extensive use of traditional hot

[6] 79 FR 4234 (January 24, 2014); correction 79 FR 4633 (January 29, 2014).

bearing and dragging equipment detectors on the NEC, Amtrak has employs wheel impact load detector (WILD) technology at the following locations:

Edgewood, MD Milepost AP75

Marcus Hook, PA Milepost AP 16.2

Monmouth Jct. NJ Milepost AN 40.8 (currently Out of Service due to High Speed track construction)

Rocky Hollow, RI Milepost AB 171.8

Mansfield, MA Milepost AB 201

An additional WILD installation was placed at Enfield, CT (Milepost AS 51.5) on the Springfield Line to control the entrance to the Shore Line at Mill River.

In addition, NS provides a "Gatekeeper" detector array at Marietta, PA on the Port Road. These include a HBD, Hot Wheel, Dragger, WILD, and over Dimension/shifted load detectors.

**Building a sound safety culture.** Looking beyond the purview of individual programs and initiatives, Amtrak is also committed to building a strong safety culture. Amtrak has several system-wide programs to address safety culture which include a confidential close call reporting system, a behavior based safety program, a labor/management drug and alcohol prevention and intervention program and an active community outreach program. A brief description of the programs is included below.

The Amtrak Confidential Close Call Reporting (C3RS) is an FRA program designed to improve safety practices by collecting and analyzing reports detailing unsafe conditions. This program is a partnership between the FRA, Amtrak, various Labor Unions, NASA and the USDOT Volpe Center. The program encourages employees to confidentially report unsafe events to NASA who will interview the reporter to seek additional details of the event. NASA prepares a report, de-identifies the report to protect the identity of the reporter and then shares the report with a Peer Review Team (PRT). The PRT conducts a root cause analysis to identify why the problem occurred and recommends corrective actions to prevent recurrence. Corrective actions are forwarded to a Support team of Amtrak managers for review and implementation.

The C3RS program began in January 2011 as a pilot program in select yards across the Amtrak system. The initial demonstration project was limited to BLET and UTU employees operating in these select yards. The program expanded in September 2013 to include all Amtrak owned and operated areas accessed by T & E crews. In April 2014 the program again expanded to include the Mechanical Department in Hialeah, Fl. The Mechanical Department plans continued expansion of the program in September 2014 to include the New Orleans, LA and Sanford, FL yards. Amtrak's Engineering Department is currently in negotiation with their labor unions to develop a C3RS program at select MOW bases. This joint labor/management safety program continues to offer solutions to identified barriers. Some of the recommended corrective actions include:

- Modifications to the Blue Signal Procedures

- Modifications to the Temporary Speed Restriction Bulletins (TSRB)
- Improved Conductor proficiency in yards
- Revisions to the Job Safety Briefing process for T&E
- Development of numerous Trend Advisories
- Modifications to Procurement contracts affecting contractors in yards

Amtrak has also embarked on a culture change initiative to improve employee safety via the implementation of a behavior based safety program. Safe-2-Safer is a multi-year risk-reduction approach to safety and security that involves every level of management, starting with the CEO and the executive team, to supervisors and front line employees. This is not a replacement for current safety and security practices — it's an approach to making them even more effective.

Safe-2-Safer is both a leadership-development project and an injury-reduction project; the two work together to change the culture in an organization to one that better promotes safety. Leadership drives culture by influencing the systems used to eliminate or mitigate exposure, and by using business processes that ensure safety systems are utilized as intended. Aligning these factors is critical for safety and security excellence because together they shape behavior where people use equipment and facilities to get work done. It is there that exposure to risks in safety and security occurs. Improved leadership is accomplished through training and coaching for all levels from the CEO to the first-line supervisor.

Safe-2-Safer also aims to reduce injuries by creating an environment in which employees are enabled to change at-risk behaviors to safe behaviors. This is accomplished through training, coaching and greater accountability for supervisors, and broader employee engagement through peer-to-peer feedback. This process gives employees significant ownership of safety: through the observation process they watch out for the safety of their co-workers, and through the feedback process they intervene when co-workers may be at-risk for injury. As an outcome of this, barriers to working safely are discovered and formally raised and removed.

Operation RedBlock (ORB) is a labor-developed, company-adopted drug and alcohol prevention and intervention program. The program emphasizes awareness, education, and prevention of drug use through union led prevention committees. The program goals are to promote a drug and alcohol free work place, to prevent employees from reporting to work under the influence, to prevent substance abuse while on the job, and to save lives and jobs in the most humanistic way through caring and compassion. Union-led, voluntary prevention committees are engaged for the basis of the Operation RedBlock drug and alcohol prevention process. Peer teams heighten co-worker's awareness to the dangers of drugs and alcohol in the workplace through educational and promotional activities. Another main function of the peer teams is to perform confidential interventions of workplace abuse and if necessary, referrals to ORB Peer Advocates, or Employee Assistance Counselors (EAP). Throughout the process, management and labor cooperate to support and insure the peer team's initiatives and confidentiality.

Operation Lifesaver's network of authorized volunteer speakers and trained instructors offer free rail safety education programs in fifty states. The organization delivers presentations more than one million people each year to include school groups, driver education classes, community audiences, professional drivers, law enforcement officers, and emergency responders. The programs are co-sponsored by federal, state and local government agencies, highway safety organizations and America's railroads. The

goal of the organization is to promote the three E's - education, enforcement and engineering to end collisions, deaths and injuries at highway-rail grade crossings and on rail property nationwide.
Amtrak has a long history of collaborating with Operation Lifesaver and has helped deliver its safety message to thousands of people via special railroad events, internal and external training activities and presentations conducted by Amtrak employees. To date, nearly 100 Amtrak employees are trained as Operation Lifesaver Presenters or volunteers. Together, they have helped spread the word about trespassing and grade crossing safety to dozens of civic organizations, first responder classes, transportation groups, and school age children in each of the eight FRA designated regions nationwide. Most recently, Amtrak created a dedicated position of Operational Lifesaver Specialist to act as a liaison between the non-profit, the railroad, Railsafe local, state and federal law enforcement partners and other outside stakeholders committed to reducing the number of grade crossing and trespasser incidents.

**Addressing freight-related risk.** On many Class I freight railroad corridors, manifest and most unit trains operate 50-65 mph and intermodal trains operate up to 75 mph. The situation on the NEC is significantly different. On the South End of the NEC, the timetable maximum speed for freight trains is 50 mph; but, under Amtrak special instruction 35-S1, between the hours of 6:00 a.m. and 10:00 p.m. freight train speeds are limited to 30 mph. Lower maximum speeds reduce available energy and lengthen warning times should a mishap occur, potentially reducing severity. Lower maximum speeds also reduce in-train forces as trains accelerate and brake, potentially reducing the frequency of “train handling” derailments.

Track-caused accidents are also less likely to occur on the NEC due to the strength of track structure and the frequency of inspection. Because high-speed zones are maintained to Class 8 standards for geometry, freight derailments associated with multiple causes (e.g., marginal truck rotation characteristics and track alignment exceptions) are very unlikely. Nevertheless, it is the nature of freight service that defective conditions can arise that present a potential derailment threat. Ensuring that freight operations do not contribute to that possibility has been a major point of emphasis.

Amtrak has understandings with Norfolk Southern (NS), CSX, Conrail-Shared Assets (CR), Connecticut Southern (CSO), Pan Am Southern (PAS) and Providence & Worcester (PW) permitting Amtrak mechanical personnel to conduct inspections for FRA and AAR defects, on selected trains bound for the NEC, on the freight railroads’ property. These inspections are typically conducted monthly. Results of inspections are provided to the host railroad, contributing to verification and improvement of freight railroad inspection quality over time. Amtrak plans to continue this practice, adjusting inspection intervals as warranted by defect ratios encountered and freight safety outcomes on the NEC.

**Actions by other NEC users.** Amtrak is not alone in making safety improvements. Other passenger operators on the NEC have come under the Passenger Equipment Safety Standards and other new FRA regulations since Tier II standards were adopted, and progress is not limited to compliance with more stringent regulations. New Jersey Transit Rail Operations, for instance, initiated one of FRA’s pioneer Confidential Close Call projects.

Freight railroads operating on the NEC have participated in safety improvements, both mandated and voluntary, during the period. Advanced equipment monitoring technology like that described above has been deployed at locations across the country, increasing the likelihood that bearing, wheel and other component problems will not progress to critical levels and cause problems on the NEC. Across the North American network, freight train accident rates have declined to historic lows.

**Bottom line.** Accordingly, Amtrak submits that the generally favorable and improving train accident record on the NEC, supported by specific, programmatic actions, and coupled with a strong effort to build a positive safety culture, supports confidence for the future. Completion of PTC on the South End in the very near future will add further confidence.

This is a much different landscape, with much surer footing, than FRA encountered when it first considered provisions for high-speed rail on the NEC in the early 1990s. Actions taken by FRA, Amtrak and other parties have moved us collectively into a new and more promising era of passenger railroading, an era ripe for additional progress.

In addition, as described in connection with the Tier III request, below, Amtrak is taking further actions to mitigate risk and build confidence in the safety of NEC operations.

## III. Acela 160 miles per hour (mph) request

Amtrak's Acela trainsets were built in full compliance with requirements that were thereafter embodied in the Tier II standards within the Passenger Equipment Safety Standards. The trainsets have been demonstrated, through service experience, to be capable of high-speed operation over the NEC at speeds up to 150 mph. As described below, Amtrak now submits that the Acela trainsets should be permitted to operate at up to 160 mph, the upper limit of Class 8 track, where conditions permit.

### A. Previous waiver request for speed zone in Rhode Island

In October of 2013, Amtrak filed a waiver request to demonstrate 160 mph operations over a segment of track in Rhode Island where operations had been conducted at 150 mph, subject to successful qualification testing. The request for relief was from the 150 mph cap currently contained in the Tier II regulations, and also the 150 mph limit contained in the ACSES Order. Amtrak submitted a strong safety case supporting the modest increase in speeds, which we incorporate by reference in this petition. Responding to docket comments from an organization representing Amtrak employees, Amtrak offered to take additional actions to strengthen safety on the subject segment and more generally on the NEC. *See* FRA Docket No. 2013-0128.

### B. Additional territory for up to 160 mph

Amtrak now requests additional relief from the ACSES Order and the Tier II speed cap to operate Acela trains (i) at up to 160 mph, instead of 150 mph, on a designated speed zone in Massachusetts and (ii) at greater than 135 mph, but not more than 160 mph, on a designated speed zone south of New York City.

**Hebronville-Mansfield.** The additional Northeast Division speed zone is from MP AB 194 (Hebronville) to MP AB 204 (Mansfield), in Massachusetts, a territory where operations are currently conducted up to 150 mph. All trains operating in the zone are equipped with ACSES, cab signals and ATC (i.e., full PTC).

In addition to Acela and Amtrak Regional trains, MBTA operates 29 trains per day, on average, within this zone. CSXT has up to 4 train movements per day in this portion of this territory from Mansfield west to Holden Interlocking at MP AB 198.3. From Holden west to MP AB 194.3, track 4 is available for freight movements toward Cape Cod.

Most of the switches off of this high-speed zone are controlled by the traffic control system and securely route trains with full PTC protection. One industrial track located off track 1 (Zayers Industrial Lead) is equipped with a hand-throw switch secured by an electric lock that can be operated only when route conditions are clear. The lead is protected by an existing derail that will be supplemented with a “crowder” to ensure effectiveness.

There are two MBTA stations in this zone, Attleboro and Mansfield. The Attleboro Station has four tracks, with the outside tracks used for boarding. A pedestrian tunnel provides access between platforms, and inter-track fencing further discourages entry by pedestrians onto the tracks. Pedestrians at this location will not be impacted by an increase in Acela train speeds on the two main tracks.

Based upon possible safety concerns associated with the potential for increased aerodynamic effects at low-level stations, Amtrak will maintain the existing maximum speed of 150 MPH at Mansfield Station. Any increase in speed for Tier II equipment above 150 MPH will require further analysis to establish potential impacts to the safety of passengers on low-level platforms.

Between New York and Washington, the ACSES Order limits maximum speeds to 135 mph. There is one distinct zone where Amtrak requests authority to raise speeds above those currently in effect.

**County to Ham.** The so-called “New Jersey racetrack” or “Raceway” between County Interlocking at MP AN 33 and Ham Interlocking at MP AN 55.5 (roughly from just south of New Brunswick to Trenton) is the subject of an FRA grant for infrastructure improvements. Amtrak is making improvements, including installation of constant-tension catenary, that will support 160-mph Acela operations. Amtrak would like to increase Acela speeds on this zone as soon as improvements permit.

This is a 4-track railroad, with Acela Express trains currently operating on the 2 and 3 tracks at up to 135 mph subject to flanking protection provided by the traffic control system and active ACSES/ACS/ATC on board. All Amtrak Regional trains using these tracks also utilize ACSES.

Conrail Shared Assets provides limited local service using portions of this zone, with an average of only two trains per day. Industries are served at Deans Siding on Track 4. The location is protected from incursion from the siding by locked crossover switch that will divert traffic away from the main. Normal operations do not require Conrail to cross over to Track 1, except at County Interlocking itself, which is just north of the proposed speed zone.

The Amtrak MOW base at Adams (MP 35) is protected from main line incursion by an interlocked split-point derail.

NJT operates a daily average of about 99 trains, using primarily tracks 1 and 4.

Passenger stations on the subject portion of the racetrack include Jersey Avenue (MP 33), Princeton Junction (MP 47), and Hamilton (MP 53).

Jersey Avenue has only one platform, on Track 4. Boarding or discharging on any other track would occur only if all tracks from the normal platform to the boarding location were out of service. The platform at Jersey Ave (Main) on track 4 is for discharging of passengers only. Passenger loading of trains at Jersey Ave is done on the lead track in the yard off of the main, where New Brunswick locals originate and terminate. The platform on track 4 is provided as a convenience for passengers who boarded a New Brunswick train to New York to ride any westbound train back. Eastbound Trenton trains do not stop at Jersey Ave.[7]

At Princeton Junction, served by Amtrak and NJT, high platforms are served by the outside tracks (1 and 4); thus, increasing speeds on tracks 2 and 3 should not affect pedestrians. Similarly, NJT's Hamilton Station has high platforms served by tracks 1 and 4, with an overhead walkway between platforms.

Amtrak submits that, with completion of PTC installation on the wayside and on-board trains, there should be no obstacles presented by the County-Ham zone to prevent operations by the Acela trainsets at up to 160 mph upon completion of improvements now underway.

### C. Status of qualification testing

Recent qualification testing at speeds up to 165 mph has supported the capability of the trainsets to provide revenue service at up to 160 mph under specified conditions. Initial testing done in the fall of 2012 found truck hunting on one of the power cars. Mitigations were studied and a new round of testing was conducted in September 2014 under an FRA-approved test plan, over each of the Acela high-speed zones addressed in Amtrak's prior waiver request and in this request. Hunting was experienced at one location with a combination of wheel and rail profiles that had been hypothesized to be problematic (i.e., indicative of the conditions leading to the exception in the prior test). Testing on a parallel track under the same conditions, but with the preferred rail profile, resulted in no exceptions. As this petition was filed, Amtrak and FRA were working to complete data reduction and analysis for the test series.

### D. Specific relief requested, including conditions

This request is for the waiver of speed restrictions specified in the ACSES Order, 150 mph in high-speed zones between New Haven and Boston (as previously requested and in the Massachusetts zone described above), and 135 mph in the high-speed zone in New Jersey, and waiver of any and all provisions of FRA regulations that may be construed to limit "Tier II" compliant trainsets to 150 mph. In short, Amtrak asks that Acela trainsets be permitted to run at up to 160 mph, the upper limit for Class 8 track, where route conditions and trainset qualification otherwise permit. Amtrak's ability to operate at up to 160 mph would be conditioned on trainset qualification approval from FRA and on completion of stipulated improvements within the identified speed zones, including equipping of all passenger and freight trains with PTC.[8]

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[7] At Jersey Avenue, there are cross track walkways for use when there is a track outage and the trains are compelled to operate on track 3 (or even track 2 if there is a two-track outage). Passengers using the cross track platforms on Track 4 are protected by the out of service and/or by enforcement of NORAC rule 121 (setting forth detailed procedures for such circumstances).

[8] FRA's September 2, 2004 letter related to qualification of the Acela trainset provided as follows: "FRA approves the operation of the Acela high speed trainsets in revenue service between Washington, DC, and New York, NY, at a maximum operating speed and cant deficiency of 150 mph and 7 inches, on the condition that speeds on curves greater than 16 minutes of curvature may not exceed 130 mph." The letter further referred to the 135 mph ACSES Order restriction. Amtrak's current request asks to waive the 135 mph cap. Actual operation at 160 mph would be based on the appropriate special approval from FRA, provided the testing recently completed has assured FRA that

### E. Safety rationale

Train operations on the NEC are conducted with a high degree of safety. As the ACSES system is extended to all track and all trains operating on the South End, and as Amtrak and host railroads implement additional risk reduction measures, safety will be further enhanced. Further, Amtrak has pursued, and will continue to pursue, a suite of risk mitigations that go well beyond minimum safety standards. Further, as described in the previous request for the Rhode Island zone and immediately above, route conditions on the three high-speed zones have been thoroughly reviewed for suitability.

The safety record for Acela service, in particular, has been excellent, and the track/vehicle interaction characteristics of the trainsets are now well understood. Amtrak submits that adjustment by waiver of the current limitations of 150 mph North of New Haven, and 135 mph south of New York, is consistent with safety subject to the conditions noted above.

Working through the RSAC, FRA has anticipated these developments. The second Engineering Task Force (ETF) recommendations, which FRA has indicated will serve as the basis for FRA's forthcoming "NPRM 1," contemplate revision of the Tier II language of the Passenger Equipment Safety Standards to set 160 mph as the upper limit for this service.[9]

### F. Public interest considerations

Gaining experience with enhanced high-speed operations will also help to provide a sound foundation for introduction of Tier III-compliance trainsets that may offer even greater advantages in service quality. In the meantime, Acela trainsets will be fully utilized to reduce trip times and ensure schedule reliability. Growing market share for Amtrak's premium service will return revenues that can help to support rail service in all of the Northeast regional markets through additional infrastructure improvements that are not dependent upon the uncertain Federal appropriations process. Thus, granting the requested relief is in the public interest.[10]

## IV. Tier III request

Throughout the decades of the 1980's and 1990's, FRA supported research and development directed at improving the safety of rail passenger operations. Part of that effort led to improvements in crashworthiness for conventional rail equipment, which became known as Tier I equipment under the Passenger Equipment Safety Standards. This effort also led to application of crash energy management principles, initially as part of the Tier II requirements. At the same time, equipment manufacturers and railroads internationally, and particularly in Europe, began to make extensive use of CEM techniques.

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160 mph operations over the subject territory is warranted, but subject to the continued restriction of 130 mph and 7 inches of cant deficiency in curves unless separately modified.

[9] ETF_001-02 – Proposed Ruletext for NPRM 1. docx., available on the RSAC web site at https://rsac.fra.dot.gov/meetings/20130614.php.

[10] Exhibit 5 provides a discussion of how Amtrak's Tier III Next Generation High-Speed Trainset Project aligns with the public policy goals of the USDOT and the Administration. Fuller utilization of the inherent capabilities of the existing Acela trainsets will return similar benefits (albeit lesser in magnitude).

As the high-speed rail movement looked forward to opportunities of the 21st Century, proponents and FRA initially welcomed the use of dedicated, grade-separated rights-of-way as a means of isolating high-speed trains from the hazards associated with motor vehicles, freight trains, and less capable passenger equipment. This vision may yet prove feasible for domestic projects such as the Texas Central Railway, as it has for Japanese Shinkansen service and similar service elsewhere.

However, as proposed high-speed rail projects have advanced domestically to this point, they have faced difficult cost barriers associated with obtaining dedicated rights of way, particularly in and around major metropolitan areas. Access to city-center stations is, of course, essential to the synergies among high-speed rail, regional and commuter rail, and transit that provide value to prospective users.

Accordingly, FRA tasked the RSAC, through the ETF, an expert element of the RSAC's Passenger Safety Working Group, to recommend proposed standards for "Tier III" passenger equipment capable of operating at very high speeds on dedicated rights-of-way, while operating safely at Tier I speeds over grade crossings and on rail lines shared with freight trains and other passenger trains.

The ETF issued recommendations, described below, that were adopted by the full RSAC on June 14, 2013; and FRA has stated that it is preparing a Notice of Proposed Rulemaking to add the Tier III standards to the passenger regulations.

This waiver request follows the logic of the ETF recommendations with respect to operations in territory involving Tier I speeds (i.e., up to 125 mph). That is, the equipment that Amtrak proposes to order would be at least as crashworthy as Tier I equipment. Amtrak expects that this would be accomplished by acquiring integral trainsets with an appropriate mix of structural protection and CEM features. At the few locations where grade crossings remain on the NEC, speeds for the Tier III equipment would continue to be limited as they are today for Acela, Regional and commuter trains.

It is the second aspect of Amtrak's proposal that involves further innovation. Amtrak proposes to operate the Tier III equipment on designated, grade-separated route segments at up to 160 mph. Portions of those route segments are used for freight service (either shared track or shared corridor), and all of them are used by other passenger trains.

Amtrak initially pursued this course at the suggestion of FRA officials interested in determining whether the California High-Speed Rail Authority (CHSRA) and Amtrak could obtain Tier III trainsets in a common or coordinated procurement based on performance specifications, holding down unit costs and contributing to the emergence of a national standard for high-speed equipment. After reviewing informal responses to the joint Request for Proposals, CAHSR and Amtrak determined that requirements for the two services could not be met by the same equipment, despite many similarities in the needs of the two organizations.

Amtrak has continued its pursuit of Tier III-capable equipment because options offered by the vendors clearly offer possible solutions that can help to enhance service quality and efficiency on the NEC going forward. More importantly, Amtrak has become convinced, through work ongoing in support of this petition, that pursuing the Tier III approach is fully consistent with safety while serving the following important purposes:

First, Amtrak needs to acquire equipment that will increase seating capacity to meet market needs. Some Tier III-type equipment being built internationally uses powered axles distributed throughout the trainset, offering seating in leading and trailing cars. Others use more compact power cars. This kind of equipment could not be built under existing Tier II requirements. Existing Acela trains accommodate 305 passengers, while Tier III trains will provide about 425 seats.

Second, equipment acquired for the NEC needs to be capable of rapid acceleration and deceleration to ensure efficient use of existing signal spacing and time slots. Although the Acela equipment accelerates at a more rapid rate than conventional trains, it is limited by the mass of the trainset.

Third, new equipment for the NEC needs to have excellent "trackworthiness." Even though built and maintained as a tilt train, the Acela has been curve limited to 130 mph because of lateral forces applied to the track structure in curves, particularly by the power cars. Even though designed to provide passenger comfort at a cant deficiency of 9 inches, the trainsets have been limited to 7 inches based on actual track/vehicle interaction characteristics. And alternatives to the Acela design are not readily available. Because standards vary in other countries, vendors in the international market have not offered relatively heavy, Tier II-type equipment that would meet the needs of the NEC.

Fourth, new equipment needs to provide further environmental and energy benefits. Acela trainsets do utilize regenerative braking, as do most contemporary train types. However, Tier II-type construction, at least as executed to date, involves more weight that affects efficiency and emissions at the power source.

Fifth, Amtrak needs to avoid the surprises, break-in issues, and cost associated with equipment uniquely built to Tier II standards—a category that does not correspond to any other set of requirements internationally. As successful as the Acela service has been, Amtrak suffered significant out-of-service time for the fleet as unexpected issues emerged. Given the equipment's known limitations and the incremental costs, Amtrak is satisfied that it makes no sense to attempt to limit the potential pool of equipment designs to that equipment built to existing Acela specifications. Going out for Tier II equipment on a "performance" basis could result in limited bids at prices reflecting a heavy load of design costs, and in any event the equipment ordered would be new and unproven in many respects. By contrast, there are a number of product lines available that respond to the Tier III requirements—trains employing technology that is extensively service-proven.

The discussion below goes beyond what has motivated Amtrak to pursue the Tier III option and discusses why this is a good choice for safety, as well as service and good fiscal sense.

### A. Engineering Task Force / RSAC recommendations

The second ETF was formed to describe performance criteria for high-speed trainsets capable of operating safely over highway-rail grade crossings, and inter-mingling with freight trains and conventional passenger trains, at Tier I speeds. Historically, conventional passenger equipment has consisted of individual locomotives, cars, and cab control cars that might be used in any train of any feasible length. Crashworthiness focused on the structural strength of elements such as collision and corner posts that would resist collapse up to specified loadings at designated locations to protect volume occupied by crew members and passengers. It was known that conventional coupling arrangements would provide some degree of practical energy absorption, and that controlled lateral movement would tend to contribute, as well. However, the subject structures were not designed to perform those functions, *per se*, and it was understood that primary reliance was to be placed on structural strength of the individual elements in the train, with the backbone of each vehicle being its "compressive strength." Because compressive strength was measured along the line of draft, the "buff" strength requirement of 800,000 pounds tended to dictate, or at least encourage, designs with heavy underframes.

Through the 1990s and the following decade, the RSAC Passenger Safety Working Group, with the support of the Volpe National Transportation Systems Center (Volpe Center), worked to upgrade the elements of the conventional train so that optimum crashworthiness could be achieved within the traditional design paradigm. Much of the equipment delivered for passenger service over the past two decades has benefitted to one degree or another from these developments.

It was this mature state that the second ETF sought to examine, comparing the traditional design paradigm with the newly maturing trainset-based approach being implemented extensively in Europe. This approach emphasizes management of collision energy throughout the train. Under this approach, each element of the train contributes to Crash Energy Management (CEM) by absorbing energy in sacrificial components such as pushback couplers or in crush zones outside the occupied volume. Rather than assuming that the first vehicle impacted needs to withstand all of the collision energy, however, the effort is to transfer much of the energy along the train, permitting numerous CEM features to "trigger" while protecting occupied volumes designed to withstand higher energy levels.

In effect, the ETF asked what kinds of accident scenarios could mature-stage Tier I equipment be expected to survive. Given those scenarios, how might it be possible to describe performance requirements that would achieve the same outcomes but allow for use of different strategies? The Volpe Center performed extensive analysis in support of this effort, and international equipment builders contributed their expertise.

Tier III equipment is required to meet—

- Criteria for protection of the occupied volume through resisting a specified quasi-static load on the collision load path (238.703),

- A dynamic collision scenario involving the Tier III equipment and a conventional passenger train impacting at 20 mph in which passenger and crew space is conserved (238.705) and serious override is avoided (238.707),

- Required measures to inhibit fluid entry to the same basic degree required of conventional locomotives and cab cars (238.709),

- The same cab end structure requirements applicable to Tier I equipment (238.711),

- Specified requirements for structural strength at a non-cab end (if any) that mirror requirements for Tier I passenger coaches (238.713),

- Through incorporation by reference, the Tier I requirements for roof and side structure integrity (238.715), and

- Requirements for truck attachment (238.717).

These requirements are designed in such a way that they permit a trainset to be accepted based on all of its safety-relevant attributes, including use of semi-monocoque construction and crash energy management features.

The ETF recommendations also deal with glazing (238.721), brake systems (238.731), interior fittings and surfaces (238.733, 238.735, 238.737), emergency systems (238.741, 238.743), and cab equipment such as alerters (238.751) and sanders (238.753). FRA may propose additional language dealing with front-facing glazing.

All of the above material is expected to be included in the first NPRM for Tier III equipment (NPRM 1).

Requirements for inspection, testing and maintenance (ITM) and safety appliances remain under discussion within the RSAC and are expected to be addressed in a second NPRM. Amtrak anticipates that equipment will be offered by vendors in the current procurement that will respond favorably to eventual requirements for glazing and safety appliances. Amtrak expects to comply with ITM requirements issued for Tier III equipment.

Separately, the RSAC, through the Passenger Safety Working Group, provided recommendations for a new System Safety Program (SSP) regulation that FRA has issued as a notice of proposed rulemaking.[11] The ETF recommendations for NPRM 1 contain several points at which railroads will be required to specify technology or procedure choices in their SSP plans. Amtrak has an active system safety process in place, including efforts to identify, evaluate, and reduce risk. If relief is granted in this docket, Amtrak will look forward to submitting a new System Safety Program Plan for FRA approval as the regulation takes effect, and amending that Program as the final characteristics of the new trainsets are determined. The plan will be dovetailed with appropriate filings under the positive train control regulations, including the requirements of § 236.1007. The SSP plan will be subject to FRA approval before trainsets enter service.

### B. NEC constraints specific to this request

As noted above, the NEC does not currently support service at Tier III speeds. However, the prevalence of curves and other civil speed locations (bridges, stations, etc.) place a premium on acquisition of equipment that is agile in its ability to accelerate and decelerate rapidly—and extremely trackworthy both in curves and on tangents. The current trainsets used in Acela Express service have proved less than ideal in this regard; and, indeed, significant reductions in trip times should be possible if suitable equipment can be identified.

The NEC alignment both benefits and suffers from the history of the railroads and communities through which it passes. Stations have generally become magnets for development, but the dense urban areas along the railroad offer few new practical opportunities, consistent with citizen preferences and cost constraints, for vertical or horizontal separation of the railroad from the surrounding landscape and infrastructure. Accordingly, just as operational constraints must be accommodated, safety enhancements to isolate the railroad and prevent unwanted and unintended incursions must be carefully selected and executed. This means that site-specific safety mitigations must be implemented in lieu of "green field" programmatic solutions.

[11] 77 FR 55372 (September 7, 2012); *see* 77 FR 70409 (November 26, 2012).

### C. Specific relief requested, including conditions

Amtrak requests a permanent waiver conferring on Amtrak the ability to utilize high-speed trainsets built to proposed Tier III standards in service at speeds exceeding 125 mph, but not more than 160 mph, on designated high-speed zones on the spine of the NEC, in lieu of equipment built to Tier II standards.[12] Given that Tier III equipment may achieve Tier I crashworthiness objectives using different design concepts, relief is also required from Tier I standards to the extent Tier III standards are not identical. The high-speed zones are described by milepost locations in Exhibit 5.

Amtrak asks that all regulations and orders inconsistent with this proposed use of Tier III equipment be deemed waived, to the extent the ETF Tier III recommendations address the subject matter. Amtrak is aware that some Tier III requirements are proposed to be identical to Tier I or II requirements; and, of course, in those instances Amtrak would comply with the Tier I or II provisions referenced in the Tier III regulatory language.

The relief needed is twofold. First, Amtrak asks that any barriers in existing regulations or orders to operating Tier III equipment under Tier II conditions be waived. Second, Amtrak asks for assurance that operations at up to 160 mph, rather than 150 mph, will be accepted as consistent with safety and in the public interest under the specific circumstances contained herein.

The specific regulations, and order of interest, are more fully discussed below.

#### 1. Regulations and order

Amtrak has sought to determine which regulations and orders may be inconsistent with the proposed use of Tier III trainsets. Amtrak is cognizant of speed restrictions in the ACSES Order referred to above, which we request be waived for the Tier III equipment operating within the proposed Tier III speed zones, allowing for speeds above 125 mph, and up to 160 mph, using Tier III equipment, in the designated high-speed zones. All other requirements regarding train control would, of course, remain in place.

Amtrak believes that the greatest clarity can be achieved by complying with a single set of standards, in this case proposed Tier III standards, for those subject matters where well-formed proposals are available. The principal regulatory topics of interest in this Petition, their treatment in existing Tier I and Tier II standards, and their treatment in proposed Tier III standards, are summarized in the following table:

[12] As a matter of administrative practice, FRA has often limited waivers to a 5-year period, ensuring that performance under the waiver and changed circumstances are considered periodically. However, when considering requests involving investments in equipment with a long useful life, FRA has more often granted "permanent" relief (without an automatic termination date). Amtrak submits that the need to obtain long-term financing makes permanent relief an appropriate course in this proceeding, should Amtrak's request be granted. Obviously, just as FRA can change regulations in a way obsoleting existing equipment, facilities or practices, FRA maintains continuous jurisdiction over any relief granted and can call up any waiver for review.

| Topic(s) | Tier I reference (49 CFR part 238) § | Tier II reference (49 CFR part 238) § | Proposed Tier III (ETF_001-02) § | Comment |
|---|---|---|---|---|
| Compressive strength; occupied volume integrity | .203 | .405 | .703 | Tier I and II standards focus on buff strength on line of draft.<br><br>Tier III focuses on strength of occupied volume along the collision load path. |
| Crash energy management; dynamic collision scenario | None | .403 | .705 | Tier I standards rely exclusively on strength (no CEM requirements).<br>Tier II standards also specify CEM targets.<br><br>Tier III standards require performance equivalent to Tier I but offer flexibility in how to achieve it. (Effectively, CEM elements will be essential unless Tier I static strength is specified.) |
| Anti-climbing | .205, .207 | .407 | .705, .707 | Tier I and II specify anti-climbing resistance at car interfaces based on strength requirements.<br><br>Tier III specifies anti-climbing performance in the dynamic collision scenario at both the colliding and coupled interfaces. |
| Forward-facing end structure, leading vehicle, structural | .211(b), or Appendix F | .409 | .711, Appendix F | Tier III utilizes the Alternative Requirements for front end structures, which are also available under Tier I.<br><br>Tier II requirements are more stringent. |
| Forward-facing, fluid entry | .209 | .409(d) | .709 | No material difference among the three tiers.<br><br>Intent of requirements is to keep material from entering occupied space. Two requirements: strength and fluid tightness.<br><br>Recent clarification provided by FRA for means of demonstration to be included in the NPRM 1. |
| End-structure integrity, non-cab end | .211(a), .213 | .411, .413 | .713 | No material difference among the three tiers, although for Tier III express flexibility is offered where cars are semi-permanently coupled in such a way as to resist disengagement and telescoping. |
| Rollover strength | .215 | .415 | .715 | No material difference among the three tiers.<br><br>Tier III requirements are taken from Tier I. |
| Side strength | .217 | .417 | .715 | Tier III requirements are taken from Tier I.<br><br>Tier II requirements are more stringent. |
| Truck-to-car-body attachment | .219 | .419 | .717 | Tier I and II are similar, although Tier II addresses component attachment.<br><br>Tier III specifies a more complex set of requirements, including component attachment, but offers the option to demonstrate performance in a dynamic collision scenario. |
| Glazing | [49 CFR part 223] | .421 | .721 | Please see separate discussion of side- and front-facing glazing, below. |

| Topic(s) | Tier I reference (49 CFR part 238) § | Tier II reference (49 CFR part 238) § | Proposed Tier III (ETF_001-02) § | Comment |
|---|---|---|---|---|
| Brake system | .231, also 49 CFR 232.407(e)(10) | .431, also 232.407(e)(10) | .731 | Tier I, II, and III requirements are similar, although Tier II and III provisions include real-time monitoring of brake system functions.<br><br>Tier III language permits use of passenger brake alarms that remain subject to engineer response at higher speeds and leaves certain related technical choices to the railroad's system safety plan. |
| Interior fixture and seat attachment | .233 | .435 | .733, .735 | Tier I and II provisions use similar approaches, although Tier II specifies higher values for power car cabs.<br><br>Tier III provisions generally permit use of domestic Tier I or U.K. (RSSB) standards (taking crash pulse into consideration), although cab seats must comply with Tier I standards. |
| Luggage racks | .233(b) | .435(h) | .737 | Tier I/II standards 8g/4g/4g.<br>Tier II standards also require racks to be enclosed.<br><br>Tier III requires either compliance with Tier I or compliance with U.K. standard (taking crash pulse into consideration). Provides flexibility not to enclose racks. |
| Emergency window egress and rescue access | .113 | .114 | .741 | General requirements applicable to Tier I and II equipment contemplate removal of specified windows intact for emergency egress and rescue access.<br><br>Tier III follows the general requirements but creates flexibility to employ other means within an approved plan. |
| Emergency lighting | .115 | .115 | .743 | Tier III requirements are the same as for Tier I and II trains, except that accelerations may be derived from the dynamic collision scenario. |
| Alerters | .237 | .447 | .751 | Tier I requires an alerter, but excepts ACS/ATC territory; Tier II is actually weaker, allowing use of a deadman.<br><br>Tier III requires use of an alerter, in the absence of a hazard analysis supporting an equally effective approach, except where *redundant* train control apparatus is in place. |
| Sanders | [49 CFR 229.131] | [49 CFR 229.131] | .753 | The Locomotive Safety Standards require operative sanders for conventional locomotives, but not for MU cars.<br><br>Tier III would require the railroad's system safety plan to specify whether sanders are used. If used, they would generally have to comply with part 229 requirements and be included in the railroad's ITM program. |

| Topic(s) | Tier I reference (49 CFR part 238) § | Tier II reference (49 CFR part 238) § | Proposed Tier III (ETF_001-02) § | Comment |
|---|---|---|---|---|
| Inspection, Testing and Maintenance | .301-.321 | .501-.505 | .803, .805 | Tier I and II ITM requirements are specified quite differently, with more scrutiny given to Tier II equipment by the railroad and FRA.<br><br>Tier III ITM is only partially specified in the ETF draft, but is currently under further development and is expected to be no less strenuous than Tier II requirements now applicable to Acela equipment. |
| Fire safety floor test procedure | Appendix B to part 238 | Appendix B to part 238 | Appendix B to part 238 | Tier III follows Tier I/II, but an alternative is provided for testing the floor assembly with protective skirts and bottom covers that are part of the equipment's design. |
| Alternative Dynamic Performance Requirements for Front End Structures | Appendix F to part 238 | Appendix F to Part 238 | Appendix F to Part 238 | Tier I and III alternatives are the same.<br><br>ETF notes Appendix will need to be revised to reflect the addition of Tier III standards. |

To the extent the Tier III standards do not create new or alternative requirements, Amtrak expects to comply with provisions of the Locomotive Safety Standards, general provisions of the Passenger Equipment Safety Standards, and Tier II provisions of the Passenger Equipment Safety Standards—as well as other applicable FRA regulations (e.g., 49 CFR part 239, pertaining to Emergency Preparedness).

Amtrak also requests permission to utilize Tier III glazing standards, with the understanding that the front-facing glazing requirement related to ballistics remains to be resolved. In Amtrak's Request for Proposal, the Schedule 1 Part A (Next Generation HST RFP), Appendix A-U.S. Laws and Regulations Matrix states that the car builder will comply with "ETF_016-03 Tier III Cab Glazing Task Group Recommendations". Since this is a Performance Based Requirements Document Amtrak was silent on prescriptive language. The RSAC ETF did not come to resolution in the final language due to lack of consensus on the ballistic requirements for the forward facing cab glazing. FRA pulled the draft language from RSAC and will pursue an independent rulemaking process. It is likely that the aerodynamic and large impact requirements will reflect agreement obtained with ETF_016-03 III Cab Glazing Task Group Recommendations. Amtrak is prepared to work with the glazing suppliers to address the final recommendation for a ballistic requirement—keeping in mind the need to maintain conspicuity as a critical function of the glazing. The issue here is that most Tier III equipment, for aerodynamic purposes, places the front glazing at a highly oblique angle. This is beneficial for protection of the cab occupants, since objects striking the glazing on a horizontal trajectory will more likely be deflected. However, the challenge is that, as the angle of glazing deviates more from the vertical, the more distortion is introduced as glass thickness increases.

Amtrak has also noted a number of references to Tier II equipment and speeds in other parts of the FRA safety regulations, based on requirements laid down principally in 49 CFR part 238. Cross-references to this body of regulations are contained in a number of FRA regulations (e.g., § 229.5), but generally they appear to be merely descriptive, rather than limiting. To the extent these cross-references and duplicative language are considered limiting, Amtrak requests that they be waived.

There are other regulatory provisions that could potentially be viewed as obstacles, i.e., The inapplicability of the Power Brake Regulations (49 CFR part 232) to passenger equipment is predicated on the presence of a "conductor's valve" accessible to passengers in each car. § 232.407(e)(10). The ETF Tier III proposal contains an alternative approach at § 238.731(d), requiring a passenger brake alarm with more complicated functionality, and Amtrak requests that this approach be authorized. Using a system that gives passengers direct control at lower speeds, while permitting the locomotive engineer to retain judgment under other conditions, better balances the competing considerations for a high-speed train. (There is no need to use a 2-way end-of-train device on a contemporary high-speed passenger train, which will have both electronic and pneumatic control systems that function independently to offer redundancy.)

There are at least two provisions of the Locomotive Safety Standards that Amtrak does not believe present an obstacle to the proposed use of Tier III equipment but that might be viewed as technically confusing. To the extent § 229.141 (MU car buff strength, etc.) might be deemed applicable to a high-speed trainset, Amtrak requests that it be waived under the same rationale for deviation from Tier I and II standards. Similarly, Amtrak requests assurance that section 229.203(b) will continue in effect, excepting Tier III trains from the crashworthiness requirements for conventional locomotives, notwithstanding any relief from the existing Passenger Safety Standards (49 CFR part 238) granted in this proceeding.

The PTC regulations, at 49 CFR § 236.1007, continue to contemplate that a rule of particular applicability (RPA) will be required for operations above 150 mph. Based upon earlier amendments to the Track Safety Standards and discussion in the ETF, Amtrak believes that this RPA requirement is atavistic, reflecting prior FRA thinking. Amtrak requests that this provision be waived, although Amtrak will comply with the balance of the section. FRA review of Amtrak's System Safety Program Plan, and other required special approvals, will permit FRA to determine that Amtrak is taking a comprehensive approach to the safety of the proposed operation.

#### 2. Reservation of safety appliance and certain other issues for later decision

Those reviewing the docket for this petition may be aware that there are a number of issues related to safety appliance arrangements and inspection, maintenance and testing of high-speed equipment that are not yet resolved in the ETF. Issues pertaining to the applicability or non-applicability of the Locomotive Safety Standards (49 CFR part 229) are also under review. To the extent it is feasible for Amtrak to incorporate ETF-recommended approaches at the time a Notice to Proceed is issued, Amtrak will do so. However, the path to obtaining formal approval may, in certain instances, depend upon the sequencing of decision making within the RSAC, the timetable of the procurement, and the specific equipment selected. In any event, if further relief from FRA requirements is needed prior to placing equipment in service, Amtrak will make a request with appropriate justifications for FRA consideration.

### D. Safety rationale

The safety case for this request starts from the premise, supported by accident analysis from the inception of Acela Express service in 2000, that passenger service on the NEC is already conducted with a high degree of safety. There have been no fatalities to passengers or crew members on freight or passenger trains operating on the spine of the NEC since the onset of Acela service in 2000 to the present day.

As discussed above, this record was supported by steady improvements in safety technology and practices, embodied in FRA regulations and further extended by voluntary risk mitigations put in place by Amtrak and other NEC stakeholders.

With this background, and subject to additional safety measures, Amtrak seeks to make effective use of the proposed 3-tier passenger equipment framework while operating at speeds in the proposed Tier II range, up to 160 mph. This approach shows fidelity to the proposed framework in the following respects:

- Grade separation has been achieved in high-speed territory. Operations over the remaining highway-rail grade crossings will, as today, be conducted only at conventional speeds. In fact, the highest speed at any of the 11 remaining crossings (all on the Shore Line in Connecticut) is 90 mph. At all of the crossings with train speeds above 60 mph, 4-quadrant gates are installed, with presence detection. If a vehicle is detected on the crossing after descent of the exit gates, the cab signal system is downgraded and the train slows to the extent feasible approaching the crossing. The lower-speed crossings are all equipped with conventional flashing lights and gates. Together with total elimination of crossings on the remainder of the NEC spine, this is the most secure set of arrangements in place nationwide.

- Amtrak does not seek to operate at proposed Tier III speeds (in excess of the proposed Tier II range), even though equipment responsive to Amtrak's current procurement may be capable of higher speeds. The reality is that the NEC alignments, together with civil restrictions and traffic constraints, do not offer attractive options for gaining trip time through very high speeds. Although highly contingent future plans do contemplate the possibility of building separate, dedicated high-speed alignments in the future, that will be a much different safety case, and one which will be fully aligned with FRA's present framework.

- Amtrak is not seeking to provide service at Tier II speeds, using Tier III trainsets, on a railroad that is dominated by freight traffic. To the contrary, the NEC has a modest amount of freight traffic, comprising less than 3 percent of total train miles. In certain of the high-speed zones, there is no freight traffic, or it amounts to a very few trains per day. Wherever there is freight traffic, Amtrak's safety mitigations will seek to hold down risk to the level that is as low as reasonably practical.

- Although there is substantial passenger service using conventional equipment on the NEC, both in terms of Amtrak regional service and commuter trains, it is not clear that this represents a significant departure from FRA's program approach. Safety requirements for Tier I passenger equipment are substantial, and the safety record of Amtrak regional service on the NEC, and of the commuter authorities, has been excellent. All trains will be subject to positive train control in a very robust form, supported by an excellent signal and train control foundation. Service using Tier III equipment will actually create greater compatibility among the passenger trains on the NEC.

- High-speed service will be supported by a robust system safety program in accord with FRA's forthcoming regulatory requirements and rooted in active hazard analysis efforts pre-dating this request for relief.

Clearly, on the other hand, this request does step outside the proposed 3-Tier framework in two important respects. First, the Tier III equipment would be operated at Tier II speeds intermingled with substantial numbers of other passenger trains as well as a relatively light freight traffic load. It is important that Amtrak demonstrate that this can be done safely, and—as discussed above and in the analysis that follows—Amtrak submits that the evidence on this issue is strong.

The other difference is that Tier III trains would be operating above Tier I speeds on a right-of-way that is not entirely "sealed" from outside influences. Significant strides have been made by Amtrak and roadway authorities over the past several decades, erecting barriers to keep motor vehicles off the railroad and providing fencing and other arrangements to reduce intrusions by those not authorized to be on the railroad. In a number of other areas, natural features such as waterways and remote forests and bogs reduce risk substantially. As explained below, some areas of exposure remain; and Amtrak is working on additional mitigations that should significantly reduce this type of risk.

### 1. Programs driving safety performance going forward

As noted above, further reductions in risk on the NEC will be driven, in part, by—

- Completion of PTC, with all movements equipped on the South End as they are already are on the North End; and

- Aggressive hazard analysis supported by the safety management elements of FRA's forthcoming System Safety Program.

In addition, specific risk mitigations already underway but not yet delivered, as well as mitigations identified in the preparation of this request, will further enhance safety, more than compensating for any reduction in passenger equipment accident performance. The new mitigations are outlined in item 4.c. below and detailed in Exhibit 6.

### 2. Future growth of service on the NEC

Amtrak's plans for long-term growth of the Acela service calls for twice-hourly service between Washington and New York and regular hourly service from New York to Boston. This growth is reflected in the Quantitative Risk Analysis (QRA) future risk cases, explained below.

Commuter rail service is likely to grow, as well, over the coming years. Firm estimates of the extent of growth were not available for this purpose, so to analyze the effect of additional commuter trains the QRA assumes a 110% growth in traffic in a sensitivity case.

In addition to expected growth in rail passenger service, there is the possibility of some growth in freight service, as well. For instance, some modest increase in crude oil traffic is possible south of Wilmington, and even some growth in export coal could occur depending on market conditions, port competitiveness, etc. Carload traffic fluctuates within economic cycles, but no consistent source of growth is known to exist in the Region. Amtrak is encouraged that its principal tenant railroads have been constructive in their requests for additional NEC train slots, responding with cooperative safety actions that ensure traffic growth is offset by active measures to reduce risk. Amtrak would expect similar cooperation in the future.

As noted in the discussion of the QRA, below, at this juncture it does not appear likely that expected traffic growth should generate risk that could not be successfully managed. Accordingly, Amtrak expects that existing, forthcoming and proposed safety programs will make it possible to maintain a high degree of safety in NEC operations for the foreseeable future, under the conditions described in this request. However, Amtrak recognizes FRA's right to call up any waiver for review and would look forward to such a review should circumstances change appreciably on the NEC. FRA Regions 1 and 2 have a continuing presence on the NEC and could, if FRA so elected, initiate any review that might become appropriate.

### 3. Influence of equipment selection on safety outcomes

Choice of equipment is the question posed by this Petition. The Tier II equipment that Amtrak is currently operating has been trackworthy within the scope of its allowed vehicle/track interaction limitations (which have been notably constrained), and it may be the most crashworthy passenger equipment in the world, with respect to the protection of crew and passengers. As noted above, however, no events have occurred in over 40 million train miles of service to date that have significantly challenged the crashworthiness features of the trainsets. Another way of saying this is that Tier I or Tier III trains operating over the same territory at the same speeds since late 2000 would not likely have encountered impacts that they could not have withstood.

There are two ways to look at the difference in risk between use of the Tier II trainsets and potential Tier III trainsets. The first is the likely frequency of events that rise to the level of FRA reportability and that involve potential hazard to crew or passengers. Amtrak does not believe that there will be significant difference in frequency in events related to equipment performance. Tier III equipment selected for its superior track-vehicle interaction characteristics would likely be qualified under more generous criteria than the existing Acela trainsets, adding to service quality, but in neither case would any significant derailment risk be expected. Tier II equipment now in service is equipped with on-board systems that monitor bearing temperature and truck performance, among other parameters, which directly benefits safety (see 49 CFR § 238.445). These functions will be included in the on-board systems of the Tier III trainsets, which under the trainset specification obligates prospective car builders to provide health monitoring on functions such as Trainset Dynamic Behavior, Bogie Instability and Defective Gearbox Monitoring, Axle Bearing Health Monitoring, Hot Box Detection and Carbody Monitoring. Lighter-weight Tier III equipment may also impose less wear and stress on the track structure when operating under similar conditions.

For purposes of the QRA, equipment defect-caused accident frequencies are assumed to be a function of train type only, and are influenced by different component designs, maintenance and inspection routines. High-speed trains are subject to more frequent inspections and are equipped with automatic condition monitoring systems, leading to lower accident frequencies. The on-board diagnostics specified for Tier III equipment will provide additional protection for this class of equipment and hence will result in a lower mechanical defect derailment risk when compared to other equipment types.

With respect to collision frequency, no material difference is expected between Tier II and Tier III equipment. Both will be protected by a proven train control system.

The second level of analysis is the potential severity of collision events involving the two types of equipment.  In this respect, the Acela trainset would have the advantage in the most challenging potential cases, e.g., collision with heavy freight equipment or a conventional passenger locomotive.  This is expected to be a set of scenarios with very low probability.  However, crew and passengers of the Tier II train would be better protected in these scenarios.

Passengers and crew of the Tier II trainset would also be better off in a collision with a conventional commuter train—the majority of which on the NEC are multiple-unit trains.  However, some of the advantage gained here might be lost due to the effects on crew and passengers of the conventional train—depending upon the degree of severity involved in the collision.

The interesting question here is this:  against which risks do Tier II crashworthiness standards insure?  Both fully-compliant Tier I trains, and prospective Tier III trains, are expected to survive impacts with conventional equipment up to about 20 mph without any significant loss of crew or passenger "occupied volume."  Tier II equipment, due to its stronger crew compartment and greater crash energy management targets, is expected to be good for about 30 mph.  No equipment internationally is expected to survive collisions with like equipment at 125 mph, let alone 150 or 160 mph.   It is well understood that train collisions at elevated speeds must simply be prevented.

FRA's judgment in describing Tier II standards was, in effect, that as maximum speeds increase average speeds will increase, as well, and that given the risks as then understood it was prudent to "push the envelope" and try to achieve the best that could be expected using robust structures and CEM principles—all the while recognizing that "passive safety" could never provide the final answer to risks posed by high speed operations.

Amtrak has no doubt that Tier II equipment might provide an extra measure of crashworthiness for an event at moderate speed, occurring in a high-speed zone around a station, in a curve, or where competing traffic made attainment of MAS impossible. However, implementation of full PTC and other targeted measures will materially reduce the risk of such an event.  Taking an active safety approach, importantly, also reduces the risk of a very high speed event occurring—one that no trainset could fully protect against.  The QRA described below illustrates that point.

In another way of looking at the question, Tier II standards include a requirement that the leading vehicle in the consist not contain passengers, which may be beneficial to the extent the requirement is implemented through use of dedicated power cars with significant mass that can displace moderate-sized objects on the right of way, without significant hazard to crew (because of the rigid cage construction of the Tier II power car).  § 238.403(f).  With respect to Tier III equipment, the ETF has ensured that the leading car will have significant structural strength.  Recognizing the difference in performance between Tier II and Tier III equipment in this scenario, Amtrak has focused mitigations, discussed below, on preventing obstructions from arising on high-speed tracks.

Protection provided by glazing presents another level of analysis.  Amtrak submits that use of the agreed-upon requirements for Tier III glazing will provide equivalent protection for cab occupants as contemplated by the ETF.  Amtrak recognizes that the issue of front-facing ballistic requirements remains unsettled and is prepared to work through this issue with the selected builder, glazing manufacturers, and FRA as the specifics of the issue are more clearly presented.

### 4. Safety findings and proposed additional countermeasures

In determining whether to make the Tier III request, Amtrak has considered the review of NEC safety performance described above (II.A.) and has confirmed the need to maintain existing regulatory and voluntary efforts undergirding that performance (II.B.), including a number of actions initiated since the end of the 2000-2012 time frame. In addition, Amtrak has reviewed, *inter alia*, the hazard analysis records for existing Acela Express operations, the accident history, insights from FRA and Amtrak personnel familiar with the NEC, NEC track charts, timetables, and special instructions, and site surveys—including live observations and review of video, pictorial and public domain information regarding risks in the proposed high-speed zones . These efforts have flowed into two inter-related streams of further inquiry. First, Amtrak has commissioned and participated in the development of a Quantitative Risk Analysis (QRA) designed to—

- Estimate the level of safety achievable using Tier III equipment, under a variety of specified assumptions; and
- Help to rank order and evaluate the effectiveness of principal candidate safety mitigations that go above and beyond those already in place.

Second, Amtrak has evaluated additional risks that involve less probable mishaps that nevertheless present the potential for severe consequences and that are susceptible to reasonably discrete, practical mitigations.

#### a. Quantitative Risk Analysis Methodology

Maintaining safety in a complex environment, while altering the strategy for protecting passengers and crew in the event of a mishap, is a major undertaking that involves many factors. In order to better understand the likely implications of proposed changes, Amtrak contracted for a risk analysis. Dr. Alan Bing, who led a previous evaluation of safety on the Northeast Corridor and has performed risk assessment work for FRA, among other clients, devised and executed the QRA model with guidance, participation and support from LTK Engineering. Amtrak staff provided critical input data and guidance, and FRA safety personnel were briefed and offered suggestions as the work progressed. Amtrak, of course, is exclusively responsible for presentation of the QRA model and its results in this setting.

As noted below, quantitative risk analyses are useful tools for *comparative* analysis of railroad operations under specifically defined circumstances. Although no QRA can definitively determine whether or when particular events may occur, a well-structured analysis can help us understand the likelihood that events may occur, given input parameters. Although Amtrak's QRA explored a significant number of sensitivity cases, the primary focus of the effort was on the influence of on accident risk (defined as probability of occurrence times estimated severity) of employing Tier III equipment in lieu of Tier II equipment and the effects of current and prospective risk mitigations. Final results were "normalized" so that risk can be understood as a function of exposure—in this case, train miles. The system analyzed was the entirety of NEC operations, both passenger and freight. This was deemed appropriate because risk mitigations selected to safeguard high-speed operations in many cases will also reduce risk for other operations on the NEC.

The risk analysis effort was grounded in analysis of accidents over the period 2000-2012, both on the NEC and on a broader territory of contiguous passenger routes (intercity and commuter). A "base case" was generated and checked against historic outcomes for plausibility. Expert judgment was applied to estimate likely severities for events involving major accident scenarios, equipment types, and speed ranges. Looking forward, probabilities were estimated based on historic accident distributions, adjusted for known forthcoming interventions—principally the completion of PTC installation. Anticipated growth in Acela service looking forward to the 2020/2025 time period, was incorporated into the calculations. Sensitivity cases were performed to gage the effect of growth in commuter and freight traffic (for which reliable projections are not available).

The QRA model is described, and findings from the assessment are reported in detail, in Exhibit 1. The following discussion describes in broad outline the structure, findings, and recommendations of the QRA.

Amtrak conducted a detailed comparative semi-quantitative risk analysis to address the question of equivalent safety for proposed operations with Tier III equipment in lieu of Tier II equipment. *Comparative* means that the primary use of the model is to compare the safety performance before and after selected changes in infrastructure, equipment and operations. *Quantitative* means that risk will be quantified by numerical metric such as the estimated number of accident and casualties over a defined period, such as 10 years, or by normalized metrics such as accidents and casualties per million train-miles of operated. The analysis is *Semi*-quantitative due to lack of full knowledge of the service or accident history. The risk analysis requires expert judgment to fill gaps in the inputs required for the risk analysis based upon experience with different operations domestically or internationally. Amtrak believes that the conduct of such an analysis using conservative estimates for parameters with uncertainty provides risk estimation results that can be used to make informed decisions about the proposed operations.

The risk analysis was carried out for the high speed zones on the Northeast Corridor where future operations at speeds exceeding 125 mph with Tier III high speed train sets are being considered. Eight high speed zones were defined and further broken down into high speed segments of constant operational conditions to calculate risks associated with the proposed operation. The total length of the proposed high speed zones is 221 miles, which is all the territory where speeds exceeding 125 mph would be possible, assuming a maximum of 9 inches of cant deficiency. While it is impossible to achieve exact risk parity between zones, it is desirable for risk levels to be similar from zone to zone. Reporting risk estimated by zone can support decisions as to where to implement location-specific risk mitigation measures.

Risks associated with future operations outside these zones, at speeds up to 125mph, were not analyzed. The analysis cases included:

- *Analysis Base Case*: The NEC as operated over the period 2000 – 2012, with Tier II Acela Express trains at speeds up to 150 mph and conventional Amtrak regional and commuter equipment. This case is the foundation on which input parameters for all future cases are estimated, and also used in model validation.
- *Future Case: Mixed Tier II and Tier III Operations:* The NEC with circa-2020 estimated traffic levels with increased high-speed service between NYC to Washington, using original Acela Express, Tier II train sets supplemented by new Tier III equipment, both operating at up to 160 mph. This case examines risks where Tier II and Tier III trains operate on the NEC at the same time.

- *Future Case: All Tier III Operations*: this case assumes hourly high-speed service between Boston and NYC and half-hourly high-speed service between NYC and Washington DC throughout the day, with Tier III trains operating at up to 160 mph. This case examines the highest density operations with only Tier III equipment intermixed with freight and conventional Tier I (commuter) equipment on the NEC.
- *A Regulatory Null Case:* for comparison with other future operations with higher traffic densities using Tier III equipment, assuming use of Tier II equipment and full implementation of current (September 2014) safety regulations. Specifically, this means implementation of PTC (ACSES + ATC) throughout the NEC and for all main track operation.
- *Risk Mitigation Cases:* Multiple analyses of the All Tier III cases after implementation of selected risk mitigation measures. These cases examine Amtrak's ability to close the safety gap that exists associated with operation of Tier III versus Tier II equipment.
- *Sensitivity Cases:* Multiple analyses of the All-Tier III case after varying selected model inputs to test the sensitivity of model results to these variations. These cases examine the impact of significant increases in freight and/or commuter traffic in addition to introduction of Tier III trainsets as well as other infrastructure or operational factors that impact system risk.

The risk model calculates risk by hazard category defined based upon the historical accident review and practical experience from other operations both domestically and internationally. The calculated risks are summed for both linear and point risks by segment within a high speed zone; across multiple high speed zones; and then for the complete corridor. A linear risk is an accident that could occur anywhere over a track segment, such as a mechanical-defect-caused derailment. A point risk is an accident that would occur at a defined location such as an interlocking. The metrics developed included normalized accidents and injuries – the number that would be expected *per million train miles* over a given time period.

The risk model was developed using historical accident and operational data and validated through comparison with the actual accident history between 2000 and 2012. Amtrak developed a team of internal subject matter experts (SMEs) and stakeholders to verify the inputs needed for the risk model. The team also developed an appropriate set of hazard categories based upon the accident history. The team leveraged their combined practical experience from domestic and international operations as well to ensure that all hazard categories typical of the operation were covered. The team recognized that not all accidents which could occur on the NEC have actually occurred and the hazard categories needed to reflect a wider pool of potential hazards.

The risk profile of the NEC operations reflective of 2012 conditions was developed and validated by comparison with actual service history. A number of sensitivity analyses were conducted to assess impact on predicted normalized accident, injury and damage rates *per million train miles* for different input parameter variations. The model was used to measure the level of risk for a given set of infrastructure, equipment and railroad operation conditions. The analysis steps included:

- Identification of relevant accident scenarios based upon past accident history from operations in similar environments both domestically and internationally. The development of hazard categories focused on those types that are expected in a high speed passenger operation.
- Characterization of the likelihood and severity of each accident. That is, determine how often the accident might occur and define a severity for the accident (consequences are indicated by casualties and property damage). This process is repeated for each hazard category. Both these

quantities are estimates from analyses of past accidents that often have to rely on sparse or incomplete data.

- Calculation of estimated risk, which is accomplished by multiplying the number of accidents by the consequences of each accident for each accident scenario to obtain, the estimated total consequences.

The risk analysis process is iterative. If the total consequences determined are greater than the baseline case or the regulatory null case, then the proposed operation must be modified to reduce either accident frequency or consequences.

### b. Other observations from risk analysis and experience

As already noted, leading up to and concurrent with the development of the QRA model—and through a process of iteration taking into account model findings—Amtrak pursued additional means to identify vulnerabilities and potential responses, e.g.,

- Hazard analysis records for the existing Acela Express operations were reviewed;

- Amtrak asked FRA personnel and Amtrak employees for input on opportunities for improvement;

- Accident records were reviewed in an attempt to identify underlying causes;

- Site surveys were conducted using Amtrak's test car and supported by review of photographic and video records and inputs from Amtrak personnel familiar with facilities and operations; and

- Amtrak and contractor personnel evaluated a significant range of possible safety improvements for feasibility and effectiveness.

### c. Risk analysis findings and new safety mitigations flowing from the safety analysis

Based upon the QRA results and other work, Amtrak was able to identify, prioritize and select risk mitigation strategies for input into the risk model for proposed future operational conditions. The following findings were drawn from the analyses:

***Finding 1: Obstruction collisions are by far the most numerous type of accident to passenger trains operating at speed on the NEC, and two groups of these accidents should be the first targets for risk mitigation:***

***1a: Implement a program of construction of fences and barriers to prevent trespass and highway vehicle access in the 20 most vulnerable route segments as indicated by the risk model and on-the-ground assessments.***

- These accidents comprise 30% of all obstruction accidents, and about 20% of all accidents involving passenger trains.

- Provided the fences and barriers are subject to good routine inspections and maintenance, Amtrak has high confidence that the majority of obstruction accidents in the selected segments can be prevented.
- The risk analysis indicates that extending a fence and barrier program beyond the most vulnerable 20 route segments is likely to be less cost-effective, and is not proposed as part of this petition.
- The fence and barrier program should remain flexible, however, as full details of the present status of fence and barrier systems in the high-speed zones were not available at the time of the risk analysis. The analysis should be updated when this information is available, followed by modification of the program as appropriate.
- Risk model results estimate that a fence and barrier program will reduce normalized train accidents from 0.293 *per million train-miles* in the Tier III base case to 0.271 *per million train-miles*, and injuries to passenger train occupants from 0.128 *per million train-miles* in the Tier III base case to 0.123 *per million train miles*. As explained below, this should make a significant contribution toward closing the risk gap.

***1b: Continue with and expand where possible an active system safety program addressing the diverse causes of obstruction collisions with Amtrak MOW equipment and materials, contractor equipment and materials, and miscellaneous objects.***

- These accidents comprise 50% of all obstruction collisions, and 35% of all accidents involving passenger trains.
- The risk model shows that reducing the occurrence of these accidents by 20%, <u>combined with the fencing and barrier mitigation (conclusion 1a)</u> reduced normalized injuries from 0.128 to 0.116 *per million train miles*, enough to offset all the increase of injuries from using Tier III trainsets in place of Tier II trainsets. The results from the regulatory null case predicted a normalized injury rate of 0.119 *per million train miles*. Relative to an all Tier III operation before mitigation, this is a reduction of 9% in normalized injuries and a 17% reduction in normalized accidents.
- Causes for these accidents are diverse, meaning that a program that emphasizes overall culture, CRM and general system safety procedures are appropriate, rather than trying to address individual accident circumstances.
- Amtrak is already working on system safety and safety culture initiatives. Amtrak will extend its Confidential Close Call Reporting System to the maintenance-of-way department with the cooperation of the Brotherhood of Maintenance of Way Employees Division (IBT) and the Brotherhood of Railroad Signalmen. Amtrak encourages FRA to continue to support C3RS programs and requests that FRA evaluate this initiative at an appropriate time.
- An improved safety culture and system safety program will support reductions in <u>all accidents</u> where human factors are a root cause.
- As part of the System Safety Program Amtrak will monitor the reduction in accidents and close calls in the period prior to the introduction of Tier III train sets into service to ensure risk reduction goals are being met.

***Finding 2: Continue with initiatives aimed at reducing accidents to freight trains operating on the NEC, avoiding high cost actions.***

- The risk to passenger operations from freight trains accidents is of a secondary accident where a passenger train collides with derailed freight vehicles after an accident on an adjacent track.

- Model analysis and historical experience indicates that this risk is low, but is subject to substantial uncertainty:
    - The actual freight traffic volume is uncertain and could grow.
    - The model input parameters used in the secondary accident calculation are difficult to estimate. A sensitivity analysis making pessimistic assumptions (doubling the likelihood of an event, doubling the time to notify an approaching train and doubling the frequency multiplier on access spurs) about their value showed that the normalized accident rate increased by 4 percent and the normalized injury rate increased by 12 percent.
- The derailment rate on the NEC is higher than that typical of long distance intermodal freight on higher track classes.
    - This is a result, in part, due nature of freight traffic on the NEC, which is short haul and servicing industries or yards.
    - Freight traffic experiences frequent switching between tracks onto sidings increasing the chance for an incident when normalized by train mile.
    - Therefore continued attention to ongoing initiatives to reduce freight accidents is warranted.
- The specific risk mitigation initiatives applied by Amtrak are:
    - Extended use of on-board sensors to evaluate train performance and obtain early warnings of incipient track geometry issues.
    - Continued application of operating restrictions, use of traditional and advanced wayside detectors, and periodic visual inspections of freight equipment by Amtrak mechanical personnel.
    - Broader application of advanced inspection technologies.

