Appendix C

June 30, 1999

Compendium of Current Positive Train Control Projects

This document contains short descriptions of the system design or architecture and functional capabilities of the various Positive Train Control (PTC) projects in place or planned for the near term. The Table at the end of this document summarizes these projects. The short descriptions were requested of the Association of American Railroads (AAR) at the PTC Rail Safety Advisory Committee (RSAC) meeting in March 1998. As the PTC projects are tested and implemented, this compendium will be updated.

Union Pacific/Burlington Northern Santa Fe Positive Train Separation Pilot

System Design

The UP/BNSF Pilot in the Pacific Northwest is a non-vital overlay to existing train control systems in all types of territory. The physical topology for the pilot is shown in figure 1. Central dispatch (PTS Server) provides movement authority to train and the train reports location to the PTS Server. The location system uses differential GPS, odometers and rate gyro to determine location. Enforcement of speed and movement authorities is on-board the locomotive. The wireless portion of the data link between dispatch and the locomotive is both 160 (BNSF) and 900 MHz (UP). Interoperability is one of the key objectives. BNSF and UP have established a digital data link through their respective dispatch centers that allows BNSF dispatch to route movement authorities to UP trains and vice versa.

Functional Capabilities

The PTS system enhances railroad safety by enforcing movement authority and speed restrictions for PTS equipped trains. The PTS system accomplishes this through three segments: the Server Segment, the Locomotive Segment and the Communications Segment. The Server Segment is logically centralized, although it may be physically distributed. Its primary function is to determine the PTS enforceable movement authority and speed limit for any train under PTS control. This information is transmitted through the Communications Segment to the Locomotive Segment located on-board the controlling locomotive of each train. The Locomotive Segment enforces movement and speed limits by stopping the train before a violation occurs. A functional diagram of the PTS system is shown in Figure C-2.

Figure C-1. Physical Topology

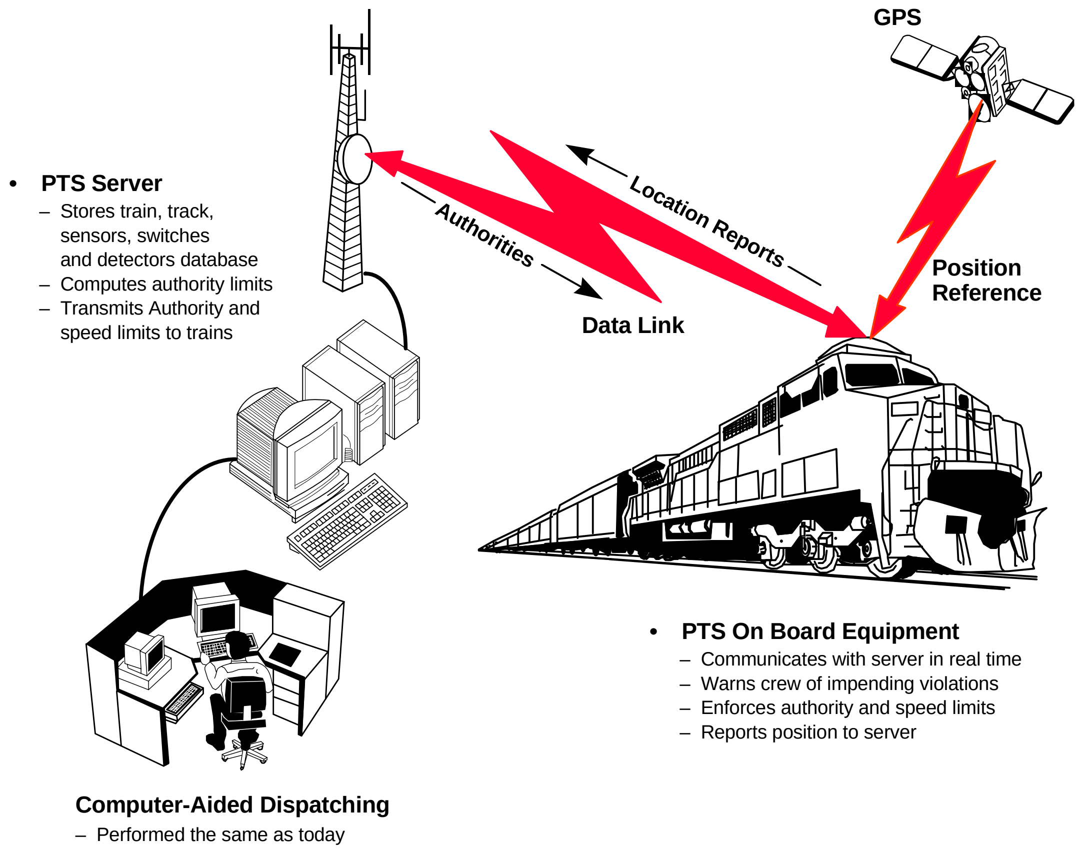
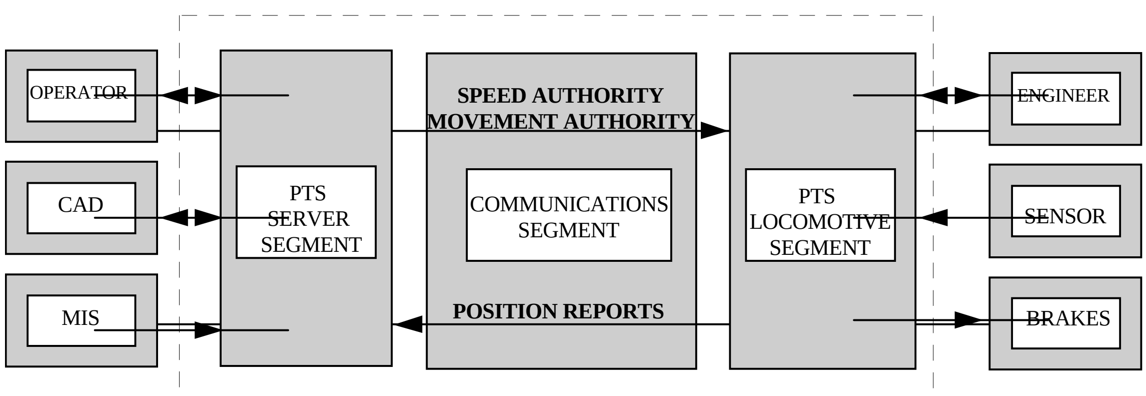


Figure C-2. Functional Diagram

PTS SYSTEM



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The purpose of PTS is to enhance railroad safety through enforcement of movement authority and speed, with some additional collision protection features and optional on-board display capabilities. The PTS system does this while maintaining current levels of operational productivity and providing a growth path to precision train control and advanced computer-aided railway management capabilities.

In PTS operations, trains continue to be controlled by fixed block signals, track warrants, work authorities, and other types of conventional movement authorities originating in the CAD system. Overlaid on these displayed authorities, and derived from them, are PTS authorities defining enforceable limits of movement for equipped trains. In CTC, 9.14 and 9.15 territory, the PTS authority is based on CAD Authorities conveying route information (track authorizations and switch settings), generally extending between two control points. The PTS system does not require any knowledge of *intermediate* signal aspects. In Track Warrant Control (TWC) territory, the PTS authority is based on a train’s current track warrant.

The PTS Server generates PTS authorities automatically. Except in special cases (such as joint authorities), the enforceable authorities for two trains are not allowed to overlap. While PTS authorities generally coincide with the underlying CAD authorities, in certain cases the requirement for non-overlapping PTS authorities means that the PTS authority is more restrictive than the CAD authority. In a following move, for instance, the enforceable authority for the following train is limited by the leading trains' rear-end position, even if the CAD authorities for the two trains overlap. The PTS system continuously monitors the position of the leading train so as to incrementally extend the following train’s PTS authority.

The PTS system protects trains against collision by enforcing PTS authorities. The on-board PTS system monitors a train’s position in relation to its enforceable movement limits and continually recalculates the braking distance to confirm that the train can safely stop within the limits. If a train approaches the point at which a safe stop within the movement limits would be impossible, the onboard system responds first with a warning and then, if the crew takes no action, with an application of braking to stop the train at the end of its PTS authority limit. The PTS architecture ensures that lack of communications will never result in a safety critical situation.

The algorithm that determines safe braking distance is instrumental to maintaining present levels of productivity. This algorithm incorporates detailed consist data and track profile data to improve the accuracy of the calculation and so keep required headways to a minimum. The pilot PTS system will only address trains that have all their motive force applied at the head end. However, the system architecture will take into consideration the need to include helper locomotive operations and remotely controlled distributed power (e.g., LOCOTROL) in a production system.

Although the PTS system makes allowance for most train movement scenarios, absolute protection cannot be provided in every case. The more prominent among non-protected cases are those involving combinations of PTS equipped and unequipped trains.

Besides movement authority, the PTS system enforces speed restrictions of various types. In addition to enforcing track speed, the PTS system enforces speed restrictions associated with track bulletins, track warrants, work authorities, bi-directional movement authority, and train-specific characteristics.

Passenger/Freight Applicability

Nothing in the design of PTS specifically limits its applicability to passenger or freight operations. As with all PTC systems the speed of passenger trains puts a burden on the communications platform and must be accounted for in the selection.

Technical Readiness

The fourth and final release of PTS has been tested. The project is currently suspended.

Amtrak Incremental Train Control System (ITCS) Project

Functions

ITCS provides the basic safety functions of preventing train-to-train collisions, protecting against overspeed, and providing protection for roadway workers operating under dispatcher authority. In addition, it provides advance start capability for grade crossing warning systems.

Architecture

The basic components of ITCS are wayside servers, wayside interface units (WIUs), the On-Board Computer (OBC), and a dispatch terminal used only for managing temporary slow orders. ITCS uses a totally distributed architecture based on an existing signal system providing the foundation for authority information. The system takes its authorities from the signal system, which protects fixed blocks based on track circuit occupancy. Track, signal and switch statuses are monitored at the wayside using WIUs which collect the necessary data from each affected location and pass it to a server responsible for data collection in a given area. Typical coverage of an individual server is 4 to 8 miles of track, spanning as many individual signals, control points and crossings as are present in that segment. Server coverage area is limited by radio coverage, both train-to-wayside radio and an independent wayside local area network (WLAN), which uses unlicensed spread spectrum radios to gather data from the outlying WIUs into the server.

The OBC carries a track profile database containing GPS coordinates and all relevant targets, which the train must respond to, including all fixed and temporary speed restrictions. Using GPS receivers and axle tachometers to track its location, the OBC continually calculates its position relative to each target and determines if a speed reduction will be required.

