IDEA

Innovations Deserving Exploratory Analysis Programs

Monitoring Train Position to Improve Emergency Response

Final Report for
Safety IDEA Project 10

Prepared by:
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April 2008

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

**INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA)
PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD**

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EXECUTIVE SUMMARY

Known as "Civil Overviews", the train monitoring system developed in this Safety IDEA project is intended for use by emergency response personnel to monitor the locations of freight and passenger trains in and around their towns and cities, enabling them to more effectively dispatch emergency vehicles. Knowing which rail crossings are currently blocked by trains and which will be blocked in the near future will inform routing decisions and, therefore, help reduce delays in responding to emergencies. This makes the Civil Overviews system an important tool for civil/municipal authorities who must deal with trains in the course of dispatching emergency vehicles.

The system offers a secure, easy-to-understand depiction of tracks, trains, and crossings in the vicinities of towns and cities, and will be located primarily in emergency dispatch centers. The computer-based display presents a map (see Figure 1 below) on which the positions of trains, the tracks over which they currently have authorities to move, direction of travel and markers indicating the locations of grade crossings are overlaid. The maps also display streets, roads and highways along with landmarks and other points of interest. Emergency personnel are thus able to monitor where trains are and where they have authorities to move, which will help them make decisions about which roads emergency vehicles should follow when it is necessary for them to cross the tracks.
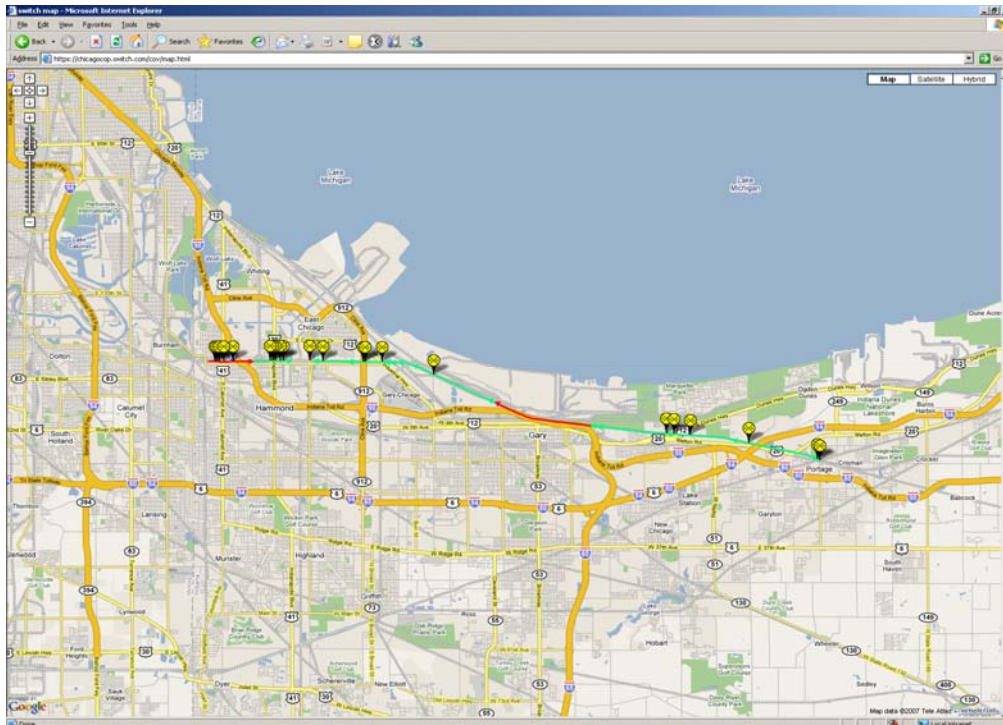
Figure 1 Google Map showing track occupancies by trains (red) and train movement authorities (green).

The Civil Overviews system receives train location information from the railroads, which may be in the form of track occupancies or, where available, GPS coordinates (this project used track occupancies), and train movement authorities. This information is updated in real or near real time and displayed on a Web-based geographical information system (GIS) display of the area being monitored. CSX railroad committed to providing Union Switch & Signal (US&S) with live data from their central traffic control system as well as technical and operational assistance (CSX's central traffic control system is the nerve center of the railroad, which keeps track of the locations of trains and the states of track, signals and switches in real time across the entire railroad). CSX also provided GPS coordinate information for their tracks in the area monitored by the Civil Overviews system for this project.

Web-based technologies—Google Maps, web-browsers and the internet—on which the Civil Overviews train monitoring system is based, offer a low cost means for emergency response facilities to access train location information. Users' computers require only a browser (Microsoft Explorer for this version of Civil Overviews) and Google Maps. The availability of train location data will also strengthen the often strained relationships between civil/municipal authorities and the railroads. The security of this railroad data is maintained using SafeWord authentication, VPN (virtual private network) connections and firewalls.

