U.S. Department of Transportation
Federal Railroad Administration

Initial Assessment of the Technical Feasibility and Potential Cost Savings of a Lower-cost Positive Train Control Activated Crossing

Office of Research and Development
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DOT/FRA/ORD-LETTER REPORT

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1.0 BACKGROUND

The North American Joint Positive Train Control (NAJPTC) Program is developing radio-based advance crossing activation capability for the Illinois Department of Transportation (IDOT) PTC project. The advanced activation capability provided by the NAJPTC system can be used as an alternative or a supplement to conventional track circuit-based methods of train detection and activation of crossing warning.

Besides providing constant warning time at Highway-Rail Intersections (HRIs), this technology also accommodates train acceleration on approach to the HRI — something not handled to any significant extent by traditional crossing systems. Some conventional track circuit-based crossing warning systems activate the crossing warning when an approaching train is a fixed distance from the HRI. This results in a variation of the time between the activation of the crossing warning and the arrival of the train at the HRI.

Other conventional track circuit based warning systems provide a constant warning time at the HRI, but the track signals used to determine the train speed become severely attenuated at the track circuit length (approximately 5150 ft) required to support high-speed (100 mph) trains. Thus, track circuit based warning systems would offer reduced reliability in high-speed operations.

In the NAJPTC advanced crossing activation system, the approaching locomotive's onboard computer (OBC) uses speed and acceleration to calculate the time the crossing protection needs to be activated to provide a constant warning time. This activation time is communicated to the crossing system via ATCS spec 200 radios. The crossing system then activates the crossing at the time commanded by the OBC.

The current NAJPTC design requires the addition of a Wayside Interface Unit (WIU) to the crossing warning system at each HRI to provide the crossing system and interface to the PTC system. The WIU is wired to the crossing activation circuit and activates the crossing based on predicted arrival times that are communicated from the PTC-equipped locomotive via the ATCS network. Arrival times at the crossing are therefore consistent regardless of train speed and acceleration.

A lower-cost alternative to the current NAJPTC advanced crossing activation architecture should be possible for processor-based crossing controllers. To reduce the overall cost of a PTC crossing, the WIU advanced crossing activation functionality could be (1) incorporated into the crossing warning system's train detection/crossing control processor, or (2) the train detection/crossing control functionality could be incorporated into the advanced crossing WIU processor. Either alternative would be beneficial wherever new crossing systems and PTC capabilities are required. Retrofit/upgrade of existing crossing systems with this capability may also be feasible. Using a single processor to replace the two that are now required to perform crossing activation and train detection/crossing control would derive cost savings. Combining this functionality into a single physical unit would also reduce the need for separate processor housings, power supplies, and installation costs.

The NAJPTC advanced crossing activation system consists of a Union Switch and Signal Microlok II with application software serving as a WIU coupled with a predictor unit for conventional crossing activation system as a safety overlay. The WIU serves as the radio interface for communications with the locomotive and provides the logic for PTC-based advance activation functionality. The conventional crossing activation system serves to provide constant warning time crossing protection in the event of a wireless activation failure or when non-PTC-equipped trains approach the HRI. In the event of a PTC-equipped train activation failure, the train speed is restricted by the PTC system to 79 mph to correspond to the limits of the approach track circuit of the conventional crossing system. Figure 1 illustrates the architecture of the system.