***Finding 3: Continue with initiatives to reduce the risk of unintended intrusion on the NEC main tracks at access points, but limited to low cost actions.***

- The risk model shows that the risk of collision to a passenger train operating on a NEC main track is low.
- Some improvements are mandated in any case to bring the NEC into full compliance with PTC requirements.
- Specific initiatives are:
    - Use of improved derailers at specific sites, and
    - Selectively improve the track quality in freight tracks adjacent to NEC main tracks.

***Finding 4: Continue with any track and interlocking improvements that are currently in progress or planned.***

- The risk of track-defect-caused accidents is already low, thus while there will be some safety benefits from these improvements, those benefits are not the primary reason Amtrak is undertaking those improvements, and no additional improvements are proposed in this petition.
- Accidents at interlockings mostly have human factor causes unrelated to track condition.
- The specific improvements planned or ongoing that are referred to in this recommendation are replacement of selected interlockings and a comprehensive undercutting program being undertaken to improve ride quality. Both are primarily concerned with improving ride quality and reducing ongoing maintenance costs. Any initiative that reduces MOW activity will reduce accident risk, given the high number of accidents associated with roadway work.

Exhibit 6 describes in more detail the selected risk mitigations.

Amtrak is now in possession of technical tool that can be updated as changes to the system are made to assess the reduction in risk. As ongoing infrastructure improvement activities are completed the model will be updated to reflect the “then-current” status of the NEC. Further as planned risk mitigations strategies are implemented these will also be updated in the risk model allowing Amtrak to gauge the change in the risk profile predicted for the high speed zones.

Amtrak will continue to monitor the changes in the risk profile before introduction of Tier III equipment onto the NEC, during the timeframe when there is overlap of the two different trainset types as well as into the future when only Tier III trainsets are used at the highest traffic densities needed to meet service needs. The risk model developed is a tool that can, and will be updated when major infrastructure changes are implemented not related to the specific risk mitigation strategies agreed upon within the Waiver Petition enabling Amtrak to articulate to FRA the relative improvements in safety after completion of such work. The risk model can also be used as a means of justifying capital expenditures for future upgrades to funding sources.

Amtrak strongly believes that the results obtained from the analyses indicate that the proposed operation of Tier III equipment at speeds up to 160 mph on the NEC can be done safely through the implementation of cost effective risk reduction measures.

### d. Stakeholder engagement plan

When Amtrak introduced the possibility that this Petition might be forthcoming in discussions with FRA, FRA safety leadership expressed interest in ensuring that appropriate planning for stakeholder engagement be demonstrated as a part of the showing underlying the Petition. Attached, as Exhibit 3, is an initial summary of the plan for this activity.

Amtrak’s plan recognizes two general categories of stakeholders—those whose role requires specific actions (e.g., concurrences, providing access to property, cooperating in physical or procedural improvements) and those who simply need to be informed so that they will understand what is transpiring in a common space or process. Many particular stakeholders may, of course, fall into both categories, depending on the point of interface.

Amtrak has sought to initiate stakeholder engagement by briefing the Northeast Corridor Commission, Amtrak labor leaders, FRA staff, and others on the purpose and scope of the Tier III project. Where submission of this Petition was clearly contingent upon stakeholder engagement, as in the case of the Massachusetts Bay Transportation Authority, initial engagement has been undertaken. If this Petition is approved, Amtrak is prepared to commence the process of working with “actionable stakeholders” across the broad range of commercial, engineering, and process-related issues involved in this effort, as well as providing information through a variety of avenues.

Significant efforts both within Amtrak and with Amtrak business partners would be required to meet the objectives of the plan. Satisfactory completion of these efforts would, of course, be integral to affirming to FRA that all necessary undertakings have been fulfilled before Tier III equipment enters service on the NEC.

## E. Public interest considerations

As previously noted, the market for premium rail service has been firmly established by the Acela Express business line, but the current fleet size and configuration is not sufficient to meet growing demand. Adding Tier III trainsets to complement and eventually replace the existing Acela fleet will enable Amtrak to serve and grow this market.

Amtrak has separately submitted to FRA a business case, supporting the acquisition of Tier III equipment and associated improvements. The business case demonstrates favorable results for the Corporation and alignment with the public policy goals of FRA and the USDOT. These results mirror the societal benefits that will flow from shorter trip times, increased capacity, increased capital investment in the NEC, and energy and environmental impacts that will be much more favorable than would be expected through investments in other comparable transportation modes or rail equipment. Overall, mobility will be enhanced in the capacity-constrained Northeast market, relieving pressure on major airports in the region. Accordingly, this proposed action is unequivocally in the public interest.

Public interest considerations are described in greater detail in Exhibit 4.

## V. Conclusions

Intercity rail service on the NEC is essential to the economic health of the region and the mobility of its people, and Amtrak's premium Acela trains provide a crucial element of that service, generating revenue needed for renewal and improvement of NEC infrastructure utilized, as well, by commuter and freight railroads. Ensuring the quality and growth of premium service into the coming decades is a recognized goal both of Amtrak and USDOT. Accordingly, Amtrak has explored whether existing Acela trainsets can be utilized more fully consistent with safety, particularly on tangent track where higher speeds are feasible; and Amtrak has explored whether use of proposed Tier III trainsets could be accomplished with an equally high level of safety. In both cases, analysis has persuaded Amtrak that these improvements are justified and warranted.

Underlying these favorable conclusions is the high level of safety already achieved on the NEC, through careful adherence to regulatory requirements and through additional voluntary measures that drive down risk materially. Amtrak is committed to continuing and enhancing the processes of hazard analysis, risk assessment, and safety management that will be necessary to address the challenges of the future.

Authorizing existing Acela trains to operate at up to 160 mph where conditions otherwise permit is a logical first step toward improved trip time and schedule reliability. Two zones on the North End, in Rhode Island and Massachusetts, can currently support an increase in speed from 150 mph to 160 mph, protected by a well-established PTC system used by all trains over the territory. Within as little as two years, infrastructure improvements and completion of PTC will create the conditions permitting increases in Acela speeds from not more than 135 mph to 160 mph on the New Jersey "Racetrack." Amtrak has taken a number of voluntary steps that go beyond FRA safety requirements, and together with compliance with important regulatory requirements for accident prevention these actions have led to a high level of safety on the NEC. Amtrak submits that FRA should waive provisions of the ACSES Order and current regulations to authorize these modest but important speed increases as the necessary special approvals for vehicle/track interaction and train control are put in place.

But the principal opportunities for growing premium service on the NEC will be realized only as newer, more nimble equipment is placed in service. Amtrak is prepared to select a vendor and issue a Notice to Proceed for manufacture of new trainsets as early as the end of this coming April—subject to FRA's approval, in this proceeding, to use Tier III equipment in lieu of equipment meeting Tier II standards.

Acquisition of Tier III equipment is necessary to achieve reduced trip times and increase capacity needed for growth. Equipment specified to Tier II standards cannot meet these needs, consistent with acquisition of service-proven technology.

Throughout the history of rail safety regulation, FRA has found a way to make progress possible, consistent with continually improving safety results. Tier II standards represent a cautious approach to equipment crashworthiness based on prior safety history and caution regarding the course of train control developments and other factors. The safety record of operations on the NEC since the introduction of Acela service offers encouragement that accident *prevention* can be relied upon more heavily with good results. This Petition explains that this good safety record was not a matter of chance, but rather was heavily influenced by actions taken by FRA and industry specifically to reduce risk—including a number of specific mitigations put in place by Amtrak to address concerns on the NEC.

Notably, from the year 2000 to date, Acela service has operated over 40 million miles with no fatalities to passengers or crew in a train accident; and there have been no train accident fatalities in other service on the NEC. Further, the Acela crashworthiness features have not been challenged by any accident-related impacts that would appear likely to have endangered passenger or crew in conventional Tier I equipment or proposed Tier III equipment.

Accordingly, recent history appears to provide a reasonable foundation for confidence going forward. Nevertheless, the QRA conducted for Amtrak in support of this proceeding defined the performance gap between Tier II and Tier III equipment for future conditions. The QRA model was then used to evaluate further safety mitigations for effectiveness in order to ensure a sharp focus on priorities. As described more fully above and in the Risk Analysis Report (Exhibit 1), this work provided confidence that mitigations could be targeted in such a way as to offset the nominal risk gap. Additional mitigations will be added, both to help offset any uncertainty in the analysis and because available, affordable remedies were found for low-frequency mishaps involving unacceptable severity.

Amtrak submits that risk mitigations pertinent to introduction of Tier III equipment—including those previously introduced, those underway, and those planned for the immediate future—clearly support a conclusion that the Tier III service will provide a level of safety equivalent to that associated with use of Tier II equipment.

Accordingly, Amtrak requests that affirmatively recognize Amtrak's safety case, as described in this Petition and Exhibits, as providing safety at least equivalent to otherwise applicable requirements, and waive specific requirements that are inconsistent with the proposed Acela/160 and Tier III service.

## VI. List of supporting Exhibits

1 Risk Analysis Report

2 A Table of Exemplary Accidents (2000-2012)

B Additional Recent Accidents of Note (2013-2014)

3 Stakeholder Engagement Strategy

4 Public Interest Discussion

5 Tier III Proposed High-Speed Zones

6 Existing and New Safety Mitigations

**Exhibit 1 to the Tier III Waiver Application**
**Risk Assessment of Proposed Northeast Corridor High Speed Operations**
**Using Tier III High Speed Trains**

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**Exhibit 1 to the Tier III Waiver Application**
**Risk Assessment of Proposed Northeast Corridor High Speed Operations**
**Using Tier III High Speed Trains**

## Executive Summary

This exhibit provides the technical justification submitted as part of the National Passenger Railroad Corporation (Amtrak) Waiver Petition to the Federal Railroad Administration for the operation of Tier III equipment at speeds in excess of 125 mph but not to exceed 160 mph on the Northeast Corridor (NEC). The proposed operation with Tier III equipment will build upon Acela Express' success by providing reliable, higher capacity, expandable and more efficient equipment needed to meet the growing demand for high-speed rail service on the NEC for the next 30 years. In order to achieve the proposed service needs, including increased passenger capacity and reduced trip times for future operations; Amtrak intends to acquire Tier III equipment built to the equipment safety standards established by the Railroad Safety Advisory Committee's (RSAC) Engineering Task Force (ETF). The RSAC ETF has established minimum structural crashworthiness requirements for Tier III equipment. Tier III equipment built to these requirements will provide equivalent or better safety performance when compared to Tier I equipment. The current operation with Tier I and Tier II equipment includes service intermixed with freight and other passenger services at speeds up to 125 mph. Above 125 mph, FRA envisioned that Tier III equipment would only operate on a sealed dedicated corridor with no grade crossings or intermixing with other trainset types.

This definition of Tier III operations does not suit the proposed operation on the NEC, which allows mixed operations with conventional Tier I equipment and freight at speeds above 125 mph up to 150 mph. Therefore, Amtrak intends to demonstrate within the Waiver Petition that Tier III train sets can be operated safely over suitable high speed zones on NEC. To accomplish this goal, Amtrak conducted a detailed comparative semi-quantitative risk analysis. *Comparative* means that the primary use of the model is to compare the safety performance before and after selected changes in infrastructure, equipment and operations. *Quantitative* means that risk will be quantified by numerical metric such as the estimated number of accident and casualties over a defined period, such as 10 years, or by normalized metrics such as accidents and casualties *per million train miles* of operated. The analysis is *Semi*- due to lack of full knowledge of the service or accident history. The risk analysis requires expert judgment to fill gaps in the model inputs based upon experience with different operations domestically or internationally. Amtrak believes that the conduct of such an analysis using conservative estimates for parameters with uncertainty provides risk estimates that can be used to make informed decisions about the proposed operations.

The risk analysis was carried out for the high-speed zones on the Northeast Corridor where future operations at speeds exceeding 125 mph with Tier III high speed train sets would be technically possible with 9 inches of cant deficiency. Eight high speed zones were defined and further broken down into high speed segments of constant operational conditions to calculate risks associated with the proposed operation. The total length of the proposed high speed zones is 221 miles. While it is impossible to achieve exact risk parity between zones, it is desirable risk levels to be similar from zone to zone. Reporting risk estimated by zone can support decisions as to where to implement location-specific risk mitigation measures.

Risks associated with future operations outside these zones, at speeds up to 125 mph were not analyzed. This is based upon the consensus reached within the RSAC ETF that equipment built to the requirements agreed upon will perform as good as or better than conventional Tier I equipment. Therefore the structural crashworthiness performance in lower speed operations is safe and in the Public's interest. The risk analysis cases conducted included:

- *Analysis Base Case*: The NEC as operated over the period 2000 – 2012, with Tier II Acela Express trains at speeds up to 150 mph and conventional Amtrak regional and commuter equipment. This case is the foundation on which input parameters for all future cases are estimated, and also used in model validation.
- *Future Case: Mixed Tier II and Tier III Operations:* The NEC with circa-2020 estimated traffic levels with increased high-speed service between NYC to Washington, using original Acela Express, Tier II train sets, supplemented by new Tier III equipment. For this future service condition, both types of train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines risks where Tier II and Tier III trains operate on the NEC at the same time.
- *Future Case: All Tier III Operations*: This case assumes hourly high-speed service between Boston and NYC and half-hourly high-speed service between NYC and Washington DC throughout the day. For this future service condition, Tier III train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines the highest density operations with only Tier III equipment intermixed with freight and conventional Tier I (commuter) equipment on the NEC.
- *A Regulatory Null Case:* This case is used to compare other future operations with higher traffic densities using Tier III equipment, assuming use of Tier II equipment and full implementation of current (September 2014) safety regulations. Specifically, this means implementation of PTC (ACSES + ATC) throughout the NEC and for all main track operation.
- *Risk Mitigation Cases:* Multiple analyses of the All Tier III cases after implementation of selected risk mitigation measures. These cases examine Amtrak's ability to close the safety gap that may exist associated with operation of Tier III versus Tier II equipment on select NEC high speed zones.
- *Sensitivity Cases:* Multiple analyses of the All Tier III case after varying selected model inputs to assess the sensitivity of model results to variations in inputs. These cases examine the impact of significant increases in freight and/or commuter traffic in addition to introduction of Tier III trainsets as well as other infrastructure or operational factors that impact system risk.

The risk model calculates risk by hazard category defined based upon the historical accident review and practical experience from other operations both domestically and internationally. The calculated risks are summed for both linear and point risks by segment within a high speed zone; across multiple high speed zones; and then for the complete corridor. A linear risk is an accident that could occur anywhere over a track segment, such as a mechanical-defect-caused derailment. A point risk is an accident that would occur at a defined location such as an interlocking. The metrics developed included normalized accidents, injuries and damage – the number that would be expected *per million train miles* over a given time period.

The risk model was developed using historical accident and operational data and validated through comparison with the actual accident history between 2000 and 2012. Amtrak developed a team of internal subject matter experts (SMEs) and stakeholders to verify the inputs needed for the risk model. The team also developed an appropriate set of hazard categories based upon the accident history. The team leveraged their combined practical experience from domestic and international operations to ensure that all hazard categories typical of the operation were covered. The team recognized that not all accidents which could occur on the NEC have actually occurred and the hazard categories needed to reflect a wider pool of potential hazards.

The risk profile of the NEC operations reflective of 2012 conditions was developed. A number of sensitivity analyses were conducted to assess impact on predicted normalized accident, injury and damage rates *per million train miles* for different input parameter variations. The model was used to measure the level of risk for a given set of infrastructure, equipment and railroad operation conditions. The analysis steps included:

- Identification of relevant accident scenarios based upon past accident history from operations in similar environments both domestically and internationally. The development of hazard categories focused on those types that are expected in a high-speed passenger operation.
- Characterization of the likelihood and severity of each accident. That is, determine how often the accident might occur and define a severity for the accident (consequences are indicated by casualties and property damage). This process is repeated for each hazard category. Both these quantities are estimates from analyses of past accidents that often have to rely on sparse or incomplete data.
- Calculation of estimated risk, which is accomplished by multiplying the number of accidents by the consequences of each accident for each accident scenario to obtain, the estimated total consequences.

The risk analysis process is iterative. If the total consequences determined are greater than the baseline case or the regulatory null case, then the proposed operation must be modified to reduce either accident frequency or consequences.

Based upon the risk model results Amtrak was able to identify, prioritize and select risk mitigation strategies for input into the risk model for proposed future operational conditions. The following findings were drawn from the analyses:

***Finding 1: Obstruction collisions are by far the most numerous type of accident to passenger trains operating at speed on the NEC, and two groups of these accidents should be the first targets for risk mitigation:***

***1a: Implement a program of construction of fences and barriers to prevent trespass and highway vehicle access in the 20 most vulnerable route segments as indicated by the risk model and on-the-ground assessments.***

- These accidents comprise 30% of all obstruction accidents, and about 20% of all accidents involving passenger trains.
- Provided the fences and barriers are subject to good routine inspections and maintenance, Amtrak has high confidence that the majority of obstruction accidents in the selected segments can be prevented.
- The risk analysis indicates that extending a fence and barrier program beyond the most vulnerable 20 route segments is likely to be less cost-effective, and is not proposed.
- The fence and barrier program should remain flexible, however, as full details of the present status of fence and barrier systems in the high-speed zones were not available at the time of the risk analysis. The analysis should be updated when this information is available, followed by modification of the program as appropriate.
- Risk model results estimate that a fence and barrier program will reduce normalized train accidents from 0.293 *per million train-miles* in the Tier III base case to 0.271 *per million train-miles*, and injuries to passenger train occupants from 0.128 *per million train-miles* in the Tier III base case to 0.123 *per million train miles*.

***1b: Continue with and expand where possible an active system safety program addressing the diverse causes of obstruction collisions with Amtrak MOW equipment and materials, contractor equipment and materials, and miscellaneous objects.***

- These accidents comprise 50% of all obstruction collisions, and 35% of all accidents involving passenger trains.
- The risk model shows that reducing the occurrence of these accidents by 20%, <u>combined with the fencing and barrier mitigation (conclusion 1a)</u> reduced normalized injuries from 0.128 to 0.116 *per million train miles*, enough to offset all the increase of injuries from using Tier III trainsets in place of Tier II trainsets. The results from the regulatory null case predicted a normalized injury rate of 0.119 *per million train miles*. Relative to an all Tier III operation before mitigation, this is a reduction of 9% in normalized injuries and a 17% reduction in normalized accidents.
- Causes for these accidents are diverse, meaning that a program that emphasizes overall culture, CRM and general system safety procedures are appropriate, rather than trying to address individual accident circumstances.
- Amtrak is already working on system safety and safety culture initiatives. Amtrak will extend its Confidential Close Call Reporting System to the maintenance-of-way department with the cooperation of the Brotherhood of Maintenance of Way Employees Division (IBT) and Brotherhood of Railroad Signalmen. Amtrak encourages FRA to continue to support C3RS programs and requests that FRA evaluate this initiative at an appropriate time.

- An improved safety culture and system safety program will support reductions in all accidents where human factors are a root cause.
- As part of the System Safety Program Amtrak will monitor the reduction in accidents and close calls in the period prior to the introduction of Tier III train sets into service to ensure risk reduction goals are being met.

***Finding 2: Continue with initiatives aimed at reducing accidents to freight trains operating on the NEC, avoiding high cost actions.***

- The risk to passenger operations from freight trains accidents is of a secondary accident where a passenger train collides with derailed freight vehicles after an accident on an adjacent track.
- Model analysis and historical experience indicates that this risk is low, but is subject to substantial uncertainty:
  - The actual freight traffic volume is uncertain and could grow.
  - The model input parameters used in the secondary accident calculation are difficult to estimate. A sensitivity analysis making pessimistic assumptions (doubling the likelihood of an event, doubling the time to notify an approaching train and doubling the frequency multiplier on access spurs) about their value showed that the normalized accident rate increased by 4 percent and the normalized injury rate increased by 12 percent.
- The derailment rate on the NEC is higher than that typical of long distance intermodal freight on higher track classes.
  - This is a result, in part, due nature of freight traffic on the NEC, which is short haul and servicing industries or yards.
  - Freight traffic experiences frequent switching between tracks onto sidings increasing the chance for an incident when normalized by train mile.
  - Therefore continued attention to ongoing initiatives to reduce freight accidents is warranted.
- The specific risk mitigation initiatives applied by Amtrak are:
  - Extended use of on-board sensors to evaluate train performance and obtain early warnings of incipient track geometry issues.
  - Continued application of operating restrictions, use of traditional and advanced wayside detectors, and periodic visual inspections of freight equipment by Amtrak mechanical personnel.
  - Broader application of advanced inspection technologies.

***Finding 3: Continue with initiatives to reduce the risk of unintended intrusion on the NEC main tracks at access points, but limited to low cost actions.***

- The risk model shows that the risk of collision to a passenger train operating on a NEC main track is low.
- Some improvements are mandated in any case to bring the NEC into full compliance with PTC requirements.
- Specific initiatives are:
    - Use of improved derailers at specific sites, and
    - Selectively improve the track quality in freight tracks adjacent to NEC main tracks.

***Finding 4: Continue with any track and interlocking improvements that are currently in progress or planned.***

- The risk of track-defect-caused accidents is already low, thus while there will be some safety benefits from these improvements, those benefits are not the primary reason Amtrak is undertaking those improvements, and no additional improvements are proposed in this petition.
- Accidents at interlockings mostly have human factors causes unrelated to track condition.
- The specific improvements planned or ongoing that are referred to in this recommendation are replacement of selected interlockings and a comprehensive undercutting program being undertaken to improve ride quality. Both are primarily concerned with improving ride quality and reducing ongoing maintenance costs. Any initiative that reduces MOW activity will reduce accident risk, given the high number of accidents associated with roadway work.

Amtrak is now in possession of technical tool that can be updated as changes to the system are made to assess the reduction in risk. As ongoing infrastructure improvement activities are completed the model will be updated to reflect the "then-current" status of the NEC. Further as planned risk mitigations strategies are implemented these will also be updated in the risk model allowing Amtrak to gauge the change in the risk profile predicted for the high speed zones.

Amtrak will continue to monitor the changes in the risk profile before introduction of Tier III equipment onto the NEC, during the timeframe when there is overlap of the two different trainset types as well as into the future when only Tier III trainsets are used at the highest traffic densities needed to meet service needs. The risk model developed is a tool that can, and will be updated when major infrastructure changes are implemented not related to the specific risk mitigation strategies agreed upon within the Waiver Petition enabling Amtrak to articulate to FRA the relative improvements in safety after completion of such work. The risk model can also be used as a means of justifying capital expenditures for future upgrades to funding sources.

Amtrak strongly believes that the results obtained from the analyses indicate that the proposed operation of Tier III equipment at speeds up to 160 mph on the NEC can be done safely through the implementation of cost effective risk reduction measures. The details of the risk mitigation prioritization and selection for implementation are discussed within Attachment 6 to this exhibit.

## 1.0 Background and Introduction to the Risk Analysis Report

### *1.1 Background*

This document provides details of the risk assessment performed to assess the safety of proposed operations of Tier III high speed trainsets at speeds exceeding 125 mph on selected high speed sections of the Northeast Corridor (NEC). This analysis supports the Waiver Petition to "**Permit Operation of Acela Trainsets and "Tier III" Trainsets on the Northeast Corridor at Up to the Maximum Speed for Class 8 Track**". The Waiver Petition fully explains the background for the proposal to use Tier III trainsets over suitable high speed zones on NEC, including measures taken to ensure the operation will be safe, and in the Public's best interest.

The risk analysis is the principal means by which Amtrak will demonstrate that the proposed operation of Tier III trainsets will be safe. More specifically, the analysis contains an evaluation and selection of candidate risk mitigation measures to ensure that the proposed operation is at least as safe as the baseline high-speed operation over the selected high speed zones. This input, combined with inputs from rail safety experts and reviews of train accident experience on the NEC, provides the required safety assurance. The report is structured as an exhibit to accompany the Waiver Petition to FRA requesting approval of the proposed operation.

The risk analysis methodology is derived from previous similar analyses performed for FRA and Amtrak, including the analysis performed in connection with the original plans for operation of Tier II Acela trains in the late 1990s, shared track operations on the NJT River Line light rail operations and Talgo operations on west coast Amtrak routes, as well as broader US and international experience of measuring and assessing passenger rail safety. Specific sources consulted included:

- "Northeast Corridor Risk Assessment – Main report and attachments". Prepared for Amtrak and FRA, by Arthur D. Little in August 1994.
- "Passenger Rail Corridor Risk Assessment". Presentation to state passenger rail officials and FRA, by Arthur D. Little in September 1997.
- "Risk Assessment of Shared Light Rail and Rail Freight Services". Report and attachments for NJT on proposed River Line operations, performed by Arthur D. Little in February 1999.
- "Risk Assessment Updates for Talgo Operations". Final Report to Amtrak, by Arthur D. Little in December 2001.
- "Risk Evaluation Framework and Selected Metrics for Tank Cars Carrying Hazardous Materials". Draft report to FRA, performed by Alan J. Bing in November 2013 (The report contains detailed information on both general freight and rail hazmat risks).

### *1.2 Objective*

This exhibit supports the Waiver Petition request by providing a comparative and semi-quantitative tool for decision makers to evaluate the safety case for using Tier III equipment built to different crashworthiness standards versus continued use of Tier II equipment.

For the purpose of this analysis, Tier III train sets are defined as being in full compliance with the requirements proposed by the Railroad Safety Advisory Committee's (RSAC) Passenger Safety Working Group's Engineering Task Force (ETF). FRA is expected to issue a Notice of Proposed Rulemaking (NPRM) in the near future that will formalize these requirements. The Tier III requirements were developed with the specific objective of allowing high speed train sets designed to international structural standards to operate in shared service with conventional US passenger equipment (which now must conform to FRA regulatory Tier I car body requirements, as well as American Public Transportation Association (APTA) Passenger Rail Equipment Safety Standards (PRESS) standards), and with conventional US rail freight services. The maximum speed for Tier III trainsets in these shared passenger and freight operations is proposed to be 125 mph. On the NEC, however, the ACELA Tier II high speed trains already operate at speeds up to 150 mph at selected locations, and Amtrak wishes to operate any new trains at up to 160 mph on the NEC in route zones shared with Tier I passenger equipment and limited freight operations. For the reasons described in the Waiver Petition, acquiring new Tier III trains for NEC operations represents significant opportunities for Amtrak. Amtrak wishes to operate Tier III train sets on selected high-speed zones, after implementing appropriate risk mitigation measures, and believes that such an operation can be implemented safely, and will offer substantial public benefits over a service using Tier II equipment.

In order to provide assurance that the proposed use of Tier III train sets at up to 160 mph will be safe, a comparative and semi-quantitative risk assessment of Tier III operations in selected high speed zones on the NEC has been carried out.

*Comparative* means that the primary use of the model is to compare the safety performance before and after selected changes in infrastructure, equipment and operations. Absolute estimates of the number of accidents and injuries are necessarily approximate, given the large number of inputs needed to perform the calculation many of which are based on sparse data. A comparison between two estimates of the same operation before and after a limited number of changes is much more reliable; given many of the inputs do not change between the inputs for the analyses.

*Quantitative* means that risk will be quantified by numerical metrics such as the estimated number of accidents and casualties over a defined period, such as 10 years, or by normalized metrics such as accidents and casualties *per million train miles* operated. Normalized metrics are preferred, as the results are independent of the scale of an operation, and permit comparisons with the safety performance of other intercity passenger rail operations, both domestically and internationally.

The analysis is *Semi*- due to lack of full knowledge of the service or accident history. The risk analysis requires expert judgment to fill gaps in the model inputs based upon experience with different operations domestically or internationally.

The risk metrics selected for this analysis are:

- Estimated train accidents over 10 years and train accidents *per million train miles* by train type, by high speed zone and for all high-speed zones combined, and

- Estimated injuries among passenger train occupants over 10 years and injuries *per million train miles* by train type, by high-speed zone and for all high speed zones combined.

Although the model develops estimates of the number of fatalities, this is simply an estimated fraction of the number of injuries based on long running experience with US passenger rail operations. The calculation of fatalities is not an independent calculation. Such a calculation is not possible; given there have been no fatalities, either on the NEC or passenger rail operations in NEC states over the 2000-2012 period for which data has been analyzed.

### *1.3 Scope*

The risk analysis was carried out on the high speed zones on the Northeast Corridor where future operations at speeds exceeding 125 mph with Tier III high speed train sets are planned, as detailed in Table 1.

**Table 1. Definition of High-Speed Zones**

| Zone | Location |
|---|---|
| North 1 | Westerly – Providence |
| North 2 | Providence – Boston |
| South 1 | New York – Trenton |
| South 2 | Trenton – Philadelphia |
| South 2a | Philadelphia – Wilmington |
| South 3 | Wilmington – Bacon I/L (MP49.5) |
| South 4 | Bacon I/L (MP49.5) - Baltimore |
| South 5 | Baltimore – Union Station |

Risks associated with future operations outside these zones, at speeds up to 125 mph have not been analyzed. Operations below 125 mph are reflective of Tier I service and the Tier III requirements proposed by FRA in the RSAC ETF are assumed to provide equivalent safety performance. The analyses cases chosen establish the current risk profile on the NEC as well as reflect changes to the operation to meet future service needs. Several future cases are necessary to establish the condition which creates the most risk – be it the mixed operation of Tier II and Tier III equipment at the same time or a future with only high frequency Tier III train set operations. In order to compare service with comparable train mileage a regulatory null case was analyzed reflecting a hypothetical future condition where just Tier II train sets are operated to meet the defined service needs, despite the fact that Amtrak does not expect that the procurement will result in additional Tier II train sets. The analysis cases comprise the following:

- *Analysis Base Case*: The NEC as operated over the period 2000 – 2012, with Tier II Acela Express trains at speeds up to 150 mph and conventional Amtrak regional and commuter equipment. This case is the foundation on which input parameters for all future cases are estimated, and also used in model validation.
- *Future Case: Mixed Tier II and Tier III Operations:* The NEC with circa-2020 estimated traffic levels with increased high-speed service between NYC to Washington, using original Acela

Express, Tier II train sets, supplemented by new Tier III equipment. For this future service condition, both types of train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines risks where Tier II and Tier III trains operate on the NEC at the same time.

- *Future Case: All Tier III Operations*: This case assumes hourly high-speed service between Boston and NYC and half-hourly high-speed service between NYC and Washington DC throughout the day. For this future service condition, Tier III train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines the highest density operations with only Tier III equipment intermixed with freight and conventional Tier I (commuter) equipment on the NEC.
- *A Regulatory Null Case:* This case is used to compare other future operations with higher traffic densities using Tier III equipment, assuming use of Tier II equipment and full implementation of current (September 2014) safety regulations. Specifically, this means implementation of PTC (ACSES + ATC) throughout the NEC and for all main track operation.
- *Risk Mitigation Cases:* Multiple analyses of the All Tier III cases after implementation of selected risk mitigation measures. These cases examine Amtrak's ability to close the safety gap that may exist associated with operation of Tier III versus Tier II equipment on select NEC high speed zones.
- *Sensitivity Cases:* Multiple analyses of the All Tier III case after varying selected model inputs to assess the sensitivity of model results to variations in inputs. These cases examine the impact of significant increases in freight and/or commuter traffic in addition to introduction of Tier III train sets as well as other infrastructure or operational factors that impact system risk.

A complete description of the Analysis Cases investigated with the Risk Model is given in Attachment 1.

### *1.4 Structure and Contents of This Report*

This report summarizes the methodology used in the risk analysis, the data required to perform the analyses and the key results obtained. Detailed descriptions of the data and corresponding tables are provided in the Attachments. The specific sections of the report that follow this introduction are as follows:

- Risk Analysis Methodology, describing the general approach to the quantitative risk analysis, including:
    - The structure and content of the spread-sheet model developed to perform the risk analysis,
    - The assumptions and data prepared for and used by the model, and
    - The approach to model validation.
- A summary of results obtained using the model, together with findings and recommendations.

The main text of the report is supplemented by Attachments, containing detailed support descriptions and data, specifically:

1 Details of model analysis cases,

2 Analysis of accident history on the NEC over the period 2000-2012,

3 Details of NEC infrastructure and train operations,

4 Estimates of accident frequency for each accident scenario,

5 Estimates of accident severity for each accident scenario and equipment type, and

6 Detailed model results for each analysis case.

## 2.0 Analysis Methodology

### *2.1 Introduction and Overview*

This section describes a general approach to comparative semi-quantitative risk analysis, followed by the details of the analyses performed for this project. This description includes both the methodology and the format of an Excel spreadsheet model developed to carry out the risk calculations. This is a parametric risk model that uses estimates of accident frequency and severity for each accident scenario, and totals the results to obtain a risk estimate for the whole operation. Suitable metrics, such as the number of accidents and injuries that would be expected over a given time period are used to measure the level of risk for a given railroad operation. It is not a simulation model, which would attempt to derive an estimate of accidents and consequences by simulating actual train movements over a period of time.

Multiple model runs are performed for each of the primary analysis cases detailed in the Scope subsection in Section 1 above, to explore the impact on estimated risk of varying key model inputs and before and after implementing selected risk reduction measures.

The specific analysis steps described in this section are typical of any comparative and semi-quantitative risk analysis and are illustrated in Figure 1.

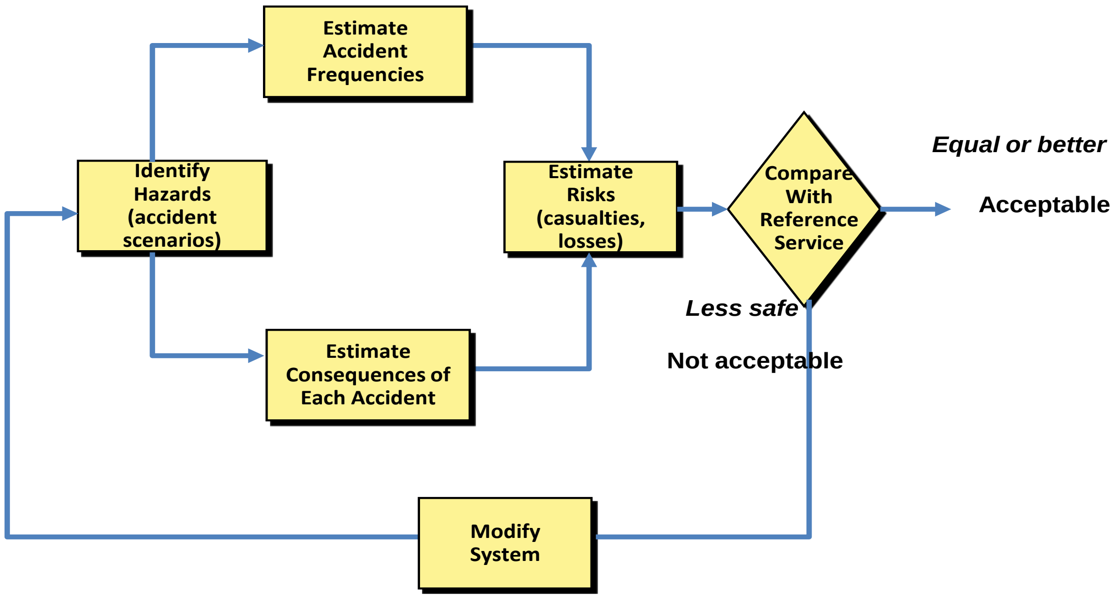


**Figure 1. Comparative and Semi-Quantitative Risk Analysis Approach**

The analysis steps comprise:

- Identification of relevant accident scenarios, in this case accidents expected in a high-speed rail passenger operation.
- Characterization of the likelihood and severity of each accident – how often might the accident occur and what is the severity of each accident (consequences indicated by casualties and property damage) that results from each accident scenario. Both these quantities are estimates from analyses of past accidents and these quantities often have to rely on sparse or incomplete data.
- Calculation of estimated risk by multiplying the number of accidents by the consequences of each accident for each accident scenario to obtain estimated total consequences.
- If the total consequences are greater than the comparative baseline case, then the system must be modified in a way that reduces either accident frequency or consequences to ensure that risk is equal to or less than that of the baseline case.

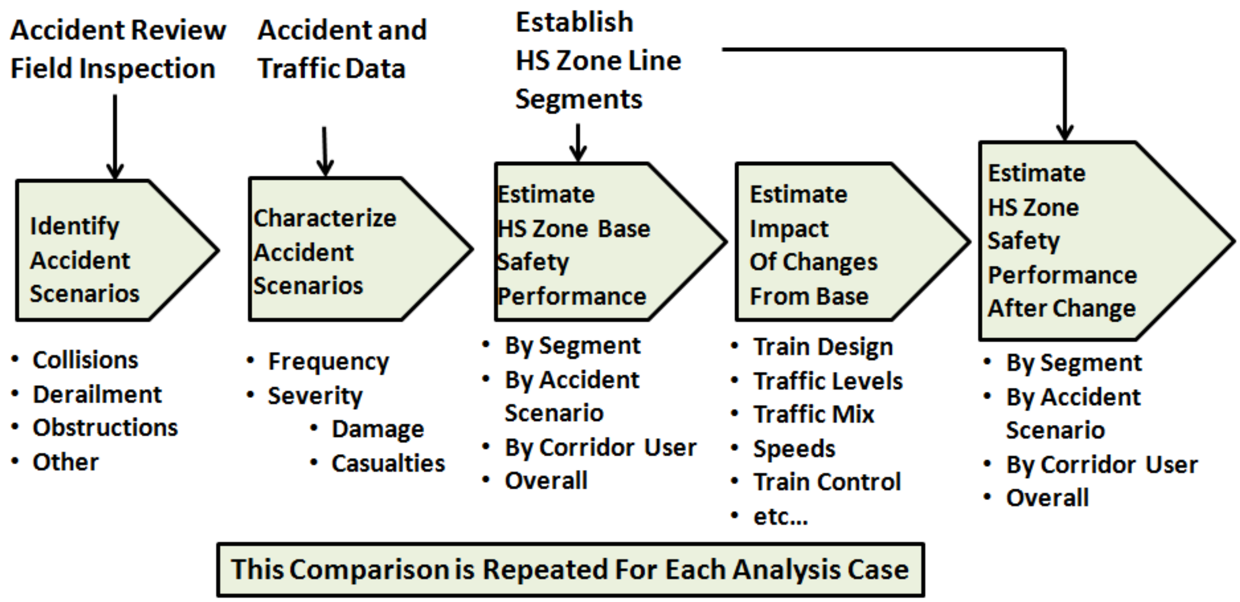


**Figure 2. Overview of NEC Risk Analysis**

The following sections describe each step in the analysis, represented as blocks in Figure 2, moving from left to right. This procedure is followed for each analysis case described in the "Scope" Subsection of Section 1 of this report, including multiple mitigation and sensitivity risk analyses. The descriptions include a narrative that summarizes the technical approach to carrying out each step in the analysis, as well as the implementation of the analysis in a spreadsheet risk model. The analysis references the Attachments that are the sources for detailed model input data.

The comparative semi-quantitative risk analysis is carried out in a series of Excel Workbooks, one for each run of the model for a specific set of inputs representing infrastructure, equipment and operations in NEC high speed zones, as detailed in Table 1 in the "Scope" subsection. The model inputs build on an initial model run representing the safety performance for NEC operations in 2012. The results from this model run were used to validate the model by comparing with actual 2012 safety performance. The inputs with further analyses cases provide safety estimates for future NEC operations with different traffic levels, types of high speed trains, and after implementation of risk mitigation measures.

In all cases, the analysis only covers selected high-speed zones, where high-speed train operations between 125 mph and 160 mph with Tier III train sets would be possible assuming a Tier III train capable of operating at 9 inches cant deficiency.

The Excel Workbook model for a single risk analysis case comprises a series of Excel Worksheets. The first two worksheets, called "Frequencies and Consequences" and "Zone and Segment Data" provide the inputs to the risk analysis. Then eight worksheets, one for each high-speed zone, carry out the detailed risk calculations. The output from each high-speed zone worksheet gives an estimate of accident numbers and consequences. Consequences are quantified by estimates of the number of accidents at each severity level and estimated casualties (injuries and fatalities) and property damage. Casualties and damage are those that would be provided to FRA in a train accident report. A final set of worksheets summarize the risk analysis outputs for each high-speed zone, for the high-speed zones on the North end and the South end and for all high-speed zones combined.

### *2.2 Identifying Accident Scenarios*

The specific accident scenarios selected for use in the risk analysis were based on accident experience on the NEC over the period 2000-2012 inclusive. Additionally the experience from several past risk analyses referenced in the introduction were also used. A full description of the analyses performed on historical NEC and other data is provided in Attachment 2. Another key factor in accident scenario selection was the likely risk mitigations that the model would be expected to evaluate. For example, if a candidate risk mitigation strategy was implementing automated inspection systems for freight equipment entering the NEC, then an estimate of freight train derailments caused by mechanical defects would need to be considered as an accident scenario.

A total of nine accident scenarios are used in the model, seven of which are linear scenarios defined as events that could occur at any point along a segment of the NEC, and two point scenarios, defined as events that can occur only at defined locations. These accident scenarios are listed below.

*Linear Accident Scenarios:*

- Train-to-train collisions on the same track.
- “Sideswipe” train-to-train collisions between trains on adjacent tracks (which would be reported as an accident Type 2 in the FRA accident report).
- Secondary collisions where a train collides with another moving or stationary train on an adjacent track after an initial accident fouls the adjacent track. This type of accident is usually reported to FRA under the cause of the original accident.
- Derailments due to track defects, with variations by track class.
- Derailments due to equipment defects, including variations by equipment type.
- Derailments having a human factors cause.
- Collisions with an obstruction that is not a train operating on the same or an adjacent track. For the purpose of this analysis, collisions with on-track maintenance or inspection equipment are included under this heading, even if originally reported to FRA as a train-to-train or sideswipe collision.

*Point Accident Scenarios:*

- Accidents at a main track interlocking.
- Accidents at an access track – where a siding, industrial track, yard track or branch line connects with a NEC main line running track.

This list does not include all accidents possible on the corridor. In particular, accidents involving only pantograph and catenary damage and fires and explosions were excluded. In the case of fires, their occurrence seems to be a function of particular equipment failures – electrical faults in electric locomotives and MU cars – and is not affected by the factors of interest in this analysis – train speed and the crashworthiness of different passenger train set designs. Pantograph and catenary failures rarely result in casualties, and their occurrence is largely independent of relationships between train speed, passenger car structural design and the frequency and severity of collision and derailment accidents.

Accident risk (accident numbers and severities per accident) is estimated separately for each scenario, because the occurrence and severity of different kinds of accidents are influenced by different input factors, and may be reduced by different risk mitigation actions. For example, collision frequency is a function of railroad traffic density (e.g. trains/ hour or day) and train control system characteristics. Increasing traffic density increases accident frequency and the number of accidents. Modifying the train control system by adding ACSES reduces accident frequency and the potential number of accidents. The crashworthiness of a train set design affects the severity of all accidents involved in a collision or derailment. The primary future condition studied in with the comparative semi-quantitative risk model is train set design differences; Tier III train sets built to Tier I crashworthiness performance levels versus Tier II equipment built to substantially enhanced crashworthiness standards.

The specific process for estimating the inputs for each accident frequency and severity are summarized in the following paragraphs, referring to the relevant Attachments as appropriate.

### *2.3 Characterizing Accident Scenarios*

Train accidents are characterized by two parameters, accident frequency and accident severity. In the case of accident severity, accidents are first characterized by the percentage of accidents at each severity level for each accident scenario, then by estimated injuries and property damage. Full details of estimating accident frequencies are described in Attachment 4. Attachment 5 describes the derivation of accident severity distributions and injuries and property damage which are the consequences of each accident.

*Accident Frequencies*

The specific accident frequencies for each hazard category, together with the sources used to estimate frequencies for the baseline and future analysis cases are discussed below. A table that summarizes the numerical values for accident frequency and factors used to calculate the estimated number of accidents in the risk model is provided at the end of this discussion.

<u>Train-train head-on and rear-end collisions</u>

This frequency has the units of trains in accidents *per million train miles*. Use of the metric “trains in accidents *per million train miles*” rather than “collisions *per million train miles*” makes it possible to estimate the risk of involvement in a collision for different train types, without a separate effort to identify the type of the second train involved in the collision.

The frequency of trains in collisions depends on:

- Traffic density as measured by the number of trains per calendar week for each track (so that the calculation combines weekday and weekend traffic)[1].
- Type of train control system in use. Applicable train control systems built into the model are Rule 251 ATC (single direction operation), Rule 261 ATC (bi-directional operation), ATC+ACSES, Full PTC and PTC Plus. Although ATC+ACSES is equivalent to PTC, the model structure allows for further train control enhancements at some future point. A base control system frequency for the NEC was estimated from the accident history, and adjustment factors applied to this frequency to obtain values for the train control systems to be evaluated by the model.

Side and sideswipe collisions

A review of past sideswipe accidents on the NEC indicated that the predominant contributing factors to the incidents were loose equipment doors, shifted loads on freight cars, or very tight clearances causing an impact with a passing train or wayside structure. The number of accidents is calculated individually for each track and train type and totaled for each track segment. Accident frequencies for trains in collisions were estimated for four operating conditions, as listed below:

- A passenger train with active tracks on one side of the train,
- A Passenger train with active tracks on both sides of the train,
- A freight train with active tracks on one side of the train, and
- Freight trains with active tracks on both sides of the train.

The frequency estimates were derived from past accident history on the NEC and a broader dataset for freight train accidents. Train control system capabilities do not affect these frequencies, but risk mitigation measures involving automated or manual visual inspections for out-of-clearance conditions, especially for freight trains entering the NEC, would reduce this risk.

Collisions due to obstruction of a main track following an accident on a main track

This type of accident is a secondary event following a collision or derailment on an adjacent track followed by a collision on the adjacent obstructed track. These accidents are quite rare, but are potentially very serious. The model treats the additional damage and casualties of the secondary collision as a separate event. There were no accidents of this type on the NEC or the broader data set of passenger train accidents in NEC states, but there was a serious accident of this type, near Bridgeport CT on the NEC in 2013, outside the period covered by the accident databases. Secondary accidents have also been a factor in catastrophic accidents such as those at Bourbonnais, IL in 1999, and Glendale CA in 2005.

Secondary accident frequency is measured by units of collisions *per million train miles*, and is dependent on the following factors:

[1] The formula for the effect of traffic density on accident frequency is derived from a TRB paper by Joseph Sussman et. al. in TRR 1742.

- Traffic density (trains/week) on the track being analyzed,
- The number of collision and derailment accidents on adjacent tracks, as estimated by the model,
- The probability that a collision or derailment on the adjacent track would obstruct the track being analyzed, estimated separately for freight and passenger trains, and
- The probability that a train operating on the track being analyzed would be unable to stop before hitting the obstruction, estimated using stopping distance and likely warning time.

Derailment due to a track defect

This accident scenario involves a single train where derailment is caused by a track defect, such as buckled track or a broken rail. Track-defect accident frequencies (accidents *per million train miles*) are higher for freight trains than for passenger trains, because the higher axle loads of freight cars and the larger number of cars in a train. In addition, the presence of freight trains operating on a specific track may increase the chance of a track-defect-caused accident involving a passenger train. Thus, track defect derailment frequency is a function of:

- FRA track class, and
- Train Type (passenger or freight train) where freight-specific factors are added to account for:
  - A higher accident frequency for freight trains, and
  - The increase in passenger train derailment frequency due to use of a track by freight trains.

These factors are applied in the formulas used to calculate track-caused derailment frequency in accidents *per million train miles* for a given track and route segment, as indicated in the formulas detailed in Table 2 at the end of this subsection.

Derailment due to a mechanical defect

This scenario is a single-train derailment caused by an equipment defect, such as a broken wheel, failed axle journal bearing, and similar failures on a locomotive, passenger car or a freight car. Equipment defect-caused accident frequencies are assumed to be a function of train type only, and are influenced by different component designs, maintenance and inspection routines. High-speed trains are subject to more frequent inspections and are equipped with automatic condition monitoring systems, leading to lower accident frequencies. Freight train derailment frequencies are higher than those for passenger trains because there are typically more vehicles in a freight train, the cars are heavier, and the materials, systems and maintenance and inspection procedures are different from those used for passenger trains.

A baseline frequency is derived from historic NEC accident data for all train types combined. This frequency and information about component design, and maintenance and inspection routines were used to derive estimates for accident frequency by individual equipment types. There were too few accidents on the NEC to be able to differentiate between train types using historical data. After discussions with Amtrak's mechanical department concerning current maintenance and inspection accident frequency estimates for other operations accident frequencies were modified for intercity long haul, commuter and freight operations.

Derailment due to human-factors errors

The errors include over-speed, especially through turnouts, misaligned switches, and for freight trains errors associated with train handling and the use of brakes. ATC and cab signals lack civil speed control, and will not necessarily prevent these accidents. ACSES/ATC does provide speed control, and can prevent some of these accidents. The exceptions would be accidents occurring in a work zone or during slow-speed operations when train controls systems are not functioning.

Because of the difference in the mix of accident causes, different risk factors apply to freight and passenger trains:

- Passenger trains – accident frequency is a function of the train control system, and
- Freight trains – accident frequency is a function of both the train control system, and a factor added for freight-unique accidents from train handling, braking errors and similar factors.

Collision with an obstruction

About half of all reported accidents on the higher speed territory on the NEC are obstruction collisions, making these accidents a prime target for risk mitigation, in spite of the accidents being less severe individually. The accidents are a mix of:

- Objects placed on the track (including motor vehicles and debris)as a result of unauthorized access to the ROW,
- Natural obstructions, such as fallen trees, falling rocks and wild animals, and
- Obstruction occurring during authorized activities on the ROW, such as track and signal maintenance and construction work by Amtrak roadway workers and contractors.

The approach used in modeling the risk of obstruction accidents was to classify each route segment in the high-speed zones as having strong, fair and weak protections in place against obstruction accidents. The classifications were based on observations made by project staff from Amtrak's track inspection car, and can be defined as follows:

- *Strong,* where precautions are in place that would eliminate a large fraction of obstructions, including secure fences and barriers where needed, improved procedures for working on the ROW, and thorough inspection regimes,
- *Fair*, represents average current conditions on the corridor, and
- *Weak*, where few precautions against obstructions have been implemented.

Given the diversity of obstruction accident root causes, however, this analysis can provide only general guidance and desirable targets, and more detailed evaluations of present conditions and potential for risk reduction are needed.

Point risk at main track interlockings

Accidents occur at primary interlockings in the high-speed zones, either because of track defects in switches at the interlocking or human factors accidents involving train movements through the switches. Accident frequency at a main track interlocking is quantified as accidents *per million main line train movements* through the interlocking, and is a function of an accident frequency coefficient multiplied by:

- Traffic volume in train movements per week on each track passing through the interlocking,
- Interlocking complexity, as indicated by the number of turnouts in each track, and
- Interlocking structure design and condition, including type of ties, type of switch and condition as observed during track inspections.

The model calculates the number of accidents at the interlocking for each track, and adds the results to obtain a total for the interlocking.

The interlocking accident frequency coefficient is estimated from historical accident data and an estimate of total train movements through interlockings and interlocking complexity in high speed territory. Accidents are considered interlocking accidents if caused by a defect of a specific interlocking component, or if there has been a human factors accident specifically involving train movement through a diverging track at an interlocking. Accidents identified as interlocking accidents are not included when estimating frequency coefficients for other accident scenarios. There is no double-counting.

Point risk at an access or egress track

Freight access and egress points are considered a particular risk on the NEC because the connecting tracks are usually under the control of another railroad which normally will lack automatic train control and, in many cases block signaling. Manual switches with electric locks are commonly used at these access points. Risk may be controlled by position detectors at the access switches, split-rail derails, careful procedures for using the access points and other methods. This scenario covers all accident types, but the majority are human factors errors in train operations when approaching or passing through the access switch.

The model assigns three levels to the effectiveness of risk controls at the access and egress points, as follows:

- *Limited*, meaning some customary risk controls are lacking,
- *Typical*, meaning risk controls are typical of the corridor in 2012, and
- *Comprehensive*, meaning that all practical risk controls have been implemented.

Accident frequency at an access or egress track is presented as accidents *per million train movements* through the access track, and is a function of the physical features of the access track. Most accidents at access tracks have human factors causes, but it is the physical features that provide protection against these accidents obstructing a NEC main track and causing an accident.

Access track accident frequency is derived from a count of the number of access point accidents in the corridor over the analysis period, divided by an estimate of total freight movements over access tracks the same period. A train movement is counted each time a freight train moves between a NEC main track and a freight-only track or a siding, industry track, and yard or branch line.

This calculation provides an estimate of the number of access track accidents. A further calculation is required to estimate the risk that an access track accident will, first, obstruct an NEC main track, and second, whether the that obstruction will lead to a collision with a train operating on the main track. To do this, the model multiplies access track accident risk by two factors:

- A factor for the fraction of freight spur accidents that result in an obstruction to an NEC main track, and
- A factor for the chance that a train operating on the NEC collides with obstructing vehicles from an access track accident. This is calculated in the same way as for accidents on an adjacent NEC main track.

This calculation provides an estimate of the number of accidents to passenger trains resulting from freight train movements at NEC freight access points. Tables 2, 3, 4 and 5 contain the base case 2012 values for accident frequencies for linear and point risks and the coefficients used for risk estimation for secondary collisions on the mainline and at access spurs.

**Table 2. Accident Frequencies for Linear Hazards**

| Look-up Table for Accident Frequencies for Linear Hazards (accidents per million train-miles) - Baseline 2012 Values | | | | |
|---|---|---|---|---|
| **Accident Scenario** | **Frequency as Function of Traffic Volume, Other Factors** | | | |
| | **Factor** | **Factor Units** | **Value** | **Value Units** |
| Train-Train Collision on Same Track - Head-On and Rear-E | Traffic Density | Base Frequency | 0.0150 | |
| | Formula | Density Index | 0.7500 | Accidents per |
| *Frequency = (Base collision accident frequency) ** | Train Control | Rule 251 ATC | 1.30 | Million |
| *(train control system coefficient)** | System coefficient | Rule 261 ATC | 1.10 | Train-Miles |
| *[(7-day train count)/NEC average train count]* | *Index* | ATC+ACSES | 0.70 | |
| | | Full PTC | 0.70 | |
| | | PTC Plus | 0.60 | |
| Train-Train Collision - Sideswipe and Similar | Train type, number of | Pass, 1-side | 0.0100 | Accidents per |
| | adjacent tracks | Pass, 2-sides | 0.0200 | Million |
| *No formula, simply apply frequency values* | | Freight 1-side | 0.0800 | Train-Miles |
| | | Freight 2-sides | 0.1200 | |
| Derailment - Track Defect | FRA Track Class | 5 | 0.015 | Accidents per |
| Passenger trains: | | 6 | 0.010 | Million |
| *Frequency = (Frequency for track class)** | | 7 | 0.008 | Train-Miles |
| *1 + (passenger-freight adjustment factor)** | | 8 | 0.005 | |
| *(number of freight trains in 7 days))* | Passenger-freight | Factor | 0.0005 | None |
| Freight trains: | adjustment factor | | | |
| *Frequency = (Frequency for track class)*(Freight multip* | Freight multiplier | Factor | 5.000 | None |
| Derailment - Equipment Defect | Equipment type | Tier II | 0.01 | Accidents per |
| | | Tier III | 0.007 | Million |
| *No formula, simply apply frequency values* | | Regional | 0.015 | Train-Miles |
| | | Commuter | 0.02 | |
| | | Freight | 0.1 | |
| Derailment - Human Factors | Control System | Rule 251 ATC | 0.020 | Accidents per |
| | | Rule 261 ATC | 0.015 | Million |
| *No formula, simply apply values, except:* | | ATC+ACSES | 0.010 | Train-Miles |
| *Freight trains only, use the following:* | | Full PTC | 0.010 | |
| *(Control system frequency) + (freight factor)* | | PTC Plus | 0.007 | |
| | Freight train factor for | Frequency | 0.05 | |
| | handling, brakes, etc. | | | |
| Intrusion Collision | Fencing, barriers in | Strong | 0.060 | Collisions per |
| | place, natural | Fair | 0.130 | Million Train- |
| *No formula, simply apply values* | surroundings | Weak | 0.200 | Miles |

**Table 3. Accident Frequencies for Point Hazards**

| Look-up Table for Accident Frequencies for Point Hazards (accidents per million train-miles) | | | | |
|---|---|---|---|---|
| **Accident Scenario** | **Frequency as Function of Traffic Volume, Other Factors** | | | |
| | **Factor** | **Factor Units** | **Value** | **Value Units** |
| Primary Interlockings (interlockings on main tracks) | Interlocking Condition | Fair | 0.6 | Accidents per Million Main Line Movements Thru Interlocking |
| | | Good | 0.5 | |
| | | Excellent | 0.4 | |
| Access Spurs - Function of Control System and Manual or Power Switch and Derail Details | Turnout Safety Features | Limited | 5.00 | Accidents per Million Movements Entering or Exiting Corridor |
| | | Typical | 3.50 | |
| | | Comprehensive | 2.00 | |

**Table 4. Coefficients for Secondary Collision Accidents**

| | Coefficient |
|---|---|
| Coefficient 1: Passenger train intrusion probability | 0.25 |
| Coefficient 2: Multiplier for freight train intrusion probability | 3 |
| Coefficient 3: Time for a train approaching the intrusion to be warned and to stop (minutes) | 3 |

**Table 5. Coefficients for Secondary Collisions at Access Spurs**

| Description of Coefficient | Value |
|---|---|
| Coefficient 1F: Probability of accident at access spur obstructing a main running track | 0.25 |
| Coefficient 2F: Time for a train approaching the obstruction to be warned and stopped (minutes) | 3 |
| Coefficient 3F: Accident frequency multiplier for spurs to passenger equipment facility | 0.1 |

*Accident Consequences – Severity Distributions and Casualty and Damage Estimates*

The risk model uses estimates of accident consequences as a function of equipment type and speed to calculate accident severity metrics. The definitions for the specific metrics used, and the procedure for developing estimates for each type of equipment used on the NEC is described in Attachment 5 and summarized in the following paragraphs. Consequences are estimated for four types of equipment:

- Commuter,
- Amtrak regional,
- Acela Express, and
- Proposed Tier III trainsets.

The consequences are a function of passenger car crashworthiness and actual or proposed speeds of operation.

The crashworthiness of different classes of equipment is a fundamental factor being addressed by the risk assessment. The consequence associated with an accident or derailment is dependent on the ability of the trainset to provide a safe volume for passengers and crewmembers in the event of an accident. The Tier III equipment crashworthy requirements have been developed within the Railroad Safety Advisory Committee's (RSAC) Engineering Task Force (ETF). Research sponsored by FRA as well as analyses conducted by international carbuilders have provided confidence in Tier III equipment performance. Specifically, Tier III equipment has been shown to perform well under a generic collision scenario with a conventional North American passenger locomotive led train. FRA is in the process of taking the work product from this effort and preparing a Notice of Proposed Rulemaking to codify the recommendations.

A critical input parameter required in developing a risk model to assess differences in risk for one equipment type versus another under similar operating conditions is the severity distribution for each of the hazard categories defined previously in the main report and in Attachment 2. There is considerable uncertainty associated with the performance of trainsets involved in collisions at higher impact speeds. Amtrak did not pursue developing a detailed Finite Element Model (FEM) of the Acela to conduct high energy collision analyses. Amtrak believes there is too much uncertainty in any numerical model's ability to accurately capture significant material failure and large deformations. Further there is no FEM for a generic Tier III trainset available. Even if there were such a model available, the results from high energy collision analyses would also be considered suspect.

Therefore a more qualitative approach was taken in defining the severity distribution for the different classes of equipment investigated within the risk model.

Two risk metrics are used in the comparative semi-quantitative risk model to quantify accident consequences:

1. The distribution by percentage of accidents within each of four severity levels from Minor to Very Serious. The severity level definitions are shown in Table 6, and are based on an analysis of actual accidents on the NEC at each level.

**Table 6. Accident Severity Level Definitions**

| Severity Levels | | Consequence Per Accident | | |
|---|---|---|---|---|
| **Level** | **Definition** | **Injuries** | **Fatalities** | **Damage ($k)** |
| **1** | Minor -less than $50k damage, no casualties | 0 | 0 | 18 |
| **2** | Moderate - greater than $50k - $250k damage, less than 10 injuries | 0 | 0 | 90 |
| **3** | Serious - greater than $250k - $1M damage, greater than 10 injuries, no fatalities | 3 | 0 | 500 |
| **4** | Very Serious - greater than $1M damage, greater than 50 injuries, more than one fatality | 3 | 0.04 | 2,000 |

Severity percentage tables are developed for each accident scenario, equipment type and speed operating on the NEC, using historical experience as a starting point. The results are entered into the model as tables on the "Frequency and Consequences" worksheet.

2. Estimates of injuries and damage per accident for each accident scenario are estimated by multiplying percentages and per-accident consequences at each Severity Level. Then, given estimates for the numbers of accidents in each accident scenario the model calculates totals for injuries and damage.

   Severity Level distributions were developed for each of the equipment types operating on the NEC; Table 7 shows the baseline distribution as a percentage of all accidents in the subject scenario.

**Table 7. Baseline Accident Severity Distribution**

| | Baseline - All Trains in High Speed Territory (80 - 150 mph) | | | |
|---|---|---|---|---|
| | Severity Levels (%) | | | |
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 37 | 43 | 15 | 5 |
| Train-Train Collision - Sideswipe and Similar | 43 | 45 | 10 | 2 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 25 | 40 | 25 | 10 |
| Derailment - Track Defect | 45 | 30 | 20 | 5 |
| Derailment - Equipment Defect | 40 | 38 | 20 | 2 |
| Derailment - Human Factors | 45 | 30 | 20 | 5 |
| Obstruction Collision | 54 | 40 | 5 | 1 |
| | | | | |
| **Point Scenarios** | | | | |
| Primary Interlocking | 45 | 30 | 20 | 5 |
| Access Spur | 25 | 40 | 25 | 10 |
| | | | | |

This distribution was developed from historical experience on the NEC together, with reference to larger train accident data sets, to provide estimates of the likelihood of Level 3 and 4 accidents. Data from NEC accidents for the period 2000-2012 were too sparse to provide meaningful estimates for very rare or severe accidents. This base line distribution was used for Tier I commuter push-pull and multiple-unit trains.

Distributions were developed for the other train types and speeds operating or proposed for operation on the NEC using the baseline commuter train Tier I distribution. The severity level percentages were adjusted toward higher values for more severe accidents if the combination of expected crashworthiness and operating speeds would result in more severe accidents. The severity distributions were adjusted towards lower severities if accidents were expected to be less severe for a given train design type. The factors considered for the different train types and speeds are summarized below:

- Accidents to Amtrak Regional trains were considered more severe than the baseline, because the equipment used (mostly Amfleet cars) were built to structural standards of the early 1980s.

These standards came out before the newer standards were implemented by FRA and APTA in the late 1990s which were applied to the newer commuter cars operating on the NEC. Further the maximum speed of Amtrak Regional services is 125 mph, whereas most commuter services operate on the NEC at a maximum of 110 mph. Since operating speeds for both Amtrak Regional and commuter services will not change, there was no need to consider how speed affects accident severity.

- Amtrak's Acela trainsets are built to the very demanding Tier II crashworthiness requirements, and accident severities are expected to be substantially lower than Tier I equipment (i.e., newer commuter equipment) at comparable speeds. Based on this consideration, and after an extensive review of recent crashworthiness research, severity distributions were developed for Acela equipment for three speed bands: 125-135 mph, 136-150 mph and 151-160 mph. The model needed the differentiation by speed because Acela speeds may be increased in the high-speed zones prior to replacement by new trainsets, and the model analysis of future cases must take this into account.
- The new Tier III crashworthiness standards are formulated to be equivalent to Tier I equipment, although achieved by different design features that place greater reliance on crash energy management (CEM). Tier III trainsets are also permitted to have passenger seating in the end vehicles. As for the Acela trainsets, severity distributions were developed for Tier III trainsets for the following speed bands 125-135 mph, 136-150 mph and 151-160 mph.

The severity distributions for all train types and speed bands were recorded in the "Frequency and Severity" tab of the risk model. This worksheet is referenced by the risk calculations for each track, track segment and high-speed zone. Attachment 5 provides a detailed discussion of the differences between severity distributions for each accident scenario.

### *2.4 Structure of the NEC Risk Model – High Speed Zones and Route Segments*

*Overview*

The overall objective of the modeling is to estimate the risks associated with high speed passenger operations on the NEC for a range of railroad operating scenarios both before and after the implementation of risk mitigation measures. The analysis focuses on territory where Tier III high-speed trainsets may be considered for operation at over 125 mph. These locations were identified by Amtrak's engineering department assuming that the highest potential speed that could be operated at 9 inches cant deficiency. No allowance was made for braking and acceleration distances.

The accident risks, to which trains operating on the corridor are exposed, vary from place to place, depending on: train speeds, traffic volume and mix, the number of running tracks and other factors. In order to represent the effect of these variations and ensure that the risk calculation properly reflects variations in operating conditions, the high speed territory on the corridor has been divided into a number of high-speed zones, and segments within each high-speed zone. With one exception, each high-speed zone represents high-speed (over 125 mph) territory between two major stations, such as

Boston-Providence or NYC –Trenton. The exception was to divide the long stretch between Wilmington and Baltimore into a shorter, more manageable distance.