The Civil Overviews train monitoring system comprises two main components: the system architecture and the map-based display. The architecture consists of several servers, client displays, network connections and software. Data from one or more railroads that move trains across the region are received in a standard format by a central COV (Civil Overviews) Web Application server. There is a VPN connection between the data server at the railroad and the COV Web Application Server, which uses encryption to secure the railroads' data. Users access the COV Web Application server through a secure socket connection (https) to a Web Login server. The server authenticates the users at login, after which they receive the requested data.

For this project, the Civil Overviews system was used to monitor CSX trains in the 4-cities region south of Chicago in the vicinity of Gary, Indiana. The tracks over which the trains are monitored run from Portage, Indiana to the Indiana-Illinois state line (this is the region depicted in Figure 1 above). GPS coordinates of track circuits, which demarcate sections of track for purposes of locating trains, enable those sections to be overlaid on a Google map of the area. As trains move along the tracks, the sections of track occupied by the train turn red and track sections for which authorities have been given to trains to move across are highlighted in green. The latter track sections will inform emergency response personnel about near-term train movements. The graphic display also allows users to zoom and pan, which is a feature of Google maps.

The Civil Overviews system has the potential to be deployed. Five Class 1 railroads account for most of the trackage in the US, so it would require working with the railroads to get the Civil Overviews system installed in towns and cities through which they run.

IDEA PRODUCT

The Civil Overviews application was built on the CAD Enterprise Services (CADES) architecture, which is a Services-Oriented Architecture (SOA) that separates into two layers the service application(s) and the presentation of data and other information from those services. Figure 2 below depicts this architecture for the Civil Overviews service. Only the web browser display is printed in black letters, since that is the particular presentation of the service's data employed on this project (the other display devices, e.g., handheld wireless devices, are shown as examples of what is possible with a Services-Oriented Architecture).

The Services Components in the figure (applications) generate data that will be provided to the Presentation Delivery Framework for display. For example, if a user is requesting train information, the train service component can retrieve the information from the Data Access component and send a train object to the Presentation Delivery Framework. That framework determines how the user wants to see the data along with the particular device that will be used to display it, and formats the information accordingly.
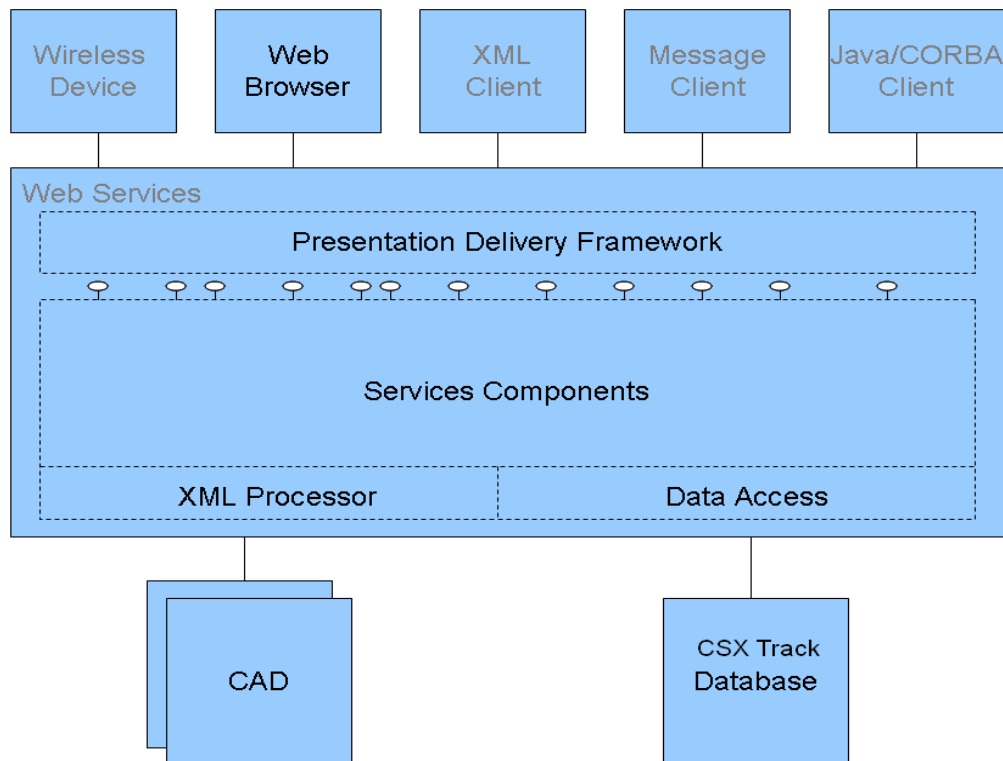
Figure 2 Civil Overviews Service-Oriented Architecture

The Services-Oriented Architecture is a software architecture that is implemented on a web server. This web server is part of a larger physical network architecture that connects the users of the Civil Overviews system with the data they will be monitoring. Figure 3 shows a schematic of this architecture. At the bottom is the railroads' central traffic control system (also known as a Computer-Aided Dispatching (CAD) system) and at the top are the users. The Civil Overviews (COV) Application Server sends updates to users' screens as it receives data from the railroad.