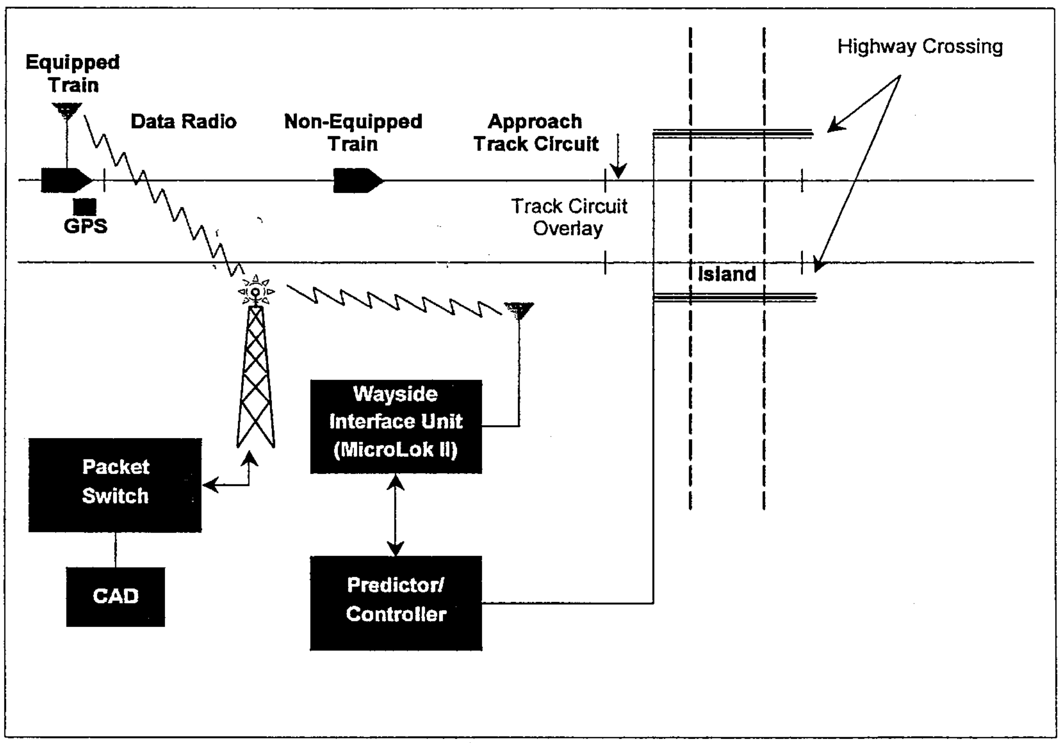

Figure 1. Current IDOT System

The Advance Crossing Warning System is designed to have PTC-equipped locomotives send a command to the crossing with the predicted time that the crossing protection needs to be activated. The locomotive command to the crossing is initiated when the locomotive determines that its predicted time of arrival is five minutes at the crossing. The equipped train continues and the wayside initiates the applicable circuitry to close the gates to provide the warning time (e.g., 30 seconds) before the train arrives at the crossing.

At train speeds greater than 79 mph, the conventional constant warning time crossing system's predictor track circuit cannot reliably detect at the required warning distance (~5200 ft); hence, a need for advanced radio activation.

If the communications link fails (i.e., no communication between the train and the crossing logic), the train is slowed to 79 mph, either by crew action or by PTC system speed enforcement, to comply with warning time requirements of the approach track circuit. The occupancy of the approach track circuit initiates the closing of the gates at the crossing.

2.0 OBJECTIVE

The overall objective of this project was to improve safety at the HRIs. The approach used to achieve the objective was to (1) increase the proliferation of constant warning time HRIs by reducing the cost of radio-based HRI technology and (2) increase the reliability of radio-based HRIs by reducing their complexity. Specifically, this project is to produce and demonstrate, through objective testing, a prototype of a lower-cost alternative to the current NAJPTC advanced activation crossing control system. This lower-cost system will integrate the WIU advanced activation functionality and processor-based crossing system functionality into a single physical unit.

As a precursor to subsequent project tasks, Task 1 required Transportation Technology Center, Inc. (TTCI) to report on an initial assessment of both the technical feasibility and the potential cost savings of the lower-cost concept previously described. This initial, qualitative assessment is to be used to guide the Federal Railroad Administration's (FRA) decision on whether to proceed with the remaining tasks of the project. A more definitive assessment of the lower-cost concept is the overall objective of the project.

3.0 TECHNICAL FEASIBILITY OF THE LOWER-COST CONCEPT

The technical feasibility of the lower-cost concept depends on (1) whether current crossing controllers are capable of being modified easily to host the added functionality provided through new software and hardware, or (2) whether current WIUs are capable of being modified easily to host conventional crossing functionality.

TTCI summarized the crossing WIU design documentation from the NAJPTC Program as a means of identifying and documenting the functionality that would be combined into a single processor and single physical unit.[1] This information was reviewed with both project staff and current suppliers of crossing control systems to make an initial assessment of the technical feasibility of the lower-cost concept. Three major suppliers agreed that the concept should be technically feasible. They also provided the answers shown in Table 1 to questions on the technical feasibility of the concept.

[1] Attachment: Description of NAJPTC Highway Crossing Activation WIU

Table 1. Technical Feasibility Criteria and Preliminary Assessment

Questions	Answers
Do either the current crossing system processors or current WIU system processors have enough spare capacity to handle the processing demands of both devices?	Yes
Can current systems support the necessary Mobile Communication Package (MCP) interface, including antenna connection?	Yes
Can current systems support the necessary Global Positioning System (GPS) interface, including antenna connection?	Yes
Is there sufficient power available in current systems to support the additional hardware?	Yes
Could the crossing functionality (train detection and crossing control) and WIU functionality be integrated in existing processors?	Yes
Do current systems use a proprietary executive (operating system)?	Yes
Are any changes to the executive anticipated? If so, can they be easily made?	Yes

Additional evidence of the technical feasibility of the concept is that similar, although not NAJPTC compatible and not as complex, advanced crossing activation functionality is already integrated into the crossings used in the Michigan ITCS project. In addition, one of the suppliers contacted has already identified a possible approach to developing the lower-cost concept and is awaiting opportunity to respond to an invitation to participate or a request for proposals, should FRA grant permission to proceed with the remaining tasks of this project.

