U.S. Department of Transportation

Federal Railroad Administration

Administrator

**1120 Vermont Ave., NW.
Washington, DC 20590**

AUG 17 2004

The Honorable Robert Byrd
Ranking Member
Committee on Appropriations
United States Senate
Washington, DC 20510

Dear Senator Byrd:

This is in response to the Conference Report on the Consolidated Appropriations Resolution, 2003 (Public Law 108-7), which provided in pertinent part as follows:

> "Positive train control.--The conferees direct FRA to submit an updated economic analysis of the costs and benefits of positive train control and related systems that takes into account advances in technology and system savings to carriers and shippers as well as other cost savings related to prioritized deployment of these systems, as proposed by the Senate. This analysis must be submitted as a letter report to the House and Senate Committees on Appropriations by October 1, 2003."

We have updated the economic analysis of Positive Train Control (PTC). The enclosed document contains our analysis.

The updated cost data show that the costs of PTC systems and components appear to be declining slowly. The analysis of safety benefits shows that the direct safety benefits of PTC would be small relative to the potential costs. The direct business benefits of PTC appear to be controversial, and when interested parties were invited to comment on an early draft of this report, there was substantial criticism of the projected business benefits. The potential business benefits rely on untested assumptions, which can only be verified through actual in-service experience with PTC. If the business benefit assumptions are correct, however, there would be fairly large societal benefits, but the railroads would receive very little of the benefits.

The enclosed report describes and quantifies the costs and possible benefits of PTC. Where benefits have been questioned during peer review, we have called attention to the basis for those questions. In several material respects, major changes have been made to recognize clearly valid critiques.

You will note the contention by railroads that other technological developments have largely made obsolete the concept—developed by the Association of American Railroads in the 1980's—that a communications-based train control platform can be employed to implement other business applications. Passenger and freight railroads have also questioned whether PTC can contribute to capacity and service quality. The Federal Railroad Administration (FRA) has not been able to capacity and service quality. The Federal Railroad Administration (FRA) has not been able to resolve this conflict in the short period available for the study, and we agree that demonstration of highly capable train control technology (such as that planned for the North American Joint PTC Program) will be an important step in helping to resolve lingering concerns.

The FRA would have liked to have been able to produce a definitive study; however, the underlying assumptions for this, or any other study of PTC business benefits, will be subject to legitimate challenge until a PTC system with features enabling business benefits is actually deployed.

Nevertheless, the question posed for study remains highly relevant. The continued health of the national transportation system requires more effective use of technology. Just as there are corridors where additional lanes of highway cannot be built, key railroad routes are also approaching capacity. It is encouraging that railroads are continuing to explore the use of PTC and PTC-related technologies to improve safety, meet their business needs, and serve the Nation.

The FRA, like the National Transportation Safety Board, strongly supports the concept of PTC as a potential deterrent to railroad collisions. However, in part because rail collisions and other events preventable by such technology constitute only about two percent (2%) of reportable train accidents in any given year, the direct safety benefits that would accrue to railroads are small relative to the costs. In fact, if rail service quality can be improved using PTC, there may be greater safety benefits to highways users through diversion of truck shipments to rail; and the accompanying report identifies other indirect societal benefits. Because the costs of most technologies decline over time, we believe that PTC will be more affordable in the future.

FRA continues to support development of PTC through the Illinois Department of Transportation (IDOT) project and provides technical assistance for industry efforts to create more cost-effective technology. At the same time, FRA is promulgating enabling regulations to establish performance standards for the implementation of PTC technology by those railroads that are actively engaged in acquiring such systems.

I appreciate your interest in railroad safety, and FRA looks forward to continuing to work with you and the Committee on transportation issues. An identical letter has been sent to the Chairman and Ranking Member of the Senate Committee on Appropriations; the Chairman of the Senate Subcommittee on Transportation/Treasury, and General Government; the Chairman and Ranking Member of the House Committee on Appropriations; and the Chairman and Ranking Member of the House Subcommittee on Transportation and Treasury, and Independent Agencies.

Sincerely,

Betty Monro

Betty Monro
Acting Administrator

Enclosure

U.S. Department
of Transportation

**Federal Railroad
Administration**

Benefits and Costs of Positive Train Control

Report in Response to Request of Appropriations Committees

August 2004

Basis for the Report:

The Conference Report on the Consolidated Appropriations Resolution, 2003 (Public Law 108-7), provided in pertinent part as follows:

> Positive train control.--The conferees direct FRA to submit an updated economic analysis of the costs and benefits of positive train control and related systems that takes into account advances in technology and system savings to carriers and shippers as well as other cost savings related to prioritized deployment of these systems, as proposed by the Senate. This analysis must be submitted as a letter report to the House and Senate Committees on Appropriations by October 1, 2003.

H.R. Rep. No. 108-10, 108th Cong. 1st Sess. 1286-7.

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Introduction and Executive Summary

Scope of this Report

During the period 1984 through 1995, the Class I railroads in Canada and the United States, through the Association of American Railroads (AAR) and the Railway Association of Canada (RAC), collectively pursued development of Advanced Train Control Systems (ATCS). During the period 1983 through 1992, the Burlington Northern Railroad (BN) developed and demonstrated the Advanced Railroad Electronic System (ARES). These technologies promised integrated communications, command and control for railroad operations, including a broad array of business applications. ATCS/ARES offered the capability to enforce Positive Train Separation (PTS), a concept embodied in National Transportation Safety Board (NTSB) recommendations intended to address collisions among trains. Systems of this type are conventionally referred to as communication-based train control (CBTC) systems and may be configured to accomplish train control functions exclusively; or the communications platform may be used to aide traffic management and other business functions, as well.

ATCS and ARES were expressly designed to provide an electronic platform, extending from the central office to the wayside and into each locomotive, on which applications useful for safety and business purposes could be executed. Business case documents were prepared to support investments in these systems. As late as 1991, FRA participated with industry in a joint conference on the future of ATCS. This was genesis of the "business case" for what we now call Positive Train Control (PTC).

In 1993, both the AAR and the BN discontinued support for deployment of ATCS and ARES.[1] This was done with little or no public explanation.

In 1994, FRA submitted to the Congress a report entitled ***Railroad Communications and Train Control***, which was responsive to a requirement contained in the Rail Safety Enforcement and Review Act of 1992 (Pub. L. No. 102-365). In that report, FRA coined the term "Positive Train Control" to refer specifically to collision avoidance (PTS), enforcement of speed restrictions (including civil engineering restrictions and temporary slow orders), and protection of roadway workers within their authorities (now considered "PTC core functions"). However, in that report FRA also used the term PTC more broadly to include other elements of advanced electronic systems that might utilize the same communications platform. Relying on cost data provided by the railroads, FRA noted that the costs to deploy PTC safety features on the national rail system would far exceed any likely safety benefits. FRA did not estimate business or societal benefits, beyond avoided accidents and casualties, in making this report. However, FRA did call attention to "business case" benefits posited for ATCS/ARES, and also recounted industry objections to making national estimates of such benefits.

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[1]Data radio employing ATCS communications specifications has been used extensively by major railroads to support removal of railroad signal system pole line.

In 1994, NTSB issued Recommendation R-94-13, concerning the Positive Train Separation project then being developed by the BN and the Union Pacific Railroad, which read:

> As part of your monitoring and oversight activities on the Burlington Northern and Union Pacific Railroad's train control demonstration project, identify and evaluate all potential safety and business benefits of the positive train control system currently proposed for the northwest region of the United States. Consider the value of these benefits in your overall assessment of the system.

Section 214 of the Federal Railroad Safety Authorization Act of 1994 (Pub. L. No. 103-440) required the Secretary of Transportation to submit a report to the Congress on the development, deployment, and demonstration of the positive train control systems. On May 17, 2000, FRA submitted a letter report responding to that requirement. The report noted progress toward deployment of PTC systems and transmitted the September 1999 Report of the Railroad Safety Advisory Committee (RSAC) to the Federal Railroad Administrator entitled ***Implementation of Positive Train Control Systems***. This report confirmed the core PTC safety functions described in the 1994 report. It also referred to additional safety functions that might be included in some PTC architecture (e.g., warning of on-track equipment operating outside the limits of authority; enforcement of hazard detection warnings; and a future capability for generating data for transfer to highway users to enhance warning at highway-rail grade crossings).

The RSAC report responded to RSAC Task 97-4 which read in pertinent part:

> Prepare a descriptive report to facilitate understanding of current PTC technologies, definitions, and capabilities including: architecture; functionality; assessment of risks; proposed augmentation of current systems; proposed replacement of current systems; examination of proposed safety benefits, other benefits, and costs, taking into account Section 1(a) of Executive Order No. 12866 ["Regulatory Planning and Review"], FRA Report to Congress entitled "Railroad Communications and Train Control" (July 1994) and recommendations of the National Transportation Safety Board.

The RSAC report again found that safety benefits of PTC could not support the investments necessary to deploy the system. The Committee was not able to reach conclusions regarding the non-safety benefits of PTC-related technologies.

For this report, the Appropriations Conferees asked FRA to "submit an updated economic analysis of the costs and benefits of positive train control and related systems that takes into account advances in technology and system savings to carriers and shippers as well as other cost savings related to prioritized deployment of these systems." The Senate Appropriations Committee report from which the study request was derived (S. Rep. No. 107-224, pg. 96-97) read as follows:

> Positive train control.—The Committee agrees with the National Transportation Safety Board that the current pace of development and implementation of collision avoidance

technologies is inadequate. No plan for industry-wide integration has been developed. Progress has been particularly slow along rail lines that primarily serve freight carriers, and even those lines with significant passenger traffic remain largely unprotected today—some 12 years after positive train control was first placed on the Safety Board's‘‘Most Wanted list. The Committee directs FRA to submit an updated economic analysis of the costs and benefits of PTC and related systems that takes into account advances in technology, and systems savings to carriers and shippers as well as other cost savings that might be realized by prioritized deployment of these systems, especially along lines that might mix freight and passenger trains.

From this sequence of events, it is evident that FRA has been asked to examine more than the safety benefits of PTC, which have been described twice before. Accordingly, for this analysis, PTC means communications-based train control technology capable of achieving PTC core functions[2] as defined by FRA and RSAC, accompanied by additional components and capabilities which might generate business and other societal benefits. If PTC, and no other components, were installed, then there would be no likelihood of benefits to shippers, and few other business benefits to carriers; hence, FRA believes that Congress was asking FRA to evaluate a reasonable version of PTC and add-on components likely to generate business benefits.

This report endeavors to describe safety benefits, and business benefits of PTC and allied business systems, which might utilize a PTC communications platform or draw information from PTC functions and utilize it to support business applications, together with the costs of those systems and applications.

Technical Approach and Summary of Findings

The report which follows attempts to present fairly conflicting analyses and assumptions. Where analytical items or assumptions conflict, FRA has attempted to present them in proximity to one another in order to make it clear that a particular issue cannot be resolved by consensus, and to avoid the reader prejudging an issue out of context.

In order to show the range of costs and benefits associated with this emerging technology, FRA described two PTC variations, called "PTC A" and "PTC B". PTC A is a relatively simpler system, such as a "non-vital overlay" which is not designed to replace the existing method of operation. PTC B is a more extensive system, intended to be a stand-alone system designed in accordance with safety principles embodied in current vital systems.[3]

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[2]See Appendix A for definitions of core functions.

[3]See Appendix A for system definitions for PTC A and PTC B.

FRA had a contractor, Zeta-Tech Associates (Zeta-Tech), examine the business benefits and costs. FRA combined that analysis with FRA estimates of modal diversion and societal consequences, and with a joint effort between FRA and the Volpe National Transportation Systems Center (Volpe) to analyze potential accident cost reductions due to PTC.

FRA then conducted a peer review workshop to which representatives of railroads (freight and passenger), labor organizations, suppliers, and shippers were invited. Draft reports were presented, and post-workshop written filings were received.

Although there was significant disagreement over the FRA contractor's report, if the contractor's analysis is correct then major benefits might arise through improved railroad productivity and reduced shipper logistical cost, caused by faster, more reliable rail shipments, and diversion of freight traffic from highway to rail.

Zeta-Tech investigated the costs, and found costs that were similar to those estimated by the RSAC in 1998-1999. However, according to peer reviewers, on-board systems can be expected to be about one-third less expensive than previously estimated.

In general, both the costs and benefits of PTC A were similar to, but smaller than the costs and benefits of PTC B.[4] There are significant timing issues which have not yet been developed fully and which could impact the results reported here. The biggest issue is that PTC might take several years to deploy and the benefits may not flow until the system is substantially complete. FRA analyzed the effects on railroads using estimates based on year 2000 flows, but the truck-to-rail diversion estimates from which total societal benefits were derived are estimated for two distinct years, 2010, and 2020. Whenever undescribed annual benefits or costs are mentioned, they refer to projections based on year 2000 data, which are not likely to be significantly different from future data if PTC is not adopted. Another timing issue is that the intermodal diversion projections were based on PTC having been in service for several years, yet a realistic timeline for systemwide adoption of PTC might not have PTC in place before year 2010.

If, and only if, Zeta-Tech's assumptions are accurate, were the railroads to purchase and install PTC B[5], it would cost them between \$2.0 and \$3.7 billion dollars, and would return them between \$25 million and \$202 million per year.[6] Shippers would receive a benefit of between \$1.55 billion and \$2.5 billion per year. PTC preventable rail accident costs would be reduced by \$40 million to \$96 million per year, but would be offset by volume related increases in rail accident costs of \$20 million to \$40 million per year.

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[4]Under the low return scenario the railroads would incur a very small net loss with PTC A, as opposed to a very small net profit with PTC B.

[5]See Appendix D for detailed tables showing the derivation of costs and benefits.

[6]Stakeholders took issue with many of Zeta-Tech's assumptions, and their disagreements are described in greater detail later in this report.

Because of modal diversion, highway accident costs would be reduced by between $266 million and $511 million per year, in 2010, and between $413 million and $785 million in 2020. Air pollution costs would be reduced by between $62 million and $120 million in 2010, and between $93 million and $180 million in 2020. Other highway costs would be reduced by between $35 million and $68 million in 2010, and between $55 million and $104 million in 2020. The total net societal benefits, would range from a low of $2.1 billion per year in 2010 to a high of $3.9 billion in 2020.

In the scenarios analyzed, the railroads receive between a net loss and 5.76% of the total societal benefits. Railroad safety benefits are a very small proportion, less than 1% of total benefits (rail safety per ton mile or train mile improves, but the increase in train miles and ton miles induces risk proportional to exposure which offsets some of the safety benefits of PTC). The bulk of the benefits goes to highway users (and the general public) who avoid accident costs, and to shippers, who as a result of competition in their own markets will have to pass the benefits on to society at large.

The study did not definitively resolve whether, in order to realize any modal diversion, railroads would have to make additional investments in yard and terminal capacity to handle the additional volume. If that were to be necessary, several hundred million dollars in additional investment might be required to realize improvements in rail service that generate the largest portion of the possible benefits. Some additional investment might also be required from highway funds to provide access to new or expanded intermodal terminals from the interstate highway system.