The railroad's CAD system at the bottom of the figure sends data to a server (Gateway) that translates it into an XML-specified common data format and sends it encrypted, through a site-to-site VPN with the IPSEC protocol to the MQ server via the internet (VPN and MQ Server are not shown). Note that the common data format was written by US&S independently of this project for purposes of translating *any* railroad's data format into a common one.

Depending on the railroad, the gateway may be a dedicated server, an application running on an existing server, or even part of the CAD system itself. Though not expected to do a great deal of processing, a railroad's Gateway may reside on a stand alone server to insure network security from the Gateway to the MQ server. The Gateway will connect to the MQ server as an MQ client sending updates and retrieving full update requests from the COV Application Server.
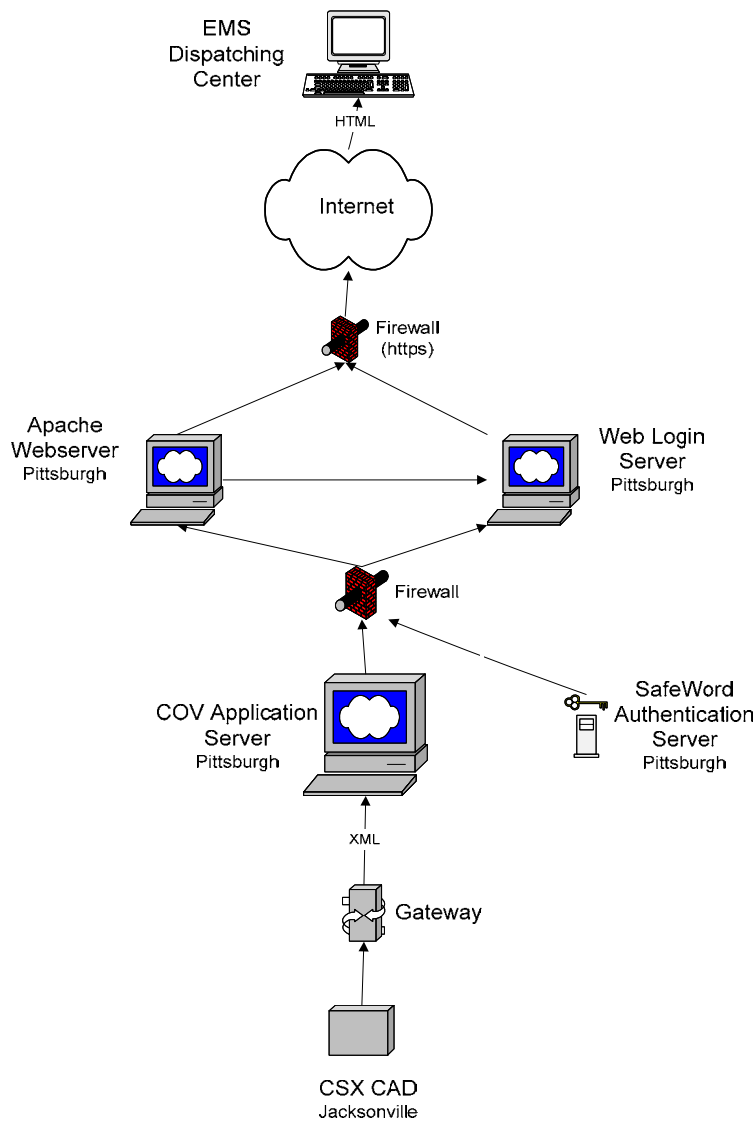
Figure 3 Civil Overviews Network Architecture

The Gateway server only sends data pertaining to the track that the Civil Overviews system is monitoring. When the COV Application Server starts up, it sends a request for all the data for the track it is supposed to monitor. The Gateway uses this set to filter out the track it should monitor.

The COV Application Server will create an input queue and an output queue for each railroad it connects to (when there are multiple railroads running through a town or city). These queues are automatically removed when the COV Application Server is down to make sure messages will not be queued up and get stale. The server will send a full update request to each railroad when it determines that it must retrieve a complete state from each railroad. This includes start up, when it sends each railroad a list of the tracks it is interested in. There is a point-to-point queue set up for incoming messages from the railroads.

On the user side of the COV Application Server, users log in using a browser secured by SSL (Secured Socket Layer), which only allows requests made to port 443, the standard port for https. Login security is implemented through a SafeWord key fob for authentication, which, at least for this project, is provided by US&S.

