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13. ABSTRACT

Interoperable Communication-Based Signaling (ICBS) refers to an implementation of a train control system based on signaling principles whose system architecture and interface are documented as Recommended Practices (from the AREMA Manual of Recommended Practices for Communications and Signaling) by the Association of Railroad Engineering and Maintenance-of-Way Association (AREMA). This project demonstrated that existing suppliers of vital (fail-safe) train control equipment can modify their products to support the system architecture and interfaces as specified. ICBS is capable of satisfying the requirements of a positive train control system.

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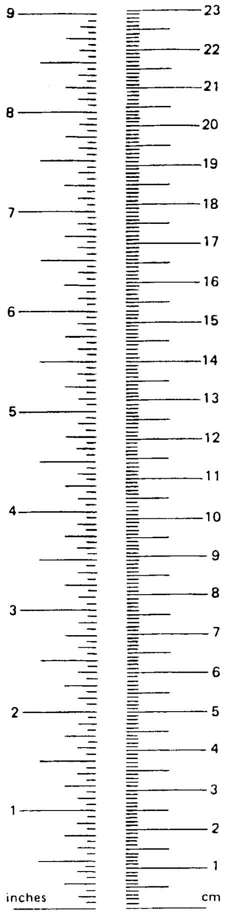
METRIC CONVERSION FACTORS

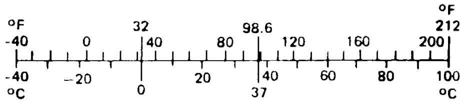
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.50	centimeters	cm
ft	feet	30.00	centimeters	cm
yd	yards	0.90	meters	m
mi	miles	1.60	kilometers	km
	AREA			
in^2	square inches	6.50	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.80	square meters	m^2
mi^2	square miles	2.60	square kilometers	km^2
	acres	0.40	hectares	ha
	MASS (weight)			
oz	ounces	28.00	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.90	tonnes	t
	VOLUME			
tsp	teaspoons	5.00	milliliters	ml
Tbsp	tablespoons	15.00	milliliters	ml
fl oz	fluid ounces	30.00	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.80	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.40	inches	in
m	meters	3.30	feet	ft
m	meters	1.10	yards	yd
km	kilometers	0.60	miles	mi
	AREA			
cm^2	square centim.	0.16	square inches	in^2
m^2	square meters	1.20	square yards	yd^2
km^2	square kilom.	0.40	square miles	mi^2
ha	hectares (10,000 m^2)	2.50	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.10	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36.00	cubic feet	ft^3
m^3	cubic meters	1.30	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius* temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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* 1 in. = 2.54 cm (exactly)

Contents

Executive Summary

This project demonstrates that the major suppliers of signaling equipment for the North American railroads can modify their existing safety-critical equipment to support operation of a vital interoperable positive train control system based on signaling principles developed over many decades. The project is referred to either as communication-based signaling (CBS) in the American Railway Engineering and Maintenance–of-Way Association (AREMA) Manual of Recommended Practices or interoperable communication-based signaling (ICBS). The terms may be used interchangeably.

Project participants included the major suppliers of signal and train control equipment within North America. These suppliers have provided a wide variety of signaling equipment, including processor-based equipment that has been in revenue service on railroads and transit properties for decades. This includes equipment designed and built to the vital (or fail-safe) requirements of rail and transit properties. The project was sponsored by the Federal Railroad Administration (FRA) Office of Railroad Development and coordinated through the Railroad Research Foundation (www.railroadresearch.org). Project management was provided by Bill Petit (www.billpetit.com) and the test environment and simulators were provided by Critical Link (www.criticallink.com). The participating suppliers include Alstom Signaling (www.transport.alstom.com), Ansaldo–STS (previously known as Union Switch and Signal) (www.ansaldo-sts.com), General Electric Transportation Systems (GETS) (www.getransportation.com), and Safetran Systems (www.safetran.com). Financial support was provided by FRA for the project management and test environment. Three of the suppliers (Ansaldo–STS, GETS, and Safetran) received funding covering approximately a third of their actual costs. Alstom entered the project later than the others and received no financial support through FRA.

This project was undertaken to verify that a set of interoperability standards developed and maintained through an industry professional organization (AREMA, www.arema.org) could be implemented. Many additional aspects exist to implementing a complete positive train control system and this project should be seen as part of a pathway toward full interoperable train control.

As part of the project, a test environment modeling four railroad sections, each representing a different railroad, was created along with a communications infrastructure for transporting messages. A conventional centralized traffic control (cTc) computer-aided dispatch (CAD) system was used to control movement through all of the sections. Each of the suppliers modified their own existing equipment to support the AREMA Recommended Practices and inserted their equipment into the proper location within the overall test environment. Onboard equipment from suppliers was used to move trains seamlessly across all the territories. Experience gained through the project was tabulated and referred to AREMA for inclusion in the next release of Recommended Practices.

All four of the suppliers demonstrated that their modified wayside equipment operated within the system and was interoperable with other equipment. Two of the suppliers demonstrated that their carborne equipment operated within the system (including across all four suppliers’ waysides) and was interoperable within the overall system.

1.0 Introduction

1.1 Background

Various forms of interoperable advanced train control systems have been investigated since 1983 (when an industry project on Advanced Train Control Systems (ATCS)) was begun. These train control systems are used to enhance the safety of conventional train control systems through continuous monitoring of train position and the ability to enforce a train to stop before an obstacle or a point where it is desired to control the train.

Since then, these systems for freight railroads have been generally called positive train control (PTC) systems. For clarity's sake, the Federal Railroad Administration (FRA) has defined PTC systems to include the following major characteristics:

- Prevent train-to-train collisions.
- Enforce speed restrictions, including civil engineering restrictions (curves, bridges, etc.) and temporary slow orders.
- Provide protection for roadway workers and their equipment operating under specific authorities.

The Railway Safety Improvement Act of 2008 mandated PTC systems for much of the nations rail infrastructure and added an additional requirement of monitoring track switch position and preventing train movement over an unauthorized route. Code of Federal Regulations Title 49 Part 236 (Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices and Appliances) is being modified to include a new Subpart I related to positive train control systems.

Various train control methods have been experimented with including non-vital overlays, vital overlays, and vital stand-alone systems. (Overlays are used as additions to existing train control systems and use those underlying systems as part of their safety justification). ICBS can be used as a vital stand-alone system or may also be used as a vital overlay system.

1.2 Objectives

Interoperable communication-based signaling (ICBS) project objectives were to develop a test system based on items in the Manual of Recommended Practices (Recommended Practices) developed by the American Railway Engineering and Maintenance-of-Way Association (AREMA). Multiple suppliers with experience in safety-critical (vital) train control and signaling systems would modify their equipment to participate in a demonstration. This demonstration would show that the defined system architecture could meet PTC objectives as well as demonstrate that multiple suppliers could develop systems according to the Recommended Practices that would be interoperable over the full system.

1.3 Overall approach

The overall approach was to define a simulated railroad operating scenario, where various sections of the test scenario would be controlled by different suppliers and onboard systems provided by any of the suppliers that could seamlessly operate over the entire test layout. Once the test layout was defined and simulators were developed, the individual suppliers would replace the simulators with their individual equipment modified to support the AREMA-based architecture. With all the simulators replaced, demonstrations were held highlighting the architecture and interoperability.

1.4 Scope

The scope of the project was to demonstrate that existing equipment from suppliers could be modified (as prototypes) showing the architecture and interoperability attributes of the AREMA defined system. The form translator (see the communication-based signaling (CBS) subsystem description) was not included in this demonstration.