The study did not examine an issue that is critical for the success of PTC–the question of communications capacity. More sophisticated forms of PTC will require rapid flows of digital data. Developments in communications technology promise a rich set of options for addressing this need. However, to the extent a PTC system requires partial reliance on a commercial service, additional costs might be incurred. That is, the data communication backbone might not be available "free" for auxiliary business functions.

I. Background

This analysis integrates several efforts, and as a result may appear to contain contradictions; however, what is presented here is FRA's best attempt to capture both the possibilities offered by PTC and related systems, and the very considerable uncertainties as to whether those benefits are attainable. At this time no in-service PTC system achieves the business benefits which may be possible. Many of the apparent conflicts are expressed in comments that FRA solicited on an early draft of this report from a group of industry experts. FRA endorses neither those criticisms, nor the original reports which were the subject of criticism. FRA does believe that it is important to present one vision of the potential for PTC and allied systems, recognizing that it will be necessary to demonstrate the technology on a significant scale before determining that the various benefits can be realized in practice.

FRA began this effort in conjunction with Zeta-Tech, and Volpe. FRA also had a group of rail industry experts review the report at a workshop and also deliver written comments. Shippers' representatives had been invited, but none participated.

For this analysis, PTC is assumed to mean communications-based train control technology capable of achieving PTC core functions as defined by FRA and the RSAC with additional components and capabilities which might generate business benefits. If PTC, and no other components, were installed, then there would be no likelihood of benefits to shippers, hence FRA believes that Congress was asking FRA to evaluate a reasonable version of PTC and add-on components likely to generate business benefits, especially to shippers. Any PTC system discussed to date by FRA or the RSAC has had both communications and train location capabilities. When these capabilities are in place, there is a relatively small additional cost to providing additional functions.

FRA believes that most full scale implementations of PTC eventually would include additional features. Nonetheless, several commenters took issue with expanding definitions of PTC. Their comments made clear that they do not believe that PTC is a necessary, nor a sufficient condition for adopting some of those technologies. Further, some commenters believe that adding functions to PTC makes it much more difficult to develop a safety case to support the PTC system, and makes additional functions less effective. If PTC were adopted without the business features, of course, no business benefits would be derived.

In the past FRA has undertaken several efforts to characterize the benefits and costs of PTC. FRA has submitted two reports to Congress, ***Railroad Communications and Train Control***, July 1994 (1994 report), and ***Report of the Railroad Safety Advisory Committee to the Federal Railroad Administrator, Implementation of Positive Train Control,*** September 8, 1999 (RSAC report). The 1994 report found that the safety benefits of PTC did not justify requiring it. The 1994 report did not include business benefits. Subsequently, FRA had a contractor analyze the business benefits of PTC and presented the results to the RSAC. When the RSAC PTC Working Group analyzed the question of benefits and costs of PTC, members could not reach agreement with respect to some of the claimed business benefits. Members of the Working Group did note that certain business benefits could be achieved by use of PTC or by other technology. Accordingly, it was agreed that the avoided cost of the non- PTC technology should be deducted from the cost of PTC systems. An analysis was presented on that basis in the September 1999 RSAC report. In this analysis, FRA continues to rely on the estimated costs of PTC preventable accidents using the methodology used in that report.

Train control has been historically associated with the safety of passenger service. All trains operating on the Northeast Corridor between Washington, DC, and Boston, MA, and certain other lines are required to be equipped with automatic cab signals (ACS) and automatic train control (ATC) systems that will prevent most train-to-train collisions. Cab signaling, accompanied by short blocks, hastens throughput of trains; and ATC, or speed control, keeps trains within the speed ranges permitted by the signal system. Where these systems are in place, accident risk associated with train-to-train collisions is significantly reduced. Communications-based technology can augment these types of systems by enforcing positive stops at absolute signals, enforcing civil and temporary speed restrictions, and protecting roadway workers with the limits of their authorities.

To date the railroads have not widely adopted PTC, although several railroads are making great strides in the development of PTC. Amtrak has two systems deployed which perform PTC core functions, the Advanced Civil Speed Enforcement System (ACSES), and the Incremental Train Control System (ITCS), both of which integrate communications-based technology with traditional signal technology to support high-speed passenger service. New Jersey Transit also has a system, Advanced Speed Enforcement System (ASES), that is compatible with ACSES, with similar capabilities. These systems are deemed cost justified on safety grounds, because of the significant exposure associated with high-density and/or high-speed service. By contrast, where speeds or lower, or where passenger service is a much less prominent part of the traffic mix, justifying the cost of PTC will be dependent upon benefits associated with freight service.

Freight railroads are working to demonstrate PTC technology. CSXT has a developmental system, called Communication Based Train Management (CBTM), which is intended as an overlay for existing operations. Burlington Northern Santa Fe Railroad (BNSF) is developing a similar overlay system, Electronic Train Management System (ETMS), which shares some components and concepts with CBTM. The North American Joint PTC (NAJPTC) project in Illinois is developing a PTC system designed (like ITCS) to support high-speed passenger service without traditional cab signals, which might have the underlying components to generate many of the business benefits analyzed here, but as of the time of this analysis, the NAJPTC system would not generate the suggested business benefits.

The Alaska Railroad, which has both an active freight business and provides passenger service, is building a Collision Avoidance System (CAS) that will address the PTC core functions.

FRA notes that each of the newer PTC systems presently under development (ETMS, CBTM, CAS) will have the ability to transmit to the central office information concerning the position and velocity of trains. Each system contemplates provision of movement authorities in dark territory[7] (with the implicit ability to more readily "roll up" authorities and enhance system throughput); and each system will draw information from existing signal systems. Each system will utilize a communications platform that, assuming adequate capacity, could be employed to support other functions. However, many questions remain to be answered. FRA and the commenters on the early draft agree that we will have a much better idea of what PTC and related systems can do only when there is an actual PTC system in revenue service and the railroad has explored potential applications.

One reason why the current implementations of PTC do not attempt the kinds of business benefits considered in this analysis is that to date the projects have had very limited scope. For example, the benefits of improved reliability of shipments depend on a wide-scale implementation. It matters little to a shipper that the shipment traveled with great reliability on 10 percent of its route. This report considers only a large scale implementation of PTC, in order to analyze the most favorable environment for shipper benefits. If PTC were installed only on some fraction of the system analyzed here, the benefits would be less than the equivalent fraction of the benefits measured here, and the costs might be more than an equivalent fraction.[8]

FRA, in attempting to answer the questions raised by Congress, had to define the PTC system in general terms, and then add the features required to attain business benefits. Many commenters thought this was inappropriate. Further, FRA had to consider the most appropriate deployment in order to achieve the results Congress requested. FRA believes that the most beneficial deployment would be a complete deployment on major rail segments, which total about 100,000 miles, and includes all Class I railroad trackage, and most trackage on Class 2 railroads. Such a deployment would be costly, but at no time did FRA attempt to ascertain who would be paying for such a system, only what the benefits would be once such a system were in place. FRA did not believe it was reasonable to assign the cost to any particular party, because under any scenario considered the railroads would not receive close to enough revenue to justify their installation of the system, given the cost of capital and the long implementation period.[9]

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[7]A movement authority in dark (unsignalled) territory occurs when a train crew is "given" a section of railroad, and no other train crew may operate on that section of railroad. This authority creates a safe zone in front of the train as it moves, but wastes the use of the railroad behind the train, which is still covered by the authority. Rolling up the authority would "give" the section of railroad back to the dispatcher, who then could use it for another movement.

[8]It bears emphasis that application of PTC to a single railroad's system, however large, would not result in full benefits. Railroads handle large volumes of interline traffic, and rail alliances are increasing important to attracting premium traffic. Railroads would need to adopt interoperable systems in order to support business applications.

[9]It is possible to conceive a competitive environment in which highway capacity is so constrained that freight railroads are able to price their service at a level permitting them to recover their cost of capital, including potential investments described here. However, despite

FRA decided to analyze two approaches to PTC, "PTC A," a relatively simpler, less capable system (and less costly system), and "PTC B," which provides its own robust method of operation, including enforcement.[10] FRA then added to the minimum safety systems those business oriented systems which FRA believes could make joint use of the equipment provided for PTC. FRA is aware that elements of each construct (PTC A or B) could be paired with business systems. FRA analyzes the two cases only to illustrate contrasts among possible applications, and not to suggest that the two are mutually exclusive.

FRA also determined, if there were shipper benefits, that might cause changes in choice of shipping mode, encouraging shippers to choose rail transportation more readily where rail and highway transportation compete. The changes in modal choice could lead to diversion, and, as shown in the analysis, could yield a significant portion of the safety benefits.

Zeta-Tech studied the direct business benefits of PTC, and the costs of PTC systems. Volpe analyzed the likely benefits from reducing PTC Preventable Accidents (PPA's). The FRA Office of Policy and Program Development, using a model developed by the U.S. Department of Transportation (DOT), estimated the likely diversion of truck traffic to intermodal rail transportation. The FRA Office of Safety integrated the other portions into this letter report, and developed the implications of diversion.

FRA originally had broken the project into four portions, but has included the comment and review process and FRA response, in order to present a more balanced outlook. A summary critique from the review process is included in each discussion item in italics. At the end of the report, a more complete summary of the critiques filed by peer reviewers is provided.

II. Results of the Zeta Tech Study

Note: FRA does not endorse these results, nor, with the caveats stated, does it have objection to these results. FRA believes the analysis to be worthwhile, but also agrees with stakeholders that challenges to the underlying assumptions present serious issues. The results are presented in order to provide one view of the relevant issues.

A. Benefits Accruing Directly to the Railroads:

1. Work Order Reporting:

The purpose of the work order system is to plan and schedule the work of train crews. However, it is not possible to schedule all work in advance, since it is impossible to perfectly predict future

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growing highway congestion, no general trend in this direction is yet discernible.

[10]See Appendix A for a detailed description of the components of PTC A and PTC B, as analyzed here.

occurrences. However, the addition of unplanned work may mean delays to cars or train crews, since without advance knowledge of work to be done, crews may run out of time before completing all scheduled work and any unplanned work. Outbound connections in yards may also be missed if large volumes of additional work delay completion of a switching shift.

Work order reporting systems send instructions over the digital data link communications network from the control center to train crews regarding the setting out and picking up of loaded and empty cars enroute. When crews acknowledge accomplishment of work orders, the system automatically updates the on-board train consist information and transmits information on car location and train consists back over the digital data link communications network to the railroad's operating data system and to customers. Work order reporting information can be displayed in locomotives on the same screens that would display PTC instructions and information.

Real-time or near real-time information will reduce additional, unplanned work, by reducing the volume of inaccurate or out-of-date information used in the generation of work orders. The earlier there is knowledge of unplanned work the better the plan is able to accommodate that work without disruption of other elements of the plan. Since yard and industry switchers and local freights perform most additional work, the benefits resulting from a reduction in additional work will be realized mostly in these services. For this reason, the analysis presented here is confined to switchers and local freights. There simply do not seem to be large benefits to be realized from real-time reporting of train consist data and completed work by unit trains and through freight trains, because those trains do not undergo much switching activity.

Zeta-Tech estimated the benefits from work order reporting to be $10 million per year, under either PTC A or PTC B[11], because the additional features of B have nothing to do with collecting and disseminating information useful for work order reporting. The methodology used to derive these benefits focuses on the ability to process a car more rapidly through a terminal area, given better and more timely information about that car, and therefore to reduce the likelihood that the car will miss the next train out of the yard for its destination. At present it does not appear, based on anecdotal information, that any Class I railroad has a work order reporting system which can provide these benefits without PTC, however, it also appears that such systems are under development.

The AAR, in its comments, said that these benefits were already being derived from other, non-PTC systems. (One of these, the UP work order reporting system, actually utilizes an ATCS communications platform.)

FRA recognizes that commercial wireless communications have become available that no longer make a train control communications platform a necessity. The widespread availability of

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[11] *Quantification of the Business Benefits of Positive Train Control*, Zeta-Tech Associates, Cherry Hill, NJ, March 15, 2004, pp. 35 *et seq*.

commercial communications services offers an alternative means of realizing these benefits. Further, most major railroads now have car scheduling programs that address the same needs. The Automatic Equipment Identification (AEI) program provides data on cars passing fixed points throughout the national rail system. Accordingly, the extent to which work order reporting might be profitably employed in the future is not known, and FRA has removed any quantified benefit from this report. FRA does believe that a PTC communications platform could help hold down the cost of work order reporting.

2. Locomotive Diagnostics:

Locomotive diagnostic systems utilize a set of sensors that monitor critical locomotive components (air intakes, fuel injectors, electrical system) and provide warnings to train crews and/or mechanical maintenance employees when components are close to failure. Most modern diesel locomotives are equipped by manufacturers with diagnostic systems, of varying complexity and sophistication. Therefore, the central question in this part of the analysis is whether real-time transmission of this diagnostic information to a central location adds significant additional value. The Zeta-Tech analysis assumed the existence of a digital data link (installed for train control purposes), and an on-board computer. In this case, the incremental cost of locomotive monitoring with real-time reporting is small.

Locomotive health monitoring systems consist of sensors mounted on engines, traction motors, electrical systems, air systems, exhaust systems, and fuel tanks on locomotives. Most new locomotives are equipped with most of these sensors. The data from all units in the consist will be displayed to locomotive crews, and are collected in on-board computers for retrieval when locomotives arrive at maintenance facilities. The data will be transmitted over the digital data link communications network to control centers, maintenance facilities, and motive power distribution centers to permit real-time monitoring of locomotive performance and efficiency. Each of those places could make an inquiry over the data link to a locomotive to receive a health status report, or the locomotive computer could be programed to make a report on an exception basis. The data will also be collected at maintenance facilities and analyzed to permit maintenance to be done on an as-needed rather than scheduled basis. Traction motor performance in both traction and dynamic braking modes will be monitored. Locomotive health monitoring systems might improve locomotive energy efficiency and emissions.

Zeta-Tech took into account the current installed base of Locomotive Diagnostic systems, some of which provide frequent reporting, and estimated the benefits to be $63 million per year, for either PTC A or PTC B[12]. Both PTC A and PTC B are assumed to provide similar communications capability for reporting locomotive health and location, so there should be no difference between the two systems. The bulk of the benefit comes from being able to detect and

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[12]*Quantification of the Business Benefits of Positive Train Control*, Zeta-Tech Associates, Cherry Hill, NJ, March 15, 2004, pp. 43 *et seq*.

respond to locomotive health problems in a more timely fashion, which yields better, less costly maintenance and fewer road failures.

The AAR commented that locomotive diagnostics were already installed on many existing locomotives, and that the benefit of more frequent locomotive health monitoring on those locomotives would be minimal.

Contrary to AAR assertions, however, Zeta-Tech took the current installed base into account in making their estimates of benefits. Zeta-Tech's study did estimate additional benefits for more frequent reporting on the existing installed base of locomotive health monitoring systems.

