National Transportation Safety Board
Washington, DC 20594

Railroad Accident Brief

Accident No.:	DCA-12-FR-004
Location:	Madison, Illinois
Date:	February 28, 2012
Time:	11:57 a.m. central standard time[1]
Railroad:	Amtrak (National Railroad Passenger Corporation)
Vehicle:	2007 Pontiac Grand Prix four-door sedan
Property Damage:	$3,794
Fatalities:	1
Injuries:	None
Type of Accident:	Highway-rail grade crossing collision

The Accident

On February 28, 2012, at 11:57 a.m., southbound Amtrak train 301-28, traveling on Union Pacific Railroad (UP) Springfield Subdivision main track 2, collided with an eastbound vehicle at the Bissell Street highway-rail grade crossing (crossing) in Madison, Illinois. Two UP signal employees were working in the UP warning system signal bungalow for the crossing when the accident occurred. Locomotive video recorder data indicated that the crossing warning system did not activate before or during the collision. The vehicle driver died as a result of the collision.

Amtrak train 301-28 was en route from Chicago, Illinois, to St. Louis, Missouri. The train did not derail. The train crewmembers and passengers did not sustain any injuries. Damages were estimated at $3,794. The temperature at the time of the accident was 48°F with partly cloudy skies and wind from the southeast at 2 mph.

UP Personnel

On February 28, 2012, the UP signal electronic technician (technician), who was assigned to the territory that included the Bissell Street crossing, awoke about 6:00 a.m. He departed his residence at 6:25 a.m., made two work stops, and then began driving to the Bissell Street crossing.

[1] All times in this brief are central standard time.

The signal inspector (inspector) awoke about 5:30 a.m. He arrived at the St. Louis, Missouri, Gateway Train Station Depot and reported on duty at 6:45 a.m. He departed the depot about 8:30 a.m. for a 2-hour drive to the Bissell Street crossing to meet the technician.

About 7:00 a.m., the technician stopped on the side of the road to join a conference call with the signal manager and other technicians. During the call, the technician discussed his work plans for the day, which involved performing software upgrades and audits. At the conclusion of the call, the technician continued driving to the St. Louis area and arrived at the Bissell Street crossing about 10:00 a.m.

As the technician began work at the Bissell Street crossing, he opened the computer-aided dispatching (CAD) software on his laptop computer and reviewed the timetable. He told National Transportation Safety Board (NTSB) investigators that he had observed three signal bungalows located within the Bissell Street crossing: the UP signal bungalow, an out-of-service bungalow, and a Norfolk Southern Railway Company (NS) bungalow.[2] He also stated that upon entering the UP signal bungalow, he noticed that some electronic equipment needed bar codes applied for inventory purposes.

The technician stated that the inspector arrived soon after he did, sometime between 10:15 a.m. and 10:30 a.m. The technician and the inspector held a job briefing to discuss the software upgrade that they were going to perform. The inspector stated that as he familiarized himself with the physical layout of the tracks and the signals, he noticed there were two UP main tracks and one NS main track. He also stated that he could clearly see that the UP was not the sole controller of the crossing. The technician and the inspector reviewed the signal circuit prints[3] to better acquaint themselves with the crossing and how it operated. They called the UP train dispatcher (dispatcher) on the telephone and requested a track and time permit[4] for UP main track 1. The dispatcher issued the track and time permit through the CAD on the technician's laptop at 10:55 a.m. The permit pertained to the area between control point 276 and control point 278 on UP main track 1 and was valid until 11:45 a.m.

The technician connected his laptop to the microprocessor of the primary highway-rail grade crossing predictor (GCP) 3000 unit[5] for UP main track 1 and performed a bootloader installation.[6] The technician then loaded a software upgrade onto the primary GCP-3000 unit. When the software upgrade was completed, the technician entered the programming parameters previously established for that crossing. The technician then repeated the process to upgrade the software on the standby GCP-3000 unit for UP main track 1.

[2] An NS track was parallel to the two UP tracks.

[3] *Signal circuit prints* are wiring diagrams that also convey track circuit lengths and frequencies.

