



Positive train control initiatives in North America: technological and institutional issues

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Abstract

The paper presents an overview of recent and current Positive Train Control (PTC) initiatives in North America, addressing the technologies deployed, along with concerns from economic, safety, user acceptability and regulatory perspectives. The seemingly slow progress in utilization and acceptance of PTC systems in the North American rail environment is explained in light of both technological and institutional barriers. The role of standards making bodies and the impact of regulatory agencies can not be overstated. Focusing on current PTC initiatives, this treatise explores the changing perspectives of the participants in these ventures – the suppliers, end users, industry organizations, and the regulatory bodies.

With a growing interest in high speed rail transportation, the upgrading of existing right of way infrastructure is the most cost-effective means of achieving this goal. Resulting in commingled freight and passenger service, it is imperative that the safety concerns of both operating entities are adequately addressed. Equally as important is the ramification of higher speed trains approaching and traversing at-grade highway crossings. The railroad/highway interface will become increasingly complex as the requirements and expectations of a national Intelligent Transportation System (ITS) evolves. ITS, which has been driven from a highway-centric viewpoint, must now contend with the railroad's historic superiority and reach a consensus over functional jurisdiction.

Finally, migration strategies, encompassing the technological barriers along with economic and institutional hurdles that must be crossed, interoperability standards, and cost benefit analyses, that will ultimately yield successful PTC systems, are summarized.



1 Introduction

The term, Positive Train Control (PTC), is the most recent incarnation of terminology applied to train control systems that had been generically termed Advanced Train Control and Positive Train Separation among other monikers. These systems seek to at least achieve, if not enhance, the functionality of their forebearers: cab signal systems, automatic train control, and automatic train stop systems, through the deployment of newer technologies. Judicious choice of these technologies should also achieve a lower cost of procurement and maintenance of these systems over their predecessors.

Regardless of the name, generic or trademarked, these PTC systems strive for common objectives:

- ◆ Prevention of train-to-train collisions
- ◆ Enforcement of speed restrictions, inclusive of civil and temporary
- ◆ Protection of roadway workers and their equipment.

2 Technology: Recent Initiatives

Several PTC and related train control systems have been tested in the past 15 years. Their technological underpinnings and relative success (or lack thereof) are cited below.

2.1 Advanced Train Control System (ATCS)

Born in the 1980's, ATCS specifications¹ were sponsored by the Association of American Railroads (AAR), which consists of the Class I freight operators in Canada and the US along with America's National Railroad Passenger Corporation, more commonly known as Amtrak. Potential users, suppliers, and consultants participated in the specification drafting and revision process with voting restricted to AAR members (railroads) only. As envisioned, ATCS would utilize off-the-shelf components in an open architecture as defined by the specifications. The original intent favored a central dispatch driven control, but evolved to accommodate a distributed architecture. ATCS relied on a track transponder based location technology, supplemented by a wheel tachometer and on-board track database. Data communications occurred over a 900 MHz UHF radio between the various devices and subsystems. This spectrum was granted to the rail industry by the Federal Communications Commission (FCC) in the US and its counterpart in Canada, the Canadian Department of Communications.

The Canadian National (CN) and the Canadian Pacific Railway (CP) engaged in extensive testing. Though technically successful, the costs associated with deployment and maintenance of ATCS system-wide were prohibitive. There was also a sentiment that the rail industry was not whole heartedly supportive of ATCS from a financial perspective, and was seeking alternatives. The effort was not in vain, as major portions of the specification, specifically the environmental and data communications protocol, proved worthy and resurfaced as the basis for future initiatives. Further, the build out of a 900 MHz RF system benefited train



operations objectives immediately along with serving as the wayside infrastructure for several subsequent train control projects.

2.2 Advanced Railway Electronic System (ARES)

ARES was conceived by the Burlington Northern Railroad (BN) in 1983. ARES development transpired concurrently with ATCS, and was frequently perceived as a competing approach. Location determination was accomplished through the Global Positioning System (GPS) in combination with odometers and an on-board track database. Data communications occurred through the existing 160 MHz VHF channels, expanded to accommodate data.