3. Fuel Savings:

PTC can let train operations be paced, so that trains do not operate at top speed for a short duration, only to wait for an extended period to acquire authority for the next track segment. A great deal of fuel could be wasted in accelerating from a stop, or from operating at unnecessarily high speeds.

In the quantification of benefits, Zeta-Tech decided to use a range rather than a point estimate for most sources of benefits. A range of 1.5% to 3.5% was selected for quantifying fuel savings. For the entire U.S. railroad industry, fuel represented an annual expense of some $3.191 billion in 2001 (source: AAR "Railroad Facts"). Thus a 1.5% to 3.5% savings produced a range of $56 million to $131 million in fuel cost savings.[13]

Commenters noted that training and monitoring of locomotive engineers is already directed at reductions in fuel consumption.

FRA is aware of active training programs that address fuel conservation, including use of simulator training. One major railroad has invested in facilities for batch downloads of event recorder information which is reviewed for appropriate train handling to conserve fuel.

Nevertheless, FRA notes that at least one ongoing PTC project contemplates implementation of train pacing. Development of precision dispatch (discussed below) will result in better use of real-time data on train position and velocity (traffic conflicts can be predicted farther ahead, permitting earlier onset of pacing). As fossil fuel costs rise, this benefit will become increasingly attractive.

FRA also agrees that it may be possible to envision provision of train pacing guidance without safety enforcement. However, it appears unlikely such an implementation would be contemplated. Further, a crew that has limited information regarding reductions in speed that

[13] *Quantification of the Business Benefits of Positive Train Control*, Zeta-Tech Associates, Cherry Hill, NJ, March 15, 2004, p. 52

may be feasible to accomplish a trip plan will tend toward operation of the train to achieve the lowest possible trip time. Accordingly, FRA believes that the range of projected cost savings is reasonable.

4. Precision Dispatch:

Precision dispatching is dispatching based on very frequent updates of the positions, and in some cases, speeds, of trains. PTC systems can provide frequent updates on train position, and in most cases speed. Most PTC systems also require modifications of the railroad's operating system and rules. A railroad can opt to install precision dispatching concurrently with PTC at a lower cost than the marginal cost of a stand-alone precision dispatching system. That is not to say that a railroad cannot attempt to install a stand-alone precision dispatching system. At least three railroads now report efforts to upgrade their computer-aided dispatching systems to include planning elements.

Precision dispatching involves traffic planners. FRA has identified two types of traffic planners which might be of use in precision dispatching:

> Tactical traffic planners (TTPs) produce plans showing when trains should arrive at each point on a dispatcher's territory, where trains should meet and pass, and which trains should take sidings. As the plans are executed, a TTP takes the very detailed train movement information provided by the PTC system and compares it with desired train performance. If there are significant deviations from plan, the TTP will re-plan, adjusting meet and pass locations to recover undesired lateness. TTPs make use of sophisticated non-linear optimization techniques to devise an optimal dispatching plan. Once a TTP prepares a plan, the dispatcher need only accept it. Then the computer-assisted dispatching system of PTC produces all authorities needed to execute the plan and sends them over the digital data link communications network to trains and maintenance-of-way vehicles. Some prototype TTPs have been developed and tested.
>
> Strategic traffic planners (STPs) - TTPs cannot function without knowing the schedule for each train. STPs measure train movements against a set of externally defined schedules that include information on scheduled block swaps and connections, both internal and with other railroads. STPs integrate a flow of information about actual train performance from the TTP, the performance of connections, and detailed consist information for all trains from operating data systems. They make cost-minimizing decisions on whether, and how, train priorities and schedules might be adjusted on a real-time basis. STPs are the highest-level real-time control system in the PTC hierarchy. STPs will be able to display the performance of trains against schedule, the real-time location of every train by type (e.g., coal, intermodal, grain, intercity passenger), and the location of trains at future times based on current performance. The Federal Aviation

Administration developed an STP (called "central flow control") to support the U.S. air traffic control system; the same philosophy could apply to railroad STPs.

The main benefit of precision dispatching is that a railroad can have a dispatch plan which is updated and optimized at frequent enough cycles to provide near optimal operations. At least one railroad has contended that precision dispatching has no benefit because rail operations are unpredictable, due to unanticipated events, such as broken rails and broken equipment. FRA disagrees, and believes that unpredictable events are better managed when a railroad can respond promptly with optimized alternatives.

Further, even in ordinary operations, precision dispatching has much to offer. According to Smith, Resor, and Patel, significant reductions in travel time are available when there is a greater availability of real-time or near real-time information for railroad dispatchers.[14] In fact, their study showed that a travel time reduction of 2.3% could be available as a result of dispatchers receiving train position information every 3.5 minutes, as can be expected under PTC A, rather than every 17 minutes, as would be expected under a classic CTC system. For this reason, the benefits of precision dispatching are included in the discussion of PTC A benefits.

FRA notes that even without precision dispatching, more precise information on where trains are would allow dispatchers to "roll up" authorities behind a train more rapidly as it passes, freeing the track for use by the next train more rapidly, which might create additional capacity, or enhanced throughput. *Nonetheless, the AAR objected to any such increases in estimated throughput.*

With effective meet/pass planning achievable with accurate position information and possibly supplemented with sophisticated computer analysis, system velocity and reliability can increase. When system velocity increases, each car reaches its destination more rapidly, and is available sooner for its next move. Likewise, each locomotive is ready more rapidly to pull its next train. This means the railroad can use less equipment to accomplish any given level of traffic.

Railroads disagree with this point, saying that they already have the cars they need to transact business, and that there is no reduction in procurement cost. Further, many cars sit idle because of seasonal or cyclical shifts in demand for cars. Nevertheless, railroads still need to replace existing stock, and to buy locomotives to service different types of business as shipper demand patterns change. Railroads could accommodate these shifts in demand with less equipment, yielding considerable savings.

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[14] *Train Dispatching Effectiveness With Respect to Advanced Train Control Systems: Quantification of the Relationship*, Randolph R. Resor, Michael E. Smith, and Pradeep Patel. **Transportation Research Record** no. 1584 (Washington, DC: 1997).

Zeta-Tech estimated these benefits at $400 million to $1 billion per year, for both PTC A and PTC B[15]*, but in a letter to FRA agreed with a point raised by the AAR, that the savings in car utilization should only be applied to the portion of the time a car is in motion*[16].

As noted above, as a result of Zeta-Tech and AAR's comments on ownership cost savings FRA has reduced Zeta-Tech's estimate of the potential savings to railroads from precision dispatch (i.e., better utilization of plant and equipment) by 75%.[17]

5. Capacity Benefits:

PTC B adds a central safety system, traffic planning functions, and the capability to both "pace" trains and apply more advanced energy management technology to reduce fuel consumption by improving train handling and the capability to implement "dynamic headways" (moving block train separation). Dynamic headways can increase line capacity by permitting shorter and lighter trains to operate on closer headways, rather than constraining all trains to the separation required by the longest and heaviest trains. Dynamic headways, in conjunction with a tactical planner, can reduce average running times.

Zeta-Tech measured the benefits of capacity improvements in terms of avoided infrastructure costs for track and signals, including maintenance. This estimate was derived by estimating the number of miles of track at or above capacity, and estimating the costs of investments that would need to be made in order to maintain an adequate level of service. Zeta-Tech estimated the benefit of improved capacity at $800 million to $1.2 billion per year.[18]

Railroad commenters, including the AAR, stated that PTC safety systems may have the effect of reducing line capacity. They noted that the conservative braking algorithms used in current PTC projects may result in trains operating a slower speeds approaching targets. Further, even if it is possible to achieve dynamic blocks, the full benefit of the technology would be realized

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[15] *Quantification of the Business Benefits of Positive Train Control*, Zeta-Tech Associates, Cherry Hill, NJ, March 15, 2004, pp.10, 11 and 52 *et seq.*. For some reason Zeta-Tech reported savings from reduced equipment ownership in Table A of that report, which refers to PTC A, at $407,996,280 to $1,040,021,170, while reporting lesser figures in Table B, which refers to PTC B, for both car ownership and locomotive ownership, however the total of the locomotive ownership savings and car ownership savings in Table B is identical to the equipment ownership figure in Table A.

[16] Letter from Zeta-Tech to Frank Roskind, dated April 22, 2004.

[17] FRA is aware that over half of the car fleet is privately owned and that some of these benefits will flow to shippers.

[18] *Quantification of the Business Benefits of Positive Train Control*, Zeta-Tech Associates, Cherry Hill, NJ, March 15, 2004, pp. 57 *et seq.*.

only in multi-track territory. A major signal supplier called attention to the technical risk associated with dynamic block architectures, noting that such projects have not been successful in conventional railroading internationally.

Demonstration of dynamic block capability is a major objective of the North American Joint PTC project, and several transit applications are presently being deployed using this approach. FRA agrees that dynamic block capability will be one of the last attributes of communication-based train control that will be deployed (due to the technical challenge, communications requirements, etc.). FRA believes that attainable PTC systems, used in combination with precision dispatching, can increase line capacity by releasing restrictions on movements to the rear of trains and more efficiently staging train operations, regardless of whether dynamic blocks are employed for freight operations.

FRA is aware of the challenges currently being experienced in developing and implementing braking algorithms within the current PTC projects. These difficulties must be overcome for PTC to be a viable safety system and contribute to the efficiency of the industry. FRA believes that these issues will be resolved through use of realistic train consist and track database information and a more refined understanding of how specific train types perform. During the period PTC is being implemented, railroads will also be converting to use of electronically-controlled pneumatic (ECP) brakes, which will lead to more extensive use of train braking; and that in turn will provide feedback on the actual performance of each individual train (as well as exception information on the braking systems on individual cars).

However, in response to comments, including those from the AAR in writing and at the Peer Review Workshop, FRA has modified the Zeta-Tech estimate, reducing it by 60%, to account for such issues as the fact that adding PTC is not as effective as double tracking in increasing capacity, and that a railroad could increase capacity substantially by installing a series of long sidings, at cost much less than that of double tracking. FRA believes this is a conservative assumption, and the societal benefits estimated remain significant even after reducing the estimate of this benefit substantially.

6. Railroad Benefit Totals:

FRA estimates that railroads have only been able to capture about 20% of the benefits of past productivity enhancements, because of competition among railroads, and competition with the highway mode.[19][20] The remainder of benefits has been passed on to shippers, typically through lower rates. In this analysis the railroads would generate between a net loss of $35.7 million and

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[19]*Association of American Railroads; Mercer analysis*, Mercer management consulting, April 2003, PowerPoint slide.

[20]*Sources of Financial Improvement in the US Rail Industry, 1966-1995*, Carl D. Martland, Massachusetts Institute of Technology, 1997

a net gain of $402 million in annual productivity benefits after maintenance expenses using PTC A, but would only retain between a loss of $7.1 million and a gain of $80 million[21]. Similarly the railroads would generate between $124 million and $1.01 billion in annual productivity benefits after maintenance expenses using PTC B, but would only be able to retain between $25 Million and $202 million annually.[22]

B. Shipper Benefits:

Zeta-Tech, in its analysis, says that PTC can enable railroads to deliver shipments more rapidly, and with greater certainty of the arrival time, *a statement with which the AAR strongly disagrees in its comments*.

The theory underlying these projected benefits is that a PTC communications system, coupled with precision dispatching, could reduce delays and help trains adhere to their schedules. Implicit in this analysis is the assumption that precision dispatching, informed by real-time information, can improve recovery from unexpected occurrences.

Reduced variability in arrival time is extremely important to shippers, as it enables them to lower logistics costs. Zeta Tech estimated this benefit using three methodologies:

1. Determine the savings shippers might realize in terms of the reduced inventory portion of logistics cost reduction if service reliability improves. This would be one measure of the total benefit available from improved service when PTC is installed. The Zeta-Tech report showed that a reduction in the cost of carrying safety stock may be a useful surrogate for a lower-bound measure of the total benefit available from improved reliability.

2. Determine what additional amount shippers might be willing to pay for improved service reliability.

3. Determine the cross-elasticity of demand and price relative to PTC-enabled improvements in transit time and its variability as reported in a study on total logistics cost that had been prepared for the Federal Highway Administration. This method for measuring the size of the total benefit provides a useful check on the first two methods used.

Zeta-Tech developed estimates of shipper benefits which ranged from $400 million per year to $2.6 billion per year. It appeared that the higher estimates might be unrealistic, so in developing a summary of benefits, Zeta Tech picked as representative figures estimates of shipper benefits

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[21]See Appendix D, Table 1.

[22]See Appendix D, Table 2.

between $400 million and $900 million per year for PTC A and between $900 million and $1.4 billion per year for PTC B.

These benefits would only occur if the improvements in service, as estimated by Zeta-Tech, were realized. AAR took strong exception to those estimated improvements in service, stating that many of the delays and uncertainties relate to handling of cars in yards and terminal areas and that even if PTC could perform as promised shippers would not see the projected service quality improvements.

FRA notes that the estimates provided above are based on achieving a 3.5-10% improvement in trip times and 3.8-11% improvement in reliability. Even though the absolute benefit numbers are large, these are modest improvements from a percentage viewpoint. FRA agrees it is not possible to say with certainty whether they might be achieved without testing and demonstrating the technology. For instance, precision dispatching requires development of very sophisticated software that proved to be a much greater challenge than originally anticipated by the first vendor to offer the product. It is also true that uncertainties with respect to yard dwell times may be more influential in affecting service quality than over-the-road planning. Nevertheless, this is an era in which all successful businesses are utilizing real-time data and analysis to address customer expectations. It is difficult to imagine that railroads, which are both capital and labor intensive, could contrive to make no gains in service quality with ready availability of current data regarding their train operations.

III. Direct Safety Benefits

FRA, through the Volpe Center, developed estimates of the safety benefits of PTC. PTC A was assumed to provide all of the safety functions of PTC B, but at a lower level of effectiveness. PTC A was assumed to be 85% effective in preventing PTC preventable accidents, while PTC B was assumed to be 98% effective. These values were part of the specifications of the systems to be analyzed, as described in Appendix A.

The Brotherhood of Railroad Signalmen (BRS) and Brotherhood of Maintenance of Way Employees (BMWE) in their comments objected to adoption of systems which would only be available 85% or even 98% of the time.

FRA believes this misconstrues the reliability of such systems, because they would be useful not only where the current system is functional, but in 85% or 98% of the cases in which the current system is not effective, increasing the mean time to an accident by a factor of 6⅔ for PTC A and 50 for PTC B.

The kinds of systems which FRA intended to model as PTC A are less expense systems that are not intended to replace existing safety systems and rules, but have limitations regarding the types of events they can prevent and may be somewhat less reliable (e.g., less fault tolerant). Nevertheless, in both systems some failures are likely to occur, and the current systems are very good. Thus eliminating either 85% or 98% of Positive Train Control Preventable Accidents is a significant achievement. Accident costs were monetized into 1998 dollars using the values in the RSAC Report on PTC. These figures were then converted to 2003 constant dollars using the GDP deflator.

