PTC Implementation: The Railroad Industry Cannot Install PTC on the Entire Nationwide Network by the 2015 Deadline

May 2013 Update

Association of American Railroads

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I. Introduction and Executive Summary

On January 18, 2012, the Association of American Railroads (AAR) submitted a status paper to the Federal Railroad Administration (FRA) titled "PTC Implementation: The Railroad Industry Cannot Install PTC on the Entire Nationwide Network by the 2015 Deadline" ("ISP," Attachment A). The ISP discussed the challenges faced in developing an interoperable PTC system and provided detailed data showing the progress that had been made.[1] The ISP concluded by stating that a nationwide, interoperable PTC network cannot be completed by the December 31, 2015, statutory deadline.

On February 10, 2012, the American Public Transportation Association (APTA) filed a companion paper with FRA, concurring with AAR that a nationwide interoperable PTC network is not achievable by December 31, 2015. In addition, in August 2012 FRA issued a report to Congress titled, "Positive Train Control Implementation Status, Issues, and Impacts." In this report, FRA reached a similar conclusion, stating, "[b]ased on the results of this report, FRA believes that the majority of railroads will not be able to complete PTC implementation by the 2015 deadline."

This paper updates the ISP and the tables that were attached to the ISP.[2] While enormous challenges remain in regard to developing a nationwide interoperable PTC system, there were many positive developments during 2012. These include:

- the first Geographical Information System (GIS) subdivision validations with FRA;
- the development and manufacture of 220 MHz radios;
- significant progress with locomotive installations;
- improvements in the availability of Wayside Interface Units (WIUs);
- radio frequency propagation studies of Chicago, Kansas City, Los Angeles, New Orleans, New York, Minneapolis, St. Louis, Toledo, and other congested metropolitan areas have been completed or are in progress;

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[1] This paper is based on information provided by the following eight railroads, which have to install PTC on routes over which TIH or passengers, or both TIH and passengers, are transported: the Alaska Railroad (ARR), BNSF Railway (BNSF), Canadian National (CN), Canadian Pacific (CP), CSX Transportation (CSX), Kansas City Southern (KCS), Norfolk Southern (NS), and Union Pacific (UP). passengers, or both TIH and passengers, are transported: the Alaska Railroad (ARR), BNSF Railway (BNSF), Canadian National (CN), Canadian Pacific (CP), CSX Transportation (CSX), Kansas City Southern (KCS), Norfolk Southern (NS), and Union Pacific (UP).

[2] This 2013 Update is intended to be read in conjunction with and as a supplement to the ISP. Attachment B updates the information in the various tables that were included in the ISP.

- FRA's modification of its regulations that permits railroads to base PTC installation on projected traffic in 2015;
- progress on the PTC Safety Plan that must be submitted to FRA before a PTC system can be certified; and
- FRA's recognition that activation of PTC should proceed from less complex to more complex areas.

Despite the positive developments in 2012 and the railroads spending approximately $2.8 billion to date to install PTC, the year confirmed and increased our understanding of the challenges that remain to completing a nationwide, interoperable PTC system. The most significant are:

- Wayside implementation continues to be constrained by the limited number of firms that provide signal design services. The signal system must still be individually redesigned and replaced at more than 7,000 locations before PTC wayside technology can be installed at those locations. Approximately 26,000 WIUs remain to be installed. This work must be accomplished without compromising signal system safety or the ability of the railroads to efficiently move the nation's freight. Based on current experience and available resources, it is likely that wayside design and installation will extend into 2018.
- The track database, including critical features such as the presence of signals and switches, must be validated. The railroads must ensure that what is displayed to the train crew via the track database and onboard system reflects what is shown by railroad signals. It is a time-consuming and labor-intensive process.
- There is limited expertise available to accelerate design and development. The railroads have been developing expertise as they build the onboard, wayside, and back office segments.
- Core software delivery dates continue to slip, particularly in connection with the Back Office Server (BOS) for I-ETMS. The railroads do not expect the final release of core software, which is necessary before the PTC system can be lab and field tested, certified, and used in revenue service, until mid-2014.
- Full system testing will likely continue into 2015, as will the need to address issues with PTC components and software identified by the testing.
- Over 75 percent of the industry's employees must receive PTC training. From the perspective of the employee retaining the material and understanding its relevance, the optimal time to train an employee is when PTC is rolled out on the employee's territory.
- Once testing is complete, the limited number of FRA personnel available to work on PTC must still review each railroad's individual Safety Plan and certify the PTC system. While the provisional certification concept advanced by FRA could reduce the delay associated with certification, even a provisional certification will require time and review by FRA.

- Portions of the PTC regulation are still not final, with potential changes that could impact the scope of the implementation effort.
- As the potential for failure of individual components became clear, systems have been designed with more redundancy, thus lengthening the design process.
- PTC cannot be rolled out on an entire railroad all at once. Implementation of PTC must occur in phases and location by location, starting with less complex areas and proceeding to the more operationally complex areas, incorporating lessons learned at each step.

It is abundantly clear that the railroad industry cannot install interoperable PTC on the entire nationwide network by the December 31, 2015, deadline.

II. PTC Components

A. Locomotives

Approximately 22,000 locomotives, which constitute most of the Class I railroads' locomotive fleet, must be equipped with PTC technology.[3] The ISP identified several reasons why equipping locomotives with PTC technology is taking longer than projected in the railroads' original implementation plans.[4] However, several of those challenges were resolved or became less of a concern in 2012:

- vendor supply chain issues and capacity have improved and available hardware (but not software) components are generally being delivered on time;
- production of the 220MHz locomotive radio began in 2012; and
- hardware design changes necessary to support the messaging system on some railroads were completed.

These positive developments aided the railroads in making significant progress on their "double touch" strategy for equipping locomotives in 2012.[5] Over 3,000 locomotives were equipped or partially equipped in 2012; over 6,000 locomotives have been equipped or partially equipped to date. While the good news is that the number of equipped or partially equipped locomotives continued to climb in 2012, most of these locomotives were only partially equipped and will have to be cycled back through a shop to complete installation and perform PTC commissioning tests.

A significant development hurdle remains with the development of the onboard software that runs on the Train Management Computer (TMC) for the railroads using I-ETMS. The complexity of the software, combined with the many interfaces with other components of the

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[3] All the estimates in this paper are premised on the PTC regulations in existence on April 1, 2013. The industry has requested amendments to those regulations that would reduce certain estimates, including the number of locomotives that would need to be equipped with PTC.
[4] ISP at 4.
[5] "Double touch" refers to shopping locomotives twice to equip them with PTC, partially installing PTC equipment at the first shopping.

PTC system, has resulted in multiple reviews of the design. The delivery date for this critical software component slipped several times over the course of 2012 and at the present time there is no delivery date for the final version of the onboard software. Nevertheless, sufficient progress has been made so that railroads plan to begin fully equipping locomotives with all necessary PTC equipment in 2013 rather than continuing to employ the double touch strategy.