Like ATCS, the test pilot proved the system technically, but the hurdle of financial feasibility coupled with a lack of industry-wide acceptance relegated ARES to test status. Of importance to later projects, was the use of GPS.

2.3 Positive Train Separation (PTS)

PTS was a joint venture of the BN and Union Pacific Railroad (UP) tested in the Northwest of the US. The system was crafted as an overlay to the existing signal system with the potential to extend beyond train separation to full train control. PTS leveraged the on-hand RF networks of each carrier – 900 MHz on the UP and 160 MHz on the BN – with minimal changes. Like ATCS and ARES, PTS was a centrally controlled system. Differential GPS (DGPS) combined with a gyroscope, wheel odometer, and an on-board track database provided location determination.

Like its immediate predecessors, the PTS pilot was deemed a technical success, with its future highly dependent upon the Alaska Railroad Corporation project (presented later). A significant achievement of this program was testing and proving the interoperability of the data communications segments over disparate networks.

3 Technology: Current Initiatives

The following summarizes the technologies utilized in on going PTC projects. Several of them are heavily reliant on the technologies and approaches tested in earlier initiatives, whereas others pursue novel approaches. In general, these projects seek to overcome one or more of the deficiencies of their precursors – economic feasibility, logical migration path, and wide support.

3.1 Incremental Train Control System (ITCS)

ITCS is an enhanced overlay system built on upon an existing traffic control system, with the potential for deployment in non-signalized (dark) territory. The system consists of a distributed wayside architecture. The control office utilizes landlines to connect the control office with wayside servers. A wayside LAN, based on spread spectrum RF technology provides the interconnectivity along the



wayside, with ATCS communications occurring between the mobile and wayside devices. On-board DGPS and track database provide location determination. As the test bed for this system involves high speed (above 80 mph) passenger train operations, interfacing to highway grade crossing warning systems is required to provide adequate warning times.

ITCS testing has been successful to date with revenue service planned for this year. Several important objectives have been proven through the testing – moderate costs and realistic migration path. Interoperability, leading to widespread support, remains to be seen.

3.2 Advanced Civil Speed Enforcement System (ACSES)

ACSES is an enhanced overlay system built on top of existing cab signals designed for operation in high speed, high density territories. Unlike other transponder based systems, the location detection function is localized to the specific train. Transponder information provides track geometry characteristics inclusive of upcoming speed restrictions, current (static) position and distance to transponder pairs in advance. Dynamic positioning is resolved via an on-board tachometer. Absolute or positive stop is enforced at interlocking home signals. As the system is intermittent, a data radio, with transmitters located at the interlockings, provides for positive stop override should conditions warrant.

ACSES will be deployed on Amtrak's Northeast Corridor, which provides commuter as well as freight service. Traffic on this corridor requires that all trains be equipped with ATC systems. At present, ACSES requires an underlying signal system exist.

3.3 Advanced Speed Enforcement System (ASES)

Similar to ACSES, New Jersey Transit's (NJT) ASES system is a transponder based overlay system designed for high speed, high density territories. It is more closely integrated with the cab signal ATC system than ACSES. A large commuter railroad, not all of NJT's lines are cab signaled. As part of this program, cab signal will be installed on all main lines. Another distinction from ACSES is the method of positive stop override at interlockings. As opposed to a data radio, train operator input of a dispatcher issued code is keyed into the on-board system to effect an override.

Intended to be compatible with ACSES, there are subtle differences in the transponder data encoding. Interoperability will be a requirement as NJT runs over Amtrak territory planned to incorporate ACSES. Akin to ACSES, this system necessitates the presence of an underlying signal system. Other railroads operating over NJT's ASES equipped lines (e.g., freight operator) will be required to have ASES equipped trains unless a waiver is granted by the Federal Railroad Administration (FRA).