Volpe applied a regression equation to the annual PTC preventable accident costs for the time period 1988-1997, which showed that accident costs had been declining, and could be predicted to decline even without the adoption of PTC. Using those estimates, PTC A would save between $36 million and $44 million per year (at 85% effectiveness) and PTC B would save between $53 and $60 million per year (at 100% effectiveness) in railroad accident costs, however the regression model had a very low coefficient of correlation, with an R-Squared value of approximately 0.10. FRA is reluctant to rely on that model, and instead developed and uses here a simpler model, which says that projected savings are equal to the historical average, plus or minus one standard deviation. Under the model used here, projected direct accident cost savings would be between $35 million and $83 million for PTC A and between $40 million and $96 million for PTC B[23]. Direct PTC safety benefits are very small compared to overall benefits, and they are further offset in part by increased railroad accident costs induced by increased rail traffic after modal diversion.

Several commenters, including the AAR, said that a better way to estimate the trend in accident costs would have been to estimate first the trend in PTC preventable accidents, and then the trend in cost per accident.

Unfortunately, all techniques have drawbacks, because the mix of accidents is changing over time. Some PTC preventable accident categories have diminished more than others, either because they have been addressed by safety initiatives, or because the environment has changed making them less likely. In any event, the impact of PTC preventable accidents remains very small compared to the cost of PTC systems.

[23]See Appendix D, Table 6.

IV. Modal Diversion

This model depends on the estimates of improved rail velocity and reliability derived in the Zeta-Tech study, which have been challenged by several commenters (see discussion above).

To assess the potential for highway to rail diversion, FRA employed the Department's Intermodal Transportation and Inventory Cost (ITIC) Model[24]. The ITIC model measures shipper logistics cost for both highway and rail. If rail can improve its service offerings, lowering shipper logistics cost vis-à-vis highway service offerings, then rail should have the opportunity to better compete and potentially capture the business from motor carriers. Business that rail can capture from highway results in shipper logistics cost savings.

FRA used input values for improved transit time and service reliability developed by Zeta-Tech. **Of course, if the Zeta-Tech estimates are not correct, then neither are the estimates derived by FRA**. Zeta-Tech estimated that transit time would improve between 3.5% and 10% and that reliability would improve by between 3.8% and 11%. Details of the impact of modal diversion can be found in Appendix B, and Appendix D, Tables 7 and 8.

One caution to readers of the diversion study: the study assumes constant railroad rates, which is not meant to be a realistic assumption. The assumption is meant to provide conservative estimates of total diversion. An artifact of using constant rates is that it appears in the study that railroad revenues will grow substantially. In reality most of that revenue would be passed on to shippers in the form of lower rates, and actual diversion would be greater. It does, however provide an indication that the shipper benefits in the Zeta Tech study might be conservative.

Heavy trucks operating over highways create a risk of accidents, and moving them to railroads removes that accident risk from the highways, although it does increase somewhat the rail safety risk. According to the diversion model, PTC will divert between 1.937 billion VMT and 3.723 billion VMT from highway to rail in 2010, which implies a safety benefit on the highway of between \$266 million and \$511 million per year. The diversion increases to between 3.005 billion VMT and 5.714 billion VMT in 2020, which implies a highway safety improvement benefit between \$413 million and \$785 million. These benefits accrue primarily to highway users.

As described here, the safety benefit from PTC would in part be offset by what FRA estimates to be volume related rail accident costs of \$20 million to \$40 million per year.

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[24]The Potential for Highway-to Rail Diversion Following Positive Train Control Operating Efficiencies, FRA, March 22, 2004

FRA estimates diversion of between 30.7 billion ton-miles and 59.5 billion ton-miles in 2010, and between 46.4 billion ton miles and 89.4 billion ton-miles in 2020. As previously noted, the 2010 figures may be overstated because the PTC systems might not be in place until 2010. This

implies reduced air pollution costs between $61.8 million and $120 million in 2010, and between $93 million and $180 million in 2020. This benefit would accrue to the general public.

In its May 2000 Addendum to the 1997 Highway Cost Allocation Study, FHWA said that the cost responsibility[25] of an 80,000 pound combination was 8.65 cents per mile, but that the actual contribution of such combinations only covered 80% of their share. That means that such trucks created a societal cost of 1.73 cents per mile, in 2000 current dollars.

Based on its diversion estimates of VMT, FRA estimates that diverting this traffic to rail could avoid societal costs of between $35 and $68 million in 2010 and between $55 million and $104 million in 2020. These benefits will accrue to highway users or governmental entities providing highways.

Again, railroad commenters strongly disputed the estimated improvements in velocity and reliability, without which benefits to shippers and the public would not be realized.

As noted above, FRA remains convinced that an integrated communications, command and control system such as PTC and allied elements should be able to contribute to improvements in service quality. Modal diversion is highly sensitive to service quality. It may be true that problems with terminal congestion and lengthy dwell times might overwhelm the benefits of PTC; or it may be that the other initiatives which the railroads have been pursing (reconfiguration of yards, pre-blocking of trains, shared power arrangements, car scheduling, AEI, etc.) might actually work in synergy with PTC.

V. Costs of PTC

AAR objected that the impact of costs on railroads were not considered.

FRA did not consider the impact on railroads of acquisition costs, because FRA did not make any policy determinations regarding how PTC might be paid for. FRA would note that if PTC were mandated then the estimated costs here might be low, because the railroads' demand would then become inelastic, and the prices of all components would rise.

Congress required FRA to emphasize two points in this report: benefits to shippers, and costs which take into account advances in technology and other economies related to technology. In 1999, the RSAC analyzed the benefits and costs of deploying PTC, and reported to the

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[25]Highway Cost Responsibility is an entire chapter in the *1997 Federal Highway Cost Allocation Study*, , Federal Highway Administration, Washington, DC, 1997, pp. V-1 *et seq*.. The basic concept is that each user should pay the highway costs it creates or"occasions."

Administrator (RSAC report).[26] Not surprisingly the results have not changed dramatically since then. The Zeta Tech Study finds slightly lower cost per locomotive, between $20,000 and $35,000 per unit for PTC A, and between $30,000 and $75,000 per unit for PTC B. The RSAC report had estimated costs between $40,000 and $75,000 per locomotive. The RSAC report expected a smaller number of locomotives to be equipped, 16,000 versus 20,000 in the Zeta Tech report. Zeta Tech also found a similar cost per route mile, $8,000 to $12,000 per mile for PTC A and $16,000 to $24,000 per mile for PTC B. The RSAC report numbers were not directly comparable to the Zeta Tech report, because route mile features and track mile features were calculated separately, however both reports estimated costs of deployment on roughly 100,000 route miles[27].

Alan Polivka, who directs the North American Joint PTC project said at the Peer Review Workshop that the costs per locomotive that he was encountering in actual purchases were much lower, and that a PTC B system could equip locomotives at a cost per unit of $25,000.

FRA accordingly has reduced the estimated cost per locomotive to $15,000-$25,000 per unit for PTC A and $20,000 to $35,000 for PTC B.

Zeta-Tech based its estimates on discussions with vendors and railroads. One obstacle to estimating or projecting costs is that systems are not usually sold on a piecemeal basis, but rather as complete systems, so one vendor might attribute a greater share of the cost to one component or another, but the total costs for systems with similar capabilities are likely to be similar.

The remaining significant acquisition cost in both reports was a combined system development and central office cost. The RSAC report estimated these costs at $85,000,000 to $235,000,000, while the Zeta Tech report estimated these costs at $100,000,000 to $500,000,000 for either PTC A or PTC B. The Zeta-Tech report states that this cost is the greatest single unknown, until at least one PTC system commences actual operation on a large scale. One other observation was that PTC A may be less capable than PTC B, but the program development, verification, validation and testing may be equally costly.[28]

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[26]Report of the Railroad Safety Advisory Committee to the Federal Railroad Administrator, September 8, 1999

[27]See Appendix D, Table 3.

[28]FRA assumes that any system will have to meet the proposed safety standard for processor-based signal and train control systems. Under that proposal a system must be at least as safe as the system which was there before it. This requires a risk assessment. The reason that combined risk assessment and other development costs may be the same for the simpler system, is that the more capable system will be designed to higher standards, and will likely use principles such as closed loops, and other high level of safety concepts, which will make it easy to prove that PTC B is at least as safe as the current systems, while PTC A is likely to use lower cost components, so proving it is sufficiently safe may prove to be more costly than proving that PTC B is safe enough.

Some commenters said that Zeta-Tech's estimates of central office costs seemed high, and that no system was under consideration that has a central office like the one apparently envisioned in the Zeta-Tech report.

These commenters did not address the fact that Zeta-Tech had combined development and central office costs. These costs might be high, but FRA believes there remains a substantial technological risk that must be accounted for, so FRA has retained Zeta-Tech's original estimate. FRA does believe this cost could be reduced substantially if the railroads were to develop only one system and apply it on all major railroads, but there does not seem to be a mechanism for accomplishing that.

Both studies totaled initial acquisition costs. The RSAC report found initial acquisition costs between $600 million and $4 billion (in 1999 dollars), while Zeta Tech found initial acquisition costs between $1.2 billion and $2.2 billion for PTC A, and between $2.0 billion and $3.7 billion for PTC B (2003 dollars). It is important to note that PTC A would describe a system more capable than the lowest cost system analyzed in the RSAC report, and the RSAC report is in 1999 dollars, while the Zeta Tech report is in 2003 dollars, so the RSAC costs would be about 91 cents on the dollar ($550 million to $3.64 billion) if converted to 2003 dollars. The lower RSAC estimates were for systems projected to be less capable than PTC A, while the higher estimates were for systems projected to be more capable than PTC B.

Both studies used a fixed percentage of initial acquisition cost to estimate annual maintenance costs. The RSAC report used a figure of 10% of initial acquisition cost, while the Zeta Tech study used a figure of 15%. There does not seem to be much basis to prefer one number over the other, however, it is clear that any cost estimate must include maintenance costs. RSAC estimated annual maintenance costs at from $60 million per year to $400 million per year, while the Zeta Tech study estimated annual costs between $182 million and $335 million for PTC A and between $307 million and $551 million for PTC B.[29]

Another cost of PTC B would be the cost of the National Differential Global Positioning System (NDGPS). PTC B needs more exact train positioning to support its first-order safety functions (including integrity monitoring). There is no marginal cost to the portion of the system which has been funded to date. The remaining construction is estimated to cost $58 million, and projected annual maintenance for the completed system will be $8.1 million per year. NDGPS will create other externalized benefits not measured in this analysis.

VI. Combined Impacts of Benefits and Costs

A. Timing Issues

FRA has added this section to address concerns raised in AAR comments about timing issues. The Zeta-Tech study had included some tables which showed rates of return, based on a five-year implementation schedule, which suggested that 20% of the annual benefits would accrue in the first year, 40% in the second, and so on until 100% were realized in the fifth year. This is not realistic. FRA explicitly rejects this assumption. A more realistic schedule would be that it

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[29]See Appendix D, Table 4

would take approximately three years to achieve funding and contracts for such a system, and it would take at least five years from then to have the system fully operational. It might be possible to move somewhat more rapidly with greater funding, but the costs would escalate, and there is a minimum critical development path which is probably in the neighborhood of three years, regardless of funding level. Hence, five years from notice to proceed would be somewhat aggressive, even if the system were fully developed at that time (which is currently not the case).

The critical paths would involve development of software and implementation of that software on existing hardware, the development and installation of on-board hardware, which would necessitate pulling locomotives out of service, and development, installation and cutover of wayside hardware, which would necessitate withdrawing tracks from service during construction and again during a cutover, with attendant testing.

Assuming that all the major railroads were to adopt compatible systems, they could probably deploy such systems in five years by rotating their locomotives through the shops over four to five years. There would be no benefit on any route until the wayside equipment was installed, and the business benefits would not occur until the central system, with its dispatch functions, was operational. An example might be 1% of annual benefits after the first year, 5% after the second, 15% after the third, 50% after the fourth and full benefits after the fifth. This would further mean that benefits could not flow at the 100% level until after 8 years of development and installation, which would mean roughly 2013, if progress toward a funding decision were to begin at the end of this year. Thus the system would not be in place to generate the 2010 benefits projected in the Zeta-Tech report.

This sort of schedule means that the investment would likely occur over five or more years, but also would not be at uniform investment levels. More likely the cost would be relatively little in the first year, more in the second, building up in the third and fourth years, and finally tailing off in the fifth year. An example might be 5% the first year, 15% the second, 25% the third, 35% the fourth, and 20% in the fifth year.

All of these time-displaced numbers raise an important issue, which FRA does not resolve here: What is the most appropriate discount rate? If FRA were to impose a requirement on the railroads, we would use a discount rate of 7% per year, and use a figure of 3% per year for sensitivity, using the guidelines in OMB Circular A-4. If the railroads were to make the investment on their own, they would use a "hurdle rate" of approximately 20% per year. The hurdle rate varies according to the potential projects available, and the railroads fund the projects with the highest internal rates of return first until available reinvestment capital is exhausted. The AAR also suggested as a rate 13.3%, the railroad's cost of capital.[30] Further, if the Federal Government were to pay, we would use a rate based on the government's borrowing costs, roughly 4%. The greater the discount rate, the less net value to an investment like PTC, which requires an investment "up front" and yielding returns over time.

[30]Correction to AAR comments, submitted April 29, 2004, which altered the cost of capital from their initial estimate of 9.4% to 13.3%.

Regardless of the discount rate used, the time lag between investment and returns would make investments in PTC much less attractive than they would otherwise appear. This effect is smallest for the lowest discount rates, and greatest for the highest rates. Since the highest discount rate is the hurdle rate, which applies to voluntary investments and in effect takes into account opportunity costs, the likelihood of completely voluntary adoption of the systems described here is relatively lower than other types of investment strategies.

B. Source of Investment Capital

FRA makes no assumptions about the source of capital. The AAR, in comments at the Peer Review Workshop, criticized the draft study, saying that if railroads were likely to receive the kinds of benefits projected, that they would adopt PTC on their own. If the railroads do adopt PTC on their own, then we can assume that they have found business benefits which warrant adoption of PTC, and have met their hurdle rates. If they don't, and the public wants to receive the potential societal benefits available, then the public can either fund PTC or require PTC. In either of the latter two cases, it is less likely the benefits projected by the Zeta-Tech study would be realized, because it is possible to adopt PTC without generating the business benefits from enhanced operations. Some of the business benefits would not occur unless the railroads were to alter their operations. It is extremely unlikely that the railroads would alter their operations to generate shipper benefits in response to a mandate, although it is somewhat more likely if there were a public-private partnership.

In light of these issues, FRA makes no assumptions about the source of capital.

C. Net Benefits

This uses the Zeta-Tech study, as modified by FRA, and relies on the assumptions that PTC would create improvements in traffic flow and reliability on the railroads. *The AAR and other commenters disagree with these assumptions*.

If the railroads were to purchase and install PTC A[31], it would cost them between $1.214 and $2.234 billion dollars, and would yield them between a net loss of $7.1 million and a net profit of $80 million per year. Shippers would receive a benefit of between $371 million and $1.22 billion per year. PTC preventable rail accident costs would be reduced by $35 million to $83 million per year, but would be offset by volume related increases in rail accident costs of $20 million to $40 million per year.