Authorities for train movement originate with the dispatcher or CAD by requesting routes through the normal CTC process, resulting in controlled signals displaying a permissive aspect. The wayside server, based on data collected from individual locations through the WLAN, periodically broadcasts the status of each object in its territory. These include signal indications, switch positions, certain track circuit statuses and several statuses from each crossing where advance start operation is used. Each status broadcast contains the status of all objects in the WLAN area and broadcasts are repeated at intervals of approximately 6 seconds. Any train in the area will receive the broadcasts and determine which statuses are relevant to its own location. Each signal indication carries an implied target speed, which is used by the OBC to calculate a braking profile to reach that speed. When any braking profile is close enough to be within 30 seconds of requiring a full service application (80 to 110 seconds for freight trains), the target information is displayed in the cab on the Compact Locomotive Display (CLD). Target information includes target speed, distance to target, time to penalty in seconds, and target type.

Operation

As trains move over the territory, the OBC logs on to each server as it approaches. This log-on process includes a verification of the track database version against a reference maintained at the server, to assure that the train is not working with a corrupted or obsolete database. In the process, the server also sends the OBC the current Temporary Slow Order (TSO) file. Temporary slow orders are created at the dispatch location and transmitted to the appropriate servers over a land-line equivalent called the Office-Wayside Link (OWL). At the server, any current TSOs are compiled into a special TSO file that is delivered to each approaching train when it logs on to that server.

For any active grade crossing so identified on the profile, the OBC continually calculates the expected time of arrival at the crossing (calculated as seconds remaining before arrival). When this time for any given crossing has reduced to about 100 seconds, the OBC transmits its arrival time estimate at the specified crossing. The server receives the message, arms the crossing to prepare for activation, and sets a delay timer to hold off activation of the crossing until the estimated arrival time has reduced to around 40 seconds. When all this is accomplished, the server then broadcasts the crossing status as armed and ready for hi-speed operation. When the delay time has expired, the server activates the crossing over the WLAN. Any loss in communications will either result in the crossing being activated prematurely, or in the train being given a reduced speed target at the beginning of the normal crossing approach so that full warning time will be obtained using the conventional start mechanism. Crossing health is also monitored at each crossing, so that a detected false activation will result in all approaching trains being given a target speed of 15 MPH at the crossing.

Train locations are not reported routinely from train to wayside, as this information is not required by the system. Targets are not based on reported locations of other trains but on signal locations and the indications displayed on each signal. Wayside signals could theoretically be removed but the fixed block location would still represent a target location, and an implied indication of an equivalent or “virtual” signal would still be employed as the basis for determining target speed at that location.

The OBC in effect defines its authorities based on the signal indication statuses it receives from the server. This status information is received on a frequent refresh cycle of approximately every 6 seconds. Failure to receive one broadcast has no immediate effect on the operation, but if three consecutive broadcasts are missed, the OBC assumes communications failure and begins a default routine that calls for reduced speed operation until communications can be restored. If ITCS is cut out (e.g. fails enroute), the train may continue at reduced speed and is still protected against possible violation by other equipped trains. In other words, a train with a failed ITCS on-board systems does not become invisible to equipped trains.

Protection of roadway workers is accomplished by the use of TSOs in the work areas. A TSO with a speed limit of 0 mph amounts to a track block applied in the exact area under authority of the roadway work authority.

Applicability to Passenger and Freight Railroads

ITCS is readily applicable to both freight and passenger service. In passenger service, ITCS is an economical approach to raising the maximum authorized speed above 79 MPH. It does this by 1) providing a fail-safe control system to satisfy Federal regulations concerning operation at 80 MPH and higher, 2) providing the additional braking distance required for operation at higher speeds without moving any signals or adding any aspects, and 3) providing adequate highway crossing warning times for higher speeds without changing any of the existing crossing start locations.

Not to be overlooked is the fact that freight carriers can use this system as well. Consider a heavily used freight line in which some form of PTC is deemed advisable and installation of electronic track circuits and continuously welded rail and elimination of pole line has resulted in a very reliable signal system with years of economic life remaining. ITCS item (1) above could become a possible solution. Also, if it is desired to operate some freight trains at say 70 MPH over a line currently signaled at 50 or 60 MPH, ITCS items (2) or (3) above will be able to accommodate this improvement without moving any signal or crossing start locations.

Deployment

ITCS is expected to be ready to deploy by mid-1999 and should have six months in service experience on the first 20 miles in Michigan by the end of 1999, and less experience on another 50 miles by early 2000. All of the essential features of ITCS have been successfully demonstrated up to 100 MPH. The supplier is now working through the safety process to ensure that all the safety-critical features will be safely executed under all possible combinations of failure modes.

Amtrak Advanced Civil Speed Enforcement System (ACSES) Project

Introduction

ACSES is a transponder based system overlaid on the existing continuous coded cab signal system in the Northeast Corridor (NEC). This system will enforce absolute stops, permanent and temporary speed restrictions, and protection for roadway workers.

The basic four-aspect continuous coded cab signal system has served the Northeast Corridor very well since the 1930's. The initial concept of feeding several simple codes to the front end of the train through the rails, with 60 years of hardware improvements, and with the addition of speed control starting in the early 1950's and mandated for all trains in the late 1980's, now protects the mix of inter-city (110 MPH), commuter (100 MPH), freight (50 MPH), and Metroliner (125 MPH) services extremely well.

The four-aspect cab signal system is based on 3 code rates (75, 120 and 180 pulses per minute (PPM)) providing four speed commands (20 MPH with no code, 30 MPH, 45 MPH and 80 MPH respectively). This system has been stretched to the limit as the maximum authorized speed has been raised from 80 MPH (1930's to mid-1950's) to the 125 MPH operation by the Metroliner service today. Now with further raising of the maximum speed to 150 MPH to accommodate the arrival of the new High Speed Trainsets (Acela Express Service), the nine-aspect system has evolved from the four-aspect system to "fill the gap" between 45 MPH and 150 MPH. This has been done by adding a 250 Hz carrier to the existing 100 Hz carrier, and by adding 270 PPM to the existing 75, 120 and 180 PPM code rates. The 250 Hz carrier allows immediate upgrades involving speeds of 80 MPH, 125 MPH and 150 MPH anywhere in the corridor (up to seven aspects) for those vehicles equipped to read the new composite (dual carrier) codes. The utilization of the 270 code (providing 60 MPH and 100 MPH speeds) has to wait until all vehicles operating in a particular area have been equipped to read the additional codes. Currently the 270 code rate is being installed only between New York, NY and Newark, NJ where only Amtrak and New Jersey Transit trains operate, and where all trains will be equipped with the full nine-aspect system. The 270 code rate will be available for future 60 MPH crossovers and for capacity improvements in heavy commuter areas.

Discussion

This progressive expansion of the existing cab signal and speed control (ATC) system is the key to interoperability for all the users in the Northeast Corridor as Amtrak migrates to 150 MPH high speed service. Large improvements in headway (capacity) and the ability to enforce all turnout speeds (including the new 80 MPH turnouts) can be obtained by investment by individual users anywhere in the corridor without adversely impacting other users. Amtrak is using this structure to advantage in achieving intercity trip time goals, but others are also investing heavily in portions of the Corridor to achieve their own goals. A good example of this is New Jersey Transit's heavy investment in the New York to Elizabeth, NJ portion of NEC to improve capacity and to provide new stations and services. This structure of the expanded ATC is facilitating these improvement programs.

By expanding on the very simple communication methods (through the rails) proven by long experience in the industry, the needs of all the users of the NEC are being met. Capacity requirements are being met by a combination of shorter blocks and additional codes which approach the much more expensive and elusive "moving block" capacities in the limit. This technology is available right now, off-the-shelf, proven, ready to install. All new on-board and wayside components take advantage of the latest microprocessor technology while functioning seamlessly with older electronic and relay systems that still have years of economic life. This approach in the NEC is also confirmed by the continuous cab signal systems used in the most modern high speed rail systems in France, Italy and Japan, for example.

While the expanded ATC described above meets nearly all the objectives of the 150 MPH high speed train service in this congested corridor, there are two things that even the expanded ATC does not do. ATC does not enforce curve and other civil speeds well, nor does it enforce positive stops at interlocking home signals. These two objectives are being met through the introduction of another well-proven technology, a transponder-based system from Western Europe. This system has its roots in Sweden in the 1950's and is now used very successfully in a number of countries around the world. This technology is the basis for ACSES which overlays the ATC described above.

ACSES is able to precisely pinpoint the beginning and end of civil speed restrictions by providing distance to target and controlling grade data through transponder "telegrams". The on-board computer is able to construct a braking curve from the transponder data which will enforce all civil speeds in 5 MPH (or even 1 MPH) increments. This same type of transponder data is also used to pinpoint interlocking home signals to enforce positive stops at these signals. This is done in conjunction with the ATC in some scenarios and in conjunction with a MCP data radio in others. There are also some auxiliary functions outside the realm of train control which are accomplished in the same way, such as tilt enable/disable and supervision of propulsion controls through phase and voltage change breaks in the catenary.

Maintenance-of-Way work (and roadway workers) in the multiple-track Northeast Corridor are normally protected by vital exit blocks at the interlockings at each end of the track involved. These exit blocks prevent the display of any aspect other than "Stop Signal" into the work area. ACSES will supplement the current protection provided by wayside signals and ATC by enforcing a positive stop at the interlocking home signals. Temporary speed restrictions will be enforced by temporary transponders initially, to be followed by the development of a data radio network which will deliver the temporary speed restrictions directly from the dispatcher's office to each train.

Applicability to Freight and Passenger Service

Cab signals and speed control (ATC) currently protect all of Amtrak's operations between Washington, D. C. and Boston, MA. This congested multiple track Northeast Corridor operates over 455 route miles with 2,3,4,5 and 6 tracks in different line segments, currently totaling 1150 track miles, and with additional main tracks being added and planned as intercity and commuter traffic continues to build. All trains operating in this corridor, including many freight trains, must be equipped with full ATC, i.e. both cab signals and speed control. There are many other corridors connected with the NEC equipped with ATC, such as: Philadelphia to Harrisburg[1] and Pittsburgh, Harrisburg to Perryville, MD, New York to Albany[1] and Schenectady, NY, Albany to Boston, MA, New Haven to Springfield, MA[1], Philadelphia to Atlantic City, NJ[1], Washington, D.C. to Richmond, VA[1]. Freight trains operate over many of these lines, and those trains are equipped with cab signals. ATC and speed control are used on many commuter lines as well.