4.0 POTENTIAL COST SAVINGS OF THE LOWER-COST CONCEPT

Table 2, which was derived through information provided by railroads and suppliers, shows that we expect the lower-cost concept to offer approximately a 50-percent savings over the current NAJPTC approach of requiring both a crossing controller and a WIU. Not included in this estimate are any savings derived from improved reliability of the lower-cost concept due to the overall reduction in the number of hardware components.

Table 2. Cost and Hardware Comparison

Cost Element	NAJPTC Advanced Activation Approach – Separate Activation and Crossing Controller Processors	Lower-cost Concept – Integrated Activation and Crossing Controller Processor
Separate Crossing System and WIU Racks	Yes	Systems integrated into a single rack
Power Supply	Yes	Systems use single power supply
Backup Battery	Yes	Systems share battery backup
Battery Charger	Yes	Systems share Battery Charger
Dedicated Computer Processor	Yes	Systems integrated to use same processing system
MCP (Radio) & Antenna	Yes	Yes
GPS Receiver and Antenna	Yes	Yes
Estimated Unit Price	$24,000	$12,000
Unit Installation Costs	Four hours of labor, in addition to normal crossing installation	One hour of labor
Estimated Annual Maintenance Costs	Lower	Lower due to elimination of hardware components

5.0 SUPPLIER PARTICIPATION

Although the suppliers contacted have all agreed that the concept is technically feasible, two of the three contacted have declined our invitation to offer a statement of interest in participating in the project — citing the lack of near-term market for the product (i.e., the lower-cost alternative), leaving only one supplier prepared to go forward.

6.0 RECOMMENDATION

The assessment to date, as reported above, has indicated the lower-cost concept to be technically feasible with a strong potential for producing a lower-cost alternative to the current NAJPTC advanced activation approach.

TTCI recommends proceeding with the project as originally planned, which includes completion of the following tasks with schedule as shown.

Months From FRA Decision To Proceed

	Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	TTCI Develops Concept of Operations (CONOPS)	■														
2	TTCI Develops Requirements Specification	■														
3	TTCI Develops Preliminary Testing Approach	■														
4	TTCI Secures Supplier Participation															
	Prepare/Issue Request for		■													
	Suppliers Prepare Response			■												
	Evaluate Responses				■											
	Negotiate Approach and Costs				■											
	Execute Agreements				■											
5	Suppliers Develop Prototypes					■	■	■	■	■	■					
6	Suppliers Install Prototypes at TTC											■				
7	TTCI Prepares Site for Testing															
	Prepare Test Plan,							■	■	■	■	■				
	Prepare Testing Apparatus								■	■	■	■	■			
	Complete Test Preparation With Suppliers												■			
8	TTCI Conducts Tests of Prototypes													■	■	
9	TTCI Analysis of Test Data														■	■
10	TTCI Preparation and Delivery of Final Report															
	Summary of Test Results															■
	Cost Impact															■

Note: The potential supplier has indicated that prototype development time might be reduced significantly through the use of off-the-shelf components. If true, this might potentially compress this schedule by an estimated 3 months.

ATTACHMENT

Description of NAJPTC Highway Crossing Activation WIU

CROSSING WIU CONCEPT OF OPERATIONS

Definitions:

WIU	Wayside Interface Unit – interfaces with field devices (control points, intermediates signals, and crossing devices) to provide status back to the office. Crossing WIUs also can activate crossing warning systems based on expected arrivals provided by approaching locomotives.
Crossing WIU	Provices the means for activation of highway crossing signals based on the predicted arrival time of a communicating train at the crossing, independent of the crossing's approach track circuits. Crossing WIUs are used where passenger train speed is greater than 79 mph.

WIU Power-up

Every time a Wayside Interface Unit powers up or automatically re-boots, a self-check is conducted on all hardware and software components. Software will be checked for possible corruption of the code as well as to whether or not the proper version of the software release is resident in the WIU in question.