While much work remains to be done in regard to equipping locomotives, the industry plans to have approximately ¾ of the locomotives required to be equipped with PTC technology fully equipped by December 31, 2015.[6]

B. Wayside Technology

For the reasons described in the ISP, tens of thousands of miles of existing signal system infrastructure still need to be replaced. As discussed previously, each of the approximately 12,300 replacement projects is complicated and lengthy, requiring individual analysis and design and signal replacements or upgrades before the WIU's can be installed at these locations.[7]

Qualified signal personnel are needed for design, installation, and validation, both in the lab and in the field. The limited number of qualified signal design firms and personnel available to the railroad industry continues to constrain how quickly railroads can complete the design, upgrade, installation, and testing required for PTC signal projects. The railroads have hired over 2,200 signal personnel specifically for PTC.[8] However, the great majority of these new hires provide assistance only with the installation of PTC at wayside locations, not with the more complicated analysis and design work that is typically handled by established signal design firms. Personnel hired for installation work are, of course, limited to performing work at locations where designs have been completed. Product availability has improved, although it continues to be a concern along with the extensive lab and field testing required for these products.

Despite these factors, railroads made considerable progress with installation of wayside technology in 2012. Over 7,000 WIU's were installed in 2012, bringing the total installed to approximately 9,700. That leaves approximately 26,000 WIU's of the approximately 36,000 total WIU's needed remaining to be installed.[9] Similarly, approximately 3,700 signal replacement projects were completed in 2012, bringing the total completed to over 5,000. However, that still leaves over 7,000 of the approximately 12,300 PTC signal replacement projects identified by the industry to be completed.[10] The sheer volume and complexity of this safety-critical work, which impacts the functioning of railroad signal systems as well as PTC, is one of the most significant reasons that the railroad industry cannot meet the 2015 deadline. This work is expected to extend into 2018.

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[6] See Table 1 in Attachment B.
[7] ISP at 6.
[8] See Table 2 in Attachment B.
[9] See Tables 3 and 4 in Attachment B.
[10] See Table 5 in Attachment B.

C. Switches

Most of the work involved in upgrading switches in non-signaled territory remains. In analyzing the technology required for switches, railroads have determined that these will be mostly turnkey solutions currently under development by several suppliers. In 2012, 227 switches were equipped with power, bringing the total so equipped to 436; 236 were equipped with WIU's, bringing the total so equipped to 361; and 36 were equipped with switch monitors, bringing the total so equipped to 148. Over 4,400 switches still need to be equipped with power and WIUs, and approximately 3,400 switch position monitors still need to be installed.[11]

D. Communications

As explained in the ISP, all PTC wayside locations and all PTC-enabled locomotives must be equipped with a complex, interoperable, wireless communications infrastructure.[12] Railroads have created a private radio frequency network capable of transmitting and receiving the data necessary to support an interoperable PTC network using spectrum in the 220 MHz band as the interoperability communications standard. To date, the seven Class I railroads have invested approximately $40 million in acquiring and managing 220 MHz spectrum.

Production quantities of PTC radios were first available in May 2012. Since then, railroads have been procuring and installing them. In parallel, railroads have undertaken numerous associated activities, including coverage analyses, site selection, antennae installation, and upgrading power supplies.

One of the key challenges that has emerged is deploying a national 220 MHz communications network for PTC that includes adequate coordination between railroads to avoid interference. Various tools are being developed to help mitigate interference, but this will continue to be a substantial task.

Some additional complexities associated with the design and implementation of the communications system became apparent in 2012. Complete signal wayside design and GIS data and train movement data are all necessary to properly design the radio network; each of these data elements must be taken into account to ensure there is adequate capacity to handle all the data. In addition, as new users roll out their PTC systems in locations where other railroads are already testing or using PTC, railroads will likely have to re-engineer their radio networks to address potential interference and ensure the additional demand for data can be met. Another issue that has emerged is the potential for delays associated with the Federal Communications Commission's environmental rules, including the separate completion of the environmental and historic preservation processes for each of the over 20,000 antenna structures required for PTC.

[11] See Table 6 in Attachment B.
[12] ISP at 8.

Four railroads have invested approximately $180 million to date in the development and installation of 220 MHz radios for base stations, wayside locations, and locomotives, each of which requires a distinct type of radio. Still, over 3,800 base station radios, over 31,000 wayside radios, and over 21,000 locomotive radios need to be manufactured and installed.[13]

Finally, in 2012 railroads studied spectrum needs in congested metropolitan areas and confirmed that railroads will need to acquire additional spectrum in Chicago. Other areas being studied include Kansas City, New York, Toledo, St. Louis, Minneapolis-St. Paul, and New Orleans. The adequacy of coverage in congested metropolitan areas will not be fully known until the PTC system is implemented and operational in those areas.

E. PTC Back Office

The pace of development of the Back Office Segment and PTC-related back office systems remains challenged by design complexity, availability of supplier resources, and scalability of the solution. Insofar as the I-ETMS BOS is concerned, the railroads and their contractors continued development in 2012, but a "final" version is not expected to be available until mid-2014.

The need to test thoroughly the PTC back office systems, including the BOS, and address issues and defects identified during the testing process also significantly impact the pace of development. Lab testing of the related technologies and systems will generally find some defects, as was the case with the initial software release for the BOS, requiring subsequent revisions of the technologies or systems that fix the defects. Unavailability of the final production version of the BOS is one of the critical factors preventing the railroads from installing PTC on the entire nationwide network by the current 2015 implementation date.

1. Back Office Server

For the over one dozen railroads implementing the I-ETMS BOS, the software version that includes essential requirements for vital overlay PTC system certification is now scheduled to be ready for testing in mid-2014. A production version of the BOS software will be unavailable until after the required lab testing, likely late 2014 at the earliest. While the railroads are considering all possible strategies to expedite this schedule, at this time there is no apparent alternative strategy or approach that would significantly accelerate the delivery date. As with the software for the locomotive, the complexity of the BOS software combined with the many interfaces with other components of the PTC system has required detailed design and analysis to ensure proper operation.

[13] See Table 7 in Attachment B.

2. Geographical Information System (GIS)

The railroads made substantial progress with respect to the GIS component of PTC systems in 2012. The industry developed a common approach to validation and verification of the data to ensure all essential data elements are captured. A common approach facilitates review by FRA and also provides non-Class I railroads a template they can use. Over 13,000 track miles were GIS mapped in 2012, bringing the total miles GIS mapped to approximately 80,000; approximately 15,800 track miles were data processed in 2012, bringing this total to over 41,000; and over 6,000 track miles of GIS data were converted to PTC subdivision files in 2012, bringing the total of converted track miles to over 9,000. However, much work remains to be done. Over 17,000 track miles remain to be GIS mapped; almost 56,000 miles remain to be data processed; and almost 88,000 miles remain to be converted to the PTC subdivision files needed for the locomotive's PTC system.[14] Furthermore, substantial work remains to be done to develop and implement sustainable processes to document and update the GIS coordinates every time one of the over 470,000 critical PTC assets are moved by more than 1 foot.

3. Dispatch

The dispatch system must interact with the PTC system via a common interoperable interface with the BOS. For some railroads, the enhancements needed for the dispatch system are extensive and have taken considerable analysis and effort to design, code, and test. Additionally, changes made to the BOS require an analysis of the effect on the interface of the dispatch system with the PTC system. At least four railroads will not have a PTC-capable dispatch system until 2014.[15]

III. The Integration and Testing Challenge

The challenges and risks associated with integrating and testing the many components of PTC have not diminished. Many of the 20 plus PTC components have been tested by the supplier and some "nearest neighbor" testing of interfacing components has started with preliminary releases of software during 2012. However, end-to-end testing of the final system of interoperable software, with all known hazards mitigated, is still one to two years away.