High-speed zones are further divided into route segments, where each segment has constant infrastructure and operating parameters such as:

- Number of main tracks,
- Maximum speeds, and
- Traffic volume and mix on each track.

Risks are calculated for each main track segment and zone, and totaled to provide overall measures of risk. This section documents the procedure used for delineating high speed zones and track segments and calculating risk.

*High Speed Zones*

The risk analysis is carried out for approximately 221 miles of the NEC, which is all the territory where speeds exceeding 125 mph would be possible, assuming a maximum of 9 inches of cant deficiency. This scope is consistent with the intent to submit a waiver petition for the use of Tier III train sets at speeds between 125 mph and 160 mph over all parts of the NEC where such speeds could be attained.

The route included in the analysis has been divided into eight high-speed zones, as shown in Table 8:

**Table 8. Details of High-Speed Zones**

| Zone | Location | Length (miles) | No. Segments |
|---|---|---|---|
| North 1 | Westerly – Providence | 26.1 | 13 |
| North 2 | Providence – Boston | 25.4 | 8 |
| **North total** | | **51.5** | **21** |
| South 1 | New York – Trenton | 38.6 | 20 |
| South 2 | Trenton – Philadelphia | 20.5 | 11 |
| South 2a | Philadelphia – Wilmington | 20.6 | 9 |
| South 3 | Wilmington – Bacon I/L (MP49.5) | 19.8 | 6 |
| South 4 | Bacon I/L (MP49.5) - Baltimore | 32.3 | 9 |
| South 5 | Baltimore – Union Station | 37.7 | 11 |
| **All South Zones** | | **169.5** | **66** |
| **Total All Zones** | | **221.0** | **87** |

The reason for dividing the route into separate high-speed zones is that each zone has a distinct mix of rail traffic types and number of running tracks, which could lead to differences in normalized risk from zone to zone. While it would be impossible to achieve exact risk parity between zones, it is desirable that risk levels be similar from zone to zone. Reporting by individual high-speed zone supports decisions such as where to implement location-specific risk mitigation measures.

*Route Segments*

The high-speed zones have been further divided into route segments. By definition, route segments must have constant operating parameters, as follows:

- Number of running tracks,
- Train speed for high-speed trains, and
- Traffic volume and mix of train types.

Constant values for these inputs are essential for the risk calculation, because risk varies when each parameter changes. For example, accident consequences increase as speed increases, different equipment types may have different equipment-defect derailment frequencies, and traffic density can affect train-to-train collision frequency.

*Operational and Infrastructure Data for the Risk Model*

Once high-speed zones and segments have been defined, the next step is to assemble model input data describing the infrastructure and operations for each zone and segment. Full details of this effort are provided in Attachment 3. The specific model input data elements are summarized below, together with the primary sources used. An example for one short high speed zone is provided at the end of this section of the report.

- Speed of operation by equipment type:
    - For 2012 conditions, the speeds were taken from the current Amtrak timetable, which provide maximum allowed speed (MAS) for each track and equipment type.
    - Speed for all train types <u>except</u> high-speed train sets were held constant for all analysis cases.
    - Speeds for high-speed train sets in high-speed zones for all future analysis cases were as calculated by Amtrak's engineering department for a train capable of operating at 9 inches cant deficiency.
- Traffic mix in specific segments and zones:
    - Freight train volumes were obtained from a series of structured interviews with Amtrak operating superintendents for each division which included a high-speed zone.
    - Conventional passenger service – commuter traffic volumes were obtained from data compiled by the Northeast Corridor Infrastructure Advisory Commission.
    - Traffic volumes for Amtrak regional service as well as long-distance Amtrak services operating on the NEC were obtained directly from Amtrak, and confirmed with the data compiled by the NEC Infrastructure and Advisory Commission.

    - Traffic volumes for Amtrak Acela high-speed service and Amtrak regional and long-distance services were obtained from the same sources.
  - Traffic volumes by track. Because the risk model performs risk calculations for each track, the input data needs to specify not just traffic volumes in a segment but how this volume is distributed over each individual track.
    - Track charts, operations data from individual commuter railroad authorities and input from subject matter experts with a background in NEC dispatching, allowed the project team to compile a segment-by-segment table of trains per week on each track, for each of the four train types – Amtrak high-speed, Amtrak regional and long distance, commuter and freight.
    - This input consists of:
      - number of tracks from the track charts
      - traffic volume on main track – using weekly totals
      - traffic volume on adjacent track – using weekly totals
  - Train control system in place by track.
    - Train control information was obtained from the Amtrak timetable for 2012 analysis cases.
  - For all future analyses cases, all tracks were assumed to be equipped with a PTC system, fully compliant with FRA regulations. Details about FRA Track Class (to understand where there is variance and impact on operational speeds current and future).
    - For 2012 analysis cases track class for each track was assumed to be consistent with the posted speed shown in the Amtrak timetable for the type of train having the highest MAS for that track.
- For future analysis cases, it was assumed that tracks currently used for Acela service would be those used by high-speed train sets in the future, and would be maintained to FRA Track Class 8. Track classes of other main tracks were held constant. Details of entry/exit points or access spurs to the NEC.
    - The details comprise:
      - the location of the entry/exit point,
      - the volume of traffic on the main track at the entry/exit point,
      - the features of the switch connecting the access track to an NEC main track,
      - the slope of the track away from or toward the main track,
      - the type of derail used, and
      - the traffic volume (trains/week) using the entry/exit point.
    - Note that while most entry/exit points are used by freight trains, there are a few that are used to access passenger equipment facilities. These details were used to assign one of three qualities to the safety related features at each access spur:
      - “limited”,
      - “typical”, or
      - “comprehensive”.
    - Each quality corresponds to a factor for accident frequency at the spur.

- Number and locations of turnouts in each main track interlocking.
    - The frequency of accidents at a main track interlocking is considered to be function of the number of trains passing through the interlocking switches, the number of switches in the interlocking, and types of switches and condition of the interlocking as assessed by automated and visual inspections.
    - An interlocking accident risk factor was assigned to each interlocking as a function of the types of switches used and inspection results, using three categories:
        - "fair",
        - "good", and
        - "excellent".
- Details of right of way (ROW) protection and precautions against obstruction accidents.
    - This factor is concerned with the risk of obstruction accidents associated with:
        - Accidental or intentional unauthorized access to the ROW by vehicles or people, leading to an obstruction of a NEC main track and a collision,
        - Activities on the ROW by Amtrak MOW forces or contractors, and
        - Natural events such as fallen trees or rock slides.
    - Such access can be prevented by suitable, well maintained fences and barriers, together with robust procedures at official access points to the ROW used by Amtrak staff and contractors.
    - The procedures must ensure gates are always locked when not in use.
- Descriptions of key crashworthiness features of different classes of equipment.
    - This information is combined with typical operating speed data to establish consequence distributions for each equipment class and accident scenario, as described in Attachment 5.
- Other features, such as passenger stations and freight yards and industrial tracks in close proximity to the main running line of the NEC that could influence risk.
    - Note: While these features are not specifically addressed in the risk model, Amtrak plans to address obvious location-specific hazards, as part of the overall system safety effort.

Once assembled, these data were used to compile the model inputs contained in the "Zone and Segment" tab of the risk model. An example of the data for a high-speed zone is shown in Tables 9a, 9b and 9c.

## Table 9a. Illustration of Zone and Segment Data – Linear Risks

| Zone South 3 -- Linear Risks | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Location | Segment Mileposts | | Segment | Number | Individual Track Data | | Maximum Authorized Speeds by Train Type (per timetable) | | | | | FRA Track | Train | Traffic Volume - Trains per Week | | | | | | Number |
| | | Start | Finish | Length (miles) | Tracks ROW Segregation | Amtrak Number | Model Reference Number | Acela | Tier III | Regional | Commuter | Freight 6:00 AM to 10:00 PM | Class | Control System | Acela | Tier III | Regional | Commuter P-P | Commuter MU | Freight | Adjacent Tracks |
| | | | | | | | | | | | | | | | 0 | | | | | | |
| S3-1 | Ragan Interlocking - | 29.7 | 33.5 | 3.8 | 3 | 1 | S3-1-1 | 110 | NA | 110 | 110 | 30 | 6 | ATC+ACSES | 0 | 0 | 0 | 20 | 75 | 15 | 1 |
| | MP33.5 | | | | Fair | 2 | S3-1-2 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 182 | 0 | 0 | 0 | 2 |
| | | | | | | 3 | S3-1-3 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 184 | 0 | 5 | 0 | 1 |
| | | | | | | | | | | | | | | | 0 | | | | | 0 | |
| S3-2 | MP 33.5 | 33.5 | 36.4 | 2.9 | 3 | 1 | S3-1-1 | 110 | NA | 110 | 110 | 30 | 6 | ATC+ACSES | 0 | 0 | 0 | 20 | 75 | 15 | 1 |
| | Ruthby Interlocking | | | | weak | 2 | S3-1-2 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 182 | 0 | 0 | 0 | 2 |
| | | | | | | 3 | S3-1-3 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 184 | 0 | 5 | 0 | 1 |
| | | | | | | | | | | | | | | | 0 | | | | | 0 | |
| S3-3 | Ruthby Interlocking | 36.4 | 38.4 | 2 | 4 | A | S3-2-1 | 80 | NA | 80 | 80 | 30 | 5 | Rule 261 ATC | 0 | 0 | 0 | 20 | 75 | 15 | 1 |
| | Davis Interlocking | | | | Weak | 1 | S3-2-2 | 110 | NA | 110 | 110 | 30 | 6 | ATC+ACSES | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | | | | | 2 | S3-2-3 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 182 | 0 | 0 | 0 | 2 |
| | | | | | | 3 | S3-2-4 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 184 | 0 | 5 | 0 | 1 |
| | | | | | | | | | | | | | | | 0 | | | | | 0 | |
| S3-4 | Davis Interlocking - | 38.4 | 41.5 | 3.1 | 4 | A | S3-4-1 | 80 | NA | 80 | 80 | 30 | 5 | Rule 261 ATC | 0 | 0 | 0 | 20 | 75 | 52 | 1 |
| | Iron Interlocking | | | | Weak | 1 | S3-4-2 | 110 | NA | 110 | 110 | 30 | 6 | ATC+ACSES | 0 | 0 | 11 | 0 | 5 | 0 | 2 |
| | | | | | | 2 | S3-4-3 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 171 | 0 | 0 | 0 | 2 |
| | | | | | | 3 | S3-4-4 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 184 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | 0 | | | | | 0 | |
| S3-5 | Iron Interlocking - | 41.5 | 47.0 | 5.5 | 3 | 1 | S3-5-1 | 110 | NA | 110 | 110 | 30 | 6 | ATC+ACSES | 0 | 0 | 11 | 0 | 5 | 59 | 1 |
| | MP47 | | | | Fair | 2 | S3-5-2 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 171 | 0 | 0 | 0 | 2 |
| | | | | | | 3 | S3-5-3 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 184 | 0 | 0 | 0 | 1 |
| | | | | | | | | | | | | | | | 0 | | | | | 0 | |
| S3-6 | MP 47.0 | 47 | 49.5 | 2.5 | 3 | 1 | S3-6-1 | 110 | NA | 110 | 110 | 30 | 6 | ATC+ACSES | 0 | 0 | 11 | 0 | 5 | 59 | 1 |
| | Bacon Interlocking | | | | Fair | 2 | S3-6-2 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 171 | 0 | 0 | 0 | 2 |
| | | | | | | 3 | S3-6-3 | 135 | NA | 125 | 110 | 30 | 8 | ATC+ACSES | 93 | 0 | 184 | 0 | 0 | 0 | 1 |

## Table 9b. Illustration of Zone and Segment Data – Point Risks for Primary Interlockings

| South Zone 3 -- Point Risks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Primary Interlockings | | | | | | | | | | |
| Milepost | Interlocking | Interlocking | Track | Number | Traffic by Train Type | | | | | |
| Location | Name | Condition | Number | Turnouts | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight |
| 29.8 | Ragan | Good | 1 | 1 | 0 | 0 | 0 | 20 | 75 | 15 |
| | | | 2 | 3 | 93 | 0 | 182 | 0 | 0 | 0 |
| | | | 3 | 2 | 93 | 0 | 184 | 0 | 5 | 0 |
| | | | | | | | | | | 0 |
| 36.5 | Ruthby | Excellent | A | 1 | 0 | 0 | 0 | 20 | 75 | 15 |
| | | | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 2 | 0 | 93 | 0 | 182 | 0 | 0 | 0 |
| | | | 3 | 0 | 93 | 0 | 184 | 0 | 5 | 0 |
| | | | | | | | | | | 0 |
| | | | | | | | | | | 0 |
| 38.5 | Davis | Good | A | 2 | 0 | 0 | 0 | 20 | 75 | 52 |
| | | | 1 | 4 | 0 | 0 | 11 | 0 | 5 | 0 |
| | | | 2 | 4 | 93 | 0 | 171 | 0 | 0 | 0 |
| | | | 3 | 2 | 93 | 0 | 184 | 0 | 0 | 0 |
| | | | | | | | | | | 0 |
| | | | | | | | | | | 0 |
| 41.5 | Iron | Good | A | 1 | 0 | 0 | 0 | 20 | 75 | 59 |
| | | | 1 | 1 | 0 | 0 | 11 | 0 | 5 | 0 |
| | | | 2 | 0 | 93 | 0 | 171 | 0 | 0 | 0 |
| | | | 3 | 0 | 93 | 0 | 184 | 0 | 0 | 0 |
| | | | | | | | | | | 0 |
| | | | | | | | | | | 0 |

**Table 9c. Illustration of Zone and Segment Data – Point Risks Entry/Exit Access Points**

| South Zone 3 - Freight Spurs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Name | Activity Level | Safety | Track | Traffic | Traffic on Connected Track | | | | | |
| (milepost) | | Mvts/Week | Features | Connected | Type | Acela | Tier III | Regional | Comm'r pp | Comm'r mu | Freight |
| 29.7 | Newport Industrial | 5 | Typical | 1 | Freight | 0 | 0 | 0 | 20 | 75 | 15 |
| 31.6 | Crowell Corporation | 3 | Limited | 3 | Freight | 93 | 0 | 184 | 0 | 5 | 0 |
| 35.6 | Harmony Industrial | 10 | Typical | 3 | Freight | 93 | 0 | 184 | 0 | 5 | 0 |
| 37.5 | General Foods | 3 | Typical | 3 | Freight | 93 | 0 | 184 | 0 | 5 | 0 |
| 38.3 | Track 5 | 5 | Comprehensiv | 3 | Freight | 93 | 0 | 184 | 0 | 5 | 0 |
| 38.5 | Delmarva Branch | 50 | Comprehensiv | A | Freight | 0 | 0 | 0 | 20 | 75 | 52 |
| 38.9 | Chrysler Lead North | 10 | Comprehensiv | A | Freight | 0 | 0 | 0 | 20 | 75 | 52 |
| 40.0 | Chrysler Lead South | 3 | Limited | A | Freight | 0 | 0 | 0 | 20 | 75 | 52 |
| 45.7 | Red Mill | 3 | Typical | 1 | Freight | 0 | 0 | 11 | 0 | 5 | 59 |

### *2.5 Model Implementation – Organization of Worksheets*

The preceding sections of the report have described the sources for the data used in the risk analysis. Specifically, this includes the derivation of accident frequency and consequence values for each accident scenario, and how the operating and infrastructure data for the high-speed zones and segments are quantified for model analyses. This section describes the structure of the risk model that starts with these inputs and calculates the number of accidents and aggregate consequences over a defined period, together with normalized values for risk for the different analysis cases. Figure 3 is a block diagram showing the structure of the model.

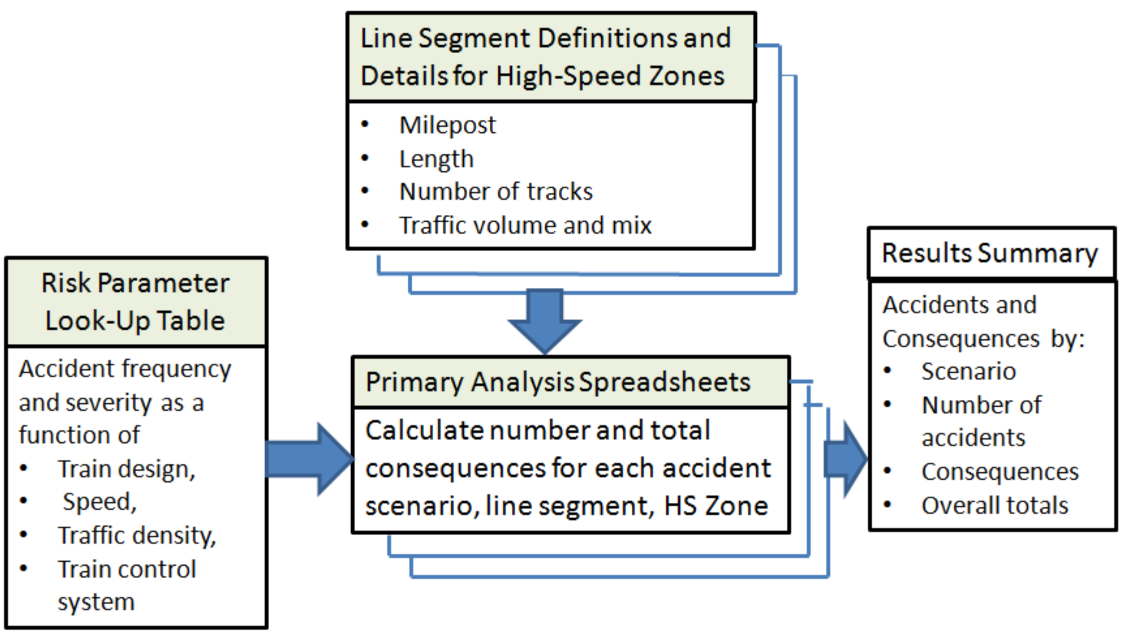


**Figure 3. Structure of the Risk Model for One Analysis Case**

The model was developed in an Excel Workbook with multiple Worksheets as described below:

- A "Frequencies and Consequences" Worksheet containing input accident frequencies as shown in Tables 3-6, and multiple tables having the same layout as Table 7 providing accident severity distributions for each equipment type, and for the Acela and Tier III high-speed train sets distributions for three speed bands: 125-135 mph, 136-150 mph and 151-160 mph.

- A "Zone and Segment Data" Worksheet containing high-speed zone and segment milepost locations, and the input infrastructure and operations data for each segment needed for the model. An example from this Worksheet is shown in Table 9a-c.
- Eight Worksheets that perform the detailed risk calculations for each high-speed zone, which comprise:
  - Calculate accident frequency for each segment, main track, equipment type, and accident scenario, using applicable frequencies and adjustment factors provided on the "Frequencies and Consequences" Worksheet.
  - Calculate the number of accidents over 10 years for each segment, main track, equipment type, and accident scenario, using applicable accident frequencies, traffic data and other inputs for each main track and segment.
  - Using the consequence distributions on the "Frequencies and Consequences" Worksheet, calculate the numbers of accidents at each severity level for each segment, main track, equipment type, and accident scenario.
  - Using the table of accident consequences (injuries and damage) for each consequence level calculate the number of injuries for each segment, main track, equipment type, and accident scenario.
  - Calculate totals for the numbers of accidents, severity level, injuries and property damage for each accident scenario and equipment type. These results are then available for transfer to a summary worksheet.
- A summary Worksheet that calculates totals for all NEC high-speed zones.

### *2.6 Model Validation*

Model validation was accomplished by comparing model results from the 2012 base case with the actual 2000-2012 accident record. The comparison was for the number of trains in accidents rather than accidents. Collisions between on-track maintenance equipment in work zones were excluded from both counts. The model cannot calculate a frequency or train-mile equivalent for work zone activities. After making both adjustments, the historical record shows 62 trains involved in accidents. For comparison with the number of accidents estimated by the model, two further adjustments were required:

- The model estimates are for trains in accidents over 10 years while the historical data is for a 13 year period, and
- The total length of high-speed territory analyzed by the model is 221 route miles, while the historical analysis identified 307.7 miles.

Making both these adjustments means that the number of accidents in the historical record should be reduced by a factor of 0.55 for comparison with model estimates, to 28.6 accidents. Table 10 compares the model estimates with the historical record for passenger and freight train accidents.

**Table 10. Comparison of Historical Data and Model Estimates for Trains in Accidents in the High Speed Zones Over 10 Years**

| | Trains in Accidents | | |
|---|---|---|---|
| | Passenger | Freight | Total |
| **Historical** | 19.3 | 9.9 | 28.6 |
| **Model** | 27.5 | 6.6 | 34.1 |

The model appears to overestimate the number of passenger trains in accidents and underestimate the number of freight trains in accidents. While the accident analysis does not provide definitive answers as to the sources of the differences, the following are suggested:

- Passenger accident estimates were based largely on actual NEC accident experience, combined with broader US passenger rail accident data. NEC accident frequencies were very low, depending on very few actual accidents, and much lower that other US passenger rail operations. Because of the sparse data, the modelers tended to err on the side of caution.
- Freight accident frequencies were derived from a mix of NEC-specific and broader freight train derailment frequencies for higher classes of track – FRA Track Class 5 and above. This appears to have resulted in an under-estimate, perhaps because operations on the NEC involved a large number of movements on and off the corridor, compared with long haul freight movements over good quality main line track.
- There is some uncertainty as to the actual volume of freight traffic on the NEC.
- It is worth noting that the higher number of freight accidents in the historical record compared with model estimates does not seem to have impacted passenger operations, where the number of accidents was very low.

In conclusion, Amtrak is confident that comparative semi-quantitative risk model estimates of passenger train accidents are conservative, and can be relied on for comparisons between future high-speed train set design alternatives. The impact of the uncertainty regarding the number of freight train accidents including secondary accidents involving passenger trains can be assessed by running sensitivity analyses which double or quadruple the freight traffic levels.

## 3.0 Risk Assessment Results and Findings

### *3.1 Introduction*

This section provides a description of the results of the analyses, presented as comparisons between the base cases and each of the future cases summarizing the risk estimates after operations, equipment and operations changes. Full details of risk assessment results are found in Attachment 6. In each comparison, the discussion includes applicable changes in infrastructure and operations, and the change in overall risk as measured by selected risk parameters. The findings presented at the end of this section are based on the risk assessment, the results of analyses of accident history on the NEC and recommendations by subject matter experts.

The risk analysis results are for the 221 miles of the NEC over which speeds between 125 mph and 160 mph may be possible. The risk model was developed to calculate both linear and point risks based upon the hazard categories defined within Attachment 2. Risk is calculated within specific high speed segments for each hazard category. The risk calculated is summed up over each individual high speed zone, over multiple high speed zones, and over the complete NEC. Refer to Table 8 for the definition of each high speed zone.

Creating a risk model with this level of granularity allows Amtrak to leverage the results from the risk model to both prioritize a number of risk mitigation strategies and then select a complement of these risk reduction measures to assure that the level of safety that exists with Tier II compliant equipment will be met or improved by operation of Tier III equipment.

Key assumptions used in developing the comparative semi-quantitative risk model and interpreting the analysis results include:

- Tier III equipment is considered equivalently safe to Tier I equipment as a result of the work product of the Railroad Safety Advisory Committee's (RSAC) Engineering Task Force (ETF). No risk calculations were conducted for operations below 125 mph.
- Risk comparisons are based upon regulatory minimum requirements – that is Amtrak should not be penalized for going beyond the minimum safety requirements established and those actions and practices that improve upon the minimum federally mandated requirements should be recognized.
- Assumptions on the generic performance of Tier III equipment are based upon the requirements developed within the RSAC ETF as specific details of the trainset design will not be known until after the equipment is manufactured and for which approval is sought.
- All future analyses cases take PTC as given.
- Amtrak applied the following risk metrics to quantify the risk:
  - Normalized accident rates *per million train miles*,
  - Normalized breakdown of Severity Levels *per million train miles*, and
  - Estimates for consequences that include normalized injuries, fatalities and damage *per million train miles*.
- System safety for the complete operation on the NEC is considered.

To illustrate the level of detail provided by the model, Figure 4 shows the model results for a single, 2.1 mile segment in South Zone 1 (between NYC and Trenton, NJ). This segment has heavy Amtrak regional and commuter traffic and well as high speed train operations. The signal system in this area is a combination of ATC per Amtrak operating Rule 251 on the outer tracks and Amtrak operating Rule 261 in the high speed tracks.

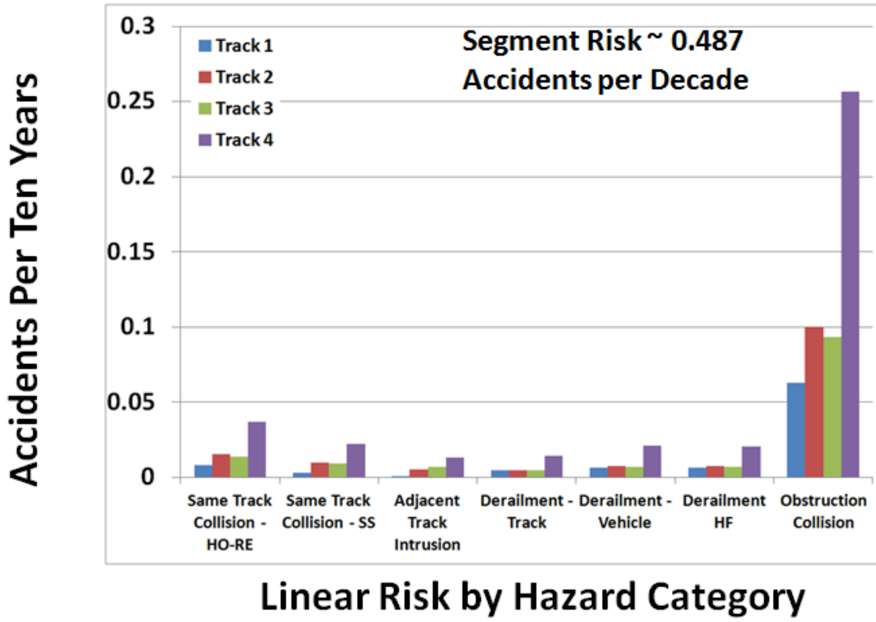


**Figure 4. Typical Results from Risk Model for a Single High Speed Segment – by Hazard Categories and Track**

The model predicts that 0.487 accidents will occur over a 10 year timeframe. The highest contributor to the risk in the segment is associated with obstruction collisions. The most likely track where such an event could take place is on the outside track which is true for the other events as well. The high-speed tracks are tracks 2 and 3.

### *3.2 2012 Base Case Risk Analyses*

Model results for the 2012 baseline analysis case are shown in Table 11.

**Table 11. Normalized Risk for the Baseline 2012 Operation on the NEC**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| Base case results | | | | | | | |
| All Zones Normalized | 0.295 | 0 | 0.308 | 0.301 | 0.322 | 0.478 | 0.307 |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | 0.143 | 0.114 | 0.033 | 0.008 | 0.123 | 0.000 | 41576 |

The normalized values are trains-in-accidents, injuries and property damage *per million train miles*. Note that accident frequency for freight trains is significantly higher than for passenger trains.

The key risk metrics from this table, which will be the primary points of comparison with the other analysis cases, are:

**Overall frequency of trains in accidents = 0.307**
**Overall frequency of injuries = 0.123**
**Overall property damage *per million train miles* = $41,576**

Figure 5 show the variation in the risk profile across the NEC for the baseline 2012 analysis case.

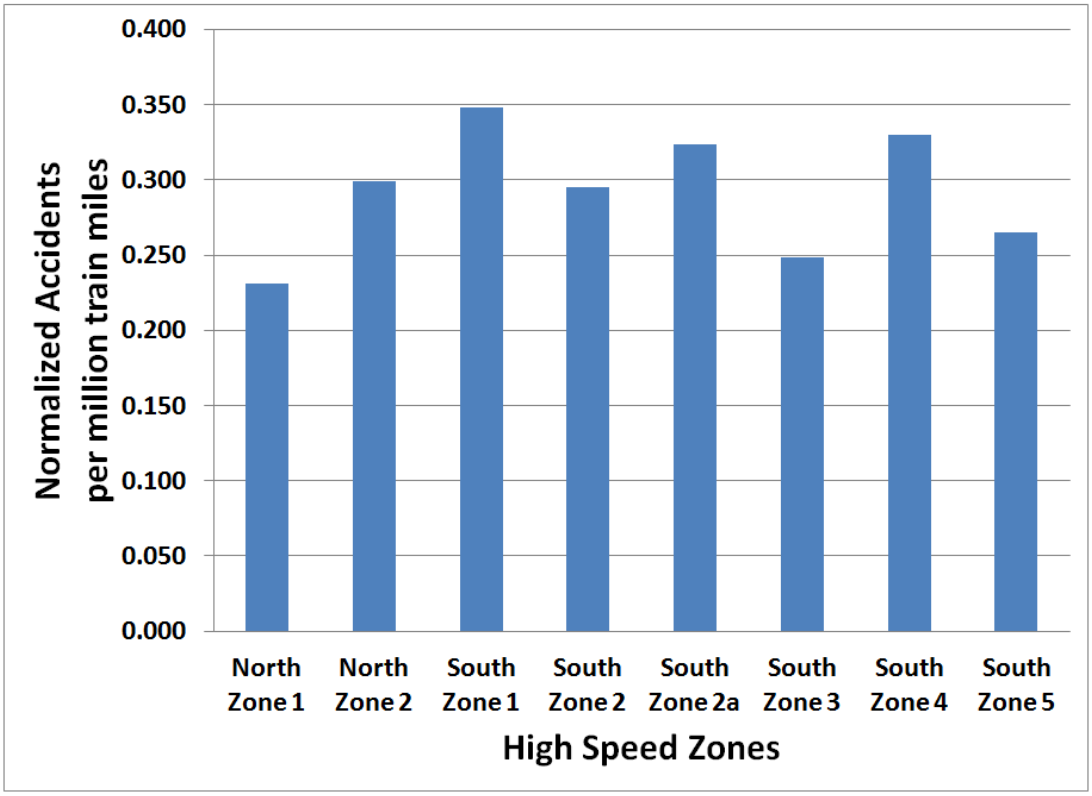


**Figure 5. Variation in Risk Profile for Base Case Circa 2012**

Risk naturally varies from high-speed zone to high-speed zone. This variation is primarily a function of traffic density (trains per track per week), changes in level of protection or ROW segregation, signal system and other factors. Despite this variation, operations on the NEC have been very successful and safe to date. This information is very useful when reviewing potential risk mitigation strategies, as it can provide a means for choosing specific locations or high-speed zones for site improvements.

### *3.3 Sensitivity Risk Analyses*

Having completed the base case representative of operations in the 2012 timeframe, it is important to run a series of alternative analyses to understand what impact may occur for variation of key input parameters in the model. The following analyses were conducted to gain a better understanding on predicted impact of key input parameters on calculated model risk.

- Full implementation of PTC.
- Impact of significantly more Tier II high speed trains (1.4X Acelas).
- Sensitivity to freight operations.
- Changes to infrastructure – ROW segregation, interlocking, access spurs.

The key results from these analyses are summarized in Table 12.

**Table 12. Example Results from Sensitivity Analyses**

| Analysis case | Normalized Risk Metrics – Values per Million Train Miles | | |
|---|---|---|---|
| | Accidents | Injuries | $ Damage |
| **2012 Base Case** | 0.307 | 0.123 | 41,576 |
| **Base Case with Full PTC** | 0.294 | 0.114 | 42,305 |
| **Base Case with 1.4x Acela Service** | 0.307 | 0.121 | 44,870 |

Findings that can be drawn from these analyses are:

- Installing PTC throughout the NEC reduces accident frequency in the high speed zones by 4% and normalized injuries by 7%. The results from this is case are used for comparison with all future risk analysis cases.

Increasing Acela service (train-miles) results in no change to accident frequency, but a slight reduction in the normalized injuries. The reduction in normalized injuries is likely due to the very high crashworthiness performance of Acela, and the higher fraction of Acela train miles in the total. Accident frequency is unchanged: a lower derailment frequency of Acela (due to automated equipment condition monitoring and more frequent inspection) may have been offset by the higher traffic densities leading to a higher collision frequency. The factor 1.4 was used to reflect the expected increase in high-speed traffic to achieve the levels of service anticipated in 2020. Changes in freight service by the following factors were also investigated: no freight, double the freight traffic and quadruple the freight traffic. Eliminating, Doubling or quadrupling freight traffic in the high-speed zones produces the expected changes in overall accident frequency, mainly due to the expected change in the number of freight train accidents. Eliminating freight entirely reduces the accident rate to 0.302 while doubling or quadrupling results in accident rates of .312 or .321 respectively. Despite these changes to the accident rates, the impact on normalized passenger injury rate is small – less than 3% for all cases.

Other analyses conducted include impact on predicted risk for increased commuter traffic by 10%, improving right of way (ROW) segregation everywhere to excellent protection and improving interlockings to the best state possible. Figure 6 is a plot of the comparison of all the analyses discussed so far.

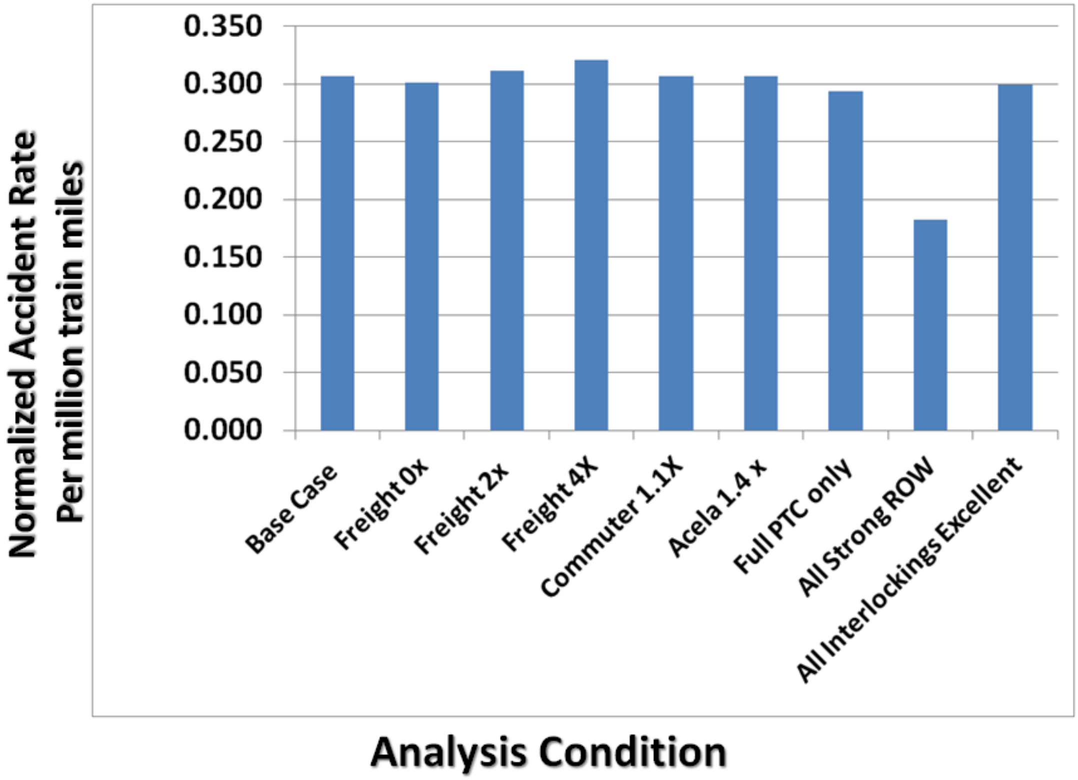


**Figure 6. Sensitivity Analyses for the 2012 Base Case – Impact on Normalized Risk**

Clearly the biggest impact on the risk predicted is associated with improvements to ROW segregation. Adding additional commuter traffic on the NEC has almost no effect on the predicted normalized accident rate. There is an increase in the absolute number of predicted accidents in a given ten year timeframe, but when normalized *per million train miles* the rate does not change. There is an improvement for interlocking improvements. However the improvement is fairly small. The results obtained suggest that if upgrades to interlockings are solely for purposes of reducing risk, they are not the most effective use of resources. The pattern observed in Figure 6 is preserved when additional analyses incorporate full compliance with PTC as shown in Figure 7.

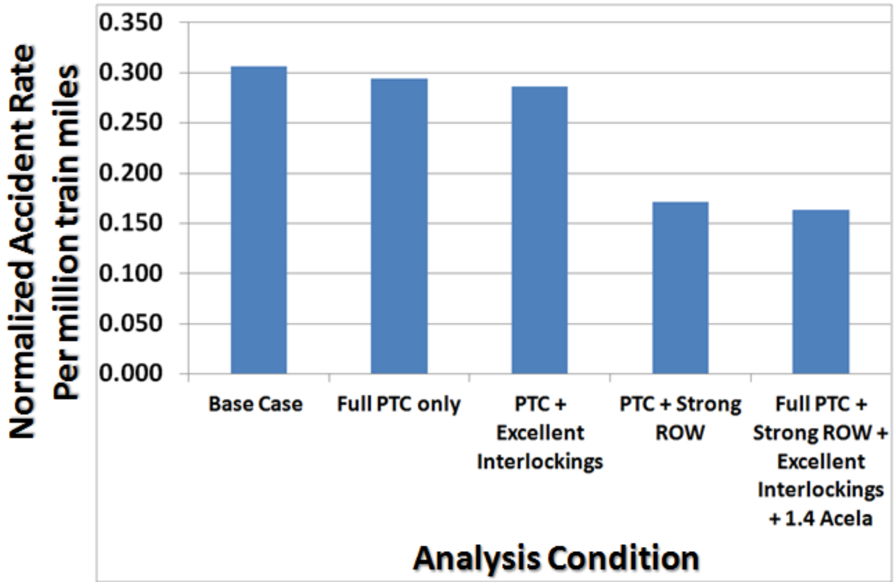


**Figure 7. Combination of Alternative Analyses with PTC as a Constant**

The results in Figure 7 for improving ROW segregation and interlocking condition assume full implementation everywhere on the NEC, which is a situation that is not likely to happen in the near future. Amtrak used these initial results showing changes to predicted risk for different risk reduction strategies to prioritize risk reduction strategies. The conclusion that Amtrak has drawn from these initial analyses is that select ROW segregation improvements is the best strategy to address the largest hazard category observed to date on the NEC: impacts with obstructions.

### *3.4 Future Case: Mixed Acela and Tier III Service, Circa 2020/2025*

This future case assumes an operation on the NEC with circa-2020 estimated traffic levels with increased high-speed service between NYC to Washington, using original Acela Express, Tier II train sets, supplemented by new Tier III equipment. For this future service condition, both types of train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines risks where Tier II and Tier III trains operate on the NEC at the same time. In addition, the following assumptions were made for all cases having this level of high-speed service.

a. Positive Train Control is fully implemented (as mandated),
b. Commuter service traffic levels remain the same as the Circa 2012 case, and
c. Freight service traffic levels remain the same as the Circa 2012 case.

The specific analyses carried out all involve variations in the type of high speed equipment operated, and are noted below:

- Service provided with all Tier II Acela trainsets. This is a hypothetical case to produce risk metrics for a "regulatory" base case for comparison with the other two cases. Mitigations would be needed if any of the key risk metrics exceed those determined in this case. It is hypothetical, because Amtrak has no specific plans to acquire additional Tier II train sets that would be needed to cover the proposed schedules.

- Mixed service provided by the existing fleet of Tier II Acela trainsets, supplemented by new Tier III trainsets to cover the proposed trips additional to current (2012) service.
- The proposed service provided by all-new Tier III high-speed trainsets.

Table 13 summarizes the key risk metrics for these three cases as well as for the original 2012 base case, with and without PTC.

**Table 13. Key Risk Metrics for Mixed Acela and Tier III Operation**

| Analysis case | Normalized Risk Metrics – Values per Million Train Miles | | |
|---|---|---|---|
| | Accidents | Injuries | $ Damage |
| **2012 Base Case** | 0.307 | 0.123 | 41,576 |
| **2012 Base Case with PTC** | 0.294 | 0.114 | 42,305 |
| **All Acela Tier II Trainsets (Regulatory Base Case)** | 0.294 | 0.119 | 43,845 |
| **Mixed Acela and Tier III Operation** | 0.294 | 0.121 | 44,469 |
| **All Tier III Trainsets** | 0.293 | 0.127 | 46,683 |

Findings that can be drawn from these results are:

- The values for the all Tier ll (Acela) case have dropped below the original base case representing 2012 service on the NEC without PTC. This is due to full implementation of PTC, as well as increasing the percentage traffic associated with an equipment type that is inspected and maintained better than the conventional Tier I fleet. Safer equipment operating for more mileage has a tendency to drive down the overall system accident rate. Comparison of the 2012 base case with PTC implemented shows that the future condition with greater traffic adds additional risk for normalized injuries and damage. This is the regulatory null case and is used to compare with the mixed traffic and all Tier III trainset service.
- The results for mixed service show that the normalized accident frequency remains constant, while normalized injuries increase by about 2%, from 0.119 to 0.121. Normalized damage increases from $43,845 from the regulatory null case to $44,469 for mixed service which his roughly 1%. This implies that the safety gap for these two types of service is small.
- The results from the all Tier-III trainsets operation show a further increase in the injury rate up to 0.127, a total increase of just over 7% compared with the regulatory null case. There is an increase in normalized damage as well, just over 6%. The detailed results provided in Attachment 6 also show a shift in the severity distribution towards more severe levels when comparing the Tier II regulatory null case with a service operated with only Tier III trainsets. This demonstrates the presence of a safety gap between the two service types. The safety gap requires application of risk reduction strategies to ensure an equivalent level of safety, as required by the safety case.

The next future case examines a further increase in high-speed trips on the NEC. The results indicate a further increase in the safety gap. A detailed examination of risk reduction strategies was deferred for that case and discussed in the next section.

### *3.5 Future Case: Increased Traffic with all Tier III Trainsets, Circa 2020/2025*

This final case investigated the safety performance of the NEC with a further increase in high-speed trips to comprise half-hourly service throughout the day between New York and Washington DC, and hourly service throughout the day between New York and Boston. As in the previous cases, the following conditions were applied to all analysis cases considered in this section:

a. Positive Train Control is fully implemented (as mandated),
b. Commuter service traffic levels remain the same as the Circa 2012 case, and
c. Freight service traffic levels remain the same as the Circa 2012 case.

The results of a comparison between the planned service with Tier III trainsets and a regulatory null case of the same service with only Tier II trainsets is shown in Table 14.

**Table 14. Key Risk Metrics for Increased High Speed Service with all Tier III Trainsets**

| Analysis case | Normalized Risk Metrics – Values per Million Train Miles | | |
|---|---|---|---|
| | Accidents | Injuries | $ Damage |
| **Increased Service with all Tier III Trainsets** | 0.293 | 0.128 | 47,517 |
| **Increased Service with all Tier II Trainsets (Regulatory Null Case)** | 0.294 | 0.119 | 43,991 |

These analyses show differences in estimated risk over the complete NEC for the two different classes of equipment. The breakdown in traffic for this condition is roughly 30 percent high-speed equipment, 34 percent Amtrak Regional, 34 percent commuter traffic and 2 percent freight traffic. This equates to approximately 111 million train miles of traffic as compared to the analysis base case, circa 2012 which had 98 million train miles. The accident rates *per million train miles* are approximately the same. However the relative difference with respect to regulatory null case for normalized injuries is 7%. The relative difference with respect to the regulatory null case for normalized damage is 8%. The relative differences are calculated by taking the difference with respect to the regulatory null case and dividing by the average of the two cases considered. This is a typical means of presenting the information in risk analysis. A relative difference greater than zero for the risk metric of concern then represents the safety gap that may need to be closed by application of appropriate risk mitigation strategies. This relative difference is greater than that calculated for the mixed Tier II and Tier III equipment case.

### *3.6 Risk Mitigation Prioritization and Selection*

The risk model has established the difference in performance between Tier II and Tier III equipment for a proposed future operation that assumes ½ hourly service between Washington, DC and New York, NY and hourly service between New York, NY and Boston, MA. This analysis case produced the largest relative difference in performance of the risk analysis cases analyzed for proposed future operations.

Lessons learned from conduct of a series of sensitivity cases on the base case, circa 2012, are summarized for the nine accident scenarios considered in the NEC risk model:

- **Head-on and rear-end train to train collisions.** These types of accidents are very rare with implementation of PTC, and therefore not much more can be done. However, collisions involving work equipment present a greater risk. Most are low speed and in work zones, but there is the chance of adjacent track fouling and a secondary collision. Mitigations involving roadway work practices, safety management and culture, CRM and similar would apply.
- **Sideswipe collisions.** These accident types include a mix of freight and passenger equipment. To date, there have been very few accidents of this type on the NEC and those that have occurred have been mostly minor in nature, caused by unsecured doors and similar events. Mitigations could include shifted load detection and inspections at freight access points, and mechanical inspection of passenger trains.
- **Track defect derailments.** Day-to-day track inspections are already very intensive. There are few accidents of this type, and 2 out of 3 from the historical accident review involved MOW activities – see comments under train-train collisions. In addition, Amtrak's forthcoming program of track improvements to improve ride quality may also yield modest safety benefits.
- **Mechanical defect derailments.** There are very few of these types of accidents and they mostly involve freight equipment. More comprehensive visual and/or automated freight car inspections at freight access points could reduce these accidents. So far freight derailments have not led to a secondary collision involving a passenger train, but the possibility exists and the model takes this into account. The benefits are likely small, but could be in line with the relative cost, if well located. The technology involved with automated inspections is maturing and Amtrak will continue to monitor progress for future implementation at an appropriate time.
- **Human factors derailments.** These types of derailments are very diverse and are mostly attributable to point risk events at access spurs. These are by far the most plentiful kind of derailments. The threat to trains operating on main tracks is a low-probability secondary collision after the initial event. Safety culture approaches are appropriate, but note that many of these accidents involved non-Amtrak operators.
- **Obstruction collisions.** Three categories exist for obstruction collisions.
    - The major category (about 50 %) involves objects that are an Amtrak responsibility – MOW equipment, materials, and other unsecured objects. These mitigations are very important, but involve more difficult-to-implement actions addressing work practices, safety culture, etc. Amtrak is implementing a significant safety culture improvement

program and working on refining operational and MOW practices to address these concerns.
    - The second category is associated with obstructions following unauthorized access, where fencing and barrier mitigations apply (about 30%). The risk model shows prevention of unauthorized access as a leading risk reduction strategy.
    - The remaining obstruction accidents concern natural events– severe weather, fallen trees, animals on the ROW, and rock falls (about 20%). These hazards can be partially mitigated through regular infrastructure and ROW maintenance programs.
- **Point accidents at interlockings.** Mitigation is possible through improved interlocking materials and components, but yield modest benefits. Evaluation using the risk model suggests that interlocking replacements already planned will result in modest risk reduction. Interlocking replacement is not worthwhile only for risk reduction, but should be conducted as part of the ride quality improvement programs underway on a timeframe defined by available resources.
- **Point accidents at access spurs.** There have been several accidents of this type but no secondary accident involving trains operating on main NEC tracks. These accidents are predominantly human factors involving freight and (in one case) a commuter operator. Benefits from installation upgrades are likely to be small, but there is no reason to not make obvious, low-cost improvements that lower the risk of a low probability but potentially very serious accident.
- **Secondary collisions.** The model calculates secondary collision risks on main tracks due to either main line accidents (collisions and derailments) and/or access spur accidents. Estimated frequencies are very low (less than one accident in 10 years) but such accidents could become very severe. The risk calculation relies on two input parameters – the likelihood that the accident will result in an intrusion onto an adjacent track and the likelihood that an approaching train will collide with the intruding vehicles. The best approach to mitigate these types of events is to prevent the initial accident.

These observations, together with inputs from railroad engineering, mechanical and operations experts, have been used to identify candidate mitigations for high-speed Tier III operations. Among the various potential mitigations, one – improving the physical segregation of the NEC right-of-way to reduce the opportunity for intrusion – is attractive as it can readily be implemented in the short term and offers a high level of risk reduction. A series of analysis cases focused on estimating the risk reduction that would result from reducing the occurrence of obstruction accidents.

Areas of weak ROW segregation were identified from detailed notes and photographs taken by Risk Focus Group members who rode the Amtrak Geometry Car, as well as review of the high definition video taken at the same time. Amtrak also contacted internal stakeholders to assess where there were locations on the NEC that were known areas of weak ROW segregation based upon observation, trespass reports or accidents.

Table 15a shows the results from selection of 20 high-speed segments for ROW segregation improvement. These segments were chosen by running the risk model and varying each high speed segment with a weak ROW segregation value to strong and then sorting by the segments that provided the most risk reduction. This calculation assumes that approximately 30% of obstruction collisions are with objects introduced onto the NEC right-of-way from the outside, and thus almost all such accidents could be prevented by well-designed fences and barriers.

**Table 15a. Selection of 20 Segments for Improved ROW Segregation – from Weak to Strong as Defined in Risk Model Inputs**

| | Accidents per million train-miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **20 Segments Weak to Strong** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones, Normalized** | **0** | **0.265** | **0.279** | **0.260** | **0.281** | **0.455** | **0.271** |
| | **Accidents by Severity Level** | | | | **Estimated Consequences Events per million train-miles** | | |
| | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | **0.124** | **0.103** | **0.035** | **0.009** | **0.123** | **0.00** | **45661** |

The second mitigation applied addresses risks due to obstruction collisions with objects on the right-of way that are the responsibility of Amtrak maintenance-of-way forces or others carrying out legitimate activities on the right-of-way. Since the root causes of these obstruction collisions are highly diverse, the specific mitigations considered are a group of related measures aimed at improving overall safety of operations on the corridor, rather than trying to develop procedures to address each individual accident cause. These measures include a program to improve the safety culture among Amtrak employees and contractors, a close-call reporting system, and a system-safety program plan. To be conservative, Amtrak has assumed that these measures could result in a 20% reduction in this category of obstruction accidents.

**Table 15b. Selection of 20 Segments for Improved ROW Segregation *PLUS* Implementation of Safety Culture Improvement and Related Programs**

| | Accidents per million train-miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **20 Segments Weak to Strong** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones, Normalized** | **0** | **0.243** | **0.256** | **0.239** | **0.258** | **0.418** | **0.246** |
| | **Accidents by Severity Level** | | | | **Estimated Consequences Events per million train-miles** | | |
| | **Level 1** | **Level 3** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | **0.113** | **0.094** | **0.032** | **0.009** | **0.116** | **0.00** | **43062** |

Table 15b demonstrates that the installation of fences and barriers on the 20 most-risky segments combined with programs to improve safety culture and system safety results in an overall reduction of 9% in normalized injuries and 16% in normalized accidents in the proposed high-speed zones. The reduction in injuries is more than enough to offset the increase in normalized injuries of 7%

due to using Tier III trainsets instead of a trainset built to Tier II requirements, similar to the Acela trains currently operating on the NEC.

### *3.7 Summary*

Amtrak is seeking approval of a Waiver Petition to FRA for operation of Tier III equipment on the NEC generally and at speeds above 125 mph and up to 160 mph in certain specific locations in order to meet future operational service needs. A successful petition must clearly demonstrate that the proposed operation is as safe as or safer than existing operations and in the Public's interest. Amtrak has identified investments that assure an equivalent level of safety through the development of a detailed comparative semi-quantitative risk model. The risk model is intended to be a tool which Amtrak can make informed decisions about both existing as well as future operations. The risk model will be maintained and updated with anticipated modifications to the infrastructure, signal system, rolling stock and operational and Maintenance of Way practices to further refine the risk profile on the NEC in areas where the Tier III equipment will be operated above 125 mph.

The risk model was developed using historical accident and operational data and validated through comparison with the actual history experienced between 2000 and 2012. Amtrak developed a team of internal subject matter experts and stakeholders to verify the inputs needed for the risk model and develop an appropriate set of hazard categories based upon the accident history. The risk profile of the NEC operations reflective of 2012 conditions was developed and a number of sensitivity analyses were conducted to assess impact on predicted normalized: accident rate, injury rate and damage rate *per million train miles* for different input parameter variations. Based upon the risk model results Amtrak was able to develop a process of identifying, prioritizing and selecting risk mitigation strategies for input into the risk model for proposed future operational conditions.

The process Amtrak used to demonstrate equivalent safety before and after introduction of Tier III equipment running above 125 mph and up to 160 mph on selected segments of the corridor involved the following steps:

1. Establish the current risk profile on the NEC using model inputs reflective of 2012 operations.
2. Run the model with inputs that reflect the state of the Northeast Corridor today making the assumption that PTC has been fully implemented. PTC will be required for future operations as congressionally mandated; hence this is the minimum regulatory comparative base risk case for current operations.
3. Run the model with Tier III Equipment traffic operating at speeds above 125 mph and up to 160 mph in selected segments of the corridor.
4. Rerun the model with only Tier II equipment under the same operating conditions and traffic levels with PTC implemented. The difference in risk calculated from the Tier III operations with the Tier II operation at the same traffic levels defines the safety gap.
5. Develop and prioritize - based on technical feasibility, cost and a judgment made by experts of potential risk reduction effectiveness - an inventory of possible risk mitigating actions.

6. Re-run the model for the case of Tier III equipment operating at speeds above 125 mph and up to 160 mph in selected high speed segments adjusting the model inputs to reflect implementing various combinations of risk reducing measures.
7. Compare the relative risk as calculated by the model of the selected risk reduction scenarios to the regulatory null base case risk. Scenarios are considered for implementation only if the model predicts a relative risk less than that of the regulatory null base case, i.e. the model predicts that the risk reduction scenario more than compensates for the increased risk of operating Tier III Equipment at speeds up to 160 mph.
8. Select the optimal risk reduction scenario based on feasibility, predicted cost, time required for implementation and effectiveness.
9. Execute a stakeholder engagement plan to inform affected stakeholders of the mitigations planned and work them to implement the mitigations.

Based upon the risk model results Amtrak was able to identify, prioritize and select risk mitigation strategies for input into the risk model for proposed future operational conditions. The following findings are drawn from the analyses:

***Finding 1:***

***Obstruction collisions are far and away the most numerous type of accident to passenger trains operating at speed on the NEC, and two groups of these accidents should be the first targets for risk mitigation:***

***1a: Implement a program of construction of fences and barriers to prevent trespass and highway vehicle access in the 20 most vulnerable route segments as indicated by the risk model and on-the-ground assessments.***

- These accidents comprise 30% of all obstruction accidents, and about 20% of all accidents involving passenger trains.
- Provided the fences and barriers are subject to good routine inspections and maintenance, Amtrak has high confidence that the majority of obstruction accidents in the selected segments can be prevented.
- The risk analysis indicates that extending a fence and barrier program beyond the most vulnerable 20 route segments is likely to be less cost-effective, and is not proposed.
- The fence and barrier program should remain flexible, however, as full details of the present status of fence and barrier systems in the high-speed zones were not available at the time of the risk analysis. The analysis should be updated when this information is available, followed by modification of the program as appropriate.
- Risk model results estimate that a fence and barrier program will reduce normalized train accidents from 0.293 *per million train-miles* in the Tier III base case to 0.271 *per million train-miles*, and injuries to passenger train occupants from 0.128 *per million train-miles* in the Tier III base case to 0.123 *per million train miles*.

***1b: Continue with and expand where possible an active system safety program addressing the diverse causes of obstruction collisions with Amtrak MOW equipment and materials, contractor equipment and materials, and miscellaneous objects.***

- These accidents comprise 50% of all obstruction collisions, and 35% of all accidents involving passenger trains.
- The risk model shows that reducing the occurrence of these accidents by 20%, combined with the fencing and barrier mitigation (conclusion 1a) reduced normalized injuries from 0.128 to 0.116 *per million train miles*, enough to offset all the increase of injuries from using Tier III trainsets in place of Tier II trainsets. The results from the regulatory null case predicted a normalized injury rate of 0.119 *per million train miles*. Relative to an all Tier III operation before mitigation, this is a reduction of 9% in normalized injuries and a 17% reduction in normalized accidents.
- Causes for these accidents are diverse, meaning that a program that emphasizes overall culture, CRM and general system safety procedures are appropriate, rather than trying to address individual accident circumstances.
- Amtrak is already working on system safety and safety culture initiatives. Amtrak will extend its Confidential Close Call Reporting System to the maintenance-of-way department with the cooperation of the Brotherhood of Maintenance of Way Employees Division (IBT) and Brotherhood of Railroad Signalmen. Amtrak encourages FRA to continue to support C3RS programs and requests that FRA evaluate this initiative at an appropriate time.
- An improved safety culture and system safety program will support reductions in all accidents where human factors are a root cause.
- As part of the System Safety Program Amtrak will monitor the reduction in accidents and close calls in the period prior to the introduction of Tier III train sets into service to ensure risk reduction goals are being met.
- As part of the System Safety Program Amtrak will monitor the reduction in accidents and close calls in the period prior to the introduction of Tier III train sets into service to ensure risk reduction goals are being met.

***Finding 2: Continue with initiatives aimed at reducing accidents to freight trains operating on the NEC, avoiding high cost actions.***

- The risk to passenger operations from freight trains accidents is of a secondary accident where a passenger train collides with derailed freight vehicles after an accident on an adjacent track.
- Model analysis and historical experience indicates that this risk is low, but is subject to substantial uncertainty:
  - The actual freight traffic volume is uncertain and could grow.
  - The model input parameters used in the secondary accident calculation are difficult to estimate. A sensitivity analysis making pessimistic assumptions (doubling the likelihood of an event, doubling the time to notify an approaching train and doubling the frequency multiplier on access spurs) about their value showed that the normalized

accident rate increased by 4 percent and the normalized injury rate increased by 12 percent.

- The freight derailment *rate* on the NEC is higher than that typical of long distance intermodal freight on higher track classes.
    - This is a result, in part, to the nature of freight traffic on the NEC, which is short haul and requires servicing industries or yards.
    - Freight traffic experiences frequent switching between tracks or onto sidings, increasing the chance for an incident when normalized by train mile.
    - Therefore, continued attention to ongoing initiatives to reduce freight accidents is warranted
- The specific risk mitigation initiatives applied by Amtrak are:
    - Extended use of on-board sensors to evaluate train performance and obtain early warnings of incipient track geometry issues.
    - Continued application of operating restrictions, use of traditional and advanced wayside detectors, and periodic visual inspections of freight equipment by Amtrak mechanical personnel.
    - Broader application of advanced inspection technologies.

***Finding 3: Continue with initiatives to reduce the risk of unintended intrusion on the NEC main tracks at access points, but limited to low cost actions.***

- The risk model shows that the risk of collision to a passenger train operating on a NEC main track is low.
- Some improvements are mandated in any case to bring the NEC into full compliance with PTC requirements.
- Specific initiatives are improved derailers, improving track quality in freight tracks adjacent to NEC main tracks, and others.

***Finding 4. Continue with track and interlocking improvements that are currently in progress or planned.***

- The risk of track-defect-caused accidents is already low, thus while there will be some safety benefits from these improvements, those benefits are not the primary reason Amtrak is undertaking those improvements, and no additional improvements are proposed in this petition.
- Accidents at interlockings mostly have human factors causes unrelated to track condition.
- The specific improvements planned or ongoing that are referred to in this recommendation are replacement of selected interlockings and a comprehensive undercutting program being undertaken to improve ride quality. Both are primarily concerned with improving ride quality and reducing ongoing maintenance costs. Any initiative that reduces MOW activity will reduce accident risk, given the high number of accidents associated with roadway work.

Amtrak is now in possession of technical tool that can be updated as changes to the system are made to assess the reduction in risk.  As ongoing infrastructure improvement activities are completed the model will be updated to reflect the “then-current” status of the NEC.  Further as planned risk mitigations strategies are implemented these will also be updated in the risk model allowing Amtrak to gauge the change in the risk profile predicted for the high speed zones.

Amtrak will continue to monitor the changes in the risk profile before introduction of Tier III equipment onto the NEC, during the timeframe when there is overlap of the two different trainset types and on into the future as only Tier III trainsets are used at the highest traffic densities needed to meet service needs.  The risk model developed is a tool that can, and will be updated when major infrastructure changes are implemented not related to the specific risk mitigation strategies agreed upon within the Waiver Petition enabling Amtrak to articulate to FRA the relative improvements in safety after completion of such work.  The risk model can also be used as a means of justifying capital expenditures for future upgrades to funding sources.

Amtrak strongly believes that the results obtained from the analyses indicate that the proposed operation of Tier III equipment at speeds up to 160 mph on the NEC can be done safely through the implementation of cost effective risk reduction measures.  The details of the risk mitigation prioritization and selection for implementation are discussed within Attachment 6 to this exhibit.

### *3.8 Report Attachments*

1. Details of model analysis cases,
2. Analysis of accident history on the NEC over the period 2000-2012,
3. Details of NEC infrastructure and train operations,
4. Estimates of accident frequency for each accident scenario,
5. Estimates of accident severity for each accident scenario and equipment type, and
6. Detailed model results for each analysis case.

# Attachment 1

# Specification of Risk Analysis Cases

## 1.0 Introduction

Quantitative Risk Assessment (QRA) is a useful tool for *comparative* analysis of railroad operations under specifically defined circumstances. Although no QRA can definitively determine whether or when particular events may occur, a well-structured analysis can help with the understanding of the likelihood that such events will occur, given input parameters.

The system analyzed included passenger service, inclusive of Amtrak high-speed service, Amtrak Regional service and freight service (short haul, long haul and commodity) over high speed segments on the Northeast Corridor (NEC) with maximum allowed speeds above 125 mph up to 160 mph. Amtrak chose to apply a system safety approach to establishing the baseline level of risk currently experienced on the mixed-traffic NEC spine, inclusive of all passenger operations as opposed to just the high speed operations. Amtrak will utilize QRA as a means for making informed decisions about the safety implications associated with the use of Tier III equipment on the NEC which is has a mixed traffic environment at speeds up to 160 mph.

The risk analysis is the principal means by which Amtrak will demonstrate that the proposed operation of Tier III train sets will be safe. More specifically, the analysis contains an evaluation and selection of candidate risk mitigation measures to ensure that the proposed operation is at least as safe as an agreed baseline high-speed operation over the selected high-speed zones. This input, combined with inputs from rail safety experts and reviews of train accident experience on the NEC, will provide the required safety assurance.

A key assumption to the conduct of the QRA is that FRA accepts the premise of safety equivalence of the Tier III CEM designs with Tier I equipment[2]. Amtrak suggests that it would not be proportional to ask Tier III equipment to behave like Tier II equipment in Tier I territory on the NEC, when that will not be required elsewhere. The Tier III risk analysis described within this report assumes that the trainsets being acquired by Amtrak are in full compliance with applicable Tier III requirements, and analysis and tests required to confirm compliance have been completed prior to introduction of such equipment into regular revenue service. The risk analysis will be carried out on the high speed zones on the Northeast Corridor where future operations at speeds exceeding 125 mph with Tier III high speed train sets are planned. Risks associated with future operations at speeds of 125 mph and lower will not be analyzed.

In order to establish to current risk profile for operations on the NEC spine the risk model was developed to reflect the existing state of operations on the NEC. Attachment 2 and 3 describe the

[2] FRA is currently working on Phase I of a rulemaking activity that will codify the equivalent performance of Tier III equipment to Tier I equipment.

process used to develop the requisite input for the risk model. Upon completion of the documentation of all operational and accident history input data, Amtrak subject matter experts (SMEs) reviewed the details of the risk model and agreed that the input is reflective of both current operations as well as what is expected for future operations.

Information pertaining to the development of the accident history, gathering of operational and infrastructure data and the accident frequencies and consequences are included in Attachments 2 through 5 and the detailed description of the risk analysis results are discussed in Attachment 6.

## 2.0 Definition of Analysis Cases

Amtrak's Risk Focus Group agreed upon a number of risk analysis cases to establish both current baseline levels of safety performance as well as a number of future cases for the proposed operation using both a hypothetical condition with more Tier II compliant trainsets similar to the existing Acela's and an alternative trainset design based upon a generic performance for a Tier III trainset. Tier III trainsets as defined within the FRA's Railroad Safety Advisory Committee's (RSAC) Engineering Task Force (ETF) will address operation of 220 mph - capable trainsets at very high speed on exclusive rights of way (EROW) and at Tier I speeds (NTE 125 mph) in mixed service with other passenger and freight traffic. This definition of operation is not reflective of the conditions on the NEC and hence the need for Amtrak to establish a means of demonstrating equivalent safety of use of a heavier more crashworthy trainset under the more demanding operational conditions.

The following analyses cases were conducted:

- *Analysis Base Case*: The NEC as operated over the period 2000 – 2012, with Tier II Acela Express trains at speeds up to 150 mph and conventional Amtrak regional and commuter equipment. This case is the foundation on which input parameters for all future cases are estimated, and also used in model validation.
- *Future Case: Mixed Tier II and Tier III Operations:* The NEC with circa-2020 estimated traffic levels with increased high-speed service between NYC to Washington, using original Acela Express, Tier II train sets, supplemented by new Tier III equipment. For this future service condition, both types of train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines risks where Tier II and Tier III trains operate on the NEC at the same time.
- *Future Case: All Tier III Operations*: This case assumes hourly high-speed service between Boston and NYC and half-hourly high-speed service between NYC and Washington DC throughout the day. For this future service condition, Tier III train sets are assumed capable of operations up to 160 mph on infrastructure that can support such speeds. This case examines the highest density operations with only Tier III equipment intermixed with freight and conventional Tier I (commuter) equipment on the NEC.
- *A Regulatory Null Case:* This case is used to compare other future operations with higher traffic densities using Tier III equipment, assuming use of Tier II equipment and full implementation of

current (September 2014) safety regulations. Specifically, this means implementation of PTC (ACSES + ATC) throughout the NEC and for all main track operation.