2.0 Project Description

2.1 Communication-Based Signaling (CBS) Origin

The process of defining the CBS system began at the 2005 AREMA Communications and Signaling (C&S) technical conference. During the roundtable discussions of railroad Chief Signal Engineers, a request was made to define an interoperable radio-based cab signal system. This in turn was assigned to AREMA Committee 37 (signal and train control systems). To proceed with this task, members of the committee, who have existing vital processor-based signaling equipment in revenue service and had expressed an interest in communication-based signaling concepts previously, met separately to determine if any prospect existed of coming to an agreement on an interoperable system based on the systems they currently have in the field or on the drawing board. The companies participating (and their current products) were Alstom Signaling (Atlas), General Electric Transportation Systems (GETS) Global Signaling (ITCS–Incremental Train Control System), Safetran Systems (vTc–virtual traffic control) and Union Switch and Signal (US&S) (CAS–Collision Avoidance System). Surprisingly, all of the companies quickly agreed that it was in the best interests of the industry to develop interoperability standards based on the common system architecture we had arrived at independently.

Of the companies participating in the original meeting, GETS, Safetran and US&S agreed to proceed with the development of draft manual parts. These manual parts were presented to AREMA Committee 37 and subsequently approved by the committee for publication the 2009 AREMA Manual of Recommended Practices for Communications and Signaling (published in Fall 2008). This manual is updated annually (and each specific manual part must be revised or reaffirmed on a five-year cycle).

2.2 CBS System Operation

Understanding the system architecture and philosophy used in developing the CBS system is beneficial. In principle, a CBS system operates the same as a conventional cab signal system except for the following:

1. Physical blocks (as determined by track circuits in conventional systems) are replaced with virtual blocks that are generally equivalent in length to track circuits in cTc territory.
2. Communications via the rails is replaced with a digital data link.
3. Train location is determined as an on-board function.
4. An onboard database is used to provide information needed for enforcing civil speeds and determining braking profiles based on attributes such as grade.

In a CBS system, instead of transmitting vital cab signal information through the rails, a radio frequency (RF) communications data link is employed for this function.

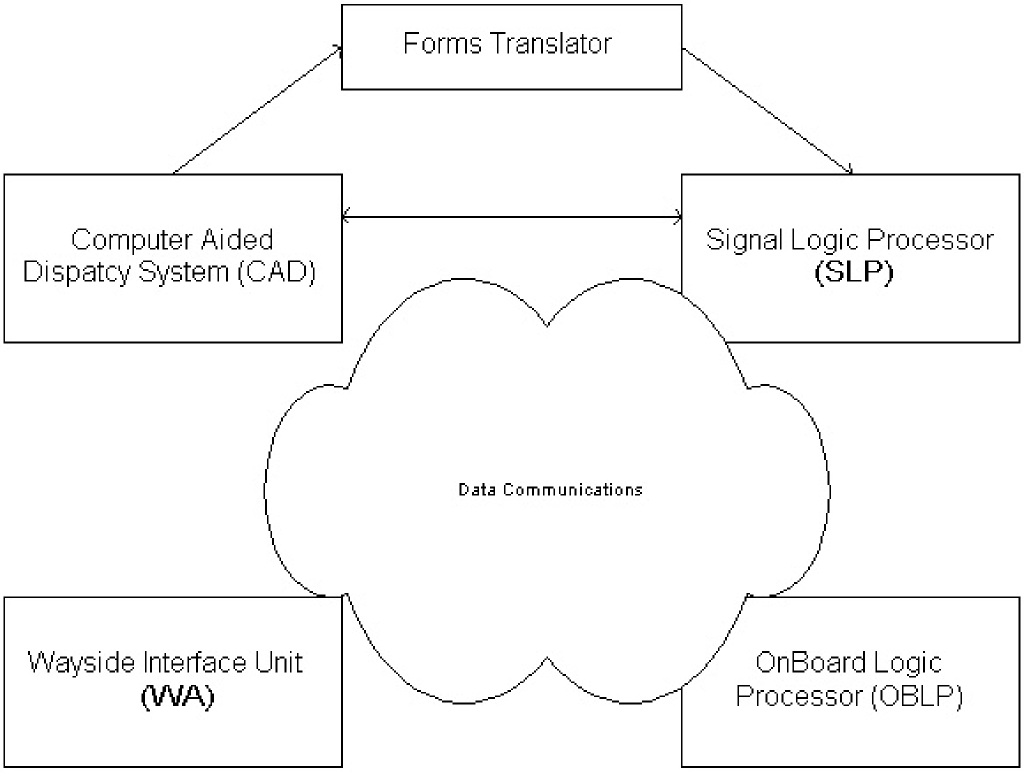

Figure 1. CBS diagram. The communications cloud represents whatever RF communication system is chosen to route the pre-defined messages between the various subsystems

In the communication-based system, the dispatcher sends requests, via the computer-aided dispatch (CAD) office system, to the signaling logic processor (SLP) to control switches and set routes just as would be done in conventional cTc operation. These operations are done using vital signal logic and principles as described elsewhere in the AREMA manual. It is important to note that the CAD requests to the SLP are not part of the vital system and are only requests to have actions performed. The actual actions are not performed until the vital logic with the SLP allows them to take place. Thus, the SLP acts on these requests if it is safe to do so, and sends indications to the CAD office system when the requests are completed. These control (requests) and indication messages between the CAD and SLP are the same as existing control and indication messages used for conventional signal systems.

The SLP sends control commands to the wayside appliance subsystem (WA) (also referred to as a wayside interface unit) to position and lock track switches and/or receives switch position information. The onboard logic processor (OBLP) reports the trains location in terms of the blocks it is occupying. The SLP determines the governing signal aspect for the block occupied (and those about to be occupied) for the train based on block occupancies, temporary speed restrictions, switch positions, other routes set within the territory; and transmits the governing signal information to the OBLP. The OBLP determines the governing aspect for the block based on the data received via the data communications link, and the civil speed data contained in the onboard database, and displays the appropriate signal aspect and/or speed limit to the operator, who in turn controls the train appropriately. If the operator does not control the train appropriately, the OBLP determines overspeed and what exceeds authority and requests brakes when required. When actual wayside signals are present the SLP will provide the OBLP with the address of the signal in place of the signal aspect. The OBLP will then request the signal status directly from the signal and use the received signal to determine the limiting aspect/speed for the upcoming block.

Because the number of possible signal aspects is not limited by the physical characteristics of the track as in conventional systems, defining a larger number of available aspects is possible so that additional information can be conveyed to the engineman. This allows more flexibility in operation and better system throughput.

The communication-based system can also allow the office dispatcher to install temporary speed limits or roadway worker authorities. These are converted through the forms translator to a format usable by the SLP, which then determines the appropriate signal aspects or allowable speeds to be sent to the train.

A more detailed look at the specific functions to be done by each of the subsystems follows.

2.3 CBS Subsystems

The following subsystems make up the CBS system. Each subsystem is responsible for the functions identified within its subsection.

- CAD System

  The office is the same as the cTc or dispatcher office system currently in use providing a central command and control facility for management of traffic and work crews within the controlled territory. Specific functions and operations are railroad dependent. This allows current dark territory to be dispatched just as if it was cTc territory with the obvious safety and efficiency benefits (e.g., following moves through a direct traffic control (DTC) or track warrant control (TWC) block).

- Form Translator

  The forms translator converts specific railroad forms data for functions such as temporary speed restrictions into commands that can be used by the SLP.

- Signaling Logic Processor (SLP)

  The SLP is responsible for the implementation of signaling principles. It calculates the appropriate signal aspect and/or speed limit for each virtual block, based on train position and travel direction; the position and travel direction of other trains; the defined authority limits; the position, status and location of switches, and any temporary speed restrictions.

  The SLP is responsible for the following functions.

  - Convert incoming messages (via the data communications network) from locomotives into appropriate block occupancy information within the SLP.
  - Convert incoming messages (via the data communications network) from wayside interface units into appropriate switch position information within the SLP.
  - Note: Interim systems may have alternative methods of entering switch position (e.g., dispatcher input based on voice radio from locomotive).
  - Execute signal logic equations to determine governing signal aspects for all blocks within the territory.
  - Convert signal aspect information into serial messages for transmission to appropriate locomotives for display.