Because of modal diversion, highway accident costs would be reduced by between $266 million and $511 million per year, by 2010, and between $412 million and $785 million in 2020. Air pollution costs would be reduced by between $62 million and $120 million in 2010, and between $93 million and $180 million in 2020. Other highway costs would be reduced by between $35 million and $68 million in 2010, and between $55 million and $104 million in 2020. These figures would remain the same for PTC B, because the modal diversion model does not distinguish between PTC A and PTC B.

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[31]See Appendix D for detailed tables showing the derivation of costs and benefits.

The total net societal benefits for PTC A, would range from a low of $762 million per year in 2010 to a high of $2.20 billion in 2020.

If the railroads were to purchase and install PTC B[32], it would cost them between $2.04 and $3.67 billion dollars, and would return them between $25 million and $202 million per year. Shippers would receive a benefit of between $1.55 billion and $2.52 billion per year. PTC preventable rail accident costs would be reduced by $40 million to $96 million per year, but would be offset by volume related increases in rail accident costs of $20 million to $40 million per year.

The total net societal benefits for PTC B, would range from a low of $2.43 billion per year in 2010 to a high of $3.88 billion in 2020.

In all of the scenarios analyzed the railroads receive between a net loss and 5.76% of the total societal benefits. Railroad safety benefits are a very small proportion, less than 1% of total benefits (rail safety per ton mile or train mile improves, but the increase in train miles and ton miles induces risk proportional to exposure which offsets some of the safety benefits of PTC). The bulk of the benefits goes to highway users (and the general public) who avoid accident costs, and to shippers, who as a result of competition in their own markets will have to pass the benefits on to society at large. Without the estimated benefit of Track Forces Terminals (TFT's)'s the railroads would incur net losses under all low return scenarios, and less than 4% of societal benefits under the most optimistic scenarios.

Another issue is the cost of PTC relative to the enterprise valuation (the sum of the market capitalization and debt) of the railroads. The systems discussed here could cost from $1.2 billion to $3.7 billion, but the enterprise value of the four largest railroads, which carry more than 90 percent of freight volume, is only $71 billion.[33]

D. Conclusions:

There remain many uncertainties about the net benefits of PTC. No current railroad management team accepts these benefits, although these benefits previously were accepted by at least one Class I railroad, which was relying on similar assumptions in its attempts to develop PTC. The management team at the railroad changed, for reasons which appear unconnected to the prior team's commitment to PTC, and the new team chose to invest its capital elsewhere. It appears that experts do not agree on the capacity and reliability issues raised in this study, and the only resolution will come if PTC, with the kind of business-related systems described here, is voluntarily deployed by a major railroad.

VII. The Peer Review Workshop

On April 13, 2004, the FRA held a workshop in order to solicit industry comment on FRA's draft report. Railroad representatives were not happy with the report, and listed several objections. There were also adverse comments from representatives of labor organizations, which had a

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[32]See Appendix D for detailed tables showing the derivation of costs and benefits.

[33]See Appendix D, Table 9.

different focus from railroad comments. Railroad signal suppliers were present at the meeting but had no comments regarding the report. FRA asked the participants for written comments and undertook to consider oral comments introduced at the meeting. FRA posted minutes of the meeting on April 21, on a website available to all workshop participants. Comments were due by April 27. FRA considered, and, as needed, incorporated comments. FRA received written comments from:

BRS
Zeta-Tech
Ron Lindsay, Communication Architecture (Comarch)
Bill Petit, on behalf of the Railway Supply Institute (RSI)
AAR
Brotherhood of Locomotive Engineers and Trainmen, Teamsters (BLE-T)
American Public Transportation Association (APTA)

AAR had asked to meet with the Administrator on Monday April 19, 2004, to discuss the PTC Benefit/Cost study. AAR representatives also met with Zeta-Tech Associates on April 21, 2004, to discuss the Zeta-Tech study.

A. AAR and member railroad comments:

The railroads' oral objections centered around two key issues, although several smaller issues were mentioned. The two key issues were that the contractor's report to FRA, by Zeta-Tech Associates, exaggerated benefits by key assumptions. The first was whether PTC could improve overall traffic velocity and reliability. The second was that whether alternative technology could provide the same benefits.

By far the most sensitive issue all raised during the all-day session was whether PTC could improve overall traffic velocity and reliability. Several reasons were offered. One commenter said that flexible block systems actually slowed throughput compared to closely spaced fixed block signals.

As noted above, FRA believes that improvements in service quality are possible and that PTC and allied systems should make a positive contribution. This study provides an indication of the magnitude of benefits based on estimated improvements in velocity and reliability. FRA agrees that demonstration of the technology will be required to determine actual effects.

Another railroad commenter said that yards and terminals would not have the capacity to handle trains if they arrived more rapidly because of a more rapid transit time across mainlines connecting terminals and yards.

FRA staff does not concur with this comment. FRA believes the effect of more rapid times between terminals and yards would have a similar effect to shortening the distance between them. The only way the railroads could cause yard capacity difficulties with the existing traffic level and more rapid mainline transit times would be to dramatically decrease the time enroute simultaneously for the entire system. Then some facilities would be overwhelmed, but such a scenario is very unlikely. FRA does agree that increased traffic might become a problem for yards and terminals, and is likely to become a problem with or without PTC, because of growing traffic. PTC might actually ameliorate the issue by doing a better job of scheduling the arrival of trains at facilities with capacity issues.

Nevertheless, to the extent traffic increased significantly, some additional yard and terminal capacity would have to be created, and that cost was not included in the contractor's study.

One point raised by the AAR was that if the terrific benefits forecast in the Zeta-Tech report were accurate, then the railroads would already have installed PTC to achieve those benefits, and that we could infer from the fact that the railroads had not yet installed PTC that the benefits were unlikely to accrue.

FRA notes that deployment of PTC under conventional assumptions, which would require railroads to finance its development and installation, would involve significant up-front costs and technical risk. FRA further notes the following:

- If PTC can yield benefits of the types and magnitudes discussed in this report, most of them will be realized by shippers and the public.
- If railroads were to elect to invest in PTC, they would face a period of 5-10 years during which costs would be incurred before the full stream of benefits was realized.
- Whatever the reason, two major Class I railroads profess to be developing PTC systems. Senior officers of these railroads have stated to FRA that, if tests are demonstrations are successful, they intend to go forward with deployment. Both railroads also profess to be going forward both for safety and business reasons.

Indeed, the AAR reports that, "The railroad industry is committed to advancing PTC technology, as evidenced by an investment of over $250 million to date." (AAR Comments at 1.) Whether that commitment is based exclusively on safety needs or also includes consideration of other benefits is for the railroads to explain. During preparation of this report, FRA requested the railroads to express their vision of the future of PTC and allied technologies, but they did not do so.[34]

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[34]Among the business benefits suggested by railroad officers in private conversations, the most prominent are: (1) avoiding investments in new signal systems on lines presently unequipped where traffic is growing; (2) removing older signal systems in light to moderate density territories; and (3) operating with reduced crews. FRA is not able to judge the plausibility of these benefits without viewing specific plans, but at least some of these benefits are likely to be achieved as PTC is deployed. For instance, a system like PTC A might provide safeguards that could permit removal of an old, difficult-to-maintain signal system under circumstances where the signal system is no longer required to expedite trains movements.

The remainder of the comments at the Peer Review Workshop did not address the study conclusions, although they were of interest.

The railroads requested that FRA ask Congress to support Build 3 of the NAJPTC project. Given the fact that most of the benefits we portray would be captured by shippers and highway users, it seems appropriate to go forward with this suggestion to the extent compatible with the Administration policy.

The AAR also submitted written comments, with five main areas of disagreement with FRA's draft (*AAR's words in italics*):

> *Definition of PTC: A new and misleading definition of Positive Train Control*.
>
> FRA agrees that we went beyond previous RSAC definitions, because the requirement from Congress addressed PTC and related systems, and because business benefits depend on additional functions beyond the safety functions. Further, FRA in its *Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations,* which was cleared by the Administrator, the Office of the Secretary, and the Office of Management and Budget, and was submitted to the Senate and House Appropriations Committees, had defined PTC differently:
>
>> Positive Train Control (PTC) systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. PTC systems will improve railroad safety by significantly reducing the probability of collisions between trains, casualties to roadway workers and damage to their equipment, and over speed accidents. The National Transportation Safety Board (NTSB) has named PTC as one of its "most-wanted" initiatives for national transportation safety. PTC systems are comprised of digital data link communications networks, continuous and accurate positioning systems such as NDGPS, on-board computers with digitized maps on locomotives and maintenance-of-way equipment, in-cab displays, throttle-brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control center computers and displays. PTC systems may also interface with tactical and strategic traffic planners, work order reporting systems, and locomotive health reporting systems. PTC systems issue movement authorities to train and maintenance-of-way crews, track the location of the trains and maintenance-of-way vehicles, have the ability to automatically enforce movement authorities, and continually update operating data systems with information on the location of trains, locomotives, cars, and crews. The remote intervention capability of PTC will permit the control center to stop a train should the locomotive crew be incapacitated. In addition to providing a greater level of safety and security, PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and

greater track capacity. They will assist railroads in measuring and managing costs and in improving energy efficiency. Pilot versions of PTC were successfully tested a decade ago, but the systems were never deployed on a wide scale.

Impact of Current Train Location Information on Average Train Velocity: An assumption that PTC will provide near real time train location information that is not available today that will greatly improve train-dispatching decisions and thereby enable dramatic (e.g. 5% to 20%) reductions in current train running times between terminals.

Zeta-Tech and the AAR disagree, but there is no easy way to determine whose assumptions are better, because we are conjecturing about systems which have never been built nor deployed. Zeta-Tech has done a significant study of dispatcher effectiveness, and it shows that dispatchers do not do a good job of maximizing throughput. An intelligent dispatch planner could improve traffic flows dramatically. The railroads are correct that no such planner has been proved. The railroads are saying that updated information on a very frequent basis offers very little to improve dispatch quality, given an intelligent dispatch system. The Alaska Railroad is implementing a PTC and has published this statement their project:

> Soon, we will employ a real-time satellite tracking system to effect a true collision avoidance operating environment. Smart circuitry will automate the essential function of deconflicting approaching
>
> vehicles on a single track, even stopping a train automatically if necessary. We continue the quest to move more trains, faster.[35]

Impact of Moving Block on Train Spacing: An assumption that PTC with "moving block" capability will enable reduced spacing between trains and thereby increase line capacity, saving billions of dollars of investment in additional trackage.

AAR (and concurring comments from APTA) said that, at least in presently foreseeable applications, flexible block systems actually reduce capacity compared to closely spaced fixed signals.

FRA understands the concern that excessively conservative braking algorithms can reduce average velocity under certain circumstances, either in a fixed or moving block context. The agency shares the railroads' frustration that this issue has not been more readily addressed. FRA believes that more realistic safety margins can be determined and computed. The North American Joint PTC Program provides one venue in which this issue will be addressed, including potential demonstration of flexible block technology.

AAR suggests a conflict between the assumption that track circuits will be retained for broken rail protection and the assumption that dynamic headways can add capacity.

[35]Patrick K Gamble President and CEO, Alaska Railroad, 2003 Annual Report Letter, April 2004

AAR is correct that there would be trade-offs that would have to be considered. FRA would anticipate that attention to rail renewals and higher quality internal rail flaw detection inspections could offset any reduced flexibility. FRA agrees that the costs of these measures have not been included; however, they would also produce additional benefits (reduced maintenance, less disruption of service, and reduced derailments).

Speed of Implementation and Realization of Benefits: The assumption (p. 5) that PTC can be fully implemented on 20,000 locomotives over 100,000 route-miles on all Class I freight railroads and many Class II railroads nationwide within five years and that major benefits (20% of full benefits in year 2, 40% in year 3, etc.) will begin flowing within one or two years of the initial investment.

FRA agrees that proportional benefits would not be realized in early years, and that 100% of benefits are realizable only after the installation is completed, perhaps with a lag for shipper reaction.[36] Five years may be too aggressive an estimate for full deployment, but the actual pace of deployment would likely depend most on funding levels. If full funding of nationwide PTC were to become a reality, FRA believes the pace of development could be much more rapid than the current pace. Obviously the benefits would not begin to flow until significant installations were complete and operational. FRA has devoted a section to this issue

Exaggeration of Shipper Benefits by failing to reduce any pass-through of rail profits to rail customers to reflect the very high capital costs to railroads of the PTC system itself.

The FRA makes no assumption about who would pay for PTC, especially in light of the fact that the overwhelming majority of projected benefits would be passed on to the general public or highway users. Therefore the FRA does not estimate the impact of the costs of PTC on the railroads.

The AAR also has some significant disagreement over the use of additional features beyond the core functions of PTC in order to derive business benefits:

The relationship between PTC and the "additional components and capabilities" is weak and largely arbitrary. The only common element is that they usually rely on wireless communications to one extent or another. Consider these points:

No Dependence of the Other Systems on PTC: None of the additional components and capabilities depends in any way on PTC for implementation or effectiveness. Indeed, since PTC is the most difficult of all these systems to implement, and no PTC has been implemented yet beyond pilot tests, any dependence on PTC would have held up implementation of these other systems. In fact, no such delay has occurred.

Prior Implementation of the Other Systems: Several of the additional capabilities have already been implemented to varying degrees by at least some railroads. Examples: Work Order Reporting on UP (contrary to the FRA Report, p. 6); locomotive diagnostics on UP

[36]See the section on timing of benefits, infra.

and CSX; precision dispatching systems currently under development on NS, UP, and BNSF.

Benefits of the Other Systems Already Obtained or Else Found to Be Small: Where the additional capabilities have been implemented, most of the benefits they offer have already been obtained. Or the implementing railroad has determined that the benefits are not significant and has elected not to pursue them further. Examples of the latter: Train pacing on several major railroads.

The Benefit Pool for Some of the Other Systems has Declined: Railroads have found that recent developments have reduced the potential pool of benefits for some of these other systems. For example, in recent years, many of the purported benefits of precision dispatching have been obtained on some railroads by running and adhering to a more scheduled operation, with much greater regularity and repetition in dispatching decisions. Likewise, the pool of benefits for locomotive diagnostics has diminished as locomotives have become more reliable. Fifteen years ago, locomotives had a mean time between failures (MTBF) of 20 to 30 days. Today, the mean time between failures ranges between 80 and 100 days.

The Benefits have Been Obtained by Other Means, i.e., Without Using a Private Wireless Network: Examples: Work Order Reporting on NS and CSX via cellular telephone and facsimile.

Large Differences in Communications Requirements: None of the additional components and capabilities has communications requirements (in geographic scope, volume, or frequency) that even come close to those of PTC. The greater communications requirements are a function of traffic, speed, and density (not of safety) and therefore are required for PTC-A as well as PTC-B, contrary to the Report. Both PTC-A and PTC-B require a highly reliable indication of which track each train is on in double-track territory. The other capabilities do not. PTC requires communication every few seconds, while work order reporting, for example, may require communication every few minutes or hours. Location information for pacing might require equipment costing about $1,000 per locomotive, versus tens of thousands of dollars per locomotive for PTC. So adding PTC on to these systems would require major modifications or even complete retooling to, and possible segregation of, the communications functionality.