- *Risk Mitigation Cases:* Multiple analyses of the All Tier III cases after implementation of selected risk mitigation measures. These cases examine Amtrak's ability to close the safety gap that may exist associated with operation of Tier III versus Tier II equipment on select NEC high speed zones.
- *Sensitivity Cases:* Multiple analyses of the All Tier III case after varying selected model inputs to assess the sensitivity of model results to variations in inputs. These cases examine the impact of significant increases in freight and/or commuter traffic in addition to introduction of Tier III train sets as well as other infrastructure or operational factors that impact system risk.

The baseline level of performance for each analysis case was taken to be a hypothetical condition where Tier II equipment would be used for the traffic mix and density investigated. This allows then for the direct comparison between the trainset designs and estimated risk taken as normalized accidents *per million train miles* and normalized injuries to passengers on passenger trains *per million train miles*.

## 3.0 Format of Results

The risk metrics chosen for basis of comparison of the two equipment types are:

- Normalized accidents *per million train miles* and
- Normalized injuries to passengers on passenger trains *per million train miles*.

Figure 1-1 is a template for how the results are presented. The accident rates are normalized by the total traffic over all the high-speed zones for each analysis case. The severity levels are presented in percentages and the sum of all 4 levels should equate to 100%. The estimated consequences are reported *per million train miles* and the damage is in $1,000 increments.

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| Analysis Case Results | | | | | | | |
| All Zones Normalized | | | | | | | |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | % | % | % | % | | | ($k) |

**Figure 1-1. Normalized Risk Presentation of Results**

Based upon the results shown in Figure 1-1 it is possible to compare the normalized accident rates between different equipment types across the complete NEC spine for an analysis case. The percentage traffic by equipment type helps understand which trainsets type contributes most to overall traffic densities across the corridor. It is possible to compare the total normalized accident rate from one analysis case against another to understand changes in potential accident occurrence. If the accident rate drops for an analysis case then whatever input parameter was modified for that case has a positive benefit to passengers on the NEC.

Comparison of Severity Level *per million train miles* is helpful to understand if introduction of one trainset type versus another has an impact on not just the number of predicted accidents but also whether the accidents will be more serious in nature. The other critical result that can be used for basis of comparing different analysis cases is the estimated consequences *per million train miles*. FRA is interested in the safety afforded the traveling Public when riding different passenger rail services therefore the Risk Focus Group focused on the projected injuries *per million train miles* as the parameter that had to be better than the baseline analysis by some margin to deal with the uncertainty associated with the inputs in the risk model. Using these risk metrics provides the basis to make informed technical decisions.

## Attachment 2

## Accident Analysis – Basis for Establishing Categories of Incidents of Concern

### 1.0 Roadmap for Historical Accident Analysis

The Accident Analysis text below includes reference to several past accident datasets obtained from the FRA Railroad Accident/Incident Reporting System (RAIRS) that were analyzed in different ways. Because there were several such analyses, a roadmap of the analyses is included for clarity. Figure 2-1 provides a means of keeping track and understanding how each individual analysis contributed to understanding the safety performance of the Northeast Corridor (NEC). In all cases, the analysis period was the 13 years 2000-2012 inclusive.

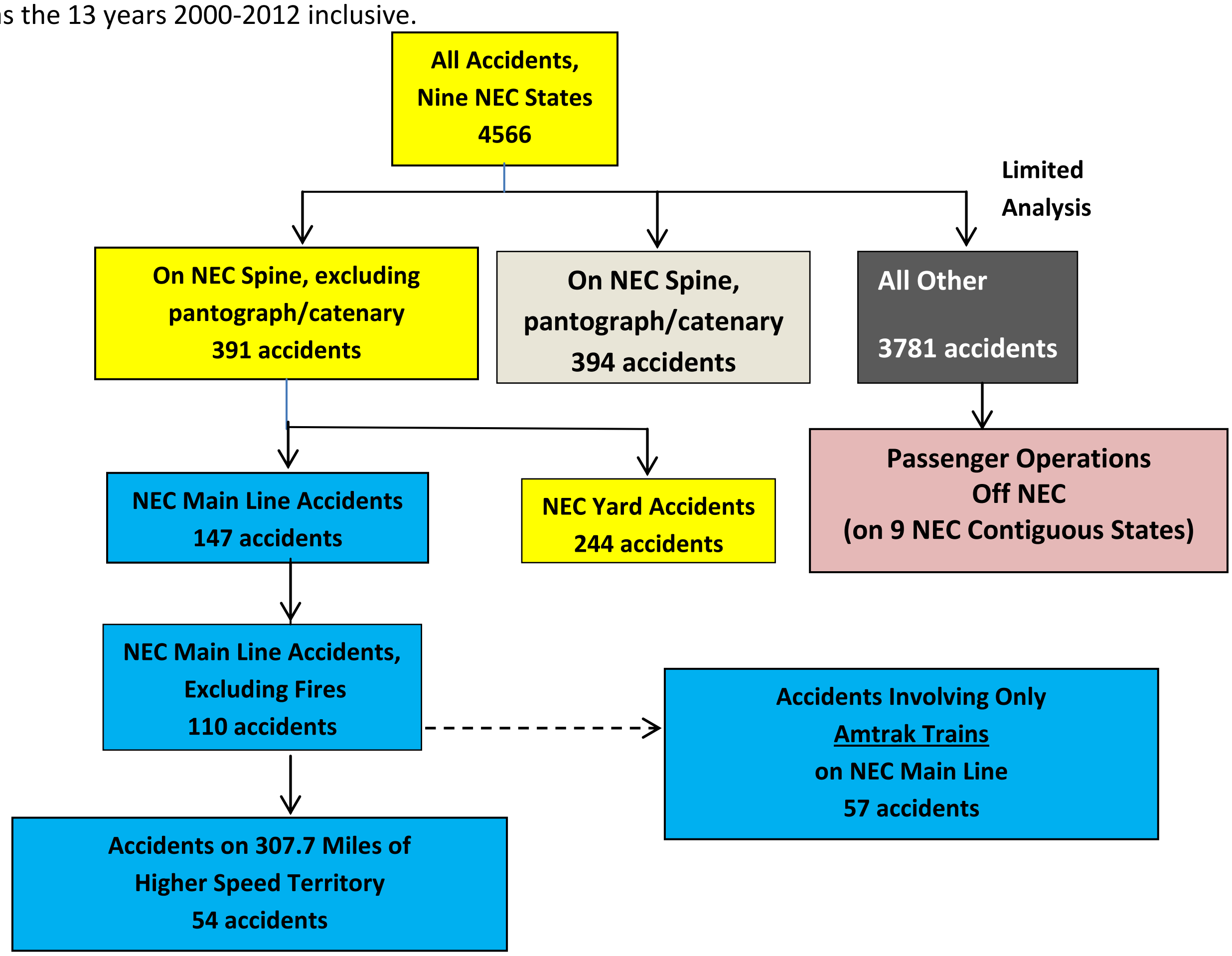


**Figure 2-1. Roadmap of Accident Analyses**

The diagram shows the flow of data from the largest data set that includes all accidents in the nine NEC states. Then the chart shows the flow of data as successive filters were applied to identify selected subsets of these data needed for analysis of NEC safety performance. The light grey box represents pantograph/catenary incidents. These are generally considered reliability rather than safety issues;

however each incident was analyzed to confirm that no serious injuries or fatalities resulted from this class of accident, and hence they were removed from further consideration. The dark grey box contains incidents determined to be off the NEC and hence not analyzed. The yellow boxes are intermediate steps in the filtering that were not analyzed in detail. The blue boxes identify data sets that were analyzed in detail as summarized below. Note that the dataset analyzed for the 54 accidents in the mainline running areas versus the 57 Amtrak only accidents was the same, but different analyses were conducted and the two accident types do not sum to the total from the parent dataset. A final dataset was analyzed of passenger operations from off the NEC in the 9 contiguous states abutting the NEC Spine.

- The initial analysis of accidents by type and speed were performed on 147 accidents, being all accidents confirmed to have taken place on the NEC main track.
- The 147 accident data set was reduced to 110 accidents by excluding all fire and explosion events. This accident type was a characteristic of particular older equipment types operating on the NEC and was unrelated to train speed. These accidents are not expected to be applicable to the safety performance of new Tier III train sets.
- Two sets of analyses were conducted on the 110 accident data set:
  - The first subset of 54 accidents analyzed occurred on higher speed territory, primarily to support derivation of accident frequencies for application in the risk model. This data set excluded lower speed accidents in passenger stations and terminals and in Metro North territory, which are not representative of high speed operations.
  - A second filtered subset of 57 accidents analyzed occurred to Amtrak passenger trains operating on the corridor. This analysis was conducted to investigate differences between the mix of accidents that Amtrak trains experience when compared with all the other train types.
- Finally, an analysis of a much larger set of accidents to passenger trains operating off the NEC, was conducted to investigate differences in accident types, causes of accidents and the mix of accidents with those involving only Amtrak and other passenger trains on the NEC. The intention is to extrapolate off-Corridor accident histories to better understand more the distribution of more severe events.

  The following paragraphs describe the filtering process and the accident analyses in more detail.

## 2.0 Establishment of Risk Focus Group

The Amtrak Risk Focus Group was established comprising members for critical internal Amtrak stakeholders as well as supporting consultants and with participation from technical staff from the Federal Railroad Administration Office of Safety. Participants included subject matter experts (SME) in track and infrastructure, signaling, operations, rolling stock design as well as inspection, testing and maintenance and safety officers. The Risk Focus Group worked collaboratively to review information contained within previous studies and investigations conducted by Amtrak as well as a fresh review of the publically available accident statistics maintained by FRA in the Railroad Accident Incident Reporting

System (RIARS)[3]. The purpose of the accident review was to establish categories of accidents for input into the comparative semi-quantitative risk model.

The Risk Focus Group started with a review of the information contained in the original risk assessment[4] conducted to determine if the operation of the Acela Express Tier II equipment on the NEC at speeds up to 150 mph in mixed passenger and freight service would be safe. Next, the Risk Focus Group conducted a detailed review of the Preliminary Hazard Analysis (PHA) conducted to support a Waiver Petition for increased operational speeds of the Acela Express Tier II equipment at specific high speed zones on the NEC at speeds up to 160 mph[5]. This second effort involved engagement with a number of internal stakeholders to define as many hazards based upon past experience, close calls and anecdotal information gathered from other operators both domestically as well as internationally. The PHA focused on train specific characteristics and impact on infrastructure, signaling and operational practices associated with an increase in maximum speed from 150 mph to 160 mph.

## 3.0 Historical Accident Review – Based Upon RAIRS Database

Amtrak initially reviewed reported train accident data for the NEC spine over the period 2000-2012. The year 2000 was selected because it was the initial year for Acela service. The year 2012 was selected because it was the last full year for which data were available at the time the review commenced. Any accident that was FRA reportable in this timeframe on the spine of the NEC was examined with special emphasis on passenger train incidents. Where multiple reports were filed for an individual accident, all of the relevant reports were retrieved and examined. Accidents reported in the 9 states through which the NEC runs were filtered from the master RAIRS database. Any accidents that occurred after 2012 were reviewed for pertinent information to ensure that major hazards were not missed. The Risk Focus Group considered a 13 year time frame long enough to contain a sufficient number of incidents to establish generalized categories of accidents of concern in conjunction with the previously described efforts.

A total of 4566 accidents remained after the first filter was applied to the master dataset to include only accidents that occurred within the contiguous states through which the NEC winds-between Boston, MA through New York City, NY on to Washington, DC. Next a detailed review of the RAIRS data was conducted to remove accidents by comparison of the accident information with Track

[3] Original Federal Railroad Incident Accident Reporting System files downloaded September 19, 2013
[4] Northeast Corridor Risk Assessment, Final Report to Amtrak and the Federal Railroad Administration, Prepared by Arthur D. Little, August 26, 1994
[5] National Railroad Passenger Corporation Waiver Petition submittal to the Docket Clerk on October 9, 2013 requesting that FRA permanently waive certain provisions of Chapter II, subtitle B, title 49 Code of Federal Regulations, and identified provisions of the Advanced Civil Speed Enforcement System (ACSES) Final Order of Particular Applicability issued on July 22, 1998 [FRA Docket No. 87-2, Notice No.7], to permit operation of Acela trainsets at speeds up to 160 miles per hour (mph) in a limited territory where operations are presently conducted at 150 mph.

Charts, Division, County and Station names. Only accidents listed with a Joint CD of 1[6] were listed in the dataset to ensure that double counting of accidents would not happen. Duplicate accident files were kept to use as a reference source for additional accident information. This process reduced the total number of accidents in the timeframe down to a manageable size. It was determined that 3781 accidents were off the NEC spine. A total of 785 accidents were left that were considered to be on the NEC spine and required further review.

***Pantograph/Catenary Events***

Details in the narrative fields were used to determine if accidents were attributable to pantograph or catenary accidents. The Risk Focus Group determined that pantograph/catenary events, although common, tended to be more of a reliability concern than a safety concern. None of the events led to serious casualty[7]. A total of 394 accidents were pantograph or catenary related and removed from the dataset used for further analyses.

***Distribution of Accidents by RAIRS "Type"***

The residual 391 accidents of interest were filtered to better understand the distribution of unique accidents by RAIRS "TYPE". A RAIRS "TYPE" distribution of accidents provides a means to better understand the categories of accidents or hazards that occur and should be considered within the risk model. The RAIRS "TYPE" parameter is broken into 13 distinct accident descriptions. The distribution of accidents by TYPE follows patterns seen from previous studies with many derailments, some train-to-train collisions (head-on, rear-end, side, raking and broken trains), grade crossings (both highway and rail), obstruction collisions, and explosions, fires and other impacts and others. A graphical depiction of the distribution of incidents by RAIRS TYPE and year is shown in Figure 2-2.

The safety of the operation of intermixed freight, commuter traffic, and Amtrak regional and high speed service on the NEC is clearly demonstrated by the scarcity of accidents on a year by year basis for such a densely travelled corridor. This is a mature system with significant traffic. System safety is ensured by enforcement of strict operating rules and practices, proactive maintenance, inspection, testing and repair practices for both infrastructure and rolling stock and other factors such as a high-performance train control system. This information is very helpful at a high level to understand potential hazards on the NEC; however, further review of the data to develop refined categories of accidents for use in the risk model was warranted.

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[6] A Joint CD 1 means that the accident report is from the primary party involved. Multiple accident records are possible and for purposes of developing accident counts they must be separated to avoid double or triple counting a specific accident.

[7] The only pantograph/catenary event which involved an injury during the period was RAIRS # 060546, February 23, 2000, at Odenton, MD. An associated 6180.55a report indicated one employee injury for one day's lost time, due to a bruise or contusion to the elbow. This accident was attributed to the unexpected movement of the train.

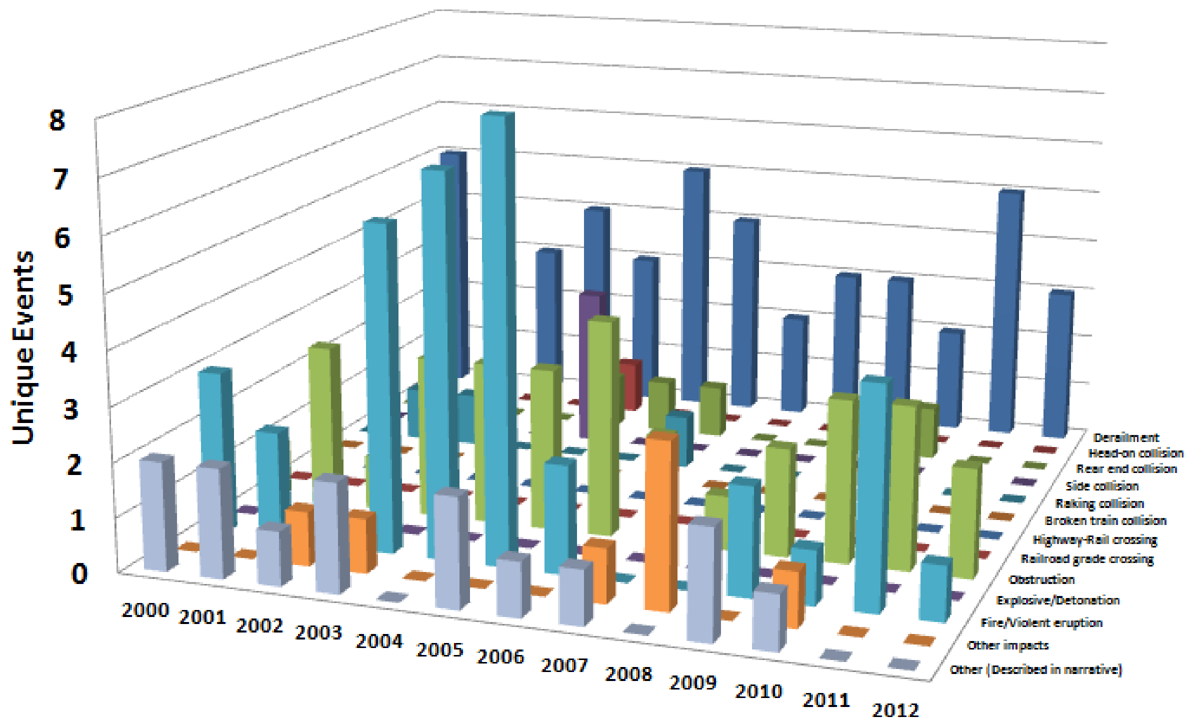



**Figure 2-2. Distribution of RAIRS Accidents by TYPE and Year**

***Exclusion of Yard Accidents***

The residual accidents were further filtered by type of track on which the accident occurred. Yard accidents were removed, because these types of events and the infrastructure conditions in yards are not considered typical of risks present in high-speed zones. Yard accidents tend to occur at lower speeds and are low energy events. A generic Tier III trainset is assumed to have adequate crashworthiness performance, as good as or better than conventional Tier I equipment under prescribed collision conditions. Additionally, the Risk Focus Group determined that yard accidents occur at locations far enough from main tracks so as to not pose any risk to the high speed operations. There were a total of 244 accidents that occurred in yards.

***Mainline, Siding and Industrial Spur Track***

The group decided that the accident analysis should focus on those accidents that occur on the mainline or entry/exit points to the corridor, which are representative of the proposed Tier III high-speed operation under consideration. After removal of the yard accidents, 147 accidents are left in the residual dataset of interest.  The breakdown of accidents by type of track is:

- 141 accidents occurred on the mainline and
- 6 accidents occurred at sidings or spurs.

There are roughly 10 mainline accidents per year. There are approximately 0.46 accidents per year on sidings and/or spurs.

The Risk Focus Group met several times to review the details of these accidents (by reading the narratives and other salient information contained in the relevant RAIRS reports) and help in the categorization of accidents into specific accident types for use in the risk model. The accidents were further parsed into groupings by cause codes and train set speed bins to better understand what types of events have occurred on the NEC and their contributing causes. Figure 2-3 depicts the distribution of accidents by RAIRS Cause Code in the 13 year timeframe investigated. The information in Figure 2-3 provides direction of where to focus attention in a risk reduction program. However further refinement of incidents into hazard categories is required for use as input into the comparative semi-quantitative risk model.

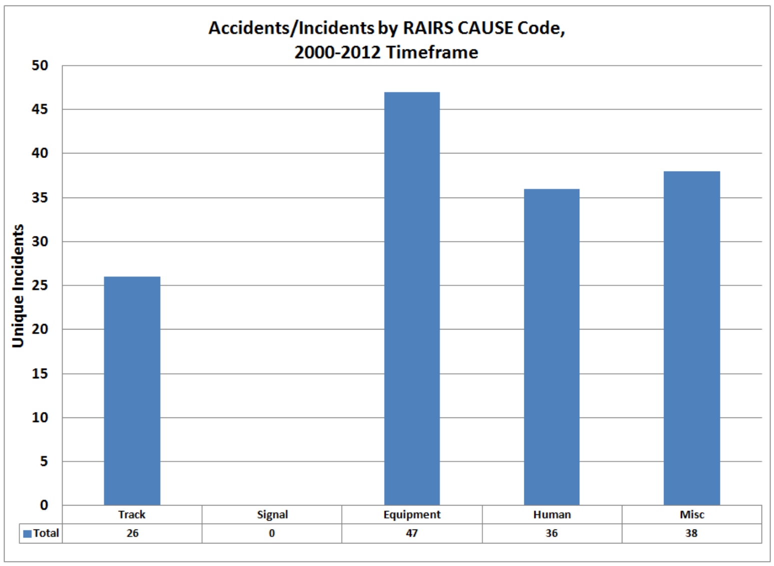



**Figure 2-3. Distribution of RAIRS Incidents by Cause Code**

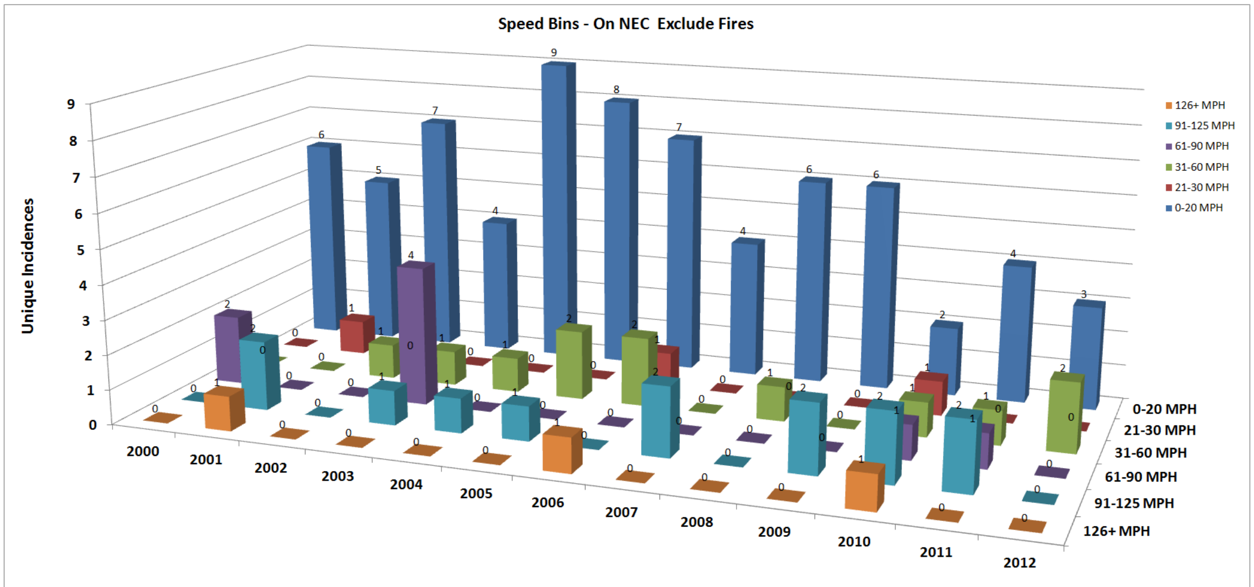
***Exclusion of Fire Accidents***

After careful consideration, the Risk Focus Group decided that inclusion of fires as an accident type in the risk model was not warranted – as the typical causes for these types of accidents are not a concern for this class of equipment. Fires can be very severe events. Fires can cause significant vehicle damage, but there have been no serious injuries or fatalities associated with this hazard type to occupants of train sets in the timeframe analyzed. Further, fires are not speed dependent events, and thus are not relevant to the safety impacts of a speed increase. When fires are removed from the dataset a total of 110 accidents are left. The Risk Focus Group focused on this subset of accidents to develop more detailed categories of hazards for inclusion in the risk model.

***Distribution by Speed of Accidents***

Next the Risk Focus Group developed information associated with distribution of accidents from this smaller set of relevant accidents by speed bins. A complementary approach to system safety includes improving collision avoidance technologies to prevent higher energy events from occurring and utilizing crashworthiness for lower energy events. The purpose of this analysis was to better understand what magnitudes of speeds are observed for collisions on the NEC.

Figure 2-4 provides the distribution of RAIRS accidents on the NEC broken down into speed bins. Of the 110 accidents included in the analysis, the vast majority (71) occur in the speed bin 0-20 mph. There were 3 accidents that occurred in the speed bin 21-30 mph. A total of 36 accidents occurred at speeds in excess of 31 mph and would be considered higher energy events. Some of the highest energy events were obstructions with small objects within the right of way (ROW) such as Acela striking a large male deer in 2001, or an Amtrak Regional train striking a fence in 2006 which caused very minor damage to the train. It is important to note that approximately one-third of the incidents involved higher speeds and a large percentage of those involved impacts with objects.




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 126+ MPH | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 91-125 MPH | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 2 | 0 | 2 | 2 | 2 | 0 |
| 61-90 MPH | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 31-60 MPH | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 0 | 1 | 0 | 1 | 1 | 2 |
| 21-30 MPH | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0-20 MPH | 6 | 5 | 7 | 4 | 9 | 8 | 7 | 4 | 6 | 6 | 2 | 4 | 3 |

**Figure 2-4. Distribution of RAIRS Accidents on NEC by Speed Bins (excluding pantograph or catenary, yard and fire incidents)**

***Hazard Categories for Inclusion in Risk Model***

The Risk Focus Group decided to categorize the residual accidents into the following classes of accidents based upon the results from previous risk assessments, hazard analyses, and review of international and domestic accident histories and hazards:

- Train-to-Train Collisions
    - Train-to-train collisions on the same track.
    - "Sideswipe" train-to-train collisions between trains on adjacent tracks (reported as accident type 2 in the FRA accident report.

- Secondary collisions where a train collides with another moving or stationary train on an adjacent track after an initial accident fouls the adjacent track. This type of accident is usually reported to FRA under the cause of the original accident. Note there were no accidents of this type in the 2000-2012 timeframe, but there was an accident on the NEC at Bridgeport, CT that involved a secondary collision after a derailment in 2013.

- Derailments
    - Derailment due to a track defect.
    - Derailment due to an equipment defect.
    - Derailment having a human factors cause.
- Obstruction Collisions – a collision with an object that is not a train operating on the same or an adjacent track.

Figure 2-5 depicts the distribution of accidents into these new categories using the residual filtered dataset (110 accidents). It should be noted that train-to-train collisions include activity between MOW vehicles as well as all other passenger and freight equipment operating on the NEC. It becomes apparent upon inspection of Figure 2-5 that the largest category includes obstruction collisions, which comprise approximately half of all reported accidents on the NEC after the exclusion of pantograph/catenary, fires and yard events.

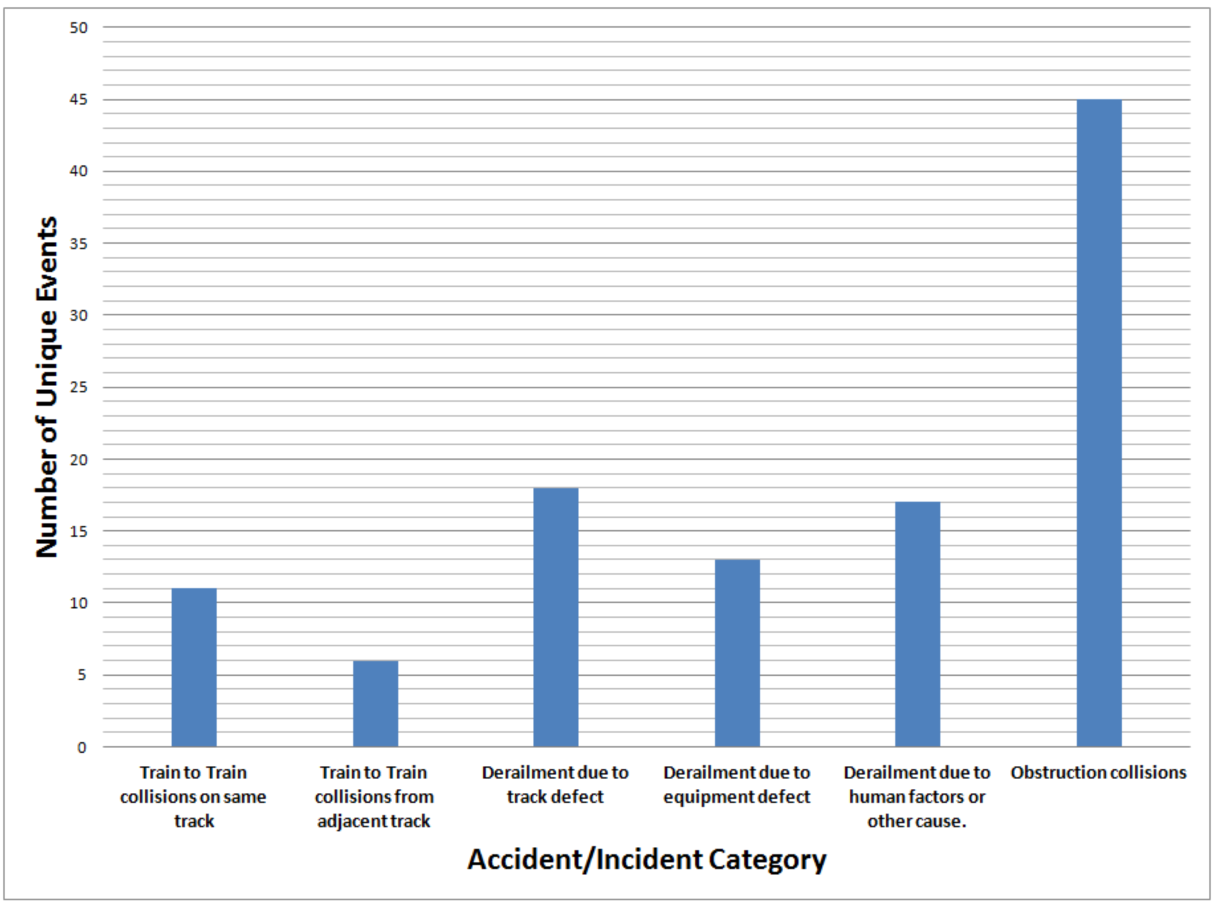



**Figure 2-5. Distribution of Accidents by Newly Defined Categories**

The Risk Focus Group decided it is important to differentiate between incidents that may occur at stations and/or lower speed operation locations from the higher speed segments of interest. Operation of equipment at lower speeds under different track conditions seen in stations and terminals is not representative of higher speed operations and track maintenance practices. The safety case being developed for Tier III equipment seeks to compare differences in high speed operation of the two trainset types (Tier II versus Tier III) in high speed operation. The dataset was therefore further filtered to include only incidents that historically occurred in areas where mainline operations exceed 80 mph. This resulted in a total of 54 accidents on 307.7 miles of higher speed operations.

Figure 2-6 depicts the breakdown of accidents in these higher speed areas on the NEC spine.

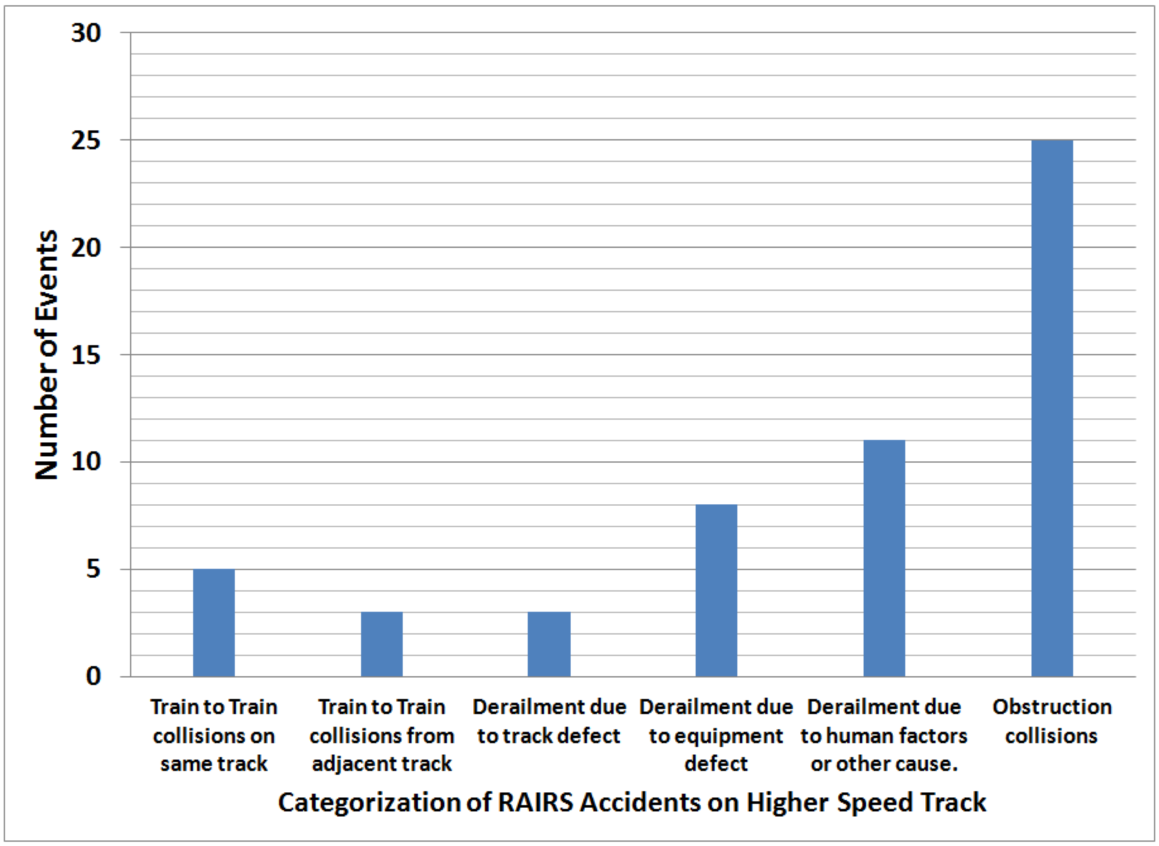



**Figure 2-6. Refined Analysis of Dataset in High Speed Areas – Breakdown of Accidents by New Categories**

**Train-to-Train Collisions**

*Train-to-train collisions on the same track*

Only one of these events involved a collision of a passenger train with a run-away freight car near Canton, MA. The remaining four accidents involved collisions between on-train maintenance equipment, probably in work zones, but only one of the four was reported as being in a work zone. It is noteworthy that all these accidents occurred in high-speed zones, where speeds may exceed 125 mph in the future.

*Sideswipe and side collisions*

There were three accidents in the database that were side or sideswipe collisions. Of the six trains involved in these accidents, three were passenger trains that sideswiped or were sideswiped by equipment with defective laterally-opening doors. One unsecured/defective door was on a NS locomotive and the remaining collisions involving two trains were freight trains or cuts of cars operating on a freight-only side track. It is not clear whether or not this last accident was near enough to possibly obstruct a NEC main track and risk causing a secondary collision.

**Derailment Accidents**

Derailment accidents have been classified into three groups by cause, as follows:

- Track defects
- Mechanical defects
- Human factors errors and miscellaneous

The paragraphs below discuss each group.

*Derailment accidents caused by track defects*

Only three accidents on the higher speed main line were caused by track defects. Only one of which involved a passenger train. The other two events occurred during MOW activities and may have been limited to within a work zone.

*Derailment accidents caused by mechanical defects*

There were eight derailments caused by mechanical defects of either freight or passenger cars, or locomotives. The description that follows is with respect to individual trains involved in a derailment. Of these eight accidents, six involved freight trains, one involved Amtrak work equipment with work zone authority and two involved passenger trains – one NJT and one Amtrak. All are assumed to be linear risks that could have occurred anywhere on the NEC, and are not associated with a defined point risk location, such as an interlocking or an access spur.

*Derailment accidents having human factors or miscellaneous causes*

There were a total of 11 derailment accidents in this category. Several appear to be point risks that occurred at an interlocking or at an access spur and not on the mainline. These data will be used to estimate point risk accident frequencies.

The breakdown of the accidents is:

- There were 5 accidents at freight or passenger spurs, three of which involved freight trains and two involved passenger movements at passenger maintenance and servicing facilities. Two of the freight accidents, but neither of the passenger accidents, may have obstructed a main track.
- There were 5 accidents at interlockings, three involving passenger trains, one involving a freight train and one accident involving MOW equipment. All three passenger trains appeared to be in regular passenger service.
- One linear risk accident involved MOW equipment.

These accidents are so diverse it is difficult to draw any clear conclusions as to cause, but a good safety culture and an effective system safety program is important in minimizing accident occurrence.

**Obstruction Collisions**

There were a total of 25 obstruction collisions. Of the 25 collisions 8 involved impacts with highway vehicles away from grade crossings, deliberate acts from trespasser and/or vandals. Five of the accidents were described as "struck debris" without other useful indication as to what the debris was. Two collisions were associated with impacts with a boulder and a large male deer. The last 10 incidents involve MOW activities or impacts with objects due to the passage of other trains or loose panels/doors on the train involved.

Because of the high involvement of MOW or contractor equipment in these accidents (for train-to-train collisions in addition to the obstruction collisions), a brief review of obstruction collisions was carried out. This showed that approximately six obstruction accidents involved MOW equipment or materials being handled by such equipment in the train-to-train events. In five out of the six cases, a passenger train struck the obstructing equipment.

Given this high involvement in accidents, it is clear that improving the safety of MOW activities and the operation of MOW equipment must be a leading candidate for risk mitigation. It is also a question of how best to use the risk model to evaluate this risk and proposed mitigation measures.

To address this question, an alternative analysis of obstruction collisions was performed, in which obstruction accidents were divided into three groups:

- Following from unauthorized access to the ROW (roughly 30%)
- Due to MOW and contractor activities on the ROW, or unsecured objects for which Amtrak was responsible (roughly 50%)
- Other, such as animals on the ROW and fallen trees and boulders (roughly20%)

Unauthorized access can be prevented or minimized by well-maintained fences and/or appropriate use of barriers at high risk locations. Attention to MOW safety procedures, a good system safety program and a good safety culture are appropriate responses to the other categories of obstruction collisions.

## 4.0 Accidents Involving Only Amtrak Trains

The Risk Focus Group investigated the performance of Amtrak only operations on the NEC spine. The previous set of results was inclusive of all operations on the NEC spine including freight, commuter, Amtrak regional as well as Amtrak Acela Express. It was important to determine if the trends obtained from the larger dataset are representative of Amtrak only operations as this can help guide the types of mitigations that can be used to offset the risk of operating a different class of equipment in the unique environment that makes up the NEC.

As depicted in Figure 2-7 below, the service history over the timeframe investigated has been very safe with few accidents (57 accidents including the 12 fires not included on the chart). The breakdown of mainline versus siding accidents is: 55 accidents occurred on the mainline and only 2 were recorded as a siding event. Several of the categories have no representative examples in accident history to date, for example there have been no head-on train-to-train, raking, broken train collisions or train accident events at highway or rail grade crossings. The largest contributor to the number of unique events has to do with obstruction collision or other impacts. The next largest contributor to the overall total is associated with fires (12) but because fires are not considered as part of the hazard categories needed for the risk model they have been removed from Figure 2-7. Derailments comprise the third largest category in the history.

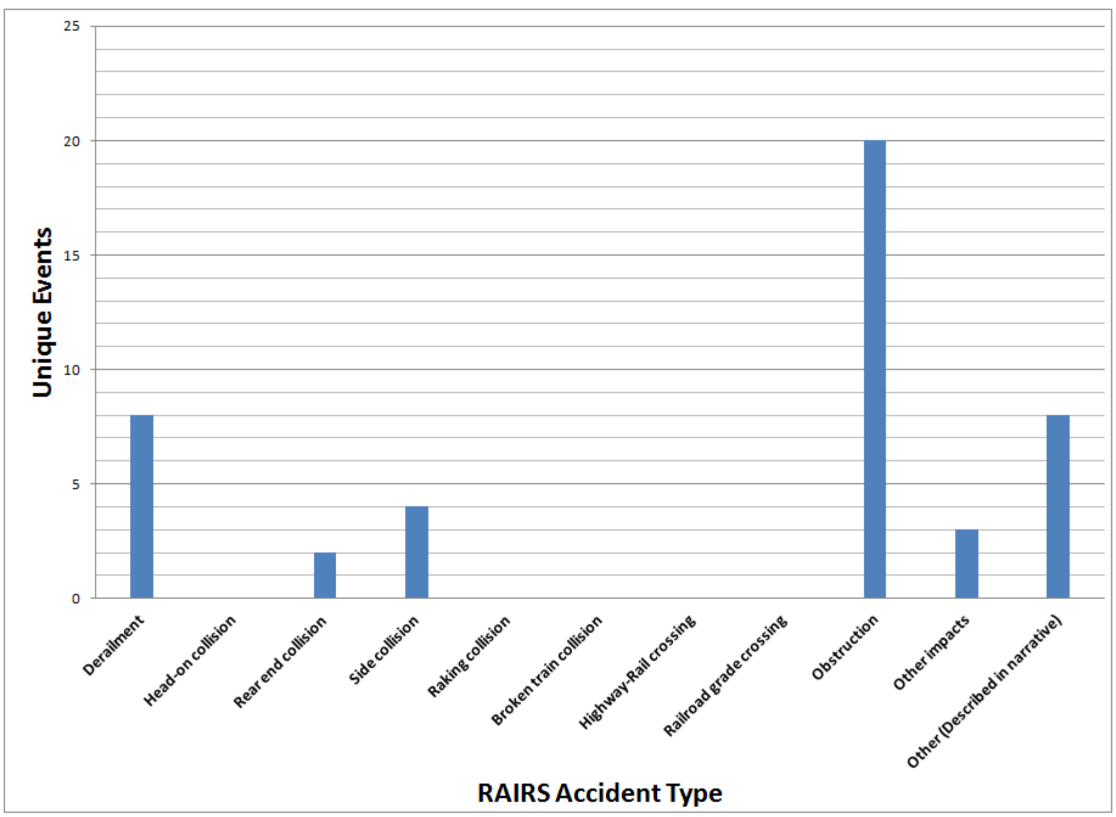



**Figure 2-7. RAIRS Accident Distribution for Amtrak Equipment from 2000-2012, Excluding Fires**

The breakdown of Amtrak only accidents, by cause code, is as follows:

- 11 track, no signal,
- 11 equipment,
- 11 human factor and
- 24 miscellaneous related accidents.

The breakdown of accidents by speed bin, similar to that described earlier for all equipment types, is depicted in Figure 2-8. Note that the three highest speed events included the impact with a large male deer in 2001, an impact with a fence from a door that swung out at speed in 2006 (note the speed was estimated in the high speed area and is above the allowable speed for the Regional trainset), and the last event involved a circuit breaker opening on the rear power car of an Acela train causing some damage but no injuries in 2007.

Similar to the pattern observed previously, the largest percentage of events (~50%) occur at the very lowest speeds where the crashworthiness design of the equipment is able to provide adequate protection to passengers and crewmembers. There are 28 incidents that occur below the crashworthy design speed of the equipment.

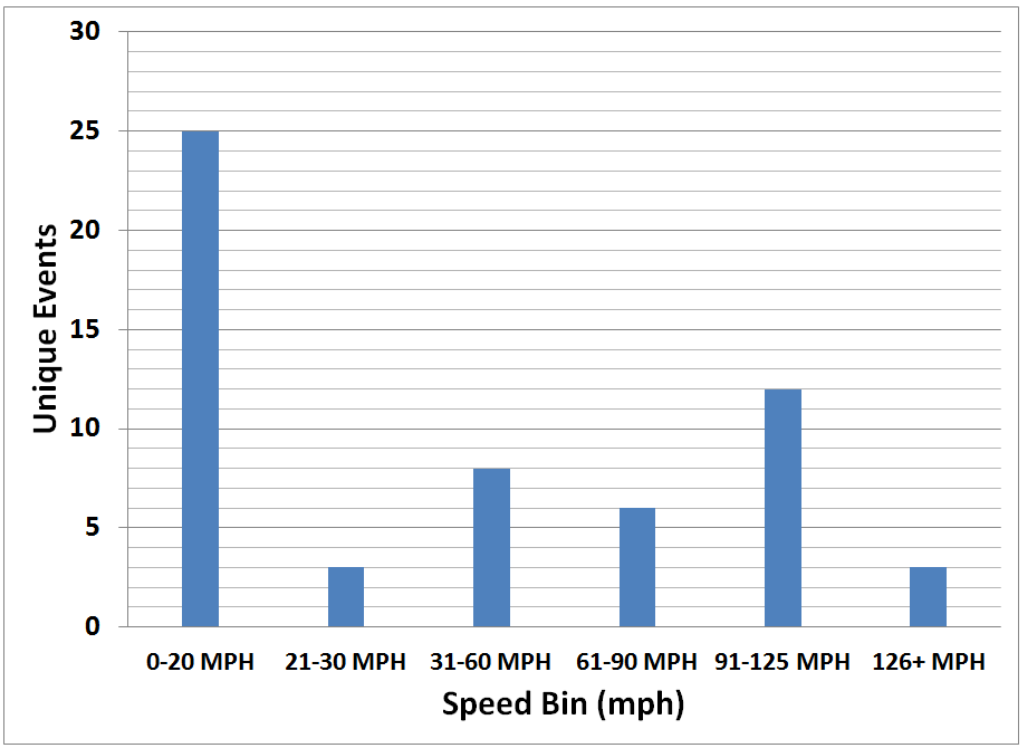



**Figure 2-8. Breakdown of Amtrak Accidents on the NEC, 2000-2012 (Excluding Fires)**

As noted previously, fires can be very severe events invoking significant vehicle damage, but there have not been injuries or fatalities associated with this hazard type to occupants of trainsets in the timeframe analyzed.  Further fires are not speed dependent events. When fires are removed from the dataset the final number of accidents of interest is 45.

The new breakdown of accidents when removing fires from consideration for purposes of categorizing incidents includes:

- 2 accidents between train-to-trains on the same track both below 20 mph;
- 4 accidents between train-to-trains from adjacent tracks with 3 of the 4 occurring below 20 mph and the last due to a door swinging out and impacting another train;
- 5 derailments due to track all below 30 mph;
- 1 derailment due to equipment defect below 20 mph;
- 2 derailments caused by human error also below 20 mph; and
- 26 obstruction collisions.

Note that the obstruction collisions are distributed within all speed bins and 16 occurred above 60 mph.

## 5.0 Summary

Review of the Amtrak only accident history over the timeframe investigated was helpful to understand that the distribution of events by the new categories developed for the larger dataset is appropriate. Understanding the distribution of events by hazard category is helpful to the risk model development. The information can be used to identify certain parameters that need to be accounted for in the risk model to replicate the past historical accident history and for projection into the future with the proposed operations.

One concern raised by the Risk Focus Group in analyzing the datasets available is that there are few accidents in each hazard category. This can potentially skew the results of the risk model. The risk analyst must be careful to weigh the fact that, just because something bad has not happened in a given dataset, does not mean that it cannot happen in the future. Therefore it is important to look at similar operations off the NEC to develop a better understanding of how distributions of accidents categorized in previous discussions change. The intention is to be able to leverage the knowledge gained from a larger dataset to help in the development of severity levels for each hazard category of accident for use in the risk model.

## 6.0 Off-NEC Accident History

In addition to the detailed review of accidents on the NEC spine the Risk Focus Group also decided to expand the historical accident review to off-corridor events to leverage the potential for more significant or severe events. The safety on the NEC has been excellent to date with no recorded fatalities and very few injuries on high-speed trains in the timeframe since the initiation of service. The Risk Focus Group was concerned that despite the excellent service history, it is possible that certain events that are probable have not occurred. Reliance on the existing dataset could skew the results in an un-conservative manner. To address this concern a similar historical accident analysis was conducted for passenger train operations in mixed service in the Northeast.

For these analyses the Risk Focus Group decided to keep the timeframe of interest the same – 2000-2012. Passenger train operations in the 9 contiguous states that abut the NEC spine were chosen. All but Long Island Railroad (LIRR) operations were included in the analysis and attention was paid to ensure that aspects of the operations that are not representative of the NEC were filtered from the dataset – such as exclusion of grade crossing accidents (RAIRS TYPE 7 accidents). Further, the Risk Focus Group only included accidents that occurred on mainline tracks or within sidings in the analysis. Care was taken to ensure that only those incidents with a Joint CD of 1 were included so as to not double count accident reports.

Figure 2-9 depicts a comparative chart of RAIRS accidents on and off the NEC in the timeframe of interest. Note that a similar pattern is apparent in the distribution of accidents. A total of 1105 accidents were included in the Off-NEC dataset. Derailments constitute the largest contributor to events followed by obstruction collisions.

***Exclusion of Fire Accidents***

Fires were treated in a similar manner as described in the previous write-up for NEC and Amtrak only events. Fires account for a large percentage of the damage experienced but typically there are few injuries associated with these events. Further the type of equipment that most often experience fires are not representative of the high speed equipment under consideration. After removal of fires from the dataset there are a total of 990 incidents. Note that there are relatively fewer derailments because of good track on the NEC. Off-corridor operations experience more obstruction collisions because the environment is not as well segregated from the Public. There are relatively similar numbers of collisions (of all kinds), but MOW equipment and freight are factors on the NEC.

***Distribution by Speed of Accidents***

Figure 2-10 depicts the distribution of events by speed bins. Note as expected there are no events occurring in the highest speed bins due to the lower class track that the equipment operates on. The largest percentage of accidents (63%) occurs at the lowest speed bin of 0 - 20 mph. An additional 15% of the events occur in the next speed bin of 21 – 30 mph. The breakdown of the accidents by the categories chosen for the purpose of input into the risk model is:

- Train-to-train accidents on the same track account for 5% of events,
- Train-to-train accidents from adjacent track account for 3% of events,
- Derailments due to track defects account for 33% of events,
- Derailment due to equipment defects account for 15%,
- Derailments due to human factors account for 27% of events and
- Obstruction collisions account for 17% of the events.

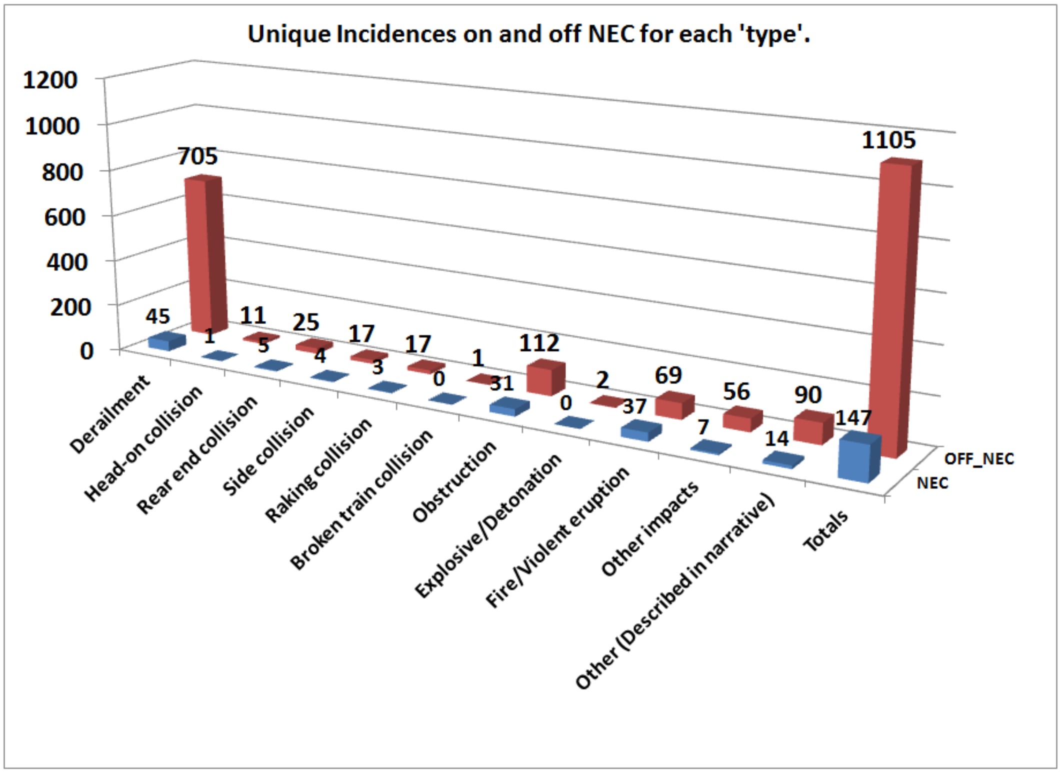
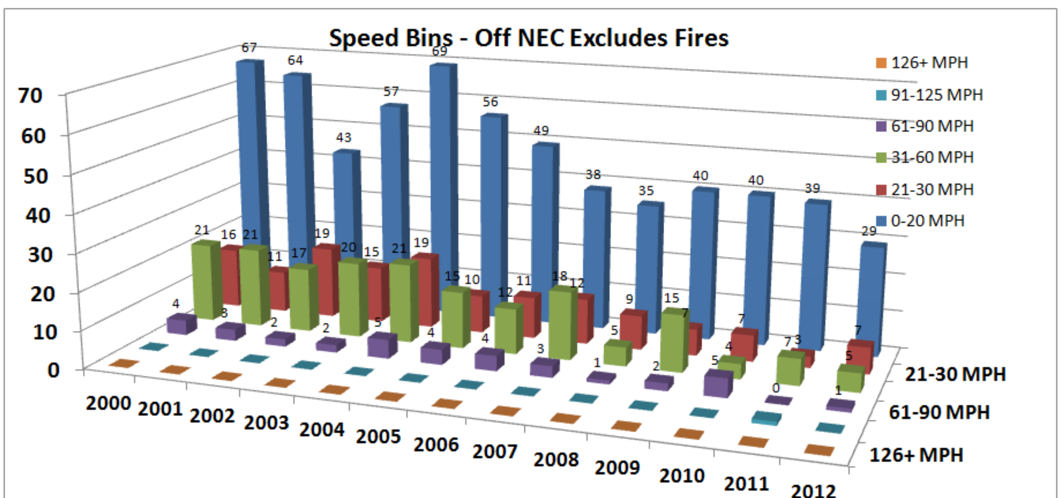



**Figure 2-9. Distribution of RAIRS Accident Type on and off the NEC, 2000-2012**




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 126+ MPH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 91-125 MPH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 61-90 MPH | 4 | 3 | 2 | 2 | 5 | 4 | 4 | 3 | 1 | 2 | 5 | 0 | 1 |
| 31-60 MPH | 21 | 21 | 17 | 20 | 21 | 15 | 12 | 18 | 5 | 15 | 4 | 7 | 5 |
| 21-30 MPH | 16 | 11 | 19 | 15 | 19 | 10 | 11 | 12 | 9 | 7 | 7 | 3 | 7 |
| 0-20 MPH | 67 | 64 | 43 | 57 | 69 | 56 | 49 | 38 | 35 | 40 | 40 | 39 | 29 |

**Figure 2-10. Distribution of Off-NEC Events by Speed**

## 7.0 Accident Consequences - Categorization by Severity Levels

The severity of accident consequences is difficult to evaluate in a passenger rail risk analysis. Severity for an individual accident has a large random element, depending on the specific circumstances of the accident, and it can be difficult to get any meaningful relationship between speed and severity from a sparse dataset. Also there are few data points at higher speeds and severities.

The approach applied by the Risk Focus Group was to define passenger train accident severity using four levels, as follows:

- Level 1, Minor: less than $50k damage, no casualties
- Level 2, Moderate: between $50k – $250k damage and less than 10 injuries
- Level 3, Serious: more than $250k – $1 million damage and more than 10 injuries or at least one fatality
- Level 4, Very Serious: more than $1 million damage and more than 50 injuries or more than 1 fatality

Given sufficient accident observations in the database, this approach can provide reasonable accident distribution metrics for a specific scenario and operating environment. The distribution is particularly useful in making a rough estimate of how many serious or very serious accidents could accompany a given number of less serious accidents. Also, data from past analysis of passenger train accidents may be helpful in providing accident severity distributions for different passenger service operating environments. This information can also be used to find out whether accident distributions vary by the kind of passenger operation or not. If there is some consistency among accident distributions (on and off-NEC), then it may be possible to estimate the frequency of more serious accidents when there are very sparse data. Supplementary data from engineering analyses or for accidents on other passenger rail operations may be particularly useful in estimating consequences vs. speed relationships and severity distributions.

**Average Severities at Each Level Based Upon NEC Dataset – All Traffic Types**

Applying the approach described above, the Risk Focus Group was able to develop averages for each of the severity levels described above for the events on the NEC. Table 2-1 depicts the values obtained from the 13 year time frame studied. Note that there have been no passenger or crewmember fatalities attributable to an accident on the NEC in the timeframe investigated. It would be non-conservative to assume that the past good experience cannot change in the future so a value for fatality was estimated based upon a larger review of historical accidents for the highest severity Level 4.

**Table 2-1. Average Severity Levels Experienced for NEC Operations between 2000 and 2012**

| Severity Levels | | Consequence Per Accident | | |
|---|---|---|---|---|
| Level | Definition | Injuries | Fatalities | Damage ($k) |
| 1 | Minor -less than $50k damage, no casualties | 0 | 0 | 18 |
| 2 | Moderate - greater than $50k - $250k damage, less than 10 injuries | 0 | 0 | 90 |
| 3 | Serious - greater than $250k - $1M damage, greater than 10 injuries, no fatalities | 3 | 0 | 500 |
| 4 | Very Serious - greater than $1M damage, greater than 50 injuries, more than one fatality | 3 | 0.04 | 2,000 |

The Risk Focus Group began the consequence analysis of incidents grouped into the categories defined from the previous work for the four severity levels defined in Table 2-1. Each of the following datasets was analyzed:

- Accidents on the NEC between 2000 and 2012 involving mixed freight, commuter, Amtrak Regional and Amtrak high speed service,
- Accidents only involving Amtrak service on the NEC in the same time period of interest, and
- Off-NEC operations that are similar to NEC operations to expand the potential number of incidents for purposes of extrapolating severities in the higher severity levels range that tend to be sparse given the excellent safety record on the NEC to date.

The distribution of consequences from historical accidents by severity on the NEC is shown in Figure 2-11. This dataset excludes accidents in yards, pantograph/catenary accidents, and fires.

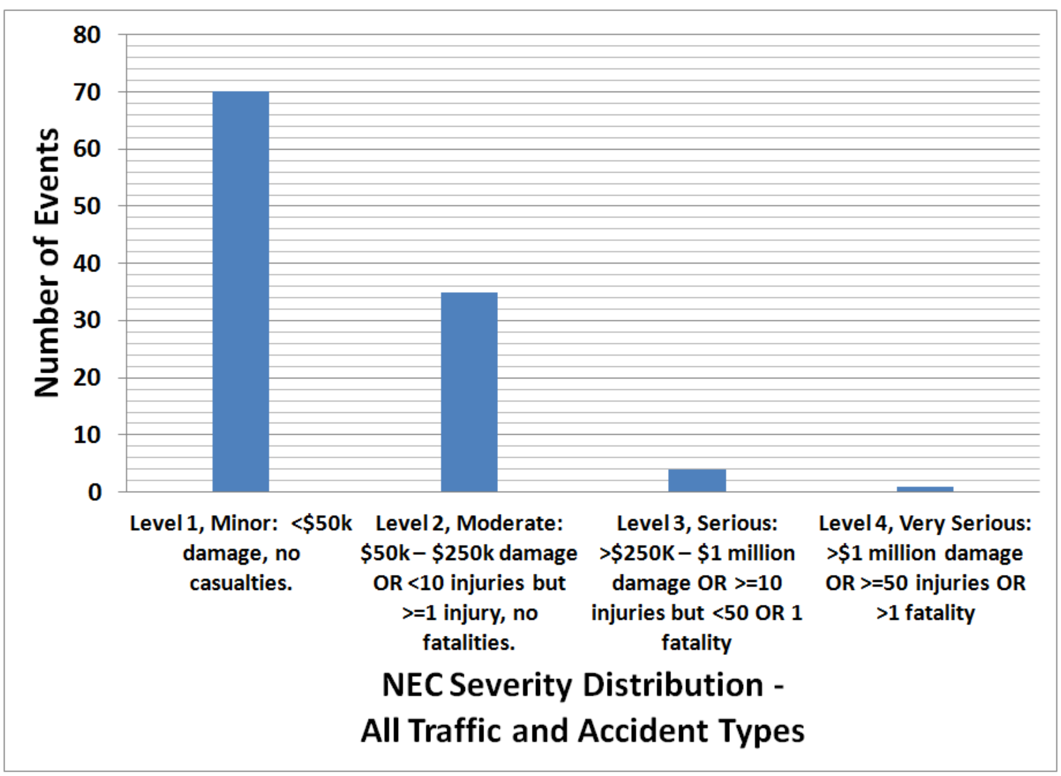



**Figure 2-11. Distribution by Severity Level of All Traffic and Accident Types on the NEC**

Another useful way to present the information is severity level by category of incident determined from the previous analysis. This is depicted in Figure 2-12. Note that there are very few Level 3 and 4 events. The largest category is obstruction collisions. Figure 2-12 represents all the accidents that have occurred whether in a high speed zone as defined above or in stations or other low speed areas.

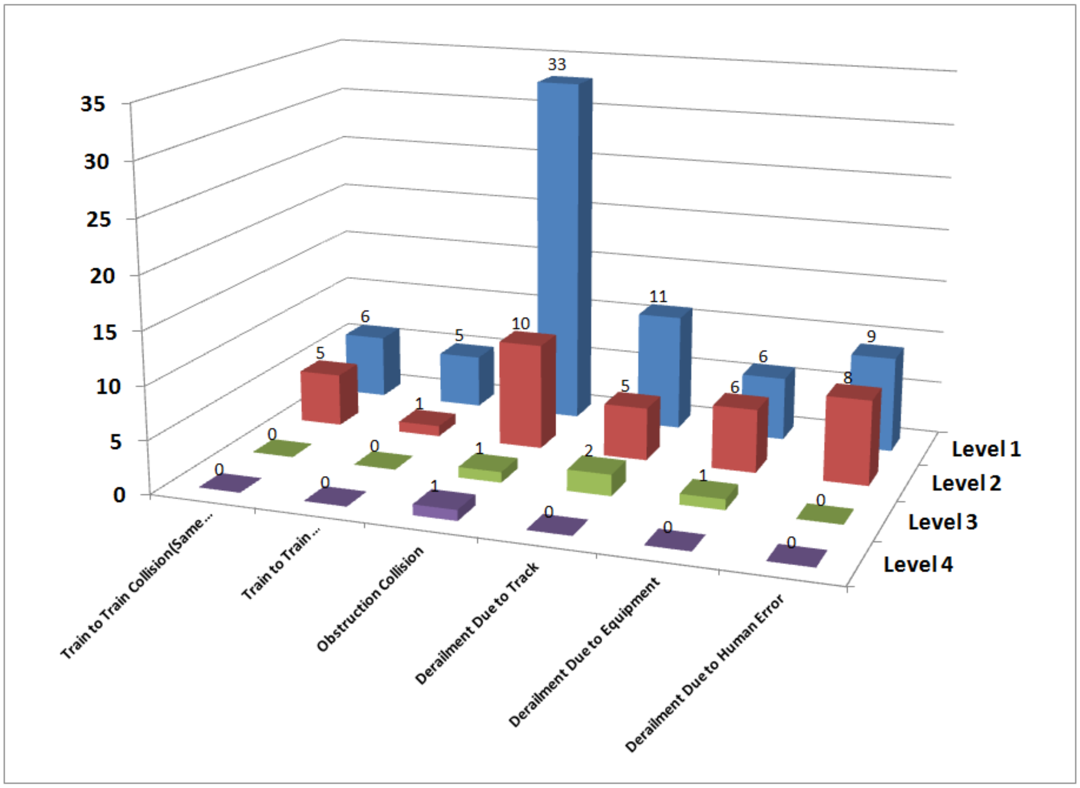



**Figure 2-12. Distribution of Severity Levels by Hazard Category – NEC All Traffic Types**

**Amtrak NEC Only - Severity Level Distribution**

A similar plot for distribution of severities for the Amtrak accidents that occurred on the NEC between 2000 and 2012 are depicted in Figure 2-13. The distribution excludes those incidents associated with yard accidents, pantograph/catenary events and fires. The distribution follows the pattern established for all traffic on the NEC for which Amtrak accounts for nearly 60%. Note again that there are few incidents that fall into the higher severity levels.

It is instructive to also provide the breakdown of accident by severity levels as shown in Figure 2-14. The pattern observed for all traffic on the NEC is preserved but there are even fewer observations for higher severity levels. This helps to demonstrate how effective the system safety has been to date. Similarly to previous observations, the obstruction class of accidents is large and should be addressed by risk mitigation measures.