Deployment

ACSES is currently being installed on 515 track miles of the NEC with a similar system to be installed on the contiguous commuter lines of New Jersey Transit (described in more detail on page C-36). Over 1000 miles are currently set to be installed with the expectation that the system will spread rapidly throughout the NEC and some of the connecting lines in the next 5 to 10 years.

BNSF TrainGuard™ Pilot Project

Purpose of Pilot Project

The Burlington Northern and Santa Fe Railway and WABCO Railway Electronics. are conducting a second pilot test of the TrainGuard™ system in southern California. This second pilot is being conducted over a more rigorous terrain and with substantially more

[1] Speed control must also be used on these lines

traffic to thoroughly test the systems capabilities and capacities in the mainline railroad operations.

The project expands on the successes of the prototype and will extend to roadway worker equipment, demonstrating its ability to notify a roadway worker crew of an approaching train and to notify the train that is intruding on a work gang.

Scope of Work

The pilot project will consist of eight locomotives equipped with Train Guard™ system hardware operating in full revenue service. These locomotives will constantly broadcast their locomotive ID, location and speed so that when another equipped locomotive gets within range they will be made aware of each other's presence on a color graphics display.

Two roadway worker vehicles will also be equipped and monitored to determine their visibility to the trains in the area.

This test will cover roughly 200 miles of BNSF mainline track and 100 miles of foreign trackage rights. This will demonstrate that if locomotives are commonly equipped, interoperability between railroads is automatic.

Functions of System

TrainGuard™is an overlay Positive Train Control system designed to prevent trains from intruding on other trains and work crews by alerting the engineer to potentially dangerous situations in the vicinity. The TrainGuard™ system currently uses the End of Train (EOT) radio to broadcast the locomotive's unique ID, its location, and its speed to anyone in the area. In prototype tests, the radios demonstrated a range of 3.5 to 7 miles so that anyone in the area (trains, roadway workers, etc.) will know that a train is approaching.

The main philosophy of the TrainGuard™ system is that by providing the engineer with improved location information and by keeping him alert to potential dangers such as other trains and roadway workers nearby, he will take preventive actions to avoid collisions. If he does not, the on-board computer will bring the train to a stop.

TrainGuard™ uses a combination of GPS, the train's tachometer, a gyroscope, and an on-board track database to determine its location. The initial pilot test of the TrainGuard™ system was over a relatively simple track structure having a single main track with sidings. The Southern California pilot track is significantly more complex with two main tracks and crossovers splitting off into single main line with sidings south of Los Angeles.

The track database will be maintained in a central location and distributed to the locomotives on an as needed basis. This database contains the grades, curves, mileposts, civil speed restrictions, road crossings, switch locations, etc. and is used to determine and display the train's location and its current stopping distance.

Details of the train consist will be input into the on-board system and stored on-board the locomotive. This information is used to determine stopping distance and speed restrictions.

An on-board computer does all of the calculations regarding stopping distance and enforcement. TrainGuard™ supports all of the core features of Positive Train Control as defined by the RSAC process but does not directly enforce violations of authority. TrainGuard™ does predictive calculations regarding collisions and will stop the train to avoid collision. Violations of speed restrictions are also enforced.

The pilot test being conducted in Southern California will include the development of a roadway workerTrainGuard™ device that will work in conjunction with the locomotive version. This will give roadway workers advance notice of a train's arrival into their work area and advise the engineer of roadway workers in the proximity, independent of their limits of authority.

Currently TrainGuard™ is a proprietary system but discussions are underway to facilitate the integration of TrainGuard™ into other architectures. TrainGuard™ could serve as a foundation for many other systems providing fundamental interoperability.

Passenger / freight applicability

Nothing in the design of TrainGuard™ specifically limits its applicability to passenger or freight operations. As with all PTC systems the speed of passenger trains puts a burden on the communications platform and must be accounted for in the selection.

Technical readiness

TrainGuard™ is currently in pilot testing on a second corridor. The results of the first pilot were very successful. A very similar system from GE-Harris is in daily operation on the Quebec North Shore & Labrador Railroad in Quebec, Canada.

Conrail/Norfolk Southern/CSXT Positive Train Control Pilot Project

Introduction

This section describes a communication based train control system with the objective of providing interoperability between railroads, open architecture and a standard message structure. This is a technology independent approach accommodating all present and future train control technologies.

Scope of the PTC System

The overall positive train control system could be simple, such as, manual entry of track warrants received by voice radio into an on-board computer, triggering warnings or enforcement for non-compliance or complicated, such as a completely automatic train control system involving wayside or central office based logic. The PTC system takes into account the flexibility needed to operate over the different territories seamlessly, because the three railroads have significant differences in infrastructure and the test corridor itself has four types of existing train control.

Although it would be desirable, it is clear that there will not be a unified PTC system installed among all the freight or passenger railroads in this country. The ability to run through different types of train control territory whether they are on one railroad or between railroads has become increasingly important. It is not always acceptable to stop trains and add equipped locomotives between those territories.

Pilot Objectives

The program objectives for the Conrail/NS/CSX pilot are:

- To improve safety by providing enforcement within existing systems
- To develop standard on-board platform to achieve interoperability with minimum cost.
- To provide a practical migration path from existing systems

Program Overview

The PTC pilot is planned in two phases. Phase I includes the design and prototype of the on-board PTC platform. The logical architecture for the on-board system is shown in Figure 1. Phase II consists of the wayside and office components to provide PTC system(s) for the whole territory the on-board platform has to operate over.

On-Board System

The key feature of the on-board system is a LonWorks communications bus using the LonTalk communications protocol. A standard set of messages using a standard format have been developed.

The questions that will have to be asked and answered by the on-board unit are:

> Who am I?
> Where am I?
> What do I need to proceed?
> Do I have what I need to proceed?

The answer to those questions will be given by various objects depending on the territory the locomotive is running on. Figure C-4 depicts the core process concept graphically and Table 1 outlines the core functions in detail.

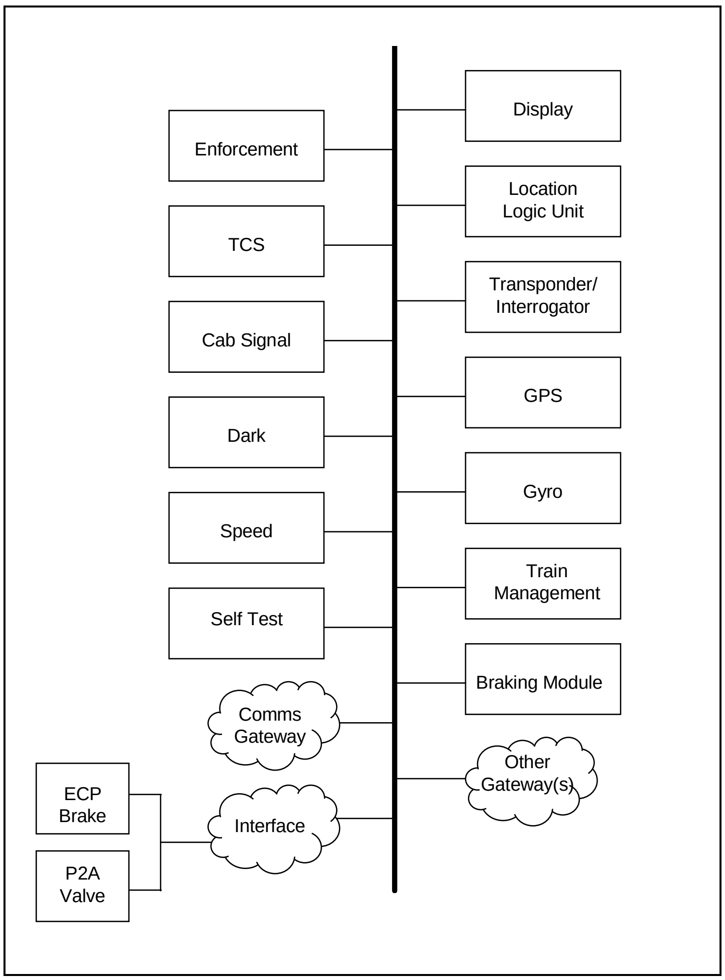


Figure C-3. Conceptual Logical Architecture

Table C-1. Core Functions

Basis for Core FunctionWork Item	Core Functions
Who am I?	d) Obtain train consist characteristics. These characteristics may be very detailed or may assume a worst case train. e) Obtain required locomotive and/or train identification. These identifications will be used when communicating with off-train systems.
Where am I?	f) Calculate the location of the train. This location may be calculated from various inputs, including absolute positioning information and relative positioning information. A train's location must account for the location of the head end and rear end of the train. g) Determine the control territory in effect at the train's location. Identify when the train has or is about to cross a control territory boundary. h) Determine the limitations on train speed for its current location.
What do I need to proceed?	i) Determine the information required to grant permission for the train to proceed. j) Identify the valid sources of this information.
Do I have what I need to proceed?	k) Determine the information available on the locomotive PTC bus. This information will include data on potential targets. l) Compare the information available to the information required. m) Determine whether the train can safely proceed with the information available.
Safe enforcement	n) Select the appropriate braking curve for the train. The braking curve may be very sophisticated or may be a simple, worst case train/grade braking curve. This selection includes reverting to more restrictive braking curves as required in the absence or decay in the quality of required information. o) Determine and monitor train speed. p) Collect all available information about potential targets.

Basis for Core FunctionWork Item	Core Functions
Safe enforcement continued	Verify that the sources of the target information are valid sources. Verify that available target information is sufficient. q) Determine the most restrictive target. Calculate the train's distance from the target. Obtain required train speed at the target. The closest target may not be the most restrictive target. r) Monitor the train's progress toward the selected targets. s) Generate proceed commands when the train is operating within its current limitations. Do not generate proceed commands when the train has, or is about to, violate either its current limitations or the required speed at the target location. Use the selected braking curve. t) Safely apply the brakes to enforce the train when there is no valid proceed instruction. u) Display enforcement status indications to the operator, including: • enforcement is active/operating; and • train is being enforced.

The objects are physically or logically connected to the communications bus as individual units, but later production models will probably consist of combining several objects assembled into one unit. The communication bus will support safety critical messages for positive train control.

The core and non-core objects and modules are shown in Figure 3, core objects are depicted by the light boxes. All other objects are non-core and may be specific to a railroad or territory.

The on-board platform is designed to meet all objectives of the PTC program. On-board hardware and software will be decoupled and individual components can be safety certified independently from the bus. This will require the bus to only be safety certified for the handling of safety-critical messages.