When a user logs onto the system, he or she is logging onto the UWA/Apache Server located at US&S in Pittsburgh. The UWA listens for all requests made to the COV Application Server on port 443. Only requests made to port 443 will be allowed by the UWA/Apache Server. If the user is not authenticated via the SafeWord Authentication Server, the request is redirected to the Web Login Server, also located in Pittsburgh which then authenticates the user (assuming he or she is authorized to access the system).

Communication between users and the UWA/Apache Server are encrypted using a certificate purchased from a trusted certifying authority. All requests first pass through the UWA to the Apache Web Server using http to a specific port if the user is authenticated. Because this port is blocked from receiving any external requests, the http request does not have to be encrypted.

The Apache Server will serve static files such as JavaScript files and images, so the COV Application Server does not have to process those requests. All other requests will be forwarded to the COV Application Server for processing using http to a specific port. The COV Application Server can only receive requests from the Apache Server.

Security on this system is paramount. The data belongs to the railroads and is considered proprietary for both security and business reasons. This is why adequate protection mechanisms are part of the network architecture, including the VPN connections, firewalls, and user login authentication through the Apache and Web Login servers. Furthermore, in a fully functioning system, the railroads will maintain a list of who among emergency responders is authorized to view the displays.

Once the train location and authority information is integrated into Google maps, the only remaining information to be displayed is the direction of the train's movement and crossing indicators. The crossing indicators are represented as "pins" on the map, which is how Google Maps specifies particular locations. Figures 4 through 6 below are snapshots of trains passing along the section of track being monitored for this project.
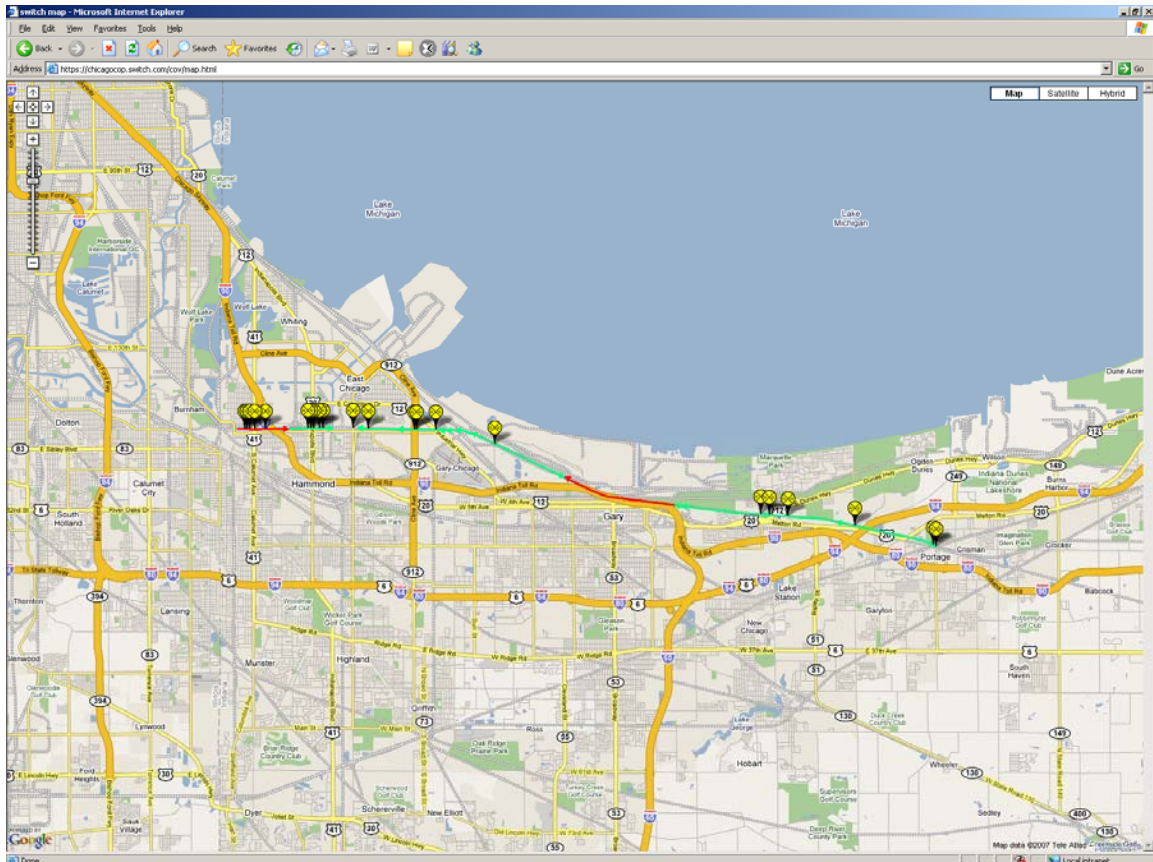
Figure 4 Google Map showing two trains (red), one traveling East and the other traveling West over double track territory. Their respective authorities are in green. There is a third train moving West, but only its authority (green) can be seen because the coverage for this CSX region starts at Portage, IN, and the train is East of that location. Crossing "pins" indicate the locations of crossings.

