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Research Results

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The North American Joint Positive Train Control (NAJPTC) Project

SUMMARY

The North American Joint Positive Train Control (NAJPTC), was an ambitious project to develop, test, and demonstrate PTC capabilities, including flexible block operations, interoperability, and advance activation of highway grade crossing devices, in a corridor with both freight and passenger service. The project's safety objectives were to: a) prevent train-to-train collisions (positive train separation), b) enforce speed restrictions, including civil engineering restrictions and temporary slow orders, and c) provide protection for roadway workers and their equipment operating under specific authorities. Additionally, the project would provide for industry interoperability, demonstrate safe operation of locomotives equipped with interoperable systems, and implement moving block functionality. The project would provide a cost-effective design in order to enhance prospects for deployment.

The NAJPTC system was developed and tested on a 120-mile corridor of the Union Pacific Railroad in Illinois (as shown in Figure 1) as a potential substitute of cab signal system to allow high-speed passenger train operation of 110 mph. The project was initiated in 2001. Due to continued delay due to the complexity and numerous scope changes of the project, NAJPTC decided to move this research project to Transportation Technology Center, Inc. in December 2006, so the Illinois corridor can be upgraded with another developed system for 110 mph operation. However, many aspects of the PTC technology were derived from this project and are currently being used in various PTC developments. Also, during the course of the development, the project addressed the design challenges faced by PTC systems and provided valuable lessons learned. These lessons are discussed in this paper. Through its open design, development, and testing, the NAJPTC system has aided other PTC projects in numerous ways.

Figure 1. Location of NAJPTC Test Site in the state of Illinois, USA

BACKGROUND

Positive train control (PTC) is a form of communication-based train control (CBTC). To satisfy the three basic safety characteristics specified by the Federal Railroad Administration's (FRA) Railroad Safety Advisory Committee's (RSAC) PTC Working Group, a PTC system must:

- Prevent train-to-train collisions;
- Enforce speed restrictions and temporary slow orders; and
- Provide protection for workers and their equipment operating under specific authorities.

Figure 2 illustrates the communications-based PTC architecture, with key subsystems and their main functions indicated.

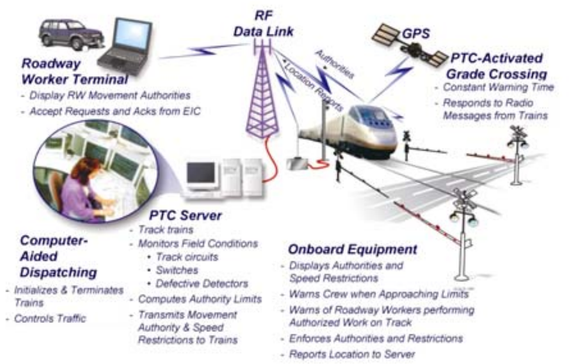

Figure 2. PTC System Architecture

PTC functions are modular to allow tailored implementation for each railroad or territory. Functionality negotiation capabilities permit trains to automatically adjust to the specifics of each deployment infrastructure. This along with an open architecture facilitates interoperability (operating one railroad's locomotive on another railroad's track under PTC) and migration (supporting different levels of functionality at various stages of evolutionary implementation).

In addition to the safety objectives listed, the PTC system would enable increasing passenger train speed to 110 mph. In Standalone Territory, it would also have the potential to increase railroad capacity (reduce excess headway as compared with fixed block signaling) by means of its moving block architecture. In Integrated Territory, however, it would operate in conjunction with fixed wayside signals to better accommodate a mix of equipped and un-equipped trains, but with negative impact upon capacity as compared with that of the conventional signaling system. This impact should diminish as accuracy of predicting braking distance improves by future development.

The moving block concept allows a train to receive a movement authority between *any* two locations, rather than being constrained to the fixed block boundaries of conventional signaling. Movement limits are updated automatically and more frequently than in conventional systems. As shown in Figure 3, this potentially allows train spacing (headway) to be reduced and track capacity to be increased in following move (fleeting) scenarios and certain "bottleneck" situations, such as where track has been downgraded or returned to service after maintenance.

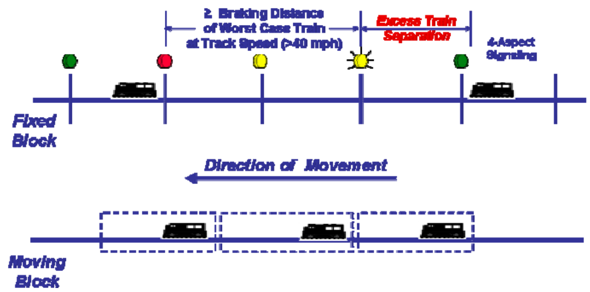

Figure 3. Moving Block has the Potential to Reduce Headways

Standalone PTC also has the potential to decrease train control system life cycle cost by reducing the amount of wayside vital equipment required (signals and track circuits).

The NAJPTC project also tackled many of the most challenging issues in the development, refinement, and testing of PTC, including:

- How to determine train location and turnout decisions with safety-critical dependability;
- How to predict enforcement braking distance accurately enough that a train will not go past the target, but not be stopped far short of the target either;
- How to verify train consist characteristics; and
- How to meet PTC system performance requirements given the performance limitations of mobile radio communications.