  - Note: signal aspects are vitally associated with specific blocks. Because the locomotive also vitally knows which block it is occupying, it is not a vital function to send the proper aspect to the proper locomotive.

  - Respond to non-vital controls and provide non-vital indications to CAD system.

  - Verifying locomotive contains the latest version of all critical databases.

  - Interface to forms translator

    - Note: The SLP may be constructed from a group of local or remote processor units, each responsible for a geographic section of railroad. Each processor unit within the SLP will be responsible for data exchanges with its geographic neighbors.

- Wayside Appliances (WA)

  The wayside appliances include signals, switches, track circuits, highway crossing controllers, defect detectors, and the equipment necessary to allow the appliances to interface to the communications links. The WA may include a wayside interface unit (WIU), which contains both the necessary control equipment and the necessary interface equipment for linking traditional signaling appliances to the communication-based system. The WA is responsible for the control of switches and determining the status of switches, track circuits, and actual signals

- On Board Logic Processor (OBLP)

  The onboard logic processor is responsible for determining the train’s current location, current speed, train integrity (if installed as a part of the system), direction of travel, and the train’s allowed speed as defined by the civil speed limit contained in the onboard database, the aspect or speed limit received from the SLP or from local devices as instructed by the SLP. The OBLP also determines train overspeed, warns the operator, and provides enforcement.

  The OBLP is responsible for the following functions.

  - Maintain a topographical representation (infrastructure database) of all blocks in the territory, using the virtual blocks as the fundamental track elements.
  - Using information from a location determination system (LDS), identify which specific block is currently occupied by train by the block address (also referred to as block ID).
  - LDS may be GPS based, transponder based or other. (Note: if based on transponders or other wayside equipment not supported by foreign roads, the locomotive may be required to operate as “unequipped” on the foreign roads.)

    - Transmit Block Occupancy information to SLP.
    - Determine signal aspect and/or speed limit information received from SLP (after verifying that the aspect received is for the occupied block).
    - Determine the maximum allowed civil speed for the block being occupied by the lead end of the train and any civil speed restrictions (‘look back’) for any block occupied by the train.
    - Display the correct signal aspect and/or speed limit based on the civil restrictions and the signal aspect/speed information received from the SLP.
    - Provide overspeed protection, via request of brake application, of most restrictive speed limit.
    - Provide overrun protection for exceeding allowable signal aspect authority via request of brake application.
    - Provide self-testing function with an indication that self-testing has been successfully accomplished.

- Communication Links

  The CBS system may use any physical communications infrastructure that is suitable. Message protocol and structure are as defined in Manual Part 23.4. The physical communication links are not vital. Vitality is maintained within the data messages.

  For CBS, a decision was made to continue the use of ATCS addressing and protocols. The ATCS addressing perfectly fits the desired operation along with capitalizing on the existing ATCS addresses widely used in the industry today. The ATCS datagram was chosen as it supports the performance and safety needs of the system. The use of ATCS addressing and datagrams does not mandate the use of ATCS frequencies and radios. The datagrams can easily be sent as a payload through any type of system (e.g., IP-based systems) that supports the needed system performance.

- Infrastructure Database

  The database defines the railroad infrastructure including track circuits (actual or virtual), signal locations (actual or virtual), and switch locations. The database defines the linkages between the track circuits, signals and switches. It defines grades, civil speed limits, signal aspects, defect detector locations, highway crossing locations, etc. The database defines everything the CBS system needs to know about the fixed infrastructure.

2.4 AREMA Recommended Practices on Communication-Based Signaling

After substantial work, the first set of manual parts was approved by the full membership of AREMA Committee 37 and published in the 2009 AREMA C&S Manual. The following is an overview of the manual parts.

23.2.1 Recommended Functional Requirements of a CBS System

This section defines the functional requirements for a Communication-Based Signaling (CBS) system, including safety-critical train protection functions and train operation functions. Systems may vary widely in complexity and not all functions are required for all systems.

23.2.2 Recommended RAMS, Environmental and Other Requirements for Signaling Systems Using CBS Architecture.

This manual part defines the recommended reliability, availability, maintainability, safety, environmental, electromagnetic compatibility, and quality assurance requirements for the CBS system.

23.3.1 Recommended Design Guidelines for a CBS System

This manual part defines the system architecture and the interfaces for a system design based on conventional signaling principles as needed to meet the functional requirements specified in Section 23.2.1

23.4.1 Recommended Communications Protocols for a CBS system

This manual part defines the recommended system communication protocols without going into specific radio or network systems. Use of ATCS protocols and addressing is recommended to meet the safety and performance requirements, as well as to leverage the large amount of existing addressing schemes currently in use and the ATCS protocol expertise. These addresses and protocols can be used over any type of communication systems, not necessarily an ATCS radio system. Given the rate of change in communication technology, this approach allows use of any desired communication framework, while maintaining the interoperability and safety requirements.

23.4.2 Recommended Communications Messages for a CBS System

This manual part defines the recommended system messages (i.e. what information are you communicating between users) used between subsystems of the CBS system. Detailed message contents are included within the manual part.

23.5.1 Recommended Onboard Database Guidelines for a CBS system

This manual part defines the structure and content of the onboard database to facilitate interoperability. It includes the naming structure for each track section, switch, signal, etc based upon ATCS addressing techniques, as well as the necessary links to define how the various components are linked together.

2.5 CBS Test Environment

In late 2007, FRA (www.fra.dot.gov) provided a grant to demonstrate the operation of an ICBS system as defined by AREMA. This includes demonstrating the ability of multiple suppliers to achieve and demonstrate interoperability by following the Recommended Practices.

The FRA grant covered a laboratory demonstration of the system with each of the participating suppliers providing interoperable equipment based on the AREMA Manual Parts. The four major signal suppliers in North America GETS (www.getransportation.com), Safetran Systems Corporation (www.safetran.com), Ansaldo-STS (www.switch.com), and Alstom (www.alstomsignalingsolutions.com) agreed to participate in the project. Critical Link (www.criticallink.com) was chosen to provide the test environment, including simulators, physical interfaces, and integration support.

To accomplish the testing, a territory had to be defined that would allow each of the participating suppliers to have a section to control, an interface to adjacent sections, an interface to a control office, and onboard systems capable of traversing all four sections. In addition, a communications router was developed that was capable of routing information throughout all four sections and all the vehicles based on the defined addresses. The approach taken was to develop a set of simulators for each of the subsystems that performed the basic functionality as well as supporting the defined interfaces. The simulators and router were based on PCs with the ICBS defined messages encapsulated and sent via an IP network. After the simulators were developed, each of the participating suppliers then used the simulators at their own facilities as a way of testing their systems before incorporating them into the final demonstration.

As each of the suppliers completed various subsystems, they were substituted into the demonstration system at the Critical Link facility in Syracuse, NY. Thus, at the completion of the project, no simulators were running as they had all been replaced by actual suppliers’ equipment.

The territory to be simulated consisted of four contiguous segments and each with double track. Figure 2 is an example of the territory to be controlled by each participant. Splitting the territory into blocks and governing signals was arbitrary. Each application of CBS will allow blocks and signals to be defined as needed to achieve the needed operational performance of that section of railroad. Each of the participating suppliers had a similar territory to control and the overall territory had four of these sections operating contiguously (i.e., a vehicle supplied by a single supplier can move seamlessly across all four sections).