[4] A *track and time permit* is a method of establishing working limits on controlled track in which a worker is notified by the train dispatcher or control operator that no trains will operate within a specific segment of controlled track until the worker reports clear of the track.

[5] Safetran manufactured the microprocessor unit, known as model GCP-3000D2, which is designed to detect trains and activate warning systems. In this brief, the microprocessor unit will be referred to as the GCP-3000 unit(s).

[6] The *bootloader installation* loaded a basic input/output system (BIOS) boot software onto the GCP-3000 unit.

The inspector worked on his laptop[7] in his truck while the technician worked in the UP signal bungalow. The inspector stated that he saw the flashing lights activate and the gate arms (crossing warning devices) lower for about 3 to 5 minutes, but he did not see any trains while he was in his truck.

The technician stated that he did not believe he was required to obtain a track and time permit when performing a software upgrade on the GCP-3000 units. He explained, however, that he had obtained a track and time permit for UP main track 1 to prevent any rail traffic from occupying the crossing train detection circuits during the recalibration of the GCP-3000 units. Although the technician followed the manufacturer's instructions for upgrading the software, the technician's assumption that he did not have to obtain a track and time permit before upgrading the software was incorrect. The software upgrade required cycling the GCP-3000 units on and off, which removed the unit from service. Cycling off the GCP-3000 units and removing them from service interfered with the operation of the crossing warning system and, therefore, required obtaining track and time permits for all three tracks before beginning the work.

The technician stated that he released his track and time permit on UP main track 1 electronically using his laptop and noticed the train dispatcher had routed trains through the area on UP main track 2. The CAD data log indicated that the technician had released the track and time permit at 11:35 a.m.

Shortly after releasing the track and time permit, the inspector entered the UP signal bungalow and started applying bar codes to the electronic components. He stated that the technician's laptop was connected to the primary GCP-3000 unit for UP main track 2 and he did not recall seeing the technician using any jumper wires.[8] He further stated that he could not see whether the lights and gate arms were activated while he was working inside the UP signal bungalow.

The technician stated that he attempted to call the dispatcher two or three times before beginning work to upgrade the software on the GCP-3000 unit for UP main track 2 but received a busy signal. He resumed working—installing the bootloader—without a track and time permit on any of the main tracks.

The technician stated that there was a considerable amount of highway traffic at the Bissell Street crossing; however, he stated he did not use a jumper wire. The technician also stated that he assumed but did not verify that the crossing warning devices would activate when cycling the GCP-3000 units off to upgrade the software.

Although the software upgrade did not require using a jumper wire, using such a wire could have prevented the crossing gate arms from activating and stopping highway traffic.

The technician estimated that he had completed about 100 software upgrades on other GCP-3000 units. The inspector stated that UP signal management considered the upgrades a

[7] The inspector stated that he was unable to connect to the Internet and was working on his laptop to resolve the connection problem.

[8] A *jumper wire* is a short conductor that is placed between two electrical terminals to bypass an intended circuit.

priority and had motivated all inspectors and technicians to install the upgraded software as quickly as possible because the railroad was subject to increased liability without it.

Vehicle

A 2007 Pontiac Grand Prix four-door sedan was traveling southbound on Illinois Route 3 on the day of the accident. The driver was the only occupant. The vehicle approached the Bissell Street intersection and merged into the far left lane to turn eastbound onto Bissell Street. The highway traffic signals displayed a green left-turn arrow, and the vehicle driver proceeded onto Bissell Street and toward the UP tracks. The Amtrak train outward-facing video recording verified that the crossing warning lights were not flashing and the crossing gate arms were in the vertical position.

The vehicle driver continued into the crossing, entering the path of Amtrak train 301-28. The train struck the vehicle on the left side, near the driver's door. The impact shoved the vehicle clear of the railroad tracks and into an out-of-service signal bungalow. The driver of the vehicle died as a result of the collision.

Amtrak

An engineer, a conductor, and an assistant conductor were operating Amtrak train 301-28 as it departed Chicago Union Station at 7:00 a.m. on the day of the accident. The train had made four scheduled station stops as it approached St. Louis; about 20 passengers were on board when the accident occurred.