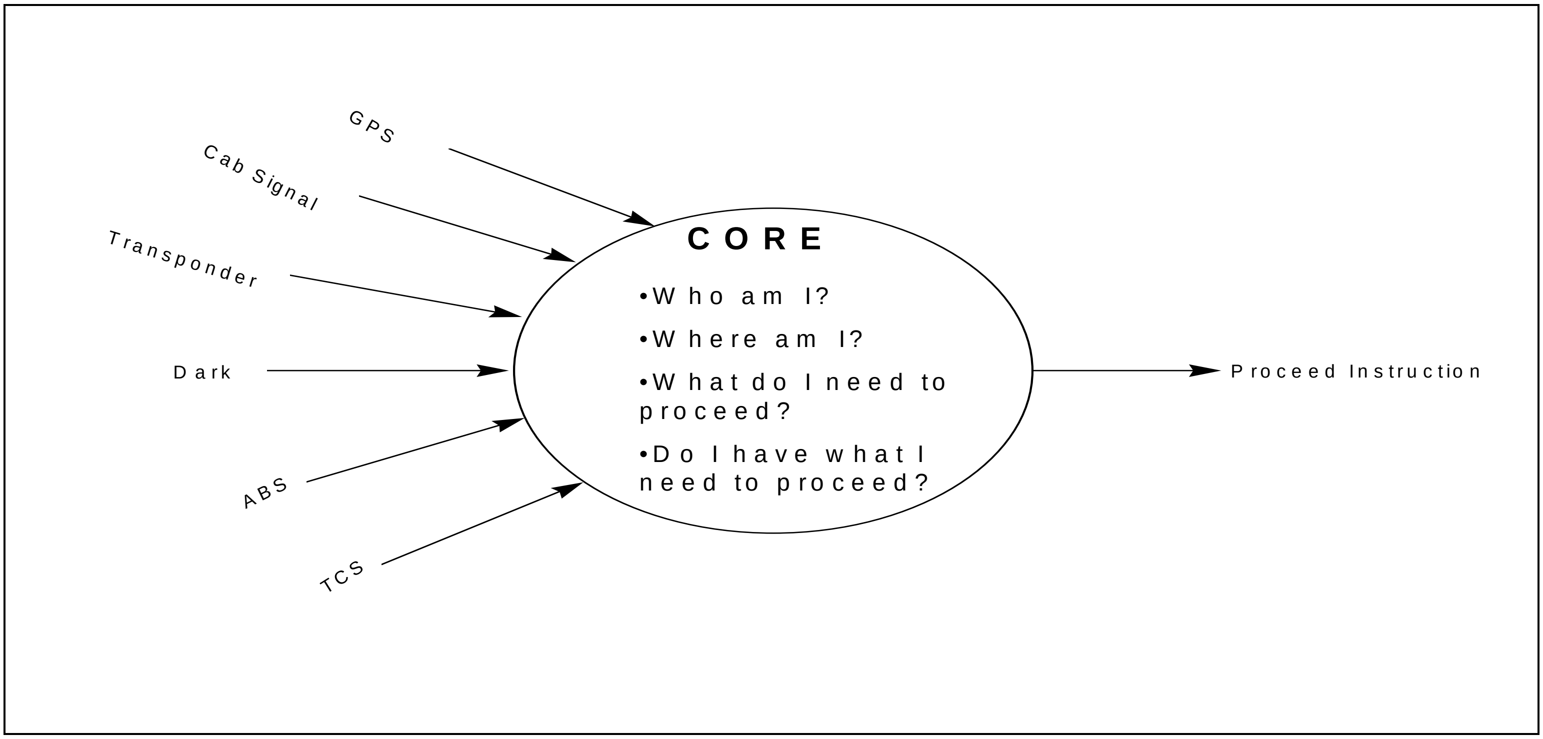


Figure C-4. Fundamental Core Processor Concept

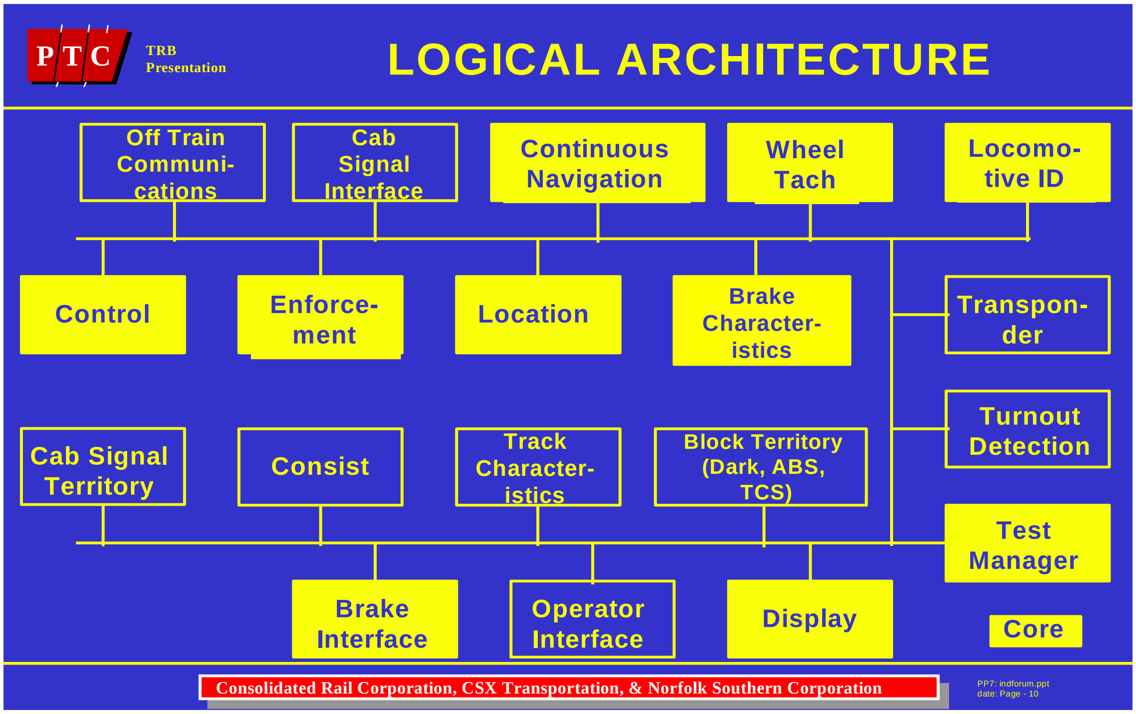


Figure C-5. Core and Non-Core Objects

The bus capacity will be designed for expansion, allowing for additional objects and the introduction of new technology without system modifications. New objects or functions would communicate with the same basic messages and message structure. After sizing the on-board unit properly the on-board system can be incrementally implemented. The on-board unit has the potential to become the standard for the rail industry and existing systems can be connected to it through interfaces as long as the standard message set is used.

Phase II Wayside Installations

Since the PTC pilot will have to accommodate four different existing train control systems it is easily conceivable that it will not be one system. The pilot attempts to take advantage of the existing infrastructure and the inherent vital logic that is already incorporated in the present systems. Migration and the economics of a train control system will dictate how rapidly one railroad may advance from a simple system of entering train orders to the final completely automatic system. The on-board platform will allow for migration and be able to accommodate various systems. In signaled territories, signal information may be received via data communications from the wayside or a transponder connected to the wayside. A central office system with a communications infrastructure can also be accommodated. Cab signal systems can be enhanced by location information, making enforcement of absolute stops possible.

Test Corridor

The PTC corridor for Conrail/NS/CSX pilot is as follows:

Program Overview Territory Description

- The Conrail Pittsburgh Line
  - 5 miles Cab Signal & TCS

- The Conrail Lurgan Branch
  - 35.5 miles TCS, 4.5 miles ABS

- The Conrail Hagerstown Secondary
  - 33.5 miles presently not signaled

- The NS Virginia Division “H” Line
  - 70 miles TCS signaling

- The NS Piedmont Division “B” Line
  - 45 miles presently not signaled

- The CSXT Spartanburg Subdivision
  - 90 miles presently not signaled

- The CSXT McCormick Subdivision
  - 30 miles presently not signaled

Summary

The Conrail, Norfolk Southern and CSX Transportation pilot represents a comprehensive PTS/PTC project that can be applied to passenger as well as freight lines, part of the test corridor from Harrisburg to CP Rockville has passenger traffic.

The project is currently in the on-board unit prototype phase. Two prototypes are being contracted for in 1999. Work on an active PTC will be developed and tested in 2000.

In that there are no current PTC/PTS Systems in revenue service among Class I railroads in the US, technical readiness can only be assumed and the pilot is designed to evaluate for the feasibility of deployment of a communications based system and a migration path that is economically achievable.

Industry/FRA/IDOT PTC Project

The Association of American Railroads (AAR), the Federal Railroad Administration (FRA), and the Illinois Department of Transportation (IDOT) have entered upon a joint program to design, build, test, and install a Positive Train Control (PTC) system on a 123 mile section of the Union Pacific Railroad from Springfield to Mazonia, Illinois. The Program will develop and recommend a set of PTC interoperability standards for industry adoption and long term maintenance, and will demonstrate application of these standards in the IDOT pilot installation.

The Program participants have agreed that the AAR's subsidiary, the Transportation Technology Center, Inc. (TTCI) will serve as prime contractor for the effort. TTCI has responsibility for overall program design, management, and administration. A Management Committee made up of railroad representatives and financial sponsors (AAR, FRA and IDOT) reviews technical and contractual decisions. Final responsibility for Program funding rests with a "Stakeholders" Committee comprised of senior representatives of the financial sponsors.

The Joint Program PTC standards and the pilot implementation in Illinois will meet overall safety objectives derived from a consensus labor-management-vendor-government discussion process sponsored by FRA and lasting over many months. This activity is called the Railroad Safety Advisory Committee (RSAC) PTC Working Group.

PTC Joint Program Design and Management Requirements

In addition to developing PTC standards and a service-ready demonstration system that will both comply with the industry standards and meet the RSAC safety objectives, the PTC Joint Program has agreed on several other project requirements:

1. The Program's PTC design will incorporate flexible block operations and advance activation of highway grade crossing devices, in a corridor with both freight and high speed passenger service (up to 125 mph).

2. A major program goal is to achieve interoperability of PTC systems from different manufacturers, installed in different types of locomotives, and operating over different kinds of signal control territory. The program will demonstrate safe operation of locomotives equipped with interoperable systems. The objective is to enable equipped trains operating from different railroads to come onto a foreign railroad at track speed. The demonstration will consider:

   - Locomotive human-machine interfaces with a minimum set of standard features, to provide the necessary and expected information for safe operation.

- Compatible communications interface(s) to/from and on board the locomotive.
- Minimum acceptable content and format of data bases used for location determination and braking enforcement.
- Minimum common set of messages between defined devices and objects (functions) on board the locomotive/track vehicles and off board controllers.