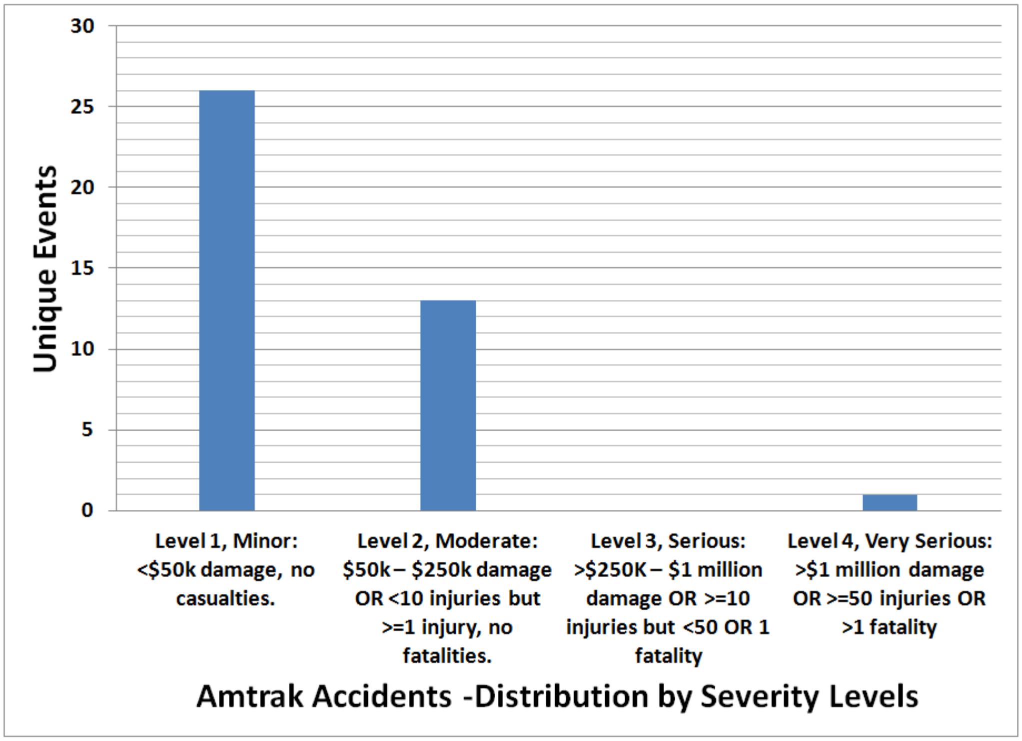



**Figure 2-13. Distribution by Severity Level for All Accident Types for Amtrak on the NEC**

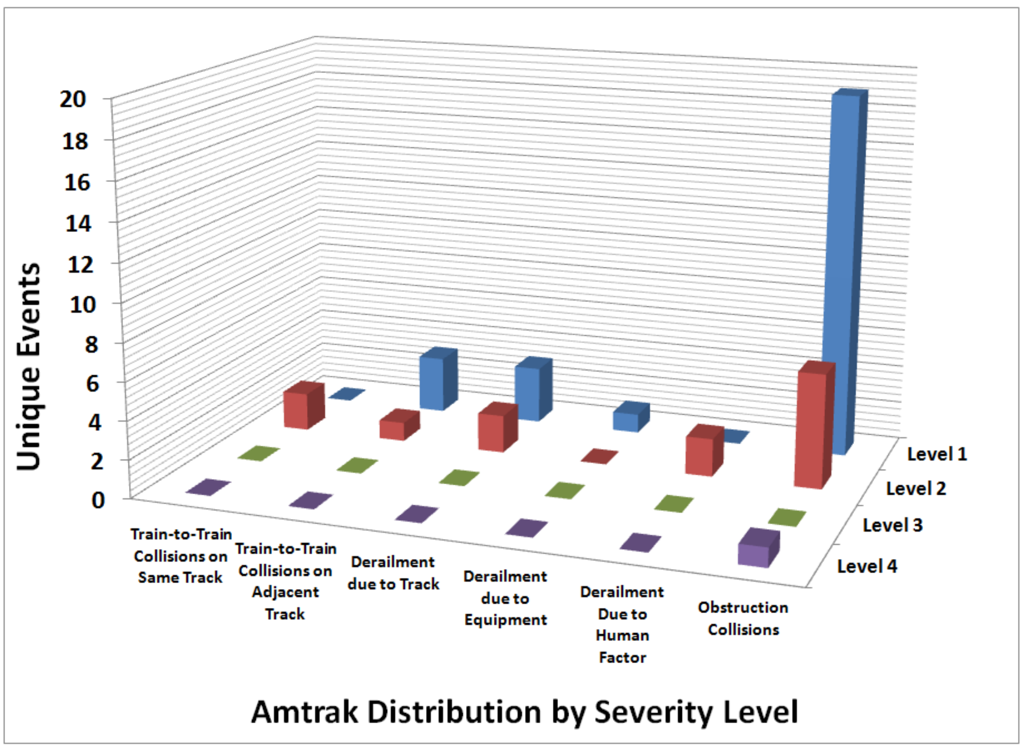



**Figure 2-14. Amtrak Distribution of Severity Levels by Accident Category on the NEC**

**Off-NEC Only - Severity Level Distribution**

Due to the sparse data for higher consequence events observed for the refined NEC and Amtrak datasets, the Risk Focus Group opted to expand the analysis to Off-NEC events that are filtered to be operationally similar to that on the NEC. The information from the larger data set will help to develop estimates for higher Severity Level events. This information is presented in Figure 2-15 and Figure 2-16. Severe train-to-train collisions, whether on the same track or on adjacent tracks, are sparse. The data suggests that for collisions with obstructions a significant portion of these events remain low level consequence but that higher level severities are possible. It is important to note that there is a significant difference in the traffic volume that operates at the higher speeds on the NEC which tends to make any event more significant. Traffic in the Off-NEC dataset tends to operate at a significantly reduced average speed and hence the obstruction distribution may underestimate the level of severity expected. Further because the amount of track and equipment inspections are less rigorous than those experienced on the NEC there is a larger percentage of the total accident set that are related to derailments.

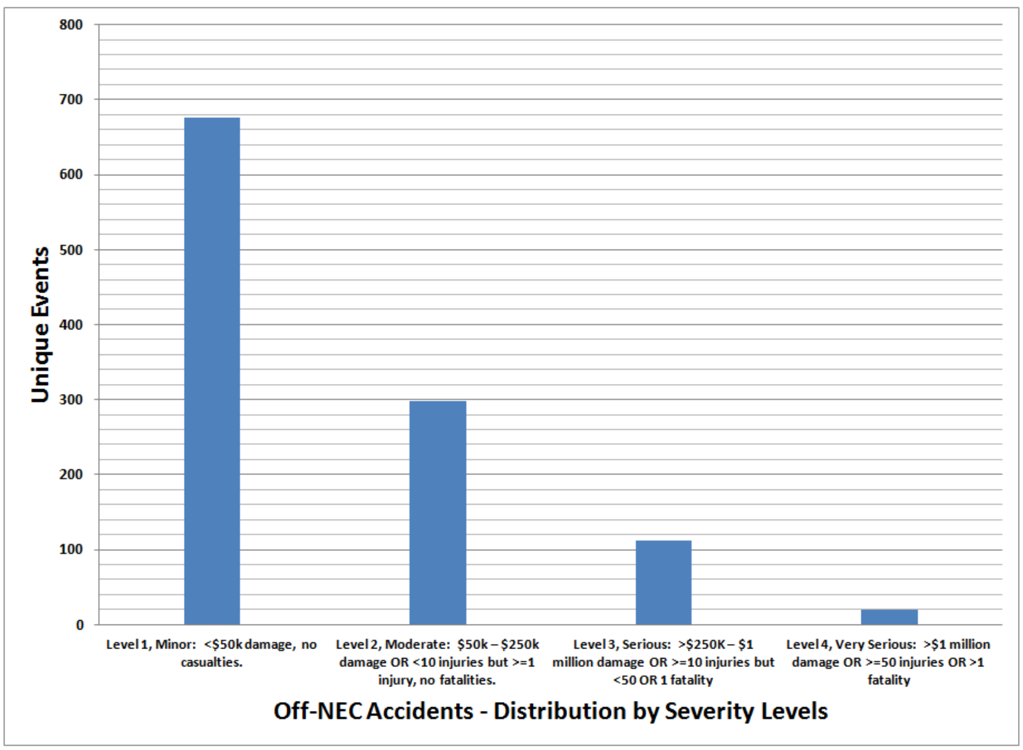



**Figure 2-15. Distribution of Severity Level for all Accident Types Off-NEC**

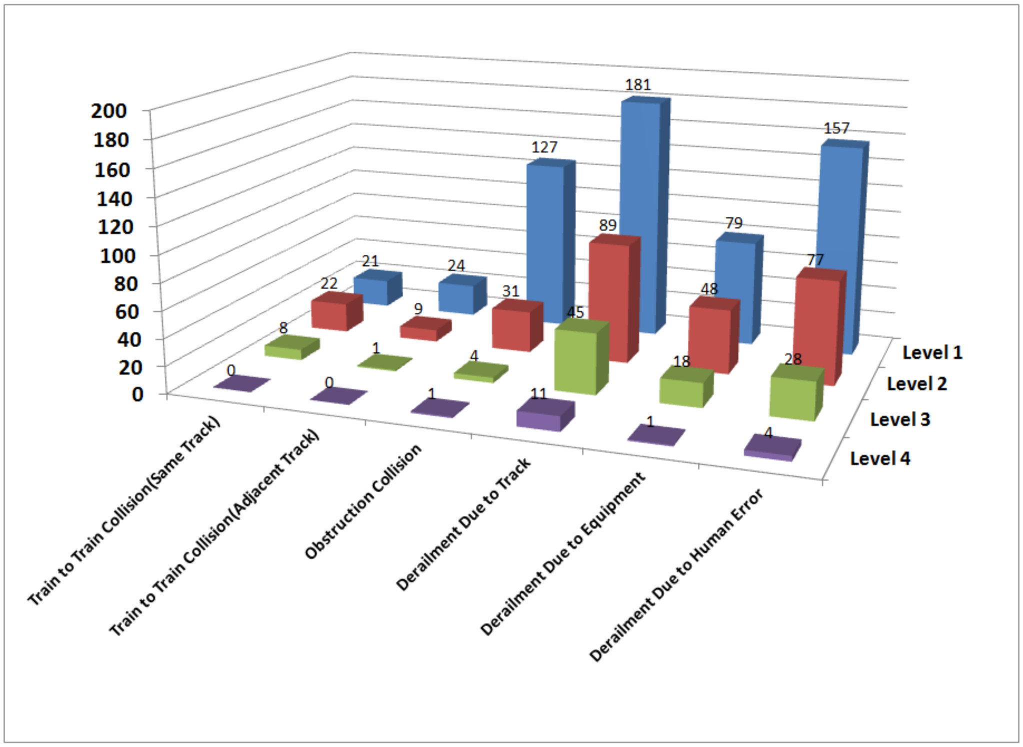



**Figure 2-16. Distribution of Severity Levels from Off-NEC Dataset, 2000-2012**

## 8.0 Summary of Results

The Risk Focus Group applied a logical approach to the review and analysis of accidents for the purpose of developing appropriate categories of hazards for inclusion in the risk model. The approach utilized included:

- Review of past risk assessments conducted on behalf of Amtrak for operation of Tier II equipment on the NEC;
- Review the hazard analysis conducted to support the Waiver Petition for operation of the Acela train sets at speeds up to 160 mph in select locations on the NEC;
- Review of domestic and international experience of passenger services accident histories; and
- Conduct of a detailed historical review of accidents using the FRA RAIRS database.

The Risk Focus Group was comprised of critical internal Amtrak stakeholders as well as supporting consultants and with participation from technical staff from the Federal Railroad Administration Office of Safety. Participants included subject matter experts (SME) in track and infrastructure, signaling, operations, rolling stock design as well as inspection, testing and maintenance and safety officers. Note that the Risk Focus Group met face-to-face several times to review the specifics of accidents on and off the NEC to assess relevance for use with the risk model.

Based upon the consensus of the participants, the categories of hazards were defined. The categories of hazards developed include the following:

- Train-to-Train Collisions
  - Train-to-train collisions on the same track.
  - “Sideswipe” train-to-train collisions between trains on adjacent tracks (reported as accident type 2 in the FRA accident report.
  - Secondary collisions where a train collides with another moving or stationary train on an adjacent track after an initial accident fouls the adjacent track. This type of accident is usually reported to FRA under the cause of the original accident. Note there were no accidents of this type in the 2000-2012 timeframe, but there was an accident on the NEC at Bridgeport, CT that involved a secondary collision after a derailment in 2013.
- Derailments
  - Derailment due to a track defect.
  - Derailment due to an equipment defect.
  - Derailment having a human factors cause.
- Obstruction Collisions - that is not a train operating on the same or an adjacent track.

Each hazard was investigated through application of parameters in the comparative semi-quantitative risk model. The risk model was used to determine the current baseline level of safety on the NEC for 2012. The risk model was also used to investigate future operating conditions on the NEC, which includes operation of Tier III trainsets at speeds up to 160 mph. The model has also been used to determine whether safety gaps exist, and if so, to evaluate the effectiveness of various mitigation measures to offset those gaps. The details of these analyses are presented in Attachment 6.

# Attachment 3

# Operational Data – Input into Risk Model

## 1.0 Planned Route of Operation in Excess of 125 mph

Amtrak is seeking a Waiver Petition for the operation of Tier III equipment on the NEC. The planned route with operations above 125 mph is shown in Figure 3-1. Amtrak's service need require that the Tier III equipment be able to operate up to 160 mph during regular revenue operations. The extent of the route where operations are planned above 125 mph is larger than current allowed operations at that speed. Amtrak requires improved trip times with the procurement of the Tier III trainsets. To enable decreased trip times, Amtrak has specified that the new equipment will be able to operate at 9 inches of cant deficiency. Amtrak seeks permission to operate at these speeds over as large an area as may be possible. Amtrak will only operate over these sections of track at the elevated speeds with the Tier III trainsets if it makes economic sense, otherwise Amtrak will continue operations at a lower speed if necessary. The following Figure shows the approximate locations of the high-speed zones. The precise definitions of the zones are provided in Table 3-1.

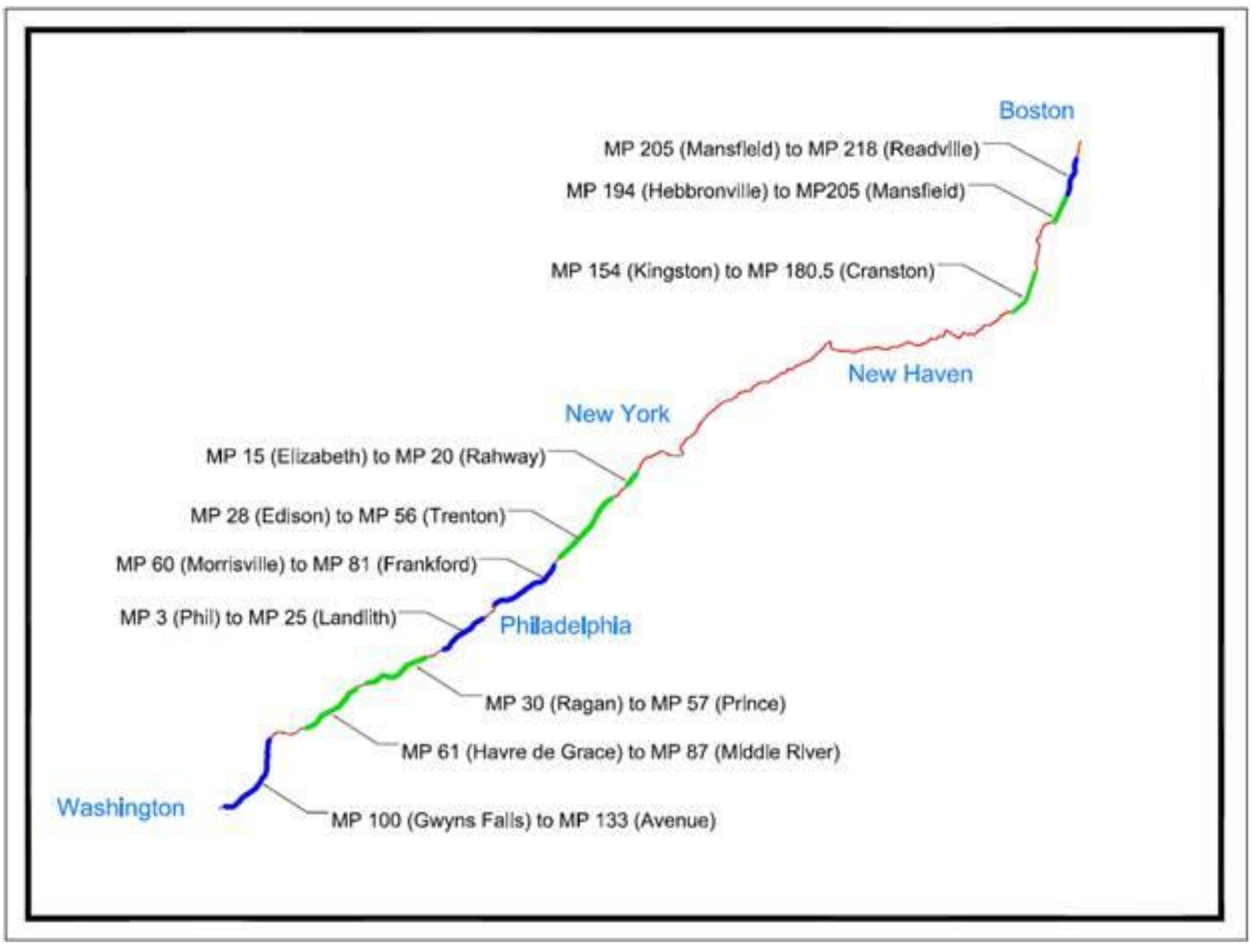


**Figure 3-1. Planned Route for Future Operations above 125 mph on the NEC**

The specific milepost locations in Figure 3-1 are approximations and the specific details of the proposed route is included in Table 3-1 below. For purposes of conduct of the risk analysis it made sense to break each of the high speed areas into a number of distinct high speed zones. The overall length of the route that Amtrak is seeking approval to run above 125 mph is roughly 221 miles. The color coding in Figure 3-1 corresponds to the anticipated maximum allowed speed (MAS) of operation.

Red denotes those areas on the NEC Spine where operations will be below 125 mph and therefore similar to Tier I equipment. At the eleven locations where grade crossings remain on the NEC, speeds for the Tier III equipment would continue to be limited as they are today for Acela, Regional and commuter trains to 90 mph. Blue denotes locations where operations are anticipated as high as 140 mph. Finally, green denotes locations where operations are anticipated as high as 160 mph.

**Table 3-1. Definition of Planned Length of High Speed Zones Where Tier III Trainsets May Operate above 125 mph**

| Zone and Segment Data | | | | |
|---|---|---|---|---|
| | | **MP** | **Length** | **No. Segments** |
| **South Zone 1** | Elmora | 14.6 | **38.6** | **20** |
| | Islin | 23.6 | | |
| | Lincoln | 25.6 | | |
| | Near Curve 268 | 26.4 | | |
| | North of Edison | 27.5 | | |
| | Ham | 56.3 | | |
| **South Zone 2** | Curve 281 | 59.5 | **20.5** | **11** |
| | Torresdale | 74.1 | | |
| | Curve 292 | 75.1 | | |
| | Bridesburg | 81 | | |
| **South Zone 2a** | Before Phil | 3 | **20.6** | **9** |
| | Darby | 5.4 | | |
| | Sharon Hill | 7.2 | | |
| | Landlith | 25.4 | | |
| **South Zone 3** | Ragan | 29.7 | **19.8** | **6** |
| | Bacon | 49.5 | | |
| **South Zone 4** | Past Bacon | 51.1 | **32.3** | **9** |
| | Curve 347 | 57.1 | | |
| | Grace | 60.6 | | |
| | Curve 361 | 86.9 | | |
| **South Zone 5** | Curve 361 | 86.9 | **37.7** | **11** |
| | River | 89.1 | | |
| | Bridge | 98.6 | | |
| | Curve 391 | 106.5 | | |
| | Sunny Run Road | 107 | | |
| | Landover N Ivy Cit | 134.6 | | |
| **North Zone 1** | N Curve 61 | 154.4 | **26.1** | **13** |
| | S Curve 47 | 180.5 | | |
| **North Zone 2** | Hebronville | 193.8 | 25.4 | **8** |
| | Readville | 219.2 | | |
| | | | **miles** | **Segments** |
| | **TOTAL** | | **221** | **87** |

## 2.0 Data Gathering – Operations and Infrastructure

Additional information required in order to facilitate the development of a comparative semi-quantitative risk model is a clear definition of the operational environment for the current and proposed operation. The sources for such information for the NEC are varied and required that the Risk Focus Group tap internal subject matter experts to provide the necessary information as well as conduct a series of in-depth site visits to establish the current state of the NEC.

The types of information gathered included:

- Speed of operation by equipment type
- Traffic mix in specific segments and zones
    - Freight
    - Conventional passenger service – commuter operations
    - Amtrak regional service as well as long distance equipment
    - Amtrak Acela high speed service
- Traffic volumes by track
    - Number of tracks
    - Track spacing
    - Traffic volume on main track – using weekly totals
    - Traffic volume on adjacent track – using weekly totals
- Train control system in place by track
- Details about FRA Track Class (understand where there is variance and impact on operational speeds current and future)
- Details about entry/exit points to the NEC
- Number and locations of turnouts
- Details of Right of Way protection
- Descriptions of key crashworthiness features of different class of equipment (to establish consequence distributions to specific hazards)
- Other features, such as passenger stations and freight yards and industrial tracks in close proximity to the main running line of the NEC

Different sources were utilized to develop the information used in the risk model. Much of the information required is available in the track charts and timetables for the NEC as well as equipment books and timetables for commuter operations along the NEC. Freight information was gathered based upon discussions with Amtrak Operations which provided details about:

- Number of freight trains entering and leaving the NEC,
- Who the operators are,
- The mix of traffic expected – short haul freight movements or longer interchange freight trains,
- The types of commodities being transported, and
- Time of day operations.

## 3.0 Timetables, Track Charts and Freight Operations

The Risk Focus Group sought source material that would provide much of the needed inputs for the risk model that are readily available in the latest version of the National Public Timetable dated July 15, 2013 and the latest revisions of the track charts available on the AB - Shoreline, the AN - New Jersey Line and the AP - Philadelphia Line. Other sources referenced included the Amtrak Intercity Consist book with an effective date of January 28, 2013 as well as the NEC Consist Book effective the same date. These documents, in addition to review by Amtrak SME, served as the basis for developing a detailed description of Amtrak operations on the NEC that was taken as typical of the time frame of interest.

In addition to the details of Amtrak operations the risk model requires definition of commuter rail operations on the NEC. Commuter operations make up a large percentage of the passenger train traffic on the NEC and it is critical to understand where these operations may overlay with the Amtrak Acela, Regional and Long Distance operations. Therefore the Risk Focus Group sought to leverage information being generated by the collaborative effort currently underway by the Northeast Corridor Infrastructure and Operations Advisory Commission. This advisory commission is comprised of the following members:

- National Railroad Passenger Corporation (Amtrak)
- Connecticut Department of Transportation- Shore Line East (SLE)
- Delaware Department of Transportation (DelDOT)
- Long Island Railroad (LIRR)
- Maryland Transit Administration (MARC)
- Massachusetts Bay Transportation Authority (MBTA)
- Metro-North Railroad (MNR)
- New Jersey Transit (NJ Transit)
- Rhode Island Department of Transportation (RIDOT)
- Southeastern Pennsylvania Transportation Authority (SEPTA)
- Virginia Railway Express (VRE)

The reference sources used for the commuter railroad operations also included details from equipment consist/manifest books and publically available schedules which were downloadable from the internet websites.

In addition to the scheduled time and make-up of individual commuter trainsets it was necessary for the Risk Focus Group to prepare a representative operation of equipment type by track in order to properly account for different aspects of risk or hazard in the risk model. This required further analysis of the information publically available with knowledge about the specific operations to properly assign traffic by type of equipment and specific track used for operations. A number of SME available from the technical pool of resources from Amtrak's consultants as well as review by scheduling experts within Amtrak Operations developed a detailed plan for typical day operations and recorded this information in a format appropriate for use in the risk model. The risk model requires a description of typical operations on a weekly basis and so the information gathered was then further consolidated and formatted for use in the risk model.

The Risk Focus Group also gathered data associated with freight operations on the NEC Spine. The approach applied was to host a number of phone calls with SMEs in Amtrak Operations in each of the operational divisions in the high speed zones of interest. A survey of questions was developed and submitted to each operational division which contained the following types of questions:

- What freight and commuter operators operate on the high speed track sections defined?
- What tracks are predominately used for freight traffic?
- Approximately how many trains operate on a weekly basis?
- Provide details associated with the operation including:
    - Entry and exit points from the NEC Spine
    - Breakdown of freight train type (local, unit, through trains)
    - What are typical lengths of different train types

The results from the discussion were captured and formatted for inclusion into the risk model.

Additional information gathered from the track charts and timetables included current operational speeds by equipment type and track, signal system rules in use by train type, special instructions and speed restrictions, locations of catenary dead sections, the location of train inspection detectors, which switches are equipped with electric locks, location of stations, and the locations of wheel impact detectors.

The Risk Focus Group also reviewed in detail the train dispatch manuals used on the NEC Spine for salient information. The manual contains instructions that supplement the NORAC Operating Rules, with details contained within the Timetable Special Instructions, and the Air Brake and the Train Handling Instructions. The information was helpful in defining specifics of operations at different locations on the Spine of the NEC.

## 4.0 Visual Inspection of High Speed Zones from Track Geometry Car

In addition to the data gathered from operational sources it was important for the Risk Focus Group to attend a number of visual inspections from the track geometry car to develop a physical sense for the system and identify potential hazards that exist within the high-speed zones of interest. Amtrak arranged for two visual inspections where key stakeholders were able to take detailed notes of the infrastructure condition and operations. In order to facilitate the visual inspections from the track geometry car a set of data books were developed based upon use of track charts, still frames from previous head-end runs on the NEC where video footage was obtained, as well as overhead satellite photographs to place the running tracks in perspective to surrounding hazards or environment. The objectives of the site visits were:

- Conduct visual inspections to identify possible hazards in locations where the proposed Tier III equipment will operate at speeds in excess of 125 mph

- Gather operational hazards from discussion with Amtrak SMEs
- Confirm which tracks are used by different equipment types in the defined high-speed zones
- Confirm details of freight operations at entry/exit locations on the Corridor as well as the frequency of use of sidings and industrial spurs

The dates for the car visual inspections were:

- January 28, 2014 between Washington DC and New York City and back
- February 26-27, 2014 between New York City and Boston and back

The information gathered from the visual inspections was extremely valuable for the risk model development. The risk analysts gained a better understanding of the operation after visual inspection of the corridor. The participants on the visual inspections noted the extent of MOW activity that occurs daily on the Corridor and the potential for small errors in practice to propagate into an event. There is less freight and passenger service on the North section of the corridor but reduced numbers of running tracks. The participants noted the ride quality experienced running over interlockings which is an important import into the risk model to address point risks. Other natural hazards were documented for potential incorporation into the risk model as point risks.

The eleven grade crossings that remain on the Corridor are in Eastern Connecticut, well away from the high speed zones of interest. There is a speed restriction over the grade crossings to 90 mph MAS and they all have implemented protection strategies to ensure high levels of safety for equipment passing through them.

On the North end of the Corridor there is less freight activity and older ROW fencing is in place. The fencing is situated around beaches and access points to the coast and was put in place to address historical concern of shore side communities. Some of the fencing is in place to help prevent debris from interfering with the catenary system.

The South end has significant freight traffic. It was observed that newer fencing is installed in places – which may have to do with security concerns as much as keeping trespassers and vandals from off the ROW. The population density is greater on the South end coupled with the denser mixed traffic – which may suggest focusing on these areas for better ROW segregation if the risk model suggests the need. In general, the observations from both the North and South end visits support the observations from the accident history - there are concerns associated with intrusion from off-Corridor. Fencing and barriers is an important input factor used in the risk model and so the visual inspection observations were formatted for inclusion in the risk model input file.

## 5.0 Mapping Historical Events with Proposed Speeds

A useful means for organizing information gathered from the site visits as well as the historical accident review was to place information about data gathered and accidents directly on the Track Charts available in order to provide a visual sense of the operation and potential locations for hazards. Figure

3-2 is an extract from one of the Track Charts. Different symbols were used for historical events such as collisions or derailments.

Three classes of collisions were recorded on the Track Chart with information taken from the RAIRS narratives:

- A red cross represents an obstruction collision,
- A green cross represents a train-to-train collision from an adjacent track, and
- A yellow cross represents a train-to-train collision on the same track.

Stars were used to denote different types of derailments:

- Red stars are for derailments due to track defects,
- Green stars are derailments due to equipment defects, and
- Yellow stars are derailments due to human factors.

At the bottom of the Track Chart the degree of curvature, gradient and speeds are shown representing the current system as operated by the timetable. The number of tracks and speeds allowed per track are also shown. The track charts were then mapped with the following information:

- A red rectangle located on the speed section of the track chart represents future speeds between 151 mph to 160 mph,
- Green rectangle represents future speeds of 136 mph to 150 mph, and
- Yellow rectangles represent future speeds between 126 mph to 135 mph.

The Track Charts were a useful tool to establish high speed segments within defined high speed zones. Figure 3-2 indicates that this is a location where both Amtrak as well as P&W operate over this section of track. There are two speeds allowed for the Tier II equipment – up to 135 mph shown by the yellow rectangle and up to 160 mph shown by the red rectangle. The comment boxes included on the chart contain specific information about the mix of traffic by week over the track. The placement of the two red crosses indicates that these are locations where obstruction collisions occurred. In this case at MP 161 the Acela train 2168 hit a large male deer at speed in September of 2001. The second incident occurred on October of 2006; a track car operating outside its authority struck a second track car. The traffic data was also inserted onto the track charts using comment balloons.

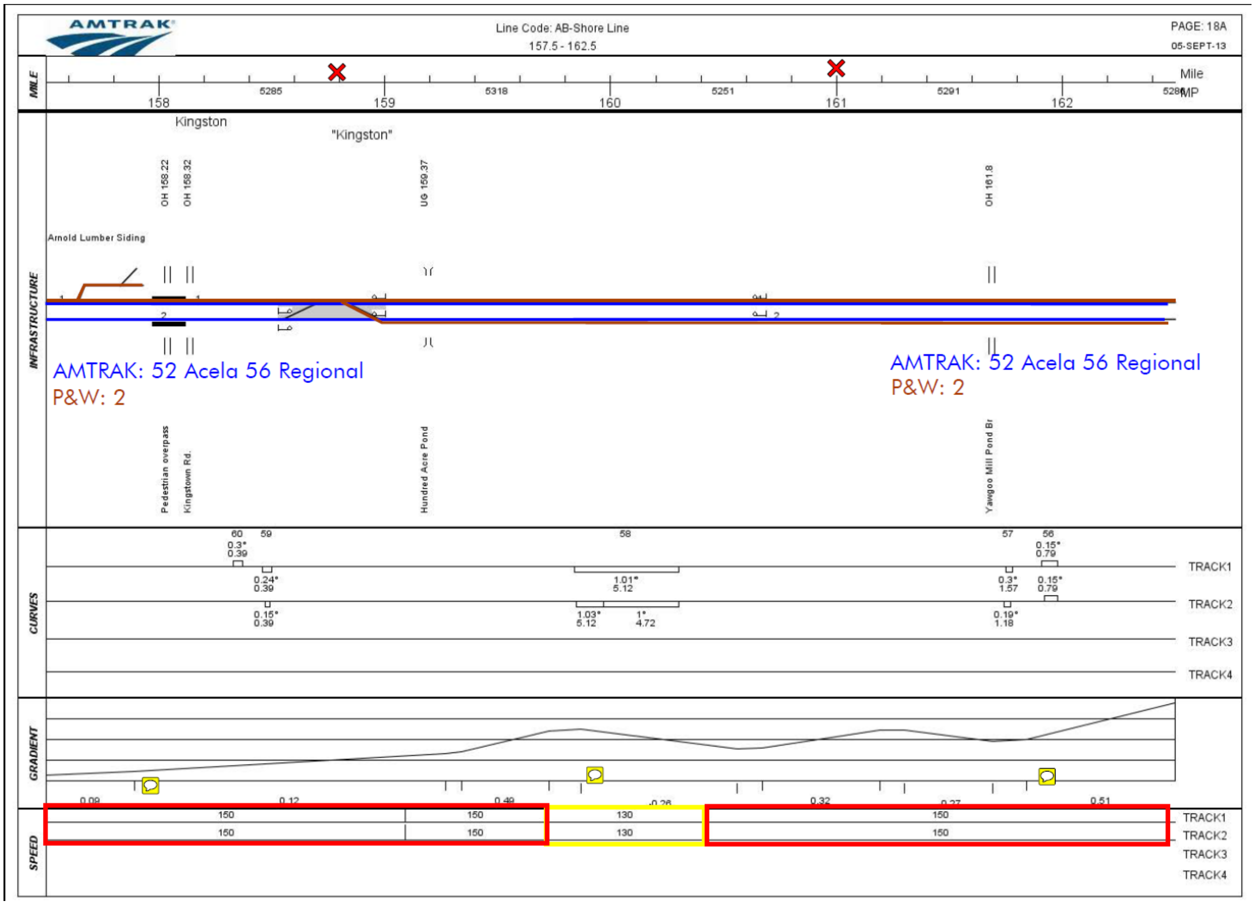



**Figure 3-2. Track Chart: Line Code AB - Shore Line – Exemplary Chart with Salient Accident and Traffic Information**

## 6.0 Definition of High Speed Zones

The route included in the risk analysis has been divided into eight high-speed zones, as listed in Table 3-1 above. Major landmarks defining the locations of the beginning and end points of the high speed zones are listed in Table 3-2. I/L represent interlockings in the table below.

**Table 3-2. Definition of High Speed Zones**

| Zone | Location |
|---|---|
| North 1 | Westerly – Providence |
| North 2 | Providence – Boston |
| South 1 | New York – Trenton |
| South 2 | Trenton – Philadelphia |
| South 2a | Philadelphia – Wilmington |
| South 3 | Wilmington – Bacon I/L (MP49.5) |
| South 4 | Bacon I/L (MP49.5) - Baltimore |
| South 5 | Baltimore – Union Station |

## 7.0 Definition of Route Segments within High Speed Zones

For input into the risk analysis each high speed zone has been further divided into route segments. By definition, route segments must have constant operating parameters, as follows:

- Number of running tracks,
- MAS train speed for the high-speed trains, and
- Constant traffic volume and mix of train types.

Constant values for these inputs are essential for conduct of the risk calculation to facilitate summation of linear risk from segment to segment. Accident consequences increase as speed increases. Different equipment types may have different equipment-defect derailment frequencies. Traffic density can affect train-to-train collision frequency. Change in number of running tracks impacts the calculation of potential for a secondary collision given that a derailment has occurred.

As described in the risk model development section, the linear risks calculated in the model use accident frequency and consequence inputs to estimate the number of accidents by severity level and consequences measures by injuries, fatalities and property damage for each track in each segment. The risk model can then sum the outputs from each segment and then for complete zones. Segment lengths may be variable, and are typically between 1 and 10 miles. The breakdown established of segments for high speed zones is shown in Table 3-1. There are a total of 87 segments included in the model. The high speed zones vary from 20 to 40 miles in length. Providing this level of granularity of the model allows for prioritization and selection of certain risk mitigations.

## 8.0 Condition of Interlockings

An important parameter in the risk model is associated with the condition of interlockings on the NEC. The risk analysts queried Amtrak subject matter experts in addition to review of detailed notes taken during the visual inspections used to assess current conditions and potential hazards. Within each high-speed zone the specific interlockings present were documented with respect to type of construction including use of wood versus concrete ties and the use of different switch designs. It was decided that an interlocking would receive a “fair” rating if constructed from wood ties with Rail Bound Manganese (RBM) frogs. Recently maintained interlockings of this type can at best receive a “good” rating for purposes of the risk model. Many of the interlockings on the corridor are constructed from concrete ties with Moveable Point Frogs (MPF) to enable stable high speed operation. The ratings for these types of interlockings are generally “good” after several years of service and “excellent” if recently maintained.

Each interlocking was discussed and notes were taken to justify the rating chosen for the interlockings. The risk model as developed assumes that the existing infrastructure is fixed through the timeframe analyzed out into the future operations. However there are several ongoing and planned improvement programs underway to improve ride quality and safety. If in the future interlockings are removed because they are currently lightly used and it is decided that continued use is not in Amtrak’s corporate interest, then the contribution to the risk can be determined by setting the traffic over the interlocking to zero. For those interlockings that currently use RBM hardware but are programmed for upgrade to MPF hardware, the ratings will be elevated to the next rating level.

Amtrak inspects switches (turnouts) using various methods on a set schedule:

1. Twice weekly visual inspections by the Track Inspector.
2. Once monthly joint inspection by Track and C&S which includes operational testing.
3. Twice annually joint inspection by ADE level managers.
4. On the high speed routes the Track Geometry Car (TGC) measures the geometry twice month on the main paths.
5. Once per year the TSAVe GRMS car measures every turnout on the NEC both main and diverting routes.
6. Twice per year rail flaw detection with vehicle.
7. Twice per year rail flaw detection with walking stick (on oil train routes and other high density areas).

Amtrak performs maintenance based upon measurements taken during inspections.

The track geometry car (TGC) is capable of measuring at track speed. The TGC measures the following key parameters: lateral and vertical accelerations, alignment, surface, and cross-level track irregularities. Indices are determined for different levels of performance and based upon the limits determined from running in both directions over the interlocking an automatic determination of the interlocking condition can be defined. Amtrak is developing an algorithm for use and will in the future be able to update the interlocking condition as time progresses.

The information gathered was formatted for input into the risk model. As improvements to the infrastructure or means of defining the condition of the interlockings change, the model can be updated to include the information.

## 9.0 Condition and Location of Access Spurs

The Risk Focus Group determined that incorporating access spurs as a point risk in the model was important based upon a review of the accident history and concerns raised based upon other operations from off the NEC. The concern is associated with switch performance for switches connected to the corridor where equipment might roll out unsecured or be shoved in the foul due to failure to protect the point of the movement as a result of human error or vandalism. All access points are already protected by switches situated to divert the offending movement or they are protected by split-point derails. There are some locations which only have top-of-rail derails in place. In every case, these arrangements are integrated with the traffic control system (e.g., through use of electric locks). Amtrak has surveyed all of the access points in order to determine the condition of the access spurs and include the access spur condition as a parameter in the risk model.

The specific parameters associated with access spur condition definition include:

- Speed of operation on mainline track connected to the switch
- The type of switch utilized (hand operated or powered)

- Whether the switch was tied into the signal system
- The type of protection implemented to protect against intrusions or roll outs
- The percent grade away from the mainline
- The use or function of the switch (access to an industrial siding versus a commuter or freight siding)
- The average distance available to keep equipment placed back away from the mainline

Using these parameters at each entry/exit location the condition of the switch was determined to be:

- Limited,
- Typical, or
- Comprehensive

Based upon the classification of the access spurs, the information was formatted and included on the risk model.

## 10.0 Future Traffic Estimates for Proposed Operation

The risk model requires clear definition of future operating conditions in order to conduct the comparative analysis. To develop the future operation conditions the Risk Focus Group met with SMEs from Amtrak Transportation to understand what is envisioned for the service with the new trainsets. The Risk Focus Group met several times to review the current traffic levels developed based upon the work described above as well as to establish reasonable assumptions for future traffic growth. The future traffic volumes on the NEC sought are for only those in the high speed zones established above where speeds might exceed 125 mph with the Tier III next generation high speed train sets. The outcome from the meetings would be used as input into the risk model which requires traffic volume estimates for two future service alternatives:

- An intermediate future analysis case for when the present Acela Tier II fleet is still in service, but supplemented by Tier III trains to implement more frequent trips.
- A final future analysis case, where all high-speed services use Tier III trains.

A critical assumption in the development of the traffic densities for high speed equipment is that the analysis should be based upon the existing infrastructure. As significant infrastructure changes occur on the system Amtrak can modify the existing risk model to reflect such changes and understand the implications of such changes on overall system safety. Major infrastructure changes require significant capital costs and the funding sources for such projects are uncertain.

For commuter operations, Amtrak stated that it is difficult to get solid estimates regarding commuter train volumes. The commuter agencies are reluctant to make firm estimates pending the outcome of the NEC Infrastructure Operations Advisory Commission negotiations regarding how capital and operating costs may be shared by users in the future. Therefore the Risk Focus Group agreed that the influence of future commuter train traffic would be investigated through sensitivity analysis.

Amtrak stated that estimating future freight operation data is very difficult due to the large number of uncertainties associated with commodity movement. Therefore without means for better estimates the Risk Focus Group agreed that the influence of future freight traffic would be investigated through sensitivity analysis.

Amtrak was provided with the following risk model input requirements:

- Provide estimates of train traffic by type by the total number of trains in a calendar week (7 days) on each main track in the high speed zones defined in Table 3-1.
- Provide estimates for changes to commuter or Amtrak Regional track assignments to accommodate the service envisioned (i.e. do more commuter trains remain on non-high speed tracks)
- Note: Amtrak Transportation was informed that there will be no attempt to analyze risk by time of day or week

The data requested for future traffic was provided in a format ready for use as input into the risk model:

- A future case of traffic representing operations in 2020 where there is a mix of high speed train types (Tier II and Tier III) to provide ½ hour peak service between New York and Washington DC and maintain the current service using only Acela Tier II trainsets between New York and Boston.
- A future case of traffic representing operations in 2020 where there is only Tier III high speed trainsets that provide ½ hour service between New York and Washington DC and hourly high speed service between New York and Boston.

## 11.0 Summary

Amtrak assembled a collaborative team comprised of SMEs from various internal Amtrak stakeholder groups along with technical support from consultants and input from technical staff from the FRA Office of Safety to support of the development of a safety case for the proposed operation of Tier III equipment on the NEC. The Risk Focus Group established the extent of the high speed zones given input on the technical specification for the procurement of the equipment and the operational details to meet service demands in the future. Amtrak was able to clearly define the existing state of operations on the NEC through reference to internal documents, review of ongoing activities within Amtrak and with partner railroads. Further Amtrak assessed future operational needs to provide the necessary input for future operational cases to be studied. Upon completion of the documentation of all operational input data, Amtrak SMEs reviewed the details of the risk model and agreed that the input is reflective of both current operations as well as what is expected for future operations.

# Attachment 4
# Derivation of Risk Model Frequencies

## 1.0 Introduction

A formula was developed for calculating train accident frequency for each accident scenario and for each of the equipment and infrastructure alternatives expected to be operated or applied in the NEC high-speed zones. The frequencies were calculated from risk model inputs entered on the "Frequency and Consequences" tab of the Excel risk model Workbook. The following paragraphs describe how accident frequency is calculated for each NEC route segment for each of the nine train accident scenarios from these risk model inputs, and the sources for each input. In all cases, traffic volume inputs are expressed as trains per calendar week (7 days) for each track and train type, to ensure that both weekday and weekend traffic are included in the calculations.

Unless otherwise stated, historic NEC accident data used to derive accident frequencies for high-speed zones included only accidents occurring on 307 route-miles of higher speed track on the NEC. Higher speed was defined as locations operated by Amtrak where speeds generally exceeded 80 mph. This excluded all territory between NYC and New Haven and most major station, terminal and other slow-speed areas, where operations are not representative of the proposed high-speed zones.

## 2.0 Head-On and Rear-End Train-To-Train Collisions

Accident frequency is calculated individually for each track in multi-track territory, thus all input parameters are provided for each track in each route segment. Collision frequencies have the units of "trains in accidents *per million train miles*". Use of this metric rather than "collision accidents *per million train miles*" makes it possible to estimate the risk of involvement in a collision for different train types, without a separate process to identify the type of the second train in a collision. In most cases, two trains are involved in each collision accident.

The frequency of trains in collisions depends on:

- Traffic density as measured by the number of trains per calendar week for each track
- Type of train control system in use. Applicable train control systems considered by the model are:
    - Rule 251 ATC (single direction operation),
    - Rule 261 ATC (bi-directional operation),
    - ATC+ACSES, Full PTC and PTC Plus.

Note: Although ATC+ACSES is currently accepted as equivalent to PTC, the model structure allows for further train control enhancements (such as an automatic link to hazard detection systems) to be either required by FRA, or selected by Amtrak, for high speed operations.

The formula used to calculate this frequency is:

*Frequency = (Base collision frequency of trains in collisions) *(train control system coefficient)* [(7-day train count)/corridor average traffic volume]$^{Index}$*

Where:

- *Base collision frequency of trains in collisions* is an accident frequency derived from safety performance of the NEC during the period 2000-2012.
- *Train control system coefficient* is the ratio between the expected performance of each train control system and the frequency of trains in collisions for 2000-2012.
- *[(7-day train count)/(NEC average traffic volume)]$^{Index}$* is an adjustment factor for the effect of traffic density on collision accident frequency.

Final values of the four inputs, Base collision frequency of trains in collisions, the train control system coefficient and the index, and the NEC average7-day traffic volume were derived from multiple sources[8]. The base frequency for trains in collisions was derived from historical experience on the NEC, both from the 2000-2012 period and, because the data were very sparse, from earlier time periods and from passenger rail operations elsewhere[9].

## 3.0 Train-Train Collision Where the Primary Cause Reported to FRA is a Sideswipe with Another Train or Fixed Structure

A review of the sideswipe accidents between 2000 and 2012, see Attachment 2, shows that the causes are events like a passing train striking loose equipment access doors, instances of usually tight clearances, and similar events that result in a collision between two trains or an impact with a wayside structure like a platform at a passenger station. There were no side or raking collisions between trains in the accident record, and such collisions are considered highly unlikely in territory equipped with ATC and ACSES. Secondary collisions, where there is an intrusion onto an adjacent track after initial accident is considered a different accident scenario, discussed in Section 4.0 below.

This calculation is performed individually for each track. As with train-to-train collisions on the same track, the frequency of trains in collisions is estimated separately for each track and train-type, and is a function of whether there are one or two running tracks adjacent to the track being analyzed, and the traffic mix on the line. Because of the chance of shifted loads and loose equipment, the chance of a sideswipe accident is higher with freight trains than passenger trains. Although traffic density on adjacent tracks was considered as a risk driver, it was rejected on the grounds that once the original fault creating the conditions for a sideswipe had occurred; a collision is highly likely, given the high traffic volumes on the NEC.

Frequencies for trains in sideswipe accidents for each of four operating conditions were estimated from the historical accident record for NEC operations and accident data for freight and passenger operations in general, as listed below:

- Passenger train with active tracks on one side of the train,

[8] Sources for inputs include: PTC cost/benefit studies by FRA, a paper by J. Sussman et.al. of MIT, which in part looked at the effect of traffic density on collision risk, and 2012 collision frequency as determined by analysis of 2012 accidents and traffic volume.

[9] The train control system coefficients were derived primarily from FRA cost-benefit analyses of alternative PTC systems, and the effect of rail traffic density on collision frequency was derived from the work of Sussman et. al.

- Passenger train with active tracks on both sides of the train,
- Freight train with active tracks on one side of the train, and
- Freight trains with active tracks on both sides of the train.

Accident frequencies for each of these operating conditions are provided in a look-up table on the “Frequencies and Consequences” worksheet of the model. The model simply looks-up the applicable frequency, and does not need to perform any calculations.

Final 2012 values for the four frequencies were derived from the analysis of the NEC accident data base and freight train accident data discussed in Attachment 2. Accident frequencies are not a function of the train control system, but mitigation actions involving automatic detection of equipment defects and clearance violations, or improved equipment inspection practices could change these values.

## 4.0 Secondary Collision Due to Obstruction of a Main Track Following an Accident on an Adjacent Track

This type of accident is a secondary event following a collision or derailment that obstructs an adjacent track, followed by a collision with another train operating on the obstructed track. The original accident would be reported to FRA under the original cause, and additional accident reports for the same event would identify the involvement of a second or third train. Secondary collisions are quite rare, but are potentially very serious. The model treats the additional damage and casualties of the secondary collision as a separate event. No such events were found in either the NEC or off-NEC 2000-2012 data, but there was an accident of this type on the NEC in 2013, near Bridgeport, CT. This accident had serious consequences, illustrating the importance of this scenario. This accident category has units of frequency of secondary collisions *per million train miles*, and is dependent on the following factors:

- Traffic density on the track being analyzed;
- The number of collision and derailment accidents on adjacent tracks, as estimated by the model;
- The probability that a collision or derailment on the adjacent track would obstruct the track being analyzed; and
- The probability that a train operating on the track being analyzed would be unable to stop before hitting the obstruction, estimated from stopping distance and likely warning time.

The formula, used to calculate an estimated number of secondary accidents, is as follows

*[(Number of passenger train-train collisions and derailments on adjacent tracks)*(coefficient 1) + number of freight train-train collisions and derailments on adjacent tracks)*(coefficient 2)]*(7-day count of trains on the track being analyzed)*(coefficient 3)*

Where:

- The number of collisions and derailments on the adjacent track is the sum of train-to-train collisions and all three types of derailment. Sideswipe collisions and obstruction collisions are not included, as most are unlikely to obstruct an adjacent track.
- Coefficient 1 is *passenger train intrusion probability;*
- Coefficient 2 is *freight train intrusion probability;* and

- Coefficient 3 is *the minimum warning time in minutes needed to prevent an approaching train colliding with the obstruction divided by 7560. 7560 minutes (7, 18-hour days) is the total time of passenger operations over one calendar week.*

There are no inputs for this accident scenario derived from historic NEC accident data. The primary sources are past analyses of adjacent track intrusion probability. Coefficient 3 is estimated from the ratio between an estimate of the time needed to notify a train operating on an adjacent track that an accident has caused an obstruction plus the time taken for that train to stop and the total number of minutes passenger rail operations during a week. This is assumed to be 18 hours a day times 7 days.

## 5.0 Derailment Due to a Track Defect

This accident scenario involves a single train where derailment is caused by a track defect, such as buckled track or a broken rail. Track-defect train accident frequencies (accidents *per million train miles*) are primarily a function of FRA Track Class, and are higher for freight trains than for passenger trains, because the higher axle loads of freight cars and the larger number of cars in a train. In addition, the presence of freight trains operating on a specific track may increase the chance of a track-defect-caused accident involving a passenger train, because of the damage freight trains may do to track. Thus, track defect derailment frequency is a function of:

- FRA track class, and
- Train Type (passenger or freight train) where freight-specific factors are added to account for:
  - A higher accident frequency for freight trains, and
  - The increase in passenger train derailment frequency due to use of a track by freight trains.

The formulas used to calculate track-caused derailment frequency in accidents *per million train miles* for a given track and route segment is as follows:

Passenger trains:

- *Frequency = (Frequency for track class)*(1+(passenger-freight adjustment factor)*(number of freight trains in 7 days))*

Freight trains:

- *Frequency = (Frequency for track class)*(Freight Adjustment Factor)*

*Where:*

- *Track Class* for the track being analyzed is taken from the value identified on the “Zone and Segment Data” worksheet,
- *7-day passenger and freight train counts* for the track being analyzed, taken from applicable “Zone and Segment Data” worksheet,
- *Passenger-freight adjustment factor* applied to reflect the increase in passenger train derailment frequency due to use of the track being analyzed by freight trains, and

- *Freight adjustment factor* is a multiplier applied to the base track-defect-caused accident frequency to reflect the higher frequency of these accidents for a freight train.

The results provide a train accident frequency for each train type operating on the track being analyzed. The value of the freight adjustment factor is derived from a comparison of broad analyses of freight and passenger train derailment accidents, and was set to 2.5.

## 6.0 Derailment Due to an Equipment Defect

This scenario is a single-train derailment caused by an equipment defect, such as a broken wheel, failed axle journal bearing, and similar failures of a locomotive, passenger car or freight car. Equipment defect-caused accidents are assumed to be a function of train type only, using the frequency values listed on the “Frequency and Consequences” worksheet for each equipment type operating on the corridor.

Differences between train types are due to different maintenance and inspection procedures used for different equipment types. High-speed trains are subject to more frequent inspections and may be equipped with automatic condition monitoring systems, leading to low accident frequencies. Amtrak passenger cars having trucks with inside bearings are equipped with on-board bearing temperature monitoring, but commuter cars with similar trucks are not. Freight train equipment defect accident frequencies are higher than those for passenger trains because there are typically more vehicles in a freight train, the cars are heavier, and the materials, systems and maintenance and inspection procedures differ from those used for passenger trains. The application of automated track-side freight car inspection systems, in particular, are a promising approach to reducing the number of equipment defect accidents, and can be evaluated by the model.

A baseline frequency is derived from historic corridor accident data for all train types combined. This figure and information on maintenance and inspection routines are used to derive an estimate of how accident frequency will vary from the baseline. There are too few accidents on the NEC to be able to differentiate between train types, except to assume that a more intensive inspection and maintenance routine will result in fewer defects and accidents. After discussions with Amtrak’s mechanical department concerning current maintenance and inspection procedures, including wayside and on-board equipment inspection systems, reasonable parameters were developed. Accident frequency estimated were further informed by freight and passenger train accident frequencies derived from other freight and passenger rail risk analyses.

The model simply looks-up the frequency based on the train types operating on each route segments and applies the appropriate frequency.

## 7.0 Derailment Due to a Human Factors Failure

The human factors failures that may cause derailment accidents for passenger trains are typically overspeed accidents and errors concerning the use of switches, such as misaligned switches. The train control method in use on a route segment is assumed to be the major driver of human factor derailments. Generally, ATC systems do not provide for civil speed enforcement, including through the diverging track at a turnout, and will not enforce an absolute stop at an interlocking signal. ACSES and PTC will enforce both temporary and permanent civil speed restrictions, and provide for an absolute stop at an interlocking signal, thus preventing most of these derailments.

Freight train operations, however, introduce additional human factors derailment risks related to train handling and braking management. High compressive or tensile forces can build up in a long freight train, leading to derailment. This kind of accident is not a factor in passenger train operations. Thus, separate risk metrics and formulas are used for freight and passenger trains, as detailed below.

*Passenger trains:* Human factors derailment frequency determined from a look-up table by train control method, specifically:

- Rule 251 ATC
- Rule 261 ATC
- ATC + ACSES
- Full PTC
- PTC Plus

No other inputs are required. Accident frequency estimates are obtained from derailment frequency on the NEC and further informed by the results of other analyses of passenger train derailments in the United States.

*Freight trains*: The frequency formula contains two terms:

- Train control method as for passenger trains, and
- An accident frequency for derailments due to train handling, braking and related errors.

The frequency formula is:

- *(Estimated derailment accident frequency due to control system frequency) + (Estimated frequency of freight train accidents due to train handling errors)*

A value for the freight factor is derived from analyses of freight train accidents as a function of accident cause and track class, with adjustments for NEC operating conditions.

## 8.0 Collision With an Obstruction

Accident frequencies for obstruction collisions are derived from historical experience on the NEC as a function of the effectiveness of measures used to control the risk of obstruction collisions. The average obstruction collision risk in high speed areas on the NEC is estimated to be 0.132 collisions *per million train miles*, using 2000-2012 accident data. These collisions are a mix of obstructions resulting from unauthorized access to the NEC right of way, actions by Amtrak staff and contractors and natural events such as large animals on the right-of-way and fallen rocks and trees. The effectiveness of efforts to control these collisions has been categorized in three levels:

- *Strong,* meaning all access points are securely fenced, Amtrak and contractor staff is careful not to leave access gates unlocked, trees adjacent to the ROW are removed or trimmed and unstable earth or rock banks are reinforced and/or equipped with a slide fence to detect falling rocks. With regard to collisions resulting from unsafe MOW or contractor activities, strong means good system safety management and effective safety procedures for activities on the right-of-way.
- *Fair*, represents average present conditions on the corridor, and
- *Weak*, where few precautions against obstructions have been implemented.

Since obstruction accidents comprise nearly half of all reportable train accidents in high-speed territory on the NEC, obstruction accidents have been divided into three categories, to support development and evaluation of risk reduction measures. These categories are, with approximate percentages of obstruction:

- Collisions with objects placed on the right-of-way resulting from unauthorized access, including motor vehicles and miscellaneous debris - 30%,
- Collisions associated with authorized activities by Amtrak or contractor staff, such as track inspection and maintenance, construction work near the ROW, etc. – About50%.
- Collisions resulting from a natural event, such as a fallen tree, a fallen rock from an unstable bank, or large animals on the right-of-way – about 20%

Note that personal injury casualties to trespassers, passengers, Amtrak staff or contractor personnel not associated with a reportable train accident are not included in this analysis.

## 9.0 Point Risk at Primary Interlockings

Accidents can occur at a primary interlocking in the high-speed zones, either because of track defects at switches at the interlocking or human factors accidents involving train movements through the switches. Accident frequency, defined as accidents *per million main line train movements* over each track, is a function of interlocking complexity as measured by the number of turnouts on each track, interlocking condition as determined by Amtrak engineering staff, and traffic volume

The risk formula for each track at the interlocking is:

> *Accident frequency in accidents per million train movements through an interlocking on each track = (Fixed frequency coefficient) * (interlocking condition factor) * (number of turnouts in track being analyzed) * (traffic volume in trains/7-day week)*(scaling factor)*

The model totals the estimated number of accidents at the interlocking for each track to get a total for the interlocking.

The fixed interlocking accident frequency coefficient is estimated from historical accident data. Accidents are considered interlocking accidents if caused by a defect of a specific interlocking component, or if there has been a human factor accident specifically involving a train movement over a diverging track at an interlocking. The frequency is derived from dividing all identifiable interlocking accidents over the period covered by the accident data by the number of train movements through an interlocking over the same period. Only train movement that pass over one or more switches in the interlocking are counted in calculating the train movements. Accidents identified as interlocking accidents are not included when estimating accident frequencies for other accident scenarios. There is no double-counting.

The scaling factor includes the following elements to ensure consistency of units in the formula, which are:

- A multiplier of 520 on the 7-day traffic volume to obtain the number of train movements over 10 years.
- A divisor of 1 million so that the train movement count is in millions, for consistency with the interlocking condition factor which is expressed in accidents *per million movements* through an interlocking.
- A divisor of 6, which is the average number of turnouts in an interlocking. This factor is needed because the model calculates the number of accidents by track, whereas the accident frequency input is for the whole interlocking.

The condition of the interlocking is derived from observations during the field inspection, from observations by Amtrak track maintenance staff, and regular track geometry measurements.

## 10.0 Point Risk at Access and Egress Locations

Access and egress locations are considered a particular risk on the NEC because the connecting tracks are often under the control of another railroad, and will normally will lack automatic train control and, in many cases, block signaling. Most access locations are for freight trains entering and leaving the NEC, but a few provide access for passenger equipment maintenance and servicing facilities. Manual switches with electric locks are commonly used at these access locations. Risk may be controlled by, position detectors at the access switches, split-rail derails, careful procedures for operations on the access tracks and other methods. This scenario covers all accident types, but most are human factors errors in train operations when approaching or passing through the access switch.

The model assigns three levels to the effectiveness of risk controls at the access and egress points, as follows:

- *Limited*, meaning some customary risk controls are lacking,
- *Typical*, meaning risk controls are typical of the corridor in 2012, and
- *Comprehensive*, meaning that all practical and effective risk controls have been implemented.

The formula for calculating risk at each access point is as follows:

> *(Number of accidents over 10 years) = (Accident frequency in accidents per million access movements at the freight spur)* (traffic volume in trains using the spur/7-day week)*(fixed coefficient)*

The fixed access point accident frequency is derived from a count of the number of access point accidents in the corridor over the analysis period, divided by an estimate of total train movements through each access location over the same period. A train movement is counted each time a train moves from or to an active NEC main track that connects to a siding, industry track, yard, branch line or maintenance facility.

The accident frequency input is derived from the details of installations at each access point and represents the variation from the NEC average in 2012. The fixed coefficient contains a multiplier of 520 to obtain train movements over 10 years and a divisor of one million to convert the train movement count to millions for consistency with the accident frequency measure.

This process yields an estimate for the number of accidents at an access location based on the details of the safety features at each track. However, a review of past accidents indicated that not all access track accidents involved an obstruction on a main NEC running track, which is the principal concern about the risks of freight operations adjacent to NEC main tracks. A further calculation requires quantification of this risk for inclusion in estimates of overall risks on the corridor. To do this, the model multiplies access track accident risk by two factors:

- A factor for the fraction of access track accidents that result in an obstruction on an NEC main track, and
- A factor for the probability that a train operating on an NEC main track fails to stop before a collision with obstructing vehicles from an access spur accident. This is calculated from the volume of traffic and train types operating on the main track in the same way as for the risk that an accident on an NEC main track would obstruct an adjacent main track and leading to a secondary accident.

The end point of this calculation is an estimate of the number of accidents to passenger trains resulting from train movements at NEC access locations.

## 11.0 Summary

The frequency input data was developed for each accident scenario and for the equipment and infrastructure alternatives expected to be operated or applied in the NEC high speed zones. A detailed description of the process used to develop input values has been described in detail. The risk model was developed so that as changes or modifications to the NEC are implemented, the input parameters can be updated to get a new estimate for the risk profile as a function of high speed segment, high speed zone, or for the overall system. This has allowed the Risk Focus group to provide recommendations to the Amtrak Risk Mitigation Group. The Risk Mitigation Group was able to prioritize and select for implementation risk reduction strategies that will ensure a robust and safe system for the proposed operation of Tier III equipment in mixed service at speeds up to 160 mph. The details of the results are discussed in Attachment 6.

The Frequency Inputs for the risk model 2012 Base Case are provided in **Tables 4.1 to 4.4** below.

**Table 4-1. Accident Frequencies for Linear Hazards**

| Look-up Table for Accident Frequencies for Linear Hazards (accidents per million train-miles) - Baseline 2012 Values | | | | |
|---|---|---|---|---|
| **Accident Scenario** | **Frequency as Function of Traffic Volume, Other Factors** | | | |
| | **Factor** | **Factor Units** | **Value** | **Value Units** |
| Train-Train Collision on Same Track - Head-On and Rear-E | Traffic Density | Base Frequency | 0.0150 | |
| | Formula | Density Index | 0.7500 | Accidents per |
| *Frequency = (Base collision accident frequency) ** | Train Control | Rule 251 ATC | 1.30 | Million |
| *(train control system coefficient)** | System coefficient | Rule 261 ATC | 1.10 | Train-Miles |
| *[(7-day train count)/NEC average train count]* | *Index* | ATC+ACSES | 0.70 | |
| | | Full PTC | 0.70 | |
| | | PTC Plus | 0.60 | |
| Train-Train Collision - Sideswipe and Similar | Train type, number of | Pass, 1-side | 0.0100 | Accidents per |
| | adjacent tracks | Pass, 2-sides | 0.0200 | Million |
| *No formula, simply apply frequency values* | | Freight 1-side | 0.0800 | Train-Miles |
| | | Freight 2-sides | 0.1200 | |
| | | | | |
| | | | | |
| Derailment - Track Defect | FRA Track Class | 5 | 0.015 | Accidents per |
| Passenger trains: | | 6 | 0.010 | Million |
| *Frequency = (Frequency for track class)** | | 7 | 0.008 | Train-Miles |
| *1 + (passenger-freight adjustment factor)** | | 8 | 0.005 | |
| *(number of freight trains in 7 days))* | Passenger-freight | Factor | 0.0005 | None |
| Freight trains: | adjustment factor | | | |
| *Frequency = (Frequency for track class)*(Freight multip* | Freight multiplier | Factor | 5.000 | None |
| | | | | |
| Derailment - Equipment Defect | Equipment type | Tier II | 0.01 | Accidents per |
| | | Tier III | 0.007 | Million |
| *No formula, simply apply frequency values* | | Regional | 0.015 | Train-Miles |
| | | Commuter | 0.02 | |
| | | Freight | 0.1 | |
| | | | | |
| Derailment - Human Factors | Control System | Rule 251 ATC | 0.020 | Accidents per |
| | | Rule 261 ATC | 0.015 | Million |
| *No formula, simply apply values, except:* | | ATC+ACSES | 0.010 | Train-Miles |
| *Freight trains only, use the following:* | | Full PTC | 0.010 | |
| *(Control system frequency) + (freight factor)* | | PTC Plus | 0.007 | |
| | Freight train factor for | Frequency | 0.05 | |
| | handling, brakes, etc. | | | |
| | | | | |
| Intrusion Collision | Fencing, barriers in | Strong | 0.060 | Collisions per |
| | place, natural | Fair | 0.130 | Million Train- |
| *No formula, simply apply values* | surroundings | Weak | 0.200 | Miles |
| | | | | |

## Table 4-2. Accident Frequencies for Point Hazards

| Look-up Table for Accident Frequencies for Point Hazards (accidents per million train-miles) | | | | |
|---|---|---|---|---|
| **Accident Scenario** | **Frequency as Function of Traffic Volume, Other Factors** | | | |
| | **Factor** | **Factor Units** | **Value** | **Value Units** |
| Primary Interlockings (interlockings on main tracks) | Interlocking Condition | Fair | 0.6 | Accidents per Million Main Line Movements Thru Interlocking |
| | | Good | 0.5 | |
| | | Excellent | 0.4 | |
| Access Spurs - Function of Control System and Manual or Power Switch and Derail Details | Turnout Safety Features | Limited | 5.00 | Accidents per Million Movements Entering or Exiting Corridor |
| | | Typical | 3.50 | |
| | | Comprehensive | 2.00 | |

## Table 4-3. Coefficients for Secondary Collision Accidents

| Coefficients for Accident Due to Intrusion From an Adjacent Track Accident | |
|---|---|
| | Coefficient |
| Coefficient 1: Passenger train intrusion probability | 0.25 |
| Coefficient 2: Multiplier for freight train intrusion probability | 3 |
| Coefficient 3: Time for a train approaching the intrusion to be warned and to stop (minutes) | 3 |

## Table 4-4. Coefficients for Secondary Collisions at Access Spurs

| Coefficients for Secondary Collision after Accident at Access Spur | |
|---|---|
| **Description of Coefficient** | Value |
| Coefficient 1F: Probability of accident at access spur obstructing a main running track | 0.25 |
| Coefficient 2F: Time for a train approaching the obstruction to be warned and stopped (minutes) | 3 |
| Coefficient 3F: Accident frequency multiplier for spurs to passenger equipment facility | 0.1 |

# Attachment 5

# Derivation of the Consequence Severity Distributions

## 1.0 Introduction

The crashworthiness of different classes of equipment is a fundamental issue addressed by the risk assessment. The consequence associated with an accident or derailment is dependent on the ability of the trainset to provide a safe volume for passengers and crewmembers if an event were to occur. The Tier III equipment crashworthy requirements have been developed within the Railroad Safety Advisory Committee's (RSAC) Engineering Task Force (ETF). Research sponsored by FRA as well as analyses conducted by international carbuilders have provided confidence in Tier III equipment performance under a collision scenario with a conventional North American passenger locomotive led train. FRA is in the process of taking the work product from this effort and preparing a Notice of Proposed Rulemaking to codify the recommendations.