The engineer stated that he sounded the horn as the train approached the Bissell Street crossing, traveling about 40 mph. The engineer stated he noticed a vehicle close to the crossing so he began to apply the train air brakes.[9] When the train was at the crossing, the engineer realized the vehicle was entering the crossing and he applied emergency braking.[10] The train struck the vehicle and traveled more than 400 feet before stopping. The engineer stated that he switched the locomotive radio to the UP radio channel and dialed 911 when the train stopped. He notified the UP dispatcher, who told him that emergency responders had been dispatched.

Accident Location and Site Description

UP Track and Operations

The UP Springfield Subdivision near the accident site consisted of multiple main track territory.[11] The track structure was designated as class 4 track[12] in accordance with Federal Railroad Administration (FRA) regulations. The UP route between Chicago and St. Louis passed

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[9] *Air brakes* refer to the braking system used on most North American railroads.

[10] *Emergency brakes* refer to the type of brake application used to stop a train in the minimum distance possible for the equipment.

[11] Multiple main track territory consists of two or more main tracks used in accordance with the timetable.

[12] Railroads determine how they will classify various segments of their track. As the class designation increases, the track must meet increasingly higher federal standards for construction, maintenance, and inspection. Federal regulations also establish maximum train speeds for each class of track.

through the Springfield and Joliet Subdivisions. Freight trains and passenger trains operated on this route.

The tracks had a maximum timetable speed of 60 mph for freight trains and 79 mph for passenger trains, with some areas of speed restrictions. Near the accident site, speed restrictions were in effect that authorized both passenger and freight trains to operate at a maximum of 40 mph on UP main track 1. Passenger and freight trains were restricted to 60 mph on UP main track 2.

The Bissell Street crossing traversed both of the UP main tracks and the NS main track and intersected them at an approximate 90° angle. The three tracks were straight and nearly level at the crossing.

The *General Code of Operating Rules*, Sixth Edition; general orders; timetable instructions; system special instructions; and signal indications of a traffic control system governed train movements on the Springfield Subdivision. A train dispatcher located at the UP dispatch center in Omaha, Nebraska, coordinated train movements and track authorities on the Springfield Subdivision.

Bissell Street Crossing Warning System

Bissell Street intersects Illinois Route 3 in a geographic east-west direction in the city of Madison, Illinois, which is a suburb of St. Louis, Missouri. Bissell Street, a two-lane asphalt road, extends about 50 feet from Illinois Route 3 and intersects the UP and NS main tracks. (See figure 1.) The crossing traffic lanes are separated by a center median across the three main tracks. The posted speed limit on Bissell Street is 30 mph. The US Department of Transportation crossing inventory information indicates an annual average daily traffic count of 1,450 vehicles for the Bissell Street crossing.

The Bissell Street crossing inventory number is US Department of Transportation number 294 473P. The crossing was equipped with an active crossing warning system, consisting of a median post with flashing lights, a Western Cullen Hayes model 3590-B gate arm, and two Safetran model S-40 gate arms with fiberglass and aluminum combination arms. There were three gate arms, and each had three lights. When the crossing warning system activated, the first two lights on a gate arm flashed alternately, while the third light located at the tip of the gate arm remained constantly lit. Each of the three gate arms was mounted on a mast, and each mast had four 12-inch light-emitting diode flashing lights. A fourth mast, which did not have a gate arm, had two 12-inch flashing lights. In total, there were fourteen 12-inch flashing lights at the crossing.

The GCP-3000 units were configured for redundant bidirectional warning. In the event of a system failure, control was switched automatically to the redundant unit. The UP and NS crossing warning systems were interconnected. Train detection on any of the three main tracks activated the crossing warning system. Disabling either of the GCP-3000 units would disable train detection on all three main tracks.