3. An overriding program goal is to provide a cost-effective design and to support logical market-based migration strategies. The system should be modular and flexible enough to enable railroads with varying levels and types of current infrastructure to develop incremental deployment plans consistent with their system safety improvement plans.

    - The National Transportation Safety Board (NTSB) has called for nationwide PTC deployment and FRA has considered using its regulatory powers to mandate PTC installations in what it considers higher risk corridors. The railroads strongly believe that, since PTC has not been shown to be cost-effective on safety benefits alone, the modular, infrastructure-specific approach -- taken within the context of overall capital and safety improvement plans -- is a superior policy.
    - The railroads argue that without interoperable standards, cost-effective systems are impossible; without cost-effective systems, wide scale deployment is unlikely; and without wide scale deployment, few safety benefits will be realized.

The IDOT PTC Joint Program will implement these overall objectives and design requirements through contracts with system engineering companies. Contracts with the systems engineering firms will spell out detailed tasks and work-breakout structures. Examples of scope of work items included in the engineering contracts follow:

1. Develop a set of recommended industry standards to enable interoperation among companies and territory types – recognizing that not every extant signal system or territory type can be accommodated at reasonable cost.

2. Develop, test and evaluate a PTC system, initially on the Union Pacific's Springfield subdivision from Springfield to Mazonia, to meet the program objectives.

3. Establish and document procedures to be used for the validation (did I build the right thing) and verification (did I build the thing right) of the safety

system hardware and software, and complete the verification and validation process for this program.

4. Provide for field and simulation testing of systems for performance to PTC specifications and interoperability standards.

The PTC Joint Program is being conducted under the following overall terms and conditions:

1. The Transportation Technology Center Inc. (TTCI, a subsidiary of the AAR) will administer the PTC Program.

2. Standards and architecture developed and adopted will be open and non-proprietary.

3. Major Program procurements will be competitive.

4. Specifications will be driven by functional and performance requirements, not specific products or technologies.

5. PTC software developed or procured through PTC Program contracts will be made available for the improvement of railroad safety and operating efficiency to the greatest extent reasonable.

6. The program may be expanded beyond its original scope by mutual agreement of the parties.

Funding, Period of Performance, and Deliverables

Funding for this program will come from the FRA, IDOT and the AAR. In kind services, including locomotives, will be provided by the individual railroads. The Program is budgeted at $60,000,000, of which the railroad industry will provide $20,000,000. The effort is expected to take four years, and the current project completion date is December 31, 2002. The major deliverables at that time are the interoperability standards, an operational prototype PTC system, and detailed performance data resulting from the demonstrations, tests and projects.

Systems Requirements and Functional Architectures

The PTC Program has selected a System Engineer team headed by ARINC of Annapolis, Maryland. The System Engineer will assist the PTC Program staff and Management Committee in defining system requirements and developing the functional architectures (designs) that form the foundation for the remainder of the program. In particular, this work item will:

- Set the tone of the PTC project's relationship with the supplier and railroad community through key industry meetings and forums;

- Establish the level of supplier participation in and support for the PTC program through the degree to which proffered requirements documents and system architectures are fairly and impartially considered;

- Continue to build and document a consensus among the program sponsors (IDOT, FRA, individual railroads, and TTCI) on the requirements for PTC (in general) and for testing and demonstration on the Springfield subdivision (in particular); and

- Define PTC system architectures and interoperability standards that provide sufficient standardization while encouraging supplier innovation and supporting railroad-unique operations.

Interoperability Standards

One of the major objectives of this joint PTC program is to demonstrate safe operation of locomotives equipped with interoperable systems. Interoperability is currently defined as safely interlining at track speed. This definition implies more detailed requirements to achieve interoperability:

- Standard, interoperable communications both to and from the locomotive;

- Consistent format and content of databases (both on-board or off-board);

- Standard messages between PTC devices, including standard content and format;

- Defined expected responses to standard messages;

- Minimum consistency of man-machine interfaces with recommended operating rules changes and training procedures;

- Achieve safety objectives and cost effective performance requirements.

The System Engineer will develop interoperability standards through a process of workshop discussions and by reviewing current and proffered standards and specifications as well as applicable new technologies. The System Engineer will then draft proposed standards, which the PTC Program will sponsor through the AAR's standards-setting committee structure. The Systems Engineer will also be responsible for configuration management of the interoperability standards for the duration of the project.

The PTC System Development and Demonstration for IDOT

The PTC Program Office, with assistance of the System Engineer, will issue a Request for Proposals (RFP) for selection of a System Developer/Integrator (SDI) in early 2000. The SDI will have responsibility for designing, fielding, testing, and documenting a PTC system that complies with draft AAR industry standards and meets the other performance objectives of the Program. The PTC demonstration test bed is a single track line with sidings between Springfield and Mazonia, Illinois, owned by Union Pacific Railroad and used for mixed freight service. The line also hosts passenger trains sponsored by IDOT and operated by Amtrak. The test segment is 123 miles long, is equipped with CTC, and has about one highway grade (level) crossing per mile.

The Springfield line is part of a proposed high speed passenger corridor sponsored by the IDOT and officially designated by the FRA under provisions of Section 1010 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Historically, this trackage was owned in turn by the Chicago and Alton; the Gulf, Mobile and Northern; the Gulf, Mobile and Ohio; the Illinois Central Gulf; the Chicago, Missouri and Western; and Southern Pacific. Upon completion of the UP-SP merger in October 1996, the line became the Springfield Subdivision of the Union Pacific. The line has been part of the premier passenger route between Chicago and St. Louis since the days of the Chicago and Alton.

IDOT proposes to reduce rail passenger travel time between the Chicago and St. Louis from the current 5 ½ hours to 3 ½ hours, and in this context wants the train control system developed by the Joint PTC Program to be revenue service-ready, not a demonstration-only installation. Since proposed passenger train speeds will reach 110 mph or more, IDOT requires the PTC on-board computer display equipment to meet the FRA requirement for in-cab signals at those speeds. Grade crossings will have to be closed or physical barriers placed in many locations over the route. Protected crossings must be given an advance start for faster trains in order to provide a constant warning time to motor vehicular traffic.

Reasons for Addressing Capacity Issues in the IDOT Design

While traffic congestion is not a problem on the Springfield-Mazonia line, freight railroads are concerned about potentially being asked to host higher speed passenger service on other freight corridors that may be operating near capacity already. Higher speed passenger service on well-used freight lines requires significant track capacity, due primarily to differential speeds for the two kinds of service. Differential speeds mean that opposing track (in double track territory) or sidings (in single track territory) must be used for faster trains overtaking slower ones. The effect on throughput capacity is analogous to that of mixing automobiles and heavy trucks on a busy two or four lane highway through undulating countryside, especially when one truck passes another on a long uphill grade!

In mixed passenger and freight territory, passenger trains typically have dispatch priority, which means greater likelihood of delaying freight trains, especially as line traffic density increases. Track configuration (e.g., single vs. double track), additional sidings (siding spacing instead of additional sidings), type of signaling, and operating policies such as the differential in train speed are key factors in determining line segment capacity.

In general, the problem of capacity losses for freight operations due to passenger traffic is because the freight train has fewer operating channels (slots) to use in getting over the road, which implies more stopping and starting – hence poorer fuel economy and greater probability of delays.

Implications for Capacity of Train Control Systems Design

There are significant implications for throughput capacity in design and implementation of train control systems. Just as more capable signaling systems were installed in the past primarily to increase capacity while maintaining safe operations, so would cost-effective, safety-enhancing train control be more likely to be deployed if it is shown that expected capacity improvements truly can be realized.

With respect to train control features, it is likely that well-designed moving (or *dynamic*, or *flexible*) block architectures will have greater ability to increase capacity than fixed block systems. Moving block architectures are particularly applicable in circumstances of: 1) dense traffic, where closer headways reduce the time interval needed for safe physical train separation, 2) differential freight and passenger train speeds, and 3) recovery from service interruptions or maintenance curfews, when fleeting or other special operations may be used.

Capacity analysis is a controversial area in railroad research because of the difficulties of allocating common costs and establishing the cause and effect relationships between capacity or throughput increases and specific capital or operating improvements. Operations simulation is probably the most useful analytical technique for estimating capacity related consequences of major changes in plant, equipment, or operating practices on a specific line segment or network. For a specific application such as the Illinois 1010 corridor, operations simulation may be capable of establishing the capacity impact of such issues as: 1) operating freight and passenger trains at substantially different speeds, 2) the value of a dynamic block train control design, and 3) the contribution of specific physical improvements in conjunction with PTC.

System Test Requirements And Performance Measures

The System Engineer will design and deploy the testing methodologies and systems necessary to prove that the PTC system implementation on the Springfield subdivision has met all its design objectives. This includes developing tests for evaluating the compliance of “foreign” locomotives, developing both operational and technical performance measures for the overall system and subsystems, reviewing SDI specifications for compliance with system design requirements, and development of a concept of operations to guide the planning of laboratory and field testing. Moreover, a battery of tests will be developed to demonstrate that the PTC system is developed according to the interoperability standards and that it meets the requirements for the efficient operation of high-speed passenger trains operating over routes and facilities also used by freight trains. These tests will be designed to evaluate system safety-related and other functions, system reliability and maintainability, and degraded operation under failure conditions. In this effort the System Engineer will work with the SDI to:

- Oversee all acceptance tests to ensure compliance with prescribed test plans.
- Configuration manage changes in test plans that may be needed.
- Maintain a log of all acceptance tests and reporting on their results to the Program Office.
- Identify the cause(s) of failed tests and research possible solutions. In situations where minor software or specification changes are required, document the changes and create/update the test plans. In cases where the proposed solution is in conflict with the Joint PTC Program requirements or the industry standards, the System Engineer will document the issue, develop recommendations for changes, and progress the issue to the PTC Program Office for resolution. Once the proper authority has authorized a change, update all affected documentation and create/update test procedures as required.

Lastly, a proposed test plan for the evaluation of the Joint PTC Program equipped locomotives on other PTC territories will be developed.

PTC Simulation Tools

The PTC Program and the industry will need simulation tools beyond those used by the Systems Developer/Integrator, and beyond the duration of the PTC demonstration, to test systems performance under a variety of situations. The PTC Simulation Tools project involves designing and developing a PTC system simulation tester or suite of testers that might included the capability to:

- Test proposed changes to the PTC interoperability standard.

- Assess conformance of suppliers' equipment to the interoperability standard.
- Assess the effects of suppliers' equipment on systems performance.
- Evaluate the work load on the locomotive engineer.
- Assess the total system performance in "stress" or "unsafe" conditions that can not be safely tested in the field.
- Assess the impact of non-PTC systems along the wayside on PTC performance.
- Assess the impact of PTC on systems safety (e.g. risk management toolset).