Railroads have been nimble in adjusting to the testing challenge. As component releases are delayed due to the complexity of the design or the need to fix defects, the interaction of those components can quickly get out of sync on the release cycle timeline. Nevertheless, railroads have revised test plans and realigned resources to conduct nearest neighbor testing with intermediate versions of software as software delivery schedules have slipped. They have taken advantage of opportunities to test releases of software and hardware to ferret out defects and issues early in the release continuum, when more extensive integration testing is not yet possible. To keep the schedule moving forward to the extent possible, railroads have undertaken

[14] See Table 8 in Attachment B.
[15] See Table 9 in Attachment B.

preliminary testing using software written to interim versions of "interface control documents" (ICDs) and written translators to bridge the gap between the different ICDs.[16] In some cases these stop-gap assemblages of software have been tested in the field with a hi-rail vehicle.

Railroad testing has identified more than 600 software defects to date, underscoring the importance of thorough testing to ensure the integrity of the PTC system. While these efforts successfully identified potential defects, only true end-to-end testing with final software will determine whether the integration of all the PTC components is effective. Based on current schedules, this will not begin until late 2014. At that time any additional defects discovered will have to be analyzed and remediated, further delaying the time at which widespread PTC implementation can proceed.

IV. The Certification Process Could Take Considerable Time

AAR remains concerned that the certification process could take a considerable amount of time and that FRA will not have the resources to review and certify PTC systems expeditiously. As FRA acknowledged in its August 2012 Report to Congress, FRA will need at least 6 to 9 months to review PTC Safety Plans, and approximately 38 railroads will need certification.[17] In an attempt to expedite final review, in 2012 the Class I railroads' Joint Rail Safety Team (JSRT) developed a format and common portions of a PTC Safety Plan and submitted drafts for FRA review and comment. In addition, in 2012 FRA and the JRST began holding quarterly meetings to facilitate communications between the parties, discuss FRA's concerns about implementation, and clarify FRA's interpretation of the PTC regulations. The meetings continue to foster a good working relationship between the industry and FRA. However, while this joint effort of the railroads and FRA is helpful, each railroad will have a unique PTC safety plan that FRA will need to review and approve. Furthermore, while railroads have been and will continue partial installation of PTC equipment prior to certification, the time required for FRA certification is one of the critical elements impacting the date by which the PTC mandate can be implemented.[18]

As FRA also noted in its Report to Congress, the shortage of qualified people extends to FRA. FRA noted that its PTC staff consists of 10 PTC specialists and 1 supervisor, who are responsible for monitoring PTC system installation and testing nationwide and for the technical review and approval of all documentation associated with the statutorily-required PTC system

[16] ICDs contain the format for how systems communicate with each other.

[17] FRA Report to Congress, p. 41. Based upon the nearly 18 months that it took for FRA to approve the PTC Development Plan, a less complex document, the approval period could take even longer than estimated by FRA.

[18] FRA in its August 2012 Report to Congress suggested a legislative change that would permit FRA to provisionally certify PTC systems. Once provisionally certified, a railroad could operate its PTC system pending final review. While a constructive suggestion that could assist in evaluating PTC systems in operation, this change would not alter the fact that the railroads cannot install PTC on the entire nationwide network by the 2015 deadline. Even provisional certification will require a review and approval process for FRA. It is difficult to imagine that process will take less than 6 months.

certification.[19] Railroads will be submitting PTC Safety Plans, amendments to their PTC filings, and other related documents. FRA, as do the railroads, faces the challenge of key personnel retiring as well as other resource constraints that impact the agency's ability to review, comment, and approve the required documentation. As FRA noted in its Report to Congress, the industry remains concerned that the continued shortage of FRA resources could delay the implementation of an interoperable PTC system.

V. Interoperability: The Current Implementation Schedules Could Adversely Affect the Reliability and Effectiveness of PTC

A. Phasing in PTC

Attachment B to the ISP discussed problems that could arise from implementation schedules under which PTC is deployed first in locations presenting complex interoperability issues. The railroads suggested a phased approach to PTC under which PTC will be implemented in less operationally complex areas first, which is a departure from current implementation plans. FRA has indicated that it agrees with this general approach. Accordingly, the railroads intend to update the implementation schedules in their respective PTC Implementation Plans to take these complex interoperability issues into account.

The PTC Reliability Study recently provided by AAR to FRA raises significant concerns over the reliability of the fully assembled PTC system. The Study underscores the need for a phased approach for implementation that will allow the railroads to assess the PTC system in operation so that failures, while they will occur, can be reduced to the extent possible and the efficiency of the railroad network maintained to the greatest extent feasible. The time needed to phase in PTC is another reason why the industry cannot meet the current 2015 deadline to implement PTC on the entire nationwide network.

B. Interoperability Standards

Ensuring the interoperability of PTC requires numerous interoperability standards. AAR and its member railroads made considerable progress towards developing those standards in 2012. Attachment C describes the status of the interoperability standards required for PTC. Of the 34 standards being developed, 18 have been finalized. Drafts of 12 more have been published for public comment.

In 2012 it became clear that the railroads also need to adopt industry standards for the ongoing use and operation of PTC. These standards are necessary in order for the railroads operating a PTC system to ensure that updates to PTC hardware and software are acceptable. In the absence of such standards, there is no assurance that upgraded PTC components and software will be compatible with and continue to work with other components of the PTC system or that interoperability will be maintained.

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[19] FRA Report to Congress, p. 41.

VI. Rolling Out PTC

As noted above and in the ISP, PTC cannot be rolled out on an entire railroad system at the same time. It must be implemented in phases and location by location, typically on a subdivision basis.

Furthermore, as also stated in the ISP, training employees remains a daunting task that places practical limits on the speed with which PTC can be safely and effectively rolled out across a railroad system. While training courses and materials continue to be developed, the railroads recognize that this training must occur in a phased approach. Employees on each subdivision will have to receive significant training immediately prior to activation of PTC on the subdivision where they work. On the Class I railroads alone, approximately 68,000 engineers and conductors, 7,200 signal employees, 2,500 dispatchers, and thousands of others, including mechanics, electricians, and supervisors, will have to be trained on PTC. Delays in designing and installing PTC affect the pace of training railroad employees.

VII. Conclusion

The railroad industry has invested a tremendous amount of time, effort and money to complete a nationwide interoperable PTC-system as quickly as possible. As of the end of 2012, the railroads had invested approximately $2.8 billion (up from $1.6 billion at the end of 2011) and had also devoted millions of man-hours to the development of PTC.[20] However, as demonstrated above, the railroads will not be able to implement PTC on the entire nationwide network by December 31, 2015.