Users will also be able to pan and zoom within the area covered by the Civil Overviews application to view specific locations or the entire region as desired.

As can be seen in Figure 4, first responders will only be able to view trains in a specified area (Portage in that figure is the East most point). This helps the railroads restrict how much data about their railroad can be viewed by any individual. When a user logs in, only the region that user is authorized to monitor—the particular municipality to which they belong—will be accessible.
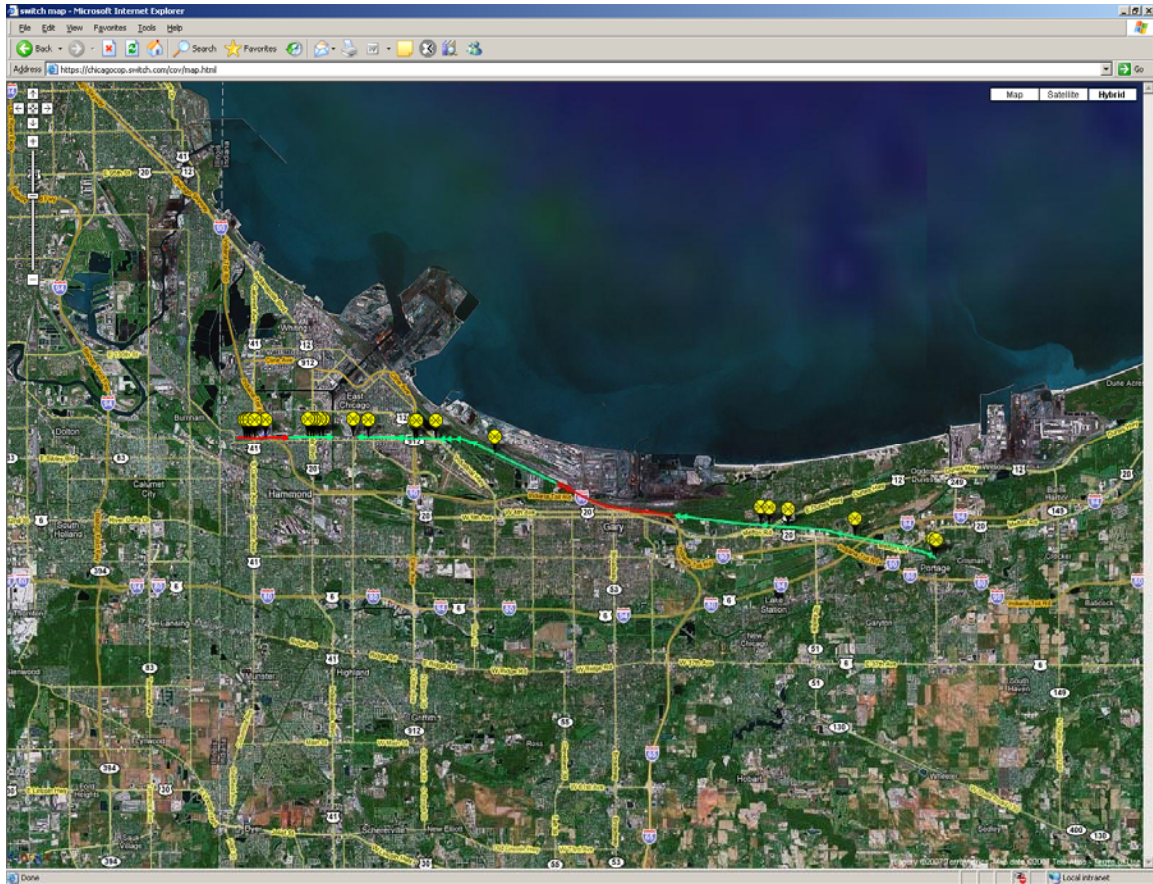
Figure 5 Google Map overlaid on a satellite image of the same region as depicted in Figure 4.
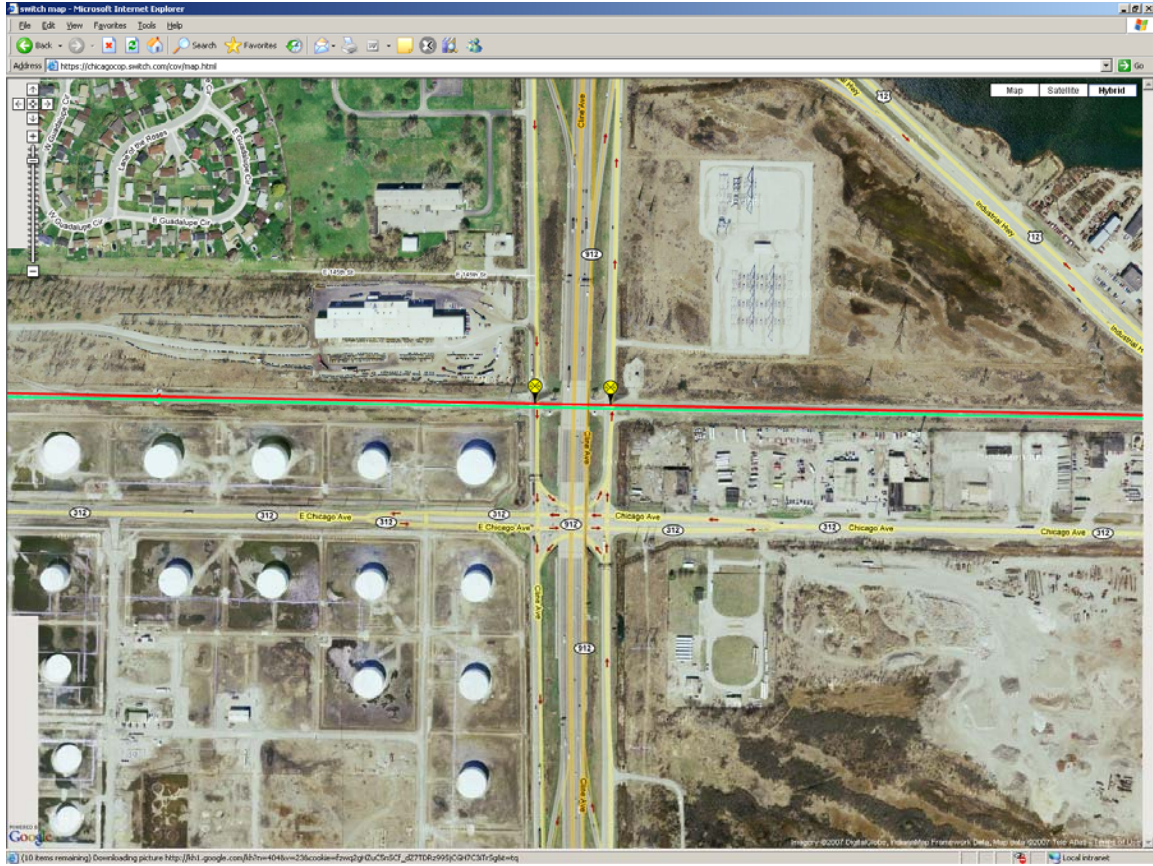
Figure 6 Google Map overlaid on satellite image of the same region as shown in Figures 4 and 5, but zoomed in much closer. There is one train (red) and another train's authority (green). The two trains are about to pass in double track territory. Two crossings are indicated by crossing "pins". Between the pins there is a highway overpass, which is why there are no crossing indicators.