The PTC Systems Engineer will develop a statement-of-work for this project as part of its support to the PTC Program Office.

Methods for Safety Verification and Validation

The implementation of PTC systems has major implications for the railroad industry safety. PTC component technologies rely on hardware, software, and hardware–software interactions to perform safety critical functions and ensure overall safe train operation. Because of the safety critical nature of the functions performed by these systems and the complexity of the technologies used, it is necessary to implement a logical and structured process to ensure and demonstrate that these systems are designed and implemented in a safe manner. The PTC Program will develop or adopt IEEE standards for a comprehensive safety assurance program -- including a safety verification and validation (V&V) methodology that is highly integrated into and coordinated with the system, hardware, and software development processes.

This part of the PTC Program Plan will review current applicable standards and recommend V&V requirements for PTC systems. Additionally, this work item will contract for the development of a risk management tool set that provides a safety performance measure for the PTC system in the environment in which it operates. The intent of this activity is to provide an overall quantitative indication of safety performance over a system's life cycle in terms of train collisions, train accidents, and injuries. To date, little operational experience exists for these new PTC technologies, and consequently the level of safety or risk associated with implementing these systems cannot be explicitly determined from historical performance. A predictive risk measurement tool set will be used to forecast PTC system safety performance in the absence of complete historical operating data.

Conclusion

The North American PTC Joint Program is an ambitious and technically challenging endeavor. It will require commitment, compromise, and consensus involving many parties with different specific interests. Our vision is that these challenges will be met with standards and designs ready for safety enhancing, industry interoperable, and cost-effective deployment. These, in turn, will help support an even broader vision of improved future railroad safety, productivity and financial performance – all based on development of superior technologies.

Norfolk Southern Location System (NSLS) Project

Introduction

The Norfolk Southern Location System (NSLS) was begun in response to a review of the railroad's history of train accidents. The system utilizes modified End of Train (EOT) equipment to permit location information to be transmitted between lead locomotives of trains. Distance between trains and calculated stopping distances are compared by each train and a decision is made if enforcement is necessary to prevent a train (or roadway worker vehicle) collision.

History, Scope, and Objective of the Project

A study was undertaken to determine if there was a cost effective way of preventing collisions. Data from collisions, near collisions, signal compliance failures, close calls, etc. were studied to identify factors common to all that, if mitigated, would have prevented the incidents. The study revealed that in most cases crew members of the trains that collided (or almost collided) were not aware of the nearness of other train(s). On this basis, it was decided to investigate development of a system that would inform train crew members automatically of other trains in their vicinity. A goal is to develop a system with minimum annoyance to the crew members.

System Design

The NSLS design utilizes radio frequency identification tags (RF ID) technology embedded in the track as a database for speed information and double track identification. Transponders located at each roadway signal contain data that includes the location of that signal and the locations of the next two signals in advance. When a train passes a transponder, its data, along with the train's identification, is broadcast on the EOT VHF frequency to other trains in the vicinity. When two trains' location reports contain the location of the second signal in advance, a safe braking distance (SBD) has been calculated. Reception of the presence of another train requires acknowledgment to prevent initiation of an automatic brake application. Determination of a SBD results in the initiation of an automatic brake application.

Pilot Project

The first pass test of these ideas occurred in January 1997 using the existing Norfolk Southern End of Train equipment. The use of End of Train equipment allows for a migration path providing the most knowledge of non-equipped trains. This would be an improvement in the current situation. This first test was to determine if the EOT system would provide enough warning to allow the engineer to understand the situation and take some reasonable action (like communicating with another train) without taking away from his train handling or other duties. This test used real world trains over a mountain territory to determine if sufficient time/distance warning could be provided by VHF radio systems. This test showed a VHF signal could be propagated over normal territory for at least 7 miles. The test also showed a non-trivial acknowledge is a reasonable interruption of the engineers' time, provided it comes when needed and does not happen very often. One interruption per train meet appeared to be acceptable, it was a seldom annoyance providing useful information.

The testing has continued with development and testing of location determination techniques (GPS based), stopping distance calculations, and crew interface. We have improved the throughput of the communications devices and have begun to work on improving the stopping distance calculation. With the start of the FRA-sponsored, RSAC PTC Working Group to address similar problems on other railroads we have also undertaken an effort to evaluate ways of efficiently enforcing civil speed restrictions. The current testing involves RFID tags embedded in the track to act as the database for speed, grade, and double track identification. As a locomotive passes over the tags in track, the tags are read and current location and information of pending events in the route are decoded. This will allow enforcement of civil engineering restrictions, a better prediction of stopping distances (less restrictive), and reduction of required actions (operator acknowledgment) for trains on non-conflicting tracks. The ultimate system we envision would also have a dispatcher data channel for temporary restrictions, the goal is to make the data flow small to fit in the communication paths currently available. The current test system displays future restrictions to the engineer with no acknowledgment required. The system will only take action to stop the train if the calculated stopping distance is not sufficient to avoid an over speed condition. The use of on-track RFID tags allows upgraded operation over certain tracks without an on-train database. This enables operation of light density track as is, without the expense, if not needed. The system is currently being developed; testing should begin in 1999**.**

Summary

The project is continuing with development and testing of location determination techniques (GPS based), stopping distance calculations, and crew interface. Means are being considered to provide protection for roadway worker employees. In addition, evaluations are being made of ways to efficiently enforce civil speed restrictions. Consideration has been given for including signal compliance but presently, that and work authorities are not being pursued. The current course of thought is to protect trains from each other and roadway workers. Signal compliance and roadway workers outside of authority limits will be handled separately. Rule compliance is not part of this project and will continue to be handled by current practices.

Technical Readiness

The availability of NSLS has not yet been determined.

Alaska Railroad CAD and PTC

Introduction

Alaska Railroad (ARRC) is in the early stages of a four-phase project to upgrade its safety and productivity through the installation of a modern train control system. The phases are defined as follows:

- Phase 1: Installation of a computer aided dispatch (CAD) system
- Phase 2: Installation/upgrade of the communications network (voice and data)
- Phase 3: Installation of PTS functions (Working with the CAD)
- Phase 4: Upgrade of the PTS/CAD functions to PTC

Phase 1 is underway with GE Harris providing the CAD system which is to be tested in early 1999. Implementation of the CAD system is scheduled for completion in May 1999. Phase 2 was completed by the ARRC in November 1998. Phase 3 is funded and under development with testing expected to begin in the fall of 1999.

System Description

Phase 1: CAD

GE Harris has provided a CAD system configured for one controlling workstation and several view-only workstations. Additional workstations may be added that can separately control districts or sub districts as small as a single station.

A central server will provide validation and central storage for the system. A second server will be configured as a hot standby to provide high reliability back up for the central computer. A communications server allows remote access to the system by authorized users.

The CAD will provide full track warrant control with compatibility to accommodate PTS and PTC evolutions in Phase 3 and 4.

Phase 2: Communication

A new communications network has been installed to provide robust coverage of both voice and data to support PTC. The network consists of fiber optic cable buried on the right-of-way between Seward and Anchorage and microwave between Anchorage and Fairbanks. Base stations have been located to provide maximum coverage of the railroad except for a branch line north of Fairbanks.

Phase 3: PTS

ARRC operates its entire network under track warrant control. It is an ideal application for the new generation of communication based train control systems. Phase 3 plans are to install PTS functionality across the network with an absolute minimum of wayside hardware. On-board locomotive hardware and central office hardware that interfaces the CAD to the on board hardware through the communication system will be implemented in this phase. This hardware will support both the PTS functions in this phase and the Phase 4 PTC operation. A diagram is shown in Figure C-6.

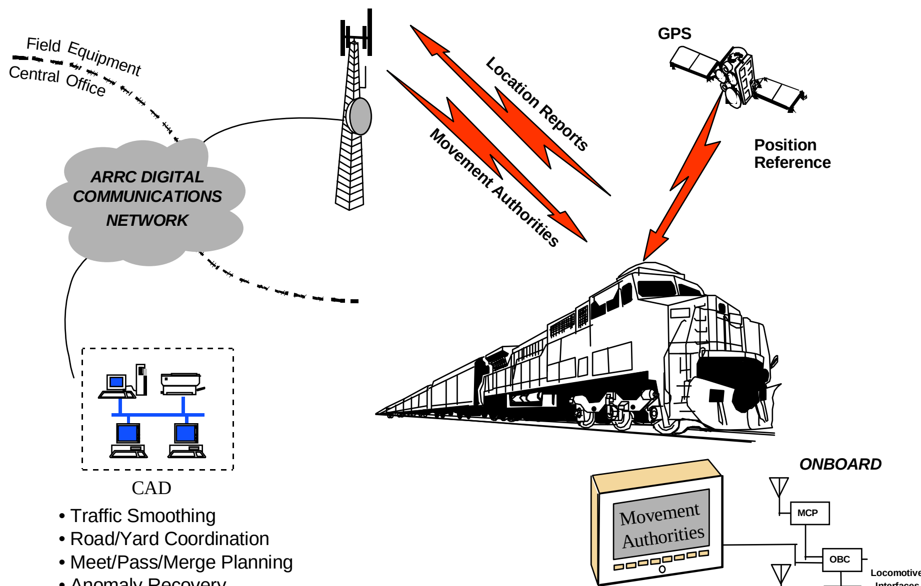


Figure 2.3

PTC System Block Diagram

Figure C-6. PTC System Block Diagram

Phase 4: PTC

In Phase 4 ARRC will upgrade the system to take advantage of the traffic planning and control benefits provided by PTC. The optimizing traffic planner software will be installed on the CAD system to permit ARRC to develop efficient, realizable movement plans for all their trains. Real time control of the trains as they progress through the network is provided. In addition the PTS protection features for roadway worker employees and vehicles will be added. This provides a terminal in each of the vehicles that are connected to the train control communication network. PTC will enforce trains and roadway worker vehicles in maintenance areas designated for slow or stop orders.

Application to Both Freight and Passenger Lines

The ARRC PTC system is configured to serve the railroad's mix of passenger and freight operations. Traffic levels vary considerably depending upon the seasons. During the Alaskan winter months the levels drop to a minimum of 5-8 trains per day. Traffic levels peak in the summer months for both passenger and freight service ranging up to 22 trains per day. Since all territory is track warrant control, the PTC system must provide protection for the entire range of levels and mixes.