No Dependence of PTC on the Other Systems: PTC itself does not depend on any of the other systems for implementation or effectiveness. The only likely synergies are that the other systems and PTC may be able to utilize some of the same equipment (e.g., some of the cabling and network on the locomotive, plus the GPS antenna).

In general, railroads have obtained many of the truly obtainable benefits of the "additional components and capabilities" through numerous, low risk, incremental changes that have had nothing to do with narrower Positive Train Control as defined by RSAC. An attempt at this stage to push these capabilities into the definition of PTC takes on the appearance of searching for additional benefits to justify imposition of PTC—currently an immature PTC—on the railroad industry.

FRA would answer these by saying the Zeta-Tech study does indeed consider the effect of benefits already attained, and is based on current data, contrary to AAR assertions. FRA agrees that synergies among elements of railroad electronic systems that might to some degree be integrated will vary. Some functions might benefit only by avoided cost. In other cases, particularly the pairing of precision dispatching and train control with frequent reporting to the central office, considerable synergies would be expected.

B. APTA's comments:

APTA took issue with the system description of PTC A and PTC B, because neither of them reflected systems like ITCS[37] *and ASES,*[38] *which are in service PTC systems enforcing fixed blocks on predominantly passenger railroads.*

FRA would point out that the definitions were chosen to demonstrate potential business benefits, and that the configurations of ITCS and ASES do not lend themselves to large business benefits. Train control systems designed to support dense passenger train traffic or higher train speeds are justified based upon their safety benefits and the degree to which to contribute to capacity. ITCS is designed to permit higher train speeds than would be the case with only wayside signaling, and it offers the additional benefit of simplifying the provision of constant warning time at highway-rail crossings. ASES is a transponder-based system that can be used to provide safety features over a wide range of territories and, where applicable, complement an ACS/ATC system. Neither ITCS nor ASES as currently configured provides real-time train operations information to the central office.

Further, APTA says that ASES has resulted in a small diminution of capacity, so therefore FRA's projected velocity enhancements are unrealistic.

FRA believes that ASES relies on conservative braking algorithms, and is overlaid on fixed block, does not have an accompanying dispatch planning system, and was never designed with the first priority being business benefits, so it is not reasonable to infer from the ASES experience that no other PTC system could enhance throughput or velocity.

C. Ron Lindsay's comments:

Ron Lindsay, a railroad contractor who works for CSX on Communication-Based Train Control, said in both oral and written comments that what the draft letter report and Zeta-Tech study discussed was really traffic control, not train control.

FRA understands the commenter's point. However, as noted earlier in this report, the request of the Appropriations Committees went well beyond train control.

[37]Incremental Train Control System (ITCS), is a PTC system installed by Amtrak in Michigan, which relies on wayside units to maintain train separation.

[38]Advanced Speed Enforcement System (ASES) is a transponder-based PTC system, installed by New Jersey Transit, and is compatible with the Advanced Civil Speed Enforcement System adopted by Amtrak for the Northeast Corridor.

D. Labor organization comments:

Two unions, BRS, and BMWE (which did not submit written comments but which participated in the workshop), had similar issues. Both objected that the Track Forces Terminals and other PTC A functions as described would not be adequate if they were only 85% effective.

FRA needs to make clear that 85% effectiveness is applicable to the remaining PTC preventable accidents, and is more than 6 times as safe the current safety methods.

BRS, in its written comments also objected to use of a figure of $2.7 million dollars willingness to pay to avoid a fatality.

FRA would point out that the actual figure was $3 million, that the same figure is used in most analyses preformed within the Department of Transportation, and that if a higher figure were used the net benefits would increase most for diverted traffic from the highway mode. FRA can provide references to additional materials defending the use of willingness to pay to avoid a fatality.

The Brotherhood of Locomotive Engineers and Trainmen (BLE-T) said that some of the efficiencies attributed to PTC could be achieved by better-trained locomotive engineers.

FRA agrees, and would further point out that better trained, or less heavily worked, dispatchers can improve railroad mainline efficiency also. Railroads have not chosen these paths to greater efficiency, perhaps because the labor costs exceed the efficiency gains.

In written comments, the BLE-T said that they did not believe that improvements in velocity and reliability would flow from adoption of PTC. They also commented that they thought that the predicted modal diversion would not occur, because shippers are satisfied with existing truck service, and that it is difficult for railroads to provide reliable service.

FRA disagrees with the assertion that reliability could not improve, hence we disagree with BLE-T's conclusion that the diversion would not happen. The principal area of potential growth is intermodal service, which marries the flexibility of trucks and the long haul efficiency of railroads. Trucking companies have become some of the railroad's most important customers.

BLE-T is also not satisfied with the definitions of PTC used in the study, claiming that any straying from the three core functions makes it harder to understand PTC and less likely that PTC would be adopted.

FRA has already responded to this concern.

E. RSI comments:

RSI had four main issues:

> *The report presumes that a PTC system must be a centralized system and goes so far as to presume the architecture of the IDOT system. This presumed architecture has never been part of previous discussions on PTC and is an undesirable precedent. All of the PTC systems in revenue service use distributed systems for safety-critical components (e.g.*

ITCS, ACSES, ASES). This holds equally true for Communication-Based Train Control systems used in the rail transit marketplace. There has never been a centralized system of the scope considered in the report installed anywhere in the world and the technical risks are very high. Several members of the committee have previously expressed concerns individually to the FRA about use of such a highly complex system in a safety-critical manner. Concern was also expressed regarding reliance on commercial off-the-shelf hardware and software in a safety-critical system.

There was a presumption at the meeting that safety-critical software can easily be modified for new or geographically different locations. This is an erroneous assumption and leads to underestimating the cost of installing new systems.

No consideration was given in the report to modifying existing signal systems at specific areas where traffic congestion may be an issue. Our experience has shown that the benefits of moving block systems are generally overstated. A well designed fixed or flexible block system provides the vast majority of the benefits of a moving block system. Thus, upgrading the existing signal system at choke points may be a much more cost-effective approach to relieving congestion on line routes. As the railroads highlighted at the meeting, congestion is more frequently affected by terminal points (yards, terminals, ports) than by line routes.

The report frequently mixes safety systems and operational systems. Many of the benefits suggested can be obtained by less expensive means (e.g. locomotive engineer training, better strategic and tactical traffic planning) without modifying the operation or intent of existing safety-critical systems.

FRA does not agree that central office systems are impossible, nor do we believe they are necessary to achieve the business benefits. However, a central office system was the system analyzed for PTC B. FRA does recognize that the likely migration path toward PTC will involve use of field signal logic to ensure route integrity.

FRA did not assume that modifying software would be a trivial exercise, and the estimated costs for the development of the system reflect FRA's understanding of the difficulty.

FRA agrees that closely spaced fixed blocks, with appropriate logic, give much of the benefits of flexible block, but in those cases where there are severe capacity constraints, FRA believes it would be less expensive to apply a developed PTC flexible block system than to reconfigure the blocks to smaller intervals, yet the flexible block if properly designed, could create greater benefit.

FRA agrees that some non-PTC systems can provide some of the business benefits, but to the extent those systems are not in place today, FRA believes it met the intent of Congress by analyzing those benefits as benefits of PTC and related systems.

F. Zeta-Tech comments:

Zeta-Tech met with the AAR on April 21, 2004 to discuss their differences on the Zeta-Tech portion of the report. Zeta-Tech wrote an explanatory letter to FRA, outlining the railroads' disagreements with the report and their responses. Zeta-Tech agrees with the railroads that the productivity improvements associated with more rapid movement of cars should only be applied to the time the cars are actually moving, which substantially diminishes the estimated savings for that element. Zeta-Tech sticks by its original estimates of improved service reliability and velocity, but agrees with the railroads that there is a substantial technological risk, which might be reduced if NAJPTC build 3 were completed. Zeta-Tech also agrees that there are certain locations where generalized assumptions about the potential of PTC to improve velocity might not apply, such as in BNSF's Flathead Tunnel. Zeta-Tech also agrees that there might be a way to achieve the bulk of the velocity improvements by combining real-time GPS positioning data with more efficient dispatch algorithms. Zeta-Tech went on to catalog several additional risks and caveats.

As a result of Zeta-Tech and AAR's comments on ownership cost savings FRA has reduced Zeta-Tech's estimate of the potential savings to railroads from precision dispatch by 75%. This seems conservative, as Zeta-Tech had said in its comments that some cars move as little as 12% of the time, and about half the ownership cost reductions were due to cars, the other half to locomotives. These benefits were a small part of the total benefits estimated by Zeta-Tech and had little impact on the total societal benefits.

VIII. Study Limitations

The commenters at the Peer Review Workshop pointed out some of the limitations of the study, but several basic limitations warrant emphasis.

First and foremost the study depends on the ability of the railroads and their suppliers to develop the type of PTC system described. At present there is no vendor offering for immediate sale such a system. In fact, such a system would need to be developed, with substantial technical risk. The combined enterprise value of the four largest Class I railroads was approximately $71 billion in March 2004. The initial cost of PTC systems could be up to $3.7 billion, according to estimate provided here, or more, if there were cost overruns. A railroad choosing to install PTC at those costs might be "betting the corporation" on a single project.

Second, the PTC system might be developed with the proposed features, but the transit time and reliability savings might fail to materialize. Commenters noted the critical role of yard and terminal capacity. Railroads aggressively shed both main line and yard capacity in the 1970s and 1980s in order to reduce costs (and often to generate cash). As business has grown, yards and terminals have become more difficult to manage. Further, the nature of the business has changed, creating mis-matches between existing facilities and needs. Railroads have reconfigured yards, and both railroads and ports have added intermodal terminal capacity. Although PTC is not an answer to these issues, neither should it be assumed that they cannot be addressed in the future as they have been in the recent past, albeit potentially at increasing cost.

On the other hand the study might be too pessimistic. The diversion model assumes constant rates. If railroads were unable to maintain current rates, which appears likely, then the shippers would divert even more traffic, and even more of the benefit would accrue to shippers and highway users.

Finally, FRA was not able to respond meaningfully to the request to consider "prioritized deployment of these systems, especially along lines that might mix freight and passenger trains." As illustrated by the discussion of the APTA comments, train control itself is important to the success of passenger operations because it enhances safety, and because in many configurations it can also enhance capacity. Nevertheless, not even legacy train control systems are installed on most of the Amtrak route network, nor are such systems in place on most commuter rail routes outside the Northeast Corridor. Achieving PTC on passenger routes where PTC or a legacy train control system is not already in place will require coordination between passenger and freight railroads. But since freight locomotives are increasingly free-running (not tied to a particular territory), it is difficult to conceive a coordinated deployment that addresses passenger safety needs well ahead of the general freight system.

Appendix A: PTC System Definitions

Several commenters took issue with these definitions.

FRA needed to tell Zeta-Tech what kind of system to develop costs for. To that end, FRA developed descriptions of possible systems, with safety levels determined in advance. FRA wanted to develop two alternatives, a lower cost system, which would be intended to get most of the potential safety benefit, and a higher end system, which would get almost all of the potential safety benefit. These descriptions were meant to be similar to existing projects under development, but with some enhancements to achieve business benefits also. The lower end system was to be called PTC Level A, the higher end system was to be called PTC Level B.

The discussion below refers to "core functions." These were derived by the RSAC, through its PTC Working Group. The core functions were functions which defined PTC for the purposes of a report to the Federal Railroad Administrator, *Implementation of Positive Train Control Systems*, September 8, 1999. These functions were:

1. Preventing train-to-train collisions.
2. Enforcing speed restrictions, including civil engineering restrictions (curves, bridges, etc.) and temporary slow orders.
3. Providing protection for roadway workers and their equipment operating under specific authorities.

The RSAC also identified additional safety functions which might be included in some PTC systems:

4. Providing warning of on-track equipment operating outside the limits of authority.
5. Receiving and acting upon hazard information in a more timely or more secure manner (e.g. compromised bridge integrity, wayside detector data).
6. Generating data for transfer to highway users to enhance warning at highway-rail grade crossings.

FRA believes that an additional feature which might be built in to PTC systems might be the ability to grant and to release authorities rapidly for roadway workers, in order to protect better roadway workers under function 3 and roadway equipment under function 4.

A-I PTC Level A

This is an ***overlay system***[39] where the existing method of operation remains and safety features are enhanced by PTC. It is intended to provide basic safety functionality and to improve the efficiency of the railroad. The system is built taking into consideration traditional "fail safe" or "closed loop" principles to the extent practicable or necessary to the particular function. The system has layers appropriate for dark and signal territory, but the implementation does not include high-speed territory (i.e., >79 mph).

This system is intended to complement a CAD similar in function to those currently in place.

This design concept will provide:

Core functions would be met with an 85% improvement over past accidents (PPA's at Level 3) as identified by the Accident Review Team. Switches are monitored at all main line track and controlled sidings where circuits exist.

Track circuits for broken rail protection where currently provided and in the future where train speeds exceed 49/59 mph.

The ability to securely transmit text messages providing movement authorities, with acknowledgment and completion possible through use of a keypad or touch screen. (Closed-loop implementation.)

The ability to track train position and to request release of authorities by train crews digitally (securely determining if and when the release has been provided). The location of the rear of the train will be determined.

Additional roadway worker protection is provided as follows (Hi-Rail Compliance Limits model extended):

Track forces terminals with location determination for on-track equipment provide warning to operator to help prevent violation of authorities and notification to dispatcher of exceedences.

All powered on-track equipment (hi-rail trucks, specialized MOW equipment) is "equipped" (i.e., units may be portable but each "lead" and "rear" vehicle of equipment traveling together will be tracked).

System warns operator and dispatcher of impending violations, alarms again if authority is exceeded. Alert provided to dispatcher.

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[39]An overlay system retains the existing method of operation, whether the method of operation is track warrants, wayside signals, or cab signals, or something else, and provides an additional margin of safety. For an overlay system to be effective in preventing accidents it must be available when the underlying system fails. FRA believes that such systems may be more likely to fail at exactly the time they are most needed, hence they will not reduce accidents by the proportion of the time they are available, but by some lower proportion. This is why FRA is using a lower effectiveness rate for PTC A than for PTC B.

Implementation of warning system is highly reliable, but not fail safe. System is not relied upon to provide roadway worker protection.

A-II PTC Level B

This level is intended to be a ***stand-alone*** PTC system (PTC becomes the method of operation) which may be deployed incrementally. There are layers within this system that address varying methods of operation and stages of migration.

If it is advantageous from a cost standpoint to use existing signal logic, from vital circuits in the field to support PTC functions, the vital circuits cannot be removed at a later date.

This system is implemented in conjunction with an advanced traffic planning program running on a next-generation CAD. The PTC server is capable of generating authorities requested through the CAD, as prompted by the planner (without prejudice to use of a more distributed architecture as appropriate).