CONCEPT AND INNOVATION

The basic idea behind the Civil Overviews train monitoring system is providing low-cost, real-time access to railroad data for people that must interact with that mode of transportation in the course of carrying out their jobs. This particular Civil Overviews application involves emergency response and addresses the need for emergency response vehicles (fire, police, medical) to cross railroad tracks on the way to an emergency. The system helps to integrate two otherwise independent modes of transportation.

The system is innovative in its use of existing web-based technologies and software available through the internet to create this application. Because the CADES architecture is a Service Oriented Architecture (SOA) the Civil Overviews system can easily be configured for different kinds of displays (laptops, handhelds, etc.) and presentations of the data (tables, maps, etc.). It uses VPN technology, encryption and firewalls to secure what is otherwise a public network, and it exploits the concept of a "mashup" that merges data from multiple sources—in this case,

railroad data and data available from Google Maps—to create a new web application. All of these technologies were combined into a web-based system that is low-cost and highly flexible.

INVESTIGATION

The following steps provide a high-level outline of the work done on this project to complete development of the Civil Overviews train monitoring system.

Step 1. The CADES architecture developed at Union Switch & Signal Inc. (US&S) was applied to the Civil Overviews Train Monitoring application. This required modifying the application and display layers of the architecture for this specific application.

Step 2. The geographic information system (GIS) database was set up. The CSX track database—that portion of the database used for this project—was converted from a standard non-geographically based track layout to one that includes GPS coordinates (see Appendix A). Selection of the particular municipality was made in conjunction with CSX railroad.

Step 3. Development of the interface to US&S' central traffic control system was straightforward, since US&S built CSX's central traffic control system. The interface, which was written in XML by US&S independently of this project, provides the Civil Overviews system with real-time dynamic train location data. The interface is open so that it can be used by any railroad to convert their internal proprietary data formats to this publicly available one.