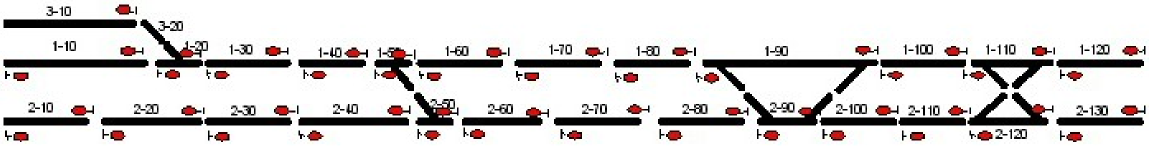

Figure 2. Example Territory for ICBS Simulation

Table 1 is a partial example of the database that is used to represent the territory. The database format and contents are specified in the AREMA Recommended Practices. Starting from the left you can see the specific identity of the block currently being occupied by the head of the train. This is used as the entry point into the database. For example the block labeled 1–10 in Figure 2 (on the left side of the diagram) identifies Track 1, Block Number 00010. This correlates to the Block ID 100010 in row 13 of Table 1. (The lead portion of the address for all the blocks consists of the RRR.LLL ATCS address, which specifically identifies the railroad number and line number being operated). Because all of the territory being discussed is on the same RRR.LLL section, that portion of the address is not included in what is shown. Methods of transitioning between RRR.LLL segments are included in the manual parts. By knowing what block is currently occupied, you can also determine the grade, curvature, civil speed limit (a code based on train type) as well as which blocks will be occupied as you progress along the track.

Row Number	Track Section (Block ID)	Track Sub-section	Sub-section Type	Ck Address	Status	St Lat	St Lon	End Lat	End Lon	St MP	End MP	Block Length (feet)	Grade	Curve	Curve Length	Civil spd	Track Section & Subsection UP	Track Section & Subsection DN	Sig Up	Sig Up type	Sig Dn	Sig DN Type
12	199900	00	99	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	99999	0	0	0	0	10001000	00000000	0	0	0	0
13	100010	00	17	0	0	43.0500	76.0000	43.0500	76.0259	0.0000	1.1364	6000	0	0	0	060	10002001	19990000	001.01.01	A	001.01.02	A
14	100020	01	03	001.03.01	0011(N)	43.0500	76.0259	43.0500	76.0272	1.1364	1.1932	300	0	0	0	060	10002002	10001000	001.01.04	C	001.01.05	C
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23	100050	01	02	001.03.02	1100(R)	43.0500	76.0791	43.0500	76.0793	3.4754	3.4848	50	0	0	0	030	10005003	10004000	001.01.10	C	001.01.39	C
24	100050	02	02	001.03.02	0011(N)	43.0500	76.0793	43.0500	76.0800	3.4848	3.5133	150	0	0	0	060	10006000	10005001	001.01.10	C	001.01.11	C
25	100050	02	02	001.03.02	1100(R)	43.0500	76.0793	43.0500	76.0800	3.4848	3.5133	150	0	0	0	060	00000000	10005001	00000000		001.01.11	C

Table 1. ICBS Simulated Territory Database

2.6 CBS SYSTEM DEMONSTRATION TESTS AND CONCLUSIONS

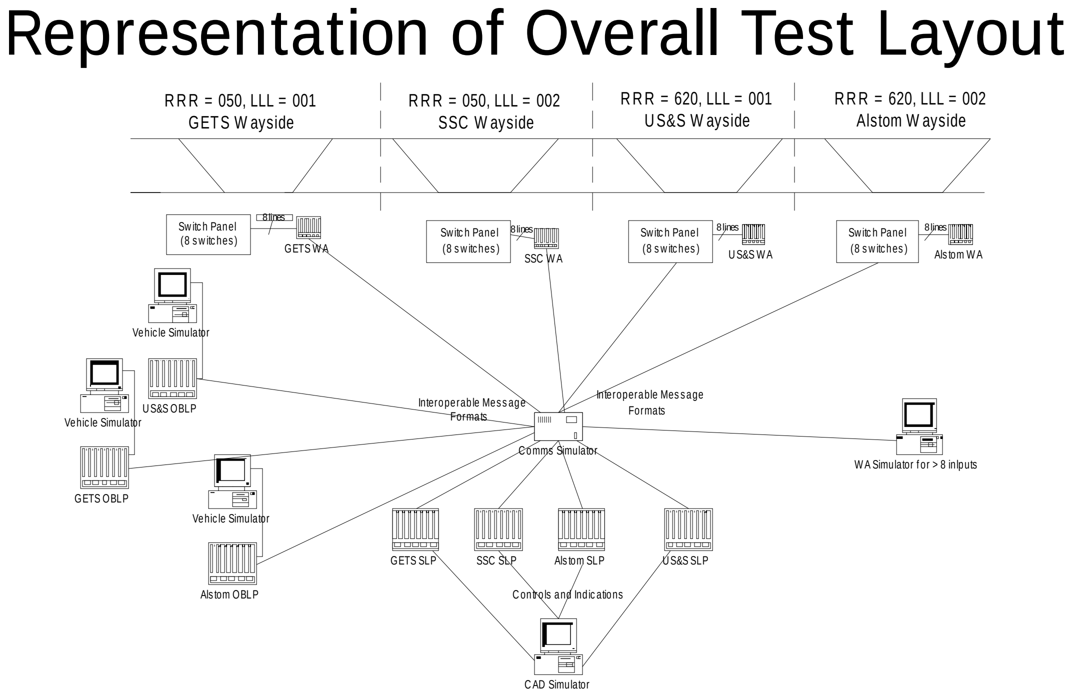
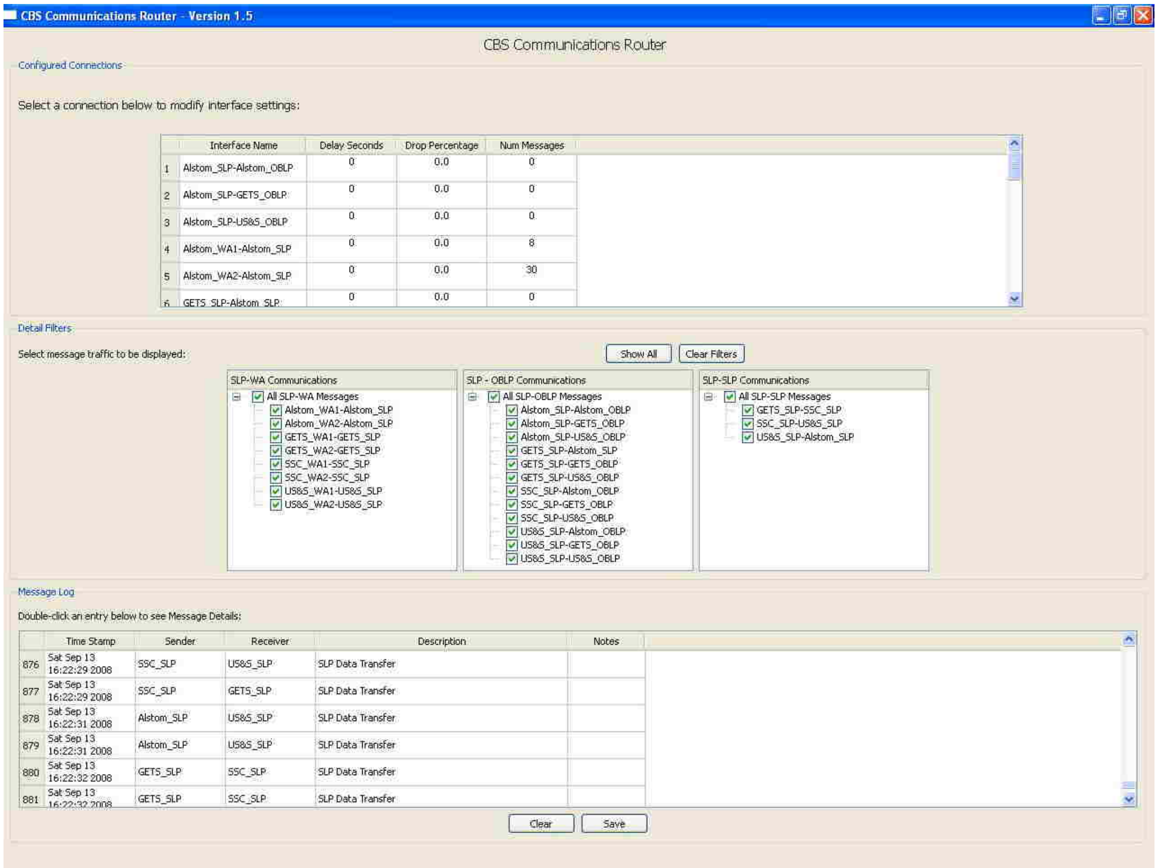