Because of all the uncertainties associated with the development and installation of PTC, it is impossible to set forth a precise timeline for completion of a nationwide, interoperable PTC network. Factors that affect a railroad's timeline for completion of PTC on its system, include variations in geography; type and age of the railroad's wayside signaling infrastructure (legacy relay technology must be converted to solid state technology); the density of train operations; the number of rail-to-rail interlockings; the number of connections with other railroads; and the number of operating environments (with different combinations of these factors) that must be addressed. In addition, until a railroad tests and installs its PTC system, it is impossible to know what other difficulties will be encountered and how they might affect progress in completing the railroad's PTC network. As discussed previously, the critical software for the back office server for I-ETMS will not be fully tested and ready to be installed until late 2014 at the earliest. Finally, the scope of the PTC network will impact a railroad's ultimate completion date.

Taking into account the above factors, the eight railroads providing data for this paper anticipate that by December 31, 2018, all PTC hardware will be installed and PTC will be in operation on most of the mandated PTC routes. (The date by which PTC will be in operation on

[20] See Table 10 in Attachment B.

all of a railroad's mandated PTC routes will vary by railroad.) The industry continues to seek ways to speed progress while maintaining safe operations in order to achieve complete deployment as soon as possible. Thus, while current projections show that a portion of the PTC network will not be completed by the end of 2018, that certainly could change.

Keeping in mind the uncertainty in projecting a completion date, Table 11 shows the railroads' current expectations regarding future annual PTC expenditures and annual installations of wayside interface units, base station radios, and PTC equipment on locomotives, as well as the number of employees they expect will be trained. (Table 11 is premised on the PTC network required by the current regulations.) Table 11 also shows by year the extent to which the railroads will have installed PTC on the routes that will have PTC capability. The year "2018 and beyond" column includes data for what the railroads currently project will remain to be done in and beyond 2018. The eight railroads anticipate they will have spent $8 billion by the end of 2018 on PTC.

This paper shows that the railroad industry has done its utmost to install a nationwide, interoperable PTC network. However, much work remains to be done. While substantial progress toward completing the network will have been made by the end of 2015, the entire project will not be complete by that date.

Attachment A

PTC Implementation:
The Railroad Industry Cannot Install PTC on the Entire Nationwide Network by the 2015 Deadline

Association of American Railroads
January 18, 2012

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I. Introduction and Executive Summary

The Rail Safety Improvement Act of 2008 (RSIA) requires passenger railroads and Class I railroads to install positive train control (PTC) on main lines used to transport passengers or toxic-by-inhalation hazardous materials (TIH) by December 31, 2015. The PTC mandate presents the railroad industry with a challenge of unprecedented scope. The nation's railroads are spending billions of dollars on the development and acquisition of PTC technology to fulfill the Congressional mandate. PTC technology will have to be installed on more than 60,000 miles of right-of-way, the precise number depending on the revisions to FRA's final rule governing the scope of PTC.

This paper discusses the enormity of the task facing the industry as it seeks to comply with the RSIA mandate for a nationwide interoperable PTC network and the impossibility of accomplishing the task by December 31, 2015.[1] The work that must be undertaken includes:

- installing approximately 38,000 wayside interface units (WIUs) that provide the mechanism for the transmission of information from wayside signals and switches to locomotives and the "back office;"
- installing PTC technology on approximately18,000 locomotives;
- installing PTC technology on approximately 4,900 switches in non-signaled territory;
- completing over 12,000 signal replacement projects;
- mapping over 60,000 miles of right-of-way and 476,000 assets;

[1] This paper is based on information provided by the following eight railroads, which have to install PTC on routes over which TIH or passengers, or both TIH and passengers, are transported: the Alaska Railroad (ARR), BNSF Railway (BNSF), Canadian National (CN), Canadian Pacific (CP), CSX Transportation (CSX), Kansas City Southern (KCS), Norfolk Southern (NS), and Union Pacific (UP).

- the development, production, and deployment of a radio specifically designed for PTC at approximately 4,100 base stations, 37,000 wayside locations, and on 18,000 locomotives;
- developing back office systems; and
- upgrading dispatching software to incorporate the data and precision required for PTC systems.

Since enactment of the RSIA and promulgation of the PTC regulations, the railroad industry has devoted enormous resources in an unprecedented effort to develop PTC systems and address myriad interoperability issues. However, much of the work to implement PTC remains to be done. For example, less than 10 percent of the WIUs have been installed, work on switches in non-signaled territory has been completed for less than 10 percent of the switches that need upgrading, only about 10 percent of signal projects have been completed, 220 MHz radios are not yet in production, and, leaving aside the unavailability of the radios, PTC equipment has been partially installed on only 15 percent of the locomotives that will need PTC equipment. While greater progress has been made in some other areas, such as the mapping element of the PTC-related GIS initiative, in no case is the industry close to completing the work that must be done for the nationwide PTC network, as measured on the basis of percentage of work completed.

Significant hurdles must be surmounted in completing the design, production, and installation of the more than 20 major components that underlie the nationwide PTC network. Essential software and hardware for many components are still under development and testing of these components must be performed after the software and hardware are available. FRA must review each railroad's PTC safety plan and certify the railroads' PTC systems after the development and testing of the components are complete, and then PTC installation must be completed. The task is made particularly complex by the need to ensure that individual railroad systems are fully interoperable and the many potential failure points and failure modes in PTC systems (across multiple interoperating railroads) are identified, isolated, and corrected. The interoperability concern has been magnified by current plans for phasing in PTC, which instead of providing for the implementation of PTC in less complex areas first to reduce operational risk, actually provide for PTC to be installed first in the areas most complex from the perspective of interoperability.

The current deadline and sequencing schedules unnecessarily create potential operational risks. Rushing development and installation and foregoing a logical plan for sequencing the implementation of PTC also increases the likelihood of instances occurring where PTC will fail to function reliably.

One item impacting the time it will take to complete installation of PTC on the nationwide network is the geographic scope of the PTC mandate. FRA took a significant step when it published a notice of proposed rulemaking providing for 2015 traffic patterns to be used to determine the geographic scope, as provided for in the RSIA, instead of 2008 traffic patterns. In addition, recognizing the need for additional modifications to the geographic scope, FRA has announced it will be initiating a rulemaking proceeding that could further reduce the geographic scope of the PTC mandate. Leaving aside technical obstacles to developing PTC, it is unlikely any freight railroad could meet the December 31, 2015, deadline without significant changes to the current geographic scope of PTC deployment. However, regardless of the ultimate geographical scope of the PTC mandate, the technical hurdles are such that a nationwide, interoperable PTC network cannot be completed by the December 31, 2015 deadline.

II. PTC Components

A. Locomotives

Approximately 18,000 locomotives, or approximately 75 percent of the industry's active road locomotive fleet, must be equipped with PTC technology. More specifically, these locomotives must be equipped with:

- a Train Management Computer (TMC) with fully functional PTC software;
- an interoperable 220 MHz radio designed specifically for PTC;
- a Communications Management Unit or Onboard Network (OBN);
- antennae arrays capable of receiving the full range of PTC data transmissions, e.g., via radio, cellular, WIFI, and GPS; and
- two computer displays, one of which must be interactive.

Additionally, every TMC must be interfaced with the locomotive's onboard systems to supply the TMC with critical information such as brake pipe pressure, horn status, and speed from the axle alternator.