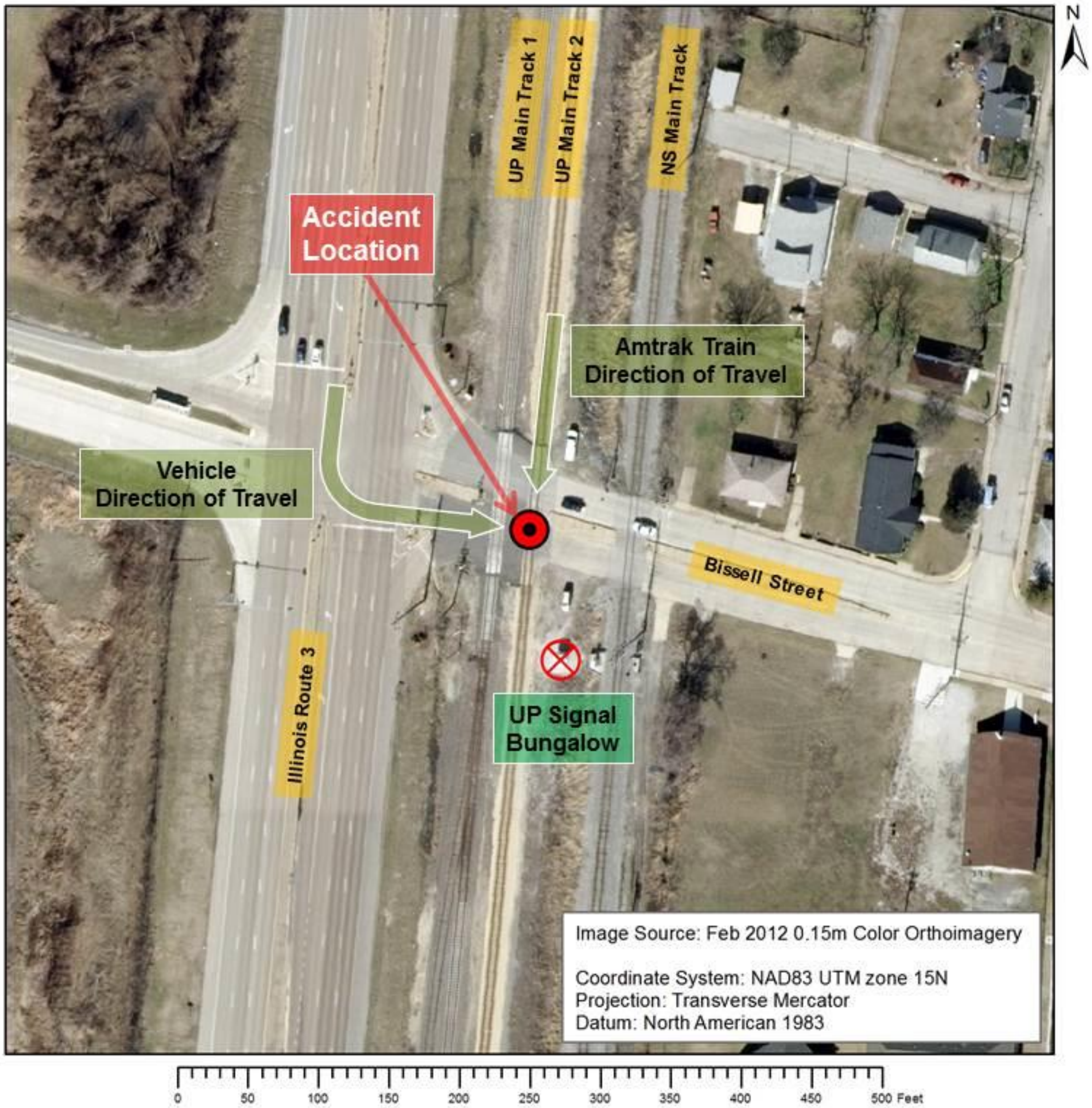

Figure 1. Accident location

The GCP-3000 units calculated the speed of an approaching train. The GCP-3000 units were designed to provide a relatively uniform warning time of 25 seconds, but the time could fluctuate slightly due to changes in the ballast[13] and track conditions or variances in the speed of an approaching train.

[13] Whether ballast is wet or dry affects the track resistance or load on the track circuit and affects the detection and speed calculations used by the GCP-3000 unit.