A critical input parameter required in developing a risk model to assess differences in risk for one equipment type versus another under similar operating conditions is the severity distribution for each of the hazard categories defined previously in the main report and in Attachment 1. There is considerable uncertainty associated with the performance of trainsets involved in collisions at higher impact speeds. Amtrak did not pursue developing a detailed Finite Element Model (FEM) of the Acela to conduct high energy collision analyses. Amtrak believes there is too much uncertainty in any numerical model's ability to accurately capture significant material failure and large deformations. Further there is no FEM for a generic Tier III trainset available. Even if there were such a model available, the results from high energy collision analyses would also be considered suspect.

Therefore, a more qualitative approach was taken in defining the severity distribution for the different classes of equipment and accident categories investigated within the risk model. The following sections describe the process used to develop accident severity distributions for use in the risk model.

## 2.0 Average Severity Levels Based Upon Accident History

The primary approach to characterizing accident consequences associated with each accident category, equipment type and speed of operation is to estimate the distribution of accident severity among four defined accident Severity Levels. A highly crashworthy trainset would tend to have less severe consequences in a given accident, meaning that there would be a smaller percentage of high severity accidents and a higher percentage of lower severity accidents. Higher speed accidents would tend to have more severe consequences, increasing the percentage of high severity accidents and reducing the percentage of lower severity accidents. The percentage distribution also varies between accident categories: train-to-train collisions tend to be more severe that other categories, resulting in a severity distribution tilted toward a higher percentage of accidents at higher Severity Levels. Obstruction collisions are generally less severe, resulting in severity distributions tilted toward a higher percentage of accidents at lower Severity Levels.

The rationale for quantifying accident severity using Severity Levels is that different accident categories can have very different severity distributions, which would not be apparent if average severity was used instead. Model results giving accident counts by severity level provide useful additional detail to help the analyst interpret the safety of a given operation.

**Table 5.1** provides definitions of each Severity Level. The definitions for each level include ranges for property damage, injuries and fatalities. An accident is assigned a Severity Level corresponding to the most severe of the three criteria. Thus an accident that results in between 10 and 50 injuries would be identified as a Level Three, even if property damage does not exceed $250k. An accident causing over $1million in property damage is a Level Four, regardless of the number of casualties. The Severity Level definitions are designed to be used for passenger train collisions and derailments only.

To provide a link between Severity Level results from the risk analysis (counts of accidents ate each Severity Level and more widely used measures of accident consequences, the average injuries and property damage per accident were calculated for each Severity Level from actual data for all NEC and Off-NEC accidents. The resulting figures, after rounding and comparing NEC and off-NEC results are also given in **Table 5.1.** Since there were no fatalities in NEC accidents between 2000 and 2012, estimated for the number of fatalities cannot be derived from accident data. Instead an indicative number of one fatality per 75 injuries was assumed, based on an analysis of a larger set of NEC and comparable commuter rail accident data.

**Table 5-1. Average Severity Levels from All Passenger Equipment Operating on the NEC**

| Severity Levels | | Consequence Per Accident | | |
|---|---|---|---|---|
| **Level** | **Definition** | **Injuries** | **Fatalities** | **Damage ($k)** |
| **1** | Minor -less than $50k damage, no casualties | 0 | 0 | 18 |
| **2** | Moderate - greater than $50k - $250k damage, less than 10 injuries | 0 | 0 | 90 |
| **3** | Serious - greater than $250k - $1M damage, greater than 10 injuries, no fatalities | 3 | 0 | 500 |
| **4** | Very Serious - greater than $1M damage, greater than 50 injuries, more than one fatality | 3 | 0.04 | 2,000 |

Note that the damage used to categorize average severity levels in the timeframe investigated is based on the dollar value reported to FRA at the time of the accident and has not been recalculated to an equivalent present day value.

Average injuries are a reasonable metric to compare one type of operation with another. However, the number of injuries or fatalities associated with a given event can be very dependent on several factors such as placement of equipment relative to initiating cause, load factors on the train, where passengers are seated, time of day and others. Amtrak placed equal weight on average damage as a proxy for the number of casualties. This approach strikes a reasonable balance between the case where a lightly-patronized train experiences significant damage but relatively few injuries, and the case where a heavily-patronized train experiences relatively minor damage but a significant number of injuries.

As noted above, no events have occurred with the Tier II equipment in over 40 million train miles of service to date, that have significantly challenged the crashworthiness features of the trainsets. That being the case, during the same timeframe Tier I or Tier III trains operating over the same territory at the same speeds would not likely have encountered impacts that they could not have easily withstood.

## 3.0 Historical Accident Severity Distribution

Historical accident severity distribution is based upon the averaged passenger train response (all types – commuter MU, commuter push-pull, Amtrak Regional and Amtrak Acela service) observed on the NEC between 2000 and 2012, and is shown below in Table 5-2. There were no Level 3 or Level 4 events for any of the hazard categories developed except for collisions with obstructions.

**Table 5-2. Accident Severity Distributions in the High Speed Areas with Operational Speeds in excess of 80 mph**

| | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| Train to Train Collision(Same Track) | 50 | 50 | - | - |
| Train to Train Collision(Adjacent Track) | 83 | 17 | - | - |
| | | | | |
| Derailment Due to Track | 67 | 33 | - | - |
| Derailment Due to Equipment | 50 | 50 | - | - |
| Derailment Due to Human Error | 30 | 22 | - | - |
| Obstruction Collision | 58 | 32 | 9 | 1 |

Adjustments to the historical distributions were considered necessary to allow for the subset of potential incidents that could have occurred but have not on the system during the 2000-2012 timeframe. A conservative approach was used when preparing base case severity distributions for input into the risk model. It is conservative when conducting the risk analysis for redistribution of accidents from lower Severity Level bins to higher Severity Level severity bins. This practice resulted in more severe normalized incidents *per million train miles* in the model. The modified severity distribution is shown in Table 5-3. Severity distributions for point risks were developed from accident history and comparison with similar linear risks. The severity distribution estimates also supported by a review of accident consequence values used in previous risk assessments.

Specific factors that were considered in developing the distributions for each accident category were:

- Train-to-train collisions can be very serious; hence it was important to increase the percentage of Level 3 and Level 4 events to account for those serious accidents s that could occur but have not. The redistribution was impacted based upon the analyses for off NEC events in a similar operating environment as well as previous work on passenger rail risk in North America.

- Accident history shows that side-swipe collisions are less severe than train-to-train collisions on the same track. The Risk Focus Group observed that this is true for accident both on and off the NEC, in part due to trainsets deflecting past each other.
- A secondary collision occurring after an initiating accident can have very serious consequences, as observed in the 1999 Bourbonnais, IL and 2005 Glendale, CA accidents that started out with smaller primary accidents leading to into very serious secondary impacts. Therefore the distribution for this accident category was heavily shifted to a higher percentage of more severe accidents as compared with all other accident categories.
- Derailments due to the different causes tend to be less severe than primary collision events as observed in the accident history. However, derailment accident distributions were adjusted to increase the percentage of higher Severity Levels, to allow for the possibility of Level 3 and 4 events, for consistency with collision accident distributions, and to incorporate experience from other studies and the expanded view of off-NEC events.

**Table 5-3. Adjusted Severity Distribution for Baseline Performance in High Speed Territory – Used for Push-Pull and MU Commuter Equipment**

| | Baseline - All Trains in High Speed Territory (80 - 150 mph) | | | |
|---|---|---|---|---|
| | Severity Levels (%) | | | |
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 37 | 43 | 15 | 5 |
| Train-Train Collision - Sideswipe and Similar | 43 | 45 | 10 | 2 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 25 | 40 | 25 | 10 |
| Derailment - Track Defect | 45 | 30 | 20 | 5 |
| Derailment - Equipment Defect | 40 | 38 | 20 | 2 |
| Derailment - Human Factors | 45 | 30 | 20 | 5 |
| Obstruction Collision | 54 | 40 | 5 | 1 |
| | | | | |
| **Point Scenarios** | | | | |
| Primary Interlocking | 45 | 30 | 20 | 5 |
| Access Spur | 25 | 40 | 25 | 10 |

A detailed review of the different types of passenger equipment in use on the NEC and the nature of the services operated by each type was carried out to develop severity distributions for application in the risk model. The factors considered were:

- The age of the equipment and the car body structural requirements applicable at the time of manufacture.
- Whether single or bi-level equipment.
- Typical speeds of operation.

The industry standard for end frames to perform gracefully up to severe levels of deformation require better attachment of end frame members to the anti-telescoping plates and roof as well as to be integrated with the side sill of equipment. In general, the commuter fleet is newer and built to these more recent requirements or standards. As such, it was decided that for purposes of future operations on the NEC with a progressively newer and more crashworthy fleet, that the commuter equipment should be reflective of the adjusted severity distribution shown above.

For similar reasons, it was decided that because the Regional Amtrak fleet on the corridor is older and built to standards which have evolved since the delivery of the equipment, that the severity distribution for that equipment type should be adjusted further as shown in Table 5-4 below. Note that the average speed of operation of this class of equipment is also greater than that of the commuter fleet and hence, if an event were to occur, the consequences of such an event could be more severe.

**Table 5-4. Severity Distribution for Amtrak Regional Equipment**

| | Speeds Amtrak Regional 80 - 125 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 32.5 | 40 | 20 | 7.5 |
| Train-Train Collision - Sideswipe and Similar | 39 | 45 | 13 | 3 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 12 | 40 | 33 | 15 |
| Derailment - Track Defect | 35.5 | 30 | 27 | 7.5 |
| Derailment - Equipment Defect | 32 | 38 | 27 | 3 |
| Derailment - Human Factors | 35.5 | 30 | 27 | 7.5 |
| Obstruction Collision | 51.5 | 40 | 7 | 1.5 |
| | | | | |
| **Point Scenarios** | | | | |
| Primary Interlocking | 35.5 | 30 | 27 | 7.5 |
| Access Spur | 12 | 40 | 33 | 15 |

## 4.0 Tier II Severity Distributions

The Acela trainsets are compliant with the requirements set forth in 49 CFR Subpart E – Specific Requirements for Tier II Passenger Equipment – which provide for a greater degree of equipment crashworthiness. The Acela is likely one of the most crashworthy trains in existence and its service history has been exemplary with over 40 million train miles to date without a major incident that has challenged the crashworthy features of the train. It should be noted that the safe crashworthy speed of the Tier II trainset (Acela) has been defined as 30 mph in a like-to-like train collision. In comparison, the safe crashworthy speed of the Tier III trainsets has been established as 20 mph for impact with a standing passenger locomotive led train.

Acela trainsets clearly have greater crashworthiness capabilities in lower energy accidents than the Tier III equipment that Amtrak is planning to procure. Further, no equipment domestically or internationally will survive collisions with like equipment at 125 mph, let alone 150 or 160 mph. Train collisions at elevated speeds must be prevented. It should be noted that for lower speed collisions, bulk crushing of the car body is limited to unoccupied portions of the vehicle. Typical safe closing speeds for conventional equipment are estimated as[10],[11]:

- Cab car led train into a standing passenger locomotive led train ~ 10-15 mph
- Locomotive led train into a standing passenger locomotive led train ~ 25 mph
- Acela train into another Acela led train ~ 30 mph

In developing the severity distribution for the Tier II equipment it is important to consider some of the key design features:

- Built with CEM for a like train-to-like train collision at 30 mph (significant energy absorption required at each interface).
- Increased buff strength in lead vehicles (1.2 million lbf).
- No passengers in lead or rear vehicles.
- Aerodynamic nose shape (colliding trains tend to move laterally to by-pass each other in collisions).

In summary, the following considerations were taken into account when developing severity distributions for high speed trainsets.

- It is important to take a balanced approach to risk mitigation – at higher speeds, application of a collision avoidance philosophy is the norm.
  - Crashworthiness is effective at low energies/speeds (limits consequences)
  - Collision avoidance is effective for medium or high energy/speeds where there are limits to what the structure can do (focus instead on limiting frequency of events)
- High energy collisions are catastrophic independent of trainset type.
- Train to train collisions are very rare and generally occur at reduced speeds where crashworthiness can mitigate consequences.
- Side swipe collisions also are very rare – there is a tendency for long aspect ratio objects to by-pass each other rather than engage. The shape of the aerodynamic nose contributes to by-pass behavior. An ability to sustain initial collision loads until by-pass behavior can occur is required.
- Derailments can and do occur, but CEM equipment has a tendency to stay in-line and upright. A review of incidents internationally and research from the U.S. DOT substantiates this behavior. The risk model developed does account for the potential for a secondary collision after the primary event.
- Impacts with obstructions have been observed at high speeds.
  - Historically the damage to equipment is limited due to the much lower mass and different shape of objects being struck in comparison with the trainsets

[10] Paper 03—4530, "Evaluation of Rail Passenger Equipment Crashworthiness Strategies", Published in the Transportation Research Record 1825, July 2003
[11] Paper RTD2006-94043, Effectiveness of Alternative Rail Passenger Equipment Crashworthiness Strategies" Proceedings of ASME RTD2006, April 4-6, 2006, Atlanta, GA

- The aerodynamic shape of the equipment has a tendency to deflect objects to the side – reference Appendix F[12] impacts with a steel coil and crashworthiness analyses presented in the RSAC ETF.
- Derailments may occur due to a primary event such as an obstruction collision, but then CEM equipment has a tendency to stay in-line and upright, the model does account for the potential for a secondary collision after the primary event.

Three separate speed regimes are investigated in the risk analysis to determine the impact of expected risk in the high speed segments (over 125 mph) by trainset type. There is no information available on the crashworthy performance of Acela equipment subjected to higher energy events. Instead the analysts reviewed the requirements defined within 49 CFR Parts 238 Subpart E and scaled the anticipated performance of the Tier II equipment based upon the baseline severity distribution established. Tables 5-5a - 5-5c are the consequence distributions developed for the Acela trainsets for each speed regime: 125-135 mph, 136-150 mph and 151-160 mph. The levels are percentages of events by category hazard; summation of levels 1 through 4 equal 100.

Establishing severity distributions for different operating speed bands enables the risk analyst to assess differences in projected risk for future operations. If necessary, the risk model can evaluate risk reduction obtained by reducing speed of operation over a given high speed zone or segment within the three speed bins defined.

**Table 5-5a. Severity Distribution by Hazard Category for Acela Trainsets for Speed Regime: 125-135 mph**

| | Acela - Speeds 125 - 135 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 44 | 40 | 12 | 4 |
| Train-Train Collision - Sideswipe and Similar | 46 | 45 | 8 | 1 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 36 | 43 | 15 | 6 |
| Derailment - Track Defect | 52 | 35 | 10 | 3 |
| Derailment - Equipment Defect | 53 | 36 | 9 | 2 |
| Derailment - Human Factors | 52 | 35 | 10 | 3 |
| Obstruction Collision | 55.25 | 40 | 4 | 0.75 |
| | | | | |
| **Point Scenarios** | | | | |
| Primary Interlocking | 51 | 30 | 15 | 4 |
| Access Spur | 36 | 43 | 15 | 6 |

[12] 49 CFR Part 238 Appendix F

**Table 5-5b. Severity Distribution by Hazard Category for Acela Trainsets for Speed Regime: 136-150 mph**

| | Acela - Speeds 136 - 150 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 37 | 43 | 15 | 5 |
| Train-Train Collision - Sideswipe and Similar | 43 | 45 | 10 | 2 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 25 | 44 | 23 | 8 |
| Derailment - Track Defect | 47 | 33 | 15 | 5 |
| Derailment - Equipment Defect | 47 | 34 | 14 | 5 |
| Derailment - Human Factors | 47 | 33 | 15 | 5 |
| Obstruction Collision | 54 | 40 | 5 | 1 |
| **Point Scenarios** | | | | |
| Primary Interlocking | 45 | 30 | 20 | 5 |
| Access Spur | 25 | 44 | 23 | 8 |

**Table 5-5c. Severity Distribution by Hazard Category for Acela Trainsets for Speed Regime: 151-160 mph**

| | Acela - Speeds 151-160 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 33 | 40 | 21 | 6 |
| Train-Train Collision - Sideswipe and Similar | 39 | 45 | 13 | 3 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 21 | 40 | 27 | 12 |
| Derailment - Track Defect | 40 | 37 | 17 | 6 |
| Derailment - Equipment Defect | 40 | 37 | 17 | 6 |
| Derailment - Human Factors | 40 | 37 | 17 | 6 |
| Obstruction Collision | 51.5 | 40 | 7 | 1.5 |
| **Point Scenarios** | | | | |
| Primary Interlocking | 35.5 | 30 | 27 | 7.5 |
| Access Spur | 21 | 40 | 27 | 12 |

## 5.0 Tier III Severity Distributions

Tier III trainsets utilize a Crash Energy Management (CEM) design philosophy to manage collision energy in a predictable and controlled fashion along the full length of a trainset. CEM designs are able to control deformations and motions at the colliding interface and impart dynamic collision loads into the supporting structure along a prescribed load path, thereby inhibiting undesirable behaviors such as buckling and override. Controlled energy absorption at coupled interfaces inhibits both these behaviors.

As agreed within the RSAC ETF, Tier III equipment is required to meet—

- Criteria for protection of the occupied volume through resisting a specified quasi-static load on the collision load path (238.703),

- A dynamic collision scenario involving the Tier III equipment and a conventional passenger train impacting at 20 mph in which passenger and crew space is conserved (238.705) and serious override is avoided (238.707),
- Required measures to inhibit fluid entry to the same basic degree required of conventional locomotives and cab cars (238.709),
- The same cab end structure requirements applicable to Tier I equipment (238.711),
- Specified requirements for structural strength at a non-cab end (if any) that mirror requirements for Tier I passenger coaches (238.713),
- Through incorporation by reference, the Tier I requirements for roof and side structure integrity (238.715), and
- Requirements for truck attachment (238.717).

These requirements are designed in such a way that they permit a trainset to be accepted based on all of its safety-relevant attributes, including use of semi-monocoque construction and crash energy management features.

In developing the severity distribution for the Tier III equipment it is important to consider some of the key design features and contrast them with Tier II design features:

- Tier III trainsets use CEM for a collision into a conventional passenger locomotive-led train at 20 mph
- Passengers are allowed in the lead equipment (closer to primary collision interface)
- Excellent acceleration and deceleration rates with lighter trainset designs
- Assumed, crashworthiness performance up to 125 mph similar to Tier I equipment
- Aerodynamic nose shape (helps equipment by-pass each other)

The severity distributions developed for the Tier III trainsets for the same three speed regimes defined for the Tier II equipment are shown in Tables 5-6a - 5-6c. Again, establishing severity distributions for different speed regimes of operations enables the risk analyst to assess differences in projected risk for future operations.

**Table 5-6a. Severity Distribution by Hazard Category for Tier III Trainsets for Speed Regime: 125-135 mph**

| | Tier 3 - Speeds 125 - 135 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 37 | 43 | 15 | 5 |
| Train-Train Collision - Sideswipe and Similar | 43 | 45 | 10 | 2 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 25 | 40 | 25 | 10 |
| Derailment - Track Defect | 48 | 36 | 11 | 5 |
| Derailment - Equipment Defect | 48 | 36 | 11 | 5 |
| Derailment - Human Factors | 48 | 36 | 11 | 5 |
| Obstruction Collision | 53 | 41 | 5 | 1 |
| | | | | |
| **Point Scenarios** | | | | |
| Primary Interlocking | 45 | 30 | 20 | 5 |
| Access Spur | 25 | 40 | 25 | 10 |

**Table 5-6b. Severity Distribution by Hazard Category for Tier III Trainsets for Speed Regime: 136-150 mph**

| | Tier 3 - Speeds 136 - 150 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 32.5 | 40 | 20 | 7.5 |
| Train-Train Collision - Sideswipe and Similar | 39 | 45 | 13 | 3 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 12 | 40 | 33 | 15 |
| Derailment - Track Defect | 35.5 | 38 | 19 | 7.5 |
| Derailment - Equipment Defect | 35.5 | 38 | 19 | 7.5 |
| Derailment - Human Factors | 35.5 | 38 | 19 | 7.5 |
| Obstruction Collision | 50.5 | 41.5 | 6.5 | 1.5 |
| | | | | |
| **Point Scenarios** | | | | |
| Primary Interlocking | 35.5 | 30 | 27 | 7.5 |
| Access Spur | 12 | 40 | 33 | 15 |

**Table 5-6c. Severity Distribution by Hazard Category for Tier III Trainsets for Speed Regime: 150-160 mph**

| | Tier 3 - Speeds 151-160 mph | | | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| **Linear Scenarios** | | | | |
| Train-Train Collision on Same Track - Head-On and Rear-End | 28 | 37 | 24 | 11 |
| Train-Train Collision - Sideswipe and Similar | 35 | 44 | 15 | 6 |
| Secondary Train-Train Collision - After Accident on Adjacent Track | 11 | 32 | 36 | 21 |
| Derailment - Track Defect | 33 | 34 | 20 | 13 |
| Derailment - Equipment Defect | 33 | 34 | 20 | 13 |
| Derailment - Human Factors | 33 | 34 | 20 | 13 |
| Obstruction Collision | 47 | 42 | 8 | 3 |
| **Point Scenarios** | | | | |
| Primary Interlocking | 30 | 27 | 25 | 18 |
| Access Spur | 11 | 32 | 36 | 21 |

## 6.0 Relative Difference Between Estimated Severity Distributions By Hazard Category

The performance of either the Tier II or Tier III trainset designs in the mid- to high-energy accidents is uncertain, as there are limits to what crashworthiness designs can achieve for such events. As shown by the accident history in Attachment 2, the majority of accidents occur at the lower energy levels where crashworthiness is an effective means for limiting the consequence. It is the norm internationally to rely on collision avoidance strategies to minimize the risk that may exist for higher energy accidents. Again, referencing the accident history discussed in Attachment 2, application of an advanced train control system is very effective in prevention of train collisions. Nevertheless it is conservative to assume that the consequences of such events are very severe if they do occur, so both the Tier II and Tier III severity distributions recognize this. Tier II equipment constructed in compliance with enhanced crashworthiness requirements are expected to perform better in accidents when compared to the Tier III equipment. Therefore, in developing the severity distributions for each hazard category, it was helpful to plot the differences in performance between Tier II and Tier III trainsets. This ensures that the differences in the distributions properly reflect the expected differences in crashworthiness performance between the two trainset types.

Figure 5-1 shows the comparison of the severity distributions for Tier II versus Tier III equipment under the first hazard category – a train-to-train collision on the same track for each of the three speed regimes that the equipment is expected to operate within. This is a plot of the relative difference with respect to the Tier II equipment – positive values indicate that the event is more severe for Tier III equipment than for Tier II equipment, while minus values indicate that the event is less severe for Tier III equipment as compared with the Tier II baseline. Note that as speed increases, there is a change from lower severity tendency to more significant consequence as expected. As a train-to-train collision would be a significant event the relative difference at the highest speed shows that the Tier III equipment is expected to perform roughly 60% worse in a Level 4 event. Again, the performance under such a condition is uncertain and is related to the post collapse behavior of the equipment after the energy absorption capacity afforded by the crush zones is exhausted. We know from the test experience documented by the FRA that once the structure which is not designed to collapse in a controlled progressive fashion is overloaded, the energy absorption capacity drops significantly. The first vehicle that experiences overload is likely to become the sacrificial crush zone for other cars in the consist. This is why prevention of such events is critical.

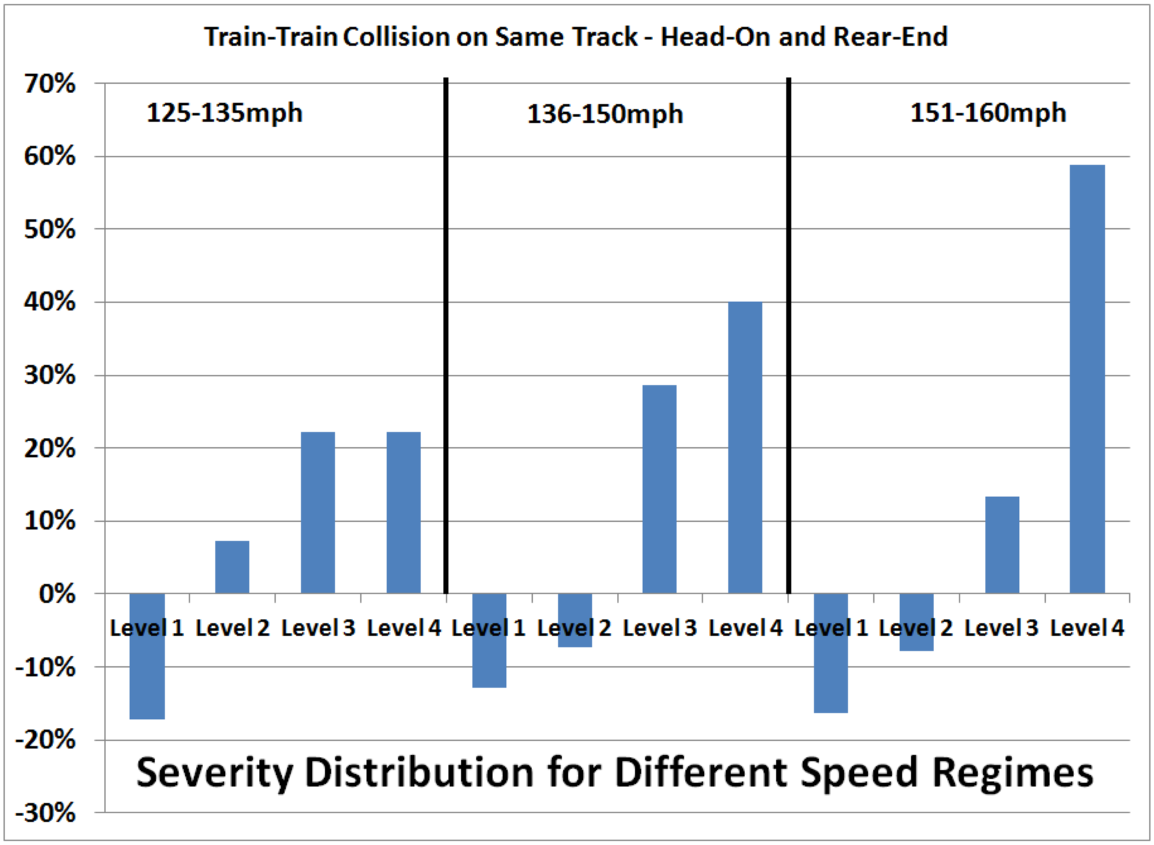



**Figure 5-1. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Train-to-Train Collision on the Same Track**

Figure 5-2, from a paper[13] sponsored by the FRA, demonstrates the behavior just described. After the peak load of the occupied volume is overcome, the force levels drop significantly and the equipment crushes catastrophically. This particular collision was between a conventional cab car-led passenger train striking a standing passenger locomotive backed up by several conventional cars. The results from this test suggest that the safe speed of the conventional single level equipment is somewhere between 10-15 mph. This class of equipment was designed to a strength based requirement of 800,000 lbf buff without permanent deformation, and did not consider an overload condition.

[13] Paper IMECE2002-33247, "Train-to-Train Impact test: Analysis of Structural Measurements", Published at the Proceedings of the IMECE 2002 in New Orleans, LA in November 17-22, 2002.

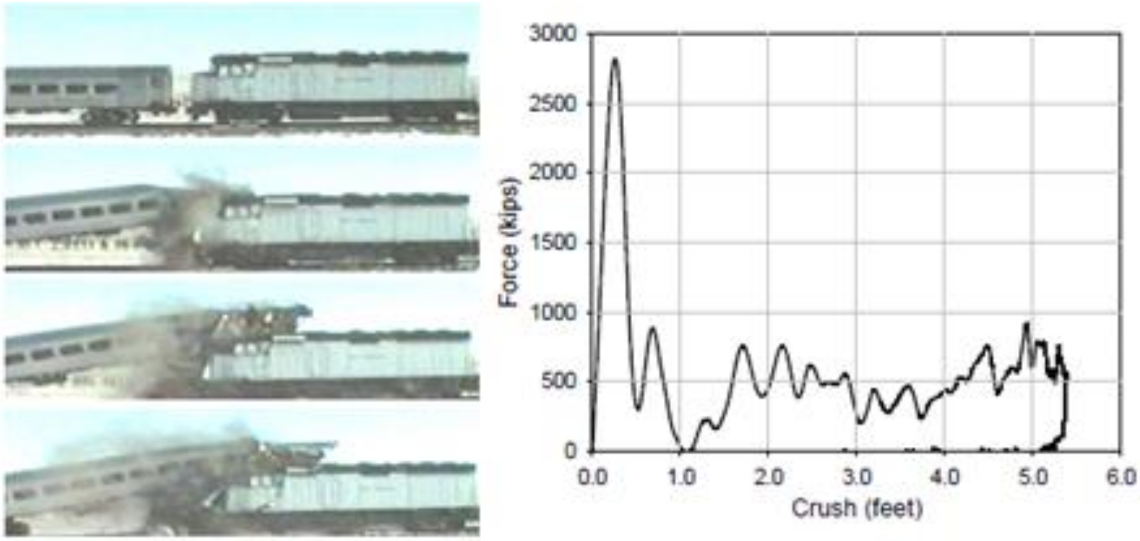



**Figure 5-2. Results from a Train-to-Train Impact Test**

Figure 5-3 is the comparison of the relative differences between Tier II and Tier III equipment for a side collision from an adjacent track at the three speed regimes defined.

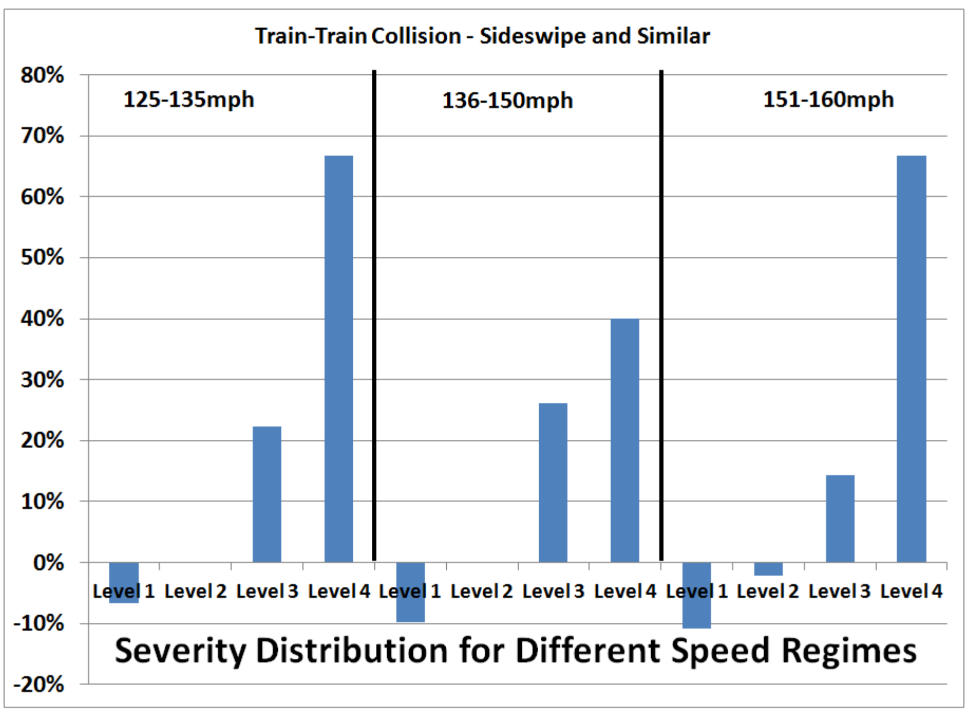



**Figure 5-3. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Train-to-Train Collision Adjacent Tracks**

Figures 5-4 through 5-10 are the relative differences for each of the other hazard categories. Each comparison illustrates that consequences for Tier III equipment increases as speeds increase, and that the Tier II Acela consistently has lower percentages of high-severity accidents than Tier III trainsets.

The severity distributions used to prepare figures 5.4 to 5.10 were used in the risk model and are considered conservative. The relative differences will have an impact on the projected number of injuries, and help quantify the safety gap that will exist between operations of the two different trainset types in a similar operating environment.

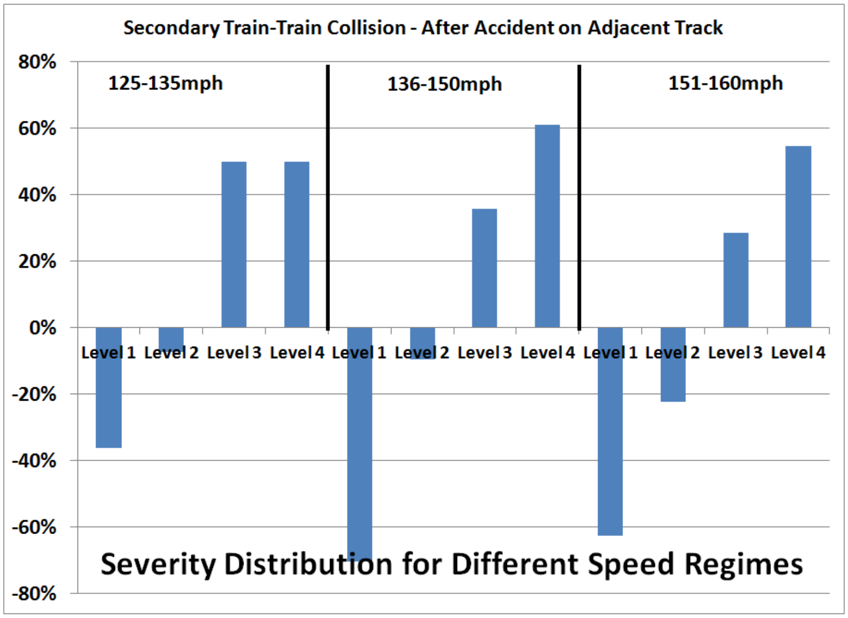



**Figure 5-4. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Secondary Train Collision**

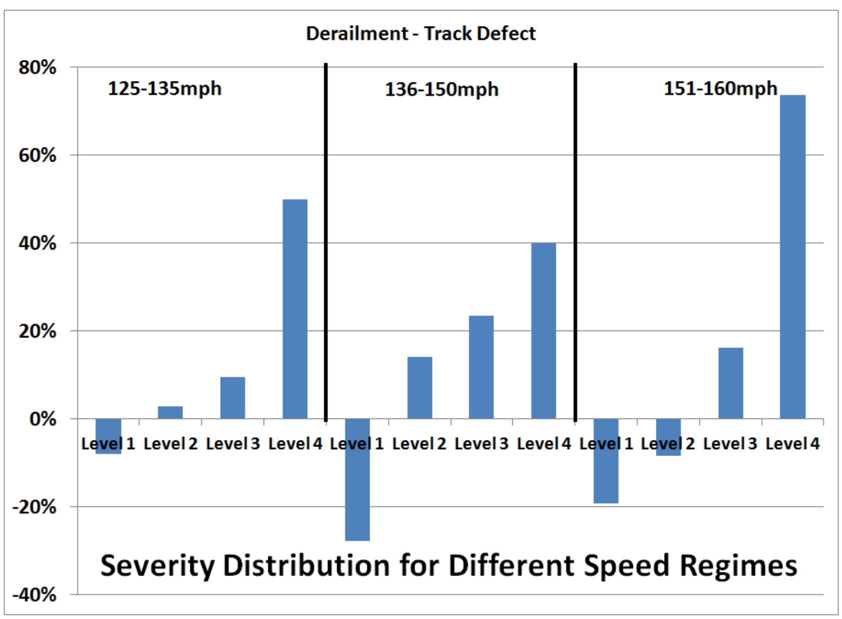



**Figure 5-5. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Derailment Due to Track Defects**

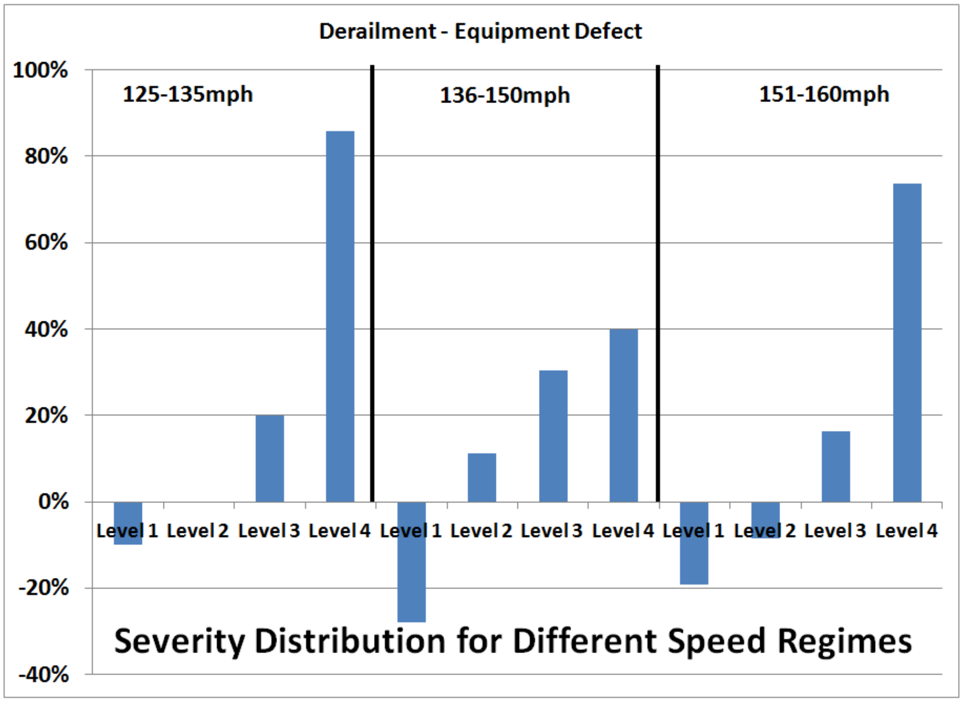



**Figure 5-6. Comparison of Severity Distributions for Tier II versus Tier III Equipment –Derailment Due to Equipment Defects**

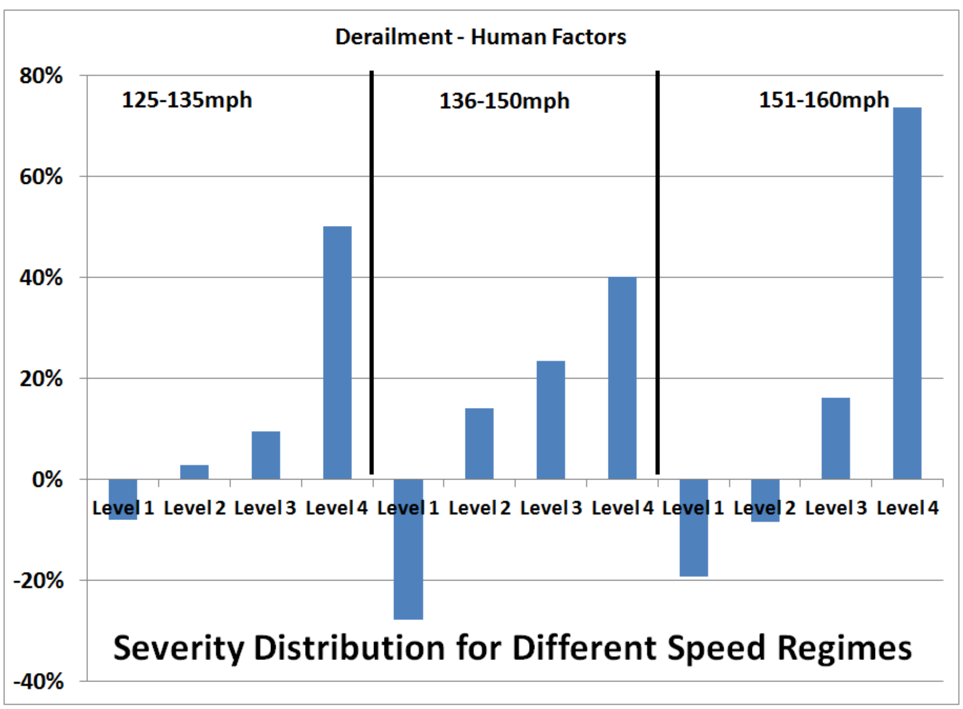



**Figure 5-7. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Derailment Due to Human Factors**

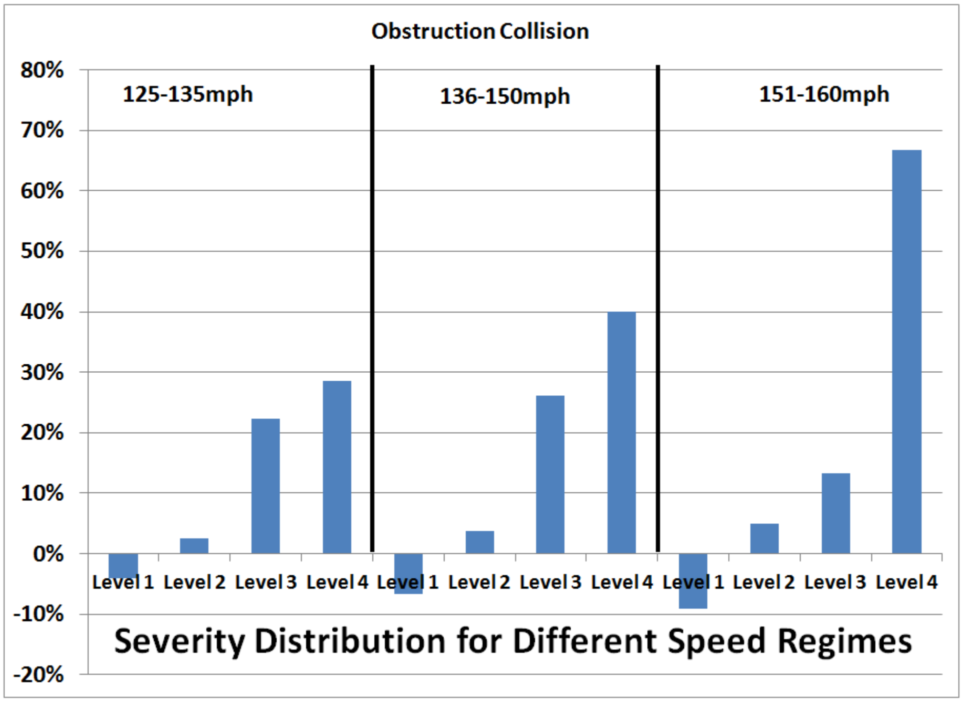



**Figure 5-8. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Collision with Obstructions**

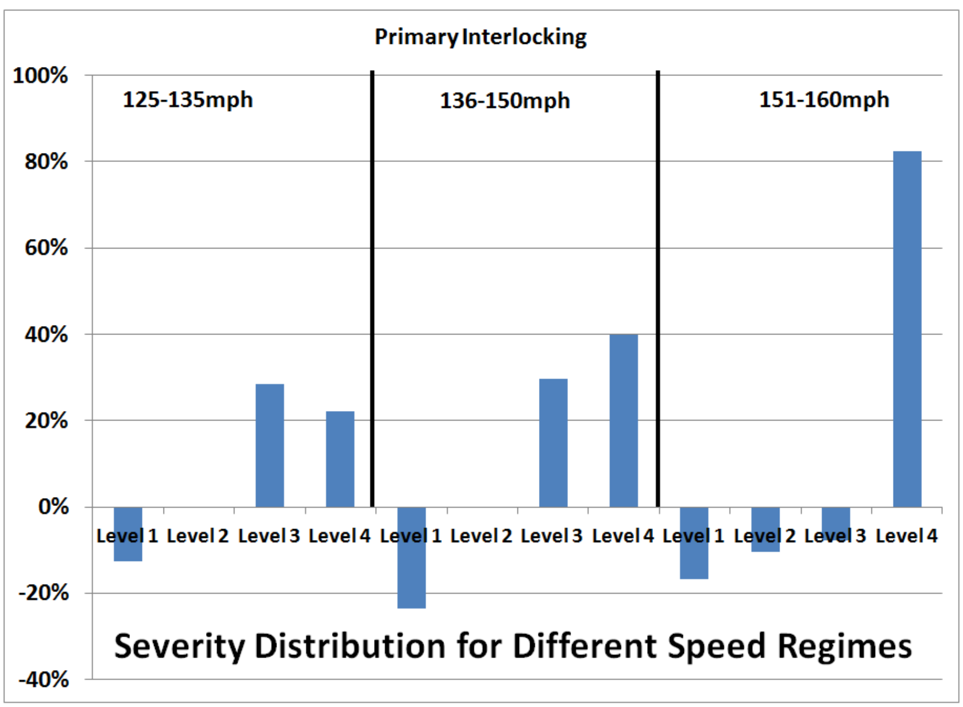



**Figure 5-9. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Accident at an Interlocking**

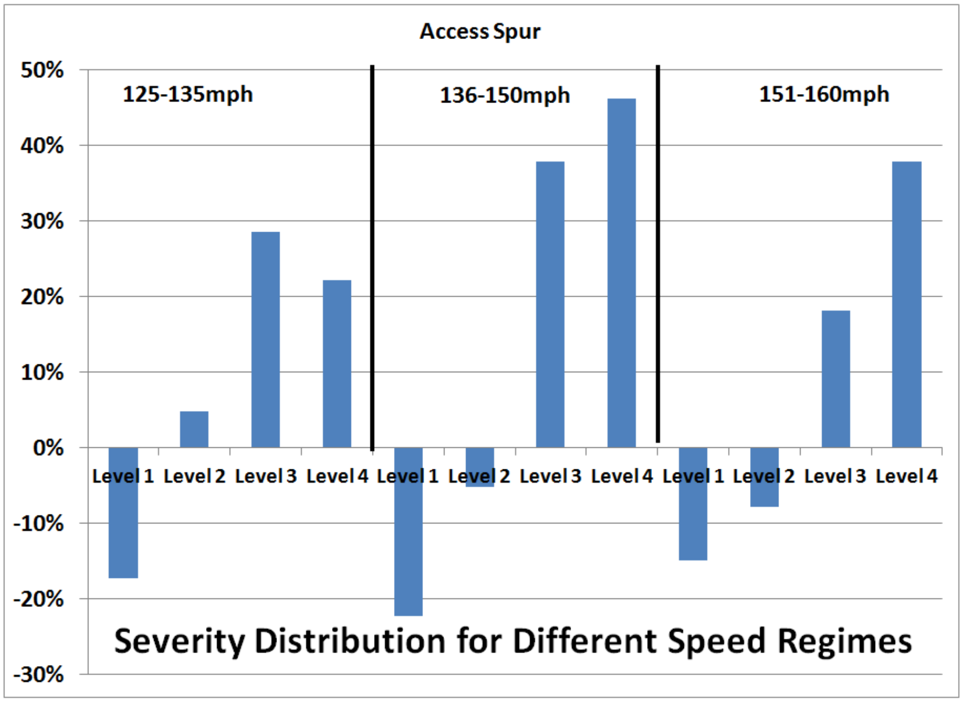



**Figure 5-10. Comparison of Severity Distributions for Tier II versus Tier III Equipment – Accident at an Access Spur**

## 7.0 Summary

The development of credible severity distributions for different types of equipment operating on the NEC is crucial to the risk calculation, and is the basis for comparing different equipment and operations alternatives. The accident history discussed in Attachment 2 was used in conjunction with review of previous work and an understanding of changes in regulatory requirements and industry standards. The risk analysts used this information along with good engineering judgment to establish severity distributions representative of each class of equipment operating on the NEC.

Amtrak chose not to pursue explicit calculation of post collision performance of CEM equipped trainsets involved in high energy accidents; no accepted analysis method is available for higher collision speeds, and there could be no confidence in any results that would be developed. The outcome of any such analysis is very uncertain, due to sensitivity to initial and boundary conditions as well as the potential for significant levels of material failure coupled with large deformations. The current state-of-the-art in numerical modeling is still immature and oversimplification of the analyses could potentially provide misleading results.

Due to the uncertainty associated with the outcome of such events, it was agreed that establishing a qualitative means for defining the severity distribution was reasonable. All agreed that the outcome of an event at low energy levels would favor reduced consequences for Acela versus a generic Tier III trainset design. Nevertheless, these types of equipment utilize CEM as a means of controlling overall trainset behavior in both collisions and derailments. If a truly high speed collision were to occur, the outcome regardless of trainset type would be catastrophic. Efforts must be focused on collision prevention and reduction of the frequency of such accidents as opposed to armoring trainsets at the expense of weight, impact on infrastructure maintenance and energy consumption.

The severity distributions developed are conservative in that consistently for every speed regime the Tier III trainsets are defined to perform significantly worse than the Tier II equipment. Differences in performance between the two trainset types can further be accessed through sensitivity analyses. Therefore Amtrak feels confident that the results as presented are reasonable for the basis of comparing the outcome of possible hazards categories that the equipment may be subjected to in the future.

# Attachment 6

# Detailed Risk Model Results

## 1.0 Introduction

The results presented in this Attachment were developed as a collaborative effort between Amtrak subject matter experts (SME), supporting technical consultants and support from the Federal Railroad Administration to develop a safety case for the operation of Tier III equipment on defined high speed zones within the Northeast Corridor at speeds above 125 mph and up to 160 mph. Several key assumptions were made in developing the scope of the risk model:

- The safety of Tier III equipment is considered equivalent to Tier I equipment based on the work product of the Railroad Safety Advisory Committee's (RSAC) Engineering Task Force (ETF), hence no risk calculations have been conducted for those operations that will be below 125 mph.
- Risk comparisons are based upon regulatory minimum requirements – that is Amtrak should not be penalized for going beyond the minimum safety requirements established by FRA regulations and should get credit for those actions and practices that improve upon the minimum federally mandated requirements.
- Assumptions on the generic performance of Tier III equipment are based upon the requirements developed within the RSAC ETF as specific details of the trainset design will not be known until after approval is sought.
- All future cases assume full application of PTC as required by current FRA regulations.
- Risk metrics chosen for safety comparisons between risk model analysis cases include:
    - Normalized accident rates *per million train miles*,
    - Breakdown of severities *per million train miles*, and
    - Estimates for consequences that include normalized injuries, fatalities and damage *per million train miles*.
- System safety for the complete operation on the NEC is considered.

The risk model was developed to calculate both linear and point risks based upon the hazard categories defined within Attachment 2. Risk is calculated within specific high speed segments for each hazard category and can then be summed up over a high speed zone or multiple zones. This level of granularity will allow Amtrak to use results from the risk model to prioritize and select an appropriate sets of risk reduction measures to close the safety gap that exists between continued operations with Tier II compliant equipment and Tier III equipment.

The starting point for the risk work was establishing the current (2012) baseline safety performance on the NEC, using accident and operational data for the period 2000-2012 the latest date that complete information was available at the start of this study. The model was then validated by comparison of predicted results from the model over a ten year time frame with actual accident history.

Once the model was considered validated, a series of sensitivity analyses were conducted to better understand the influence of selected input parameters on predicted results. The output of these analyses provided a sense of the confidence bounds applicable to model predictions, and was useful for setting appropriate goals for safety improvements. Finally the proposed future operations to meet Amtrak's service needs were analyzed to estimate the risks associated with mixed Tier II and Tier III operations as well as risks associated with future operation where the Tier II fleet is retired and the Tier III service operates with a significantly increased frequency.

## 2.0 Baseline Risk Results – Circa 2012

As detailed in Attachment 1, the Base Case is defined as the NEC as operated over the period 2000 – 2012, with Tier II Acela Express trains at speeds up to 150 mph and conventional Amtrak regional and commuter equipment. The input frequencies and consequences were collected and placed within a lookup table within the model based upon the work described in Attachments 2 through 5. The risk model calculates the risk by individual track in each segment, along with any point risks for each of the respective hazard categories defined. Risk is then summed from segment to segment through the complete high speed zone. There are eight high speed zones defined, six on the South side of the NEC and two on the North side. Table 6-1 provides the breakdown of high speed zones and number of high speed segments used in the model.

**Table 6-1. Breakdown of High Speed Zones on the NEC**

| Zone and Segment Data | | | | |
|---|---|---|---|---|
| | | **MP** | **Length** | **No. Segments** |
| **South Zone 1** | Elmora | 14.6 | **38.6** | **20** |
| | Islin | 23.6 | | |
| | Lincoln | 25.6 | | |
| | Near Curve 268 | 26.4 | | |
| | North of Edison | 27.5 | | |
| | Ham | 56.3 | | |
| **South Zone 2** | Curve 281 | 59.5 | **20.5** | **11** |
| | Torresdale | 74.1 | | |
| | Curve 292 | 75.1 | | |
| | Bridesburg | 81 | | |
| **South Zone 2a** | Before Phil | 3 | **20.6** | **9** |
| | Darby | 5.4 | | |
| | Sharon Hill | 7.2 | | |
| | Landlith | 25.4 | | |
| **South Zone 3** | Ragan | 29.7 | **19.8** | **6** |
| | Bacon | 49.5 | | |
| **South Zone 4** | Past Bacon | 51.1 | **32.3** | **9** |
| | Curve 347 | 57.1 | | |
| | Grace | 60.6 | | |
| | Curve 361 | 86.9 | | |
| **South Zone 5** | Curve 361 | 86.9 | **37.7** | **11** |
| | River | 89.1 | | |
| | Bridge | 98.6 | | |
| | Curve 391 | 106.5 | | |
| | Sunny Run Road | 107 | | |
| | Landover N Ivy Cit | 134.6 | | |
| **North Zone 1** | N Curve 61 | 154.4 | **26.1** | **13** |
| | S Curve 47 | 180.5 | | |
| **North Zone 2** | Hebronville | 193.8 | **25.4** | **8** |
| | Readville | 219.2 | | |
| | | | **miles** | **Segments** |
| | **TOTAL** | | **221** | **87** |

Figure 6-1 is a plot of the linear risk calculated for a single high speed segment in South Zone 1 (between New York NY and Trenton, NJ). This shows the level of detail available to illustrate what level of detail was available to support informed choices about risk reduction strategies. The model predicts that 0.487 accidents will occur in a 10 year timeframe in this segment. The highest contributor to the risk in the segment is associated with obstruction collisions. The most likely track where such an event could take place is on the outside track (track 4) which is true for the other accident categories as well. The high speed tracks are tracks 2 and 3. This high speed segment is 2.1 miles long. This is a segment with high Amtrak Regional and commuter operations in addition to the Acela. The signal system in this area is a combination of ATC per Rule 251 on the outer tracks and Rule 261 in the high speed tracks.

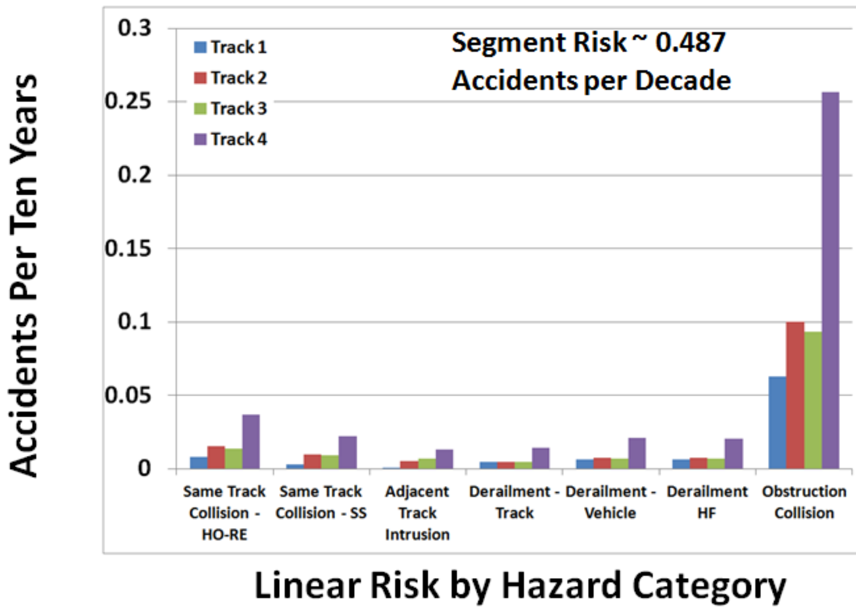



**Figure 6-1. Linear Risks Calculated in South Zone 1, High Speed Segment 4**

The output from the risk model after summation of both linear and point risks across the NEC in the defined high speed zones are shown in Table 6-2. The normalized accident rate is 0.306 accidents *per million train miles*. The risk model is also capable of estimating normalized accident rate by equipment type as shown in Figure 6-2. Tier III equipment (highlighted in red on Figure 6.2). The largest contribution to the risk is from freight operations, with a rate of 0.468 accidents *per million train miles*. This accident rate occurs despite the fact that freight makes up a very small percentage of the overall traffic volume on the NEC as shown in Figure 6-3, roughly 2% of the traffic. Total traffic volume on the defined high-speed zones is 98 million train miles over a decade of service.

**Table 6-2. Normalized Risk for the Baseline 2012 Operation on the NEC**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| Base case results | | | | | | | |
| All Zones Normalized | 0.295 | 0 | 0.308 | 0.301 | 0.322 | 0.478 | **0.307** |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | 0.143 | 0.114 | 0.033 | 0.008 | **0.123** | 0.000 | **41576** |

Table 6.2 also shows an overall severity distribution heavily weighted towards Severity Level 1 and 2 accidents with much smaller likelihoods of a Level 3 or 4 accidents. The predicted normalized injuries *per million train miles*, taken as a key metric for purposes of the safety case, is 0.123. The calculated normalized damage *per million train miles* is $41,576

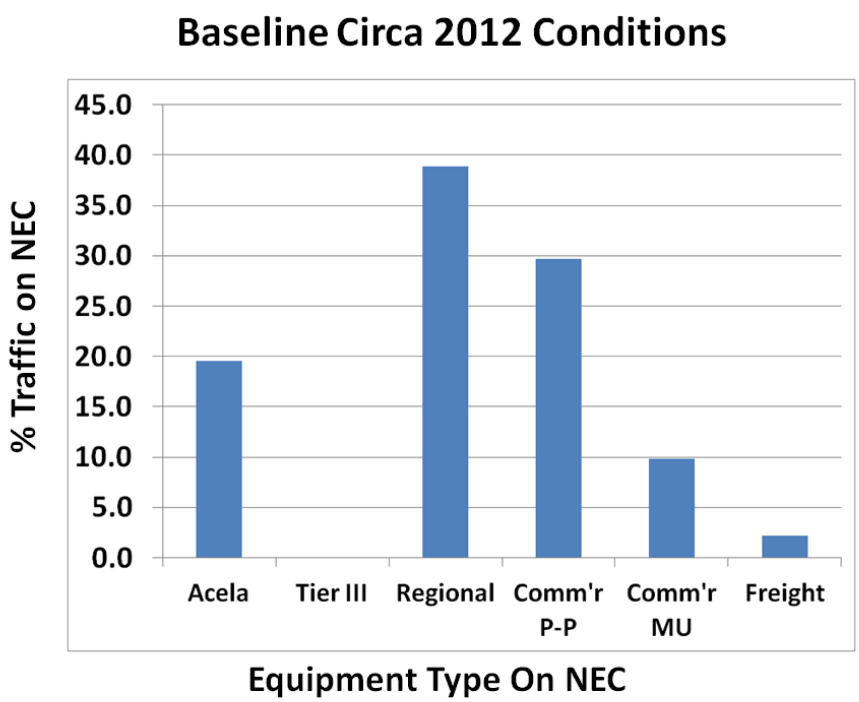



**Figure 6-2. Breakdown of Traffic on the NEC by Equipment Type**

Figure 6.2 illustrates the percentages of train-miles operated in the defined high-speed zones, showing clearly the small percentage of total traffic represented by freight operations. Amtrak regional services make up the largest percentage of train-miles

It is also instructive to look at the variations in accident frequency as a function of high speed zone, as shown in Figure 6-3. Naturally, risk varies from zone to zone with accident frequency varying from a low of 0.23 to a high of 0.35 accidents *per million train miles*. This variation corresponds roughly to variations in traffic density on these zones, likely because traffic density means more intensive maintenance-of-way activities and more complex operations. This information is very useful when reviewing potential risk mitigation strategies, as it can provide a means for choosing specific locations for site improvements. Any mitigation that targets high-risk segments, as recommended for right-of-way segregation, will tend to narrow these variations. However, operations on the NEC have been very successful and safe to date despite this variation.

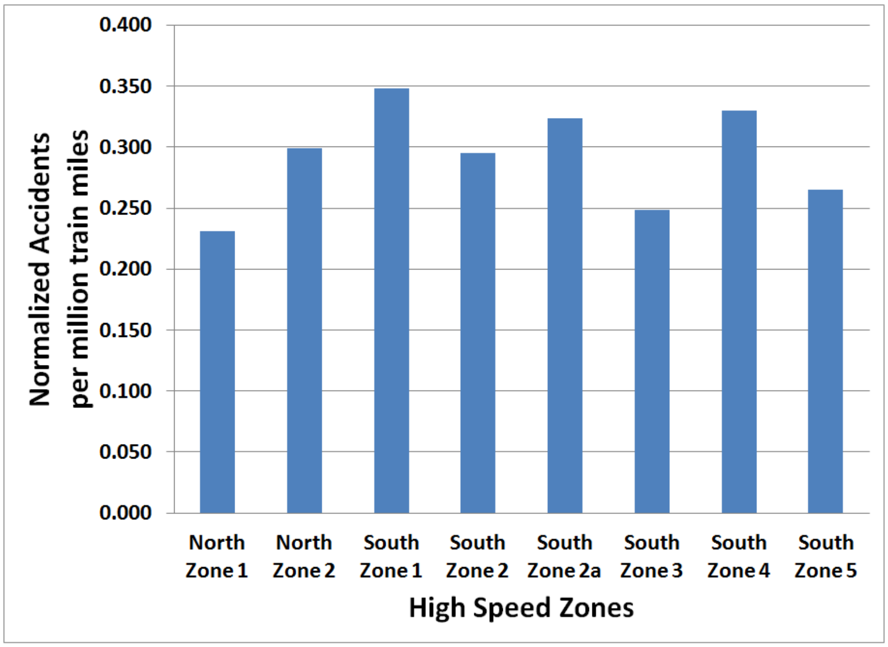



**Figure 6-3. Variation in Risk Profile for Base Case Circa 2012**

## 3.0 Sensitivity Risk Analyses

Having completed the 2012 base case, a series of alternative risk analyses were carried out to understand for the affects of variation of key input parameters to the model. The following analyses were conducted to gain a better understanding on predicted impact on risk.

- Full implementation of PTC.
- Impact of 40% more Tier II (Acela) high speed-trains. The 40% figure corresponds to the proposed increase in high-speed service.
- Sensitivity to the volume of freight operations.
- Changes to infrastructure – ROW segregation, interlocking improvements, access spurs improvements.

One of the first cases to run was - full implementation of Positive Train Control as required by Congressional mandate and federal regulation. Modifications were introduced into the Zone and Segment sheet for the risk model and all existing signal system descriptions were updated to be fully PTC compliant. The results from the analysis are shown in Table 6-3. As expected the normalized accident rate *per million train miles* has dropped from 0.307 to 0.294. The normalized injury rate has also dropped to 0.114 from 0.123. This is roughly an 8% relative change in the predicted injury with respect to the original 2012 base case analysis. One of the key assumptions for the modeling effort was to include full compliance with PTC for all future cases.

**Table 6-3. Alternate 2012 Base Case Analysis with Full PTC Implementation**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| Full PTC only | | | | | | | |
| All Zones Normalized | 0.286 | 0 | 0.297 | 0.285 | 0.306 | 0.471 | 0.294 |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | 0.138 | 0.109 | 0.031 | 0.007 | 0.114 | 0.000 | 42305 |

In order to understand the impact of increased high-speed train traffic on the NEC a case was run with a 40% increase in current Acela traffic. The results from that an analysis is shown in Table 6-4. Interestingly the normalized accident rate *per million train miles* does not increase. The additional accidents that may occur due to the increased traffic are offset by the fact that a higher fraction of the train miles operated are subjected to more stringent inspection, testing and maintenance practices. Similarly, the injury and damage rates *per million train miles* decline slightly, due to the superior crashworthiness of Acela trainsets. The actual normalized accident rate for the Acela goes up slightly but when averaged over all traffic on the corridor there is little change to the overall accident rate. This is symptomatic of a large and mature operation. There is inertia to change.

**Table 6-4. Alternate 2012 Base Case Analysis with 1.4 Times Acela Traffic**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| 40% more Acela | | | | | | | |
| All Zones Normalized | 0.297 | 0 | 0.310 | 0.302 | 0.322 | 0.479 | 0.307 |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | 0.144 | 0.115 | 0.032 | 0.008 | 0.121 | 0.000 | 44870 |

Another way to look at the comparison of the2012 base case with the 2012 base case plus additional Acela traffic is to observe the change in the severity distribution predicted. Figure 6-4 is a bar chart showing this comparison. The distribution shifts slightly with an expected higher number of Severity Level 1 and Level 2 accidents and fewer Severity Level 3 and 4 accidents.

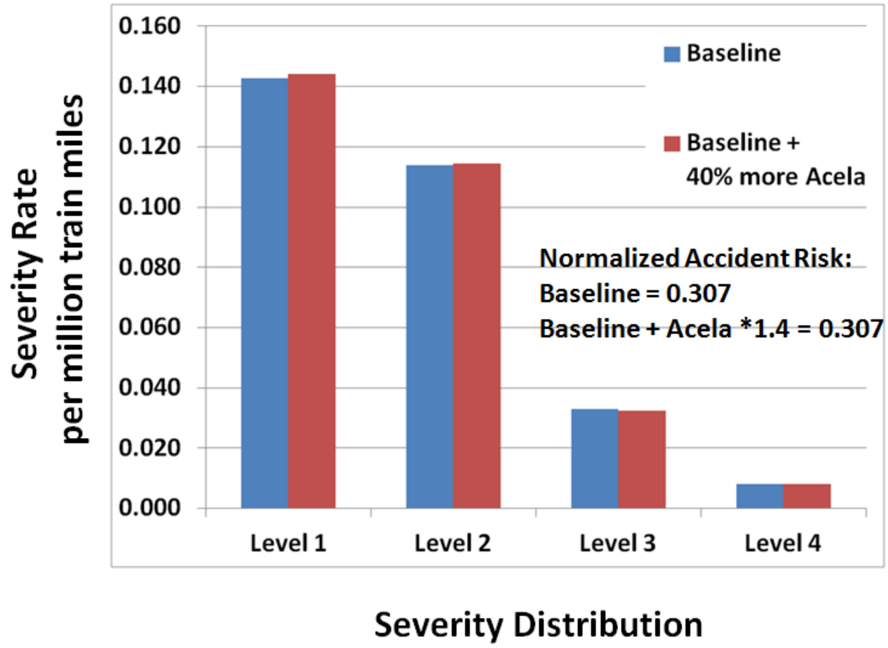



**Figure 6-4. Severity Distributions for 2012 Base Case and 2012 Base Case with 40% Additional Acela Traffic**

The next set of analyses conducted tested the impact on system risk as a function of the volume of freight operations. Four cases were analyzed: zero freight, base case freight, 2X freight and 4X freight. Table 6-5 lists the changes in accident rate by equipment type and overall on the NEC. Figure 6-5 is a plot of normalized accident rates *per million train miles* for the three conditions.