This design concept, in addition to the core functions covered by Level A, will provide:

Core functions would be met with an 98% improvement over past accidents (PPA's at Level 3) as identified by the Accident Review Team. All main line switches and *existing* defect detectors monitored by WIUs.

Enforce positive stop for trains where a stop is required.

Flexible-block capability, but implementation of flexible block would occur only where capacity constraints warrant.
No requirement to install additional hazard detectors.

Advance highway-rail grade crossing activation where speeds exceed 79 mph.

Other characteristics:

Track circuits will be retained for broken rail protection in existing signal territory (may be lengthened) but not required in existing dark territory unless speeds are increased to greater than 49/59 mph.

System will have the ability to alert nearby trains when any train goes into emergency.

Additional roadway worker protection is provided as follows:

Track forces terminals with location determination for on-track equipment provide warning to operator to help prevent violation of authorities and notification to dispatcher of exceedences.

All powered on-track equipment (hi-rail trucks, specialized MOW equipment) is "equipped" (i.e., units may be portable but each "lead" and "rear" vehicle of equipment traveling together will be tracked).

System warns operator of impending violations, alarms again if authority is exceeded. Terminal is treated in same manner as other “targets,” so braking is initiated by the OBC where necessary to stop approaching trains even when outside of authority.

Terminal is capable of requesting and releasing authorities digitally.

Implementation of warning system is fail safe and may be relied upon to provide roadway worker protection under appropriate circumstances.

Implementation of digital authorities function is closed-loop and secure.

Appendix B: Implications of Modal Diversion

This model is dependent on the Zeta-Tech study estimates of improved transit time and reliability, and none of the estimated benefits in this model would be realized if the transit time and reliability do not improve.

To assess the potential for highway to rail diversion, FRA employed the Department's Intermodal Transportation and Inventory Cost (ITIC) Model[40]. The ITIC model measures shipper logistics cost for both highway and rail. If rail can improve its service offerings, lowering shipper logistics cost vis-à-vis highway service offerings, then rail should have the opportunity to better compete and potentially capture the business from motor carrier. Business that rail can capture from highway results in shipper logistics cost savings.

FRA used input values for improved transit time and service reliability developed by Zeta-Tech. Zeta-Tech estimated that transit time would improve between 3.5% and 10% and that reliability would improve by between 3.8% and 11%. The lower numbers were used in developing low range scenarios, while the higher numbers were used to develop high range scenarios, both for 2010 and 2020. FRA only considered the impact on highway moves over 500 miles. FRA further constrained its estimates by assuming that rates would remain constant. If the railroads were to pass on part of their productivity benefit to shippers, then the diversion and total societal benefits would be even greater. Details of the impact of modal diversion can be found in Appendix D, Tables 7 and 8.

One caution to readers of the diversion study: the study assumes constant railroad rates, which is not meant to be a realistic assumption. The assumption is meant to provide conservative estimates of total diversion. An artifact of using constant rates is that it appears in the study that railroad revenues will grow substantially. In reality most of that revenue would be passed on to shippers in the form of lower rates, and actual diversion would be greater. It does, however provide an indication that the shipper benefits in the Zeta Tech study might be conservative.

B-I Indirect Safety Benefit:

Heavy trucks operating over highways create a risk of accidents, and moving them to railroads removes that accident risk from the highways, although it does increase somewhat the rail safety risk. According to the 1997 Highway Cost Allocation Study, the average accident risk per Vehicle Mile of Travel (VMT) was 13 cents. FRA, in an effort to be conservative, estimates that the accident cost per heavy truck VMT is 13 cents, in 1997 dollars. FRA accepts that the accident rate is declining, so it will also accept that as the value in 2000 constant dollars, but will inflate it to 2003 dollars using the GDP deflator.

According to the diversion model, PTC will divert between 1.937 billion VMT and 3.723 billion VMT from highway to rail in 2010, which implies a safety benefit on the highway of between \$266 million and \$511 million per year. The diversion increases to between 3.005 billion VMT and 5.714 billion VMT in 2020, which implies a highway safety improvement benefit between \$413 million and \$785 million. These benefits accrue primarily to highway users.

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[40]The Potential for Highway-to Rail Diversion Following Positive Train Control Operating Efficiencies, FRA, February 25, 2004

As described here, the safety benefit from PTC would in part be offset by what FRA estimates to be volume related rail accident costs of $20 million to $40 million per year. The offsetting cost on railroads would be less than a 1% increase in rail accidents. FRA believes that the diverted freight could be accommodated by 1% more trains, resulting in 1% more train accidents, and 3/4% more grade crossing accidents and trespasser fatalities, because grade crossing and trespasser incidents are not a direct linear function of train miles where trains run on busy corridors. FRA believes that the risk of train accident costs is proportional to train miles. FRA further believes that the risk to trespassers is not going to increase as quickly as the number of trains, because in higher density corridors the trespasser who dwells for a long time on the tracks will be hit by the first train to go by, so the number of trains is not proportional to risk. To accommodate this factor in risk, FRA assumes that risk to trespassers will only increase 3/4 as fast as the number of trains. Further, the risk of grade crossing accidents is not proportional to the number of trains. In those corridors with more trains, the risk per train is less because crossing users are more aware of the presence of trains. Here too, the FRA assumes that risk will rise only 3/4 as quickly as the number of trains.

There are roughly ten fatalities a year, and a total of $270 million in property damage and about 200 injuries a year in train accidents. If the willingness to pay to avoid a fatality is $3,000,000, and the willingness to pay to avoid an injury in a train accident is $25,000, then the total train accident cost is about $300 million per year. One percent of that would be $3 million. There are approximately 400 grade crossing fatalities a year. If fatality costs are half of grade crossing accident costs, then given a willingness to pay to avoid a fatality of $3 million, the total grade crossing accident cost would be $2.4 billion per year. Three fourths of a percent of that would be $18 million per year. There are approximately 500 trespasser fatalities per year. Given a willingness to pay to avoid a fatality of $3 million, the total societal cost of trespasser fatalities would be $1.5 billion per year. Three-fourths of a percent of that would be $11.25 million per year. The total offsetting accident cost on railroads would be approximately $32.5 million. FRA will use a range of $20 million to $40 million to represent offsetting safety costs. Although at some point in the future PTC may be used to activate crossing gates with less expense or better timing, for purposes of this study PTC is assumed not to have any direct effect on crossing accidents.

B-II Environmental Benefits:

In its May 2000 Addendum to the 1997 Highway Cost Allocation Study, FHWA said that the air pollution cost per mile of heavy combination trucks was 3.85 cents per mile.[41] In Table 11 of the Comprehensive Tuck Size and Weight Study, FHWA said that 80,000 pound, five axle tractor-semitrailer combination get 4.81 miles per gallon. This implies a cost of 18.52 cents per gallon of diesel fuel, in 2000 current dollars. FRA derived the gallons per 1,000 ton-miles from the miles per gallon figure, the diversion model's estimate of VMT diverted, and the diversion model's estimate of ton-miles diverted. This worked out to be 6.93 gallons per 1,000 ton-miles. FRA then derived the equivalent fuel per ton-mile of rail transportation, using the Association of American Railroads' Railroad Facts for 2003, which indicated that railroads move 404 ton-miles per gallon, and using a circuity factor of 1.138, to account for the fact that for the average move it

[41]The diversion model here only addresses intermodal freight, which is hauled by combination vehicles. Straight trucks are much less often used for moves in competition with intermodal freight.

move it takes 13.8% more miles of rail travel than equivalent highway travel. This yielded and average of 2.82 gallons per thousand equivalent ton-miles.

FRA estimates diversion of between 58.1 billion ton-miles and 112 billion ton-miles in 2010, and between 90 billion ton miles and 171 billion ton-miles in 2020. This implies reduced air pollution costs between $62 million and $120 million in 2010, and between $93 million and $180 million in 2020. This benefit would accrue to the general public.

B-III Reduced Allocated Highway Cost Burden:

In its May 2000 Addendum to the 1997 Highway Cost Allocation Study, FHWA said that the cost responsibility[42] of an 80,000 pound combination was 8.65 cents per mile, but that the actual contribution of such combinations only covered 80% of their share. That means that such trucks created a societal cost of 1.73 cents per mile, in 2000 current dollars.

Based on its diversion estimates of VMT, FRA estimates that diverting to rail will avoid societal costs of between $35 and $68 million in 2010 and between $55 million and $104 million in 2020. These benefits will accrue to highway users or governmental entities providing highways.

[42]Highway Cost Responsibility is an entire chapter in the *1997 Federal Highway Cost Allocation Study*, , Federal Highway Administration, Washington, DC, 1997, pp. V-1 *et seq*.. The basic concept is that each user should pay the highway costs it creates or"occasions."

Appendix C: Track Forces Terminals

Several commenters said that these terminals do not yet exist, and that the potential benefits are highly speculative. AAR had very specific comments, detailed below.

FRA envisions that roadway workers, who include track repair workers, signal workers, and other railroad employees making repairs on or in the foul envelope[43] of the track, may be equipped with portable terminals which can request authority to occupy track, and to release authorities. This equipment may be incorporated with other track inspection equipment. Some railroads now equip their track inspectors with handheld units which record the location and nature of track defects, using GPS for location information. If a railroad had a precision dispatch system, and the handheld devices were upgraded to provide robust and reliable communication, then track forces could request authority to occupy track, in some cases where they now operate with lookouts, or wait for extended periods to establish voice contact with dispatchers. The track forces could also request a release of their authority more easily after completing work, making more track available for trains.

Zeta-Tech discussed, but did not measure this benefit:

> These benefits have not been explicitly quantified. Track forces terminals offer the promise of more time on track for MOW forces, through better knowledge of train movements. This benefit will be highly line-specific, and will be of most value on the highest-density segments of the network. This makes it very difficult to quantify for the entire U.S. railroad network.
>
> However, an order of magnitude estimate can be made. While no quantification of this benefit has been undertaken, it should be noted that [total] Class I railroad spending on track and structures capital and maintenance items (include track, bridges and buildings, communications, and signals) for 2001 was $10.123 billion. This is a very substantial number. If track forces terminals can produce even a 5% to 15% improvement in the efficiency of MOW work, this could potentially be worth between $0.5 billion and $1.5 billion annually to Class I railroads. Anecdotal evidence alone would appear to support at least a 5% savings in maintenance costs due to improved productivity.

In its initial draft of this letter report, FRA estimated the benefit of track forces terminals for PTC A, which will be treated as less capable, lower cost instruments, at $300 million to $500 million per year, and for PTC B, which will have more capable instruments, at $500 million to $1.5 billion per year.

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[43]The foul envelope is the area around a track which must remain clear in order to avoid being hit by a train.

The AAR responded:

> *The Report offers an absurdly high and cavalier estimate of the benefits of "track forces terminals," i.e. a simple 5% to 15% of total maintenance of way expenditures ($10.1 billion in 2001) or $500 million to $1.5 billion annually. The Report makes no effort to quantify the number of track forces terminals units, track gangs using the units, or trains affected. The Report also double-counts capital expenditures by adding them to total maintenance-of-way expense without subtracting out depreciation. Thus, a capital expenditure in 2001 is counted once in full as a capital expenditure and again (partially) as depreciation expense. Capital expenditures in earlier years are also partially counted as 2001 depreciation. So, $10.1 billion minus $2.3 billion depreciation is $7.9 billion (after rounding).*
>
> *These maintenance of way expenses and expenditures include substantial amounts that PTC will not reduce at all, notably rail, ties, ballast, hardware, other materials and supplies, insurance, leases, etc. AAR is not aware that anyone is arguing that PTC or "track forces terminals" will reduce the need for track maintenance or track materials. Total expensed MOW labor and fringes, arguably the pool in which more efficient MOW work windows and communications would yield benefits, runs about $1.5 billion annually for the Class I freight railroads. The Report's high end PTC-B benefit estimate claims a benefit equivalent to 100% of expensed MOW labor and fringes. That would imply that track forces terminals will save something approaching 100% of MOW labor, which is not a very plausible assumption.*
>
> *A more plausible, but still quite arbitrary, benefit from track forces terminals might be 3% to 5% of expensed MOW labor and fringe benefits, or about $45 million to $75 million annually, after full implementation. That equates to about 15% of what FRA estimated under PTC-A and 5% to 10% of what the Report estimated under PTC-B. The Report (p. C-1) claimed much greater benefits for track forces terminals under PTC-B than under PTC-A because of "more capable instruments." But it is unclear what is meant by "more capable instruments." It is also hard to see how "more capable instruments" would make such a huge ($1 billion/year) difference in dollar benefits or how they would be tied to PTC-B.*

FRA agrees that depreciation, and several other categories of expense are not affected, but AAR only suggested considering expensed MOW costs. Many MOW costs are treated as capital expenditures, and are not treated as expenses. In the *AAR Analysis of Class I Railroads, 2002*, the AAR shows on line 311 that MOW compensation was $1,791,749,000, a figure which does not include fringes. On line 167 the Freight Service Expense for MOW and structure compensation was 1,013,802,000, and on line 168 the Freight Service Expense for MOW and structure fringe benefits was $461,779,000, or 45.55% of the compensation. If we apply the 45.55% to the total MOW compensation, we would estimate fringes at $816,127,865, for a total MOW labor cost of $2,607,876,865. FRA uses this last figure as the basis for estimating possible savings from TFT's, although some other categories of costs would be affected. The railroad MOW labor cost does not include any contract labor costs, but the savings to contractor labor would be as meaningful. Further, there are costs to employing labor, for administration, training and supervision, which are not included here. There would be some savings in machinery costs, as the machines would be able to do more work per year, reducing the capital carrying costs for machines, and reducing any depreciation which might occur simply because a machine ages, although any depreciation due to wear and tear caused directly by working would be unaffected. If preventive maintenance or inspection were to be come more efficient there might be material savings. Last, there might be savings in transportation costs, because track forces would be able to release track back to the operating personnel more rapidly.

For all of these reasons, FRA will continue to apply the same percentages it had in the draft report, but will apply them to the much smaller fully fringed labor cost. For PTC A, FRA will use a low percentage savings of 3% and a high of 5%. For PTC B FRA will use a low percentage of 5% and a high percentage of 15%. The additional capabilities of PTC B might permit much more rapid attainment of authorities, and might provide other productivity enhancements relating to the actual MOW work. The calculations are shown in Appendix D, Table 9.

These are rough assumptions about devices which do not yet exist. The NAJPTC project is considering such devices and is working on a specification for them, and a subgroup of the RSAC is also investigating what such devices might do and how they might be specified.