The process of initializing a WIU commences as soon as power is supplied to the WIU. Upon detection of power supply, the WIU will perform the following functions:

1. **A self test to determine its own health.** It will check all its memory and verify the integrity of the embedded software.
2. **A link-up with all attached devices.** The WIU will link up with the data radio, through the communication handshaking.

WIU initialization will not proceed if a failure in the WIU is detected at this point.

WIU Initialization

If WIU powers up successfully, it will proceed to Initialization automatically, as follows:

1. **A link-up with the communication network.** The WIU will attempt to make contact with the communication network.
2. **A link-up with the Server.** In this step the WIU reports to the Server the status of all attached equipment, the software version number, and the supported functional capabilities. The Server verifies that an acceptable

version of software is resident in the WIU. If the software version is acceptable, the NAJPTC system instructs the WIU to activate the set of PTC functions applicable for the WIU type and location. If the software version is unacceptable, the Server does not command activation of WIU PTC capabilities; however, if the WIU is located at a control point or at an intermediate signal, it will retain its CTC capabilities.

CROSSING WIU HARDWARE ARCHITECTURE

General Hardware Design Comments

The WIU shall

- have a design life of at least twenty-five (25) years.
- have a MTBFF of no less than 40,000 hours.
- have an availability of approximately 99.94% to support a total system availability of 99.9% in the revenue service configuration. System availability shall be defined as the probability that a system is capable of operating at a random point in time.

The MCP shall be ATCS Spec 210 compliant.

The Control Unit shall be capable of sending and receiving data to and from the Office and Locomotive Segments utilizing a synchronous RS-422 serial data link, connected to the MCP with a MS3116F14-15SZ connector per ATCS Specification 200 Appendix O.

All WIU hardware shall use the standard fail-safe design using railroad standard practices as widely in service today.

If a failure is detected it shall cause the wayside signal to go to a more restrictive state. If a total failure should occur, communication to the PTC system could be lost and all wayside signals in the affected location shall go to stop.

The Field Segment equipment shall operate without mechanical or electrical damage "as specified in ATCS Specification 110" in ambient air temperature between the limits of +70°C and -40°C in combinations of relative humidity of 95 percent or less.

To the extent permitted by COTS design, the equipment shall be capable of withstanding, without permanent damage or degradation from meeting the reliability or maintainability requirements specified in ATCS Specification 110 for Wayside Bungalows, the storage temperature range of -55°C to +85°C.

The Field Segment electronic equipment shall meet the requirement of the ATCS Specification 110. The Field Segment electronic equipment shall withstand the specified vibration requirement of the ATCS Specification 110: 2mm peak to peak between 5 and 10 Hz 1.5 g peak between 10 and 200 Hz.

Mobile Communications Package (MCP)

MCP 900MHz Data Radio

The Non-Development Item (NDI) MCP radio meets the ATCS Spec 200 and 210 requirements, and provides the communication link to the IDOT PTC territory Spec 200 system. This system, in turn interfaces the Office Segment for system management.

Wayside MCP 900 MHz Data Radio Mount

The MCP will be mounted to a Non-Developmental Item (NDI) metal shelf, which will be installed in the US&S provided 19" equipment rack in each bungalow. The shelf requirements can be satisfied by Wabtec Railway Electronics (WRE) part number 827-9577-001 and associated WRE mounting hardware. The equipment rack will hold the MCP data radio / shelf and other US&S provided equipment.

Wayside MCP Antenna

A COTS 6dB gain, 806-960 MHz, 50 ohms nominal impedance, omni-directional antenna and associated hardware will be mounted on top of a 55' wooden pole (approximately 7' of pole in the ground) with 7/8" Heliax coaxial cable, connecting the 900 MHz MCP and the antenna. The antenna requirements can be satisfied by Decibel Products DB586. The 7/8" Heliax coaxial cable requirements can be satisfied by Andrews Corporation LDF5-50A.

Global Positioning System

GPS CLOCK

The WIU shall include a GPS receiver clock to provide a UTC time reference (HRS107). The GPS will be a Commercial Off the Shelf (COTS) unit , used to synchronize the time of day. (HRS263) Correct time of day will be used to maintain message validation, and for advance activation and event recording. The GPS receiver shall communicate though a dedicated serial port of the Control Unit. (HRS264) The WIU shall maintain a date/time synchronized within +/- 5 seconds of UTC time. (HRS265) The core of the CNS Clock™ is a GPS receiver module. The standard version of the CNS Clock™ features the best available receiver, the Motorola Oncore UT+. Each of the external 1 PPS output signals are independently buffered to improve their drive capabilities and to prevent damage to the GPS receiver module. The buffers will drive +3 volts into a 50 ohm termination with a rise time of <10 nsec. The normal logic polarity is positive going at the epoch time, but this can be inverted if desired.