Bissell Street Highway Traffic Signal Interconnection

The intersection of Illinois Route 3 and Bissell Street was equipped with a traffic signal system to direct vehicles through the intersection. The signal system was interconnected with the crossing warning system to activate the simultaneous preemption phase.[14]

The initial highway traffic preemption phase sequenced the traffic lights to provide a green signal to westbound vehicles on Bissell Street, which allowed vehicles to move off the crossing when a train was approaching. The traffic lights for eastbound vehicles on Bissell Street approaching the crossing were sequenced to provide a red signal, while the crossing warning system was activated for approaching trains until trains were clear of the crossing. The traffic lights for northbound vehicles on Illinois Route 3 displayed a “No Right Turn” indication to warn drivers that a train was approaching or traversing the crossing. The traffic lights for southbound vehicles on Illinois Route 3 were sequenced to display a red left-turn arrow to warn drivers that a train was approaching or traversing the crossing. Following the completion of the initial highway traffic preemption phase, the traffic signal system permitted highway traffic movements that did not conflict with railroad train operations through the intersection.

The Investigation

The investigation determined that the following were not factors in the accident: the track; the train mechanical conditions; the weather; the visibility of the crossing warning devices; the training, qualifications, medical conditions, or work/rest/sleep histories of the Amtrak train crew and the UP signal employees; portable electronic device usage; or alcohol or illegal drug use by the UP signal employees.

Field Inspection and Testing

The GCP-3000 unit data recorders were downloaded from the equipment in the Bissell Street UP signal bungalow. Then data recorder inputs were verified, associated electro-mechanical relays (relays) were tested, the traffic interconnect circuit was verified, ground tests were conducted, and the standby battery power was tested. The track circuit approach lengths were measured. The termination shunt frequency was verified. Cable insulation resistance tests were conducted, and warning system operational tests were performed. No defects were noted.

Reenactment

NTSB investigators reenacted the accident by installing the upgraded software on the standby GCP-3000 unit for UP main track 2 and having an exemplar train travel southbound at 39 mph through the crossing. Investigators then downloaded the data from the standby GCP-3000 unit data recorder. The warning system was then switched to the primary GCP-3000 unit on UP main track 2. The exemplar train was again moved southbound at 39 mph

[14] *Simultaneous preemption phase*—a cycle of the highway traffic signal system initiated by the highway traffic signal controller unit at the same time the GCP-3000 unit detects an approaching train.

through the crossing. Investigators again downloaded the data from the primary GCP-3000 unit data recorder. The crossing warning devices activated correctly during each reenactment.

Investigators then installed the previous software version on the primary and standby GCP-3000 unit and conducted two additional reenactments with the exemplar train traveling 39 mph on UP main track 2 through the crossing. The crossing warning devices activated correctly during the additional reenactments. The data were downloaded from the data recorder on the two GCP-3000 units after each exemplar train movement.

During all of the reenactments, the highway traffic signal system displayed red signals prohibiting southbound vehicles from turning left to travel eastward on Bissell Street.

Investigators could not replicate the conditions leading to the accident without applying a jumper wire to the relay. Applying a jumper wire to the crossing relay, which was the main relay used to activate the crossing warning system, prevented the crossing warning devices from activating when a train was approaching the crossing and allowed the highway traffic signal system to establish a green left-turn arrow for highway traffic moving southbound on Illinois Route 3.

Laboratory Examinations and Testing

Field inspection and visual examination of the relays (see figure 2) used by the crossing warning system determined that three relays (1GCP, 2GCP, and NFSXR) exhibited damage on two of the contacts (12 and 13). NTSB investigators took custody of the three damaged relays and one undamaged relay and submitted them to the NTSB Materials Laboratory for further examination.

The NTSB Materials Laboratory examination identified metallic splatter and thermal-related discoloration on the armature of the three relays. The plastic cases for the relays had consistent sooting[15] patterns on the case walls nearest to the damaged contacts. The three relays also exhibited arc damage on the contacts. The remaining relay contacts showed signs of thermal damage in the form of discolored and sooted areas around the tip of the contact, as well as discoloration of the support springs. There was also evidence of slight surface wear on the undamaged contacts.

The NTSB Materials Laboratory determined that the presence of splatter, discoloration, and sooting was indicative of an electrical arcing event. The evidence of material transfer on the rear left contact for relay 2GCP was also indicative of an electrical arcing event where the contacts were closed during the event. Laboratory staff could not determine if the contact surfaces had been fused at the time of the accident.