METHODS

The NAJPTC project was a multiyear effort with a phased development plan staged according to software builds, each of which added features to the previous one:

- Build 1 – Location determination, reporting, and tracking; Office, onboard, and communications infrastructure.
- Build 2A – PTC Integrated Mode operation at 79 mph; Track bulletins; Predictive and reactive enforcement.
- Build 2B – PTC Standalone Mode operation; Crossing advance activation; High-speed (110 mph) passenger train operation; Upgraded radio frequency (RF) communications.
- Build 3 – Verification of consist length and weight; Pacing; Roadway worker terminal; Functional negotiation; Integral defect detectors; Emergency braking enforcement; Display of predictors; Online track database update capability; and Cab signal interoperability demo.

Builds 1 and 2A were developed and tested on a 120-mile centralized traffic control line of the Union Pacific Railroad (UP) in Illinois, as illustrated in Figure 1. Trains operating on this line are UP freight trains and Amtrak passenger trains.

The 120 miles of PTC territory was divided into two categories of roughly 60 miles each: **PTC Integrated Territory** and **PTC Standalone Territory**. PTC Standalone Territory was to demonstrate the capacity improvements achievable with moving block operation. All trains on PTC Integrated Territory were constrained by conventional fixed signals, so it would not show capacity improvements but was intended to demonstrate efficient handling of non-equipped trains mixed with PTC-equipped trains.

RESULTS

Benefits Derived

Benefits from the NAJPTC project are:

- By integrating inertial sensors with Differential Global Positioning System (DGPS), tachometer readings, and map matching, NAJPTC's onboard Location Determination System increased the ability to dead reckon in areas lacking satellite coverage (such as in tunnels or "urban canyons"), significantly improved track resolution ability, and improved the detection of failure modes over systems that do not incorporate inertial sensors.
- Portions of the NAJPTC system's hardware and software implementation have been reused by other PTC projects.
- Open specifications/design documents from the NAJPTC project have been utilized in other PTC projects.
- Being the first to attempt many new train control approaches, NAJPTC testing in Illinois identified a number of design challenges from which valuable lessons were learned and solutions developed, benefiting other PTC projects.
- The NAJPTC system made greater use of commercial, off-the-shelf hardware and software components than prior vital train control systems.
- The first project to apply new FRA rule (49 CFR Part 236 - Subpart H). Safety case (Product Safety Plan, or PSP) provided a template and source material for other PTC projects.

Design Challenges and Solutions

Location Determination, and Track Discrimination and Entry Point Protection. The NAJPTC system uses a combination of technologies shown in Figure 4 to address these issues. NAJPTC's location determination system features a multiple-sensor, inertial navigation system (INS) design with diverse self-checking for safety. When temporarily out of DGPS signal coverage, the INS components allow the system to continue operating by dead reckoning.

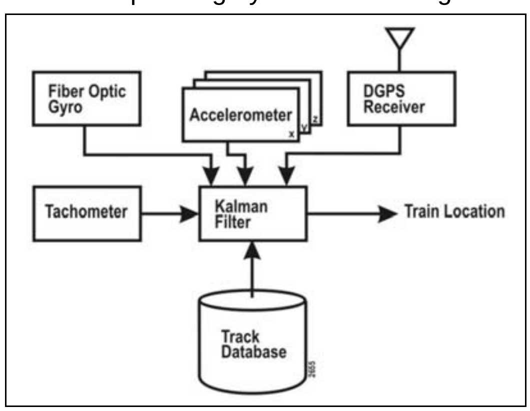

Figure 4. Multi-sensor Location Determination System provides high-integrity track discrimination and dead reckons through GPS outages.

Consist Determination and Verification. The NAJPTC system design addresses the problem of uncertain freight train consist characteristics with two modes: Unconfirmed and Confirmed. When a train is initialized, it enters Unconfirmed Consist mode. When sufficient data becomes available for NAJPTC to verify the consist characteristics with adequate integrity for safety-critical purposes, it transitions to Confirmed Consist mode.

Mobile Radio Communications. Based on preliminary analysis and requirements, the Advanced Train Control System (ATCS) Specification 200 standard was the RF data link selected for the NAJPTC project. Evolving requirements proved the 1980's-era ATCS data radio system's performance insufficient for NAJPTC's needs. Various potential solutions were assessed and ultimately a separate project was initiated to specify the requirements to develop and test a new generation interoperable higher performance data radio system suitable for use with PTC systems.

Lessons Learned

The NAJPTC project was one of the most complex system development/integration projects undertaken. The complex, highly distributed system included mobile nodes and was required to meet stringent safety, availability, and performance requirements. The requirements for NAJPTC far exceeded those of any train control system previously implemented.

In addition to detailed technical results in the final report, lessons learned include: the necessity for incremental development of such complex systems; the need for thorough and unambiguous specifications; ensuring that the system developer thoroughly understands the system requirements, as well as the underlying rationale and train operations; open communication and a cooperative working relationship between the railway and system developer; early test planning; proper rigorous sequence of development steps; having a productive test environment; milestones to demonstrate visible and quantifiable progress during development; maintaining focus on *system* performance; and the need for more adaptive and robust braking algorithms.

CONCLUSIONS

CBTC offers the promise of significant potential benefits in railroad safety, capacity, and efficiency. This report has identified key issues encountered on the NAJPTC project, along with chosen solutions and lessons learned. The experiences gained from this project have benefited other PTC developments and have led to the inception of subsequent projects to further address issues identified on the project.

ACKNOWLEDGEMENTS

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