Figure 3. Architecture of the simulation environment

The dispatch office (CAD Simulator in Figure 3) is based on existing US&S control office technology, provides simulated office control for routing trains and tracking movement. The dispatch office communicates with the SLPs individually over a GENISYS communications link. This link transfers the nonvital controls and indications discussed previously. GENISYS is a communications protocol widely used in existing cTc systems and was chosen primarily due to availability of existing hardware and tools. A variety of other protocols currently being used (e.g., ATCS, IP, and Datatrain) could have easily been substituted. Each of the suppliers provided the SLPs for their specific section. The SLPs communicate through the communications router to the WAs (for monitoring and controlling switches), trains within their territory, and adjacent SLPs (necessary for trains to know advance information as well as to allow trains to be cleared out of territories behind them).

All communications between the SLPs, OBLPs and WAs were routed through the communications router (identified as communications simulator in the above drawing. Each of the subsystems within the complete territory has a unique address based on the ATCS addressing schemes described in the AREMA Recommended Practices and in wide use throughout the rail industry today. Messages from each device were transported via an IP protocol to the communications router, which then routed the messages to the correct location based on the embedded ATCS destination address in the message. Figure 4 shows a screen capture of the CBS Communication Router.



Select a connection below to modify interface settings:

	Interface Name	Delay Seconds	Drop Percentage	Num Messages
1	Alstom_SLP-Alstom_OBLP	0	0.0	0
2	Alstom_SLP-GETS_OBLP	0	0.0	0
3	Alstom_SLP-US&S_OBLP	0	0.0	0
4	Alstom_WA1-Alstom_SLP	0	0.0	8
5	Alstom_WA2-Alstom_SLP	0	0.0	30
6	GETS_SLP-Alstom_SLP	0	0.0	0

Select message traffic to be displayed:

SLP-WA Communications
- ☑ All SLP-WA Messages
  - ☑ Alstom_WA1-Alstom_SLP
  - ☑ Alstom_WA2-Alstom_SLP
  - ☑ GETS_WA1-GETS_SLP
  - ☑ GETS_WA2-GETS_SLP
  - ☑ SSC_WA1-SSC_SLP
  - ☑ SSC_WA2-SSC_SLP
  - ☑ US&S_WA1-US&S_SLP
  - ☑ US&S_WA2-US&S_SLP

SLP - OBLP Communications
- ☑ All SLP-OBLP Messages
  - ☑ Alstom_SLP-Alstom_OBLP
  - ☑ Alstom_SLP-GETS_OBLP
  - ☑ Alstom_SLP-US&S_OBLP
  - ☑ GETS_SLP-Alstom_SLP
  - ☑ GETS_SLP-GETS_OBLP
  - ☑ GETS_SLP-US&S_OBLP
  - ☑ SSC_SLP-Alstom_OBLP
  - ☑ SSC_SLP-GETS_OBLP
  - ☑ SSC_SLP-US&S_OBLP
  - ☑ US&S_SLP-Alstom_OBLP
  - ☑ US&S_SLP-GETS_OBLP
  - ☑ US&S_SLP-US&S_OBLP

SLP-SLP Communications
- ☑ All SLP-SLP Messages
  - ☑ GETS_SLP-SSC_SLP
  - ☑ SSC_SLP-US&S_SLP
  - ☑ US&S_SLP-Alstom_SLP

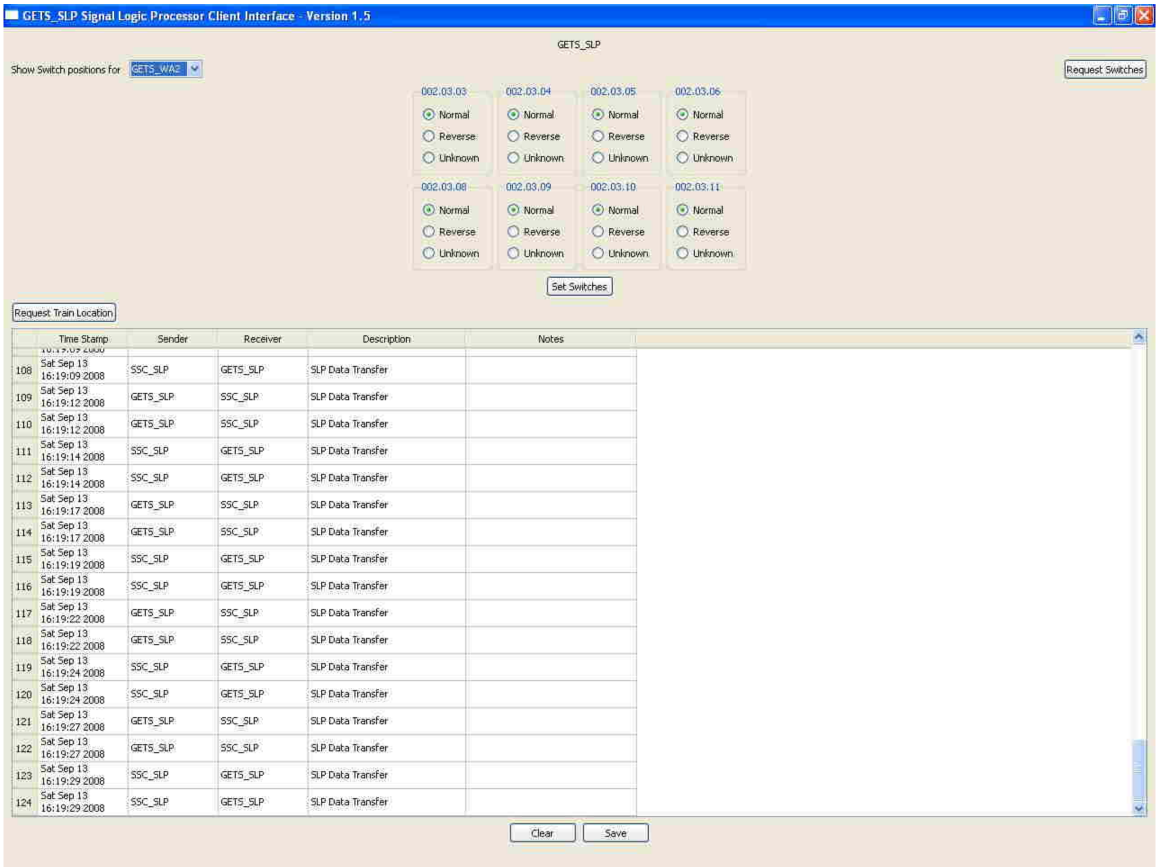
Double-click an entry below to see Message Details:

	Time Stamp	Sender	Receiver	Description	Notes
876	Sat Sep 13 16:22:29 2008	SSC_SLP	US&S_SLP	SLP Data Transfer	
877	Sat Sep 13 16:22:29 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
878	Sat Sep 13 16:22:31 2008	Alstom_SLP	US&S_SLP	SLP Data Transfer	
879	Sat Sep 13 16:22:31 2008	Alstom_SLP	US&S_SLP	SLP Data Transfer	
880	Sat Sep 13 16:22:32 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
881	Sat Sep 13 16:22:32 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	

Figure 4. CBS Communication Router

The upper portion of the screen shows each of the available communication paths. Each path can be individually selected and a delay time or error rate can be entered into that specific path. This feature will allow any future testing to closely simulate actual RF transmission delays (e.g., approximate different data transmission rates) or to simulate system response when a certain percentage of each transmission along that specific path is corrupted. The middle screen allows the user to select which of the transmission paths should be displayed in the lower portion of the screen. With this capability, the user can focus on messages among specifically identified subsystems to enhance debugging. The bottom portion of the screen shows in real time the messages being sent over the chosen links. Selecting any of the messages individually brings up a detailed screen showing the actual contents of the message (e.g., ATCS address, CBS message header, actual message contents). In addition, all of the data being seen can be recorded to a file for later analysis.