3.4 PTC Platform Project

Initiated in 1997, the project was sponsored by three eastern US freight railroads (Conrail, CSXT, and Norfolk Southern) and the FRA. The goal was to define an on-board platform using an object-oriented approach that recognizes and supports various underlying signal/train control systems: dark territory, traffic control, cab signal and communications based train control. Subsequent to evaluation of several data link structures and protocols, the Echelon LonWorks bus was chosen. Echelon has also received the imprimatur of the IEEE for rail transit vehicle applications (Standard P1473-L). Prototypes and objects developed by different suppliers have been successfully tested for interoperability.

This program, whose next phase is the development and testing of wayside objects and connectivity to the on-board platform, is under the direction of the North American Joint Positive Train Control (NAJPTC) program which also administers the IDOT PTC Project discussed later.

3.5 TrainGuard™

An enhanced form of a Proximity Warning System (PWS), TrainGuard™ is strictly an overlay system providing location, speed, heading, and predicted stopping distances amongst equipped locomotives. No interface to wayside signal systems or a dispatch office is required. The location determination system consists of GPS, gyroscope, tachometer and an on-board track database. Data transmissions between locomotives occurs in the end-of-train (EOT) 450 MHz spectrum.

To be tested and deployed on the Burlington Northern-Santa Fe Railroad (BNSF), TrainGuard™ supports the basic objectives of PTC, but lacks information concerning signal apparatus status and movement authorities. A similar system is installed in Quebec, Canada that permits one person crew operation.

3.6 Communications-Based Train Management System (CBTM)

CBTM as envisioned by CSXT is a centrally controlled, overlay system for dark territory that enforces improper train movements more economically than a conventional signal system or full-blown PTS/PTC system. CBTM takes a distributed approach with wayside zone controllers responsible for monitoring traffic within their jurisdiction, processing movement authorities granted from central dispatch and maintaining a track profile database. Location determination consists of GPS, tachometer and switch position status (derived from the zone controller). Presently, data communications will occur over the existing, available 160 MHz VHF band, primarily used for voice communications.



Although CBTM is classified as non-vital, the system should improve safety in dark territory. Potential drawbacks include inability to provide positive stop at speeds below 8 mph, availability of bandwidth in chosen RF spectrum, and applicability in signaled territory.

3.7 Alaska Railroad Corporation Project (AARC)

The AARC is an outgrowth of the BNSF/UP PTS project using similar technologies and extending support to roadway workers. Location determination relies on DGPS, gyroscope, wheel tachometer, and an on-board track database. The system is centrally controlled utilizing an ATCS derived RF link and protocol. Unlike PTS, the system will function in both dark and signaled territory.

The upgrade to AARC's infrastructure is extensive, encompassing a Computer-Aided Dispatch (CAD) system, communications network, wayside and mobile devices. The system will support both passenger and freight operations.

4 Technology: Emerging Initiatives

A number of initiatives are in their infancy presently. Although several technologies have been chosen or are initially favored, part of the process will be to validate that selection. These projects increasingly focus on the objectives of economics, migration and interoperability.

4.1 Norfolk Southern Location System (NSLS)

NSLS is an in-house design concept initiated by the Norfolk Southern Railroad (NS) in response to an extensive review of train incident history. Conceptually similar to the BNSF TrainGuard™ project, the NSLS is classified as a Proximity Warning System, with a primary objective of informing train crews of other trains in the vicinity. The system is based on track embedded RF ID tags, similar to those used for Automatic Equipment Identification (AEI) systems deployed throughout North America. The tags provide current location, track number, speed restrictions, and distances to the next two signals. This information is broadcast over the EOT channel to other equipped trains in the area. The on-board system calculates a safe braking distance (SBD) algorithm, providing train crew warning and enforcement if required.

Development and testing of GPS based location determination, SBD algorithms and train crew interface continues. Extending protection to roadway workers and inputting of temporary speed restrictions from central dispatch is under study. NSLS meets the core objectives of PTC systems in an affordable manner, but is not considered interoperable.



4.2 Illinois Department of Transportation (IDOT) PTC Project

Co-sponsored by IDOT, FRA, and AAR, the IDOT PTC project was formulated to develop, test, and implement a system that met the core objectives of a PTC system in a cost-effective and interoperable manner. The system must accommodate flexible block operations and advanced activation of highway grade crossing warning devices on a mixed service 120 mile segment of the UPRR. The system design is required to support high speed operations, although the corridor is not currently capable.