An RS232 driver provides 1 PPS time synchronization to an attached computer. The 1 PPS signal is normally connected to the computer's DCD input, but connection to CTS or DSR is supported.

The RS232 I/O ports are buffered and isolated from the GPS receiver module. Two RS232 ports are provided, a primary and a secondary. This allows, for example, control and monitoring using the Tac32 software on one port while the other port is used for:

- RTCM SC104 Differential GPS signal input, or
- Motorola proprietary binary Differential GPS signal input, or
- Motorola proprietary binary Differential GPS signal output, or

- A second computer, also running the full Tac32 software.
- A second computer, running NTP software. This permits the CNS Clock™ to be used as a network timing master per RFC1589.

Timing Antenna

The 24 dB active patch, Antenna97 operates from 5 VDC at just 20 mA supplied by the CNS Clock. The Antenna97 features a molded-in 6 meter 1/8 inch diameter RG-174 coaxial cable. The antenna design reflects the high standard for performance when operating in foliage/urban canyon environments and in the presence of electromagnetic interference.

The small footprint, low profile package and the shielded LNA (low noise amplifier) offers significantly enhanced performance while operating in a variety of GPS environments. Direct mount makes the antenna suitable for a number of different installation configurations.

The Antenna97 is a high performance active antenna with vertical cable feed. It is designed for easy installation

General Specifications:
Operating Frequency: 1575.42 ± 1.023 MHz (typical)
Gain: 30 dB (min), N.F. 2.2 dB (max), Filtering: -60 dB (typ) @ 1575.4 ± 50MHz
Polarization: Right hand circular, Output: VSWR 1.5 (typ) 2.5(max).
Power supply: 5 ± 0.5 VDC, Current: 20 mA (typ), 27 mA (max).

CROSSING WIU SOFTWARE DESIGN

The design of the Crossing Wayside Interface Unit Field Segment Application (WFSA) computer software configuration item (CSCI) is composed of several computer software components (CSCs). The following CSC's are used:

- Executive CSC
- Application CSC
- ATCS Protocol CSC
- GPS Protocol CSC
- Real Time Clock CSC
- Highway Crossing Activation CSC

Executive CSC

Executive CSC is the operating system of all WIUs. The Executive Computer Software Component is a Commercial Off-The-Shelf component provided by the WIU manufacturer.

Application CSC

Application CSC is the WIU Application Program. It is responsible for controlling all functions of the WIU.

ATCS Protocol CSC

The ATCS protocol Computer Software Component is responsible for initialization of the Mobile Communication Package, initial processing and internal routing of all inbound ATCS protocol messages, and processing and transmission of outbound ATCS protocol messages. Unique message sequence number assigned by sending communications application layer for all messages sent for a specific Message ID. Sequence number shall be a sequentially increasing number increased by one (rollover at limit to 1) on each transmission for that particular Message ID. A zero sequence indicates reset of the sequence. The range of values is 1-255.

This CSC is initiated by the executive's serial communication handler's initialization CSU. Upon activation, it performs the required component initialization and configuration and initializes the Mobile Communications Package. It calls the necessary functions to perform basic error checking and routing on incoming ATCS protocol messages and formats and transmits outbound ATCS protocol messages.

GPS Protocol CSC

The GPS Protocol Computer Software Component is responsible for obtaining UTC time and time status from the GPS time standard receiver. This component implements the master end of a master-slave communication link over which the current UTC time is periodically requested. This CSC includes the following Computer Software Units:

This CSC is initiated by the executive's serial communication handler's initialization CSU. Upon activation, it performs the required component initialization and configuration. It calls the necessary functions to periodically poll the GPS time standard receiver to obtain UTC time and receiver status from the GPS time standard receiver.

Real Time Clock CSC

The Real Time Clock Computer Software Component is responsible for maintaining UTC time between updates from the GPS time standard receiver.

This CSC is initiated by the executive's reset.c CSU. Upon activation, the real time clock CSC performs the required component initialization and configuration. The system timer executive provides the time source for the real time clock CSC once it has been started.

Highway Crossing Activation CSC

The Highway Crossing Activation Computer Software Component is responsible for controlling highway crossing devices based on commands received from approaching locomotives.

This CSC is initiated by the executive's unit initialization (reset.c) CSU. When started, the highway crossing activation CSC performs the required component initialization and configuration. The system timer executive and the real time clock CSC provide the time source for the highway crossing device handler in normal operation.