[15] *Sooting* is a black powdery form of carbon produced from electrical arcing.

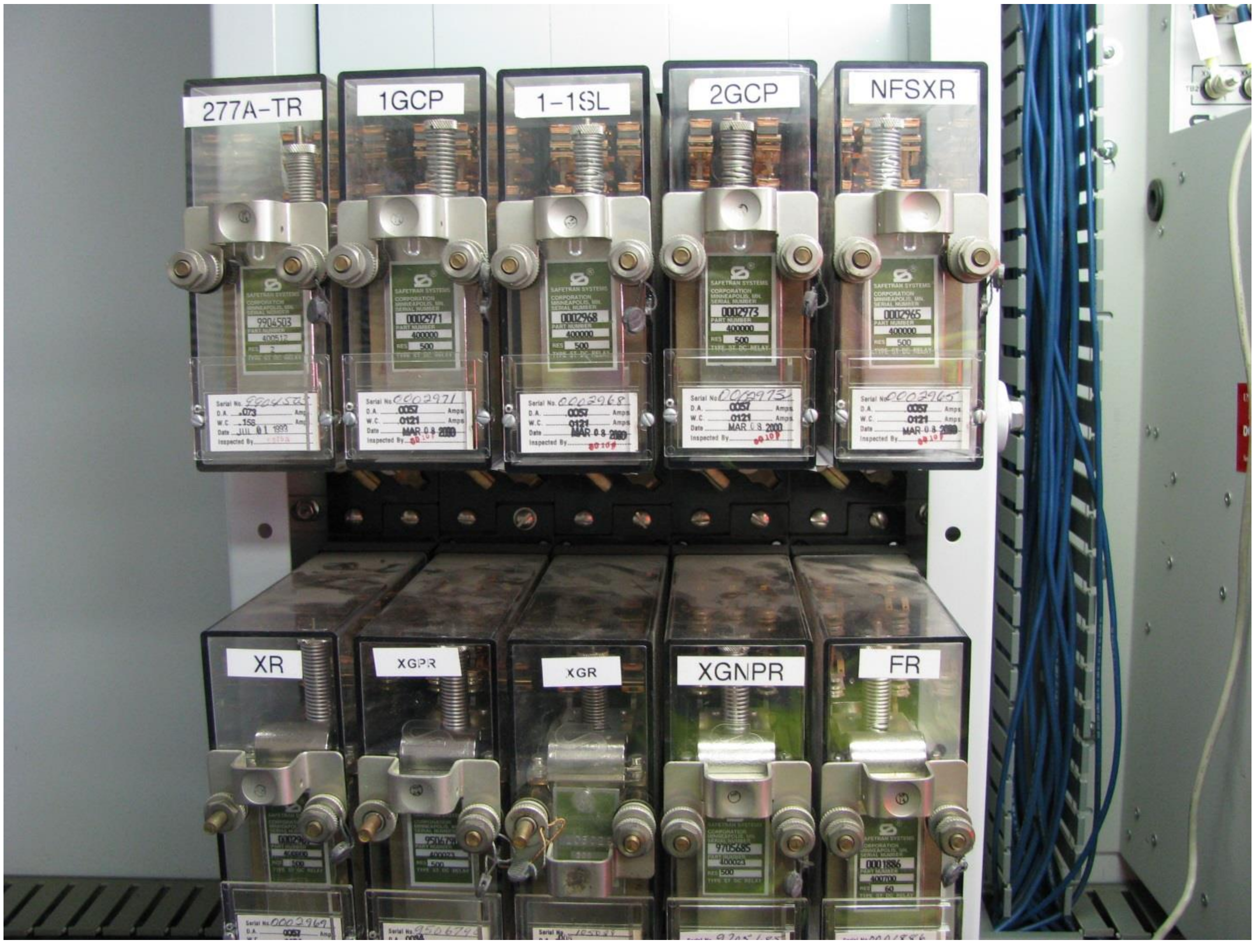

Figure 2. Relay rack in UP signal bungalow at Bissell Street crossing

NTSB investigators took custody of the GCP-3000 unit for UP main track 2 for testing by the manufacturer. The investigators specified the tests to be conducted and observed the testing at the manufacturer's facility. Examination of the 12 plug-in printed circuit modules[16] found no damage to the electronic components. The top retaining clips, used to lock the printed circuit modules in place within the chassis, were cracked on two of the modules of the main unit. Despite the cracked retaining clips, both modules were seated properly in the 43 pin connectors and operation of the unit was not affected.