The sponsors have solicited input from the railroad community to refine objectives and examine technologies. System architecture has been defined functionally without requiring specific technologies aside from the ATCS spectrum for data communications. Among the tasks is an evaluation of location determination technologies including, but not limited to, GPS, DGPS, inertial navigation systems (INS), transponders, and hybrids thereof. The ATCS channels will also be subjected to load analysis for their suitability for downloading databases and communication with highway grade crossing warning devices. Other candidates to augment the overall communications requirements, both voice and data, include GSM-R, APCO P-25 (operates in the re-channelled 160 MHz spectrum), and IEEE 801.11 (wireless LAN).

Additionally, Program Management for this project, the Transportation Technology Center (a whole owned subsidiary of AAR), is chartered with the following:

- ◆ Develop an industry standard for PTC system interoperability
- ◆ Establish and document verification and validation procedures
- ◆ Formulate simulation and field testing criteria for component performance to PTC specifications and interoperability standards.

5 Technology: PTC and ITS Meet at the Grade Crossing

The Intelligent Transportation System (ITS) Program was established when the US Congress passed the Intermodal Surface Transportation Efficiency Act in 1991 to promote safe, expeditious movement of goods and people across transportation boundaries. The railroad industry has until recently been passive about specification developments, hence the highway-centric flavor of the work to date. So far, improvements in grade crossing safety have resulted from educating the motoring public and state DOT funded installation of active warning systems.

The connectivity as envisioned by ITS requires a higher level of intelligence on both sides of the highway-rail interface than currently installed. Coupled with the FRA's requirement for PTC-like train control systems to be deployed on high speed (> 79 mph) passenger corridors, it is only natural that these PTC systems support an ITS interface. Several of the current or proposed ITS and PTC pilot projects are listed here.



5.1 Michigan ITCS and IDOT PTC

Both of these systems seek to achieve advanced activation of crossing warning systems to accommodate high speed train operations as well as slower freight moves via bi-directional RF messaging between the train and the crossing equipment. No response from the crossing, a perceived fault in the crossing equipment (included false activation) would cause speed enforcement on the approaching train to ensure adequate warning time. ATCS Spec 200 compliant radios provide the communications link. There is concern that the bandwidth capacity of these radios may not meet the data loading requirements in territories containing cascaded crossings.

5.2 LA Metro Blue Line and Amtrak Mystic, Connecticut

Both of these applications incorporate vehicle detection via inductive loops and four-quadrant gates with the logic to provide egress for a vehicle within the crossing limits. The Amtrak system also provides a RF link between the crossing and approaching trains and on-board intelligence to slow or stop the train in the event of a stalled vehicle.

5.3 Minnesota Guidestar Project ; IDOT Metra-Milwaukee North Line

These projects utilize low-powered RF transmitters at the crossings to convey train presence at or approaching the crossing to equipped highway vehicles (school buses and emergency services). The range of these transmitters is 240–365 meters. The former will use a visual display, and the latter will activate a combination audible/visual warning.

5.4 North Carolina Sealed Corridor Project

The primary objective of this project is to determine warning system effectiveness in light of risk reduction. Highway median barriers, longer gate arms, four-quadrant gates, and video surveillance of highway traffic at the crossings. The surveillance provides law enforcement with the evidence to prosecute violators. Combinations of these approaches are currently being implemented by the state DOT and Norfolk Southern.

5.5 Long Island Railroad (LIRR)

Inductive loop vehicle detectors, augmented by video, and a spread spectrum RF link for crossing to train communications are featured in this project. Per ITS architecture, the system will include an Intelligent Crossing System with interfaces to dynamic signage and Emergency Management System (EMS) Vehicles via the ITS system. EMS vehicles can request priority clearance provided adequate train braking distance exists.



5.6 Future Applications

With the exception of the LIRR, none of these systems can claim strict adherence to ITS principles as there is not an intelligent connection to a traffic management system. Though some of the systems embrace the concept of providing information to highway vehicle drivers, concern has been expressed over the design principles and motorist reaction to in-vehicle warning systems. If the systems are not reliable or intelligent enough, the motorist may become complacent. If not designed to fail-safe principles, their operation could actually degrade safety.