Appendix D: Detailed Tables

	Table 1 Summary of Estimated Annual PTC Benefits *Using Zeta-Tech* *Assumptions, modified*		
PTC A		Low	High
Line Capacity	Avoided Investment	N/A	N/A
	Avoided Maintenance	N/A	N/A
Precision Dispatch (Zeta Tech original)	Equipment Ownership	$407,996,280	$1,040,021,170
Precision Dispatch (FRA revision, 25%)	Equipment Ownership	$101,999,070	$260,005,293
Work Order Report	Car Ownership	$0	$0
Loco Diagnostics	Loco Maintenance	$28,567,603	$28,567,603
	Loco road failure	$34,603,875	$34,603,875
Fuel		$55,949,775	$130,549,475
Track Forces Terminals		$78,236,306	$130,393,843
Total Railroad-only Benefits		$299,356,629	$584,120,089
Less Annual Maintenance Cost		-$335,047,500	-$182,038,500
Railroad Net Profit		-$35,690,871	$402,081,589
Railroad Profit Retention	20.00%		
Railroad Net Profit Benefits		-$7,138,174	$80,416,318
Shipper Direct Benefits		$400,000,000	$900,000,000
Passed on Productivity		-$28,552,697	$321,665,271
Total Shipper Benefits		$371,447,303	$1,221,665,271
Direct Safety Benefits		$34,900,192	$82,964,877
Total Estimated Net Direct Benefits		$399,209,321	$1,385,046,466
Total Estimated Indirect Benefits, 2010		$363,225,582	$531,103,148
Total Estimated Net Benefits, 2010		$762,434,903	$1,916,149,614
Total Estimated Indirect Benefits, 2020		$560,974,549	$815,070,747
Total Estimated Net Benefits, 2020		$960,183,870	$2,200,117,213

The figures in Table 1 start with figures from the Zeta-Tech report, but omit benefits for work order reporting and line capacity benefits. FRA further reduced the projected benefits of precision dispatching because the Zeta-Tech report did not take into account the large time periods during which equipment is normally idle. FRA added benefits for track forces terminals. FRA then subtracted the maintenance costs of PTC, from Table 4. Under the low estimate, the net result was a loss to the railroad. FRA assumed that the railroad would retain 20% of the profit or loss. The remaining loss was assumed to have been passed on to shippers under the line "passed on productivity." Shipper benefits were taken from the Zeta-Tech report. Direct safety benefits were estimated by FRA, see Table 6. Indirect benefits were taken from Table 7. Note that although indirect benefits are projected for 2010, assuming PTC is in Place, FRA does not believe a system could be deployed by that date.

Table 2
Summary of Estimated
Annual PTC Benefits
Using Zeta-Tech
Assumptions, modified

PTC B		Low	High
Line Capacity (Zeta Tech estimate)	Avoided Investment	$299,532,652	$422,005,064
	Avoided Maintenance	$507,967,244	$761,956,956
Line Capacity (FRA revision, 40%)	Avoided Investment	$119,813,061	$168,802,026
	Avoided Maintenance	$203,186,898	$304,782,782
Precision Dispatch (Zeta Tech original)	Equipment Ownership	$407,996,280	$1,040,021,170
Precision Dispatch (FRA modification)	Equipment Ownership	$101,999,070	$260,005,293
Work Order Report	Car Ownership	$0	$0
Loco Diagnostics	Loco Maintenance	$28,567,603	$28,567,603
	Loco road failure	$34,603,875	$34,603,875
Fuel		$55,949,775	$130,549,475
Track Forces Terminals		$130,393,843	$391,181,530
Total Railroad-only Benefits		$674,514,125	$1,318,492,583
Less Annual Maintenance Cost		-$550,756,500	-$306,538,500
Railroad Net Profit		$123,757,625	$1,011,954,083
Railroad Profit Retention	20.00%		
Railroad Net Profit Benefits		$24,751,525	$202,390,817
Shipper Direct Benefits		$900,000,000	$1,400,000,000
Passed on Productivity		$649,762,600	$1,116,101,767
Total Shipper Benefits		$1,549,762,600	$2,516,101,767
Direct Safety Benefits		$40,237,868	$95,653,623
Total Estimated Net Direct Benefits		$1,614,751,993	$2,814,146,206
Total Estimated Indirect Benefits, 2010		$531,103,148	$698,980,714
Total Estimated Net Benefits, 2010		$2,145,855,141	$3,513,126,921
Total Estimated Indirect Benefits, 2020		$815,070,747	$1,069,166,945
Total Estimated Net Benefits, 2020		$2,429,822,740	$3,883,313,151

The figures in Table 2 start with figures from the Zeta-Tech report, but omit benefits for work order reporting. FRA reduced the estimated line capacity benefits, based on comments. FRA further reduced the projected benefits of precision dispatching because the Zeta-Tech report did not take into account the large time periods during which equipment is normally idle. FRA added benefits for track forces terminals. FRA then subtracted the maintenance costs of PTC, from Table 4. In this case the net result was a profit for the railroad. FRA assumed that the railroad would retain 20% of the profit or loss. The remaining loss was assumed to have been passed on to shippers under the line "passed on productivity." Shipper benefits were taken from the Zeta-Tech report. Direct safety benefits were estimated by FRA, see Table 6. Indirect benefits were taken from Table 7. Note that although indirect benefits are projected for 2010, assuming PTC is in Place, FRA does not believe a system could be deployed by that date.

Table 3: Summary of
PTC Costs
Using Zeta-Tech
Assumptions, modified

1. PTC A		Initial System Cost Low	High
	Vehicles	$307,590,000	$512,650,000
	Wayside	$794,000,000	$1,191,000,000
	Central	$100,000,000	$500,000,000
	Track Force Units	$12,000,000	$30,000,000
	Total	$1,213,590,000	$2,233,650,000
2. PTC B			
	Vehicles	$307,590,000	$717,710,000
	Wayside	$1,588,000,000	$2,382,000,000
	Central	$100,000,000	$500,000,000
	Track Force Units	$48,000,000	$72,000,000
	Total	$2,043,590,000	$3,671,710,000

Table 3 figures were taken directly from the Zeta-Tech report.

	Table 4: Estimated Annual Maintenance		
Maintenance as % of Initial Cost	15.00%		
PTC A		$182,038,500	$335,047,500
PTC B		$306,538,500	$550,756,500
Annual Net Profit after Maintenance			
PTC A		-$7,138,174	$80,416,318
PTC B		$24,751,525	$202,390,817

Table 4 figures were taken directly from the Zeta-Tech report, and reflect the assumption that annual maintenance would be 15% of the figures in Table 3. When used in Tables 1 and 2, the low costs are paired with the high benefits and high costs with low benefits, in order to establish a range.

Table 5
Railroad Percent of Benefits

PTC A 2010	-0.33%	2.29%
PTC A 2020	-0.29%	2.07%
PTC B 2010	1.15%	5.76%
PTC B 2020	1.02%	5.21%

Table 5 shows what percentages of the benefits shown in Tables 1 and 2 were likely to accrue to the railroads. Those percentages are derived by dividing the railroad retained benefit by the total societal benefit. In the case of the low estimate for PTC A, the railroad incurs a net loss, while society experiences significant gains.

Table 6
PPA History and Projection

	Level 3 PPA costs 1998 constant dollars	Level 3 PPA costs 2003 dollars	Roadway Worker 2003 dollars	Total 2003 dollars
1988	$77,398,979	$84,756,824	$8,475,682	$93,232,507
1989	$51,231,291	$56,101,535	$5,610,153	$61,711,688
1990	$82,571,728	$90,421,315	$9,042,131	$99,463,446
1991	$85,444,331	$93,566,998	$9,356,700	$102,923,698
1992	$26,538,195	$29,061,018	$2,906,102	$31,967,120
1993	$56,634,363	$62,018,244	$6,201,824	$68,220,068
1994	$58,311,313	$63,854,611	$6,385,461	$70,240,072
1995	$89,320,642	$97,811,806	$9,781,181	$107,592,987
1996	$33,030,077	$36,170,043	$3,617,004	$39,787,048
1997	$28,651,370	$31,375,080	$3,137,508	$34,512,588
1998	$32,732,864	$35,844,576	$3,584,458	$39,429,034
1999	$78,834,337	$86,328,633	$8,632,863	$94,961,496
2000	$32,602,317	$35,701,619	$3,570,162	$39,271,781
2001	$72,507,167	$79,399,978	$7,939,998	$87,339,975
total	$805,808,974	$882,412,280	$88,241,228	$970,653,508
mean	$57,557,784	$63,029,449	$6,302,945	$69,332,393
Standard dev.	$23,471,728	$25,703,040	$2,570,304	$28,273,344
All affected PPA"s				
Low range				$41,059,049
High range				$97,605,738
PTC B	Effectiveness	98%		
Low range				$40,237,868
High range				$95,653,623
PTC A	Effectiveness	85%		
Low range				$34,900,192
High range				$82,964,877

Total estimated PTC preventable accident costs is derived from a database of PTC preventable accidents maintained by the Volpe Center. The costs of these accidents are calculated using implied costs derived for the RSAC study. These costs are in 1998 dollars, and are updated here using the GNP deflator.

All systems diversion, 2010	Table 7 Low	High
Diverted VMT, Heavy combinations	1,936,769,710	3,722,731,141
Allocated costs per VMT (Heavies)	$0.0865	$0.0865
Percent of Allocated Cost not borne by users	20%	20%
Heavy Vehicle Accident Cost per VMT	$0.13	$0.13
Diverted ton-miles	30,728,700,000	59,468,380,000
Highway fuel use per ton-mile (gallons)	0.0131035424656372	0.0131035424656372
Rail fuel use per ton-mile (gallons)	0.00281666159039317	0.00281666159039317
Environmental cost per gallon	$0.1852	$0.1852
Reconstruction Congestion costs per year	$0	$0
Total Heavy VMT	124,119,000,000	124,119,000,000
Percent of Reconstruction Cost avoided	1.56%	3.00%
Reduced Allocated Costs	$33,506,116	$64,403,249
Reduced Highway Accident Costs	$251,780,062	$483,955,048
Reduced Fuel Use Societal Costs	$58,537,437	$113,285,839
Constant 2003 Dollars:		
Reduced Allocated Costs	$35,396,866	$68,037,524
Reduced Highway Accident Costs	$265,988,011	$511,264,632
Reduced Fuel Use Societal Costs	$61,840,705	$119,678,559
Total Indirect Diversion Benefit	$343,823,615	$661,644,136
Total Indirect Diversion Benefit, 2003 Dollars	$363,225,582	$698,980,714
PTC A Total Indirect Diversion Benefit, 2003 Dollars	$363,225,582	$531,103,148
PTC B Total Indirect Diversion Benefit, 2003 Dollars	$531,103,148	$698,980,714

Detailed explanations of the derivations of Tables 7 and 8 can be found in Appendix B. Tables 7 and 8 are based on similar numbers, but Table 7 refers to indirect effects in 2010, while Table 8 refers to indirect effects in 2020. When Table 7 was prepared, FRA had not yet come to the conclusion that it would be extremely difficult to have full deployment of PTC by 2010, but nonetheless, Table 7 results can be interpolated with Table 8 results to estimate societal impacts during migration to PTC. The first input to both tables is diverted truck miles. This refers to estimated diversion of truck miles, from the diversion model. There are high and low estimates for both tables. The allocated costs, and percentage of allocated costs not borne by users are from the Highway Cost Allocation Study. The accident cost per Heavy VMT is from the Highway Cost Allocation Study, and is the accident cost for all vehicles. It may be too conservative. The diverted ton-miles are from the diversion model. Highway fuel use per ton mile is based on miles per gallon for heavy trucks, from the Truck Size and Weight Study, diverted ton-miles, and diverted truck miles. Railroad fuel use per ton-mile is based on the AAR fact book. The environmental cost per gallon is derived from the environmental cost per mile, from the Highway Cost Allocation Study, multiplied by the number of miles per gallon, for heavy trucks, from the Truck Size and Weight Study. Reconstruction Congestion Costs is a blank placeholder, which represents the additional congestion costs added by heavy trucks, which wear highways out more rapidly, leading to reconstruction under traffic, which in turn causes congestion. FRA was not able to quantify this, yet it might be an important variable in future studies. Percent of reconstruction cost avoided was derived from estimated total truck volume and estimated diverted volume form the diversion study. This number is not further used in the calculations, and would have been multiplied by the reconstruction congestion cost, were it available. Reduced allocated cost is the allocated cost per mile, times percentage not borne by user, times diverted miles. Reduced accident cost is diverted miles times accident cost per mile. Reduced environmental cost is reduced environmental fuel cost per ton mile, times diverted ton-miles. All of these figures were in year 2000 constant dollars and were adjusted to 2003 constant dollars.

All systems diversion, 2020	Table 8 Low	High
Diverted VMT, Heavy combinations	3,005,145,374	5,714,268,102
Allocated costs per VMT (Heavies)	$0.0865	$0.0865
Percent of Allocated Cost not borne by users	20%	20%
Heavy Vehicle Accident Cost per VMT	$0.13	$0.13
Diverted ton-miles	46,379,460,000	89,421,020,000
Highway fuel use per ton-mile (gallons)	0.0131035424656372	0.0131035424656372
Rail fuel use per ton-mile (gallons)	0.00281666159039317	0.00281666159039317
Environmental cost per gallon	$0.1852	$0.1852
Reconstruction Congestion costs per year	$0	$0
Total Heavy VMT	163,881,000,000	163,881,000,000
Percent of Reconstruction Cost avoided	1.83%	3.49%
Reduced Allocated Costs	$51,989,015	$98,856,838
Reduced Highway Accident Costs	$390,668,899	$742,854,853
Reduced Fuel Use Societal Costs	$88,351,760	$170,344,900
Constant 2003 Dollars:		
Reduced Allocated Costs	$54,922,755	$104,435,330
Reduced Highway Accident Costs	$412,714,345	$784,774,153
Reduced Fuel Use Societal Costs	$93,337,450	$179,957,463
Total Indirect Diversion Benefit	$531,009,673	$1,012,056,592
Total Indirect Diversion Benefit, 2003 Dollars	$560,974,549	$1,069,166,945
PTC A Total Indirect Diversion Benefit, 2003 Dollars	$560,974,549	$815,070,747
PTC B Total Indirect Diversion Benefit, 2003 Dollars	$815,070,747	$1,069,166,945

For details on derivation of Table 8, see the discussion following Table 7.

Table 9
Track
Forces
Terminals

MOW Rail Freight Service Expense, 2002		
Compensation (Line 167)	$1,013,802,000	
Fringe Benefits (Line 168)	$461,779,000	
Fringe Benefit as percentage	45.55%	
Compensation		
MOW and structures (Line 311)	$1,791,749,000	
Compensation x percentage= fringes	$816,127,865	
Total MOW labor expense	$2,607,876,865	
	Low	High
Percentage improvement, PTC A	3.00%	5.00%
Percentage improvement, PTC B	5.00%	15.00%
Savings, PTC A	$78,236,306	$130,393,843
	$130,393,843	$391,181,530

Line numbers refer to AAR Analysis of Class I railroads, 2002

These figures were based on the AAR Analysis of Class 1 railroads, and assumed percentage values of productivity improvements. Since these devices do not yet exist, these numbers involve a great deal of speculation. The total compensation for MOW employees as a portion of rail freight service expense, shows that fringes were 45.55% of base compensation. A substantial portion of MOW expenditures is not expense, but rather is an accrual to capital. That is what FRA believes to be the relevant universe against which to apply estimated productivity enhancements. The savings are the Total MOW labor expense times the assumed percentage improvements in productivity.