The GCP-3000 unit was energized with a 13.1 volt direct current, 4.0 amp source while the relay driver output was monitored with a multimeter. The relay driver output measured 16 volts when the GCP-3000 unit was energized. The relay driver output dropped to zero volts when the GCP-3000 unit was cycled off. The relay driver output from the GCP-3000 unit energized the crossing relay.

[16] The primary and standby GCP-3000 units each used six plug-in printed circuit modules.

The BIOS boot software was then initiated to configure the GCP microprocessor to search for an operating system program to install instead to access programs stored in its internal memory. During the 45 seconds it took to install the bootloader, the relay driver output voltage was monitored with a multimeter and was observed dropping and remaining at zero.

A software update installed a new operating system program onto the GCP-3000 unit. The software update was repeated three times while the relay driver output voltage was monitored with a multimeter. The test was performed with a ballast resistance at 16 ohms to represent normal ballast conditions, with a ballast resistance of 4 ohms to represent wet ballast conditions and with a ballast resistance of 20 ohms to represent dry ballast conditions. During all three tests, the relay driver output voltage dropped and remained at zero until all parameters were entered and the tracks were recalibrated. All of the tests were repeated with an exemplar GCP-3000 unit to verify operational status. The exemplar unit performed in the same manner as the GCP-3000 unit from the Bissell Street crossing performed.

Bissell Street Crossing Warning System Operation

The NTSB Materials Laboratory was unable to determine whether the arcing damage on the contacts of the three relays was preexisting damage or the result of using a jumper wire. Although the technician and the inspector told NTSB investigators that they did not use a jumper wire, the following additional investigative information collectively indicates that either the technician or the inspector likely used a jumper wire to falsely energize the relay, thereby disabling the Bissell Street crossing warning system:

- NTSB investigators reviewed the Springfield Subdivision signal records for the 6 months before the accident. There were no reports of any malfunctions for the Bissell Street crossing warning system. Maintenance records indicated that all required tests and inspections had been performed and completed in accordance with federal requirements.
- Postaccident field testing of the Bissell Street crossing warning system determined that the relays and the warning system operated as designed.
- Postaccident reenactments could not replicate the conditions leading to the accident without using a jumper wire on the relay to keep the crossing warning system from activating with a train approaching the crossing.
- During postaccident interviews, the UP inspector stated that he observed the Bissell Street crossing warning system operate during the first software upgrade before the accident. This indicated the crossing warning system activated as designed when the GCP-3000 unit was cycled on and off during the software upgrade.
- Postaccident field and lab testing of the GCP-3000 unit determined it was operating as designed.
- Postaccident testing determined that the simultaneous preemption interconnection between the highway traffic control system and the crossing warning system functioned as designed.

- Postaccident reenactments of a train approaching the crossing could not replicate a green left-turn arrow for southbound vehicles on Illinois Route 3 (for eastward movement onto Bissell Street) without applying energy to the crossing relay to prevent the crossing warning system from activating.

UP Signal Training

The inspector was hired in November 2007 as a signal apprentice. He completed the signal apprentice training in about 2 years at the UP training facility in Salt Lake City, Utah. He began working as a signal inspector in the fall of 2009 and continued in that capacity until the accident occurred.

The technician was hired in April 1989, in the track department. In 1990, he transferred to the signal department and began his signal apprentice training. He completed the signal apprentice training at the UP training facility in Salt Lake City. His training lasted about a year and a half. He worked various positions in the signal department and began working as a signal technician in the summer of 2011. He had not received any UP training for the technician position he held at the time of the accident. The technician further stated he had not received any specific formal training regarding upgrading software onto a GCP-3000 unit. He stated his knowledge about software upgrades came from reading the manuals and conversations with the equipment manufacturer.