The wiring, cabling, welding, cutting, and connecting of locomotive components required for PTC is made particularly complex by the variety of locomotive models. The largest railroads have 15 to 20 different models of locomotives on which PTC equipment will need to be installed, some of which have been in service for several decades. The age and variety of the locomotive fleet contribute significant additional time, complexity and costs to the effort to install PTC equipment on locomotives. A unique PTC design is required for each unique locomotive configuration.

For a number of reasons, equipping locomotives with PTC technology is taking longer than projected in the railroads' original implementation plans:

- as should be expected with a program of this magnitude and complexity, vendor supply chain and quality control issues have arisen with respect to both hardware and software;
- some equipment suppliers do not have the capacity to satisfy overall industry demand in a timely fashion, resulting in delivery delays;
- to facilitate the transmission of PTC messages to and from the locomotive, on some railroads the TMC required a design change for a processor to support the messaging system that has not yet been delivered in a stable, functional form;
- onboard software, which runs on the TMC, has not yet been delivered with full functionality;
- an initial version of 220MHz radio software was just made available in the fourth quarter of 2011 – production radios are not expected to be available until May/June of 2012; and
- the delivery dates for the Communications Management equipment, manufactured by several suppliers, have slipped.

The delay in equipping locomotives has forced railroads to go to a "double touch" strategy for equipping locomotives with PTC technology. Railroads take locomotives out of revenue service to make modifications required for the installation of brackets, wiring, and cabling, which will ultimately support the onboard PTC components when they become available. At the same time, the railroads install any components that are available. The railroads will have to re-shop these same locomotives in the future – again taking them out of revenue service – to install the remaining on-board PTC components.

Of the approximately 18,000 locomotives the railroads are planning to equip with PTC technology, only about 2,600 have been partially equipped – and a substantial amount of work remains to be done on those locomotives. Insofar as equipping locomotives is concerned, most of the work remains to be done. Table I in Attachment A shows the status of the installation of PTC equipment on locomotives for each railroad.

B. Wayside Technology

Wayside signal systems interface with PTC through wayside interface units (WIUs) installed at each wayside signaling location. WIUs translate the signal logic into PTC information. There are currently two types of WIUs under development by railroad signaling suppliers, "integrated" and "standalone" configurations. The integrated WIU will be applied to newer, microprocessor-based signal systems. Where integrated WIUs are used, the existing signal system's processor hardware and software must be upgraded. Standalone WIUs will be applied to older, non-microprocessor-based signal systems (and some older microprocessor-based systems as well). The installation of standalone WIUs is more complex than integrated WIUs because separate WIU hardware and software must be installed, along with hardware interfaces to the existing signal system, and the entire location must be "recommissioned." Note that it will be impractical from a lifecycle perspective to apply standalone WIUs to some older signal systems. For these systems, reliability concerns and the high cost of design, installation, and maintenance will drive the railroads to replace the underlying signal system and use an upgraded signal system combined with integrated WIUs.

Every location that requires PTC will need some or all of the work listed below:

- install and position PTC radio and GPS antennas at wayside locations and base radio sites;
- cable work;

- replace or upgrade battery power;
- install lightning & surge protection;
- replace track circuits where necessary;
- replace signals where necessary;
- replace bungalows where new ones are required due to PTC equipment size constraints;
- perform in-service tests as applicable that can include running through every available combination of routes to insure signal indication accuracy; and
- update configuration management as applicable.

Product availability has been a problem as suppliers strive to develop interoperable equipment and undertake the safety-critical development and testing required for signaling equipment. Furthermore, railroads subject the equipment to extensive lab and field testing. While one supplier has WIUs available, WIUs from other suppliers are not yet ready for production in large quantities.

For the reasons described above, tens of thousands of miles of existing signal system infrastructure will need to be replaced, at a cost of approximately $1 billion. Each replacement project is complicated and lengthy. At each signal location the following steps must be performed: a) a physical survey must be conducted to determine what PTC solution will be needed; b) the signal system must be completely redesigned; c) new signal bungalows must be fabricated and put in place; d) new wiring from the bungalow to each track circuit, switch, and signal mast must be installed; and e) the communications infrastructure must be installed. Moreover, during the process of changing to a new signal system, installing WIUs, and testing every affected route, railroad operations are interrupted.

Another significant issue is the limited number of qualified personnel available for signal work. The PTC signal projects require a substantial amount of work in a limited period of time. Historically, railroads are staffed for a fairly stable amount of signal work from one year to the next. The PTC work dramatically increases the workload for signal personnel, resulting in a tripling, quadrupling, or an even greater increase in the number of locations where signal work is required. The limited number of qualified signal personnel available to the railroad industry constrains how quickly railroads can complete the design, installation, and testing work required for PTC signal projects, as well as adversely impacting projects to increase railroad capacity (and the increase in demand for signal personnel combined with the limited number available has resulted in a tremendous increase in signal engineering and installation costs). While the railroads are actively hiring new employees and retaining contractors and training them in railroad signaling systems and PTC requirements, it typically takes 18 to 24 months for an individual to receive the training and gain the experience necessary to handle the complexities of PTC. The industry has already hired more than 2,000 additional signal personnel specifically for PTC, as illustrated in Table 2 in Attachment A, and is planning to hire hundreds more. Of course, hundreds of existing employees who previously handled other signal work are now also working on PTC.

Of the approximately 38,000 WIUs that must be installed for PTC, only about 3,300 have been installed to date. As is the case with equipping locomotives, most of the work with respect to installing WIUs remains to be accomplished. Similarly, only a small number of the signal replacement projects that must be done have been completed. Of the approximately 12,200 PTC signal replacement projects, only about 1,200 have been completed. Tables 3, 4, and 5 in Attachment A show the status of WIU installation and signal replacement projects for each railroad.

C. Switches

In non-signaled territory, every switch will require an upgrade to become PTC-capable. For the most part, these upgrades will require: a) the provisioning of utility or localized power (e.g. generators, solar panels, etc.) to the location, given that many switches in non-signaled territory are "hand throw" or "spring" switches; b) the installation of a switch position monitor; c) the installation of a WIU; and d) the installation and configuration of communication systems. Providing power to a switch location requires trenching along the right of way and burying cable.

Most of the work involved in upgrading switches lies ahead. Of the approximately 4,900 switches that need to be equipped with power and WIUs, only about 200 have been equipped with power and 100 with WIUs. Furthermore, switch position monitors have been installed at only about 100 of the approximately 3,700 locations that need them. Table 6 in Attachment A shows the status of each railroad's progress in non-signaled territory.

D. Communications

All PTC wayside locations and all PTC-enabled locomotives must be equipped with a complex, interoperable wireless communications infrastructure, largely through a combination of communications media. More specifically, the railroads will utilize Wide Area Networks for voice and data communications for wayside and field operations (leased & private circuits, fiber, and microwave systems). Many railroads will require upgrades to their Wide Area Networks to increase capacity, enhance reliability, provide redundancy, and support current digital communications protocols (e.g., Internet Protocol). The specific communications technology deployed at a particular location will depend on the railroad's communications network. The infrastructure required for each communications path is different, as is the availability and maturity of the components of each infrastructure type.