The SLP simulator reads an input file at start-up to set the states for signal and switch indications. For example, all the signals might be cleared for a movement in one direction on one track and the opposite direction on the other track. Messages are supported for links between the SLP, adjacent SLP, WAs and OBLPs. Figure 5shows the SLP simulator for the GETS territory. The upper portion of the display shows the status of all the switches in the territory. This can also be used to change a switch position causing the SLP to generate a switch position command message to be sent to the proper WA. The lower portion of the display shows all of the messages being handled by the SLP.



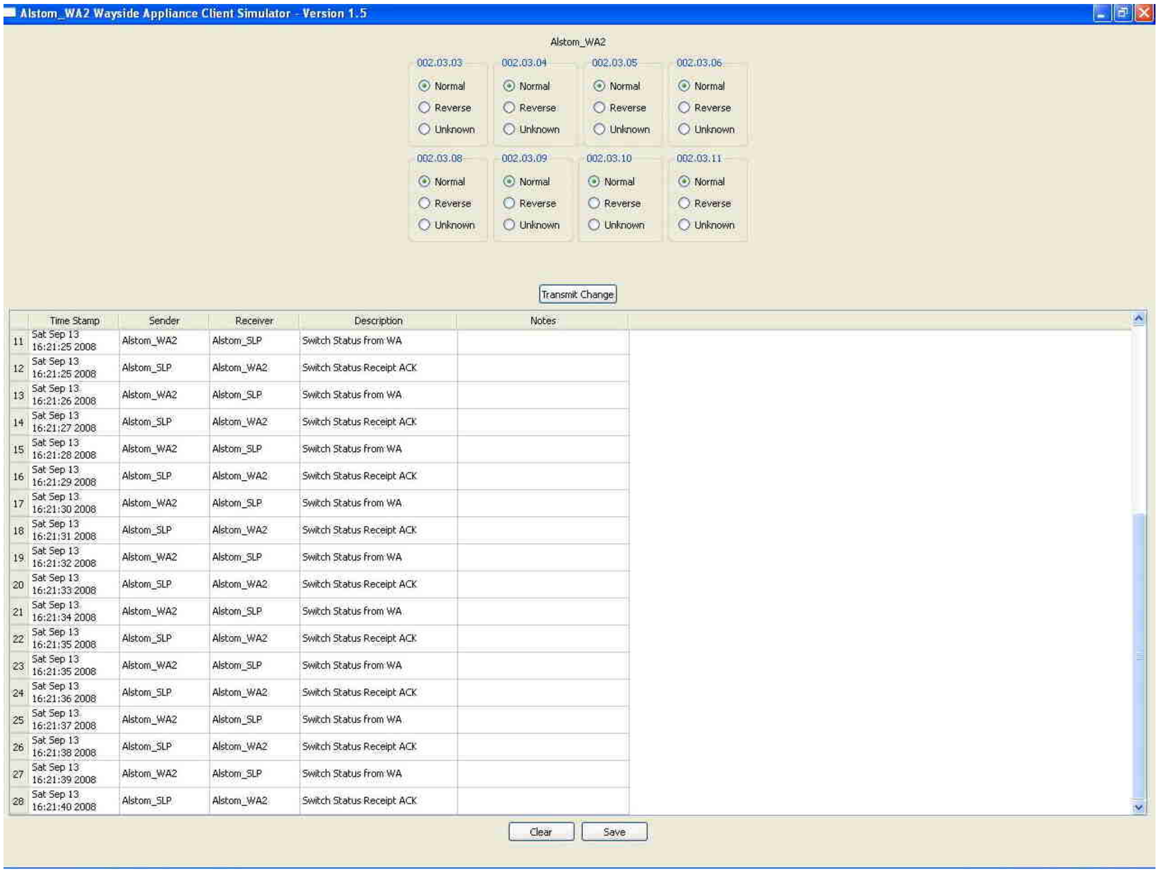
Show Switch positions for GETS_WA2

002.03.03: ● Normal ○ Reverse ○ Unknown
002.03.04: ● Normal ○ Reverse ○ Unknown
002.03.05: ● Normal ○ Reverse ○ Unknown
002.03.06: ● Normal ○ Reverse ○ Unknown
002.03.08: ● Normal ○ Reverse ○ Unknown
002.03.09: ● Normal ○ Reverse ○ Unknown
002.03.10: ● Normal ○ Reverse ○ Unknown
002.03.11: ● Normal ○ Reverse ○ Unknown

	Time Stamp	Sender	Receiver	Description	Notes
108	Sat Sep 13 16:19:09 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
109	Sat Sep 13 16:19:12 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
110	Sat Sep 13 16:19:12 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
111	Sat Sep 13 16:19:14 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
112	Sat Sep 13 16:19:14 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
113	Sat Sep 13 16:19:17 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
114	Sat Sep 13 16:19:17 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
115	Sat Sep 13 16:19:19 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
116	Sat Sep 13 16:19:19 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
117	Sat Sep 13 16:19:22 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
118	Sat Sep 13 16:19:22 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
119	Sat Sep 13 16:19:24 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
120	Sat Sep 13 16:19:24 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
121	Sat Sep 13 16:19:27 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
122	Sat Sep 13 16:19:27 2008	GETS_SLP	SSC_SLP	SLP Data Transfer	
123	Sat Sep 13 16:19:29 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	
124	Sat Sep 13 16:19:29 2008	SSC_SLP	GETS_SLP	SLP Data Transfer	

Figure 5. GETS Signal Logic Processor Simulator

The WA simulator (Figure 6) receives messages from the SLP causing switches to be moved, then sends the message back to the SLP when the actual movement has taken place. The upper portion of the display shows the status of the switches and the lower portion shows all of the messages passing through this particular WA. By selecting a different position for the switch than actually commanded to in the upper portion of the display, a switch can be forced to an improper position (or an unknown position) and the information sent to the proper SLP.