Technical Readiness

The technical approach and system architecture chosen for the ARRC PTC has been proven in the BNSF/UP PTS project in the Pacific Northwest. The ARRC PTC project is scheduled in phases dependent on funding becoming available. If fully funded, Phase 4 could be implemented in 18 months.

CSXT Communications Based Train Management Project

CSXT's Communication Based Train Management (CBTM) program is developing a safety enhancement overlay system for providing enforcement of train movement based upon movement authority. Initially, CBTM is being designed for fixed block, non-signaled territory referred to as Direct Train Control (DTC). CBTM, as originally conceived, will provide for the three core objectives of PTS/PTC systems as defined by the RSAC-PTC Working Group.

Functions

CBTM will be an overlay system that operates in the background to current operating procedures. All of the current procedures, including the dispatcher's process of determining authority, the voice transmission of the authority to the crew, and the acknowledgment of the authority by the crew back to the dispatcher, will remain unchanged. For CBTM to function, a parallel data communication system with associated office and on-board hardware will be installed to handle the "enforcement parameters" that will be aligned with the restrictions of the authority. These parameters are referred to as targets and include speed restrictions, end points of the authority, alignment of switches, and other criteria that may be deemed appropriate for CBTM enforcement.

The generation of targets takes place in several ways. First, each time the dispatcher generates or revises a movement authority using the CAD system, a message is sent to the CBTM platform to translate the authority's requirements into specific points against which the train will be monitored for speed and distance. For example, an authority to occupy specific blocks, or a temporary speed restriction, is handled by CBTM generating the locations as targets for which the on-board CBTM hardware will provide enforcement. A second method of generating targets is the issuance of Form W's which provide for work gang protection under CSXT's operating rule 707. The MOW targets will be obtained from the CAD system and added to the targets generated by the issuance of movement authorities. Other targets may be dynamic if CBTM is developed to monitor the status of certain fixed locations as the track is traversed, e.g., alignment of switches.

Not all movement authorities will be obtained from the dispatcher. In the case of roadway workers, the train crew must obtain authority from the employee in charge (EIC) of the work gang before entering a work zone that is in effect. CBTM will prompt the crew within a specified distance of the work zone to determine whether they have obtained authority to enter the work zone. CBTM will also challenge the crew as to the ability of the train to make it through a forthcoming work zone if CBTM calculates marginal capability based upon speed, distance, and the starting time of the work zone.

Overall, with a CBTM operation, the train crew retains responsibility for the operation of the train with CBTM initiating a penalty brake application when it predicts the train will exceed its limits of authority or speed restriction. In addition, CBTM will provide reactive enforcement when the train exceeds the current speed limit.

It is anticipated that the design of CBTM will support the expansion of its application to signaled territory.

Architecture

CBTM consists of three primary levels: mobile, zone, and office as shown in Figure 1 System Architecture:

- The office controller provides the interface with the CAD and MIS system to primarily obtain the results of dispatcher activities, Form W schedules, consist information, and permanent speed restrictions. There is no enforcement analysis made at this level.

- The zone controller provides oversight for a particular segment of the railroad, e.g., sub-division, and accepts the data from the office controller. The zone controller also maintains the track database for its segments that is used to develop the targets for each train under its supervision based upon the information received from the office controller. As CBTM expands in functionality, it is possible that the zone controller will become the first level for train management, e.g., meet/pass planning. Again, as with the office controller, there is no enforcement analysis done at the zone level.

- The mobile platform is responsible for determining train location and analyzing the need for enforcement based upon its generation of targets. Location will be performed through the use of GPS, tachometer, and monitoring the routing through switches. There will no be on-board track database, per se. Instead, the train will be provided sufficient detail from the zone controller for the train to determine enforcement requirements.

In addition to the above platforms, a wireless data communication network will be installed which will support mobile to zone controller, mobile to wayside, and wayside to zone controller requirements that have yet to be completely determined. One key aspect of CBTM will be the monitoring of switch alignment so as to provide for "which track the train is on" analysis as well as to provide an additional level of safety of assuring the proper alignment of selected manual switches.

Application to both Freight and Passenger Lines

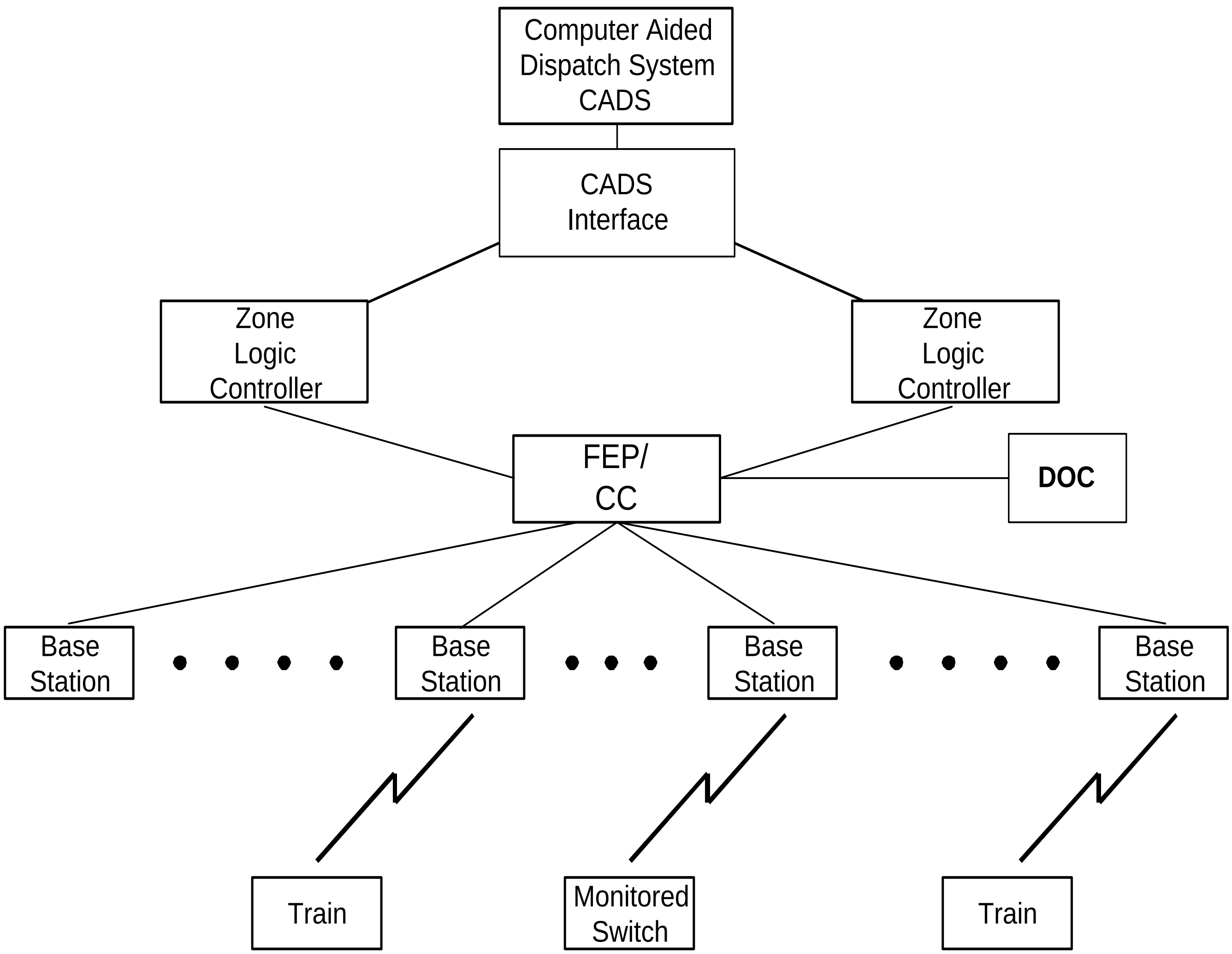
CBTM is applicable to any equipped train, whether passenger or freight. The only difference is defining the braking characteristics of the train so as to adjust the braking curves for enforcement targets appropriately to ensure that the distance and speed targets are not exceeded.

Technical Readiness

CBTM has been designed only for non-signaled territory at this time. The pilot demonstration for the initial design is scheduled to be complete in the first quarter of 1999. A chief constraint as to deployment in dark territory across CSXT's system will be the selection of the communication link technology. Currently, CBTM is using available VHF channels for data. However, this alternative may not necessarily be available as a system-wide solution. Additionally, if CSXT elects to expand the capability of CBTM to address signaled territory, then a uniform on-board platform will need to be designed so the locomotive fleet can be properly equipped for universal coverage.

Figure C-7.

System Architecture



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New Jersey Transit's PTC Project

Overview

On February 9, 1996, NJ Transit (NJT) experienced a near-head-on collision between two scheduled passenger trains, resulting in three fatalities at a busy interlocking in Secaucus, NJ. To prevent similar accidents and improve safety, a decision was reached to equip all lines with automatic enforcement systems to supplement the existing wayside signaling systems. NJ Transit's project is organized in two phases. The short-term phase equips all of NJT's territory with some form of enforcement system. The long-term phase ends with all of NJT's territory equipped with a system that meets the core feature safety functions of Positive Train Control (PTC), as defined by the FRA-sponsored RSAC PTC Working Group.

The project adds Automatic Train Control (ATC) and Positive Train Stop (PTS) to existing or improved wayside signal systems. By integrating these two complementary systems into what is known as the Advanced Speed Enforcement System (ASES), the safety goals are accomplished by enforcing temporary and permanent speed limits, signal indications, and positive stops at Stop or Stop and Proceed signals.

NJT operates about 310 scheduled trains daily over portions of Amtrak's Northeast Corridor (NEC) where FRA requires ATC equipment. NJT's entire fleet of locomotives, cab cars, and multiple-unit passenger cars is equipped with this system to allow them to be used on any territory over which they might operate. The wayside portion of this system transmits a continuously coded 100 Hz. high-level carrier current through the rails to an approaching train. The discrete rates at which the carrier current is coded correspond with the wayside signal aspects so that the information transmitted to the train can be used to repeat the signals in the cab of the train. The on-board equipment decodes the cab signal rates received by inductive pickup from the rails. It provides 4-aspect cab signals, or 9-aspects on a future system to be installed on the NEC with a 100/250 Hz. carrier signal. The cab signals instantly reflect any changes in conditions governing the safe movement of the train. The system requires the train engineer to acknowledge any signal downgrade, and enforces an associated speed limit for each cab signal aspect providing automatic speed control. A change to a restricting cab signal (code-change) is provided before the train reaches a wayside stop signal.