Ensuring the safety of train movements and highway users is a critical requirement for signal personnel involved in the installation, inspection, or repair of railroad signal systems and crossing warning systems. The UP *Signal Tests and Standards Manual* lists all the monthly, quarterly, and annual tests and inspections for crossing warning systems required by the FRA. The manual also contains procedures for work activities such as the use of jumper wires and obtaining the proper authority for and documentation of their use. The use of jumper wires bypasses safety-critical circuits in crossing warning systems and must only be used with caution. Additionally, FRA regulations at Title 49 *Code of Federal Regulations* (CFR) 234.209 prohibit interfering with safety-critical circuits in crossing warning systems without first taking the necessary steps to provide for the safety of train movements and highway users.

Both the technician and the inspector had progressed through various positions during their careers with the UP signal department. Their positions required them to be knowledgeable of railroad signal systems and crossing warning systems. Testing, maintaining, and repairing these systems sometimes required the technician and the inspector to bypass safety-critical circuits, and therefore their jobs also required them to be knowledgeable about the procedures to provide for the safety of train movements and highway users before they commenced any work that could alter the safety-critical functionality of these systems.

UP Signal Management Oversight

The UP *Signals Test and Standards Manual* had a section dedicated to crossings that included all FRA-required testing and inspections and detailed guidance and procedures for disabling and enabling circuits. However, UP management audits of compliance with the manual were not required.

Title 49 CFR 236.4 states, “The normal functioning of any device shall not be interfered with in testing or otherwise without first taking measures to provide for safety of train operation which depends on normal functioning of such device.” However, the UP did not require or conduct operational testing or spot checks to ensure compliance with this regulation.

Postaccident Actions

On March 8, 2013, the NTSB issued Safety Recommendations R-13-1 and -2 to the Federal Transit Administration (FTA) and Safety Recommendations R-13-3 and -4 to the FRA. The recommendations requested that each agency issue safety advisories containing best practices for managing jumper wire use as well as a discussion of the circumstances of this and another railroad accident[17] involving improper use of jumper wires.

On June 3, 2013, the FRA issued Safety Advisory 2013-04, *Importance of Clear Safety Procedures for Temporary Removal From Service of Highway-Rail Grade Crossing Warning Systems and Wayside Signal Systems*.[18] The safety advisory referenced the two NTSB accident investigations and reemphasized the importance of ensuring the safety of the traveling public and railroad employees when crossing warning systems and wayside signal systems are temporarily removed from service for the purpose of testing, inspection, maintenance, or repair. The safety advisory contained recommended actions for railroads to follow to ensure safety.

On July 2, 2013, the FTA issued a safety advisory to address the NTSB recommendations. The safety advisory recommended that rail transit agencies review their current maintenance programs to ensure they were in agreement with FRA Safety Advisory 2002-01. The FTA further recommended that rail transit agencies at a minimum should assess how jumper wires are used in the signal maintenance program; establish policies and procedures agencywide for the proper temporary deactivation of wayside train signal systems, crossing warning systems, and other devices; and establish training for all affected employees to ensure they understand the instructions. The safety advisory also recommended that state safety oversight agencies meet with the rail transit agencies to review the safety advisory and incorporate a review of the jumper wire procedures as part of the Three Year Safety Review.

Following the accident, the UP made changes to its Employee Risk Assessment Mitigation Process. Managers are now required to perform frequent audits for compliance with the UP *Signals Tests and Standards Manual*, including disabling/enabling procedures used in crossing warning systems maintenance activities.

The UP also conducted followup inspections of all GCP-3000 unit software upgrades performed by the technician involved in this accident.

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[17] National Transportation Safety Board, *Amtrak Train 350 Derailment, Niles, Michigan, October 21, 2012*, RAB-13/05 (Washington, DC: National Transportation Safety Board, 2013).

[18] *Federal Register* 78, no. 106 (June 3, 2013): 33146-33148.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Union Pacific Railroad signal inspector and signal technician to provide for the safety of train movements and highway users prior to disabling the highway-rail grade crossing warning system at the Bissell Street crossing. Contributing to the accident was the failure of Union Pacific Railroad management to ensure proper procedures were followed during the software upgrades to provide for the safety of train movements and highway users.

Adopted: March 27, 2014