Step 4. Development of the user interface involved mashing track and train location data with cartographic information provided by Google Maps. Besides the data, only Microsoft's Internet Explorer web browser is required to monitor trains. Panning and Zooming are features of Google Maps. Railroad-related information for display includes train locations (through track section occupancies), train movement authorities (also via track sections), direction of train movement, and crossing indicators.

Step 5. The various parts of the Civil Overviews architecture were set up and integrated in the lab. They include the COV Application Server, Web Login Server and Apache Server as well as client machine(s). A connection to the CSX CAD system was also established.

Step 6. The system was thoroughly tested in the lab. There was no need to first test it on a simulator because US&S has a direct connection to live data from CSX. So testing was done with live data from the beginning. Figures 4 through 6 above are snapshots of the display screen taken during the test period.

Currently, anyone with authorization to use the system, a key fob password from SafeWord, a computer with Google Maps and Microsoft Internet Explorer installed, and access to the internet can receive train data and monitor train movements across the specific area selected for this project. Setup time is minimal.

PLANS FOR IMPLEMENTATION

The Civil Overviews train monitoring system will be tested at an emergency dispatch facility in the 4-cities region as soon as CSX decides to move forward with field testing. Currently, CSX has

dropped their participation in a field test in the project for internal reasons. In light of this, US&S is investigating the possibility of conducting field tests with another railroad. Union Pacific railroad is currently the most promising candidate. The company is the interested in building a geographical information system display of their entire railroad, which would provide the track coordinate database required to run the COV application. Preliminary discussions with Union Pacific managers indicate that they would be open to supporting a field test.

The following steps outline the Civil Overviews system deployment and testing at any field test site.

Step 1. Visit municipal authorities from the selected field test site and determine location (dispatch facility) for user displays. Location must already have computers and access to the internet.

Step 2. Set up appropriate authorizations in the CSX track database server. This will involve setting up proper login files with user names and passwords. Users at the field site will also be provided with a key fob.

Step 3. Bring system up and initialize (logon, download rail database information, bring up Google Maps, etc.). Emergency personnel at the facility will be trained on how to use the system and how to interpret what they are looking at on the screen. They will be allowed to use the system for an extended period of time.

Step 4. Data on the routing of emergency vehicles will be collected by emergency personnel for an extended period (e.g., a couple weeks). The data will be analyzed for frequency of emergency vehicle re-routes due to the presence of trains. Dispatching personnel and other users will compare the results with what would have been done without the Civil Overviews system.

Beyond field testing US&S plans to work with the railroads to implement Civil Overviews in municipalities across the country. In addition to CSX, the COV architecture is currently able to receive data from Union Pacific railroad and Burlington Northern Santa Fe (BNSF).

CONCLUSIONS

The Civil Overviews system is fully functional and ready to be deployed. The screen display includes all required features, and the architecture, as depicted in Figure 2, is set up for receiving CSX data. User authentication is necessary for someone to use the system and the COV Application Web server is up and running at US&S' facilities in Pittsburgh.

The primary benefits of the Civil Overviews system in its current form are 1) improvements in response times to reach emergencies by first responders when blocked railroad crossings are a factor, and 2) increased integration/coordination between two different modes of transportation. The system could also be used to benefit the traveling public by displaying the locations of trains at commuter and metro stations (in addition to the predicted arrival times that are frequently displayed).

US&S plans to work with the railroads to implement the Civil Overviews system nationwide. The first two railroads it will work with are CSX and Union Pacific because both railroads have

US&S central traffic control systems, which are already accessible to US&S. Once there are a number of installed systems at municipalities through which these railroads run trains, US&S will approach the other Class 1 railroads, Norfolk Southern and BNSF, as well as Kansas City Southern. As the system is installed in emergency response facilities in various towns and cities, US&S will maintain the COV Web Application servers in Pittsburgh, providing a 24x7 service. Civil Overviews will thus become a SaaS (Software as a Service) application for US&S.

PRINCIPAL INVESTIGATOR PROFILE

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Appendix A: CSX Area Track Diagrams