Railroads were forced to create a private radio frequency network capable of transmitting and receiving the data necessary to support an interoperable PTC network because of the need for greater coverage and reliability than provided by the cellular networks in the U.S. The industry adopted 220 MHz as the interoperability communications standard. To date, the seven Class I railroads have invested approximately $40 million in acquiring and managing 220 MHz spectrum. The railroads might need to invest even more to acquire additional spectrum to ensure adequate coverage in certain congested metropolitan areas and have commenced radio frequency propagation studies in Los Angeles and Chicago to determine if their holdings are sufficient to support PTC in the more heavily trafficked and populated areas. In addition, because no 220 MHz radio existed, the freight railroad industry again took the initiative, this time to commission the design of a 220 MHz radio through a railroad-owned company, Meteorcomm, LLC. To date, approximately $140 million has been invested in the development of three distinct radios, for base stations, wayside locations, and locomotives. If field testing of the radios is successful, production radios for field deployment should begin to be available in May 2012.

The development work for PTC communications will not be finished once radios are available for deployment. This 220 MHz data radio network will require significant radio frequency planning and coordination to ensure sufficient coverage has been provided without interference. It is likely that areas of high PTC traffic congestion will result in very complex frequency coordination and necessitate the sharing of railroad communication infrastructure. This type of effort has never been undertaken on the scale and timeline required to support interoperable PTC.

The deployment status for base stations, wayside locations, and locomotive communications is shown in Table 7 in Attachment A. As Table 7 shows, only a small number of 220 MHz radios have been installed for testing purposes.

E. <u>PTC Back Office</u>

The numerous technologies and systems which comprise or support the PTC Back Office Segment are another complex aspect of PTC. The Back Office Segment is responsible for several core PTC functions, including:

- providing the PTC interface to and from existing transportation information technology systems, such as crew, locomotive, and dispatch systems, which are different at each railroad; and
- providing a centralized source of PTC-enabling information for the locomotive equipment and WIUs.

The Back Office Server (BOS) performs the functions of the Back Office Segment. There are also a number of back office systems which provide inputs into the Office Segment. Two major data inputs are from the railroads' existing dispatch systems and their Geographic Information Systems (GIS), which are being developed or enhanced for PTC.

The pace of development of the Back Office Segment and PTC-related back office systems is affected by available resources. Railroad-specific back office technology is developed by a very small number of companies. Railroads spent fairly consistent amounts with these firms prior to PTC, affecting these firms' ability to ramp up their efforts in support of the railroad industry. Furthermore, the number of technology professionals who have intimate knowledge of railroad operations is very small. The limited resources available affect the timing of work on design, development, coding, integration, and testing. In addition, because each railroad's transportation information technology system is unique, the details and scope of the back office development required for PTC differ for each railroad, minimizing the ability to apply the work done for one railroad to another railroad's PTC system.

The limited resources available together with the statutory deadline of December 31, 2015, have forced the railroads to develop PTC technology in a less efficient way than would otherwise be the case. Systems design, development, and testing that normally would be undertaken sequentially must happen in parallel, which results in more defects in the development process than would be the case if time permitted a more efficient, sequential development process. Furthermore, because of the limited resources available to the railroads, the substantial resources required for planning, designing, and testing PTC components means that fewer resources are available for other service and safety technology projects.

The need to thoroughly test the PTC back office systems, including the BOS, and address problems identified during the testing process, also significantly impacts the pace of their development. Lab testing of the related technologies and systems will generally find some defects, as was the case with the initial software release for the BOS, requiring the railroads to wait for a subsequent version of the technology or system that fixes the defects.

1. <u>Back Office Server</u>

Most railroads do not have final BOS software available. For example, the "final" version of the BOS software that will be used by a number of railroads is not scheduled to be delivered until late 2012. At that time, the railroads will need to lab test the software. Thus, a production version of this critical BOS software will likely not be available until the first quarter of 2013, at the earliest.

2. <u>Geographical Information System (GIS)</u>

With respect to GIS, the accuracy of the information required for PTC is significantly more precise than what is required to run a safe and efficient railroad in a non-PTC environment. Field assets that are critical to PTC – and there are approximately 500,000 of these – must be geo-located to a horizontal precision of less than 2.2 meters (~7 feet) and a vertical precision of 0.8 meters (~2 feet) to provide the accuracy necessary to safely warn or stop a locomotive. Furthermore, it is not just the PTC routes that must be mapped. Yards, industry, and other connecting track also must be mapped to account for entry onto and exit from PTC track. Over 63,000 miles of right-of-way will be mapped, perhaps considerably more depending on the outcome of the PTC rulemaking proceedings. In essence, PTC is requiring each railroad to undertake a complete, highly-precise physical survey of the track and wayside infrastructure in a fashion not seen since the 1917 federal government survey of railroads.

After mapping is completed, additional data from multiple railroad systems must be incorporated into a PTC data model for use onboard the locomotive in a "subdivision file." These data points include all track classes, clearance points, quiet zones, and bit assignments for wayside communications. There are over 200 attributes that must be included. Railroads must verify and validate the accuracy of the GIS data and the way the onboard system interprets the data. Every mile must be traversed prior to "turning on" PTC to make sure the rail network is represented accurately. Furthermore, any time a critical PTC asset along any of the over 60,000 miles of PTC territory is subsequently moved more than 1 foot, which could be for operating or safety reasons, new GPS coordinates must be acquired and the data translated into information for PTC purposes.

The status of the GIS/GPS efforts required to support PTC is shown in Table 8 in Attachment A

3. <u>Dispatch</u>

Railroad dispatch systems, most of which have been upgraded in the last 10 years, are milepost-based and generally require a precision of one-tenth of a mile to operate trains safely. The level of precision required for PTC requires some dispatch systems to be rewritten or perhaps even completely re-architected to convey movement authority information to PTC with significantly greater precision, e.g., to the ten-thousandth of a mile. Railroads are working with their dispatch system developers to incorporate this precision and other enhancements required for PTC. Table 9 in Attachment A shows the dates by which railroads expect their dispatch systems will be PTC capable. Most railroads will not have PTC-capable dispatch systems until the end of 2012 or the beginning of 2013.

III. The Integration Challenge

PTC is a system of systems. While the RSIA and FRA regulations set forth PTC's core functions, there are myriad requirements for system components that comprise the total PTC system. The development of these components requires hundreds of subject matter experts to create and document component requirements, develop the components, and test them. At every juncture of the process, integration issues must be analyzed and potential or actual defects or risks mitigated. That must be done by the railroads. While suppliers primarily undertake the development of PTC components, it is up to the railroad to integrate the components and integrate the components with the railroad's existing technology systems. From a timing perspective, PTC components will not be ready until the suppliers are finished with their testing and the railroads complete their integration testing.

More specifically, PTC systems are comprised of more than 20 components, including the:

- Back office server;
- Train management computer;
- Interoperable electronic train management system software;
- Authentication systems to verify users;
- Track database of over 200 characteristics of track and trackside assets;
- Interface and enhancements to the dispatch system;
- Security application for message integrity;
- Interoperable train control messaging system;
- 220 MHz data radio for base station communication;
- 220 MHz data radio for locomotive communication;
- 220 MHz data radio for switch and signal communication;
- Communication switching network for interoperable back office communication;
- Computer display units for onboard the locomotive;
- Locomotive messaging system to route messages off the locomotive;
- GPS sensors onboard the locomotive;

- Crash hardened memory module onboard the locomotive;
- Onboard network devices for communications;
- Switch position monitors; and
- Integrated and stand-alone WIUs.