**Table 6-5. Freight Impact on Normalized Accident Risk, Base Case 2012**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| Base case results | | | | | | | |
| All Zones Normalized | 0.295 | 0 | 0.308 | 0.301 | 0.322 | 0.478 | **0.307** |
| Freight 0x case results | | | | | | | |
| All Zones Normalized | 0.294 | 0 | 0.306 | 0.299 | 0.321 | 0 | **0.302** |
| Freight 2x case results | | | | | | | |
| All Zones Normalized | 0.296 | 0 | 0.309 | 0.302 | 0.323 | 0.482 | **0.312** |
| Freight 4x case results | | | | | | | |
| All Zones Normalized | 0.299 | 0 | 0.311 | 0.305 | 0.324 | 0.489 | **0.321** |

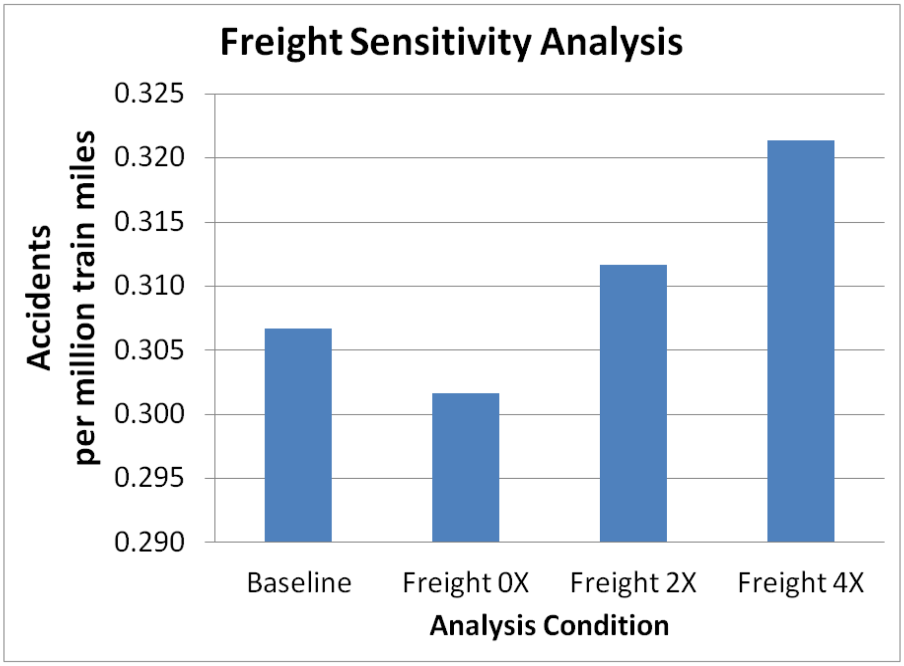



**Figure 6-5. Sensitivity of Result to Freight Traffic on the NEC – Base Case 2012**

Accident rates drop as expected with a reduction in the freight traffic. This change impacts the Amtrak Regional equipment and commuter service more so than it would the Acela, since the services normally operate on tracks shared with freight traffic. There is an increase in the accident rate as expected when the freight traffic is doubled and then quadrupled. However the relative difference with respect to the 2012 base case is approximately 1.5% and 4.5% respectively, indicating that freight does not have a substantive impact on the high speed operational risk. The effects of varying freight traffic volume on passenger train accident rates is very small, always being less than +/- 5%.

Other analyses conducted include impact on predicted risk for improving Right of Way (ROW) segregation and improving interlockings. Figure 6-6 is a comparison of all the analyses discussed so far. The biggest impact on the predicted risk is associated with improvements to ROW segregation. There is an improvement when interlocking condition is modified to the highest level but the risk reduction is small relative to the likely cost. This result obtained suggests that if upgrades to interlocking are planned for ride quality, or passenger comfort or durability, then these activities should continue but improving interlockings solely to reduce the accident risk is unlikely to be cost effective. The pattern observed in Figure 6-6 is preserved when additional analyses incorporate full compliance with PTC as shown in Figure 6-7. The results in Figure 6-7 for improving ROW segregation and interlocking condition assume implementation everywhere on the NEC is not likely to be practicable. Instead the results can be used to help with the prioritization of risk reduction strategies, including selection of the high-risk locations and segments for mitigation. Select choice of ROW segregation and other improvements is a good strategy to address the largest hazard category observed to date on the NEC: impacts with obstructions.

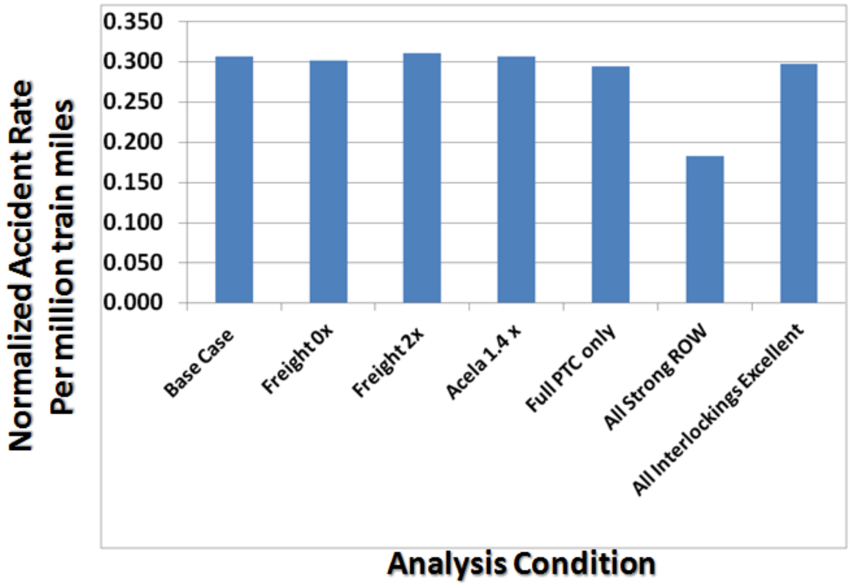



**Figure 6-6. Sensitivity Analyses for the 2012 Base Case – Impact on Normalized Accident Risk**

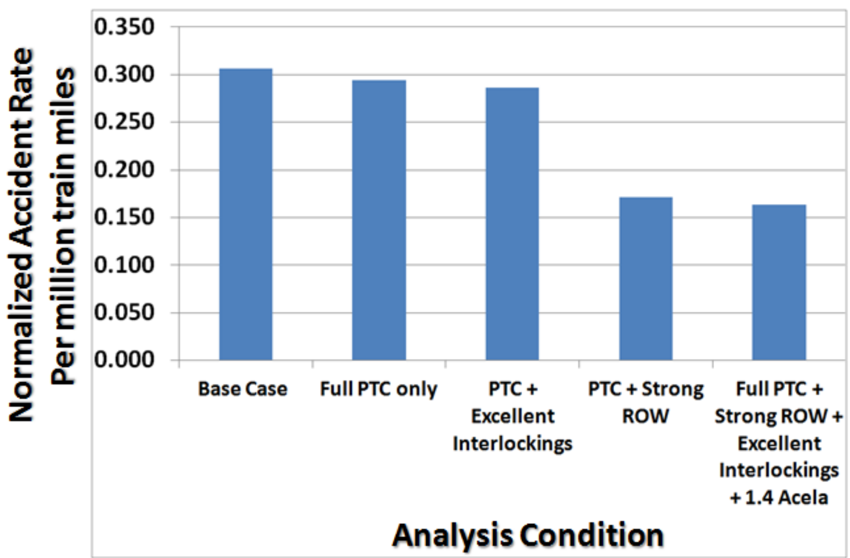



**Figure 6-7. Combination of Alternative Analyses with PTC as a Constant**

## 4.0 Future Case – Mixed Traffic Densities Circa 2020/2025

The following assumptions were made for all future cases:

a. Increased high-speed traffic, at two levels; an intermediate with mixing of trainset types and a final level with only Tier III equipment.
b. Positive Train Control is fully implemented (a regulatory requirement).
c. Commuter service remains the same as the Circa 2012 case.
d. Freight service remains the same as the Circa 2012 case.

The first future case has traffic representing operations in 2020/2025. The proposed traffic density includes increased usage of high speed Tier II trainsets to provide ½ hour peak service between New York and Washington DC while maintaining the current service between New York and Boston using only Tier II trainsets. The calculated normalized risk is shown in Table 6-6. This first case using the required traffic levels to meet the service defined is the regulatory null case. The regulatory null case assumes use of only Tier II equipment. The second future analysis case with the same traffic density is the mixed trainset operation case. Both Tier II and Tier III trainsets are used to meet the service required. This case helps define whether mixed operations present greater risk than the regulatory null case. The final analysis case with the same traffic density assumes a condition where only Tier III equipment is used. This case is necessary to assess if the mixed traffic case presents greater risk than an all Tier III operation. The traffic volume associated with this future case is 102 million train miles over a decade of service.

**Table 6-6. Normalized Risk for Future Case with ½ hr Peak Service from New York to Washington DC and Regular Service Between New York and Boston – All Tier II Trainsets**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **Future Base Case 1** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones Normalized** | 0.288 | 0 | 0.299 | 0.287 | 0 | 0.471 | **0.294** |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | 0.136 | 0.109 | 0.032 | 0.008 | **0.119** | 0.000 | **43845** |

The value of the normalized accident rate *per million train miles* is 0.294 and the normalized injury rate *per million train miles* is 0.119. These values have dropped below the base case representing 2012 base case (refer to Table 6-2 above). This is in part due to full implementation of PTC as well as increasing the percentage traffic operated by equipment that is inspected and maintained better than the conventional Tier I fleet, and is built to higher crashworthiness requirements. The derailment frequency due to equipment failures is 0.01 accidents *per million train miles* for Tier II equipment versus 0.015 for Amtrak Regional service and 0.02 for commuter equipment. Safer equipment operating for more mileage has a tendency to drive down the overall system accident rate. In this analysis case the Acela service comprises 23.8% of the traffic on the NEC and Amtrak Regional is 37.1%. Commuter operations account for nearly 37% of the traffic and freight is roughly 2% of the traffic. The change in the injury rate is roughly 2% better for this future case in comparison to operations from Circa 2012.

The next case analyzed was the future case with the traffic density just described but with a mix of Tier III and Tier II trainsets. The existing Acela trainsets remain in service and are supplemented by the new Tier III trainsets to meet the needs of more frequent service between New York and Washington DC. Existing Tier II equipment would continue to operate between New York and Boston at current traffic levels. The results from the analysis are shown in Table 6-7. This analysis case was run to assess if there is greater risk for the mixed operation when compared to either the "all Tier II Acela" regulatory baseline case just discussed, or a case when all services are operated with Tier III equipment. The value of the normalized accident rate *per million train miles* is 0.294 and the normalized injury rate *per million train miles* is 0.121. The accident rate is the same as the regulatory comparison case with Tier II equipment only at the same traffic level. There is a small difference in the injury rate predicted, but the relative difference with respect to the regulatory base case is small. The estimated consequences reflected by the normalized damage also increase slightly. When comparing the severity distribution between the two cases, note that there is a slight shift towards more severe levels for the mix of Tier II and Tier III trains.

**Table 6-7. Normalized Risk for Future Case with ½ hr Peak Service from New York to Washington DC and Regular Service Between New York and Boston – A mix of Acela and Tier III Trainsets**

| Future 1 - mixed service | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
|---|---|---|---|---|---|---|---|
| All Zones Normalized | 0.287 | 0.288 | 0.299 | 0.287 | 0 | 0.471 | 0.294 |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | 0.136 | 0.110 | 0.032 | 0.008 | 0.121 | 0.000 | 44469 |

The next analysis case conducted was traffic representing operations in 2020/2025 where there are increased Tier III high speed trainsets that provide ½ hour peak service between New York and Washington DC and that maintain the current traffic level between New York and Boston. The results from the analysis are shown in Table 6-8. This analysis case was run to assess if there is greater risk for the Tier III only operation when compared to either the projected regulatory baseline case just discussed. The value of the normalized accident rate *per million train miles* is 0.293 and the normalized injury rate *per million train miles* is 0.127. The accident rate is the same as the regulatory comparison case with Tier II equipment only at the same traffic level. There is an increase in the injury rate predicted, with the relative difference with respect to the regulatory base case just over 10%. The estimated consequences reflected by the normalized damage are slightly more as well. When comparing the severity distribution between the two cases, note that there is also a larger shift towards more severe levels for the Tier III-only case when compared to a Tier II only case at the increased traffic levels proposed. This demonstrates the presence of a safety gap between the two service types that will require application of risk reduction strategies to provide an equivalent level of safety as required by the safety case.

**Table 6-8. Normalized Risk for Future Case with ½ hr Peak Service from New York to Washington DC and Regular Service Between New York and Boston – All Tier III Trainsets**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| Future Case 1 - All Tier III | Acela | Tier III | Regional | Comm'r P-P | Comm'r MU | Freight | Total |
| All Zones Normalized | 0 | 0.285 | 0.299 | 0.287 | 0 | 0.471 | 0.293 |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | Level 1 | Level 2 | Level 3 | Level 4 | Injuries | Fatalities | Damage |
| | 0.133 | 0.110 | 0.033 | 0.009 | 0.127 | 0.000 | 46683 |

## 5.0 Future Case – Increased Traffic with All Tier III Trainsets Circa 2020/2025

The last set of analyses conducted to assess the presence of a safety gap from the proposed operation of alternative trainset types was conducted with the largest traffic densities provided by

Amtrak to meet the service needs required. This future case has traffic representing operations in 2020/2025 where there is an increase in the traffic density of high speed Tier III trainsets between New York and Washington DC to provide ½ hour peak service and between New York and Washington DC to provide hourly service. The results from this case are shown in Table 6-9.

**Table 6-9. Normalized Risk for Future Case with ½ hr Peak Service from New York to Washington DC and Hourly Service Between New York and Boston – All Tier III trainsets**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **Future 2 - No Acela - All Tier III** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones Normalized** | **0** | 0.285 | 0.302 | 0.278 | 0.305 | 0.473 | **0.293** |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | 0.133 | 0.110 | 0.034 | 0.009 | **0.128** | **0.000** | **47517** |

The regulatory basis for comparison for this analysis case assuming all trains are Tier II Acela's, is shown in Table 6-10.

**Table 6-10. Normalized Risk for Future Case with ½ hr Peak Service from New York to Washington DC and Hourly Service Between New York and Boston – All Tier II Trainsets**

| | Accidents per million train miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **Future 3 - All Tier II** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones Normalized** | 0.288 | 0 | 0.302 | 0.278 | 0.305 | 0.473 | **0.294** |
| | Accidents by Severity per million train miles | | | | Estimated Consequences per million train miles | | |
| | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | 0.137 | 0.110 | 0.032 | 0.008 | **0.119** | **0.000** | **43991** |

These analyses show differences in estimated risk over the complete NEC for the two different classes of equipment. The breakdown in traffic for this condition is roughly 30 percent high-speed equipment, 34 percent Amtrak Regional, 34 percent commuter traffic and 2 percent freight traffic. This equates to approximately 111 million train miles of traffic as compared to the analysis base case, circa 2012 which had 98 million train miles. The accident rates *per million train miles* are approximately the same. However the relative difference with respect to regulatory null case for normalized injuries is 7%. The relative difference with respect to the regulatory null case for normalized damage is 8%. The relative differences are calculated by taking the difference with respect to the regulatory null case and dividing by the average of the two cases considered. This is a typical means of presenting the information in risk analysis. A relative difference greater than zero for the risk metric of concern then represents the safety gap that may need to be closed by application of appropriate risk mitigation strategies. This relative difference is greater than that calculated for the mixed Tier II and Tier III equipment case.

## 6.0 Risk Mitigation Prioritization and Selection

The crashworthiness differences and potential impact on accident consequences as measure by normalized accident rate *per million train miles*, normalized injury *per million train miles* and damage *per million train miles* is the issue addressed by the risk analysis. The risk model was able to establish the difference in performance between Tier II and Tier III equipment using these risk metrics over the high speed zones defined for a proposed future operation that assumes ½ hr service between Washington, DC and New York, NY and hourly service between New York, NY and Boston, MA. This analysis case produced the largest relative difference in performance of the risk analysis cases analyzed for proposed future operations.

The lessons learned from conduct of a series of sensitivity cases on the base case, circa 2012 are summarized following the list of accident scenarios, starting with linear scenarios, then point scenarios and finally secondary accident scenarios looking at the sequence accident – obstruction of an adjacent track – secondary collision between intruding vehicles and an approaching train.

- **Head-on and rear-end train to train collisions.** These types of accidents are very rare with implementation of PTC, and therefore not much more can be done. However, collisions involving work equipment present a greater risk. Most are low speed and in work zones, but there is the chance of adjacent track fouling and a secondary collision. Mitigations involving roadway work practices, safety management and culture, CRM and similar would apply.
- **Sideswipe collisions.** These accident types include a mix of freight and passenger equipment. To date, there have been very few accidents of this type on the NEC and those that have occurred have been mostly minor in nature, caused by unsecured doors and similar events. Mitigations could include shifted load detection and inspections at freight access points, and mechanical inspection of passenger trains.
- **Track defect derailments.** Day-to-day track inspections are already very intensive. There are few accidents of this type, and 2 out of 3 from the historical accident review involved MOW activities – see comments under train-train collisions. In addition, Amtrak's forthcoming program of track improvements to improve ride quality may also yield modest safety benefits.
- **Mechanical defect derailments.** There are very few of these types of accidents and they mostly involve freight equipment. More comprehensive visual and/or automated freight car inspections at freight access points could reduce these accidents. So far freight derailments have not led to a secondary collision involving a passenger train, but the possibility exists and the model takes this into account. The benefits are likely small, but could be in line with the relative cost, if well located. The technology involved with automated inspections is maturing and Amtrak will continue to monitor progress for future implementation at an appropriate time.
- **Human factors derailments.** These types of derailments are very diverse and are mostly attributable to point risk events at access spurs. These are by far the most plentiful kind of derailments. The threat to trains operating on main tracks is a low-probability secondary collision after the initial event. Safety culture approaches are appropriate, but note that many of these accidents involved non-Amtrak operators.

- **Obstruction collisions.** Three categories exist for obstruction collisions.
    - The major category (about 50 %) involves objects that are an Amtrak responsibility – MOW equipment, materials, and other unsecured objects. These mitigations are very important, but involve more difficult-to-implement actions addressing work practices, safety culture, etc. Amtrak is implementing a significant safety culture improvement program and working on refining operational and MOW practices to address these concerns.
    - The second category is associated with obstructions following unauthorized access, where fencing and barrier mitigations apply (about 30%). The risk model shows prevention of unauthorized access as a leading risk reduction strategy.
    - The remaining obstruction accidents concern natural events– severe weather, fallen trees, animals on the ROW, and rock falls (about 20%). These hazards can be partially mitigated through regular infrastructure and ROW maintenance programs.
- **Point accidents at interlockings.** Mitigation is possible through improved interlocking materials and components, but yield modest benefits. Evaluation using the risk model suggests that interlocking replacements already planned will result in modest risk reduction. Interlocking replacement is not worthwhile only for risk reduction, but should be conducted as part of the ride quality improvement programs underway on a timeframe defined by available resources.
- **Point accidents at access spurs.** There have been several accidents of this type but no secondary accident involving trains operating on main NEC tracks. These accidents are predominantly human factors involving freight and (in one case) a commuter operator. Benefits from installation upgrades are likely to be small, but there is no reason to not make obvious, low-cost improvements that lower the risk of a low probability but potentially very serious accident.
- **Secondary collisions.** The model calculates secondary collision risks on main tracks due to either main line accidents (collisions and derailments) and/or access spur accidents. Estimated frequencies are very low (less than one accident in 10 years) but such accidents could become very severe. The risk calculation relies on two input parameters – the likelihood that the accident will result in an intrusion onto an adjacent track and the likelihood that an approaching train will collide with the intruding vehicles. The best approach to mitigate these types of events is to prevent the initial accident.

These observations, together with inputs from railroad engineering, mechanical and operations experts, have been used to identify candidate mitigations for high-speed Tier III operations. Among the various potential mitigations, one – improving the physical segregation of the NEC right-of-way to reduce the opportunity for intrusion – is attractive as it can readily be implemented in the short term and offers a high level of risk reduction. A series of analysis cases focused on estimating the risk reduction that would result from reducing the occurrence of obstruction accidents.

The first set of high speed segments chosen for improvement were based upon the visual inspections conducted to establish the current status of the NEC for Circa 2012 operations. Detailed notes and photographs were obtained from the Risk Focus Group members who rode the Amtrak

Geometry Car as well as review of the high definition video that was taken. Amtrak also contacted internal stakeholders to assess where there were locations on the NEC that were known areas of weak ROW segregation based upon observation, trespass reports or accidents. Table 6-11 shows the results from selection of 20 high-speed segments for ROW segregation improvement. These segments were chosen by running the risk model and varying each high speed segment with a weak ROW segregation value to strong and then sorting by the segments that provided the most risk reduction. This calculation assumes that approximately 30% of obstruction collisions are with objects introduced onto the NEC right-of-way from the outside, and thus almost all such accidents could be prevented by well-designed fences and barriers.

**Table 6-11. Selection of 20 Segments for Improved ROW Segregation – from Weak to Strong as Defined in Risk Model Inputs**

| | Accidents per million train-miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **20 Segments Weak to Strong** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones, Normalized** | **0** | **0.265** | **0.279** | **0.260** | **0.281** | **0.455** | **0.271** |
| | **Accidents by Severity Level** | | | | **Estimated Consequences Events per million train-miles** | | |
| | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | **0.124** | **0.103** | **0.035** | **0.009** | **0.123** | **0.00** | **45661** |

The second mitigation applied to address risks due to obstruction collisions with objects on the right-of way that are the responsibility of Amtrak maintenance-of-way forces or others carrying out legitimate activities on the right-of-way. Since the root causes of these obstruction collisions are highly diverse, the specific mitigations considered are a group of related measures aimed at improving overall safety of operations on the corridor, rather than trying to develop procedures to address each individual accident cause. These measures include a program to improve the safety culture among Amtrak employees and contractors, a close-call reporting system, and a system-safety program plan. To be conservative, Amtrak has assumed that these measures could result in a 20% reduction in this category of obstruction accidents.

**Table 6-12. Selection of 20 Segments for Improved ROW Segregation *PLUS* Implementation of Safety Culture Improvement and Related Programs**

| | Accidents per million train-miles | | | | | | |
|---|---|---|---|---|---|---|---|
| **20 Segments Weak to Strong** | **Acela** | **Tier III** | **Regional** | **Comm'r P-P** | **Comm'r MU** | **Freight** | **Total** |
| **All Zones, Normalized** | **0** | **0.243** | **0.256** | **0.239** | **0.258** | **0.418** | **0.246** |
| | **Accidents by Severity Level** | | | | **Estimated Consequences Events per million train-miles** | | |
| | **Level 1** | **Level 3** | **Level 3** | **Level 4** | **Injuries** | **Fatalities** | **Damage** |
| | **0.113** | **0.094** | **0.032** | **0.009** | **0.116** | **0.00** | **43062** |

Installation of fences and barriers on the 20 most-risky segments combined with programs to improve safety culture and system safety results in an overall reduction of 9% in normalized injuries and 16% in normalized accidents in the proposed high-speed zones. The reduction in injuries is more than enough to offset the increase in normalized injuries of 7% due to using Tier III trainsets instead of a trainset built to Tier II requirements, similar to the Acela trains currently operating on the NEC.

## 7.0 Summary

Amtrak is seeking approval of a Waiver Petition to FRA for operation of Tier III equipment on the NEC generally and at speeds above 125 mph and up to 160 mph in certain specific locations in order to meet future operational service needs. A successful petition must clearly demonstrate that the proposed operation is as safe as or safer than existing operations and in the Public's interest. Amtrak has identified investments that assure an equivalent level of safety through the development of a detailed comparative semi-quantitative risk model. The risk model is intended to be a tool which Amtrak can make informed decisions about both existing as well as future operations. The risk model will be maintained and updated with anticipated modifications to the infrastructure, signal system, rolling stock and operational and Maintenance of Way practices to further refine the risk profile on the NEC in areas where the Tier III equipment will be operated above 125 mph.

The risk model was developed using historical accident and operational data and validated through comparison with the actual history experienced between 2000 and 2012. Amtrak developed a team of internal subject matter experts and stakeholders to verify the inputs needed for the risk model and develop an appropriate set of hazard categories based upon the accident history. The risk profile of the NEC operations reflective of 2012 conditions was developed and a number of sensitivity analyses were conducted to assess impact on predicted normalized: accident rate, injury rate and damage rate *per million train miles* for different input parameter variations. Based upon the risk model results Amtrak was able to develop a process of identifying, prioritizing and selecting risk mitigation strategies for input into the risk model for proposed future operational conditions.

The process Amtrak used to demonstrate equivalent safety before and after introduction of Tier III equipment running above 125 mph and up to 160 mph on selected segments of the corridor involved the following steps:

1. Establish the current risk profile on the NEC using model inputs reflective of 2012 operations.
2. Run the model with inputs that reflect the state of the Northeast Corridor today making the assumption that PTC has been fully implemented. PTC will be required for future operations as congressionally mandated; hence this is the minimum regulatory comparative base risk case for current operations.
3. Run the model with Tier III Equipment traffic operating at speeds above 125 mph and up to 160 mph in selected segments of the corridor.

4. Rerun the model with only Tier II equipment under the same operating conditions and traffic levels with PTC implemented. The difference in risk calculated from the Tier III operations with the Tier II operation at the same traffic levels defines the safety gap.
5. Develop and prioritize - based on technical feasibility, cost and a judgment made by experts of potential risk reduction effectiveness - an inventory of possible risk mitigating actions.
6. Re-run the model for the case of Tier III equipment operating at speeds above 125 mph and up to 160 mph in selected high speed segments adjusting the model inputs to reflect implementing various combinations of risk reducing measures.
7. Compare the relative risk as calculated by the model of the selected risk reduction scenarios to the regulatory null base case risk. Scenarios are considered for implementation only if the model predicts a relative risk less than that of the regulatory null base case, i.e. the model predicts that the risk reduction scenario more than compensates for the increased risk of operating Tier III Equipment at speeds up to 160 mph.
8. Select the optimal risk reduction scenario based on feasibility, predicted cost, time required for implementation and effectiveness.
9. Execute a stakeholder engagement plan to inform affected stakeholders of the mitigations planned and work them to implement the mitigations.

Based upon the risk model results Amtrak was able to identify, prioritize and select risk mitigation strategies for input into the risk model for proposed future operational conditions. The following findings are drawn from the analyses:

***Finding 1:***

***Obstruction collisions are far and away the most numerous type of accident to passenger trains operating at speed on the NEC, and two groups of these accidents should be the first targets for risk mitigation:***

***1a: Implement a program of construction of fences and barriers to prevent trespass and highway vehicle access in the 20 most vulnerable route segments as indicated by the risk model and on-the-ground assessments.***

- These accidents comprise 30% of all obstruction accidents, and about 20% of all accidents involving passenger trains.
- Provided the fences and barriers are subject to good routine inspections and maintenance, Amtrak has high confidence that the majority of obstruction accidents in the selected segments can be prevented.
- The risk analysis indicates that extending a fence and barrier program beyond the most vulnerable 20 route segments is likely to be less cost-effective, and is not proposed.
- The fence and barrier program should remain flexible, however, as full details of the present status of fence and barrier systems in the high-speed zones were not available at the time of the risk analysis. The analysis should be updated when this information is available, followed by modification of the program as appropriate.

- Risk model results estimate that a fence and barrier program will reduce normalized train accidents from 0.293 *per million train-miles* in the Tier III base case to 0.271 *per million train-miles*, and injuries to passenger train occupants from 0.128 *per million train-miles* in the Tier III base case to 0.123 *per million train miles*.

***1b: Continue with and expand where possible an active system safety program addressing the diverse causes of obstruction collisions with Amtrak MOW equipment and materials, contractor equipment and materials, and miscellaneous objects.***

- These accidents comprise 50% of all obstruction collisions, and 35% of all accidents involving passenger trains.
- The risk model shows that reducing the occurrence of these accidents by 20%, combined with the fencing and barrier mitigation (conclusion 1a) reduced normalized injuries from 0.128 to 0.116 *per million train miles*, enough to offset all the increase of injuries from using Tier III trainsets in place of Tier II trainsets. The results from the regulatory null case predicted a normalized injury rate of 0.119 *per million train miles*. Relative to an all Tier III operation before mitigation, this is a reduction of 9% in normalized injuries and a 17% reduction in normalized accidents.
- Causes for these accidents are diverse, meaning that a program that emphasizes overall culture, CRM and general system safety procedures are appropriate, rather than trying to address individual accident circumstances.
- Amtrak is already working on system safety and safety culture initiatives. Amtrak will extend its Confidential Close Call Reporting System to the maintenance-of-way department with the cooperation of the Brotherhood of Maintenance of Way Employees Division (IBT) and Brotherhood of Railroad Signalmen. Amtrak encourages FRA to continue to support C3RS programs and requests that FRA evaluate this initiative at an appropriate time.
- An improved safety culture and system safety program will support reductions in all accidents where human factors are a root cause.
- As part of the System Safety Program Amtrak will monitor the reduction in accidents and close calls in the period prior to the introduction of Tier III train sets into service to ensure risk reduction goals are being met.
- As part of the System Safety Program Amtrak will monitor the reduction in accidents and close calls in the period prior to the introduction of Tier III train sets into service to ensure risk reduction goals are being met.

***Finding 2: Continue with initiatives aimed at reducing accidents to freight trains operating on the NEC, avoiding high cost actions.***

- The risk to passenger operations from freight trains accidents is of a secondary accident where a passenger train collides with derailed freight vehicles after an accident on an adjacent track.
- Model analysis and historical experience indicates that this risk is low, but is subject to substantial uncertainty:
    - The actual freight traffic volume is uncertain and could grow.

    - The model input parameters used in the secondary accident calculation are difficult to estimate. A sensitivity analysis making pessimistic assumptions (doubling the likelihood of an event, doubling the time to notify an approaching train and doubling the frequency multiplier on access spurs) about their value showed that the normalized accident rate increased by 4 percent and the normalized injury rate increased by 12 percent.
- The derailment rate on the NEC is higher than that typical of long distance intermodal freight on higher track classes.
    - This is a result, in part, due nature of freight traffic on the NEC, which is short haul and servicing industries or yards.
    - Freight traffic experiences frequent switching between tracks onto sidings increasing the chance for an incident when normalized by train mile.
    - Therefore continued attention to ongoing initiatives to reduce freight accidents is warranted.
- The specific risk mitigation initiatives applied by Amtrak are:
    - Extended use of on-board sensors to evaluate train performance and obtain early warnings of incipient track geometry issues.
    - Continued application of operating restrictions, use of traditional and advanced wayside detectors, and periodic visual inspections of freight equipment by Amtrak mechanical personnel.
    - Broader application of advanced inspection technologies.

***Finding 3: Continue with initiatives to reduce the risk of unintended intrusion on the NEC main tracks at access points, but limited to low cost actions.***

- The risk model shows that the risk of collision to a passenger train operating on a NEC main track is low.
- Some improvements are mandated in any case to bring the NEC into full compliance with PTC requirements.
- Specific initiatives are improved derailers, improving track quality in freight tracks adjacent to NEC main tracks, and others.

***Finding 4. Continue with track and interlocking improvements that are currently in progress or planned.***

- The risk of track-defect-caused accidents is already low, thus while there will be some safety benefits from these improvements, those benefits are not the primary reason Amtrak is undertaking those improvements, and no additional improvements are proposed in this petition.
- Accidents at interlockings mostly have human factors causes unrelated to track condition.
- The specific improvements planned or ongoing that are referred to in this recommendation are replacement of selected interlockings and a comprehensive undercutting program being undertaken to improve ride quality. Both are primarily concerned with improving ride quality

and reducing ongoing maintenance costs. Any initiative that reduces MOW activity will reduce accident risk, given the high number of accidents associated with roadway work.

Amtrak is now in possession of technical tool that can be updated as changes to the system are made to assess the reduction in risk. As ongoing infrastructure improvement activities are completed the model will be updated to reflect the “then-current” status of the NEC. Further as planned risk mitigations strategies are implemented these will also be updated in the risk model allowing Amtrak to gauge the change in the risk profile predicted for the high speed zones.

Amtrak will continue to monitor the changes in the risk profile before introduction of Tier III equipment onto the NEC, during the timeframe when there is overlap of the two different trainset types and on into the future as only Tier III trainsets are used at the highest traffic densities needed to meet service needs. The risk model developed is a tool that can, and will be updated when major infrastructure changes are implemented not related to the specific risk mitigation strategies agreed upon within the Waiver Petition enabling Amtrak to articulate to FRA the relative improvements in safety after completion of such work. The risk model can also be used as a means of justifying capital expenditures for future upgrades to funding sources.

Amtrak strongly believes that the results obtained from the analyses indicate that the proposed operation of Tier III equipment at speeds up to 160 mph on the NEC can be done safely through the implementation of cost effective risk reduction measures.

# Exemplary Northeast Corridor Accidents/Incidents 2000-2012 for Consideration
## Red text: Location in high-speed zone

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| | | | | **2012** | |
| 125627 | Industry (no record) | 6/20/2012 | MP 19.4 Claymont DE | H022 - Failure to properly secure engine(s) or car(s)<br><br>CLAYMONT STEEL (INDUSTRY) DERAILED 2 CARS AT THE CITY STEEL SWITCH AT MP 19.4.<br><br>Amtrak comment: It is believed that the cars were derailed by the derail prior to the main line switch. | Track etc. dmg. $15K<br>Equip. dmg. $2K |
| +125610 | NJT 201210619 | 9/29/2012 | MP 20.5 Rahway NJ<br><br>Tk. 1(5) | M402 (Obstacle fouling -- motor vehicle not at xing) (both records)<br><br>'TRAIN #7828 STRUCK AN OCCUPIED VEHICLE LOCATED ON THE SOUTHSIDE OF TRACK #1 FOULING THE TRACK THAT WAS TRAVELING WEST TOWARDS TRAIN. 1 INJURY, DAMAGED 1370. (Amtrak)<br><br>NJTR TRAIN 7828 OPERATING EAST ON 1 TRACK STRUCK AN OCCUPIED VEHICLE. DRIVER OF VEHICLE WAS A 92-YEAR OLD MALE. (NJT) | NJT Train 7828 at Rahway NJ MP 20.5 operating on Tk 1 (5) -- damage to NJT $17.4K |
| 124542 | MBTA 1500 | 7/5/2012 | MP 166.5 North Kingston RI<br><br>Stony Interlocking<br><br>Tk 1 (8) | H221 – Automatic block or signal displaying stop, failure to comply (both records)<br><br>MBTA TRAIN 8802 DERAILED WITHIN STONEY INTERLOCKING NHB MP166.5. TRAIN PASSED THE 3E SIGNAL ON #3 TRACK IN STOP POSITION AND DERAILED THE LEAD TRUCK ALL WHEELS CAB CAR # 1714 OVER 31 SWITCH. (Amtrak)<br><br>TRAIN #8802 OPERATING EAST TOWARD PROVIDENCE RI RAN THRU A STOP INDICATION AT STONEY INTERLOCKINGTHE ENGINEER REALIZED THAT THE TRACK WAS NOT LINED FOR HIS TRAIN AND STOPPED THE TRAIN WITHIN THE FROG. HE THEN SPLIT THE SWITCH ON THE REVERSE MOVE AND SUBSEQUENTLY DERAILED ON THE MOVEABLE POINT FROG. (MBTA) | Improper use of ACSES stop over-ride; serious potential<br><br>Improper adjustment of movable point frog may have been an additional condition of the event<br><br>Track dmg. $50K<br>Equip. dmg. $3K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 123345 | None | 3/29/2012 | MP 168 Davisville RI<br><br>Tk. 1(7) | H705 - Moveable point switch frog improperly lined<br>H605 - Failure to comply with restricted speed<br><br>HSR TRAIN 2171 DERAILED LEAD POWER CAR PC/2026 AT MP 168, DAVISVILLE.<br><br>Amtrak comment: At Davisville there was a switch failure and the switches had to be hand cranked by the maintainers. The train was stopped by the signals. The dispatcher was directly involved and both main tracks were involved. The train was given rule 241 permission by the stop signal by the dispatcher. This is the circumstance where the stop override switch would be used. The failure was that the maintainers gave the dispatcher permission to use a crossover that was not properly lined and the engineer in operating at restricted speed did not see or stop short of a switch not properly lined. | Track dmg. $133K<br>Equip. dmg. $64K |
| +122988 | None | 2/27/2012 | MP 98.5 Baltimore<br><br>Tk.1(7) | M404 (Object or equipment on or fouling track)<br><br>TRAIN 2104 OPERATING WITH LOCOMOTIVE E/2003 IN THE LEAD, 6 CARS AND E/2001 TRAILING STRUCK INTER-TRA'CK FENCE BETWEEN #1 AND #2 TRACK. THE SIDE PANEL DOOR ON POWER CAR 2003 WASNT PROPERLY LATCHED AND STRUCK THE FENCING. | Track dmg. $18.2K<br>Equip dmg. $2.1K |
| | | | | **2011** | |
| 122121 | SEPTA 11975 | 12/13/2011 | MP 87.9 Philadelphia<br><br>MP87.7, per SEPTA<br><br>2 SUB (5) | E69L - Other wheel defects (LOCOMOTIVE)<br>T223 - Rail Condition - Dry rail, freshly ground rail.<br><br>E79L – Other locomotive defects, describe in narrative (SEPTA)<br><br>SEPTA TRAIN 9745 WITH E/2302 AND 5 CARS DERAILED ENGINE UNIT 2302 WEST OF GIRARD INTERLOCKING ON TRACK #2 DUE TO FRESHLY TRUED WHEELS AND DRY RAIL. (Amtrak)<br><br>DERAILED AT INTERLOCKING, CREW TESTED (SEPTA)<br><br>Amtrak comment: The cause was the AEM-7 derailed on a short warp condition on SEPTA's property and landed on Amtrak's side of the line. The mitigating factors were the freshly trued wheels, and the suspension design of the AEM-7 that makes it derailment prone due to short warp. While this can be considered on the spine of the NEC it was not on the "Main Line trackage" of the NEC but on a connecting track through Zoo interlocking. Amtrak has a short warp standard, SEPTA does not. | Train speed 15 mph<br><br>Track dmg. $10K<br>Equip. dmgs. $60K |
| 121571<br><br>See, also, next item | MARC 121072 | 9/13/2011 (10:12a) | MP 100.5 Baltimore<br><br>Tk. 1(6) | M404 - Object or equipment on or fouling track, other (both records)<br><br>MACZ TRAIN 414 WITH 1 ENGINE AND 5 CARS STRUCK DEBRIS, DAMAGING ALL SIX UNITS. | Track dmg. $0<br>Equip. dmg. $3K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| +121083 | None | 9/13/2011 (10:20a) | MP 100.5 Halethorp MD<br><br>Tk. 3(7) | M404 – Object or equipment on or fouling track other<br><br>TRAIN 2109 WITH 2 ENGINES AND 6 CARS STRUCK DEBRIS, DAMAGING UNIT 2024. | Operating at 110 mph<br><br>Equip. dmg. $2M |
| 119677 | None | 5/9/2011 | MP 178.8 Warwick RI<br><br>Tk 3 (3) | T104 - Disturbed ballast section<br><br>WORK TRAIN EXTRA DERAILED BALLAST CAR C/11862 WHILE OPERATING OVER AREA OF PREVIOUSLY DUMPED BALLAST | Track dmg. $0.3K<br>Equip. dmg. $10K |
| +119240 | None | 3/25/2011 | MP 61.0 Have de Grace MD<br><br>Tk. 3(7) | M404 – Object on or fouling track, other<br><br>TRAIN 2121 STRUCK DEBRIS ON THE TRACK. | Train 2121<br><br>Equip. dmg. $19K |
| 118776 | On LIRR EQ20110201 | 2/7/2011 | MP 3.7 Queens (Harold)<br><br>Tk. 1(4) | H221 - Automatic block or interlocking signal displaying stop indication, failure to comply<br>H821 - Automatic cab signal, failure to comply<br>(both records)<br><br>TRAIN 2158 DERAILED LEAD UNIT 2007 AT 845 SWITCH AT HAROLD INTERLOCKING ON THE LONG ISLAND RAILROAD DUE TO OPERATING PAST A STOP SIGNAL.<br><br>Amtrak comment – Acela train in Harold interlocking – a misroute on east side of New York City. Crew involvement in event. | Track dmg. $0.03K<br>Equip. dmg. $46K |
| **2010** | | | | | |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 117649 | MBTA<br>1225 | 10/27/2010 | Boston<br>Tower One<br>(1) M | E64C - Worn Flange (Amtrak)<br><br>MBTA TRAIN 32 DERAILED ONE CAR ON AMTRAK TRACK IN BOSTON, MA. AMTRAK DETERMINED THE CAUSE TO BE A THIN FLANGE ON MBTA CAR 749, WHICH CAUSED SWITCH DAMAGE, WHICH CAUSED THE CAR TO DERAIL (Amtrak)<br><br>T314 – Switch point worn or broken(MBTA)<br><br>WHILE PROCEEDING EAST TO STATION ON TRACK 2 COACH #749'S LEAD AXLE WHEEL # 1 DERAILED WEST OF THE #32 SWITCH. THE DERAILED WHEEL TRAVELED SEVERAL FEET UNTIL CLIMBING BACK ONTO THE RAIL AT THE #32 SWITCH. ROOT CAUSE "STOCK RAIL OF SWITCH POINT 21A SLIP SWITCH WORN. PER CONVERSATIONS/EMAILS WITH AMTRAK THEY WILL USE CODE E64C. MBCR DOES NOT AGREE WITH THE PRIMARY CODE AMTRAK IS USING. SEE EMAILS WITH PAPER COPY OF REPORT. UPDATED 5.26.11 (MBTA)<br><br>Amtrak comments: There were four derailments at Tower 1, and this one was one of them. The cause is still under serious dispute between Amtrak, MBTA, and Volpe. The cause that Amtrak and Volpe agree on is a failed primary suspension on the Kawasaki bi-level cars. All four cars that derailed exhibited the same broken primary coil springs on a tear down inspection. Amtrak installed a home designed truck performance detector at Cove that found certain Kawasaki cars exhibited significantly higher L/V ratios than the normal population of vehicles. On inspection those cars were found to have broken primary coil springs like the cars that derailed. MBCR has a program in place to inspect cars for the broken springs and has been replacing them on a regular basis even though they dispute this as the cause. The switch points while worn were not broken, nor worn beyond any legitimate limits. | Appears to be issue limited to yards and terminals (i.e., very sharp turnout geometry)<br><br>Track dmg. $52K<br>Equip. dmg. $2.6K |
| 117620 | NJT<br>201010684 | 10/25/2010 | NYNY<br><br>Tk 2(1) | E68C - Loose wheel(both records)<br><br>NJT TRAIN 6621 WITH ENGINE 4424 AND 8 CARS, DERAILED A CAR ON AMTRAK TRACK DUE TO LOOSE WHEEL ON NJT CAR. (Amtrak)<br><br>TRAIN #6621 DERAILED ENROUTE THROUGH THE U-LADDER IN NYPS DAMAGING COACH #5315AND #5307 DUE TO WHEEL ON COACH #5307 THAT MIGRATED OUTWARD ON AXLE AND PICKED POINT ON FROG. (NJT) | Terminal event at 13 mph<br><br>1 passenger injury 55A found; claimed neck injury, sudden stop<br><br>Track dmg. $80K<br>Equip. dmg. $5K |
| 117576 | SEPTA<br>0909109112 | 9/9/2010 | MP 1.7<br>Philadelphia<br><br>Tk 4(2) | H404 – Failure to comply with mandatory directive (both records)<br><br>SEPTA TRAIN 541 STRUCK A PIECE OF RAIL BEING DRAGGED BY AN AMTRAK CONTRACTOR AT MILEPOST 1.7 ON TRACK 4 NEAR PHILADELPHIA, PA. (SEPTA similar / neither record explains the event) | Train operating at 25 mph, 3:23 p.m.<br><br>Equip. dmg. $9K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 117158 | None | 9/17/2010 | Philadelphia, Race St. Yard<br><br>Tk 25(1) Y | E69C - Other wheel defects (CAR)<br><br>WORK TRAIN CREW KN-716 SHOVING DRAFT OF 11 HERZOG HOPPERS DERAILED THE 5TH CAR C/6312 IN RACE ST YARD. DUE TO A VERTICAL FLANGE, THE WHEEL OF C/6312 LIFTED UP OFF OF THE RAIL CAUSING THE DERAILMENT. | |
| +116327 | NJT 201007420 | 7/1/2010 | MP 53.6 Hamilton NJ<br><br>Tk. 1(4) | M402 – Object or equipment fouling track (motor vehicle not at xing)<br><br>TRAIN #3806 STRUCK AN UNOCCUPIED VEHICLE FOULING TRACK #1 WHILE ENROUTE EAST ON THE NEC NEAR MP 53.6'CAUSING DAMAGES TO COACH #1394 AND THREE CREW INJURIES. (NJT)<br><br>NJT TRAIN #3806 STRUCK AN UNOCCUPIED VEHICLE THAT WAS FOULING TRACK # 1 CAUSING DAMAGES TO NJT C/139 (Amtrak) | 3 employees injured<br><br>Equip. dmg. $44K |
| +115654 | None | 5/6/2012 | MP 108.4<br><br>Tk. 3(7)<br><br>Linthicum MD | M501 – Interference (other than vandalism) with RR operations by a non-RR employee<br><br>TRAIN 2153 WITH POWER CAR 2009, 6 CARS, AND POWER CAR 2020 STRUCK A TRESPASSER AT MILEPOST 108.4 ON MAIN TRACK 3. POWER CAR 2009 SUSTAINED MAJOR DAMAGE. | Train 2153 at 108 mph<br><br>Equip. dmg. $25K |
| 114947 | None | 2/25/2010 | MP 9.0 Norwood PA<br><br>Tk 3(6) | M404 - Object or equipment on or fouling track, other<br><br>AMTRAK TRAIN 2151 REPORTED STRIKING TWO TRESPASER AT NORWOOD STATION ON 3 TRACK. BOTH TRESPASSERS WERE CONFIRMED FATALITIES. THE FRONT NOSE CONE OF POWER CAR 2038 SUSTAINED DAMAGE BUT REMAINED SECURE | Train 2151 operating at 108 mph<br><br>1 passenger injury (no 55A)<br><br>Equip. dmg. $22K |
| +114883 | None | 2/22/2010 | MP 222 Boston<br><br>Tk. 3(4) | H402 – On-track equipment rules, failure to comply<br><br>VACUUM TRUCK AU-18673 STRUCK THE REAR OF A RENTED VACUUM TRUCK NEAR BOSTON, MA. | 5:00 a.m.<br><br>1 employee injury<br><br>Equip. dmg. $57K plus $14K |
| **2009** | | | | | |
| +114039 | None | 12/4/2009 | MP 63.0<br><br>Tk. 4(7)<br><br>Aberdeen MD | M404 – Object or equipment fouling track, other<br><br>TRAIN 67 WITH ENGINE 920 AND 6 CARS STRUCK A LARGE TREE THAT WAS IN THE CATENARY AT MILEPOST 63. | Train 62 5:49 a.m. operating at 100 mph<br><br>Track dmg. $15K<br>Equip. dmg. $22.6K |
| 113400 | None | 9/23/2009 | MP 8.4 Guilford CT [sic; should be 89.4]<br><br>Tk 2(1) M | H607 - Failure to comply with restricted speed or its equivalent not connected with block/interlocking signal<br>H705 – Moveable point switch frog improperly lined<br><br>A TRACK EQUIPMENT MOVE CONSISTING OF A BRANDT TRUCK, A FLAT CAR, AND 4 HOPPER CARS, DERAILED WHILE MOVING OVER THE 24 SWITCH AT MEADOW INTERLOCKING. | Move at 5 mph 12:45 a.m.<br><br>Track dmg. $17.8K<br>Equip. dmg. $16K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 112551 | Conrail Shared Assets 054469 | 7/8/2009 | MP 65.3 Bristol PA (Grundy)<br><br>Tk 1 (6) | H702 - Switch improperly lined (both records)<br><br>CONRAIL FREIGHT WPBS-03 DERAILED 1 CAR WHILE OPERATING FROM O TRACK TO NO. 1 TRACK EAST AT GRUNDY. DERAILMENT OCCURRED ON WESTWARD SHOVING MOVE FROM 5 TRK TO O TRK RESULTING IN AN IMPROPERLY LATCHED HAND OPERATED SWITCH. SUBSEQUENT EASTWARD MOVE PULLED DERAILED CAR APPROX 1700 FEET CAUSING ALL OF THE RESULTING INFRASTRUCTURE DAMAGE. (Amtrak)<br><br>FP11 CREW WAS CROSSING OVER TRACK 5 TO TRACK "0" WHEN ONE CAR DERAILED TO PREVIOUSLY RUN THRU SWITCH (Conrail) | 5 mph derailment, but at 4:50 p.m.<br><br>Track dmg. $40K<br>Equip. dmg. $2.4K |
| +112484 | None | 7/2/2009 | MP 194.5<br><br>Tk. 2(7)<br><br>Attleboro | H402 – Motor car or on-track equipment rules, failure to comply<br><br>A JUNIOR TAMPER MACHINE A 11267 RAN INTO THE BACK OF A SWIVEL DUMP TRUCK AG 95399 AT MP 194.47 IN ATTLEBORO, MA. | 2:45 a.m.<br><br>Equip. dmg. $21.6K |
| 112413 | None | 6/22/2009 | MP 5.1 NYNY (Harrold)<br><br>NHV 1(3) | M406 - Fire, other than vandalism, involving on-track equipment<br>E59L - Other axle and journal bearing defects (LOCOMOTIVE)<br><br>TRAIN 55 WITH ENGINES 907 & 902 AND 5 CARS SUSTAINED A FIRE TO ENGINE 902 DUE TO A LOCKED #2 AXLE ON ENGINE 902. | Equip. dmg. $36.6K |
| 111771 | None | 4/28/2009 | MP 11.2 Newark<br><br>Tk 2 (2) | T110 - Wide gage (due to defective or missing crossties)<br><br>WORK TRAIN ENGINE DERAILED TWO WHEELS ON THE WEST END AXLE AT NEWARK AIRPORT STATION. A CONCRETE TIE BROKE WHERE THE RAIL IS CLIPPED WHILE THE ENG 772 WAS OPERATING OVER THE LOCATION. THIS CAUSED THE TRACK GAUGE TO WIDEN AND THE TWO WHEELS ON THE WEST END TRUCK DROPPED INTO THE GAUGE OF THE TRACK. | Derailment at 2 mph, but at 2:35 p.m.<br><br>Equip. dmg. $21K |
| +111443 | None | 3/26/2009 | MP 35.0 New Brunswick NJ<br><br>Tk 2(7) | M402 – Object or equipment fouling track – motor vehicle<br><br>TRAIN 172 WITH ENGINE 651 AND 7 CARS OPERATING NO. 2 TRACK STRUCK AN AUTO THAT WAS ABANDONED AND FOULING THE TRACK. | Train 172 1:10 a.m. at 120 mph<br><br>Equip. dmg. $47.4K |
| | | | | **2008** | |
| 110522 | None | 12/11/2008 | MP 93 Baltimore<br><br>Tk. 3 (7) | M402 - Object or equipment on or fouling track (motor vehicle)<br><br>TRAIN 175 ENGINE 657 OPERATING, STRUCK A MINIVAN FOULING THE WEST SIDE OF 3TRK AT MP93.45 | One injury reported, 55A found (broken hip, trespasser) |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
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| 113562 [number and date have been verified; may be late-reported] | MBTA 0730 | 9/18/2008 | Boston South Station<br><br>Tk 3 (1) M | M505 - Cause under investigation (Amtrak)<br><br>T314 – Switch point worn or broken (MBTA)<br><br>MBTA TRAIN # 614 OPERATING WITH THE CONTROL CAR 1716 IN THE LEAD, 6 CARS, AND E/1126 IN THE REAR, DERAILED 2 CARS AT MP228 SOUTH STATION TERMINAL. (Amtrak)<br><br>STUDENT ENGINEER AT THROTTLE, OFFICIAL ENGINEER ON RECORD TRACK MAINTAINED BY AMTRAK, INCIDENT UNDER INVESTIGATION. AT APPROXIMATELY 1:37 PM AMTRAK'S SOUTH STATION TERMINAL DISPATCHER REPORTED TO THE MBCR CHIEF DISPATCHER, SOUTH-SIDE, THAT TRAIN NO. 614, A REVENUE SERVICE, WHILE INBOUND TO TRACK 3 LEAD TOWER 1, DERAILED. IT WAS REPORTED THAT THE FOURTH CAR, #709 AND THE FIFTH CAR, #932, HAD DERAILED AT MILE POST 228. IT WAS ALSO REPORTED THAT THERE WAS A SMALL FIRE UNDER LOCOMOTIVE 1126 THATHAD BEEN EXTINGUISHED. THERE WERE NO EMPLOYEE OR PASSENGER INJURIES. PASSENGERS WERE DETRAINED THROUGH THE HEAD END DOOR WITHOUT INCIDENT. THERE WAS AMTRAK RAIL INFRASTRUCTURE DAMAGE AS WELL AS SIGNIFICANT DAMAGE CAUSED TO THE WHEELS AND TRUCKS OF CARS 709 AND 932. (MBTA) | One of the events near Tower 1 involving sharp turnout geometry and Kawasaki bi-level cars (see 117649)<br><br>Operating at 11 mph<br><br>Track dmg. $20K<br>Equip. dmg. $40K |
| 108181 | MBTA 0670<br><br>CSX | 3/25/2008 | MP 214 Canton MA<br><br>Tk 1 (8) | The probable cause of the accident was either failure to apply the handbrake on the rail car TTZX 864041 when the car was initially set-out at the Cohenno facility or that the handbrake was subsequently released at a later time. A contributing factor was an ineffective derail located at the Cohenno industrial spur. The derail located on the MBCR Stoughton Branch failed to derail the car prior to reaching the main track of the Stoughton branch.<br>FRA HQ-2008-33.<br><br>M599 - Other miscellaneous causes (Amtrak)<br><br>M507 – Investigation complete, cause not determined (MBTA)<br><br>MBTA TRAIN 917 WAS STRUCK BY A RUNAWAY FREIGHT CAR | 135 passengers and 3 employees injured when MBTA train was struck by runaway freight car<br><br>Track dmg. $3K<br>Equip. dmg. $876K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
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| 107558 | MARC 106955 | 2/7/2008 | W. Terminal<br><br>Tk 13 (1) Y | The probable cause of this collision is non-compliance with restricted speed. A contributing factor is the Conductor failed to give proper distances to the Engineer when backing up and also changed the method of communication, Radio communication to hand signals, without notifying the Engineer.<br>FRA HQ-2008-16<br><br>H607 - Failure to comply with restricted speed or its equivalent (both records)<br>H211 - Radio communication, improper (both records)<br><br>WHILE MACZ TRAIN 419, WITH CC 7852, 5 CARS AND ENGINE 4903, WAS ALIGHTING PASSENGERS, MACZ ENGINE 49<br>12 STRUCK THE REAR OF TRAIN 419, CAUSING CAR 7873 TO DERAIL. (both records) | Not reportable on 6180.54. Included because FRA published investigation report<br><br>8 passengers injured, 55a found<br><br>Impact was at 3:00 a.m.<br><br>Track dmg. $5K<br>Equip. dmg. $178K |
| 107409 | None | 3/13/2008 | MP 186.1 Providence | The National Transportation Safety Board determines that the probable cause of the March 13, 2008, accident involving a roadway work group that was struck by eastbound Amtrak Acela train 2154 in Providence, Rhode Island, was the foreman's failure to communicate critical changes made to on-track safety protection and to utilize all assigned trackmen as watchmen while working in a hot spot. Contributing to the accident was the watchman's failure to recognize that he was poorly positioned to perform his duties.<br>NTSB RAB0904 | Not reportable on 6180.54. Included because NTSB published investigation report<br><br>1 contractor employee fatal<br><br>2 employees serious<br><br>1 employee minor |
| 107219 | None | 3/2/2008 | W. Terminal<br><br>Tk 25 (1) M | FRA investigation results agree with Amtrak officials that the cause of the collision was a failure of the engineer to control the use of train brakes and failure to control the speed of the movement.<br>FRA HQ-2008-23<br><br>H099 - Use of brakes, other (Amtrak)<br><br>TRAIN 98 EQUIPMENT, CONSISTING OF 10 CARS, WAS OCCUPYING TRACK 25 AT WASHINGTON TERMINAL. ENGINEER ON SOUTH END OF LOCOMOTIVE E/659 WITH UTILITY CONDUCTOR ON GROUND GUIDING MOVE, ROUGH COUPLED AGAINST TRAIN 98 CONSIST AS A RESULT OF THE ENGINEER APPLYING THE THROTTLE WHEN HE SHOULD HAVE APPLIED THE BRAKE. | Not reportable on 6180.54. Included because FRA published investigation report<br><br>4 employees and<br>8 passengers injured<br><br>Track dmg. $00<br>Equip. dmg. $5K |
| 106738 | NJT 200801038 | 1/17/2008 | MP 54.1 Hamilton NJ<br><br>Tk 1 (5) | E29L - Other body defects, (LOCOMOTIVE)(both records)<br><br>NJTR TRAIN 3842 DERAILED CAR 1491 ON AMTRAKS MAIN TRACK #1. (Amtrak)<br><br>#3 AXLE OF MU #1491 DERAILED ON TRAIN #3842 ON THE NORTHEAST CORRIDOR AT MP 54.1 AFTER FAILURE OF HEATING TRANSFORMER MOUNTING BRACKET CAUSED TRANSFORMER TO DROP INTO GAUGE OF TRACK #1.<br><br>Amtrak comments: The heating transformer fell off of the MU car and got wedged under the axle and traction motor of the MU car derailing that axle. Area was showered with ballast stones and shards of disintegrating transformer windings. | Operating at 61 mph<br><br>Amtrak report shows 2 employees injured; 55A shows foreman and extra gang laborer, both with injuries due to rock thrown up by the derailment (days restricted 39 and 69 )<br><br>Track dmg. $80.5K<br>Equip. dmg. $37.4K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
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| 106719 | None | 1/15/2008 | MP 99.2 Baltimore<br><br>Tk 1 (6) | H104 - Employee asleep<br><br>BURRO CRANE TC58830 WITH TWO 20 TON CARTS SHOVING ON NO.#1 TRACK RAN INTO THE BACK OF A STOPPED WELDING TRUCK AJ25408 AT MP99.2. THE FOREMAN HAD INSTRUCTED THE OPERATOR OF THE BURRO CRANE TO STOP AT AUTOMATIC SIGNAL 993, BUT THE OPERATOR FAILED TO STOP AND STRUCK THE REAR OF THE TRUCK DUE TO OPERATOR FALLING ASLEEP. THE TRACK WAS OUT OF SERVICE UNDER FORM D AUTHORITY. THE RELATIONSHIP BETWEEN THE POSITIVE DRUG RESULT AND THE CAUSE OF THE ACCIDENT COULD NOT BE DETERMINED. | At 3:45 a.m., operating at 15 mph<br><br>Note employee asleep and positive drug test<br><br>Equip. dmg. $10K |
| **2007** | | | | | |
| 104956 | None | 7/14/2007 | MP 195.3 Attleboro<br><br>Tk 2 (7) | M402 - Object or equipment on or fouling track (motor vehicle)<br><br>TRAIN 82 WITH ENGINE 905 AND 7 CARS STRUCK 2 VEHICLES ABANDONED ON THE TRACK NEAR ATTLEBORO, MA. | Operating at 120 mph<br><br>Track dmg. $1K<br>Equip. dmg. $100K |
| 104866 | None | 7/3/2007 | Philadelphia Penn Interlocking<br><br>6 Walnut (5) | T299 - Other rail and joint bar defects<br><br>EQUIPMENT FOR TRAIN 607 (CABCAR 9646, 5 CARS, AND ENGINE 928) WAS BEING SHOVED SOUTHWARD AT PENN INTERLOCKING WHEN ENGINE 928 DERAILED. THE CAUSE WAS SHORT WARP ON RAIL 1 AND 11/16 INCHES WITHIN 10 FEET, BUT MEETS MW 1000 INSPECTION REQUIREMENT.<br><br>Amtrak comments: The committee for this derailment determined that the cause was again the AEM-7 vs. short warp. The comment that the condition met MW1000 criteria is partially wrong the short warp standard on Amtrak is 1.25" however there was an out clause that stated that it did not apply to track that did not carry revenue passenger trains. This derailment caused that exception to be removed from the standard. | Inspection criteria for track changed after this derailment<br><br>Track dmg. $4.5K<br>Equip. dmg. $41K |
| 103306 | None | 1/17/2007 | MP 38.4 Newark DE<br><br>Tk 2 (6) | E62C - Broken plate<br><br>TRAIN 90 WITH LOCOMOTIVE 927 AND 6 CARS STOPPED IN EMERGENCY DUE TO A BROKEN WHEEL ON CAR 25085. | Operating at 110 mph<br><br>Equip. dmg. $205K |
| **2006** | | | | | |
| 103050 | None | 12/18/06 | MP 83.5<br><br>Middle River MD<br><br>Industrial Track | H399 – Other general switching rules<br><br>KP705 WITH ENGINES 724 & 723 AND 3 MACZ CARS WAS PULLING NORTH ON A TRACK WHEN TWO OF THE CARS DERAILED. THE CREW FAILED TO REMOVE A WHEEL CHOCK AND RAN OVER IT, CAUSING THE DERAILMENT. THE RELATIONS HIP BETWEEN THE POSITIVE DRUG RESULT AND THE CAUSE OF THE DERAILMENT COULD NOT BE DETERMINED. | Non-revenue move operating at 6 mph on Track A, adjacent to track 1 (7)<br><br>Track dmg. $3K<br>Equip. dmg. $115K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
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| 102833 | CSXT 000027009 | 11/16/2006 | MP 121.5<br><br>Bowie MD<br><br>Tk. 1(6) | E07C - Rigging down or dragging (both records)<br><br>CSX TRAIN B70716 DERAILED 3 CARS DUE TO BRAKE RIGGING DOWN ON UNIT 392929 AND KNOCKING DOWN A CATENARY POLE. (Amtrak)<br><br>B70716 OPERATING ON AMTRAK DERAILED 3 CARS ACCOUNT OF BRAKE RIGGING DOWN ON CSXT 392929 AND KNOCKINGDOWN A CATENARY POLE.*** (CSXT) | CSXT derailment at 10 mph<br><br>Tk. Dmg. $426K<br>Equip. dmg. $32.4K |
| 102555 | None | 10/29/2006 | MP 158.8<br>Kingston RI<br><br>Tk. 1(8) | H403 - Movement of engine(s) or car(s) without authority<br><br>THE TRACK FOREMAN OPERATED TRACK CAR TC AA23776 OUTSIDE OF HIS AUTHORITY LIMITS AND ENTERED THE INTERLOCKING LIMITS ON TRACK 1 AT KINGSTON, RI. TRAIN 163 THEN STRUCK THE TRACK CAR. | Train 163, operating at 37 mph, 12:53 p.m., struck track car outside its authority<br><br>2 contractor employee injuries; 55a showed shoulder injuries<br><br>Track dmg. $1K<br>Equip. dmg. $32K |
| 102239 | None | 9/26/2006 | MP 26.6<br>Wilmington<br><br>Tk. 2(2) | T309 - Switch (hand operated) stand mechanism broken, loose [INCORRECT]<br><br>TRAIN 819, OPERATING WITH LOCOMOTIVE 911 AND 3 CARS, DERAILED THE REAR TRUCK OF THE LOCOMOTIVE. THE MOVEMENT AT WINE INTERLOCKING WAS A FACING POINT MOVE ACROSS THE NUMBER 12 SWITCH FROM 2 TO 2 TRACK ON AN APPROACH SIGNAL. THE LOCOMOTIVE WAS TRAVELING AT 26MPH WHEN IT RODE UP OVER THE SWITCH AND WENT 521 FEET BEFORE STOPPING.<br><br>[One locomotive derailed]<br><br>Amtrak comments: This was a special train operating against the normal current of traffic through the number 12 switch; cause was the classic AEM-7 vs. Short Warp condition. Train was routed through this not normal route due to late night operation and movements around MW outages. This is a power interlocked switch at Wine interlocking. The normal move through this switch is trailing northward and not seeing the short warp. | 1 employee injured; conductor, stress related syndrome; no lost time; 55a found<br><br>Track dmg. $15K<br>Equip. dmg. $22K |
| 101033 | MNCR 2006061412 | 6/14/2006 | MP 41.3<br>Norwalk CT<br><br>Tk 3(5) | T314 - Switch point worn or broken (both records)<br><br>TRAIN 93 WITH ENGINE 904 AND 8 CARS DERAILED THE ENGINE AFTER GOING OVER A SWITCH ON MNCW #3 TRACK NEAR NORWALK, CT.(Amtrak)<br><br>PROCEEDING 3 TO 1 WEST OVER THE 13B SWITCH AT CP241 AMTRAK 93 ENGINE 904 DERAILED. INCIDENT IS CLASSIFIED AS A SLOW SPEED WHEEL CLIMB DERAILMENT OVER THE REVERSE POINT OF THE 13B SWITCH. (MNCR) | Operating at 12 mph<br><br>Track dmg. $10K<br>Equip. dmg. $97K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
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| 101029 | None | 6/14/2006 | MP 91.4 Baltimore<br><br>Tk 1(7) | H302 - Cars left foul<br><br>TRAIN 1662 WITH ENGINE 664 AND 2 CARS STRUCK THE UNDERCUTTER (A14909) THAT WAS FOULING NO.1 TRACK WHICH CAUSED TRAIN 1662 AND THE UNDERCUTTER CONSIST TO DERAIL.<br><br>Amtrak comment: Undercutter was brand new and had a manufacture defect in the locking mechanism for the bucket wheel. The crew parking the machine did not realize that the bucket wheel was unsecured when they left the machine. The wheel slowly swung out and fouled the adjacent track before being struck by the passing shop move. | No passengers on equipment, 9:30 p.m., speed 35 mph<br><br>3 employees injured on board (sprains, strains) .55A found<br><br>Track dmg. $150K<br>Equip. dmg. $900K + $300K |
| 100777 | MNCR 2006052003 | 5/20/2006 | MP 16.2 New Rochelle (MNCR)<br><br>Tk 1 & 3 (2) (MNCR) | T314 - Switch point worn or broken (both records)<br><br>TRAIN 66 WITH ENGINE 917 AND 6 CARS DERAILED THE LAST 2 CARS IN NEW ROCHELLE, NY, DUE TO WORN AND CHIPPED SWITCH POINT. (Amtrak)<br><br>AMTRAK 66 TRAVELING EAST THROUGH CP 216 ON THE NEW HAVEN DIVISION DERAILED WHILE LINED TK1 - TK3 ON THE 13A SWITCH. (MNCR)<br><br>Amtrak comment: This is on the spine of the NEC at the property line between Amtrak and MNCR at the east end of the Hell Gate Line, derailment happened wholly on MNCR property. | Shown as 3:45 a.m. at 15 mph<br><br>Track dmg. $300K<br>Equip. dmg. $97K |
| 100265 | NS 023892 | 1/20/2006 | MP 62.8 Aberdeen MD [Havre de Grace]<br><br>OLD LINE (M) | H020 - Failure to apply suff. number of hand brakes on cars (3 records)<br><br>NS CONSIST HO4 WAS PULLING SOUTH WITH 1 UNIT, 8 LOADS, AND 5 EMPTIES, WHEN ETCX 27641 ON COMSTAR LEAD ROLLED OUT AND STRUCK AND DERAILED 9TH AND 10TH CARS IN TRAIN. (Amtrak)<br><br>HO4 PULLING SOUTH WITH 1 UNIT, 8 LOADS, 5 EMPTIES, 1840 TONS, WHEN ETCX 27641 ON CONSTAR LEAD ROLLED OUT AND STRUCK AND DERAILED 9TH AND 10TH CARS IN TRAIN. (NS) | Old Line is a freight-only line that connects with Track 2 at Oak.<br><br>Track dmg. $1.5K<br>Equip. dmg. $$8.8K |
| **2005** | | | | | |
| 099315 | None | 12/25/2005 | MP 114.9 Odenton<br><br>B Track (1) M | M502 - Vandalism of on-track equipment, e.g., brakes released<br><br>DRAFT OF 14 AMFLEET CARS ROLLED SOUTH FROM B TRACK TO THE SOUTH END SPLIT/RAIL DERAIL RUNNING OVER S<br>AME. THE FIRST 4 CARS WERE DERAILED. VANDALS REMOVED HAND BRAKES FROM SOUTH END OF 14 CAR DRAFT. | Track dmg. $30K<br>Equip. dmg. $25K |
| 099203 | NS 023301 | 12/8/2005 | MP 74 Edgewood MD<br><br>Tk 3 (6) | E53C - Journal (roller bearing) failure from overheating (both records)<br><br>NS FREIGHT TRAIN 34A DERAILED 2 CARS AT MILEPOST 74.0. (Amtrak)<br><br>TRAIN 34A WITH 2 ENGINES AND 42X67 CONSIST TRAVELING SOUTH DERAILED ON #3 AMTRAK MAIN. (NS) | NS train operating at 28 mph, 6:30 a.m., derailed 2 cars<br><br>Track dmg. $100K<br>Equip. dmg. $6.5K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
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| 097914 | CSX 000014629 | 8/23/2005 | MP 19 Bronx NY (Oak Point?)<br><br>Tk 5 (1) M | H503 - Buffing or slack action excessive, train handling (both records)<br><br>DUE TO IMPROPER TRAIN HANDLING, CSX TRAIN DERAILED ON CSX YARD TRACK AND THEN FOULED AMTRAKS MAIN LINE, CAUSING TRACK DAMAGE. (Amtrak)<br><br>BUFFING OR SLACK ACTION EXCESSIVE TRAIN HANDLING. TRAIN DERAILED ON CSX YARD TRACK, THEN FOULED AMTRAK MAINLINE FOR 24 HOURS CAUSING $60,000 TRACK DAMAGE FOR AMTRAK, AMTRAK INC#097914 AND $500 TRACK FOR CSX.** | CSX yard move at 3 mph derails and fouls Amtrak main<br><br>Track dmg. $60K<br>Equip. dmg. $36K |
| 097800 | None | 8/16/2005 | MP 208.6 [sic]<br><br>Mansfield, MA<br><br>Tk. 2 (6) | H401 – Failure to stop train in clear<br><br>BALLAST REGULATOR A14117 MADE CONTACT WITH TAMPER A10707 WHICH WAS STOPPED ON NO.2 TRACK AT MP203.6 IN MANSFIELD. | MOW equipment collision at 5 mph; 1:25 a.m.<br><br>3 injuries<br><br>Equip. dmg. $3.5K, but total dmg. Shown as $38.5K |
| 097383 | None | 7/9/2005 | MP 65.5 Aberdeen MD [actual location Bush River Bridge 71.8]<br><br>Tk 4(7) | E79L - Other locomotive defects<br><br>TRAIN 57, WITH LOCOMOTIVE 949 AND 5 CARS, STRUCK THE BUSH RIVER BRIDGE CAUSING DAMAGE TO THE BRIDGE, THE LOCOMOTIVE, AND 3 CARS. THE BATTERY BOX OF LOCOMOTIVE 949 BECAME UNSECURED BY FAILURE OF THE SAFETY BAR. THE BATTERY BOX THEN WAS EXTENDED OUT AND STRUCK THE BRIDGE. THE SAFETY BAR WAS COMPROMISED BY A DEBRIS STRIKE EARLIER IN THE DAY WHEN LOCOMOTIVE 949 WAS USED ON TRAIN 2253. | Train 57, operating at 110 mph, damaged bridge account insecure battery box<br><br>Track dmg. $45K<br>Equip dmg. $100K |
| 096093 | SEPTA 040505R005 | 4/5/2005 | MP 5.9 Darby PA<br><br>Tk 4(5) | M404 - Object or equipment on or fouling track, other (Amtrak)<br><br>M402 – Object or equipment on or fouling, motor vehicle (SEPTA)<br><br>SEPTA TRAIN 9231 STRUCK A PRIVATE CONTRACTORS BACKHOE NEAR DARBY, PA. (Amtrak)<br><br>BACKHOE OPERATOR CAME IN CONTACT WITH TRAIN CAUSING EXTENSIVE DAMAGE TO TRAIN. (SEPTA) | SEPTA train operating at 60 mph<br><br>1 passenger injury (leg sprain)<br><br>Equip. dmg. $10.5K |
| 095227 | NS 019809 | 1/11/2005 | ~MP 59-89 Perryville to Bayview Yd.<br><br>Tk 3(4) | E62C - Broken plate (both records)<br><br>NORFOLK SOUTHERN Z50 50TH CAR NS27859 (LOADED COAL HOPPER) SUSTAINED A BROKEN R-3 WHEEL, CAUSING TRACK DAMAGE NEAR PERRYVILLE, MD. (Amtrak)<br><br>TRAIN Z50 LOADED COAL TRAIN FOR BALTIMORE WITH 2 ENGINES AND 105X0 CONSIST, 14300 TONS EXPERIENCED A BROKEN WHEEL R3 ON LOADED COAL HOPPER NS 27859 CAUSING TRACK DAMAGE ON AMTRAK MAIN FROM PERRYVILLE, MD TO BAY. (NS) | NS train operating at 30 mph with 105 loads, at 2:00 a.m. experienced broken wheel (no derailment)<br><br>Track dmg. $43K<br>Equip. dmg. $0.5K |