7088322148   CSX Division North   09:44:53 a.m.   02-16-2007   1 /
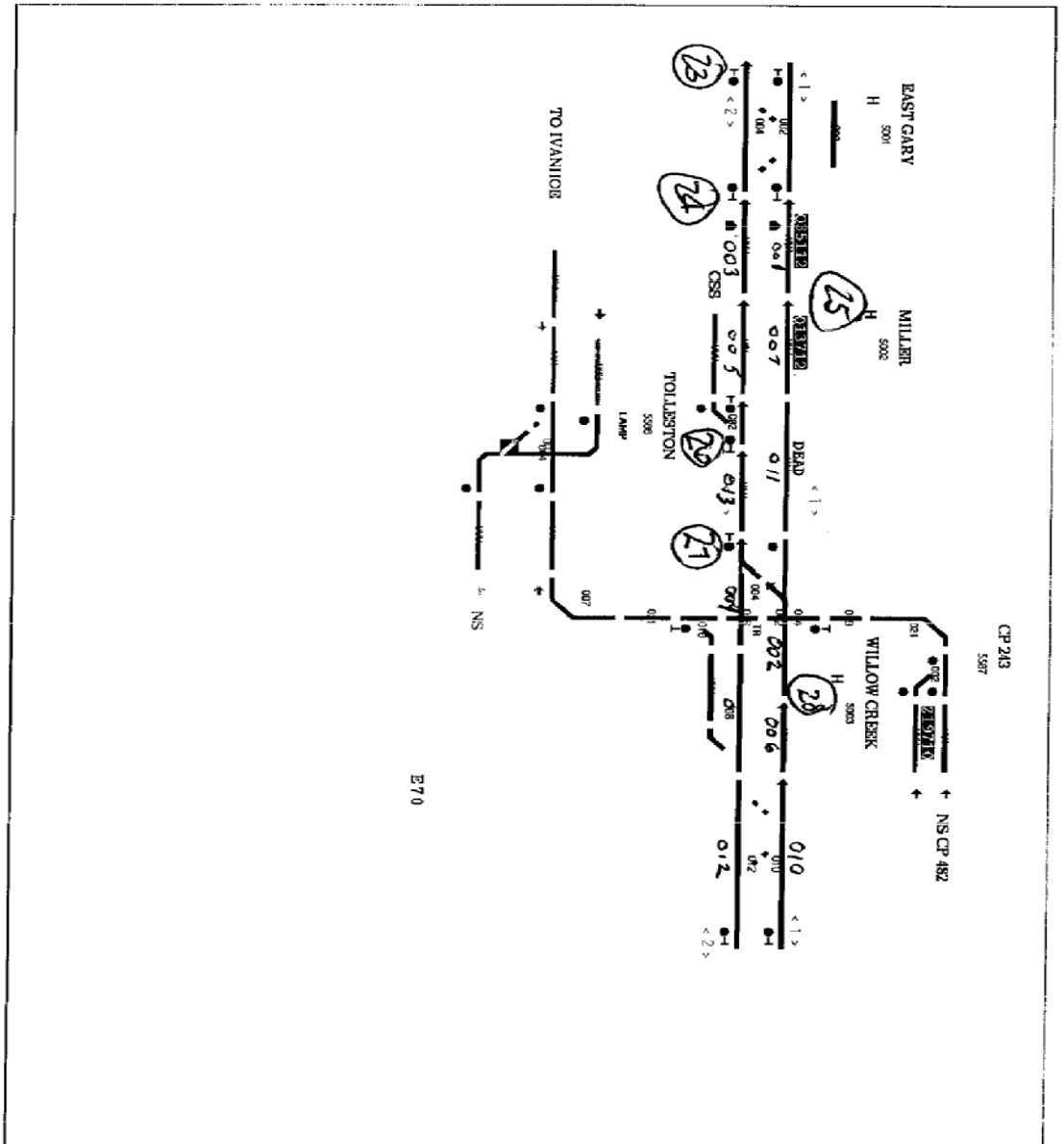
7088322148   CSX Division North   09:45:00 a.m.   02-16-2007

CSX Transportation
Four Cities - Crossing Project
Track Circuit Endpoint Coordinates

Location		Coordinates			Location		Coordinates		
8	N	41°	37.820	'	21	N	41°	36.804	'
	W	87°	31.317	'		W	87°	21.764	'
9	N	41°	37.813	'	22	N	41°	36.721	'
	W	87°	31.014	'		W	87°	21.525	'
10	N	41°	37.820	'	23	N	41°	36.152	'
	W	87°	29.619	'		W	87°	18.377	'
11	N	41°	37.839	'	24	N	41°	36.134	'
	W	87°	28.357	'		W	87°	18.174	'
12	N	41°	37.839	'	25	N	41°	35.961	'
	W	87°	28.286	'		W	87°	15.890	'
13	N	41°	37.840	'	26	N	41°	35.774	'
	W	87°	37.805	'		W	87°	13.660	'
14	N	41°	37.829	'	27	N	41°	35.336	'
	W	87°	27.605	'		W	87°	11.155	'
15	N	41°	37.826	'	28	N	41°	35.276	'
	W	87°	27.467	'		W	87°	10.995	'
16	N	41°	37.815	'	29	N	41°	35.142	'
	W	87°	26.304	'		W	87°	10.495	'
17	N	41°	37.798	'					
	W	87°	25.106	'					
18	N	41°	37.794	'					
	W	87°	24.932	'					
19	N	41°	37.789	'					
	W	87°	24.660	'					
20	N	41°	37.676	'					
	W	87°	24.212	'					