While some of these components existed in some form prior to PTC, none were designed or tested for positive train control or to work in concert with so many other components in this system of systems. Furthermore, many of these components are first-generation technologies being conceived, designed, and developed for PTC. All of these components must function correctly and reliably, or the entire PTC system will fail. In the case of the first-generation technologies, the likelihood of problems arising is significantly higher than with proven system components.

The safe integration of these many components is verified by the railroads' through testing. Every major railroad has a "PTC lab" where testing of the system is conducted, as well as designated "pilot territories" where field testing occurs.

Multiple phases of testing must take place before PTC systems are ready to be put through the rigors of real operations. Simulators have been developed to create mock operational environments for testing. Each system component is connected to other components for integration testing. The process is iterative, with components being added to the test until the entire system is assembled in the lab environment to verify system functionality.

At any point during testing, defects in the components or their interface with other components can be revealed. When that occurs, research must be conducted to determine the cause, the software or hardware must be modified, and new testing must take place. Each defect potentially impacts the schedule for implementing PTC, depending on the functionality and complexity of the issue. Defects found during field testing can be particularly problematic, causing significant "rework" and delays. Finding a defect places in jeopardy all of the previous work done on individual components and their integration.

The variety of suppliers, the timing of development of the individual components, the interpretation of designs and standards, the enhancement of legacy systems, the dependencies between modules, and interfaces all add complexity, risk, and time to the implementation of PTC. It is only when the development of all components is complete and the components are brought together to be tested, that is, validated and verified (V&V) to meet the requirements, that the PTC system can be submitted for FRA approval and run as a PTC System. Validation and verification is expected to take at least 12 to 18 months to complete.

IV. The Certification Process Could Take Considerable Time

Section 236.1015 requires that FRA grant a railroad a "PTC System Certification" before a railroad can place a PTC system in service. To obtain certification, railroads must submit detailed "PTC Safety Plans" containing complete PTC system designs. That means that all the technical hurdles described in this paper must be surmounted before FRA will grant certification. AAR is concerned that FRA will not have the resources to expeditiously review and certify PTC systems. Approximately 40 railroads will need certification. While railroads have been and will continue to partially install PTC equipment prior to certification, any delays in certification will impact the timing of completing installation. The timing of FRA certification clearly will impact the date by which the PTC mandate can be implemented.

FRA and the industry have good reason to be concerned about the adequacy of FRA resources and the timing of FRA approval of PTC systems. The process for FRA approval of PTC Development Plans took nearly 18 months and discussions are still ongoing concerning conditions FRA sought to impose. The PTC Safety Plans will be significantly more complex and voluminous than the Development Plans. Moreover, FRA might seek changes in the Safety Plans, including design, hardware, or software changes, making timely approval even more problematic.

V. Interoperability: The Current Implementation Schedules Could Adversely Affect the Reliability and Effectiveness of PTC

A. Phasing in PTC

Attachment B discusses the reliability and effectiveness problems that could arise from implementation schedules under which PTC is deployed first in locations presenting complex interoperability issues. Implementation of PTC in operationally complex areas such as Chicago and the Northeast Corridor, where multiple railroads operate and rail traffic levels are very high, is potentially more difficult and presents a greater risk of problems arising than in other areas. Furthermore, deploying PTC in areas of greater risk before areas of lesser risk runs counter to deployment strategies in most technology development programs. To minimize risk in areas with a comparatively high risk of interoperability problems, Attachment B discusses a phased approach to PTC under which PTC will be implemented in less operationally complex areas first, which is a departure from current implementation schedules.

A phased approach addressing interoperability issues potentially impacts the timing of PTC implementation. A properly phased approach is inconsistent with the December 31, 2015, deadline. Assuming all other technical problems with the 2015 deadline did not exist, the railroads could ignore the benefits of phasing from the perspective of the complexity of interoperability and seek to install PTC as rapidly as possible in all areas at once in order to meet the 2015 deadline. However, to do so would potentially increase operational risk. It would be in the public interest to give the railroads more time to implement PTC in a manner that minimizes overall risk.

B. Interoperability Standards

Ensuring the interoperability of PTC requires numerous interoperability standards. AAR and its member railroads have devoted considerable effort towards developing those standards. Attachment C describes the status of each of the interoperability standards required for PTC.

VI. Rolling Out PTC

Once the technical issues are resolved, FRA certifies the PTC systems, and PTC equipment is installed, the railroads will roll out PTC. This is not a simple matter. Most railroads will roll out PTC on a subdivision basis. On each PTC subdivision a number of milestones will occur prior to commissioning PTC, including the installation of WIUs, equipping locomotives, training employees, ensuring the accuracy of the track information, and installing and testing of communications infrastructure. Revenue service demonstrations will take place on all routes and every potential signal display will have to be tested. Only at that point will PTC be ready.

The time it will take to train employees should not be underestimated. On the Class I railroads alone, approximately 60,000 engineers and conductors, 6,500 signal employees, 2,400 dispatchers, and thousands of others, including mechanics, electricians, and supervisors, will have to be trained on PTC. That cannot happen overnight.

VII. The Railroads' Tremendous Investment in PTC

The railroads have already invested approximately $1.5 billion and spent millions of man-hours on the development of PTC and will be spending billions more – FRA estimates the industry's installation costs will amount to $5.5 billion. Without going into the opportunity cost of this diversion of capital and human resources to PTC, the railroad industry has already devoted enormous resources to the effort to meet the government's PTC deadline. Table 10 in Attachment A shows the individual railroad investment levels in PTC through 2011.

VIII. Conclusion

In December 2010 the United States Government Accountability Office (GAO) published a report expressing concerns about the ability of the railroad industry to meet the 2015 RSIA deadline (and concerns about PTC diverting funding from other critical needs).[2] GAO recognized the industry was embarking on the development and installation of unproven technologies, with much work to be done. GAO's fears have proven to be well founded. Despite the railroads having spent approximately $1.5 billion to develop and install PTC, the December 31, 2015, deadline for implementation of a nationwide interoperable PTC network is not achievable.

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[2] GAO, "RAIL SAFETY: Federal Railroad Administration Should Report on Risks to the Successful Implementation of Mandated Safety Technology http://www.gao.gov/assets/320/314033.pdf.

Attachment B

PTC Data[1]

Table 1. Equipping Locomotives with PTC

Railroad	ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# to be equipped	54	4000	1,000	1,143	4,100	591	3811	7,267	**21,966**
# partially equipped to date	53	917	58	163	1705	40	1383	1591	**5910**
# fully equipped	0	146	0	0	0	0	0	0	**146**

Table 2. Railroad Signal Personnel Hired or Retained Due to PTC

ARR	4
BNSF	820
CN	32
CP	35
CSX	494
KCS	36
NS	300
UP	539
Total	**2260**

[1] The data in this Attachment is based on estimates as of December 31, 2012, current PTC implementation plans on file with FRA (including amendments to plans that have been approved by FRA), and the regulations in existence on December 31, 2012.