Dynamic roadway signage is another means in the ITS arsenal to provide train movement information to the motorist. The literal messages proposed for display may generate conflict with, or at least distraction from, the “traditional” visual warning cue of flashing red lights and almost instinctive reaction. This existing prompt has been in use since the 1920s and is codified in Federal and state statutes.

Several technologies are under examination for in-crossing vehicle detection. They include inductive loops, video imaging, radar and laser scanning and small RF transmitters embedded within the road surface. The ability to prevent a train-vehicle accident is still a function of train braking distance. Even with inadequate braking distance, this type of advanced warning could still reduce collision severity.

Recently, the National Transportation Safety Board (NTSB) has urged the railroads to actively participate in ITS standards development. It is incumbent upon the rail industry to preserve their historic priority at this interface and not permit abusive invocation of EMS vehicle overrides of train operations.

6 Institutional Issues

Institutional issues or barriers can be both social (human factors related) and organizational (standards and regulatory bodies). The introduction of new technology, coupled with a different approach to performing tasks, is perceived by many in the workforce as threatening. The end user or operator of systems utilizing new or novel technologies should be brought into the development process to ensure successful deployment and acceptance. Recent PTC initiatives have increasingly taken this approach, inviting labor representation through defining overall system requirements, inclusive of input to display format and content of the on-board display. End users have also contributed to studies addressing the potential for complacency and over-reliance on automatic and semi-automatic train control systems adversely impacting safety. This is a radical departure from the rigidly defined specifications from earlier efforts: ATCS and the AAR’s Locomotive System Integration (LSI)².

End user participation has permeated the regulatory process as well. Decision making by consensus has become the order of the day as all concerned parties (labor, railroad management, suppliers, standards bodies and the regulatory



agencies) pursue rule making appropriate to PTC systems. The FRA, created in 1967, is chartered with the oversight task of ensuring compliance by the carriers to safe operating principles, inclusive of signal and train control systems. To date these rules and standards have been prescriptive in nature, targeting outmoded systems (lever-based control machines and electromechanical systems), with punitive enforcement³. Through the Railroad Safety Advisory Committee (RSAC), the FRA is presently crafting a performance oriented addendum to address electronic and microprocessor based signal and train control systems. Representative of all concerned parties, RSAC is addressing appropriate measures to determine safety assessment, risk analysis, and performance objectives for systems over their entire life cycle.

7 Economics

Numerous studies over the years have attempted to capture the costs and benefits of PTC systems with varying degrees of acceptance. Without rolling in business benefits, focusing on safety related savings alone, the studies conclude that PTC systems do not present an economic advantage. Further, the quantification of the business benefits – improved asset utilization and fuel consumption, increased line capacity and productivity – have been called into question. Further aggravating the economic case are the costs associated with migration. At present, the FRA must be petitioned and waivers granted to roll out PTC systems, particularly where not all of the equipment running over that territory would be equipped with the new train control system.

8 Conclusion

That safety improvements will be mandated is inevitable. PTC systems, whether overlaid on existing systems or forming the foundation of safety and business improvement initiatives, coupled with the decreasing costs of newer technologies, will undoubtedly be deployed to address these objectives. To achieve implementation, all parties should revise their entrenched position and be willing to compromise without sacrificing safety. Labor needs to understand railroad management's business case; management must consider labor's concern over training and job security; standards bodies should expedite their processes and relinquish turf wars; suppliers must embrace the concept of interoperability, and the regulatory agencies should remove roadblocks from the migration path to implementation of PTC systems.

References

- [1] Association of American Railroads, Operations and Maintenance Department, *Advanced Train Control Systems Specification*, Revision 4.0, May 1995.



- [2] Association of American Railroads, Mechanical Division, *M-591 Locomotive System Integration Operating Display Specification*, Revision 4.2, February 1997.
- [3] Federal Railroad Administration, *49CFR236: Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances*, October 1998.