The PTS system provides digital data to trains intermittently only as they pass over transponders along the tracks. Fixed transponders located at each wayside signal are encoded with the permanent features of the railroad such as milepost location, speed limits, and grades. They are also interfaced with the circuits that control interlocking and automatic signal aspects and dynamically adjust their message to transmit the signal aspect. Responding to a 27.115 MHz magnetic down link from the passing train, each transponder will communicate 180 useful bits of information at 50 Kb/s to the train on a 4.5 MHz up link. The fixed transponders are logically linked so that at any point, the system knows the expected location of at least the next transponder. Portable transponders will be used to enforce temporary slow orders and work zones. They will be located braking distance away from the restricted zone, much as the approach and approach speed limit signs are used today. Obtaining the physical as well as dynamic features of the railroad will allow the onboard computer to enforce a target speed limit or stopping point with a precision braking profile without the need to maintain an on-board database.

On-board space constraints require a fully integrated ATC/PTS system reusing existing wiring and giving full 9-aspect cab signaling. Therefore, the on-board ASES computer integrates PTS target speed and positive stop enforcement features with the ATC system and conveys the information continuously to the locomotive engineer on a readily interpreted graphical display. It operates in conjunction with, and enhances the capabilities of existing and future ATC systems, and is functionally compatible with the Advanced Civil Speed Enforcement System (ACSES) and 9-aspect high-density ATC being installed on the NEC high-speed lines. This will preserve the interoperability necessary for the NJT fleet to operate fully on the NEC. Other railroads operating over NJT PTS-equipped lines will be required to have their trains equipped with PTS, unless FRA waiver precludes this requirement.

Short-Term Project Phase Description

Using in-house forces, NJT is adding the wayside equipment and circuitry to provide 4-aspect ATC on an additional 252 track miles in 152 route miles of existing signaled territory. ATC coverage will increase to about 83% of its property.

Design and installation of the ATC portion of the project is by in-house forces, at a cost of $23 million. As of May 1, 1999, four Metro-North cab cars and 197 track miles of wayside equipment have been placed in service, with completion expected late in 1999.

In December of 1997, US&S was awarded a contract to design and furnish the complete ASES, including a demonstration on 5 types of motive power and control cars. The ASES will be installed on 109 locomotives and cab cars and the intermittent PTS equipment will be added to 46 track miles where existing wayside signal systems will not be immediately equipped with ATC. The contractor will perform on-board installation; wayside installation is in-house. The portion of the contract awarded is $16.6 million. The schedule called for a functional demonstration in June of 1998, but integration issues delayed the project and final prototype demonstration occurred in March and April of 1999. Current projections have the functional system in service by December of 1999.

Long-Term Project Phase Description

The five-year project calls for installation of the complete ASES throughout NJT's Commuter Rail System.

Included with the installation of ATC on the remaining portion of NJT’s property is bi-directional signaling where only Automatic Block Signaling exists today, microprocessor-based grade crossing predictors for highway crossing control, and vital processor interlockings. In-house forces will perform this installation.

The ASES contract includes the options to equip NJT’s remaining fleet of 244 locomotives, MUs, and cab cars, as well as the design and furnishing of the wayside portion of the system on 423 track miles in 264 route miles. It will be overlaid on existing electrified and diesel-only territory that is already equipped with the 100-Hz 4-aspect ATC. This would bring the total contract to $43 million (not including force account installation).

To have a functioning system on NJT property in the shortest time, the best results are obtained by integrating both systems.

Appendix C

Overview of Current/Completed Positive Train Control Initiatives - Status as of January 1999

Initiative	Description	Status
BNSF/UP PTS Pilot in the Pacific Northwest	Overlay to existing train control systems in all types of territory. Central dispatch provides movement authority to train, train reports location. Location systems uses differential GPS, odometer and rate gyro. On-board enforcement. RF link is both 160 and 900 Mhz. On-board enforcement of authorities. GE-Harris was systems integrator. Interoperability is key. BNSF and UP established data link through their respective dispatch centers.	Pilot is complete. There were four software releases. Costs about $36 million with $15 million each from the railroads and $6 million from GE-Harris. Testing was completed in July 1998. No Federal or State funding.
Michigan DOT/Amtrak/Harmon	Incremental train control system (ITCS) an overlay on existing signal system, has future dark territory capability, not interoperable at present, can be made interoperable through concepts being developed in CSX/CR/NS pilot, wayside authority generator sends movement authorities to train via 900 Mhz data link. Differential GPS based on-board location system. On-board enforcement	FRA grant to Michigan for $9 million. $5 million in private funds. Have completed test runs and are finishing validation of "vital" software. Will equip 25 locomotives, and 10 wayside servers along 70 miles of track in Michigan on Amtrak's Detroit - Chicago line by mid 1999. Cut over will begin in July 1999 and revenue service is scheduled for early 2000.
Enhanced Proximity Warning System.	A new approach to "PTS" that relies on broadcasting of train positions on the EOT radio at 450 MHz. The receiving locomotive engineer is alerted to the presence of the other train(s). Each locomotive has a track database, which will filter the information to determine if a potential conflict exists. Includes on-board enforcement if engineer does not respond to alert. Uses GPS, odometer and rate gyro for location system.	BNSF has tested three locomotives in Topeka area, and equipped 10 locomotives in the LA basin for further testing. Similar system installed on QNS&L in Quebec as a part of agreement between Canadian Government and railroad to allow the railroad to use one person crew.
NS/CSX/Conrail pilot in Maryland, Pennsylvania and Virginia Harrisburg to Manassas Junction	A pilot providing interoperability by establishing an on-board platform capable of accommodating present and future technologies. Systems will build on existing infrastructure.	Contract let to Rockwell in mid 1997 for the design work on the on-board unit . $1.5 million Federal grant money in 97 & 98. $400,000 and in kind services from participating freight railroads. Two phases – phase I on board platform design January 1998, two on-board prototypes in early 1999, phase II wayside systems specifications January 1999, production system June 1999 over entire pilot territory from Harrisburg, Pennsylvania to Manassas, Virginia

Appendix C

Initiative	Description	Status
Industry/FRA/IDOT PTC Program	The program will develop, test and evaluate a PTC system, initially on the Union Pacific's Springfield subdivision from Springfield to Mazonia. The Program will include PTC Program interoperable units (e.g. locomotives) operating over other selected lines equipped with different train control technology meeting the adopted minimum interoperability standards	Funding for this program will come from the FRA, IDOT and the AAR. In kind services, including locomotives will be provided by the individual railroads. The scope of the program needs to be determined before the program cost can be finalized. An initial estimate of the program cost is $60,000,000, of which the railroad industry will provide $20,000,000, and it is expected to take four years to complete. The FRA and IDOT have made $15,000,000 available for the program.
Amtrak ACSES (advanced civil speed enforcement system). Limited to signaled territory	Transponder based overlay enhancement to automatic train control (ATC), 9 aspect cab signal, specific to the NEC, NJT is looking to procure similar technology, provides for civil speed enforcement through in track transponders, and positive stop at interlocking home signals. Most safety-critical data is picked up from codes in the rail and transponders supplemented by data radio at the interlockings. Will eventually have a radio link from the dispatcher to provide the means to send temporary speed restrictions to the train.	Over 500 miles of track in the north end of the NEC from New Haven to Boston, and in four selected areas on the south end between New York and Washington. $71 million in Federal funding for project. Contract was awarded to GEC Althsom.
Norfolk Southern	Under going review to: determine accident causes, determine what information and when received would have prevented each accident, design equipment to provide information, then add enforcement & test equipment to ensure function and limit annoyance factor. Human factor approach similar to BNSF enhanced proximity warning system.	Bench trials undergoing. Field trials in 1999.
Alaska Railroad	Positive Train Separation, Seward to Fairbanks to replace voice track warrant system (DTC). No signal on current line. GE-Harris is systems integrator. Train track is providing upgraded CAD (computer aided dispatching). Central dispatch approach with rf link - like ATCS. Location determination is GPS based. Includes upgrading microwave to digital.	FRA grant $3 million each in 99 and $5 million in FY00. Will take two years to implement. Will equip dispatch center, install communications and equip 45 locomotives. Four phases - first to upgrade dispatch center (implementation scheduled May 1999), second to complete communications system design (completed November 1998), and third and fourth to install PTC. Funding for FY 00 is uncertain.

Appendix C

Initiative	Description	Status
CSXT	Pilot communications based train management system (CBTM). An overlay, safety enhancement system for train movement in non-signaled (DTC) territory that provides both predictive enforcement, as to approaching speed and authority limits, and reactive enforcement to excessive speed. Protection will be provided to roadway worker employees to keep trains from entering MOW work areas without permission from the track supervisor.	CSXT has a contract with Wabco Railway Electronics for a turnkey installation of a CBTM pilot to be completed in 1999. The pilot will operate over approximately 120 miles of territory between Spartanburg, SC and Augusta, GA with 6 locomotives to be equipped.
New Jersey Transit ATC & PTC Project	The objective of this project is to implement technology to make the railroad safer. It consists of two systems for enforcing civil speed restrictions, signal indications, and positive stops at "Stop" or "Stop and Proceed" signals. The complementary system, using wayside transponders at interlockings and automatic signals interfaced to signal aspects, is called (PTS). It will be integrated into the remaining existing wayside signal systems and operate in conjunction with, and enhance the capabilities of the existing and future CCSS and ATC systems. On-board speed and positive stop enforcement features will be controlled using an integrated display for ATC & PTS (vs. Amtrak's separation of systems). The PTS installed on NJT will be functionally compatible with the system being installed on Amtrak's Northeast Corridor (NEC). This will preserve the interoperability necessary for NJT equipment to operate on the NEC. Onboard space constraints require a fully integrated CCSS/PTS system reusing existing wiring and giving full 9-aspect ATC compatibility on entire fleet.	The existing NJT fleet is equipped with Automatic Train Control (ATC) providing automatic speed control using 4- and 9-aspect cab signaling equipment. NJT is adding wayside 4-aspect coded 100 Hz Continuous Cab Signal Systems (CCSS) to an additional 214 track miles in 131 route miles of existing signaled territory, increasing ATC to about 76% of its System. Design and installation is by in-house forces, at a cost of $23 million. Contract awarded to US&S to design and furnish complete PTS on approximately 115 track miles in 72 route miles of territory. Included are 109 locomotives and cab cars with installation performed by the contractor; wayside installation is in-house.Final prototype demonstration occurred in March and April of 1999. Project completionis scheduled for December of 1999. Option to equip the remaining 244 locomotives, MUs, and cab cars, as well as 423 track miles in 264 route miles including electrified and diesel-only territory having an existing 100-Hz 4-aspect CCSS in service. The portion of contract awarded is $16.6 million, with total contract valued at $43 million (not including force account installation).