Table 3. Integrated WIU Installation

Railroad	ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# integrated WIUs required to be deployed	54	5709	1061	491	5029	620	4249	11895	**29108**
# integrated WIUs deployed to date	0	4518	67	49	487	238	597	3003	**8959**
# integrated WIUs remaining to be deployed	54	1191	994	442	4542	382	3652	8892	**20149**

Table 4. Stand-alone WIU Installation

Railroad	ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# stand-alone WIUs required to be deployed	38	1180	699	620	1167	217	1096	1934	**6951**
# stand-alone WIUs deployed to date	0	209	0	15	10	42	39	452	**767**
# stand-alone WIUs remaining to be deployed	38	971	699	605	1157	175	1057	1482	**6184**

Table 5. Signal Replacement Projects

Railroad	ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# locations of signal replacement required	0	3965	134	66	1724	364	1850	4200	**12303**
# locations replaced to date	0	2490	89	26	561	180	597	1255	**5198**
# locations remaining to be replaced	0	1475	45	40	1163	184	1253	2945	**7105**

Table 6. Switches in Non-Signal PTC Territory

Railroad		ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# non-signaled switch locations needing power & WIUs	# needed	64	1180	227	481	973	148	728	974	**4775**
	# equipped with power to date	4	209	0	11	85	30	39	58	**436**
	# remaining to be equipped with power	60	971	227	470	888	118	689	916	**4339**
	# equipped with WIUs to date	4	209	0	11	10	30	39	58	**361**
	#remaining to be equipped with WIUs	60	971	227	470	963	118	689	916	**4414**
# non-signaled switch locations needing switch position monitors	# needed	0	0	227	481	973	148	728	974	**3531**
	# equipped to date	0	0	0	11	10	30	39	58	**148**
	# remaining to be equipped	0	0	227	470	963	118	689	916	**3383**

Table 7. Communications Deployment

Railroad		ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# Base station 220 MHz radios	# needed	33	731	181	134	1285	120	700	1036	**4220**
	# installed	3	297	0	0	30	0	62	4	**396**
	# of future installations needed	30	434	181	134	1255	120	638	1046	**3838**
# Wayside location 220 MHz radios	# needed	78	5863	1751	687	5299	828	5478	13700	**33684**
	# installed	0	1282	0	0	748	0	78	102	**2210**
	# of future installations needed	78	4581	1751	687	4551	828	5400	13598	**31474**
Locomotive 220 MHz radios	# needed	54	4000	1000	1143	4100	591	3811	7267	**21966**
	# installed	0	146	0	1	20	0	0	2	**169**
	# of locomotives remaining to be equipped	54	3854	1000	1142	4080	591	3811	7265	**21797**

Table 8. Status of PTC GIS Projects

Railroad		ARR	BNSF	CN	CP	CSX	KCS	NS	UP	**Total**
# PTC assets to be* mapped and extracted for GIS consumption		2800	95925	25630	17802	114731	9641	77000	130000	**473529**
# track miles required to be GIS mapped	# miles mapped to date	600	13925	80	865	21455	1977	16107	25000	**80009**
	# miles to be mapped	0	10562	4300	1871	110	250	0	0	**17093**
# track miles required to be data processed	# miles processed to date	600	9758	20	273	7742	153	231	22500	**41277**
	# miles remaining to be processed	0	14729	4300	2463	13823	2074	16107	2500	**55996**
# track miles GIS data to be converted to PTC subdiv files	# converted to date	600	6455	0	273	1420	153	231	300	**9432**
	# remaining to be converted	0	18032	4300	2463	20145	2074	16107	24700	**87821**

*The calculation of assets to be mapped includes the following: integer mileposts; signals; crossings; switches; interlockings/control point locations; permanent speed restrictions; the beginning and ending limits of track detection circuits in non-signaled territory; clearance point locations for every switch location installed on the main and siding tracks; and inside switches equipped with switch circuit controllers.

Table 9. Status of PTC Dispatch System Projects

Railroad	Date System will be PTC-capable
ARR	April 2013
BNSF	Completed
CN	1st quarter 2014
CP	June 2014
CSX	3rd quarter 2014
KCS	1st quarter 2014
NS	3rd quarter 2013
UP	Completed

Table 10. PTC Investment

Railroad	PTC investment through December 31, 2012 ($)
ARR	34,000,000
BNSF	739,694,000
CN	55,900,000
CP	102,340,000
CSX	585,000,000
KCS	50,374,000
NS	443,466,772
UP	$759,000,000
Total	**$2,769,774,772.00**

Table 11. PTC Timeline Based on PTC Regulations as of 12/31/2012

Railroad **Class 1s**

Component	Thru 2012	2013	2014	2015	2016	2017	2018 and beyond*	Totals
Locomotives Partially Equipped	6,031	4,242	1,365	678	650	314	77	13,357
Locomotives Fully Equipped	224	987	6,948	7,425	4,425	1,509	448	21,966
Percent Complete	1%	6%	37%	71%	91%	98%	100%	
Wayside Interface Units installed	9,726	5,300	4,950	5,837	4,210	3,988	2,048	36,059
Percent Complete	27%	42%	55%	72%	83%	94%	100%	
Base Station Radios Installed	403	976	1,285	1,267	222	52	34	4,239
Percent Complete	10%	33%	63%	93%	98%	99%	100%	
PTC Route Miles Implemented	207	1,085	8,320	15,516	11,983	12,760	12,341	62,213
Percent Complete	0%	2%	15%	40%	60%	80%	100%	
Employees Trained	5,724	4,013	10,930	28,692	16,520	13,276	17,545	96,700
Percent Complete	6%	10%	21%	51%	68%	82%	100%	
PTC Spending ($M)	2,770	1,377	1,403	1,221	572	393	241	7,978
Cumulative Spending ($M)	2,770	4,147	5,549	6,771	7,343	7,736	7,978	

*The year 2018 and beyond column includes data for what the railroads currently project will remain to be done in and beyond 2018. Because of all the uncertainties associated with the development and installation of PTC, it is impossible to set forth a precise completion date. The railroads currently project that by the end of 2018, all hardware will be installed and PTC will be in operation on approximately 90 percent of the mandated PTC routes, by mileage. The industry continues to seek ways to speed progress while maintaining safe operations in order to achieve complete deployment as soon as possible.

Assumptions:

1 -70% confidence factor in accomplishing the above metrics.

2 - No FRA accomodation on yard movements in PTC territory. The spreadsheet only reflects the cost of equipping yard locomotives. The spreadsheet does not reflect the potential cost of operational impacts such as reduced operational efficiency and potential expenses that will be associated with resolving technical issues such as overloaded communications systems and the potential impossibility of accommodating PTC equipment on remote control locomotives.

3 - Costs represent capital expenses only, no operating or maintenance expenses.

ATTACHMENT C

ITC Sourced Specifications	Total	Started	Delivered to AAR and Published for Comment	Revised and Sent to Railway Electronics Standards Committee for Adoption	Final Version Released by AAR
Interface Control Documents	8	8	4	3	3
Requirements Specifications	14	14	12	9	8
Architectural Specifications	2	2	2	2	2
Database Definitions	2	2	4	3	2
Protocol Specifications	3	3	3	3	2
Recommended Practices	1	1	1	0	0
Test Plans	1	1	1	1	1
Test Reports	0	0	0	0	0
Total Specifications	31	31	27	21	18