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| | | | | **2004** | |
| 094407 | MNCR 2004102821 | 10/28/2004 | MP 71<br>New Haven<br><br>Tk 1(3)<br><br>3/1 CROSS-OVER | H299 - Other signal causes(Amtrak)<br><br>H704 – Switch previously run through (MNCR)<br><br>TRAIN 2191 PASSED BY MNRR CP271 WITHOUT A SIGNAL AND STOPPED WITH LEAD POWER CAR AND COACH 3201 OVER THE 13 SWITCH. AFTER RECEIVING SIGNAL FROM DISTRICT G, TRAIN 2191 PROCEEDED, WITH CONDUCTOR ON THE LEADING END, AND SHOVED EAST CAUSING COACH 3201 TO DERAIL DUE TO SWITCH LINED AGAINST MOVEMENT FOR TRAIN. (Amtrak)<br><br>TRAIN 2191 TRAVELING WEST ON TRACK 3 VIOLATED STOP SIGNAL. RAN THROUGH SWITCH AND MADE UNAUTHORIZED REVERSE MOVE RESULTING IN DERAILMENT. (MNCR)<br><br>Amtrak comment: The train did have permission of the DS to make the reverse move. All involved failed to take into consideration the condition of the run through switch. | Train 2191 derailed one car on MNCR switch<br><br>1 employee injured (37 days lost back strain) 55a found<br><br>Track dmg. $15K<br>Equip. dmg. $150K |
| 094099 | None | 10/1/2004 | MP 178.8<br>Warwick RI<br><br>Tk. 2(6) | E29C - Other body defects, (CAR)<br><br>MDZ SURFACING UNIT WITH 3 PIECES OF TRACK EQUIPMENT WAS TRAVELING WEST ON #2 TRACK, UNDER FORM D PERMISSION, WHEN THE REAR CAR DERAILED DUE TO TRANSFER CASE DROPPING INTO GAUGE OF TRACK. | Work equip. at 12:15 a.m., 20 mph, derailed one unit<br><br>1 employee injury (13 days lost, 31 restricted) per 55a<br><br>Track dmg. $110K<br>Equip. dmg. $110K |
| +093777 | None | 8/30/2004 | MP 152.3<br>Kingston MA<br><br>Tk. 2(5) | M404 – Object or equipment fouling track, other<br><br>TRAIN 2170, WITH PC 2034 AND PC 2032 AND 6 CARS, STRUCK DEBRIS AT MP 152.6, 6 MILES WEST OF KINGSTON, RI | Train 2170 at 20 mph<br><br>Equip. dmg. $63K |
| 092857 | None | 6/16/2004 | MP 77.6<br>New Haven<br><br>Tk 2(6) | H205 - Flagging, improper or failure to flag (Amtrak)<br><br>AMTRAK SHORE LINE EAST TEST EXTRA WITH ENGINE 6695 AND 3 CARS STRUCK 3 PIECES OF CONTRACTOR EQUIPMENT AT MP 77.6, EAST OF NEW HAVEN, CT.<br><br>Amtrak comment: The conductor, who was not used to providing this protection, assumed that a when the ET department took the power off the wire that the track was rendered unusable. Gave the contractor permission to occupy the track with equipment without providing a foul, track out of service, or notifying the dispatcher. A diesel powered extra train came up the line and struck the fouling equipment. | Test train hit contractor on-track equipment<br><br>1 contractor fatal<br>3 contractor injuries<br>1 employee injury<br><br>Track dmg. $8K<br>Equip. dmg. $60.5K |

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|---|---|---|---|---|---|
| 092111 | LIRR EQ20040402 | 4/19/2004 | MP 1.0 NYNY<br><br>Line 2 (3) | H222 - Automatic block or interlocking signal displaying other than stop, failure to comply (both records)<br>H605 - Failure to comply with restricted speed<br><br>TRAIN 183 WITH ENGINE 929 AND 6 CARS, OPERATING IN LINE 2, STRUCK THE REAR OF LIRR TRAIN 2099. THE ACCIDENT WAS CAUSED BY THE FAILURE OF THE AMTRAK ENGINEER TO COMPLY WITH THE REQUIREMENTS OF RESTRICT ED SPEED IN CONTROLLING THE MOVEMENT OF HIS TRAIN. (Amtrak)<br><br>TRAIN 183 WITH E/929 AND 6 CARS, OPERATING IN LINE 2, COLLIDED WITH THE REAR OF STOPPED LIRR TRAIN 2099, FAILURE OF THE AMTRAK ENGINEER TO COMPLY WITH THE REQUIREMENTS OF RESTRICTED SPEED IN CONTROLLING THE MOVEMENT OF HIS TRAIN. LONG ISLAND RAILROAD - EQUIPMENT WAS STRUCK FROM BEHIND BY AMTRAK EQUIPMENT. | Rear end collision, one car derailed, speed 10 mph, 2 55as<br><br>27 passengers injured (LIRR)<br>2 employees injured (LIRR), including one with 235 days restricted<br><br>2 employees injured (Atk) – bruises sprains, no lost time per 55a<br><br>Track dmg. $5K<br>Equip. dmg. $50K + $25K |
| +091185 | None | 1/24/2004 | MP 31.4 New Brunswick NJ<br><br>Tk. 2(6) | E29C – Other body defects (car)<br><br>TRAIN 146 OPERATING ON NO.2 TRACK SIDESWIPE TRAIN 19. THE WEST END BAGGAGE CAR DOOR OF CAR 1002 ON TRAIN 19 CAME OFF THE TRACKS AND SWUNG OUT, STRIKING CAR 44916 ON TRAIN 146. THE LEFT SIDE DOOR TRACK AND CAR BODY DOOR FRAME OF BAGGAGE CAR 1002 WAS BENT, WHICH ALLOWED THE DOOR TO DISENGAGE FROM THE TRACK, WHICH ALLOWED THE DOOR TO SWING OUT. | Train 19 at 110 mph, Train 146 also at 110<br><br>Equip. dmg. $4K + $10K |
| **2003** | | | | | |
| 090218 | NJT 200310763 | 10/31/2003 | MP 19.7 Rahway NJ<br><br>Tk A (4) | T315 - Switch rod worn, bent, broken, or disconnected (both records)<br><br>NJT TRAIN 3818 WITH 6 ELECTRIC MOTOR UNITS AND 6 ELECTRIC TRAILER UNITS DERAILED THE FIRST CAR. (Amtrak)<br><br>EASTBOUND COMMUTER TRAIN CONSISTING OF SIX (6) ELECTRIC MOTOR UNITS AND SIX (6) ELECTRIC TRAILER UNITS DERAILED 1ST CAR ACCOUNT HIGH SPEED SWITCH ROD BROKEN. LEAD TRUCK DERAILED. REAR (WEST) EIGHT ELECTRIC MU'S CUT AWAY FROM DERAILED PAIR, REVERSED WEST TO METRO PARK TO DISCHARGE PASSENGERS. NO INJURIES TO PASSENGERS OR EMPLOYEES. (NJT) | NJT train operating at 15 mph derailed first car<br><br>Track dmg. $1.5<br>Equip. dmg. $16K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 079010 | NJT 200307487 | 7/14/2003 | MP 5.8<br><br>Secaucus NJ | E53L - Journal (roller bearing) failure from overheating-<br>H218 - Failure to comply with failed equipment detector warning (both codes, both records)<br><br>NJT COMMUTER TRAIN 3920 DERAILED CARS 1359 AND 1368. THE NJT CREW FAILED TO PROPERLY PLACE TEMPILSTIK DURING INSPECTION, AFTER HOT JOURNAL ACTUATION AT EDISON, NJ (Amtrak)<br><br>EASTBOUND COMMUTER TRAIN CONSISTING OF SIX (6) ELECTRIC MOTOR UNITS AND SIX (6) ELECTRIC TRAILER UNITS DERAILED 6TH AND 7TH CARS ACCOUNT #2 RIGHT SIDE WHEEL BURNED OFF ON 6TH CAR. TRAIN WAS PREVIOUSLY INSTRUCTED TO STOP AND INSPECT FOR OVERHEADING OR ANY UNUSUAL CONDITION. (NJT) | NJT train operating at 69 mph derailed two cars, failed bearing, one car down embankment<br><br>16 passengers injured<br><br>Track dmg. $149K<br>Equip. dmg. $45K |
| 077678 | None | 4/10/2003 | MP 191.9 Attleboro<br><br>Tk. 1(8)<br>Tk. 2(6) | T104 - Disturbed ballast section<br><br>TRAIN NO.#66 OPERATING WITH ENGINE 948 AND 6 CARS REPORTED BALLAST WAS THROWN UP WHILE PASSING TRAIN NO.#2151 AT MP192, CAUSING DAMAGE TO ENGINE UNIT 948. (Same narrative, 2 records) | Train 66 operating at 85 mph at 5:40 a.m. received ballast strike while passing 2151, which was operating at 101 mph; clear weather, temp. 35 F.<br><br>Track dmg. $2K<br>Equip. dmg. $32K |
| **2002** | | | | | |
| 075253 | None | 9/22/2002 | ~MP 57-61 "Perry Hall MD" [sic]<br><br>Tk 2 (5) | H204 - Fixed signal, failure to comply<br><br>DURING TRACK MAINTENANCE BETWEEN PRINCE AND GRACE, MD, A BURRO CRANE, PUSHING TWO CARTS, DERAILED THE 2 CARTS WHEN THE OPERATOR PASSED A STOP SIGNAL. | Work equip. derailed 2 carts 5:00 a.m.<br><br>Track dmg. $42K<br>Equip. dmg. $15K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 073902 | MARC 073903 | 6/17/2002 | MP 95.9 Baltimore<br><br>Tk. 6(2) | The National Transportation Safety Board determines that the probable cause of this accident was the Amtrak engineer's loss of situational awareness in the moments before the collision because of excess focus on regulating train speed, which led to a failure to comply with signal indications. Contributing to the accident was the engineer's lack of familiarity with and proficiency in the operation of the diesel-electric locomotives assigned for the trip and the lack of a positive train control system.<br>NTSB RAB0301<br><br>H204 - Fixed signal, failure to comply (both records)<br><br>AMTRAK TRAIN #90 STRUCK MARC TRAIN #437 AT CHARLES INTERLOCKING OUTSIDE OF BALTIMORE, MD (Amtrak)<br><br>AMTRAK TRAIN #90 STRUCK MARC COMMUTER TRAIN #437 OUTSIDE OF BALTIMORE, MD. (MARC)<br><br>Amtrak comment: The NTSB report to some extent appears to miss the principal point. The issue here was an inexperienced engineer who worked the brakes on a down grade to the point of exhausting the air supply. A train control intervention at that point would not have been effective. | 4 employees injured (MARC)<br>1 employee injured (Amtrak)<br><br>1 passenger injured (MARC)<br><br>5 passengers injured (Amtrak)<br><br>Track dmg. $34K<br>Equip. dmg.<br>$2 million (MARC) and $150K (Amtrak) |
| 072947 | SEPTA 041202R003 | 4/12/2002 | MP 56.4 Trenton<br><br>FAIR INTERLOCK ING<br><br>Tk 1(1) M | E69C - Other wheel defects (CAR) (Amtrak and SEPTA secondary)<br><br>M599 – Other misc. causes (SEPTA)<br><br>SEPTA 7783 DERAILED IN TRENTON, NJ ON #1 TRACK AT FAIR INTERLOCKING WHEN PEDESTAL TIE STRAP AT WHEEL LOCATION L2 OF MULTIPLE UNIT SEPTA 339 SHOWED EVIDENCE OF SECUREMENT BOLT MISSING, ALLOWING STRAP TO DROP WHILE PASSING THROUGH MORRIS INTERLOCKING AND STRIKING THE C-3 ROD AT THE 21 SWITCH THAT CAUSED THE WHEEL TO LIFT UP AND OFF THE RAIL, AND DROOP AT THE HEEL BLOCK OF THE SWITCH. (Amtrak)<br><br>WESTEND TRUCK DERAILED (MU309) ON NO.1 TRACK AT FAIR INTERLOCKING. (SEPTA) | SEPTA train operating at 20 mph derailed one MU<br><br>Track dmg. $21K<br>Equip. dmg. $20k |
| +072183 | Conrail Shared Assets 051685 | 2/9/2002 | MP 16.8 Linden NJ<br><br>Tk. 2(2) | M205 – Oversized load, misrouted(both records)<br><br>TRAIN WPME10 STRUCK THE B&O OVERHEAD BRIDGE ON THE METROPOLITAN DIVISION, TAKING DOWN THE CATENARY POLES. (Amtrak)<br><br>WPME10 TRAVELING WITH MERX 000011, EXCESSIVE DIMENSION 10 DEEP TOOK DOWN CATENARY WIRES. (Conrail) | Track dmg. $100K |
| | | | | **2001** | |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| 071972 | CSX<br>110130024 | 11/25/2001 | MP 19<br>Bronx<br><br>Tk. 5(1)<br><br>Oak Point Yard | H704 – Switch previously run through<br>M503 – Vandalism of track or track appliances<br><br>CSX FREIGHT Y221 DERAILED 6 CARS AT OAK POINT YARD AND STRUCK TWO AMTRAK CATENARY POLES, KNOCKING THEM DOWN. | Track dmg. $5K |
| +071656 | None | 12/27/2001 | MP 213.9<br><br>Tk. 2(7)<br><br>Canton Junction | H702 – Switch improperly lined<br><br>TRAIN 174 WAS BEING OPERATED THROUGH CANTON JUNCTION WHEN THE ENGINE AND FIRST CAR DERAILED. | 16 mph<br><br>Track dmg. $0.3K<br>Equip. dmg. $84K |
| 071268 | MBTA<br>070759 | 10/22/2001 | Boston<br><br>Tk 1 (1) M | H216 - Interlocking signal, failure to comply (both records)<br><br>ENGINEER ALLEGEDLY RAN THROUGH STOP SIGN AT TOWER ONE INTERLOCKING IN BOSTON, MA (both records) | MBTA train passed signal at 10 mph<br><br>Track dmg. $25K<br>Equip. dmg. $00 |
| 069558 | None | 8/8/2001 | W. Terminal<br><br>42 Track Y | E49C - Other truck component defects, (CAR)<br><br>TRAIN 92 WITH 2 ENGINES AND 17 CARS DERAILED 2 CARS NEAR WASHINGTON, DC UNION STATION. | Derailment of revenue train at 12 mph, no injuries<br><br>Track dmg. $20K<br>Equip. dmg. /$65K |
| 068802 | None | 6/18/2001 | MP 62.7<br>Havre de Grace MD<br><br>Tk 3(4) | H499 - Other main track authority causes<br><br>A BMS (BALLAST MANAGEMENT SYSTEM) MACHINE WAS OPERATING AT MILEPOST 62.8 NEAR HAVRE DE GRACE, MD, WHEN IT STRUCK THE #43 SWITCH, CAUSING DAMAGE TO BOTH THE SWITCH AND THE BMS MACHINE. THE CAUSE WAS DETERMINED TO BE THE ABSENCE OF A GROUND MAN DIRECTING THE MOVEMENT. | Track dmg. $9K<br>Equip. dmg. $2.4K |
| +068364 | None | 6/2/2001 | MP 103<br>Halethorpe MD<br><br>Tk. 3(6) | M503 – Vandalism<br><br>TRAIN 103 STRUCK DEBRIS PLACED ON TRACK OUTSIDE OF BALTIMORE. | Train 143 at 90 mph<br><br>Equip. dmg. $7K |
| +067499 | NS<br>005179 | 4/12/2001 | MP 39<br>Newark DE<br><br>Tk. 2(6) | E79L – Other locomotive defects<br><br>TRAIN 56 WAS SIDESWIPED AT MILEPOST 39 NEAR NEWARK, DE, BY AN IMPROPERLY SECURED DOOR ON NS ENGINE 9463.(Amtrak)<br><br>HIGH VOLTAGE CABINET DOOR OPENED ON LEAD UNITS NS 9463 AS AMTRAK TRAIN 56 PASSED 12G WHICH WAS ON 1TRACK PASSED WITH NO CREW ABOARD. CABINET DOOR SCRAPED THE SIDE OF 5 CARS AND WAS KNOCKED OFF ITS HINGES. (NS) | Train 56 at 110 mph raking collision<br><br>Equip. dmg. $9.1K +0.5K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| +066759 | CDOT 066209 | 1/17/2001 | MP 84.9 Branford CT<br><br>Tk. 1(4) | M404 – Object or equipment on or fouling track, other<br><br>CDOT TRAIN 3604 STRUCK BOULDER EAST OF BRANFORD, CT STATION. (both records) | Track dmg. $1K<br>Equip. dmg. $1M |
| | | | | **2000** | |
| 064813 | P&W 000907 | 9/25/2000 | MP 129 Groton<br><br>West Leg Wye (1) Y | T314 - Switch point worn or broken (both records)<br><br>P&W TRAIN NR2 DERAILED ENGINE 2008 DUE TO SWITCH POINT PICKED AT GROTON, CT. (both records) | Clear of main? 10:30 a.m.. 9 mph<br><br>Track dmg. $8K<br>Equip. dmg. $00 |
| 064083 | Conrail Shared Assets 050849 | 9/6/2000 | MP 12.3 Newark NJ<br><br>Tk 3(1) M | T311 - Switch damaged or out of adjustment (both records)<br><br>CR FREIGHT TOMT DERAILED FOUR CARS WEST OF NEWARK, NJ. TRAIN UNDERPOWERED CAUSING TRAIN PRESSURE LIFT OFF OF 17TH HEAD CAR WITH REAR END RUN IN DUE TO INSUFFICIENT POWER TO ACCOMMODATE FOR GEOGRAPHICAL CONDITIONS ON A HILL. (Amtrak)<br><br>Q262 WITH 59 CARS DERAILED 16TH THRU 19TH HEAD CARS ON SIDE AND STRUCK AMTRAK C&S PICK UP TRUCK ADJACENT TO TRACK. NO INJURIES INVOLVED. CAUSE T311 - SWITCH OUT OF ADJUSTMENT. (Conrail) | Conrail at 1:50 a.m. at 10 mph with 58 loads & 1 empty derailed 4 cars<br><br>Track dmg. $120K<br>Equip. dmg. $21.5K |
| +063937 | NS 004378<br><br>MARC 064532 | 8/29/2000 | MP 75.4 Edgewood MD<br><br>Tks. 2&3(6) | E29C – Other body defects (car)<br>M299 – Misc. loading procedures (provide narrative)<br><br>METAL INFORMATION PLATE ON CAR CR607034 ON NS TRAIN SCRAPED SIDE OF MACZ TRAIN CAUSING DAMAGE TO OUTSIDE OF FIVE MACZ CARS AT EDGEWOOD, MD. MACZS INCIDENT # IS 064532.<br><br>METAL INFORMATION PLATE ON CAR CR 607034 ON NS TRAIN SCRAPED OUTSIDE - SIDE OF MACZ TRAIN CAUSING DAMAGE TO FIVE MACZ CARS AT EDGEWOOD, MD. (NS) | MARC train at 115 mph<br><br>Equip. dmg. $10K |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| +063876 | PW 000809 | 8/24/2000 | MP 106.0 Old Saybrook CT<br><br>Tilcon Siding | H303 – Derail, failure to apply or remove<br>H306 – Shoving movement, absence of worker on point<br><br>PW CREW SHOVED LOADED GONDOLA ICG246606 OVER DERAIL, DERAILING CAR. CAR THEN STRUCK A CATENARY POLE, KNOCKING IT FROM ITS FOUNDATION AT OLD SAYBROOK, CT. (Amtrak)<br><br>TRAIN NR-2 SHOVED 26 CARS OFF ON TILCON SIDING WITH THE HIND CAR GOING OVER THE DERAIL AND THEN CUTAWAY FROM CARS TO SERVICE ANOTHER CUSTOMER FURTHER DOWN THE TRACK. TRAIN NH-1 CAME INTO THE TILCONSIDING TIED ON TO CARS TO TAKE BACK TO NEW HAVEN, CT FOR CUSTOMERS IN THAT AREA. THE CREW OF NH-1 PULLED THE CARS ABOUT 10 RAIL LENGTHS WHEN THE ENGINEER SAW THE DERAILED CAR BOUNCING ALONG THE GROUND. THE ENGINEER PUT THE EMERGENCY BRAKES ON THE TRAIN AND THE CAR CAME TO REST UP AGAINST A CATANARY POLE FOR AMTRAK'S TRACK 3 AND SHEARED OFF THE FOUNDATION BOLTS SUPPORTING THE POLE AND BENT THE POLE ITSELF. THE POLE DID NOT FALL OR CAUSE ANY INTERRUPTION TO AMTRAK SERVICE. CREW MEMBERS OF BOTHCREWS WERE TESTED FOR CAUSE. (PW) | Track dmg. $85K<br>Equip. dmg. $1K |
| 063032 | NS 001806 | 6/25/2000 | Perryville South Leg Wye (1) M | E48C - Broken, missing, or otherwise defective springs(both records)<br><br>NORFOLK SOUTHERN TRAIN DERAILED DUE TO A END RIGHT SIDE LEAF SPRING ASSEMBLY OUT OF PLACE CAUSING TRUCK NOT TO SLEW PROPERLY AT PERRYVILLE, MD. (Amtrak)<br><br>NS23W PULLING WEST FROM AMTRAK NEC OVER SOUTH LEG OF WYE AT PERRYVILLE ON PORT ROAD BRANCH, WHEN 21ST HEAD CAR DTTX 54055 DERAILED A END. SUBSEQUENTLY TRAVELING 2.5 MILES AND RESULTING IN DERAILMENTOF 20TH AND 22ND CARS. DUE TO AR CORNER LEAF SPRING OUT OF POSITION ON DTTX 54055 RESTRICTING THE TRUCK ROTATION ON A END OF CAR. (NS) | NS move of 18 loads and 10 empties at 8 mph, 1:35 a.m. [CLEAR OF MAIN?]<br><br>Track dmg. $8.5K<br>Equip. dmg. $15.6K |
| 062044 | CSX 050030053 | 5/18/2000 | MP 197 Attleboro MA<br><br>Tk 4(1) (Amtrak)<br><br>MIDDLEBORO SEC 224 (CSX) | E34L - Draft gear/mechanism broken/defective (both records)<br><br>T199 – Other track geometry defects(CSX)<br><br>CSX FREIGHT TRAIN DERAILED ENGINES 6232, 5836, 9012 AND 9011 AT ATTLEBORO, MA (Amtrak)<br><br>SHOVING TRAIN ONTO MIDDLEBORO SECONDARY WHEN LOCO SCFX 9012 DERAILED, AND CAUSED OTHER 3 LOCOS TO DERAIL. PER EA FARR, NO DAMAGE TO THE 2 CSXT LOCOS BUT THE 2 SCFX LOCOS (SOUTHCOAST FLORIDA) WERE IN APREVIOUS DERAILMENT IN [CUT OFF – NOT COMPLETED] | At 3:30 a.m., 6 mph, CSX fgt. with 41 loads and 19 empties derails 4 engines<br><br>Track dmg. $8K<br>Equip. dmg. $00 |
| +062043 | None | 5/18/2000 | MP 14.5 NYNY<br><br>Tk. 1(6) | M404 – Object or equipment fouling track – other<br><br>TRAIN 133 STRUCK A TREE IN CATENARY AT HELLGATE, NEW YORK, NY. | At 90 mph<br><br>Equip. dmg. $19.2 |

| Amtrak Inc. # | Other RR? (inc. #) | Date | Location, 6180.54* | Cause/ Summary | Comment/casualties damage estimates |
|---|---|---|---|---|---|
| +061753 | None | 4/28/2000 | MP 82.2 Philadelphia<br><br>Tk. 2(5) | M503 – Vandalism of track or track appliances<br><br>TRAIN 124 STRUCK COFFING STRAPS HANGING FROM G ST BRIDGE AT PHILADELPHIA, PA. DUE TO VANDALISM. | Train 124 at 70 mph<br><br>Track dmg. $3K<br>Equip. dmg. $15 |
| 060546 | None | 2/23/2000 | MP 112.4 Odenton MD | T499 - Other way and structure defect<br><br>TRAIN 67 HAD PANTOGRAPH DAMAGE AT GROVE INTERLOCKING, SOUTH OF BWI, MD. STATION DUE TO BROKEN KUPLER COUPLER. | 1 employee injury for 1 day lost time, bruise or contusion to elbow, unexpected movement<br><br>[NOTED AS A RARE CASE OF INJURY ASSOC. WITH PANTOGRAPH/WIRE ISSUES] |
| | | | | | |

***Legend:** **M** **Main track (provided only where class of track is 1 or X)**
**Y** **Yard track**
**(1), (2), etc.** **Class of track (49 CFR part 213)**

## Stakeholder Engagement Plan

Early and effective stakeholder engagement will be a key part of the process that Amtrak will use to introduce the service contemplated in this waiver and the safety mitigation associated with it. Amtrak fully realizes the importance of stakeholder engagement planning and execution for smooth and timely introduction of the new service and the safety mitigations required to support it.

The table below identifies key stakeholders, anticipates the concerns these stakeholders may have and summarizes the key elements of Amtrak's engagement strategy for each of them. Stakeholder engagement will occur at various phases of the program. Amtrak plans to engage each stakeholder at the earliest point that is practicable. For some, that may include engagement during preliminary design. For others, it would be pre-construction engagement.

Stakeholder concerns will vary according to type of stakeholder (informative vs. actionable). Actionable stakeholders will have actionable tasks as part of their operations to ensure safety, and informative stakeholders need to be informed of Amtrak actions to improve safety on the NEC. These stakeholders need to be aware but don't necessarily have any actions to take.

If review and concurrence on implementation of risk mitigations is needed, then Amtrak will contact the stakeholders as soon as Amtrak identifies a specific potential action may be need to be performed by them. If Amtrak implements risk mitigations that improve conditions for all users on the NEC, prior to actual implementation, Amtrak will provide information will provided for situational awareness of stakeholders.

Amtrak has already implement portions of the stakeholder engagement plan. Amtrak included FRA staff and gave them complete and total visibility to the waiver development and to the quantitative risk assessment model development from the start of these efforts. Amtrak has started the process of engaging the internal Amtrak stakeholder – operating department and labor organizations.

### Summary of Amtrak's Stakeholder Engagement Plan

| Identified Stakeholder | Likely Concerns | Amtrak's Engagement Strategy |
|---|---|---|
| Freight Railroads that Operate on Corridor | • Safety risks associated with new equipment class.<br>• Implementation of mitigation strategies that impact their operations.<br>• Need for refined Emergency Response training and coordination.<br>• Potential for changed/reduced track access. | • Inform them of specifics of hazard analysis/risk assessment<br>• Inform RRs of risk mitigation strategies that do not require direct action from RRs<br>• Establish process to discuss actionable mitigations, review and approve jointly<br>• Refine existing Emergency Response contacts and protocols if necessary<br>• Continue to coordinate Emergency Response planning and drills |

| Identified Stakeholder | Likely Concerns | Amtrak's Engagement Strategy |
|---|---|---|
| Commuter Railroads that Operate on Corridor | • Safety risks associated with new equipment class<br>• Implementation of mitigation strategies that impact their operations<br>• Dispatching changes<br>• Need for refined Emergency Response training and coordination | • Inform them of specifics of hazard analysis/risk assessment<br>• Inform RRs of risk mitigation strategies that do not require direct action from RRs<br>• Establish process to discuss actionable mitigations, review and approve jointly<br>• Refine existing Emergency Response contacts and protocols if necessary<br>• Continue to coordinate Emergency Response planning and drills |
| Rail Transit that Operates Adjacent to Corridor | • Safety risks associated with new equipment class<br>• Implementation of mitigation strategies that impact their operations<br>• Need for refined Emergency Response training and coordination | • Inform them of specifics of hazard analysis/risk assessment<br>• Inform RTs of risk mitigation strategies that do not require direct action from RTs<br>• Establish process to discuss actionable mitigations, review and approve jointly<br>• Refine existing Emergency Response contacts and protocols if necessary<br>• Continue to coordinate Emergency Response planning and drills |
| Emergency Responders | • Safety risks associated with new equipment class<br>• Safety features of new equipment<br>• New training needs<br>• Changes in response protocols | • Meet to discuss and determine training needs and protocol changes<br>• Re-establish response protocols<br>• Provide training |
| Amtrak Labor Organizations | • New safety risks<br>• Impacts on work rules<br>• Who does what work<br>• New training needs | • Early involvement of labor organizations<br>• Listen to the concerns they express<br>• Address the concerns expressed<br>• Determine impact on work rules, who does what work and training needs<br>• Keep labor organizations informed |
| Amtrak Operating Departments | • Changes in responsibilities<br>• Operating impacts<br>• Staffing and training<br>• Inspection and maintenance of mitigations | • Early involvement in planning<br>• Define responsibilities<br>• Determine impacts and needs to meet them<br>• Resolve any conflicts |
| FRA | • Approval of waiver<br>• Waiver conditions<br>• Adequacy of safety case supporting waiver<br>• Implementation of safety mitigations<br>• Adequacy of stakeholder engagement | • FRA team involved in monitoring waiver development<br>• Complete transparency of the model used to make the safety case<br>• Safety case that anticipates FRA's major concerns<br>• Development of mitigations that go beyond equivalent safety<br>• Paying attention to stakeholder engagement |

## Tier III Next Generation High-Speed Trainset Project
## Project Benefits

While the project has significant commercial benefits to Amtrak, this project also strongly aligns with the public policy goals of the USDOT including investment in critical transportation needs. Today, A*cela Express* is America's high-speed rail service. Its continuing success validates the central thesis of the Administration's high-speed rail program that high-speed rail can be a safe, cost-effective, energy efficient and environmentally benign strategy for providing the intercity mobility needs that are foundational to a growing national economy and what Americans view as an important element of their quality of life.[1] The project will build upon *Acela Express'* success by providing reliable, higher capacity, expandable and more efficient equipment needed to meet the growing demand for high-speed rail service on the NEC for the next 30 years. The significant net financial benefits that flow from this project also places the nation's system of intercity passenger rail service on a more stable financial foundation.

- The project will result in a significant expansion of Amtrak's most lucrative line of business, the Acela Express, where capacity constraints are already limiting the ability of that service to meet intercity mobility needs and contribute to investment in critical infrastructure needs. The number of *Acela Express* seats will increase by 40% except during peak hours where the addition of half hourly service will increase the number of available seats by 180%.

- The project will generate an increase of approximately $2.4 billion in direct domestic economic activity between 2015 and 2021. This economic activity will create or preserve over 18,500 total jobs-years (both direct and indirect) over the next seven years, an annual average of over 2600, and over $230 million in additional Federal tax revenue.

- The project will enhance Amtrak's ability to invest in the NEC in addition to those funds made available through an uncertain annual appropriations process. These investments will support the infrastructure that hosts over 750,000 passengers each day who travel on Amtrak or one of the eight commuter services that rely on the NEC infrastructure. This aligns with section 9102 of the President's Grow America Act legislative initiative that proposes grants for returning the NEC to a state-of-good-repair and proposes using the operating surpluses of the NEC to help meet the capital needs of the NEC. When compared to the alternative of continuing to operate the existing trainsets, between $5 billion and $6 billion more of Amtrak's operating surplus will be

[1] See for example National Rail Plan Moving Forward, A Progress Report September 2010, U.S. Department of Transportation, Federal Railroad Administration, September 2010, pp 10-13

invested in the NEC over the next 30 years. Amtrak estimates that this investment will generate an annual average of over 2500 jobs (both direct and indirect) per year between 2025 and 2045 and total additional Federal tax revenues in excess of $860 million.

- The project will place an emphasis on recruiting and training veterans and those not traditionally represented in rail equipment manufacturing for jobs created as a result of this project. This aligns with the Administration's public policy goals concerning hiring of veterans including the Veterans Skills to Jobs Act and the VOW to Hire Veterans Act and has been recognized by non-governmental organizations such as Jobs to Move America.org.

- The project will provide an increase in domestic manufacturing for several years and help set the stage for increased competitiveness of U.S.-based manufacturing in the international high-speed rail marketplace. The equipment Amtrak seeks is service-proven and thus likely part of the existing marketplace for high-speed equipment. By manufacturing components for such equipment for Amtrak, domestic manufacturers would be positioned to offer such components internationally. This aligns well with the President's plan to revitalize American manufacturing.

- The project will significantly increase the value of the Secretary of Transportation's security interest in the NEC that flows from the USDOT's mortgage on Amtrak-owned portions of the NEC and the USDOT's lien on Amtrak's assets. A portion of these enhancements would flow from the capital investments in the NEC made at no cost to the Federal Government. In addition, the project would address a shortcoming in the Secretary's security interests in NEC operations. The USDOT's lien does not extend to 19 of the 20 total Acela trainsets specifically those that were financed commercially. As proposed, this project would provide the Secretary with a first lien on the new equipment, a very important part of the going concern value of the NEC since *Acela Express* service accounts for most of the NEC's operating surplus. When viewed from the going concern perspective, Amtrak estimates that this increase in value of the Secretary's security interest in the NEC would be in excess of $4 billion.

- The project is an economical way to increase the capacity of the Hudson River tunnels as an interim capacity enhancement until the Gateway Project is completed. The project does this by increasing the number of seats per *Acela Express* tunnel passage by 40% with the base configuration of the new trainsets and by nearly 100% if the options to expand the new trainsets are exercised By having the capacity to operate two trains in tandem (a capability not possessed by the current equipment), the number of seats per transit could increase to as many as 1200 (if Amtrak were to exercise the options to expand the new trainsets) vs. 304 seats in the current equipment which will provide Amtrak added flexibility in the event one of the tunnels is out of service for an extended period of time.

- The project will sustain and build on the impact that Amtrak's NEC services already have had in facilitating the development of sustainable, walkable communities where travelers have options other than single passenger automobiles. Stations served by *Acela Express* are among the most robust intermodal passenger transportation hubs in the country and have contributed to the revitalization of urban centers. The beneficial impact of Amtrak services would be expected to grow with the expanded *Acela Express* services.

- The project will improve the energy efficiency of *Acela Express*, reduce reliance on fossil fuels and lower emission of air pollutants, including greenhouse gases, resulting from intercity passenger travel in the congested Northeast Corridor. Based upon typical performance of modern high-speed trains and the current mix of sources of electricity for the NEC, the energy consumption and carbon emissions per seat-mile will be reduced by 28% when compared to the current equipment used for *Acela Express*, and be only one-third that of aviation. Of particular note is that approximately 30% of the electricity Amtrak purchases for NEC electric traction comes from low or no air pollutant emission sources (e.g. hydro and nuclear). In addition, approximately 8% of the electricity used by the trainsets will come from regenerative braking of the trainsets, turning unavoidable waste energy into useful power which is the ultimate source of green energy.

- The project will expand upon the proven ability of Amtrak's service to serve as a substitute for air service between congested airports in the NEC thus lessening the demands placed upon other programs of the USDOT. The FAA reports that four airports serving the south end of the NEC will need additional capacity by 2025 even with planned improvements. Indeed, airports in metropolitan areas served by *Acela Express* account for more than half of the national air flight delays. The project's ability to lessen the demand for aviation investments is demonstrated by Amtrak's share in 2012 of the combined rail/air market between Washington and New York City (76%) and between New York City and Boston (54%).

**Exhibit 5**
**Amtrak Petition Acela/160 and Tier III**

## Zone and Segment Data

| | | MP | Length | No. Segments |
|---|---|---|---|---|
| **South Zone 1** | Elmora | 14.6 | **38.6** | **20** |
| | Islin | 23.6 | | |
| | Lincoln | 25.6 | | |
| | Near Curve 268 | 26.4 | | |
| | North of Edison | 27.5 | | |
| | Ham | 56.3 | | |
| **South Zone 2** | Curve 281 | 59.5 | **20.5** | **11** |
| | Torresdale | 74.1 | | |
| | Curve 292 | 75.1 | | |
| | Bridesburg | 81 | | |
| **South Zone 2a** | Before Phil | 3 | **20.6** | **9** |
| | Darby | 5.4 | | |
| | Sharon Hill | 7.2 | | |
| | Landlith | 25.4 | | |
| **South Zone 3** | Ragan | 29.7 | **19.8** | **6** |
| | Bacon | 49.5 | | |
| **South Zone 4** | Past Bacon | 51.1 | **32.3** | **9** |
| | Curve 347 | 57.1 | | |
| | Grace | 60.6 | | |
| | Curve 361 | 86.9 | | |
| **South Zone 5** | Curve 361 | 86.9 | **37.7** | **11** |
| | River | 89.1 | | |
| | Bridge | 98.6 | | |
| | Curve 391 | 106.5 | | |
| | Sunny Run Road | 107 | | |
| | Landover N Ivy Cit | 134.6 | | |
| **North Zone 1** | N Curve 61 | 154.4 | **26.1** | **13** |
| | S Curve 47 | 180.5 | | |
| **North Zone 2** | Hebronville | 193.8 | 25.4 | **8** |
| | Readville | 219.2 | | |
| | | | **miles** | **Segments** |
| | **TOTAL** | | **221** | **87** |

# Risk Mitigations: Existing, Planned, Proposed

## Introduction

This Exhibit summarizes the risk mitigations, above and beyond Federal safety requirements, or consistent with but not specified by Federal requirements, that support a high level of safety going forward.

- ***Existing mitigations*** are those completed through 2012 (the end of the risk assessment base period).
- ***Planned mitigations***, some of which are already fully or partially competed, are post-2012 actions that are funded and will be completed as part of Amtrak's continuing efforts to improve safety on the NEC.
- ***Proposed mitigations*** are new actions conceived to support the proposed Tier III service. Most of these would be funded as part of the capital sought for the Tier III equipment acquisition.

Other approaches to risk mitigation that are not yet proven to be technologically feasible or cost effective are referred to here as ***potential opportunities***. Although there is no way to "score" potential opportunities in this context, and Amtrak does not seek to do so, it is important for FRA and commenters to understand that other approaches have been recognized and will be evaluated for usefulness and feasibility.[1] These efforts, both exploratory and practical, will be detailed in Amtrak's technology implementation plan under the forthcoming Risk Reduction Program. Although these efforts do not presently forecast the type and extent of further risk reductions, the trajectory of safety improvements enabled by applied technology is undeniably favorable.

Amtrak wishes to emphasize that the listed mitigations should not be viewed as the exclusive mitigations Amtrak will employ over the coming decades, during which Acela trains would operate at up to 160 mph and Tier III trains would be acquired to augment and eventually replace the existing Tier II fleet. Amtrak fully expects that changes in the traffic levels, service experience, insights from risk reduction programs, and opportunities presented by emerging technologies, among other factors, will lead to further improvements in safety over the period, just as the past decade has witnessed progress that could not have been foreseen at its beginning.

## Mitigations Organized by Objectives

### 1.0 Obstruction Collisions

[1] Amtrak is not able to accept conditions tied to specific "potential opportunities" and still proceed with the proposed projects. These concepts are still in the formative stage; and issues such as technical maturity, cost, reliability and ultimate effectiveness are not determined in such a way as to make them commercially feasible at this point.

As noted in the Risk Analysis Report, obstruction collisions[2] constitute the largest portion of the train accidents that occurred over the 2000-2012 period. Reducing these events will require better physical separation of the corridor from surrounding roadways and access paths, and better management of activities by Amtrak maintenance of way (MOW) personnel and contractors (including Amtrak contractors and third-party contractors performing work next to the railroad).

About 30% of obstruction collisions and 20% off all accidents involving passenger trains involve incursions of some kind from outside of the right of way. In some cases motor vehicles stray onto the railroad or may be deliberately placed there. In other cases, various forms of trash or other large objects are placed on the track structure. These weaknesses relate to deliberate incursions on the right of way, but also the potential for accidental incursions. Any significant obstacles introduced from outside the right of way onto high-speed tracks present the potential for derailment and possible secondary collisions. Given the operating speeds in the subject zones, it was observed that preventing incursion is likely a more effective measure than merely detecting the intrusion (which may come too late, given the frequency of train movements).

Improved physical separation using recognized industry standards (for highway or rail facilities, as appropriate) can often be achieved, and Amtrak's various departments have made strides toward this end in recent years (existing mitigations). At the same time, road authorities have improved guard rails on roadways. However, risk analysis conducted in support of the instant Petition noted a number of locations where physical separation is lacking, and in some cases accidents have occurred at the subject locations.

Two general strategies were identified for follow up. The first is erection of security fences at various locations along the NEC where trespassers might take the opportunity to place obstructions or otherwise endanger train movements. The second is erection of barriers, which might be sited on roadways or Amtrak property, to deflect motor vehicles that might otherwise stray onto the right of way and into the path of high-speed trains.

> **1.1 Proposed Mitigations/fencing and barriers:** Amtrak will install new fencing and/or barriers, as required by the circumstances, at locations in the 20 most vulnerable segments of the high-speed zones. Amtrak has provided FRA staff with details concerning the locations and treatments involved and has requested that the location information be treated as security-sensitive information (SSI) pending completion of improvements. The quantitative risk analysis model suggests that these mitigations should make significant contributions toward closing any risk gap between Tier II and Tier III equipment.[3]

Amtrak maintenance-of-way operations, while generally conducted with a high degree of safety, necessarily present a concern when they are conducted on or adjacent to a high-speed track. The potential for equipment to foul adjacent tracks during maintenance activity, the potential for work trains to derail on disturbed track, and the possibility that work equipment will stray outside its limits of authority all present practical challenges. Amtrak MOW forces currently do a good job of following the necessary rules and procedures, completing work safely—often during hours of darkness—despite the

[2] Most of these events are reported to FRA as obstructions, but some are also reported as "train collisions" even though MOW equipment (not moving as a train) is involved.

[3] Amtrak's right-of-way barrier plan, required under 49 CFR § 213.361(c), will be revised to include these improvements. The plan will be submitted to FRA for its approval.

difficulty.  Nevertheless, about 50% of the obstruction accidents during the study period involved collisions with Amtrak MOW equipment and materials, contractor equipment and materials, and miscellaneous objects.  The Risk Analysis Report indicates that reducing these events by 20%, when coupled with the fencing/barrier mitigations described above, would be sufficient, in combination with the fencing/barrier actions described above, to close the nominal risk gap.

**1.2 Planned Mitigations/C3RS:** Amtrak has recently opened talks with its employees represented by the Brotherhood of Maintenance of Way Employes Division (IBT) and the Brotherhood of Railroad Signalmen for establishment of a Confidential Close Call Reporting System (C3RS) program for the engineering department.  FRA research has verified the usefulness of C3RS programs in identifying precursor events and providing a context for resolution of underlying causes, while contributing to a positive safety culture.  In addition to helping address hazards of specific interest in this proceeding, C3RS programs can also assist in reducing non-train incidents that cause personal injuries.  Amtrak encourages FRA to continue to support for C3RS programs and requests that FRA evaluate this initiative at an appropriate time.

**1.3 Potential Opportunities:** Although Amtrak has an unusually strong record in providing for protection of MOW workers and their equipment using the strength of the traffic control system backed up by effective train control, it remains possible for MOW equipment to stray outside of established work zones or foul adjacent track.  Amtrak will include among its options for technology development possible means of reducing this potential through specialized collision prevention and/or electronic work order systems.

As part of the development and implementation of a revised system safety process, Amtrak will evaluate technology-based mitigations to reduce risk associated with roadway construction and maintenance activities on an on-going basis. An annual review of emergent technology will be conducted. The results of evaluations will be reviewed with the FRA at the high speed hazard review session.

**2.0 Derailment Prevention**

Derailment prevention is important for all classes of passenger and freight trains.  Increasingly robust FRA standards governing vehicle-track interaction, combined defects, and rail integrity, among other topics, are already contributing to reductions in derailment potential across the national rail system and on the NEC.  Additional approaches can augment the beneficial results of regulatory compliance.

**2.1 Existing Mitigations/hot bearing detection:** The steps Amtrak and its tenants are taking to reduce the potential for a freight derailment that might foul a high-speed track, as discussed below under 3.0, will in many cases also address concerns related to derailment of other passenger equipment on or adjacent to high-speed tracks.  In addition,

- All Amtrak equipment is either fitted with hot bearing detection, with exceptions presented to the locomotive engineer, or utilizes outside bearings that can be monitored on the wayside.  Although most commuter equipment does not have on-board hot bearing detection, those commuter cars with outside bearings are checked by existing wayside hot bearing detectors.

**2.2 Existing Mitigations/track geometry.** Technology to reduce track-related derailment risk, including the risk of derailment fouling high-speed tracks, is employed at a level exceeding Federal requirements:

- A crewed Track Recording car is operated over the high-speed route every two weeks. (The FRA requirement is once per month.) The success rate for the two week operation over a year is about 80%. The issues for not attaining 100% are weather (particularly in winter when snow prevents the effective operation of the track geometry car), failure of the track geometry car systems during a test, failure of the train to complete the journey, and reroute of the train off of the high speed route for various reasons.
- A crewed Track Recording car is operated over the Alternate Main tracks on the NEC every two months. (The FRA requirement is once every two months for Class 7 track, once per year, for class 6 track, and no requirement for Class 1 thru 5 track.)
- A crewed Track Recording car with Gage Restraint Measurement System technology is operated over every track in the NEC, including crossovers, yard and terminal trackage once per year. (The FRA requirement is that all Class 8 and 9 track is tested once per calendar year. There is no requirement for class 1 thru 7 track.)
- Autonomous Ride Meters (ARM) deriving data from accelerometers are used every day on 18 of the 20 Acela Trainsets, three Amfleet cars, and a Cab Car. (The FRA requires carbody acceleration measurements be taken on one vehicle operating at class 8 and 9 speeds four times within any 7 day period.)

**2.3 Existing Mitigations/rail integrity:** FRA's January 2014 final rule on rail integrity is strengthening internal rail flaw detection and rail management practices across the industry.[4] Amtrak measures to further reduce the chance of derailment and secondary collisions caused by rail failures include the following:

- Rail testing of the route of oil trains is performed at twice the federally mandated frequency, from twice annually to four times annually.
- In addition to the federally mandated twice a year "walking stick" rail test on the high speed turnouts and crossovers, all turnouts and crossovers are tested once a year with the walking stick.

**2.4 Proposed Mitigations/adjacent tracks:** Amtrak has identified four locations where tracks other than Amtrak-maintained running tracks are located adjacent to and within 25 feet (track centers) of high-speed tracks. FRA staff has called attention to the risk posed at such locations should a derailment occur that could foul a high-speed track. At these locations, regardless of the party currently performing maintenance, Amtrak will offer assistance or inducements such that the tracks are maintained to standards at least one FRA class above that corresponding to the maximum authorized speed, but not less than FRA Class 2. Amtrak personnel will inspect these tracks at the frequency required for the (elevated) class and type of service. Any impediments presented by owning/maintaining entities will be reported to FRA with a request for assistance in gaining cooperation.

[4] 79 FR 4234 (January 24, 2014); correction 79 FR 4633 (January 29, 2014).

**2.5 Proposed Mitigations/on-board systems monitoring:** Amtrak will extend its use of on-board sensors to evaluate train performance and integrity and to obtain early warnings of incipient track geometry issues.

- As noted above, Autonomous Ride Meters (ARMS) are already used on most Acela trains and certain other equipment. Looking forward, Amtrak plans the following:
  - The installation of ARMS units on the last two Acela trainsets; and
  - Inclusion of ARMS units or equivalent into the proposed new Tier III trainsets.
- In addition to the vehicle/track interaction monitoring focused on truck performance, the new trainsets will include gearbox monitoring, axle bearing health monitoring, hot box detection, and carbody monitoring. System and subsystem health will followed by a diagnostic system, and findings will be linked to the data recorder for traceability.

**2.6 Potential Opportunities:** Commuter authorities operating trains on the NEC can contribute to safety by equipping new rolling stock with on-board hot bearing detection, utilizing outside bearings, or both. Amtrak will encourage the commuter authorities to take advantage of this opportunity. Amtrak requests FRA support to encourage cooperation by other users of the NEC.

## 3.0 Freight-Related Hazards

Although freight-related risks did not rank toward the top in the quantitative risk assessment, Amtrak recognizes that this an area of considerable uncertainty, given the potential severity of an event, such as a derailment with secondary collision, involving a high-speed train and freight rolling stock. Accordingly, Amtrak has focused sharply, both in the past and during this investigation, on means of reducing these risks.

### 3.1 Existing Mitigations/equipment defect detection:

- Amtrak has understandings with Norfolk Southern (NS), CSX, Conrail-Shared Assets (CR), Connecticut Southern (CSO), Pan Am Southern (PAS) and Providence & Worcester (PW) permitting Amtrak mechanical personnel to conduct inspections for FRA and AAR defects, on selected trains bound for the NEC, on the freight railroads' property. These inspections are typically conducted monthly. Results of inspections are provided to the host railroad, contributing to verification and improvement of freight railroad inspection quality over time. Amtrak plans to continue this practice, adjusting inspection intervals as warranted by defect ratios encountered and freight safety outcomes on the NEC.
- Although not mandated, use of hot bearing and dragging equipment detectors is common across the national rail system. Amtrak has been particularly aggressive in utilizing these arrangements. In the most recent inventory, the following fully active detector locations were catalogued:
  - Between New York and Washington, 41 dragging equipment and 8 hot bearing locations; and
  - Between New Haven and Boston, 7 dragging equipment and 8 hot bearing locations.
- FRA research and development has hastened the introduction of advanced inspection technologies that can monitor the health of the freight car fleet and target interventions, often at an early and very effective stage. In addition to extensive use of traditional hot bearing and dragging equipment detectors on the NEC, Amtrak employs wheel impact load detector (WILD) technology at the following locations:

  Edgewood, MD Milepost AP75

Marcus Hook, PA Milepost AP 16.2
Monmouth Jct. NJ Milepost AN 40.8 (currently Out of Service due to High Speed track construction)
Rocky Hollow, RI Milepost AB 171.8
Mansfield, MA Milepost AB 201

An additional WILD installation was placed at Enfield, CT (Milepost AS 51.5) on the Springfield Line to control the entrance to the Shore Line at Mill River.

In addition, NS provides a "Gatekeeper" detector array at Marietta, PA on the Port Road. These include a HBD, Hot Wheel, Dragger, WILD, and over Dimension/shifted load detectors.

**3.2 Existing Mitigations/operating restrictions:**

- Freight train speeds on the NEC are limited by timetable to 50 mph
- Between New York and Washington, freight train speeds are further limited to 30 mph between the hours of 6:00 a.m. and 10:00 p.m.

**3.3 Planned Mitigations/equipment defect detection:** As part of a revised operating agreement, NS will add (construction to start this fall) an acoustic bearing detector on the NS Pittsburgh line at Denholm, PA ahead of Enola and Harrisburg Yards, and also hot bearing and dragging equipment detectors on the Delmarva and Delaware City Lines ahead of entrance to the NEC. These efforts will further contribute to identification of emerging issues before freight equipment enters onto the NEC.

**3.4 Potential Opportunities:**

- Amtrak is actively considering the use of acoustic bearing detection on the NEC.
- Amtrak has placed in service a strain gage installation at Cove Interlocking to evaluate truck performance that, if successful, may also have merit for use in territory with significant freight service.
- Amtrak and a freight partner are also exploring the possible use of light detection and ranging (LIDAR) or other advanced technology to detect shifted loads and other out-of-plate conditions at one or more freight entry points.

**4.0 Train-to-Train Collisions and Impact with Other Rail Rolling Stock**

Amtrak is completing installation of ACSES on the remainder of NEC (South End) tracks, and all trains will be required to be equipped before any relief is utilized in a high-speed zone. Although the ACSES system has functioned admirably to enhance safety, adjustments of equipment and operating procedures for use of ACSES remains an area where safety can be improved. As previously reported in responsive comments regarding Amtrak's petition for 160 mph authority for the Acela trains in Rhode Island, Amtrak is committed to working with its NEC partners to implement more secure procedures for use of the ACSES stop override button.

**4.1 Planned Mitigation/ACSES stop override:** The ACSES stop override button, which is already required to be located away from the engineer's normal position in the cab, will be sealed and monitored to ensure that it is employed only with express permission from the train dispatcher, in appropriate circumstances.[5] Verification of the device's security will be included in the daily locomotive or trainset inspection.[6]

As noted during the survey of current and potential high-speed territory, some risk may remain regarding switches off main track in high-speed territory where equipment might roll out, unsecured, or be shoved in the foul due to failure to protect the point of the movement or as a result of vandalism. These locations are primarily industrial sidings, but MOW bases and commuter maintenance locations are also of interest. Many potential locations are already protected by switches situated to divert the offending movement, while others are protected by split-point derails. However, at some locations only top-of-rail derails are in place. In every case, these arrangements are integrated with the traffic control system (e.g., though use of electric locks).

**4.2 Proposed Mitigations/protecting switches.** Amtrak has surveyed access points, and where strong protection is not already in place will install split-point derails or will supplement top-of-rail derails with "crowders" to ensure more effective protection. Placement of derails will be evaluated to determine if they are appropriately sited, given available space, grades, and other factors. For purposes of relief to operate Tier III equipment, FRA will be provided with a report upon completion of work in each high-speed zone, specifying locations and improvements completed.

As illustrated by the Canton Junction collision experienced by MBTA, control of train movements may not always eliminate risk related to impacts with rolling stock. Some of the exposure in this regard is under Amtrak's control, but much of it is not.

**4.3 Potential Opportunities.** Amtrak is evaluating the feasibility of a hazard survey directed at main lines that join the NEC at locations in or proximate to a high-speed zone, where gradient on the approaches to the NEC would permit equipment to roll out. This activity would need to be conducted in concert with railroads dispatching the territories, railroads conducting passenger and freight operations on those lines, and industries/contract facilities along the lines. Depending upon the findings, periodic follow-up at locations with particular vulnerabilities might be indicated.[7] Guarding against the potential for equipment to proceed downgrade unsecured, however rare the scenario, could further strengthen confidence in the safety of high-speed operations.

**5.0 Safety Culture**

As more fully described in the Petition and under 1.0, above, Amtrak recognizes that a positive safety culture is crucial to its efforts across the wide range of train accident hazards, and essential to

[5] Amtrak is evaluating whether exceptions or special procedures may be appropriate for certain circumstances such as work train service. Any such arrangements will be documented and shared with FRA for review.
[6] FRA has provided assurance that normal operation of the stop override button, in the limited circumstances intended, will not be deemed to constitute a failure requiring special testing of the on-board system.
[7] Amtrak has also considered the use of split point derails approaching such junctions. However, in addition to requiring the consent and cooperation of other parties in some instances, (i) effectiveness cannot be guaranteed under many conditions and (ii) placement of such a derail itself creates a risk that must be continually managed. Accordingly, while Amtrak does not exclude the possibility of using such a solution, addressing the issue at its source is greatly preferred.

prevention of personal injuries, as well. Amtrak's labor organizations play an integral role in growing partnerships across departments and territories, including the NEC.

**5.1 Existing Mitigations/programs:**

- Confidential Close Call Reporting System (C3RS) (operating/some mechanical locations)
- Safe-2-Safer (behavior-based safety)
- Operation RedBlock (labor-led alcohol/drug prevention)
- Operation Lifesaver (highway-rail crossing safety and trespass prevention)

**5.2 Planned Mitigations/program extension:** As noted above, C3RS is now being extended to the engineering department (MOW and S&TC).

## Administration of Mitigation Commitments Going Forward

Amtrak is aware that, to the extent both existing and new risk mitigations are relied upon to maintain an acceptable level of safety, FRA will want to see continuing evidence that they are being maintained and are effective. Accordingly, if FRA acts favorably on this waiver request, Amtrak will file for approval by the Associate Administrator for Railroad Safety/Chief Safety Officer a risk mitigation verification plan, identifying the steps that will be taken and the officials responsible for those actions. The plan will specify, for instance, how frequently fences and barriers relied upon to reduce "point risks" will be inspected and how rapidly any exceptions must be remedied. This plan will be integrated into Amtrak's System Safety Program, and would be subject to revision as the program is reviewed and approved by FRA. Prior to requesting authority to proceed with use of Tier III equipment at speeds greater than 125 in any high-speed zone, Amtrak, over the signature of the Vice President Operations, will file a verification report affirming that the requisite actions have been taken as applicable to that zone or zones. Twelve months thereafter, and each 12 months thereafter, Amtrak will file an annual verification report affirming that actions are being undertaken as planned and providing available information concerning the efficacy of those actions. If work on individual high-speed zones has to proceed piecemeal, Amtrak would confer with FRA regarding consolidation of reports and adjustment of the annual cycle. Amtrak will retain for a period of 5 years reports of inspections, tests, reports, and evaluations used in preparing each verification report. That material will be available for review by FRA safety personnel.

Current and proposed risk mitigations are based on current knowledge, experience and technology—all of which should grow and mature over time. Waiver conditions should not lock in approaches that may become obsolete or may prove insufficient over time. Accordingly, Amtrak also requests that it be permitted, with specific review and approval by the Associate Administrator or that person's delegate identified in writing, to substitute equally or more effective mitigations responsive to the same risks as further knowledge and experience is gained and new technologies are developed and successfully demonstrated.