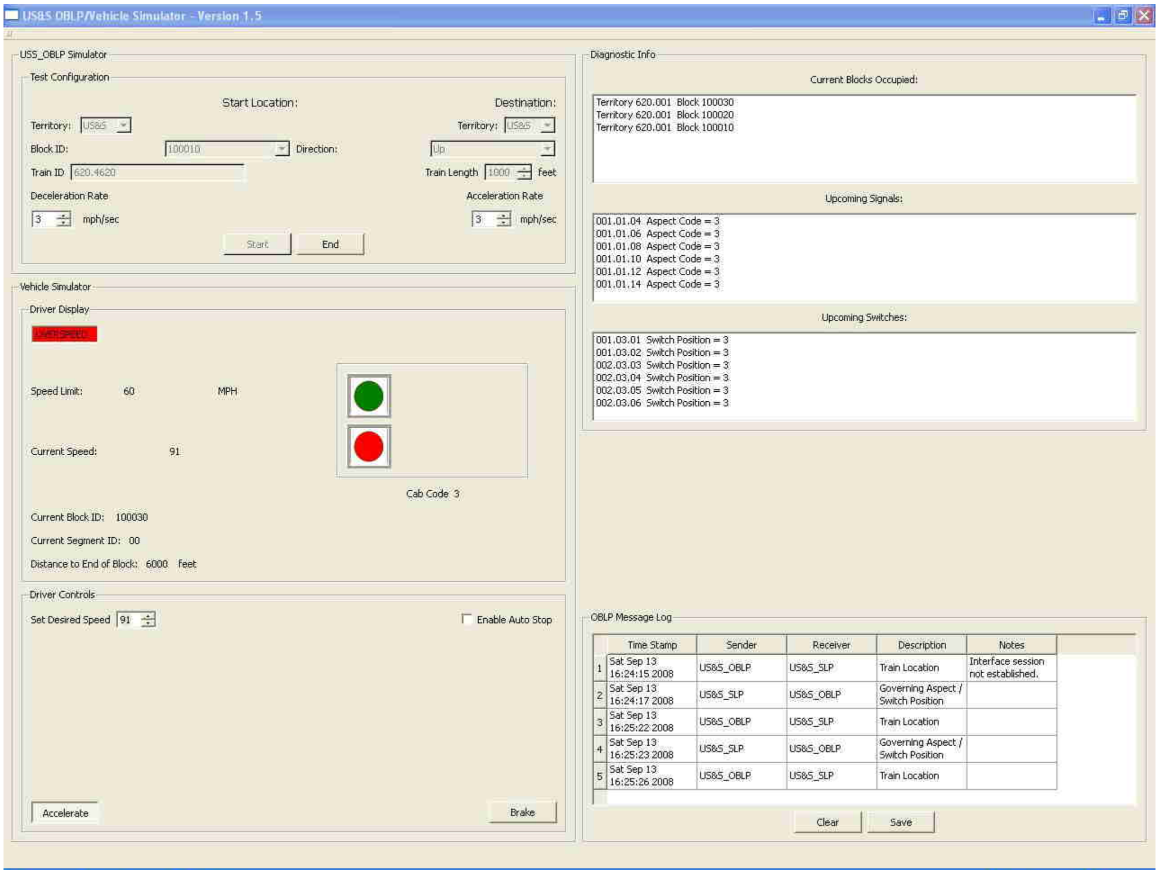
002.03.03: ● Normal ○ Reverse ○ Unknown
002.03.04: ● Normal ○ Reverse ○ Unknown
002.03.05: ● Normal ○ Reverse ○ Unknown
002.03.06: ● Normal ○ Reverse ○ Unknown
002.03.08: ● Normal ○ Reverse ○ Unknown
002.03.09: ● Normal ○ Reverse ○ Unknown
002.03.10: ● Normal ○ Reverse ○ Unknown
002.03.11: ● Normal ○ Reverse ○ Unknown

	Time Stamp	Sender	Receiver	Description	Notes
11	Sat Sep 13 16:21:25 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
12	Sat Sep 13 16:21:25 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
13	Sat Sep 13 16:21:26 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
14	Sat Sep 13 16:21:27 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
15	Sat Sep 13 16:21:28 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
16	Sat Sep 13 16:21:29 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
17	Sat Sep 13 16:21:30 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
18	Sat Sep 13 16:21:31 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
19	Sat Sep 13 16:21:32 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
20	Sat Sep 13 16:21:33 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
21	Sat Sep 13 16:21:34 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
22	Sat Sep 13 16:21:35 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
23	Sat Sep 13 16:21:35 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
24	Sat Sep 13 16:21:36 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
25	Sat Sep 13 16:21:37 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
26	Sat Sep 13 16:21:38 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	
27	Sat Sep 13 16:21:39 2008	Alstom_WA2	Alstom_SLP	Switch Status from WA	
28	Sat Sep 13 16:21:40 2008	Alstom_SLP	Alstom_WA2	Switch Status Receipt ACK	

Figure 6. Alstom Wayside Appliance Simulator

The OBLP simulator provides both vehicle movement simulation, and message handling capability for OBLP functionality. For the movement simulation, the upper left portion of the display is used to define the desired movement, from there, you can select the territory, block ID and desired direction where the simulator will initiate movement. You can also select the desired acceleration and deceleration rates for the train. When you start the simulation, the simulator initiates sending location messages from the specified location. At the lower left of the display, you can select the desired speed and choose to either accelerate or brake. After setting the desired speed, the accelerate button will cause the train to accelerate to and then maintain that speed. The simulator also has the capability of enforcing a stop prior to a absolute stop aspect (e.g., a red signal) being approached. This capability can be overridden by deselecting the “enable autostop function” on the screen. The center section of the display on the left shows the current cab signal aspect for the block being occupied, the identity of the block (and subsection of the block) being occupied, the current civil speed (as determined from the database), the actual speed, and the distance to the end of the block. If you have accelerated to a level above the currently allowed speed, the red overspeed indication will flash.

On the upper right side of the display, you can see the identities of the blocks being occupied by the entire train (from front to rear), as well as the status of the signals and switches being approached. The lower right portion of the screen shows all the messages sent and received by this OBLP.



Territory: US&S
Block ID: 100010
Train ID 620.4620
Deceleration Rate 3 mph/sec
Territory: US&S
Direction: Up
Train Length 1000 feet
Acceleration Rate 3 mph/sec

Speed Limit: 60 MPH
Current Speed: 91
Cab Code 3
Current Block ID: 100030
Current Segment ID: 00
Distance to End of Block: 6000 feet
Set Desired Speed 91

Current Blocks Occupied:

```
Territory 620.001  Block 100030
Territory 620.001  Block 100020
Territory 620.001  Block 100010
```

Upcoming Signals:

```
001.01.04  Aspect Code = 3
001.01.06  Aspect Code = 3
001.01.08  Aspect Code = 3
001.01.10  Aspect Code = 3
001.01.12  Aspect Code = 3
001.01.14  Aspect Code = 3
```

Upcoming Switches:

```
001.03.01  Switch Position = 3
001.03.02  Switch Position = 3
002.03.03  Switch Position = 3
002.03.04  Switch Position = 3
002.03.05  Switch Position = 3
002.03.06  Switch Position = 3
```

	Time Stamp	Sender	Receiver	Description	Notes
1	Sat Sep 13 16:24:15 2008	US&S_OBLP	US&S_SLP	Train Location	Interface session not established.
2	Sat Sep 13 16:24:17 2008	US&S_SLP	US&S_OBLP	Governing Aspect / Switch Position	
3	Sat Sep 13 16:25:22 2008	US&S_OBLP	US&S_SLP	Train Location	
4	Sat Sep 13 16:25:23 2008	US&S_SLP	US&S_OBLP	Governing Aspect / Switch Position	
5	Sat Sep 13 16:25:26 2008	US&S_OBLP	US&S_SLP	Train Location	

Figure 7. Union Switch & Signal OnBoard Logic Processor Simulator

When fully integrated, the demonstration showed the ability of trains controlled by different suppliers OBLP's (each simulating a different railroad) to seamlessly move through the four territory sections, each of which is controlled by equipment from a different supplier. The following figures show the equipment supplied by each of the suppliers.

Figure 8. ICBS project equipment located at the Critical Link facility

In Figure 8, starting from the left in the back are the GETS OBLP rack, the Alstom OBLP rack, the Alstom rack with SLP and WA, the GETS rack with SLP and WA, the Safetran rack with SLP and WA, and the US&S rack with SLP and WA. In the front of Figure 8 are two screens for the CAD system (one showing the complete territory and one with a more detail view). Next to those screens are screens for the communications router and other simulators if needed. Figure 9 shows a close-up view of the CAD screens.

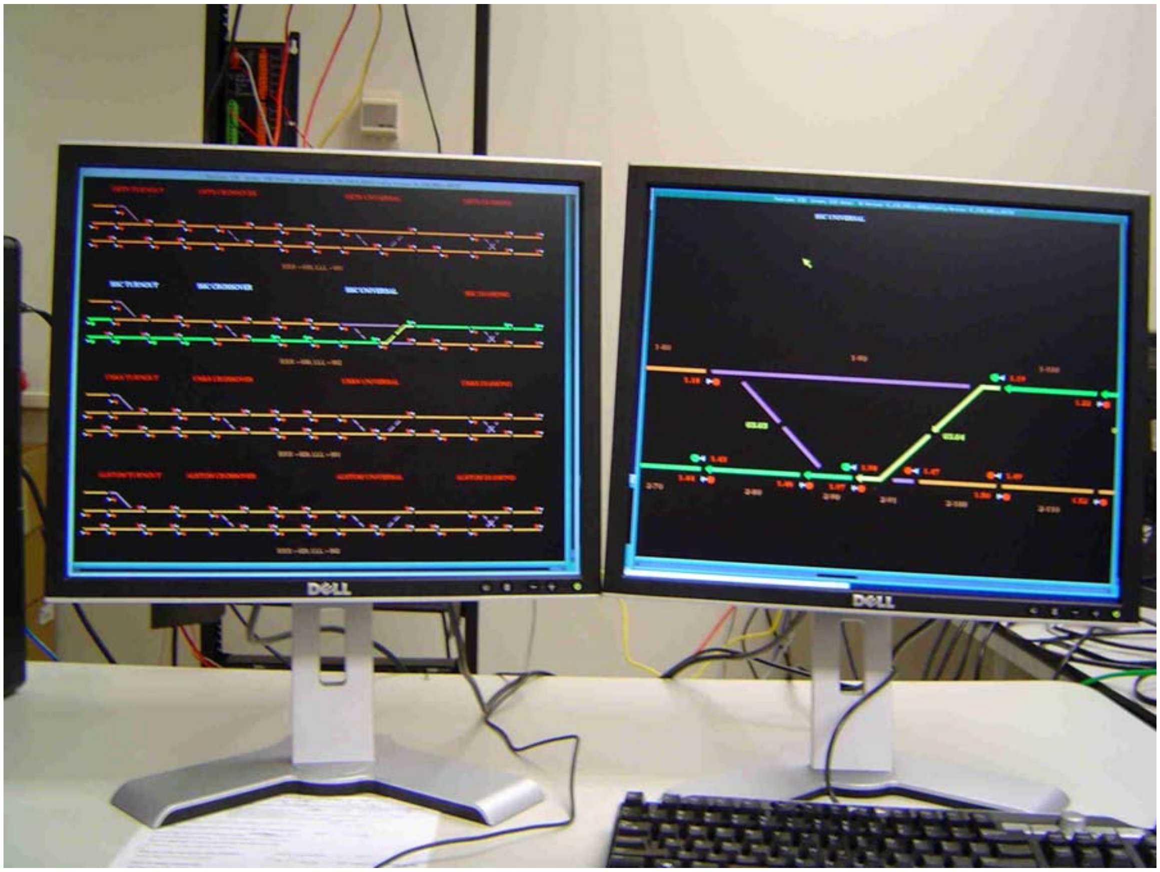


Figure 9. A close-up of CAD screens

The GETS UltraCab carborne equipment is also the equipment currently being used in revenue service on the incremental train control system (ITCS) system installed on the Michigan High Speed Rail Line as well as in revenue service for the ITCS installation in China. The CRT screen is used for their vehicle simulation as well as showing aspect information. The normal ITCS display is located to the left of the rack.

Figure 10 The GETS carborne equipment

The Alstom carborne equipment includes the MicroCabmatic™ equipment currently in revenue service. This is the same equipment that will be used for equipping the New York City area Metro North Railroad vehicles for ACSES and conventional cab signaling.

Figure 11. Alstom OBLP

The Alstom rack (see Figure 12) contains their SLP and WA. This equipment is based on their VPI® Vital Processor Interlocking product used widely in revenue service around the world.

Figure 12. Alstom SLP and WA

Figure 13. GETS SLP and WA

Figure 14. Safetran SLP and WA.

Figure 15. The Anslaldo-STS (US&S) equipment. Both their SLP and WA are based on their MicroLok® product line

With all the suppliers’ equipment in place, the following scenarios were verified as working. As a way of demonstrating that the overall architecture and message interoperability operated as intended.

- Control / Monitoring of power switches

  Starting with a request from the control office, a control message was sent via the GENISYS link to the appropriate SLP, the SLP verified that conditions permitted safely moving a switch and sent the CBS message through the communications router to the WA controlling the addressed switch. The WA changed the physical output controlling the switch and sent the appropriate CBS message to the SLP when the switch had been physically moved (simulated movement). The SLP then sent the indication back to the control office so that the control office could show the position of the switch in the field.

- Supplier A OBLP operation on Supplier B territory

  Each of the OBLP suppliers was controlled across all four sections of the test setup to demonstrate interoperability with all of the other suppliers. This included handoff from one section to another (additional details below). Various switches were thrown and signals cleared in front of the train movement so that a variety of routes were taken throughout the territory.

- Upgrade/Downgrade of Cab Signal

  Once in a block, the cab signal for a suppliers locomotive would be upgraded (changed to a less restrictive aspect) or downgraded (changed to a more restrictive aspect) by having the office request upgrades or downgrades of the signals in front of the train.

- Overspeed / Profile Stop

  Although not part of the interoperability Recommended Practices, the OBLP would cause the train to go into a braking mode if the train exceeded the civil speed allowed in the database, or cause the train to stop prior to an upcoming red signal (positive stop).

- Clear for following move with a second supplier 's OBLP following through the territory

  One suppliers' OBLP was controlled through the territory with a second suppliers' OBLP immediately following the first move (at a safe distance). This includes following moves between sidings—a property inherent to signal systems.

- Two suppliers' OBLP's proceeding in one direction (following moves) through a territory with a third OBLP (simulated to look like a third supplier) traveling in a different direction (on a different track or cleared for a route that would not put it in conflict with the first moves).

- Supplier A OBLP leaving Supplier B territory and entering Supplier C territory.

  This includes the ability to obtain signal and switch information from Supplier C for the OBLP before entering the territory, as well as conveying information back to Supplier B territory allowing the blocks to be cleared after the OBLP has left the territory. This also included verification that "traffic" logic was defined, which would prevent two trains from being cleared for movements toward each other at supplier boundaries.

- Change in the available onboard information when the switch and signal status is changed on the planned route.

  This verified that Supplier A locomotive could see information from changes in Supplier C route status (e.g. switch and signal information) prior to entering Supplier C territory.

As expected, we learned new information as the detailed designs of the subsystems and messages were implemented by each of the suppliers. Continuous communication among the participants keeps everybody aware of corrections or enhancements that are necessary for the successful implementation of the project.

Lessons learned from this demonstration project were used to enhance and expand these manual parts, but subject to committee approval. Status reports are provided to AREMA Committee 37 as well as other interested parties, such as the AAR Railway Electronics Standards Committee (RESC). These lessons learned were used to update the AREMA Manual Parts described above and they have been submitted to AREMA Committee 37 for approval. Most likely, they will be published in the upcoming 2010 Manual of Recommended Practices for Communications and Signaling.

Successful completion of this demonstration showed a high level of cooperation among the principal suppliers of signaling systems for North American railroads toward implementing an interoperable system that should serve the railroads well for the long-term future. The CBS approach can be viewed either as a complementary enhancement or an alternative to overlay systems currently being tested by some North American railroads. Overlay systems are safety justified based on the underlying method of operation being maintained, if that underlying method be rules-based (e.g., dispatcher issued train orders) or signals-based (cTc). Without the ability to change the underlying method of operation, operating efficiencies are more difficult to achieve, such as closer spacing, increased velocity, or the ability to support following moves between switching points. Because CBS is based on well-accepted signaling principles and implementations are based on proven safety-critical architectures (many already in revenue service), CBS can be used as a stand-alone system allowing replacement or enhancement of the existing method of operation. Removing the physical limitations of existing wayside-based cTc systems provides for improved performance (e.g., ability to increase traffic density by shortening block length or by increasing the number of signal aspects available). Additional capabilities through the use of digital radio transmission allows for continuous onboard display of signal aspects, which allows them to be updated mid-block as well as providing continuous speed enforcement.

3.0 References

[1] AREMA Manual of Recommended Practices on Communications and Signaling (2009), www.arema.org